Mining for Metals in Wales

By F. J. North

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We learn from the history of nearly all ages that very many men have been made rich by the mines.

Georgius Agricola, De Re Metallica, 1556.

PREFACE

This monograph has been prepared by the former Keeper of Geology in the Museum, who served as Acting-Keeper of the newly established Department of Industry pending the appointment of the present head of the Department, Mr. D. Morgan Rees, M.A. It provides a brief summary of the widely dispersed literature of the subject, synthesized in the light of personal observations over many years.

An adequate history of the mining industry in Wales has yet to be written, but in the meantime the bibliography here included will, it is hoped, lead those who wish for further information to the more important of the works in which it can be found.

As the Department of Industry develops, and especially when the galleries in the new west wing become available, exhibits illustrating many of the operations described in these pages will play an increasingly important part, and information and objects likely to be of assistance in preparing such exhibits will be welcomed in the Department.

D. DILWYN JOHN,

April, 1962.

Director.
CONTENTS

List of illustrations vi
Introduction vii
1. The origins and distribution of ores 1

THE FIRST PERIOD
From prehistoric times to the Dark Ages

11. Mining in prehistoric times 8
III. Mining by the Romans 12
IV. The Dark and Middle Ages 30

THE SECOND PERIOD
From the Tudor Renaissance to the Mine Adventurers

V. The Tudor Renaissance and the Mines Royal 33
VI. The Company of Mine Adventurers and the Steward ship of Lewis Morris 44
VII. Notes on mining practice 51

THE THIRD PERIOD
The last two centuries - climax and decline

VIII. Copper mines 57
IX. Gold mines 65
X. Lead and zinc mines 69
XI. Iron and manganese mines 85
Bibliography 101
Index 109

LIST OF ILLUSTRATIONS

PLATES
1. Cwmystwyth mine in 1699 11. " Darrein Hill or Roman Works " (Darren mine) in 1670. 111. " Comsumlock Hill " (Cymysyrnlog mine) in 1670. IV. Parys Mountain mine, Anglesey, in 1785. V. " Patchworks " (for iron ore), Beaufort, Mon., in 1858. VI. Shaft, adit, and cross-cuts, c. 1888. VII. Stoping in a mine, c. 1888.
VIII. Water-wheel at Trecastell (lead and zinc) mine, near Conway, c. 1912.

TEXT FIGURES
1 Fire-setting in a mine. iS
2 Shafts, adits, and winding gear. 38
3 Bellows for ventilating a mine 40
4 The Van (lead) mine, Llanidloes 72
5 The Van (lead) mine, Llanidloes 74
6 Haematite ore in Glamorgan 92
INTRODUCTION

In Wales,
Valeys bryngeth forth food,
And hilles metal right good.

Ranulf Higden, in Polychronicon,
trans. John de Trevisa, 1387

It is appropriate that the first contribution from the Department of Industry to the Museum's series of publications should relate to mining for metals, for although Stone Age man fashioned implements from wood and stone and engaged in agriculture, weaving, and the making of pottery - all of them represented amongst the industries of today - it was the recognition of the potentialities of metals that laid the foundations of our present material civilisation.

Weapons and tools could be more varied, often more effective, and more easily produced in quantity in metal than in stone, whilst metal gave greater opportunities than stone for the exercise of craftsmanship and the expression of artistic taste. Increasing demand called for increasing activity and ingenuity in discovering new sources of supply, and increasing availability evoked new applications, so that, today almost everything we need is either made of metal or fashioned by tools and machines of metal, or is the produce of husbandry in which appliances largely or entirely of metal play an essential part.

The subject is of special interest to Wales because, although their output is now relatively small, its mines have made major contributions to the world's supply of metals, and the development of processes for extracting metals from their ores owes much to pioneer work in the Principality.

Although the Museum's several Departments deal with different materials and different aspects of human activity and interest they have common aims: one is to accumulate and preserve information and objects, especially objects, illustrating the natural history of Wales and the activities of man therein; the other is to make the collections available for study, instruction, and enjoyment. The Department of Industry, although introducing new conceptions and new techniques, will take its place as a member of this integrated series.

Established to illustrate the history of industry in Wales and the application of science and technology to the industries of today, the Department will look to geology to explain the origin and distribution of the rocks and minerals upon which industry depends and to archaeology for records and examples of the achievements of early man in using them. Continuing the stories of botany and zoology it will illustrate processes and products dependent upon materials of plant and animal origin, and, in relation to architecture it will illustrate the preparation and utilisation of many of the materials that are fundamental to this age of steel, concrete and glass. It will demonstrate the continuity of human achievement, which, to mention only one of many 'industrial activities - the use of molten metal - gave socketed axes and the like in early days, furnishes the castings without which modern machines could not be made, and is the means whereby artistic talent in many ages has been given permanence in bronze and iron. It will deal with those aspects of industry in Wales that lie outside the sphere of interest of the Welsh Folk Museum at St. Fagans.

As the subject is so vast and its literature so voluminous it is not possible to do more, within the limits that necessity imposes, than indicate the distribution of the ores, the circumstances in which and the people by whom they have been exploited, and the methods adopted at various times to raise them. Additional information and illustrations must be sought in the publications enumerated on pages 101 to 108 and indicated in the text by numbers enclosed in brackets.
1. THE ORIGINS AND DISTRIBUTION OF ORES

You taught Volcanic airs to force Through bubbling lavas their resistless course,
O'er the broad walls of rifted Granite climb, And pierce the rent roof of incumbent lime.
Erasmus Darwin, in *The Botanic Garden*
(The Economy of Vegetation, 1792)

Most metals have so strong an affinity for oxygen and other elements that very few occur in nature in a metallic state. Gold is one that does and Welsh mines have yielded ores containing it, but copper, lead, silver, zinc, iron and manganese, which are also present in Wales, occur as chemically combined constituents of minerals and rocks and have to be isolated by more or less complex smelting operations. In the circumstances this monograph should properly be entitled "Mining for metalliferous ores in Wales," but the shorter title has euphony to recommend it.

Ore is a commercial term, not a scientific one, and it denotes any rock or mineral that is worth exploiting as a source of metal. The term is sometimes applied also to minerals that are useful by reason of their chemical composition or physical properties rather than on account of the metals they contain: examples are the minerals barites, pyrites, and fluor spar (fluorite). The first is used, amongst other ways, in the manufacture of paint, as a filler in heavy papers and textiles and (by reason of its high relative weight) in coal-cleaning and mineral-separating processes involving the use of a heavy medium; the second is a source of sulphur and the third is used as a flux to increase the fluidity of the slag produced when metals are smelted, in the ceramic industry, and in the manufacture of hydrofluoric acid.

The output of barites from Wales has never been great. For about thirty years after 1883 small but at the time important amounts were produced from the Pompren mine near Aberdaron in Caernarvonshire, but in recent years a small mine in Carmarthenshire (about 2 miles east of Carmarthen) has been the only Welsh source. The mineral was present in the veinstones of certain old lead mines but not being in demand when the mines were being worked it was discarded. Some of the older shales of Wales contain pyrites (sulphide of iron), a mineral which occurs also in many metalliferous veins, but the only mine worked specially for it was at Cae Coch, near Trefriw in Caernarvonshire. There, a pyritic rock, containing about 20 per cent of sulphur and occurring along the junction between shales and an intrusion of igneous rock (diabase) was worked in the second half of last century and to a small extent during the first world war. Fluorspar occurs in the lead mining region of north-eastern Wales, but not in sufficient quantity to encourage exploitation.

The availability of metals depends upon the discovery of ores, and the means by which ores can be worked are determined by their mode of occurrence. It is, therefore, necessary to know something of the nature and origin of ores in order to appreciate the sporadic distribution of metalliferous mines and the great diversity of methods for working them.

Ores have been formed in a variety of ways which can best be understood in the light of what we know and can surmise about the constitution and structure of the medium in which they occur—the crust of the earth. This is a zone some 30 miles in thickness to which man has access, or the character of which he can deduce by applying his knowledge of the way in which rocks have been formed and are arranged. The names of the Systems into which the rocks of the crust have been divided for convenience in reference and study are given in the Table of Strata, page 6. Some rocks represent material that was worn from land regions, was deposited on the floors of oceans or lakes, and subsequently uplifted to provide the material out of which new lands have been fashioned. These, because they originated as sediments, are known as sedimentary rocks, but others represent material that was once in a molten condition. Because of their association with heat they are known as igneous rocks, from the Latin, ignis, fire, and may have solidified in large deeply buried reservoirs, or in fissures that allowed the molten material (magma, as it is called) to penetrate the overlying strata or even to reach the surface and flow as lava from volcanoes.

The sedimentary rocks occur in layers, built up as, due to movements that take place in the material of the crust, mostly imperceptibly but occasionally with violence, land areas have tended to sink beneath the sea and sea floors have been elevated to become dry land. The layers vary in character according to the material from which they were derived, in thickness according to the length of time during which conditions allowed any one series to accumulate, and in extent according to the area
eventually covered by the sea or lake in which they were deposited. Sediments deposited in lakes are of necessity more limited in thickness and extent than those of marine origin.

Accumulations of pebbles - shore deposits - became conglomerates, whilst sediments in which sand (usually grains of the mineral quartz) predominate gave rise to sandstones, and those that originated as muddy deposits gave rise to clay, shale, or mudstone - clay when the rock readily softens and breaks down to mud in the presence of water, shale when it occurs in thin, well defined layers and less readily softens when wet, and mudstone when it is hard, compact, and but little affected by water. Deposits consisting largely of shells and shelly debris, and the skeletons of marine creatures such as corals, or of other calcareous material extracted from the sea by animals or plants, become limestones.

Some sedimentary rocks contain metallic constituents in sufficient quantity to serve as ores. Amongst them are the clay ironstones that were formerly worked in South Wales and the manganese ores of Merionethshire. Occurring in layers, rarely more than a few inches in thickness, and intercalated with other rocks, usually shales or mudstones, such ores have to be mined by methods similar to those employed in coal mines - for a coal-seam is a relatively thin layer of special character in a series of stratified rocks. When followed underground the excavations for their removal have flat roofs and floors but incomconsiderable height - no more than is necessary to enable the miners to work - and they spread laterally from passages driven into a hillside where the ore outcrops, i.e. reaches the surface, or from shafts sunk to reach layers that may be deeply buried. The workings may be horizontal or inclined according to the disposition of the strata in which they occur.

During the cooling and solidification of the earth there was a tendency for the heavier constituents to sink and for the lighter ones to rise, so that the metallic constituents are more abundant in the lower layers of the crust and the zones that lay beneath it. At great depths the fabric of the earth is hot enough to melt but is prevented from doing so by the pressure of the rocks that rest upon it, but when, from time to time, local movements in the crust diminished or temporarily removed the pressure, some of the deeply buried material passed into a molten condition and invaded the super incumbent rocks, carrying the metals with it. Much of the magma cooled where it was formed giving rise to large masses of coarsely crystalline igneous rocks, the existence of which is revealed only when the material covering them at the time of their formation has been worn away by the processes of denudation, but some of it was forced into the upper regions of the crust, and occasional outbursts of volcanic activity indicate that, in common with the processes of sedimentation and denudation, the formation and movement of magma still goes on.

As the molten material formed in past ages cooled, some of its constituents solidified before others and there was a tendency for the metallic elements and compounds to be concentrated in the portion that remained fluid longest and was intruded farthest.

The formation and intrusion of magma was often associated with the strains and stresses to which the crust has been subjected during the readjustments that followed the transfer of loads from a region that was being elevated and worn away to an adjacent region that was sinking beneath the sea to receive the products of denudation. The movements resulted in the formation of cracks and zones of weakness in the surrounding rocks, into which the last remaining liquid portions of the magma penetrated for considerable distances, forming, when solidified, steeply inclined wall-like 'dykes' rising through the enclosing strata, or layers separating bedding planes giving rise to 'sills,' whilst the water vapour and other gases that were discharged as the magma cooled penetrated even farther than the magma itself. The cracks often occur in parallel and intersecting series and provided convenient situations for the deposition of the minerals - some metallic, some non-metallic, especially quartz - that were present in the magma or the hot waters that rose from it.

Such infillings are often arranged in layers parallel to the sides of the fissures in which they occur - fissures that may be widened as the deposition proceeds - and the lodes rise through the enclosing strata like more or less steeply inclined walls completely enclosed in rock. The lead, zinc and copper ores of Cardiganshire and Merionethshire and some of those in North Wales were formed in this way, and the task of the miner is to follow the lodes (sometimes called veins), extracting the ore but removing as little of the country rock as possible and concentrating effort on those parts of the lode that yield the greatest amount of the richest ore. It often happens that the metalliferous minerals are more abundant where the lodes out through one kind of rock than through another, and the recognition of this tendency is often of considerable help in searching for productive ore.
Because some of the metallic constituents tended to remain in solution longer than others the minerals were deposited in the lodes in an ascending order, e.g., copper pyrites first, followed by blende (zinc ore) and that in turn by galena (lead ore). It is for this reason that the ore for which a lode may have been first exploited tends, as the mine-workings extend to deeper levels, to be first associated with and eventually replaced by another - lead ore by zinc ore, for example.

As the temperature and pressure continued to fall the remaining superheated water, still charged with silica, made its way into the fissures and their ramifications, adding to the quartz that is the principal non-metallic constituent of most mineral veins. Gold that may have been present in the original magma is likely to have been concentrated in these late-arriving siliceous waters and to have been deposited with the quartz.

All these processes took place when the rocks in which the ores now occur were deeply buried and subjected to the high temperatures which obtain at great depths; it is as a result of the weathering and wearing away of the material that once covered them that the mineral-filled fissures and their enclosing rocks have been brought sufficiently near to the surface for man to have become aware of them.

When gold was present in the rocks undergoing denudation the metallic particles remained unchanged, except in being worn to smaller particles, and became an ingredient of the debris that, washed into streams, was carried along to form sediments in the lakes and seas into which the rivers discharged. Being heavy, the gold tended to lag behind and to accumulate in hollows in the beds of streams or to be deposited in situations where the velocity of the water was checked, giving rise to ore-bearing gravels. Conspicuously different from the non-metallic constituents of the gravel the gold attracted attention to itself, and isolating it by simple washing processes was in all probability the first 'mining' operation to be undertaken.

It is as compounds with sulphur that most of the metallic minerals were deposited from the uprising vapours and solutions e.g. as copper pyrites or chalcopyrite (sulphide of copper and iron), blende (sulphide of zinc), and galena (sulphide of lead). but in the upper levels of the lodes, where they come within the influence of rainwater (with its dissolved oxygen and carbon dioxide) that soaks downwards from the surface, many of the sulphides underwent chemical change and were converted into oxides or carbonates of the metals concerned. These in turn tended to pass into solution and to be carried down to the level of the water-table, i.e., the level below which rocks are saturated with water. Here they were re-deposited, enriching the veins at that level and often entering into new combinations to produce the strikingly coloured and crystallised minerals that are characteristic of collections made during the early stages of the exploitation of the veins.

Sometimes the ascending gases and solutions permeated the country rock itself - depositing sufficient of their metallic content to convert the rock into massive ores the working of which calls for procedure different from that appropriate to the exploitation of lodes. The copper ores of Parys Mountain in the north of Anglesey, resulted in part from the mineralization of shales associated with an igneous intrusion.

Some segregations of ore consist of metallic compounds that were contained in waters that rose in the strata until they encountered impermeable beds which prevented their further upward movement and caused them to spread laterally and deposit their minerals in underlying permeable or cavernous rock. Some of the lead ores of north-eastern Wales originated in this way. Other segregations resulted from the redistribution of metallic compounds that, after being incorporated into sedimentary rocks, had passed into solution in descending ground-waters. Such ores may have been deposited in fissures or cavities to which the mineralised waters had access or they may have replaced, by chemical change, a soluble rock like limestone that was dissolved away in the process. Although they spread in the direction of the strata with which they are associated segregations of this kind tend to be irregular in distribution, boundaries and extent, and so in consequence are the cavities produced as they are mined. The haematite iron ores of South Wales and north-eastern Wales probably originated in this way.

This brief account of the origin and arrangement of ores, with special reference to those that occur in Wales is devoid of the qualifications that would be necessary in an ad hoc work on the subject, but it will serve to show why they vary so much in character and mode of occurrence, and will prepare the way for a consideration of the distribution of mines, the methods employed in. working them and the changes in fortune they have experienced -in short, for an account of 'mining for metals in Wales.'
The story divides itself into three parts, each dealing with a period of rise and decline. The first period extends from prehistoric times to the Dark Ages and the second from the rise of the Tudors to the latter half of the eighteenth century. The division between the second period and the third is ill-defined because the revival in some areas began whilst the decline in others was still in progress. The third period will not end until the last metal mine in Wales has closed down. At present there is only one, an iron mine, but although the prospects for a renewal of non-ferrous mining do not appear promising, it would be unwise to assert that further exploration, or changes in technical processes or in market conditions, may not lead to renewed activity in some of the ore-fields.

As shown in the Tables below, ores occur and have been worked to a greater or lesser extent in all the counties of Wales, and as, for the most part, they represent material brought from the deeper layers of the crust, they are most abundantly developed in regions occupied by the outcrops of the older rocks.

### Table 1

| Anglesey  | Cp L | 1 | m |
| Caernarvon | Cp L | 1 | m |
| Merioneth  | G Cp L | 1 | m |
| Denbigh    | Cp L | S Z 1 | m |
| Flint      | Cp L | S Z 1 Co |
| Montgomery | Cp L S Z |
| Cardigan   | Cp L S Z |
| Radnor     | L |
| Brecon     | L | 1 |
| Monmouth   | L | 1 |
| Glamorgan  | L | 1 |
| Carmarthen | G Cp L 1 |
| Pembroke   | L S | 1 |

**Table 1**

Table 1. Table of strata indicating the names of the Systems into which rocks have been divided - the oldest being the lowest in the Table - and the geological distribution of ores in Wales.

### Table 11

| Anglesey  | Cp L | 1 | m |
| Caernarvon | Cp L | 1 | m |
| Merioneth  | G Cp L | 1 | m |
| Denbigh    | Cp L | S Z 1 | m |
| Flint      | Cp L | S Z 1 Co |
| Montgomery | Cp L S Z |
| Cardigan   | Cp L S Z |
| Radnor     | L |
| Brecon     | L | 1 |
| Monmouth   | L | 1 |
| Glamorgan  | L | 1 |
| Carmarthen | G Cp L 1 |
| Pembroke   | L S | 1 |

**Table 11**

Table 11. The geographical distribution of ores in Wales. G Gold ; Cp Copper ; L Lead ; S Silver ; Z Zinc ; 1 Iron Co Cobalt ; M Manganese.
THE FIRST PERIOD
From prehistoric times to the Dark ages

11. MINING IN PREHISTORIC TIMES
Not only corn and other fruits for sustenance and store, Were now exacted of the earth, but 'eft they 'gan to dig, And in the bowels of the earth insatiably to rig For riches couched and hidden deep in places near to hell.

Ovid, The Metamorphoses (c.A.D.12),
trans. A. Golding, 1565

All that is really known of the ancient state of Britain," said Dr. Johnson in conversation with William Robertson, the historian," is contained in a few pages. We can know no more than what the old writers have told us." If that were really so we should have a very inadequate picture of the part which metals played in the life of the early inhabitants of Wales.

Roman writers said very little about metals in Britain and not all of that was correct. Cicero told his young lawyer friend, Trebatius, who was with Caesar's expedition in 54 B.C., of hearing that there is not an ounce of gold or silver in Britain, whilst according to Caesar himself tin was produced in the interior, iron in the coastal districts, but bronze was imported. As time went on and more information became available, Strabo the Greek geographer who died in A.D. 25 was able to include gold, silver, and iron amongst the exports from Britain, and Pliny the Elder, writing about half a century later mentioned lead as well as the other metals, adding that because it was so plentiful the Romans had to introduce regulations restricting its production.

Fortunately, however, the situation is not as unpromising as Dr. Johnson imagined, for there are other sources of information than the records left by old writers. Far from constituting the whole of the story they reveal its incompleteness and inspire research to build upon the foundation they provide, for, as Francis Bacon pointed out in his Advancement of Learning, knowledge derived from old writers and accepted without critical examination will not rise above that knowledge any more than water will rise higher than the spring in which it originated.

What Dr. Johnson did not realise was that in addition to and much more informative than the meagre notes left by old writers are the tangible indications of the activities of early man that are widely scattered in the countryside or tantalisingly hidden by a thin covering of soil. Unlike written records, which are not likely to yield more information than has already been derived from them, the material evidence increases as new discoveries are made and interpreted. Still meagre for the prehistoric ages, as far as mining is concerned, it has already assumed sufficient proportions for Roman times.

Objects of gold, copper, and bronze, dating from the Bronze and Iron Ages that have been found in the Principality for the most part arrived as finished articles or were fashioned from imported metal and are indicative of awareness of the characteristics of metals and of ability to manipulate them rather than evidence of indigenous mining. The gold ornaments include bracelets in the form of incomplete rings, and torcs - twisted ribbons bent in the form of a hoop a foot or more in diameter or spirally wound as though intended for use as armlets - and although some of the other objects for which no close parallels outside Wales are known might have been of local manufacture, the nature and distribution of the majority suggests that they originated in Ireland.

The articles of bronze - weapons, implements, and ornaments of the Bronze and Early Iron Ages - found in Wales are both numerous and varied. There is evidence that some were fashioned by itinerant craftsmen for amongst the hoards (groups of objects found together in circumstances suggesting that all were deposited at the same time) there are unfinished, broken, and obsolete weapons, scraps of bronze, and tools for working metal. Moulds in which tools and weapons were cast (e.g. chisels and palstaves) have been found in North Wales whilst an Early Iron Age settlement in the sand-dunes at Merthyr Mawr in Glamorgan yielded fragments of crucibles in which bronze had been melted, as well as brooches of that metal.
The essential ingredients of bronze are copper and tin, but no tin occurs in Wales - the nearest sources of supply are in Cornwall - and although copper ores occur in several localities in Wales there is no certain evidence that they were exploited to any appreciable extent to provide metal for the pre-Roman bronze-working craftsmen. Similarly no pre-Roman lead mines have been recognised in Wales and yet as will appear in due course there are reasons for believing that the pre-Roman inhabitants were aware of the existence of the ores, both of copper and of lead, and may have made tentative efforts to exploit them in a small way. We are not likely to find indubitable traces of their mines for they would have been surface excavations obliterated by later operations or by the ravages of time.

If it is reasonable to assume pre-Roman awareness of local sources of copper and lead, there is a much stronger case for assuming a similar awareness of the occurrence of iron, although it does not necessarily follow that the possession of weapons and other objects of iron involved the exploitation of local ores.

The characteristics of an iron sword (associated with Iron Age objects of bronze) found in the peat at the bottom of the lake, Llyn Fawr, in Glamorgan, indicate that it is of continental origin, whilst comparison with similar objects from other districts suggests that the iron objects - including a spear, chains for securing parties of slaves, chariot tires, and various tools - in the unique hoard found at Llyn Cerrig Bach near Holyhead in 1943, came from the south and east of England and had been made at various times from about 150 B.C. to the middle of the first century A.D.

The tools include blacksmith's long-handled tongs of remarkably modern appearance, and some smaller tongs such as could have served to hold pieces of metal or leather whilst being riveted, so that although the objects may not have been made locally their owners were able to command the services of skilled craftsmen to repair or modify them. Another interesting pre-Roman iron object - a magnificent fire-dog - found in peat at Capel Garmon in Denbighshire, is also indicative of manipulative skill but does not aid in the search for early iron mines.

From the beginning of the 1st century B.C., when the Celtic civilisation developed an emphasis on warlike activities, there was an increasing interest in iron, which, once the art of smelting it had been mastered, could be produced more easily than bronze, and towards the end of the Iron Age the ores of the Forest of Dean were being exploited - it is not inappropriate to mention them here for they are similar in nature, origin, and mode of working to the haematite iron ores that occur in Glamorgan, and provided some of the ores that were smelted and some of the iron objects that have been found on Iron Age sites in Wales.

The ores furnished metal for the manufacture of weapons, tools, and appliances of various kinds, and also for 'currency bars.' These were flat iron bars that could have originated as discarded rough-outs for swords, and although considered to have been used as currency - they were no doubt the "tallies of iron of a certain standardised weight" mentioned by Caesar - it is probable that they were also taken in exchange with a view to use in the owner's smithy. The bars were widely distributed, especially in the south of Britain, but they were also represented in the Llyn Cerrig hoard.

Iron slag found in the Iron Age hill-fort at Llanmelin near Caerwent suggests that ore was taken from the Forest of Dean to be smelted on the site, and the occurrence of slag in other hill-forts, e.g., Ffridd Faldwyn in Montgomeryshire and Dinas Enirys near Beddgelert in Caernarvonshire, indicates the exploitation of iron ores that occur in North Wales, though not necessarily in the immediate locality of the fort concerned. The nature and distribution of these ores will be considered in a subsequent chapter, page 85.

The hill-fort period extends over about 1,000 years, from about 300 B.C. until well into the Dark Ages, and spans both prehistoric and Roman eras, but the precise date of the slag has yet, in most cases, to be determined. At Dinas Etrrys, for example, the iron working appears to have come at a relatively late stage in the occupation of the site, for the Early Iron Age metal objects found there are of bronze and the evidence of iron-working - iron objects and a smelting pit - belongs to a later period, from the 4th to the 6th centuries A.D.

The presence of slag is not, however, always an indication of local smelting. Slag found in the fort at Rhos Tryfan near Caernarvon, for example, was of a kind more likely to have been derived from a forge than from a smelting hearth or furnace.
The most that can be said for the period covered by this chapter is that systematic mining for iron began earlier than for the other metals that occur in Wales, and that the ores were often taken to a place where the metal was to be used, or where conditions were specially favourable for smelting them (e.g. an abundance of timber for fuel and a windy site to provide a natural blast for the furnace). The location of the actual mines has yet to be determined.

111. MINING BY THE ROMANS

Gold cannot gold appear, until man's toil Discloses wide the mountain's hidden ribs, and digs the dusky ore, and breaks and grinds Its gritty parts.


The Roman invasion of Britain was related to a desire to find fresh mineral resources to exploit, and Roman mines in various parts of Europe - in Spain for example - indicate that the newcomers were able to command the services of men who were highly skilled in mining techniques. It is not surprising, therefore, that their entry into an ore-bearing region in Wales was quickly followed by mining activity - so quickly indeed as to suggest that those whose territory they were invading were aware of the existence of the ores and were making tentative efforts to exploit them.

Although the products of Roman mine activity have been found in Wales - 'pigs' of lead in Flintshire and cakes of copper in Anglesey, for example - few indubitable remains of Roman workings have been recognised. As with those of prehistoric man the extensive developments of later times effectively destroyed most of them.

Roman origin has been claimed for some old lead workings in north-eastern Wales - Ffos y Bleiddiaid, near Abergele, and Talar-goch, near Dyserth, for example - on the grounds that ancient tools had been discovered in them, and once made - usually by writers more enthusiastic and credulous than technically fitted to make them - the claims were repeated until "tradition " became "history," but as will appear later they cannot always be substantiated.

Our picture of mining in Wales in these early days still has to consist too much of extracts from the records left by writers of varying competence, and too little of knowledge based upon critical examination of material evidence that has survived or may reward purposeful search. But although scanty, evidence of Roman mining is not entirely wanting in Wales and in mining districts that extend from Wales into the adjacent English counties, and, aided by contemporary descriptions of Roman techniques in Europe and records of old mining practices that survived because they were so well adapted to the purpose for which they were intended, we can envisage the miner of Roman and Romano-British times at his work.

A Roman gold mine. Substantial remains of what can with good reason be regarded as a Roman mine occur near Pumpsaint, about 7 miles S. E. of Lampeter. Pre-Roman exploitation, if there were any, would have been on too small a scale for traces of it to have survived.

Strata near the junction between the Llandovery Series of the Silurian System and the underlying Bala Series of the Ordovician System were intensely folded during periods of crustal unrest and the originally soft shales were crushed and hardened. Subsequently the strata were invaded by waters that were highly charged with silica and contained also small quantities of gold, the minerals being deposited, for the most part, at horizons where the distorted condition of the strata allowed the solutions to accumulate. With the precious metal were metallic sulphides, including pyrites, which has a brassy appearance and is often mistaken for gold by those whose optimism exceeds their experience.

There are two gold-bearing bands in the crumpled strata, one about 90 feet above the other, and known respectively as the Roman and Pyritic lodes. The gold content of the ore is small - usually no more than about 4 dwt. to the ton of selected ore - but it is probable that richer ores occurred in the material that has been mined away; otherwise it is difficult to see why the Romans commenced work there at all.
Old workings extend for nearly a mile along the side of a hill on the east bank of the River Cothi
and in this instance they were so extensive that later operations have done little to obliterate them. At
first the ore was dug at the surface as from a quarry that in time developed into a deep trench - the
principal working was about 300 feet long and in parts about 50 feet deep - but as the gold bearing
layers varied from a few inches to a foot in thickness and were steeply inclined, the open workings
(opencasts in modern terminology) soon became too deep, and the amount of overburden to be
removed in order to reach the ore too great, for continued work on the same lines to be profitable.
Instead, the ore was followed by excavating cavern-like openings and tunnels where the auriferous rock
was most abundant or was richest, producing features that suggested the name Ogofau (caves) by
which the mine has for long been known. The name Dolaucothi mine has also been applied to it from
its nearness to the mansion of that name.

Writing in the Cambrian Register for 1818, Eliezer Williams, Vicar of Lampeter, said of the mine,
"Sir Joseph Banks and several other persons of superior discernment who critically examined it were of
the opinion that it must anciently have been considered as a gold mine," but no evidence to justify the
opinion was then forthcoming. The ore had been so thoroughly cleaned out before work was
discontinued that when Murchison examined the site during the course of the studies that provided the
foundation for his monumental work The Silurian System, he saw nothing to indicate what the mine
had yielded. The matter remained in doubt until about 1845 when De la Beche found a minute particle
of gold in a fragment of ore during the course of the first official Geological Survey.

Few contemporary objects have been found in the workings but there are records of wooden
beams for supporting the roof, a cradle-shaped vessel for carrying the ore, and part of a water wheel.
The ore was picked out by means of iron chisels and hammers, but the smooth concave surfaces which
some of the workings display suggest that the process known as fire-setting was used to shatter the
massive rock in order to facilitate its removal - an operation for which explosives are now used - and
this points to the Roman writer Pliny as a source of help in envisaging the miners at work.

The usual method was to light a fire of brushwood and logs against the face to be excavated and
when the rock was sufficiently heated to quench it with water. The expansion due to heating followed
by the contraction induced by sudden cooling shattered the rock and the cracks so produced were
planes of weakness, along which blocks of irregular shape could be dislodged by picks and wedges.
Although well adapted for opencast workings an objection to fire-setting underground was (as Pliny
observed) the noisome smoke and steam that were produced. Fire-setting continued to be practised for
many centuries, even after the invention of gunpowder. Georgius Agricola whose work on mining and
metallurgy (De Re Metallica, 1556) is a treasury of information upon those matters, gives a quaint
illustration of the process in operation, see Figure 1.

A discovery made during an attempt to re-open the mine in 1909 suggested the use, at least in the
working place explored, of an improved method of fire-setting, the art of which was subsequently lost.
The ash was usually about two feet from the working face, not against it, and its amount was small,
suggesting economy in the use of fuel. The rock-debris at the foot of the face was granular quartz,
resembling sand, not as usually the case, angular heat-cracked fragments. Experiments to discover the
conditions under which such debris could have been produced showed that the rock had been heated
rapidly and for a short time, and then quenched at a lower temperature than was reached by the usual
method. The temperature was related to a point at which the crystalline character of the quartz
underwent a fundamental change, but the knowledge must have been gained empirically and not as a
result of reasoning or instrumental test.

For reasons that will appear later, rock so disintegrated would have been more easily treated than
large fragments for the separation of the gold. Since the discovery was made during the examination of
a working that had not been previously explored and by a person competent to recognise its
significance, it may well be that the method was used also in other parts of the mine and that the not
very substantial evidence either failed to survive, if in exposed places, or was obliterated by earlier
investigators who did not recognise its significance.
Shattering rock and ore, to facilitate excavation, by lighting a fire against it and quenching the heated surface with water.

As the cavern-like openings penetrated farther into the hillside some form of ventilation became necessary. Pliny described a contemporary method for ensuring it. “As the air became noxious with depth,” he wrote, the condition would be "remedied by, constantly shaking linen cloths, thus setting the air in motion." This practice, like fire-setting, continued in use for long after Roman times. It too was described and illustrated by Agricola.

At a later stage in the development of the Ogofau mine two tunnels were driven from the opposite (northern) side of the hill. Cut through about 180 feet of barren rock, and at different levels, their purpose appears to have been to intercept the gold-bearing ores at greater depths than could be conveniently reached by continuing the work from the south, and also to facilitate the drainage of the workings. They were early examples of the adits or levels that were introduced as a novelty in the 17th century, as a means of reaching ore deeply buried in the hills of Cardiganshire and of draining the mines without the expense of pumping.

The use of the tunnels for drainage has been questioned on the grounds that near their mouths they appeared to slope downwards into the hillside, but whilst the upper tunnel, which has long been inaccessible, may have been used for haulage since a piece of wood shaped like a porter's yoke is said to have been found in it, water in the lower tunnel flows slowly towards the exit. The floor of that tunnel was paved along one side with large roughly set slabs as if to provide a dry surface for walking.

New information that came to light during attempts to re-work the mine about thirty years ago has been recorded by O. Davies, who was able to explore an old working, about eighty feet below the adits previously known and so low that it would have been flooded without the use of drainage machines. Such a machine would have been expensive, and its installation is probably an indication of the richness of the ore it was hoped to obtain. The rock had been dislodged by fire-setting and a good deal of timber was found. There were large beams, probably intended for use as supports but not so used, and others that from their shapes would have served as cross pieces to rest upon upright posts. There were also boards and branches for laying across the frames provided by the supporting posts in order to prevent loose stones from falling down on the workmen.
One of the most significant of the finds was a curved board about 41 inches long at the outer edge. Two roughly triangular holes about five inches long and fifteen inches apart had been cut in it, and along the outer edge there was a row of holes containing round headed nails. The curve suggests that the board was part of a circle thirteen or fourteen feet across, and the holes that it was a section of the rim of a drainage wheel of a kind found in Roman mines on the continent. Such wheels, which replaced the Archimedean screw for raising water, were rotated by treads on the rim or by grasping the spokes, and what is known of Roman practice elsewhere suggests that they raised the water by means of earthenware or leather buckets, the attachments for which are supposed to have passed through the triangular holes.

Because a Norman mound stands on a site overlooking the workings it has been suggested that they may have been in part, if not entirely, of Norman origin, but there is no documentary evidence to that effect. There was, on the other hand, a Roman settlement in the vicinity and the Roman character of the work is supported by what Pliny had to say about Roman gold mines in general.

After recording that gold was sometimes obtained by washing the sands of certain rivers, he said that in other circumstances they excavated hollows, supported for a time by arches of rock which were afterwards allowed to cave in, or else sought to reach the ore by means of horizontal tunnels or vertical shafts. This is what happened during the development of the opencast at Ogofau and the subsequent penetration of the hillside.

A human touch is given by Pliny's description of the measures taken to ensure the safety of the miners when the time came to allow the undermined rock to collapse, thus exposing a new face and providing a mass of debris that could be searched for ore. When the pillars that had been left to support the roof were cut away "the coming downfall gives warning that is instantly perceived by the sentinel who is set to watch upon a peak of the mountain. By voice as well as by signal he orders the workmen to be immediately summoned from their labours and at the same moment takes to flight himself."

Although, as the work proceeded, as little barren rock as possible would be removed, the excavated material would not be uniformly rich and after being smashed sufficiently small by means of hammers the obviously worthless material could be discarded and the selected ore subjected to further treatment. The products of normal fire-setting would have been, according to Pliny, broken, pounded, and ground to powder - operations necessary because the particles of gold were for the most part very small and could not otherwise be separated from the associated quartz. The debris from the improved method of fire-setting would be more easily reduced to the required small size.

Near the entrance to the workings at Ogofau there was a large block of stone, roughly quadrangular in shape, with faces some two feet across, each bearing depressions - obviously the result of attrition - made by the successive wearing of elliptical grooves moved progressively across the stone. A mining engineer who examined the stone some fifty years ago suggested that the gradual shallowing of the depressions towards their edges showed that the grooves were made by a suspended pestle swinging parallel to the major axis of the stone and moved laterally as a new groove became necessary. The only other way the depressions could have been produced would have been by two men, facing each other, alternately drawing and pushing a large stone over the material that was to be ground. There can be no doubt but that the stone is one of the mortars in which the ore was pounded, one face after another being brought into use as became necessary.

Tradition (according to Eliezer Williams) provides the stone with a name, Carreg Pumpsaint, and a more romantic origin, associating it with the five saints after whom (by one explanation) Llanpumpsaint derives its name. They, it is said, overcome with fatigue while on a pilgrimage to St. David's, rested their heads upon it, but a storm arose and "the drops of rain were soon congealed into hailstones which were driven with so much force on the heads of the weary pilgrims that they were beaten so hard against their pillow that the vestiges they left are still discernable." A more prosaic opinion cited by Williams was that miners used the stone, "not for a pillow, but for the purpose of clearing away the recommititious earth from the ore, and the cavities were formed by repeatedly pounding the drossy substance to obtain more valuable ore."

The gold in the powdered material was much heavier than the quartz and other minerals with which it was mixed and the separation was effected by a process resembling that by which the metal is naturally
concentrated in gravels in the beds of rivers - by washing the lighter particles away. This involved the controlled use of rapidly flowing water and arrangements to ensure a supply of water at a higher level than the washing floors, the descent to which would give it the necessary velocity and energy. Pliny refers to the toil and expense of bringing water along the ridges of hills to the place where it was required. The gradient had to be carefully controlled so that there would be a good head of water at the dressing floor, and the conduits had to be cut through the rock or carried by means of wooden troughs suitably supported on trestles. At the end of the conduit, he said, they dug a reservoir provided with sluices which, when open, would allow the water to rush with force down to the place where it was to be used.

This is exactly what was done at Ogofau. Water was taken from the River Cothi west of what is now Bwlch-y-rhiw farm, about seven miles away, just above a small waterfall with a drop of about fifteen feet. Thence it was conveyed to the mine by a carefully graded conduit - the fall is only about fifteen feet - that was mostly a rock-cut channel from 21 to 4 feet wide and 1- feet deep, and, where necessary to avoid a long detour, in wooden troughs supported by trestles; these have, of course, long since disappeared. As the water had to be carried in an open channel and not under pressure in pipes, the construction of so long a conduit, following a winding course along the sides of valleys and with so small a fall, called for skill such as the Romans are known to have possessed and exercised in the construction of the aqueducts that gave Rome so excellent a water supply.

At the mine end of the aqueduct, on the brow of a hill overlooking the workings and the washing floor, the water was led into a rock-cut tank and thence into a small reservoir at a lower level, in what is now a swampy hollow, south of the road to Caer. A depression in the hillside between the two in all probability occupies the site of a second tank. The upper tank had two outlets that could have been controlled by sluice gates, one parallel to the hillside and leading via the second tank to the reservoir and the other facing down the hill, towards a shallow trench leading to the adits below. The tanks and reservoir were high enough above the workings for the water discharged from them to descend with sufficient velocity to accomplish its dual purpose - to sweep away the debris resulting from mining and to wash the non-metallic ingredients from the powdered ore.

Apart from the pitted stone nothing has been found of the plant ‘used for the treatment of the ore but as the miners followed so closely the typical Roman practice as recorded by Pliny, it is not unreasonable to assume that those who worked at the washing floors did the same. In that case the pounded material would be spread in wooden troughs or in shallow trenches and water from the reservoir allowed to flow over it. At intervals on the floors of the trenches there would be placed either transverse boards (riffles) to interrupt the flow of the water and ensure the deposition of the heavier particles, or layers of what Pliny described as "ulex, a rough prickly plant," well adapted for arresting particles of gold whilst the lighter sandy debris was washed away. As the washing proceeded a 'concentrate' would accumulate on the bottoms of the troughs from which the gold could be picked out or isolated by further washing in shallow pans agitated by hand. This is another of the early operations described and illustrated by Agricola. It was also the practice when the troughs were lined with 'prickly plants' for the carpet of debris to be removed from time to time and burnt leaving the metal to be recovered from the ashes. Fragments of crucibles found near the workings may have been used to melt collected particles of gold.

The mine is situated near the junction of the Twrch and Cothi rivers, not far from where the streams were crossed by the military road between the forts at Llanio and Llandovery, so that the work could easily have been kept under military supervision and protection - mines, especially those for gold and lead, were regarded as imperial property.

The limits of the period during which the mine thrived are uncertain, but pottery found in association with it suggests activity at the beginning of the 2nd century A.D., quite soon after the Roman entry into the region. Attempts have been made, with varying but in general little success, to exploit the ore in modern times and reference will be made to them in a later chapter.

**Copper** :-Excavations for copper ores which may reasonably be regarded as having Roman associations occur on Llanymynech hill in Montgomeryshire. The ore - chalcopyrite with small quantities of the green copper carbonate, malachite - occurs in veins in the Carboniferous Limestone and was obtained from shallow pits and tunnels. The principal working, known as the Ogo or Ogof, began, like some of the gold workings at Dolaucothi, as a cave-like excavation and then followed the ore underground.
Three galleries radiated from the Ogo. One followed the main vein for about 200 yards and, dividing near its end into two, gave access to irregular passages dug to follow off-shoots from the vein. Two shorter galleries leading from the cave at right angles to the trend of the main vein were probably exploratory. Some shallow pits and opencasts near the western margin of the hill probably represent workings that were roughly contemporaneous with the excavation of the Ogo.

The condition of the walls of the galleries suggests that fire setting was practised and there is evidence that single-bladed picks were used for dislodging the rock. J. F. M. Dovaston, a barrister with antiquarian leanings whose home was near Oswestry and who had opportunities to explore the workings in the early part of the last century, described small holes at the ends of the galleries large enough to admit a man’s hand, and so disposed as to suggest that the ore ran off into narrowing fissures in the rock and was picked out with a long tool for as far as it was possible to reach. The ore was broken and sorted in the mine and much of the waste material was stowed in the inner galleries where heaps of stones were found, cemented together by stalagmitic material deposited from the calcareous waters that percolated through the limestone.

Habitation refuse and bones found in the cave suggest that the labourers lived in it. One skeleton was associated with a bracelet and an axe or wedge, and although Roman mine labourers sometimes lived in the workings it is possible that when the Ogo was abandoned as a mine other people lived and were buried in it. The period during which the mine thrived is uncertain but Roman coins recorded from it point to the 2nd century A.D., with occupation lasting into the 3rd.

Cakes or ingots of copper about a foot in diameter and 21 inches thick, stamped with Roman inscriptions have been found in Anglesey (especially in the northern and western parts of the island where at least 16 have been recorded) and also, though rarely, on the mainland in Caernarvonshire. These suggest that the Romans worked the copper ores on Parys Mountain near Amlwch and smelted them in the neighbourhood, thus anticipating by many centuries the working of a mine that was destined to become world famous.

The ingots were made by pouring the molten metal into a flat circular mould, perhaps a cavity in the ground. The central part of the upper surface of each disc is raised above the level of the smooth narrow marginal band produced as the metal cooled against the side of the mould. This was due to the escape of gases occluded in the molten metal and indicates the use of a sulphur-bearing ore like copper pyrites - the Parys Mountain ore is of this nature.

As the ore is massive and compact and would have been difficult to work with primitive tools the early operations would have resulted in shallow excavations that have been obliterated by tile more extensive workings of later days. Marks of fire-setting are said to have been observed whilst old excavations were being encroached upon, but they are not necessarily indicative of Roman activity, and there are records of the finding of stone hammers like those associated with other ancient mines in Wales, and blocks of stone slightly hollowed as if used as mortars.

Underground workings in Carboniferous Limestone penetrated by veins of copper ore at Great Orme, Llandudno, were probably commenced in Roman times because coins of the 3rd and 4th centuries A.D. have been found in the spoil heaps. Picks of horn and bronze and wedges of stone, found amongst the debris, suggest that the mine may have been worked before the arrival of the Romans, whilst bones found in one working show that, as at Llanymynech, people lived in the cavernous entrance and some were buried in the inner recesses. It would seem that, except for one source in Cheshire - Alderley Edge - Wales provided all the copper that was mined by the Romans in Britain.

Iron :- Iron was one of the commodities the Romans hoped to gain from their conquest of Britain and they made use of such ores as were adapted to the smelting processes then known. It is, however, unlikely that their mining would have been more extensive than was necessary to satisfy local needs for the rich ores of Gaul would have made large-scale export from Britain unnecessary. It is no doubt for this reason that the mines do not appear to have been under official control, as was the case with those yielding gold and silver-bearing lead.

Tangible evidence for Roman iron-mining in Wales is less abundant than that for smelting because ample supplies of ore were to be found near the surface and the shallow open pits from which
it was dug were obliterated by the more extensive operations of later miners or have been obscured by soil or vegetation.

**Haematite** - a rich ore consisting of oxide of iron - occurs in the Carboniferous Limestone at a number of places in Glamorgan between Tafl’s Well, north of Cardiff, and Llanharry, south of Llantrisant, all of them just outside the southern margin of the South Wales Coalfield. The ore often exposed at or near the surface draws attention to itself by the rich red tint it imparts to the rocks with which it is associated. As old workings (e.g., at Ty-isaf, near Llanharry) have been encroached upon in modern times fragments of coarse red pottery have been found. In 1762 a coin of Antonius Pius (2nd century A.D.) was unearthed as the debris of ancient excavations was being removed at Bolston Gaer, near Miskin, and heaps of slag found in the neighbourhood suggest that the ores were exploited on a fairly large scale but the smelting was inefficient by later standards because some of the slag was taken to be re-smelted at a neighbouring iron works. Not all the ore was smelted locally because there is an abundance of slag under the road connecting the north and south gates of the Roman fort at Cardiff, and there are indications of Roman movement along a road from Llantrisant that crossed the orefield and went via Llandaff to Cardiff. Similar ore lay nearer at hand at Tafl’s Well, north of Cardiff, but there is no evidence that the Romans made use of it.

Iron slag and the remains of a smelting hearth in association with the early 2nd century villa at Ely, some two miles west of Cardiff and connected with the Roman road from Caerwent to Carmarthenshire, also indicate the transport of ore because none occurs in the immediate vicinity. John Storrie, who first examined the site in 1893, recorded the finding of fragments of two kinds of iron ore amongst the debris - one resembling some highly ferruginous Carboniferous Limestone that occurs near Rhiwbina, about 5 miles away in a direct line to the NE, an ore with very distinctive characters because it contains an abundance of fragments of the stems of fossil crinoids (sea-lilies), and the other resembling a more compact earthy ore that occurs near Wenvoe, about 2-1 miles to the SW. Unfortunately, no specimens are now available for examination, but Storrie was a competent observer and his identifications can be safely accepted. That being so it would appear that the ores in the localities referred to were worked on a small scale by or on behalf of those who occupied the Ely villa. It was not until the middle of the nineteenth century that attempts were again made to exploit them - at Rhiwbina unsuccessfully, and at Wenvoe with indifferent success for about 5 years (1859-64).

Although no recognisable Roman iron workings are now to be seen in Glamorgan we can envisage their character because the methods adopted would have been similar to those employed in the Forest of Dean where similar ores occur under similar conditions. There, the earliest workings, probably commenced before the arrival of the Romans and continued by them, resulted in irregular pit-like excavations from 20 to 30 feet deep, with short cavern-like galleries driven from the sides, or pits sunk into the bottom, when bodies of rich ore were encountered. Such excavations, the extent and number of which was increased by post-Roman miners, are locally known as Scowles, a name of uncertain origin; they make the ground very uneven, while giant beeches and yews combine to make the scene grotesquely picturesque.

No provision was made for draining the workings, probably because the country rock, the Carboniferous Limestone, was well provided with fissures through which water could pass, and they showed few signs of planned operation or mechanical skill such as characterised the gold mine at Dolaucothi. This does not necessarily indicate incompetence on the part of the miners because, with ore so situated and usually softer than the rock in which it occurred, systematic deep mining would not be needed. When one excavation became unproductive or difficult to work it was only necessary to open another nearby.

A chance discovery during excavations by R. E. M. Wheeler in the vicinity of a Roman temple at Lydney, also in the Forest of Dean, provided an illustration of a Roman method of planned exploration for an ore body. In this instance it is not necessary to rely upon records of workings that no longer exist or upon what can be seen in workings the original characters of which have been obscured by the activities of curious visitors or serious observers, and the following account is based upon an examination of the mine in the condition in which it had been abandoned by its 3rd century operators.
Excavation of a Romano-British hut-floor in search of traces of earlier occupation revealed a trench that had been cut below the surface level of the surrounding rock. The upper portion was filled with mixed debris containing fragments of Roman pottery and a coin of Carausius (A.D. 287-293) and the lower part contained broken pieces of rock. The trench proved to be about 5 feet deep and from 3 to 4 feet wide, and after extending for about 18 feet it gave place to an underground passage - like the mouth of a railway tunnel at the end of a cutting.

The entrance to the passage had not been completely blocked by debris and as there were numerous signs of excavation for iron ore in the vicinity - irregular debris-filled holes - it was assumed to be a mine adit and the writer was invited to discover how far it penetrated and what it would reveal. The passage varied in width from 18 inches to 24 and had, like the trench outside, been cut to follow a joint-fissure in limestone (a dolomitic variety of the Carboniferous Limestone). The fissure was filled with hard purplish red clay or marl, rich in oxide of iron. One side of the passage followed the line of the joint and was relatively smooth, whilst the opposite side was uneven because it had been excavated in the rock.

At first the floor of the passage was strewn with debris like that encountered in the lower part of the trench. This was not material that had fallen from the sides and roof for they were intact and bore the marks of the tools by which they had been shaped; nor was it material produced during the cutting of the passage for it brought the floor, near the entrance, to within little more than 3 feet of the roof - an inconveniently small space in which to work. It was, no doubt, material thrown in after the abandonment of the passage - the tail-end of the debris with which the lower part of the trench had been filled.

The roof of the passage inclined downwards, but less steeply than the slope of the debris on the floor, so that the headroom gradually increased to nearly 5 feet: then, about 17 feet from the entrance, there was an excavation in the roof sufficiently extensive to permit a man to stand upright and manipulate his tools. Beyond this the excavation-debris which had not been removed nearly filled the passage and prevented further exploration.

The passage was evidently an exploratory road cut to follow a vertical band of ferruginous clay that filled a joint-fissure in the rock. In the Forest of Dean such clay, known to local miners as clod (although it has no relation, either in nature or mode of occurrence to the ‘clod’ of the coal miner), is often sufficiently rich in iron to have been regarded as ore, but in the present instance the low iron content of the material removed indicates that the work was not undertaken for the purpose of recovering ore. The miners were evidently following the clay in the not unreasonable but unrealised hope that it would lead to an ore-body. Starting as a chimney-Eke cavity one of the roof-excavations penetrated forwards and upwards, tapering as it went, for a distance that could conveniently be reached by a miner manipulating a long bar, whilst the other went backwards and upwards for a shorter distance.

In what remained of the end face of the passage the undisturbed clay was continuous between its two enclosing walls of rock and on it there were the marks of tools - sharp vertical furrows made by a pick-hammer like those used throughout the history of mining for the removal of soft or fragmentary material and well adapted for use in a confined space. Similar marks occur on the roof, especially near the exploratory excavations, and on the thin layer of clay lining the smooth side of the passage. Very few could be seen on the opposite side, with its irregular surface produced by the removal of stone intersected by bedding planes and small joints. No actual pick was found in the debris, but a toy model, made of iron and about 3-1 inches long, was recovered from the floor of the late 3rd century hut adjoining the entrance to the mine. It resembled the full-size picks found in Roman iron-mines in Spain.

The character of the excavation itself left little room for doubt but that it was the work of Roman miners who were carrying out a planned operation. The passage and its roof cavities were not the result of haphazard digging, and justify the belief that mining in Glamorgan would have been similarly purposeful as soon as it became necessary to seek or to follow ore that could not be conveniently obtained from open excavations. The Romans may, indeed, have been responsible for what were described as “old workings which by their form appear to have been of Roman origin” seen near Llechau in the neighbourhood of Llanharry, for it was within their competence to have made them, but
circumstantial evidence suggests that they are more likely to belong to the Tudor era of iron mining, and they will be referred to in that connexion.

**Lead**: The Romans used considerable quantities of lead, mostly for water pipes and tanks, and Rome enjoyed a well organised water supply in which water received from stone aqueducts into tanks was distributed to all parts of the city through leaden pipes. An account of the history and operation of the undertaking was prepared by Julius Frontinus (c. A.D. 97) who subdued the Silures, founded the fortress of Caerleon, and later became water commissioner in Rome.

Britain was an important source of lead in the Roman empire, and the extent of the industry is indicated by the fact that more than 60 ingots or 'pigs' of lead, most of them between 150 and nearly 200 lb. in weight, have been found in various parts of the country, presumably in many instances having been either lost or stolen in transit to the continent.

The molten metal was poured into moulds with splayed sides and ends, giving rise to flat rectangular slabs with bevelled edges. Letters in reverse were stamped into the bases of the moulds so that the smaller face of each 'pig' bears an inscription that often gives information from which the place of origin and date of manufacture can be inferred.

The Romans were obtaining lead from mines in the Mendips as early as A.D. 49, only six years or so after their second invasion, and as they gained control of other parts of the country they developed mines in Derbyshire, Yorkshire, Shropshire, Flintshire, and probably also in Denbighshire and Cardiganshire. Of the Welsh ventures the most important were in Flintshire.

Six 'pigs' with inscriptions indicating Flintshire origin are known to exist. Most of them were found in the neighbourhood of Chester, whilst one found near Tamworth in Staffordshire, suggests transport along Watling Street. Only one, the latest to be recorded (in 1950) was found within the confines of the county - at Carmel near Holywell. According to Camden (writing in 1590) some 20 pigs were found on the shores of the Mersey, near Runcorn a location which has prompted the suggestion that they were lost *en route* to the Roman site at Warrington. Their inscriptions indicated a Flintshire origin but their subsequent fate is unknown - they were in all probability melted down as a convenient source of about a ton and a half of metal.

Although the 'pigs' are indubitable evidence of lead mining by the Romans, equally indubitable remains of their mines are not forthcoming. The ore being, as Pliny recorded, abundant near the surface, the Roman mines were shallow excavations and small underground workings that have been either obliterated by the more extensive operations of later times or are now too obscure to be recognised, and whilst there are numerous published references to tools and coins said to have been found *in* Roman lead mines in North Wales an examination of the sources of the information reveals more of wishful thinking than of valid evidence.

It has long been customary to regard Ffos y Bleiddiaid, a long trench on the north side of the rock near Abergele that has Castell Gawr on its summit, as a Roman lead mine on the strength of the finding there of "some hammers and tools almost decayed to dust." In his *Handbook for the Vale of Clwyd* (1856), Wm. Davis said that the excavations involved as much as can be done without the aid of gun-powder," and that "in driving into the mountain some years ago, the miners discovered that the Romans had dug deep into the bowels of the earth before them. They had followed the ore where it was large enough to admit of a small man and where it opened out into a larger chamber they had cleared it quite away. When the vein became too small to admit a man they were obliged to relinquish the ore ... They seem to have worked the mines completely out. They have never paid any other companies."

There can be no doubt but that the workings described are very old and may indeed embody Roman work, but the available evidence does not justify the description "some of the largest and most perfect Roman mines in Britain" that has been applied to them, probably misquoting the author of the *Handbook for the Vale of Clwyd* who said that Castell Gawr was "one of the most complete Roman fortified camps in the kingdom!"

Similarly, although the Romans undoubtedly mined lead at Talar-goch near Dyserth in Flintshire, excavations that have been traditionally claimed as of Roman origin yield no conclusive evidence to that effect. In a well-known work on prehistoric and Roman Wales, for example, it is stated that a
Roman coin "found in an old floor of the Talar-goch lead mine, near Dyserth, shows that the cutting was open about the middle of the third century," but this, misquoting or misinterpreting the published reference on which it is based, is a claim that cannot be substantiated. In recording the discovery of the coin the manager of the mine said that it had been found under the ore dressing floor. This could be taken as implying a floor then in use (1887) although the writer of a communication to the Chester Archaeological Journal refers to it as a disused dressing floor. Neither writer claimed that it was a Roman dressing floor and in any case a coin (it was later identified as of Gordian 111 - A.D. 243-4) found on or under a dressing floor throws no light upon the date of any surviving mine working.

As will appear later there is documentary evidence that lead was being produced from time to time from the 13th century onwards, and, whilst the coin may be taken as indicating that lead ores were worked here by the Romans, as it was in other parts of north Wales, the most that can at present be said of old workings that can still be seen or are recorded as having been seen but do not now exist, is that they are earlier than the modern period of intensive mining that began in the middle of the 18th century. The strings of ore that appear in the rocky sides of Graig Fawr would have attracted attention and have been easily worked, but it is not likely that the Romans could have been responsible for any of the more deeply-seated workings that lie beneath the thick covering of water-bearing Glacial deposits that rest upon the Limestone.

Although recognisable traces of their mines had disappeared even before Pennant's time, there can be no doubt but that the important lead ores of the Halkyn and Minera districts were worked by the Romans for the remains of their lead smelting floors have been found at Pentre, on the river Dee, near Flint. They were in a ruinous condition but the evidence upon which they could be dated suggests that the site was occupied from the end of the first century A.D. to the middle of the second.

Coins and other Roman relics have been found, either alone or in association with lead slag, in other parts of Wales where lead ores occur, e.g. at Llanymynych Hill near Llanidloes ; near Trefeglwys in the Upper Severn Valley in an old excavation on Cefn Pwll Du, near Ruperra in Monmouthshire, and near Machen, also in Monmouthshire, where coins were found in an old working and pieces of lead and lead ore associated with charcoal were found in Roman occupation layers exposed during the making of a road. But whilst these discoveries may be accepted as evidence of lead production in Roman times they throw no light upon the working conditions in the mines.

Substantial remains of leaden water pipes of 7-inch bore were found during the excavations at Caerleon by the late V. E. Nash Williams. They were part of a water-supply system of typical Roman pattern and their presence at Caerleon is not surprising, seeing that the fortress was founded immediately after the final defeat of the Silures by Frontinus. There were also various small objects of the same metal and it is tempting to think that the ore might have come from the workings at Machen or Cefn Pwll Du, which are only about 8 miles away, but in that region the ore is rarely present in paying quantity and efforts to exploit it in modern times have been short-lived. The quantity of metal involved in the pipes alone is such as to suggest derivation from a richer source, e.g., the highly productive mines of Mendip.

Some ancient workings for lead (possibly also for copper) in the vicinity of the Cwmystwyth mines on the slopes of Plynlimon probably indicate Roman activity. The principal ancient working is an open-cut some 50 yards long and from 10 to 12 yards wide. As it is partly filled with debris the original depth is not known but it is reasonable to assume that not less than 5,000 tons of rock was extracted. The selected ore was pounded by stone hammers fashioned from a hard grit of local origin, and of a type regarded by Oliver Davies as” old Celtic, approximately contemporary with the Roman period, though surviving after it.”

Silver: Although they found no silver ore in Britain the Romans obtained a considerable amount of that metal from ores of lead. Silver is present in many lead ores and remains in the metal at the end of the smelting operation. It can be isolated by roasting the silver-bearing lead in the presence of air, causing the lead to combine with oxygen to form lead oxide, litharge, and continuing the process until only the silver remains in a metallic condition. The lead is not wasted as a result of the refining operation because the litharge can be smelted as if it were an ore and the metal recovered.

At first the recovery of silver would have been conducted in a hearth or shallow crucible of clay and the lead oxide removed as it formed (or, as Richard Watson, Bishop of Llandaff put it, when
describing the process as carried out at Holywell in 1782, "driven off, as cream is blown off from milk, by the blast of the bellows" in order to expose more metal to the heated air, but discoveries at Silchester near Reading show that the Romans were aware of the value of bone-ash (burnt bones) for the purpose. Hearths or crucibles made from that material absorb the molten litharge as blotting paper absorbs water, and are not corroded by it as are vessels made of clay. It was not until well into the nineteenth century that more convenient methods of recovering the silver were introduced.

It is likely that the silver produced by the Romans in Britain was exported, for very few objects of silver have been recorded from their sites. The silver head of a standard such as was used by orderlies on the personal staff of the provincial governor was, however, found at Caerleon.

Many of the leaden 'pigs' bear the stamp EX ARG or EX ARGENT. It has been suggested that this means 'desilvered,' but as some that are so marked contain more silver than those not bearing the stamp the inscription more probably means 'from the silver works.' It may have stood for EX ARGENTI FODINIS, meaning that the pigs were the products of mines that were regarded as potential sources of silver.

None of the 'pigs' of Flintshire origin bear the stamp but their silver content ranges from less than a quarter of an ounce to about two thirds of an ounce to the ton, whilst a piece of Roman lead found on the Pentre smelting site had over an ounce of silver to the ton and the ores in that region may contain from five to ten times as much as that. There can be little doubt but that the lead of the Flintshire 'pigs' had been de-silvered, and it is evidence like this, relating to the smelting and treatment of the ores that helps in the reconstruction of our picture of the extent and distribution of Roman lead mining ventures in Wales when direct evidence in the form of mines is not forthcoming. The inclusion of the names of Vespasian and Domitian in the inscriptions on 'pigs' known to be of Flintshire origin indicates that they were made from ore mined in the last quarter of the first century A.D., and also that, since silver was the more important product, lead mining was an Imperial monopoly.

IV. THE DARK AND MIDDLE AGES

Almost all the people live upon the produce of their herds .... They pay no attention to commerce, shipping, or manufacture.
Ciraldus Cambrensis. The Description of Wales
A.D. 1188.

The Romans introduced new standards of living and new skills and were both able and willing to exploit the metalliferous deposits of Britain to a greater extent than had previously been the case, but after they left, mining in Wales languished almost to the point of disappearance.

For the centuries preceding the Norman Conquest negative evidence is to be found in the Welsh Laws that were codified by flywel Dda. This entitles us to assume that certain things were not done because there is no indication that they were. There are, e.g., in the Dimetian version of the Codes, references to wild animals and hunting, to tame animals and crops, to houses and farms and to implements and utensils, but no mention of mines or quarries or of tools or appliances associated with them.

Iron seems to have been a comparatively rare commodity because the price of an axe was two pence, although a plough or a day's ploughing cost no more. A large anvil cost 60 pence and a set of blacksmith's tools 120, but a three years old horse only 96. The high value of objects made of iron may have been due to scarcity because only a small amount was mined in Wales or it may have resulted from the high cost of transport from other centres of production, but that the metal was regarded as of special importance to the community is indicated by one of the Triads -Three things in common to a country and kindred; mast woods; hunting; and an iron mine; and exclusive ownership is not to be claimed to one or the other of them. The Triads, of which two series have been preserved in early Welsh manuscripts, were forms of expression in which persons or things were grouped in threes, with a title indicating the points of likeness.
There are indications that lead ores were being mined, if not actually in Wales, at least in regions from which they could be easily obtained, but we have no information concerning the extent and location of the mines. Giraldus Cambrensis described the church of St. John the Baptist at Llanthony (built in the early part of the twelfth century in the heart of the Black Mountains) as having a roof of lead, and there are thirteenth century references to the use of lead for the roofs and gutters of houses.

It is recorded in the *Annals of Margam* that about 1231 the Lord of Glamorgan had discovered lead, silver, and iron, but the locations are not mentioned. A few years later, Philip, son of William de Cornely, granted to the Abbey the right to all the iron and lead on the cast side of the road from Newton Nottage to Cornelly, with right of way for two-wheeled and four-wheeled carts, but such grants do not necessarily mean that they were successfully implemented.

Interest in mining seems to have received new impetus in the time of Henry III, but, again, references to ores are not accompanied by information relating to the mines. Indications of lead mining in the time of Edward I include a grant to the burgesses of Flint of timber from local woods for the purpose of smelting their ores, but the work was on a small scale because for 1283 the profit was only £5. In another year it was 5s., due to pestilence which had resulted in the death of many miners and the refusal of others to work.

Also for the time of Edward I the accounts of the Chamberlain of Chester (preserved in the Public Record Office) include references to annual payments by the miners of Haliwell (Holywell) for their liberties, and there were also payments in 1301-2 for lead from the mines at Englefield, but the accounts for 1305-6 include, for the same mines, "nothing inasmuch as the minerals taken from the lead mines in this year were not yet purified by fire on account of a deficiency of timber." The deficiency appears to have been temporary because in subsequent years the payments ‘were resumed. [58] Some of the lead was used by William le Plummer of Flint for work on the roofs of the castles at Flint and Rhuddlan and iron from the mines at 'Ewelowe' was used for the castle at Flint. [58, p. 161]

The Register of Edward the Black Prince includes mid fourteenth century references to the smelting of lead ores from mines at Halkyn and near Bodelwyddan for use in roofing the castles built by Edward 1, whilst later in the century John de Helagh was appointed steward of the lead mines in Flintshire. During the reign of Richard 11, however, only enough metal was produced to supply the needs of the castles and manors in the neighbourhood.

Even at this early date there seems to have been a scarcity of skilled miners so that most of the mining in Wales was directed if not actually done by "outlandish men" introduced for the purpose and liable to be moved as necessity required. During the reign of Edward 1 some Englishmen were brought to work iron mines and a forge near Wrexham, leaving a record of their stay in the name of the township, Moreton Anglicorum, whilst in 1295 lead miners from North Wales were sent to cope with increasing activity in the mines of Cornwall.

Early in the following century German miners were brought over to smelt copper ore that had been discovered near Rhuddlan, but the venture failed because the ore proved to be of little value. Memoranda in the lists of "Necessary Expenses," recorded that "the aforesaid miners could make nothing of the said ore and therefore immediately the said trial had been made they were discharged," also "that the value of the copper produced by these miners would not pay for their wages." The value of the ore must have been very small, because a "miner who helped the aforesaid [German] miners—received 3d. a day, and "two other workmen digging the ore from the aforesaid mines," only 2d. a day.

Although poor in copper the ores contained lead and there were payments "To Robert Fynour for making three fodders of lead from the ashes left by the aforesaid miners as of no value, and to show how much gain he could make from the said mines.---His wages were 6d. a day, and a fodder was a little less than a ton.

In 1380 a "Bill of Privy Seal" gave Ralph le Leche and Ralph de Bagstowe authority to "take two miners and three other suitable workmen in the Peak of the County of Derby, bring them to Flint, and put them on the lead works there." Mine work seems to have been by no means popular because the two Ralphs were given "full power to imprison the disobedient." Ralph le Leche was probably the brother or son of John Leche, surgeon (leech) to Edward 111.
It transpires therefore that during a large part of the millennium after the departure of the Romans there was little activity in the metal mines of Wales. From the twelfth century onwards there are records (mainly relating to lead) that indicate a revival of interest and a limited amount of production, but for this long period we must be content with meagre indications that mining took place and it is not likely that we shall ever know much, if anything at all, about the mines themselves. It may well be that some of the ancient workings dating from before the introduction of gunpowder—workings often attributed to the Romans simply because they are obviously old—belong to this period.

A factor that militated against the development of mines in Wales, in spite of the interest indicated by the grants to search for ores, was the remoteness of many of the promising locations and the high cost of transport. The Minister's Accounts relating to the castle at Brecon (c. 1327) for example, include an amount of 26s. 11d. for lead bought at Shrovesbury, but the cost of transporting it was 24s. 5d. Ore bought at Shrewsbury is more likely to have come from the neighbourhood of Minsterley than from the less accessible ores in Montgomeryshire.

THE SECOND PERIOD
From the Tudor Renaissance to the Mine Adventurers

V. THE TUDOR RENAISSANCE AND THE MINES ROYAL
.... around Plynlymmon's brow,
Where precious minerals dart their purple gleam.
John Dyer. The Fleece, 1757.

A new era of mining in Wales began when Henry VII, in the first year of his reign (1485), made Jasper, Duke of Bedford and certain others Commissioners and Governors of his metalliferous mines in England and Wales for a period of 20 years. The metals included in the grant were silver, gold, lead, tin, and copper, and the grantees were to pay to the king "the fifteenth part of pure gold and silver, and to the lord of the soil the eleventh part with liberty to dig and search, etc., except under the Houses and Castles of the King and his subjects."

In his Fodinae Regales (1670) which was a history of the "Chief Mines and Mineral Works in England and Wales," Sir John Pettus remarked that the King, by his wise action in granting this commission and "in other ways raised vast sums of money and, left his rich coffers to Henry VIII. Who added to the bulk by the sale of Abbies, etc. But before Henry VIII, his death, almost all the Treasures of his Father and his own were consumed, and what remained was left to Edward VI, an Infant, whose experience could not guide him to the Care of such affairs; then followed Queen Mary, who matching Spain, was thereby interested in the Wealth of Europe, and needed no other support: so this concern stood neglected for above 70 years." The Duke of Bedford and his colleagues do not appear to have been very active in Wales, although Leland, writing in 1538, mentioned traces of mining and smelting lead at "Clothmoyne" and a "great mine digging for Leade in Conuestwith."

The revival initiated by Henry VII did not get into its stride until the days of Elizabeth, when it became more than ever necessary to exploit the country's mineral resources to provide wealth for the Treasury and metals for making munitions. About three years after her accession Elizabeth brought some experienced miners from Germany and in 1564 granted the mines in Wales and certain counties in England to one of them, Daniel Houghstetter (Hochstetter), a partner in an Augsburg firm concerned with mines in the Tyrol. Amongst other things he revived the work in Cardiganshire but when he commenced operations in Cumberland, within the domain of the Earl of Northumberland, the Earl objected on the grounds that the land had already been granted to him by the Crown. The matter was argued before Judges at Westminster, who gave it as their opinion that notwithstanding the grant of lands to the Earl the Queen had the right to search for treasure in anyone's ground.

This ruling profoundly affected the trend of affairs in Wales, because in order to prevent a recurrence of such disputes the Queen, in 1568, created a Corporation of 24 persons, with William, Earl of Pembroke, as the first Governor. It was entitled "The Society for the Mines Royal" and was given "the Grant and care of Gold, Silver, Copper etc. within 8 English counties ... and all of Wales."
Through its leases to potential operators the Society was responsible for the development of several mines in Cardiganshire.

The Crown's main interest was in precious metals, and the emphasis on the mines of Cardiganshire was dictated by the fact that many of the lead ores were rich in silver. A Mine Royal was one which yielded gold or silver in such quantity that the value of the precious metal was greater than the combined cost of extracting it and of the base metal that was lost in the process. Such a mine belonged to the Crown by prerogative. Although apparently simple the definition did not prevent disputes regarding its application because the amount of silver that could be extracted from the ore depended in large measure upon the skill (or desire!) of the operator. To cite examples, although they disturb the chronological sequence of this review, when Sir Hugh Myddleton was a lessee of the Society in the early part of the 17th century, he came into dispute with Sir Richard Pryse of Gogerddan concerning a mine at "Tallabont in Wales, whether Royal or not Royal ... whereupon several eminent lawyers subscribed their opinions and the matter was soon quieted." Many years later, a similar dispute arose when the ore at Bwlch yr Esgair on the estate of Sir Carbery Pryse was being developed under a lease granted to Sir Humphrey Mackworth, and this, as will appear in due course, resulted in a radical change in the law that, in effect, broke the monopoly of the Mines Royal Society.

The operators of the Mines Royal, like the Romans many centuries earlier, used bone-ash to absorb the litharge produced during the extraction of the silver from the smelted lead, for there are references in 1578 to payments for "2 men to gather the bones of beasts perished on the mountains, as also from good towns and for "burning bones and preparing them to ashes."

In 1580 Thomas Smythe - referred to as Customer Thomas Smythe when he became a collector of customs in 1557-67, who had looked after the Society's interests in Cornwall, was granted a lease of mines in Cardiganshire where his manager, Charles Evans, dug shafts in the Cwmsymlog district. Local support for his project seems to have been forthcoming for a member of the Herbert family, probably aware that his kinsman William Herbert, Earl of Pembroke had been Governor of the Mines Royal, is said to have built the original mansion of Hafod in the Ystwyth valley as a result of "having embarked upon some mining ventures in the neighbourhood." Unfortunately Smythe's other ventures were not successful and after a short period of activity during which about 40 men were employed in his Cardiganshire mines they were abandoned and remained idle for many years. A factor contributing to the stagnation of the industry at this time was the dearth of experienced miners to replace, as they died, the Germans brought over by the Queen.

The next important operations were undertaken by Sir Hugh Myddleton, born in 1560 in the parish of Henllan in Denbighshire, and son of Richard Myddleton, for many years Governor of Denbigh Castle. Amongst his numerous activities Hugh achieved success in cloth making in his own county, completed the New River scheme for augmenting the water supply of London, reclaimed land at Brading in the Isle of Wight, conducted goldsmith's and banking businesses in London and, early in the 17th century, embarked on mining ventures in Cardiganshire. The last named were very successful and when he was created a Baronet in 1622 one of the reasons given for excusing him the fee usually imposed in such circumstances was, "For finding out with a fortunate and prosperous skill, exceeding industry and no small charge, in the county of Cardigan, a Royal and rich mine, from whence he hath extracted many silver plates which have been coyned in the Tower of London for current money."

Myddleton took a lease of the Cwrnsyrnlog mine-Cumsumblock or Consumblock in many contemporary records, Korneshomelocke in an enquiry by Sir Owen Wynn of Gwydir, Cansomloch in the "Itinerary" of John Ray (1658), and Anglicised to Come-some-luck, in reference no doubt to the fortunes it yielded. He paid the Mines Royal Patentees £400 a year but the silver content of the lead was so high - said to be as much as 65 ounces to the ton - that his profit amounted to £24,000 a year. To meet the increasing demand for silver he was, in 1625, authorised to impress labourers from any part of the kingdom to work in the mines.

Unfortunately, instead of using his huge fortune for the exploratory work and development that is so necessary for the successful continuance of mining, he spent it on the New River scheme for London, and when he died in 1631 his Welsh mines were in a state of neglect. As the author of Fodinae Regales observed when referring to the decline of Myddleton's fortunes, "great wits and purses seldom know how to give bounds to their designments and by undertaking too many things, fail in all."
Others besides Myddleton were attracted by the prospect of wealth from the lead mines. In 1617 a twenty year lease of the mines and ores of lead in a parcel of land called Craggiemoine in a tenement called Briwriant in the parish of Llanvyhangell y Croythen, Cardigan was granted by Sir Henry Hobart (chancellor to Charles, Prince of Wales, later Charles 1) to William Winckfield and Matthewe de Quester, both of London although presumably, from their names, of foreign origin. The rent was £100 per annum, but the mines seem not to have been as productive as was anticipated or else the method of working them was inefficient, because ten years later when the lease was renewed to Matthewe and Josse (Josiah) de Quester the rent was only £25.

Whilst Myddleton and others were active in Cardiganshire the Wynns of Gwydir in North Wales were not unaware of the potentialities of their own region and there are several references in the Wynn family papers to lead mines, but the operations seemed to have been on a small scale and did not pay. In 1621 the Wynns were complaining of the low price of lead and of competition from abroad but in the following year Maurice Wynn wrote from Hamburg to his father, Sir John, suggesting that certain mines should be reopened so that 24 tons of lead lying at Beaumaris could be increased to 100 tons and shipped to the continent. A little later he advised his father not to close the mines because the value of lead was rising and their own lead was purer than that from the mines in England whence London was mostly supplied.

In 1625, not long before his death, Sir John wrote to Myddleton mentioning the latter's success in reclaiming land in the Isle of Wight and suggesting that he might embark on a similar scheme in the estuary of the River Glaslyn in order to reclaim Traeth Mawn. The letter continued, "I have leade oare in my ground in great store . . . 'yf yt please you to come hither ... yt may be that you shall find here that will tend to your commoditie and myne." Myddleton replied that he felt unable to embark on new schemes and did not take part in the development of any mines in north-eastern Wales. The plan for reclaiming Traeth Mawr was implemented nearly 200 years later by Mr. W. A. Madocks who built the embankment from the Merionethshire side of the estuary to Portmadoc.

Sir John's successor, Sir Owen, sent to Cardiganshire (in 1655) to "enquire if there by at the lead mines any outlandish man that bath skill in mines in the ground," but he was not successful in finding one and many years were to elapse before profitable mining was resumed in the north-east. Not for the first time in their history the remoteness of many potential mines militated against their successful development. In an enquiry about a lead mine at Gamallt Sir Owen said that the work must be in summer because the mine was high in the mountains and far from any house and inconvenient for the miners to come to work. In addition, he added, "Firing, timber, a house to lodge in and a house to keep implements in will be needed."

The next great figure in Cardiganshire lead mining was Thomas Bushell. As a boy he had been in the service of Sir Francis Bacon who, observing his natural talent, befriended him and, as Bushell gratefully acknowledged, instructed him in "many secrets in discovering and extracting metals."

A few years after Myddleton's death Sir F. Godolphin, a Cornish mine-owner, suggested that Bushell should collaborate with him in developing the mines in Cardiganshire. He thought, no doubt, that Bushell's knowledge of hydraulics would enable him to devise methods for ridding the mines of the water that limited the depth to which they could be worked, and the two partners secured a lease from Myddleton's widow. Godolphin died soon afterwards and in 1637 Bushell commenced operations on his own.

His first attempts were not very encouraging. His predecessors had sunk shafts from sites on the tops of mountains and foul air and water prevented access to the more deeply seated ores. Drainage and ventilation were necessary before ore-winning could be resumed on a large scale. In addition to practical difficulties Bushell encountered local opposition and became involved in a dispute with Lady Myddleton over the terms of the lease, but, undeterred, "1 began," he wrote, "with a cheerful heart to cut through the Rockes of the mountains at their lowest level." It was about four years before his "hopes could give any happie assurance that the minerall beds of the earth's riches lay fast lock'd in these barren Rockes."

Whereas the earlier prospectors had relied mainly on opencasts and shafts sunk downwards from the surface, and Myddleton "by an engine [i.e. a pumping engine] had wrought the vein several yards
under water," Bushell, in addition successfully applied the method that had been tried by the Romans at Ogofau and drove nearly horizontal tunnels (adits or levels) at the lowest possible situations on the sides of the hills. The object was to cut the deeper parts of the lodes and provide an outlet for water, capable of draining all the workings above and so, in many instances, make it possible to work during wet wintry weather as well as in summer. The adits were driven in a slightly upwards direction "so that all the water they meet with conveyeth itself away as in a channel by the declivity of the place." They also served as passages along which ore could be carried without the expense of winding it up a shaft. Writing of his work in A Just and True Remonstrance of His Majesty's Mines Royal in the Principality of Wales, 1642, Bushell described how he "cut six hundred fathoms thorow the rock at the lowest levels for discovering the best vein of Cumsumblock, and two hundred fathoms thorow the mountain at Tallabont," and several adits one above another at Koginean [Goginan]." The adits functioned "day and night for the Drayning of the water, which Sir Hugh Myddleton did not do, they only working upon the superfices of the earth, their work being drowned with water before they could sink to the best of the vein." The men engaged in the operations included 60 miners mentioned by name, 200 others unnamed, with, as ancillary staff, 3 moniers, 6 refiners, 9 smelters, and 9 washers.

FIGURE 2

SHAFTS ADITS AND WINDING GEAR
(from De Re Metallica, by G. Agricola, 1556)

Agricola's description - Three vertical shafts, of which the first, A, does not reach the tunnel; the second, B, reaches the tunnel; to the third, C, the tunnel has not been driven. D, tunnel.
As Myddleton had found, pumps could not discharge enough water during wet weather, and many
years later when Sir Humphrey Mackworth was working the mines his steward had to report "I have
done what was possible in the winter time, the water being so strong that we were not able to sink
down our sumps till the Weather grows warmer so that the men may be able to work naked in the
water."

Bushell did not re-invent the practice of driving adits but probably learnt it from miners who came
from Germany, where it had been used since the end of the 13th century. It forms the subject of some
of Agricola's illustrations which show the relation between shaft and adit. One is reproduced as Figure
2, and an allusion in Fodinae Regales to an official who would "dyall and level the works " indicates
that instrumental methods were used in order to ensure that the adit should reach the shaft or vice versa

When the workings were in communication with both shaft and adit the difference in altitude
between the outlets - the one much higher than the other - would ensure the circulation of air through
them, but Bushell also adopted a German method for ventilating the mines without sinking a large
number of shafts. It consisted of " two men's blowing wind by a pair of bellows on the outside of the
adit, into a pipe of lead, daily lengthened as the mine is made longer, whereby the candle in the mine is
kept burning and the diggers recruited constantly with a sufficiency of breath." Bushell, by implication,
suggested that it was Bacon who thought of this method of ventilating mines and Fuller in his Worthies
of England referred to it as "the master-piece of Sir Francis Bacon, Lord Verulam", but in fact,
although Bushell was the first to use it in Britain neither he nor Bacon devised the method. It was a
well-established continental practice described by Agricola, whose illustration is reproduced in Figure
3. Whilst primarily intended to provide fresh air for the miners, ventilation also served to diminish risks
arising from the ignition of explosive mixtures of gas (damps) that, although usually associated with
coal mines were occasionally encountered in metalliferous mines as well.

In a letter to Bushell describing an accident at the "Tallabont mine, Thomas Brodway said that " The
four workmen about one night (as their manner was) withdrew to take Tobacco within ten fathoms of
the Addit's mouth, lest in the forefield it should damp the ayre which was conveyed to them by your
lead pipes with bellows." Suddenly there was "a mighty and feareful noise" and Bartholomew
Clocker, "a well-experienced miner, resolved that the work was holed." The adit had penetrated so
close to the shaft of the mine, which was waterlogged, that the wall or roof of the latter collapsed and
water rushed into the workings and "arose a full yards height at the adit mouth." It was fortunate that
the "smoke banquet" had not ended, for had they been back in their working places the men would
have been overwhelmed. Four hours later, when the flow of water had abated, they went in to see what
damage had been done, but after penetrating for about 60 fathoms the candle of the leading man "
enkindled a vapour which came on him with three or four flames and he suddenly returning had his
haire burnt off and his cloathes scorched, in which conclusion it gave a crack like the report of a peece
and in a fierce gust of wind blew out the Candles of the men coming after him."

It is interesting to speculate on the reason for the presence of the explosive gas, which appears to
have entered the adit at the time of the inrush of water, and was, no doubt, a mixture of methane and
air. Methane is a product of the decomposition of vegetable matter and whilst it is frequently met with
in coal mines where it is derived from the coal and the associated carbonaceous shales, it is not
normally found in metalliferous mines.

Bubbles of gas rise from the water in marshy places (hence one of its names, marsh gas) and it
may be that drainage from a swamp had made its way into the "Tallabont" workings. On the other hand
the gas may have resulted from the decomposition of carbonaceous shales that had been penetrated, or
from the rotting of timber that had been used to support the older workings. "Light carburetted
hydrogen" of natural origin was encountered in the mid-nineteenth century Van mine near Llanidloes
when the lode was first reached and it was also met with in Cornish mines where it was attributed to
the decomposition of timber in the damp parts of the mines. In general, however, the ventilation of
metalliferous mines in Wales has been more concerned with providing fresh air for the miners and their
lamps than with avoiding explosions.

Having regard to the discomforts and hazards of mining it is not a matter for surprise that Bushell,
like others before him, had difficulty in securing sufficient workmen and in addition to petitioning the
King for powers to impress condemned criminals, issued an "Invitation by letter to Condemned men
for petty Felonies to work in the mines of their own country rather than be banished to Slavery in
Foreign Parts."
A method used by Thonas Bushell in his seventeenth century Cardiganshire mines.

Progress in mining was also affected by the increasing difficulty in obtaining the wood necessary for supporting the workings and smelting the ores. Even before Leland's time wood had become scarce in some parts of the mining region, for, of the abandoned work at "Comestwith " he said, "But summe men suppose it sesid byeawse the wood is sore wastith” Some 40 years later (1577) Wm. Harrison, in. his Description of England, noted that "There were mines of lead sometime in Wales, which endured so long till the people had consumed all their wood by smelting of the same." The consumption of fuel in contemporary ironworks in South Wales illustrates the magnitude of the problem for it took the wood from an acre of forest to produce three tons of iron.

Although mining activity declined from time to time, either by reason of legislation restricting the felling of timber or because of the rising price of charcoal, the insistent demand for metal sooner or later made it worth while to start again. Bushell made proposals for overcoming the difficulty in an address to "The Most High and Mighty Soveraign.--- He referred to" whole Forrests of woods formerly consumed for this purpose (i.e., smelting lead and extracting silver) and said that in consultation with other miners and smelters he had found that "by altering the earthy substance of the turfe into charkie cynders ... your Majestie's Tufrraries will furnish Your Mines Royall with fuell to all future ages."

In this claim he was rather over-optimistic and within a few decades coal was being used in place of wood and charcoal for smelting lead, but it was not until well into the 18th century that a satisfactory substitute for charcoal in iron smelting was found, in 'charkied' coal, i.e., coke.

Bushell's efforts at Cwmsymlog were not successful because his adit "struck much short of reaching the Bottom," and believing the mine to be exhausted he concentrated upon workings at Darren Fawr, Tal-y-bont, Bron Llwyd, Goginan, and Cwm Ervin. At first his profits were small and most of his effort was expended in driving adits, but, optimistic concerning the future, he sought and received from Charles I "liberty to give Your Majestie's impression to such Silver as the mole-like miners cast out of the earth," and instead of the silver being sent to London, as it was in Myddleton's time, it was coined in a mint at Aberystwyth.

Grateful for favours received, Bushell loyally supported the Crown during the Civil War and his profits enabled him to clothe the army and lend the King a considerable sum of money, but when the
Parliamentary forces gained control he left Wales to engage with varying success in mining ventures in the Mendips. For some years little useful work was done in Cardiganshire, not because the mines were exhausted or because no one was available to work them but from lack of local interest and enterprise.

In 1688, Sir Orlando Gee, Registrar to the Court of Admiralty, leased the lead mines of "Gwaith y Moine" near Ysbyty Ystwyth jointly to Morgan Herbert of Hafod and Thomas Desbry. Although described as a miner of Llanavan the name of the latter suggests that he was of foreign origin and it was probably by him that the practical work was undertaken. In 1670 a "Company for the Working of the Mines Royal in Cardigan and Merioneth" had been formed, but it seems to have done no more than spend its capital, and the same applied to the "Company of the Copper Mines of the Principality of Wales," created in 1694.

Although outside the sphere of interest of the Mines Royal Society there was a revival of activity in iron mining in South Wales during Tudor times. It was on a small scale, for in a mine near Llantrisant in the time of Henry VIII only three men were employed - one hewing, one timbering, and one bringing up the ore, with a fourth man carrying the ore to the furnace. Some old workings attributed to the Romans may well belong to this period. One was met with during nineteenth century exploitation of the Llanharry ore-field and was described as consisting of a narrow pit from the bottom of which two low headings were driven in opposite directions. Each heading led to a "stall" - a chamber from which the ore had been removed. The stalls were rectangular in plan but had sloping roof and floor due to the inclination of the strata in which the ore occurred. (Fig. 6 i)

Although a plan and section that accompanied the contemporary description of the mine are not to scale, calculation, based upon the information that the pit was sunk about 75 feet from the outcrop, and the known inclination of the strata, shows that the shaft was approximately of the depth given for the Tudor mine - 30 feet - and that the other dimensions were appropriate to a mine of those days.

Sussex was then one of the most important iron ore producing regions and soon after 1560 Sir Henry Sidney who had ironworks at Robertsbridge turned his attention to Glamorgan. Like the Queen he brought Germans to instruct his own men in improved methods of working. Some 20 years later Sir Henry's son, Sir Robert, sold all the "iron myne in the manor of Coity English" to John Savage. Myne (mine) in this transaction means ore, and not the place from which it was obtained.

We know little about the mines themselves, but there are numerous records of iron being sent away, in lots ranging from 18 to 168 tons, to places as far apart as Rye in Sussex and Dublin. The ore mined in Glamorgan was haematite (iron oxide) like that which had been worked by the Romans, but the Hanbury Iron works at Pontypool, founded about 1565 by Capel Hanbury, used another type of ore - the so-called clay ironstone, a highly ferruginous rock interstratified with the coal-bearing strata and mined by methods quite different from those employed in haematite mines. These developments laid the foundations of the iron industry that spread along the northern margin of the coalfield and for a time made that region one of the most important centres of iron smelting in the world - but that belongs to a later period and will be dealt with in a subsequent chapter.

VI. THE COMPANY OF MINE ADVENTURERS AND THE STEWARDSHIP OF LEWIS MORRIS

Where fair Sabrina flows around the coast, And aged Dovey in the ocean's lost.... Louring and black the rugged coast appears, The sullen earth a gloomy surface wears; Yet all beneath, deep as the centre, shines With native wealth and more than India's mines.

Thomas Yalden. To Sir Humphrey Mackworth, on the mines late of Sir Carbery Pryse. (1710)

An important phase of activity in Cardiganshire began in 1690 when lead ores were found at Bwlch yr Esigair Hir on the estate of Sir Carbery Pryse. They were so rich in silver that the mine became known as the Welsh Potosi and the discovery resulted in another dispute concerning the respective rights of the Crown and the owner of a mine that was claimed to be Royal. The Crown regarded Esigair Hir as a Mine Royal because of the alleged silver content of the ore, but Sir Carbery resisted the claim and the case was tried at Westminster.
On behalf of the Mines Royal Society and the Crown, 'proof was produced that the silver content of the ore was 60 oz. per ton, making the mine a Mine Royal, and on behalf of Sir Carbery, equally convincing 'proof' that it yielded only 4 oz. per ton. The dispute was settled in Sir Carbery's favour and an "Act to prevent Disputes and Controversies concerning Royal Mines " passed, giving the proprietor of the soil the right to work such mines, and the Crown the right to purchase the ore at a fixed price.

This, in effect, broke the monopoly of the Mines Royal Society which soon afterwards ceased to function because the Governor died and, in the words of a contemporary writer, "It is supposed that the members of the Society are all extinct or totally discouraged by the late Act of Royal Mines which by setting so high a price on the pre-emption of all sorts of ores has in effect ruined the Society and destroyed that undertaking."

It is said that Sir Carbery was so elated that he rode from London to Esgair Hir with the news in 48 hours - unusually speedy travel having regard to the roads of the time. The difference made by the Act was described by Sir Humphrey Mackworth who in 1698 formed the Company of Mine Adventurers of England. Previously, he said, the lands of the proprietors "were torn up to the very bowels and covered with Heaps of Rubbish ... to the great grievance and oppression of the Subject," with the result that "those who had estates endeavoured to conceal their mines" whilst under the new conditions "they all laboured to find them out."

Mackworth also had something to say about the divergent claims made by the assayers concerning the silver content of the ores. "I am," he wrote, "charitably disposed to believe that all these different oaths may be consistent ... for 'tis certain that in most veins there be small ribs and knots of ore visibly richer than the other parts thereof," and one of those who supplied a sample to be refined "might pick choice pieces for the King and the Patentees " whilst the other " picked the worst he could meet with near to the surface of the ground for Sir Carbery Pryse."

Mackworth, who came of an old Shropshire family, was a lawyer and when he married the heiress of Sir Herbert Evans of the Gnoll, Neath, he used the wealth so acquired in the prosecution of various industrial schemes. Commencing with coal mines at Neath he later turned his attention to the lead mines in Cardiganshire and on three occasions between 1701 and 1713 was M.P. for the County.

Sir Carbery Pryse started a company to develop his mines but soon ran into difficulties because the workings became waterlogged, and, unable to raise funds to drive the necessary levels for drainage appears to have been advised by his steward William Waller, who had been brought from the north of England, to invite Mackworth to supply capital, and experience in wisely using it, so that the mines could be properly drained and developed.

When Sir Carbery died shortly afterwards (without issue) his kinsman Mr. Edward Pryse sold his interest in the mines to Mackworth and with a view to enlisting further financial support Waller wrote a circular giving a glowing but rather exaggerated account of the mining prospects. The' Mine Adventurers Company' was financed by the proceeds of a lottery and Waller wrote An Essay on the Value of the Mines late of Sir Carbery Pryse in which he expressed concern that so great a treasure should " lye dead " for want of capital and by reason of disputes and lawsuits.

Waller's claims were extravagantly optimistic. The vein he said, "can't be parallel'd in any part of the Christian world," and given the funds necessary to work the mines adequately, "Tis plain that this nation can never want silver," but as a contemporary writer put it, " He is a sanguine man and such men are apt to believe what they mightily wish for." His descriptions were accompanied by plans, sections, and illustrations that are too crude to add much to the meagre information we have about the mines themselves and the way in which they were worked - see, e.g., Plate 1. He pointed to Mackworth as the one person possessing the qualifications necessary for putting the affairs of the mines in order.

In 1700 there appeared A Familiar Discourse concerning the Mine Adventure, ostensively by William Shiers, the Secretary to the Company, but actually by Mackworth himself. Presented in the form of a dialogue between a learned Doctor of Divinity who asked questions and an Eminent Merchant of London who answered them, it gave an optimistic account of the undertaking - of plans for improving the condition of the miners whilst at work, for providing for them when " Decay'd," and of steps to be taken to improve the methods employed in the mines. "Two men in Blasting upwards with Gun powder," he wrote, "can raise more ore than 6 men working downwards with Gad and sledge."
A gad was a stout iron wedge.

Asked to define a level the merchant explained that "A Level is called in some places an Adit, in others a Sough or Drain ... It is carried on from the bottom of a hill at a dead level ... to drain off all the water from the mines as they work them," and to do so "without any charge at all." The miners, he said, removed the ore from the roof of the level in several stages one above the other until they met the shaft that was being sunk downwards. "When we have sunk down as deep as we conveniently can for water we bore a hole through the rock quite down to the level and so let off all the water in the mine." For boring the hole "We have sharp chizels skrew'd to Iron Rods about four feet long, which are also skrew'd together to what length you please, with which we pounce the rock into a powder, and by continually turning about we keep the hole round ... We can bore a yard a day in very hard rock."

By this time coal had replaced charcoal in the smelting operation and The Merchant explained that "The nearest place [i.e., where there is coal] is Neath or Swanzey in Glamorganshire and therefore it is contrived to save charges in freight, that the same vessels which bring coal to oar to be smelted in Cardiganshire shall carry back oar to coal to be smelted at Neath."

There had been smelting houses at "a place called Garege at the mouth of the Dovey but when the dialogue took place there was "no smelting house in Cardiganshire with proper furnaces for present use." The Merchant explained that they were glad to use those at Neath because "with the advantage of having Timber, Lyme, Sturbridge Clay, Iron and other necessaries much more cheaply there, we can do our business more cheap at Neath than in Cardiganshire." In sending his ore to Neath Mackworth was following a lead given more than a century earlier by Thomas Smythe when he was in charge of the copper mines operated in Cornwall by the Mines Royal Society, and it was this early transport of ore to coal which laid the foundation of the world-wide reputation that the Swansea Bay region was to acquire for nonferrous metallurgy.

Like Bushell before him Mackworth experienced difficulty in getting sufficient men for his mines and he asked the Government to send him "criminals condemned for small offences and of able serviceable bodies," but some of them disliked the prospect so much that they absconded in spite of the death penalty that awaited them if caught.

Unfortunately the cost of driving adits for drainage absorbed the profits from the small amount of ore that could be raised, and in order to maintain the Company's credit ore was brought from Flintshire and smelted as if it were of Cardiganshire origin. Added to this it was hinted that Mackworth and his associates had drawn more than they should from the proceeds of the lottery, whilst difficulties created by jealous opponents of his coal mining activities at Neath led to expensive legal disputes and a quarrel with Waller ended in the latter's dismissal. Each accused the other of unfair dealings and after a complaint in the House of Commons Mackworth was found guilty of fraud and violation of the Company's charter, but the fall of the Whig ministry saved him from the results of the ruling. Some of his friends wrote pamphlets supporting him, but other contemporary writers denounced the Mine Adventure, which, due to mismanagement if not actual dishonesty, temporarily ruined the industry. It was an early example of the ill-effects of speculation and subordination of the practical miner to the company promoter.

Whilst the boom lasted it brought prosperity to the region. When Daniel Defoe visited Aberystwyth in 1725 he described it as "enriched by the coals and lead which is found in its neighbour-hood "and as "a very dirty black smoky place ... However they are rich and the place is very populous." He was, of course, wrong in thinking that coal was found in the lead mining region, and at the time of his visit the importation of coal for use in local smelting houses had been discontinued in favour of sending the ore to Neath.

The Company of Mine Adventurers continued to operate after Mackworth had severed his connection with it, but by 1744 the leases of Esgair y Mwyn and Cwrasymlog had been given up, and only four mines were being worked - Pen Craig Ddu, Grosgwynion, Cwmystwyth, and Eurglawdd. Cardiganshire continued however, to be an important lead mining region and the principal persons concerned were Chauncey Townshend, a Swansea industrialist who leased mines from the Adventurers, Sir Thomas Bonsall who also had a mine at Cwmystwyth, and Lewis Morris, a prominent member of a well-known Anglesey family. A man of many parts - poet, philologist, and antiquarian -
after working as a land surveyor Morris became Collector of Taxes at Holyhead and between 1737 and 1748 produced a series of charts of the Welsh coast. In 1746 he was appointed Deputy Steward of the Crown Manors in Cardiganshire—a post that proved to be extremely difficult and frustrating. In the year after his appointment he set miners to reopen some old drowned workings at Nant y Creiau, Llanbadarn Fawr, but the volume of water and the wetness of the season rendered the attempt abortive. In 1751 one of his agents re-discovered lead at Esgair y Mwyn between Strata Florida and Ysbyty Ystwyth. There he found that "the ancient Britons (or as some think the Romans) dug an opencast … having discovered the ore on the surface of the rock." The workings were, he said, "so ancient that a thickness of black soil is grown on the rubbish and Hillocks which they left."

He leased the mine in partnership with three miners and the success of his first year's working excited the cupidty of the local landowners who disputed his claim and that of the Crown to the mine. They incited riots with a view to taking possession of the mine and soldiers were sent down to protect it and provide labour for its continued working. Large payments were made for the supply of liquor to the soldiers and "to the miners to encourage them to keep possession for the Crown." Morris, as the local representative of the Crown, had to bear the brunt of the attacks, and in 1753 his opponents managed to get him thrown into Cardigan gaol for more than a month. Partly because of political pressure and partly on account of his own un-businesslike methods he got little support from headquarters and he appears to have engaged in private prospecting - quite legitimately, but somewhat to the detriment of his official duties.

His correspondence with the Surveyor General, Thomas Walker, and his representatives Thomas Chambers and John Sharpe, throws light upon the difficulties with which he had to contend. Writing to Sharpe in 1744 about the Bwlch Gwyn mine, which, he said, was also known as Gwaith Newydd Ysturn Tuan because it was near an old mine at Ysturn Tuan, he said that although worked by Thomas Powell (i.e., of Nanteos, near Aberystwyth) it was on common land and in his opinion Powell had no claim to it.

He suggested that the 'Company of Mine Venturers ' told one another that they should try to discover mines in the wild mountainous country where it was unlikely that anyone would obstruct them under the existing regime. He enlarged upon what he regarded as Powell's illegal claim in A Short History of the Crown Manor of Creuddyn in the County of Cardiganshire (1771), describing it as "Mr. Powell's Scheme of converting all the King's Commons in Cardiganshire into Freeholds, in order to deprive His Majesty of his Mines and other Royalties in that County."

In a letter to Walker (1745) he complained of a threat by Powell that if he (Morris) dared to go on a freeholder's land he would be prosecuted for damages, and he alleged that poor people known to give him any assistance were "severely prosecuted when any little debts or anything else can be anywhere picked against them. In short," he said, "all the difficulties they possibly can think of they accumulate together purely to obstruct the Survey."

He also complained (to the Earl of Powys) of what he regarded as sharp practice on the part of Townshend, who claimed the right to be washer, weigher, carrier and buyer of ore (at Esgair y Mwyn). He would, said Morris, "account to nobody for what he took off the bank, so as he may carry it where he pleases and leave it in houses about the Country and ship it off where and when he pleases and give what account he pleases of it." In the circumstances he would "leave behind all the hard and difficult ore and take only the best."

In the draft of another letter to Lord Powys, written as to one with a vast property in ye mining Country in Wales ... and disposed to encourage this curious and useful art," he gave his views upon matters to be considered when searching for new mines. He expressed disapproval of "Ignorant practical miners who pretended to be masters of some prodigious arcanum. such as ye virg. divinat." (divining rod) and in a passage subsequently deleted, observed, with irony, "and one qualification sufficient for a miner in these days is to have been born in Germany or Hurigary."

Emphasising the importance of the location of a mine, he wrote, "A mine poor in ore if well situated may be more profitable than a very rich vein ill-situated, and by an ill situation a mine producing plenty of ore may be worked to loss … Suppose you have a new discovered mine in a swamp or flat ground … where there is no river or brook near, the ground soft and boggy, the rock
Shaley and loose and full of Joynts, no Timber or coal nor Smelting House, no ' r seaport within many miles ... no village nor Hay, Grass, nor Corn. Suppose the vein of ore here a foot wide, a vast Estate in ye eye of a person that knows no better. But when you consider ye inconvenience this minework is subject to you'll see it in another light. To this work you can have neither Level, water engines, wind engines, Horse ... nor Fire engines to drain ye water, which must be very busy because of ye shattered stone receiving into its beds all day water from ye neighbouring hills. A great deal of timber will be wanted which will come very dear because provision and lodgings will be scarce and ye carriage of it great." The letter went on to enumerate the advantages of a mine more favourably situated and the steps that should be taken to reach a newly discovered vein.

Whilst Bushell and his successors were working in Cardiganshire there was activity in the lead mining region of North Wales, but in general the operations were spasmodic and on a relatively small scale. One of the larger venturers was Sir Roger Mostyn who in the time of Charles 11 smelted his ores in a furnace equipped with a water-wheel to work the bellows.

The emphasis in this region in the 17th century was upon coal mining. The Myddletons were already operating in the days of Elizabeth, and as many of the mines were easily accessible to the sea there was a steady traffic in coal from Flintshire to Chester and to Ireland. Before the end of the century " The Governor and Company for smelting down Lead with Pit Coale and Sea Coale " was active in Flintshire and, with other companies, had furnaces at many places in the lead mining area, e.g., Whitford, Holywell, Flint, Mold and Hawarden.

As the Act which ended the Crown monopoly and the control of the Mines Royal Society began to make itself felt in North Wales where the lead ores were rich in silver, the fortunes of many of the local families - the Grosvenors, the Mostyts, and the Hamners -were greatly improved. In 1703 Sir George Wynne of Leeswood inherited a small freehold on Halkyn Mountain worth about £30 a year and when rich lead ores were discovered and exploited its value rose in about 25 years to £2,000 per annum, but in this region also, as in Cardiganshire, disputes and law-suits absorbed profits that should have been used for the development of the mines. Those in which Wynne became involved so impoverished him that when he died in 1756 he was insolvent.

By the end of the 17th century some of the mines were sufficiently deep to encounter difficulties due to water but around Hawarden where the ventures were profitable enterprising owners installed pumps worked by the atmospheric engine very soon after it was invented by Newcomen in 1712. About the end of the 17th century veins of lead ore at Llangynog in Merionethshire, which may have been worked in Queen Elizabeth's time, were successfully exploited and gave good yields until difficulties due to water became insuperable. The systematic working of the ores at Minera began early in the 18th century.

VII. NOTES ON MINING PRACTICE

'Tis art and toil
Gives Nature value, multiplies her stores.

Reference has been made in the preceding chapters to some of the ways in which ores were reached and raised - to shafts and adits, to drainage and ventilation - and it will be convenient to conclude this review of the second phase of metal mining in Wales, and introduce the third phase, with a general picture of the mines in operation. The majority of the mines controlled by the Mines Royal Society and the Mine Adventurers were in steeply inclined narrow lodes, and it is with such mines that this brief account will be principally concerned, leaving workings in other kinds of ore to be dealt with in their appropriate context.

In *Fodinae Regales* Pettus gives an interesting picture of what were regarded as ideal arrangements for the control of mines. The " Officers necessary to be imploied by the Society " should include, he said, " a Chief Steward who ought to understand the whole concern of the Mills and Works," an " Under Steward to reside at the Mines ... and to dyal and level the works, and as occasion requires to provide Timber and other necessaries," a Paymaster, a " Clarke to receive and deliver out coal and oar and keep an exact accopmt of the oar delivered to the Smelters," a Carpenter, a Smith, 50 or 60 Carriers " with horses usually carrying two bags containing 200 lbs. weight of oar." The Myners were to" finde
themselves Iron, Steel [i.e., tools] and Candles at their own charge," whilst the Masters' only finde Tymber for the works, Ropes, Pumps, Tubs, and sieves to cleanse the oar, and bags to carry it to the Mills."

The foregoing is extracted from a detailed account of the administration of the mines but there are, unfortunately, few descriptions of the mines themselves. Illustrations like those in Waller's Description of the Mines (Plate 1) and in Fodinae Regales (Plates II and III) depict the distribution of adits and shafts in a diagrammatic way, but the accompanying text gives no information about the methods adopted to extract the ore. This reticence is not difficult to understand, for rival interests were involved. The miners were reluctant to give others the advantage of their experience, whilst, regarding the mines primarily as a source of quickly acquired wealth, neither the landowners through whose estates the lodes passed, nor the promoters who developed the mines were inclined to publish technical descriptions of their undertakings for the benefit of contemporaries or posterity. The dialogue in the Familiar Discourse was published more with a view to obtaining further financial support than to describing the operations in other than general terms.

Methods in vogue up to the sixteenth century are well described in Agricola's De Re Metallica and, as so much of the early work in Wales was done under the direction of German miners and mining practice changed slowly, his general descriptions can be taken as applying in large measure to Welsh mines. Cornish miners also played their part in Wales and the accounts of Cornish practice given by William Pryce in Mineralogia Cornubiensis (1778) are also helpful.

The earliest mine works were, as we have seen, opencasts in which fire-setting was often employed to facilitate the removal of the rock. When further work in this manner became impracticable the deeper ores were reached by adits and shafts, and sometimes by inclined passages. One such was described by Lewis Morris when he began to work the Esgair y Mwyn mine. In opening the old bottoms, he said, ladders of solid pieces of timber were found" on an inclination fit to walk on and carry the ore to land."

The fact that the timbers had been shaped by axes and not by saws suggests an early date for the workings. Morris thought they were opened at about the time of Queen Elizabeth, and the discovery of a tobacco pipe in one of the shafts also points to the sixteenth or early seventeenth century. The men affected by the accident in Bushell's " Tallabont " mine were, it will be remembered, enjoying a "smokie banquet."

Bushell's method of conveying air to the working end of an adit has already been mentioned, but in a hilly region like Cardiganshire a combination of adit and shaft was possible and largely employed. An adit drained all the workings above it and provided a convenient means for conveying ore to the surface, whilst a shaft also gave access to the workings, and, when it communicated with an adit, helped to ensure a circulation of air through the mine. Some shafts were sunk in the lode itself, either directly from the surface, or, especially when the lode was not steeply inclined, from a point some distance from it, meeting it beneath the surface. A slanting shaft was used, for example, in the lead mine at Llanrwst, but since the majority of lodes are more or less steeply inclined and their inclination is not always uniform the task of raising ore up shafts sunk through them increased as the mine grew deeper.

In due course shafts in the lodes were replaced by vertical shafts sunk through the adjacent strata, with horizontal “crosscuts” leading from them to the lode. (Plate VI) This was normal practice during the nineteenth century. The cross-cuts were separated by vertical intervals of about 10 fathoms, but sometimes more. Distances in mines were, it may be noted, usually given in fathoms.

In order to diminish the length of the cross-cuts the shaft was sometimes sunk in such a position as to intersect the lode, usually about half way down to the greatest depth at which it was anticipated to work. (Plate VI) When the mouth of a shaft was situated on a hill an adit would be driven, from as low a position on the hill-side as possible, to meet it in order to provide an outlet for water from that part of the lode which lay above it, and for water pumped from lower levels.

Work in the lode itself was essentially the same whether shafts were inclined or vertical. Horizontal roads or levels were driven from the cross-cuts along the line of the lode and the ore
brought to the bottom of the main shaft ready for raising to the surface. Small perpendicular shafts were cut from one level to another, called winzes if they were carried down to a lower level, as they usually were in Welsh mines, or rises (raises) if they were carried upwards from a lower to a higher level. The cutting of levels and winzes set free a certain amount of ore but the object in making them was to prepare for working the lode. The levels provided roadways along which ore and rubbish could be carried to the shaft, or timber for supporting the workings taken from it, whilst the winzes served as shoots down which ore could be passed to the levels that served as haulage roadways and also facilitated the passage of air through the mine.

The levels and winzes divided the lode into many rectangular blocks as illustrated in Figure 4 ii, a section showing a lode as it would appear if the rock on one side of it were removed.

The workings resulting from the removal of the ore between one level and another had the appearance of steps (or stopes) and the process of making them was stoping or stepping. When the steps were cut downwards, to be compared with excavating a flight of stairs, they were underhand stopes, and when they were cut above the miner's head, so that the resulting roof resembled the underside of a staircase, they were overhand stopes. (Plate VII)

In underhand stoping work was commenced on the floor of a level. The stopes varied in depth to a maximum of about five feet and when one was advanced far enough another was commenced beneath it, each miner cutting into the face of the step above him, and the process continued until the next lower level was reached. Underhand stoping prevailed in Welsh mines until about the end of the eighteenth century, when overhand stoping was introduced from Germany where it had been practised for some time. By this method the excavation proceeded upwards.

Work was commenced at one of the lower corners of one of the blocks into which the lode had been divided by levels and winzes, and the lode broken down to a height of about 6 feet. When the first stope had advanced far enough another was commenced above, and then a third, giving eventually a series of working places like steps, each one a little behind the other. As the work proceeded the roof of the level at which it commenced was timbered to provide a floor on which the rubbish could accumulate whilst the level itself continued to serve as for transport. The rubbish formed an irregular heap resting at the natural angle of repose and the broken ore from one stope fell on the rubbish from the one below it and was cast down until it eventually reached the level. (Plate VII)

When the pile of waste material was not high enough to provide a working place from which the excavation of the roof could be continued, platforms of wooden beams (stemples) were erected at a convenient height, to form a floor on which the rubbish of the upper workings could accumulate. Birch, alder, and oak were most frequently used for timbering the mines. The stoping continued until it reached the next winze and the whole of the block of ore had been removed. Whether overhand or underhand, stoping could proceed simultaneously on several levels and at various parts of one level, and whilst this was going on the system of levels and winzes was extended laterally and in depth, in order to give access to ore to be worked when the blocks already made available were exhausted.

The opening of a mine thus involved expensive preparation in order to ensure the profitable extraction of the ore, and in many instances, as Warington W. Smyth, then mining geologist to the Geological Survey and later Chief Mineral Inspector to the Crown, had to record when describing the mines of Cardiganshire and Merionethshire in 1848, "from want of sufficient means or knowledge these precautions were neglected, and the quick recovery of the good ore being the main objective, a mine that might, in better hands provide a lasting source of profit, may yield part of its treasure and be crippled, abandoned, and left with a bad name to deter future speculators." The Welsh mines also suffered from failure to provide adequate support for the adits which were so essential to their continued working. Wooden supports were generally used, but although stone was available it was rarely used for dry walling, even in work intended to last for several years. The result was that, again quoting Smyth, scarcely a season elapsed after a mine ceased to work, although not necessarily exhausted, before the mouth of the adit was closed in a heap of ruins whereas elsewhere, even after several years, entrance was practicable.

The old workings discovered by Morris yielded the remains of wicker baskets in which the ore was carried on men's shoulders, but where possible wheelbarrows were used - a mode of transport that was by no means easy on the rough uneven floors. In the larger and better equipped mines tramways were laid and the ore conveyed in small wagons or trams. The ore was raised to the surface in kibbles -
baskets, or buckets made of wood with iron hoops or, as the mines grew deeper and the loads heavier, made of sheet iron. They were of necessity strong because of the buffeting they received as they came into contact with the sides of the shaft, due to the twisting and swaying of the rope or when a full kibble going up collided with an empty one going down. In inclined shafts the lower side was often lined with timber in order to reduce the friction as the kibbles were dragged over it. It was not until the nineteenth century that cages, and guides on the sides of the shaft to ensure their even running, were installed in metal mines—rather later than in coal mines—thus making it possible to raise the ore in the wagons by which it had been conveyed from the working places to the shaft. Cages were used, for example, in the mid nineteenth century Van Mine in Montgomeryshire.

Single-link chains or hempen ropes were used for raising the baskets or the kibbles. Wire ropes were tried, even before 1850, but those chosen were not suited to the purpose and gave rise to prejudice against their use. The kibbles were wound to the surface by windlasses erected over the shafts— as depicted in the illustration of Cymsyrnlog mine in Fodinae Regales. (Plate 111) Sometimes the pithead gear was sheltered by a simple shed-like structure. Morris, for example, recorded that at Esgair y Mwyn there were five framed shafts with coves over them and two without coves. There was also a covered arbour, open at one end, for the timber-men to work in.

Drainage down to adit level was affected by the adit itself, but water from below that level had to be raised either manually or by machine. In the workings discovered by Morris some dished shovels were found and he thought that they were used for throwing water from one dam to another at a higher level. This operation would do no more than dewater the place where the men were working, and it is more likely that the shovels were used for throwing ore from one stage to another in the workings until it reached either the surface, or a place from which it could be raised by other means. Writing in 1671, the author of Some Observations on the Mines of Cornwall... describing the art and manner of digging a load, said that when the ore had been ripped "the shovel-men convey it off and land it by casting it up with shovels from one shamble to another."

The same writer said that water was raised in keebles (the Cornish term for kibble), leather bags, or buckets, and some such means seems to have been used in the workings that Morris described, for he also recorded seeing a groove in the rock near the middle of the working which seemed to have been made by a rope drawn over it as if in hauling buckets containing water.

The windlasses erected to raise the ore served also to raise buckets or barrels filled with water. In a letter to Lord Powys Morris advised raising the water from Esgair y Mwyn by means of common barrels rather than going to the expense of erecting a horse-driven whimsey.

As the mines grew larger and deeper pumps were installed, driven by water-wheels in Cardiganshire but elsewhere more usually by means of steam engines. The water from all parts of the mine drained into a sump at the bottom of the engine shaft, up which it could be lifted, usually (because the height to which water could be lifted by one stroke of the pump was limited), in stages by a number of pumps working simultaneously at different levels.

Water-wheels like the one used for pumping and sometimes for winding ore at Treecastell Mine near Conway (Plate VIII) were once familiar features in the landscape of mining regions. A model of one used for pumping at Gilfach Copper mine, Cipwrth, near Cwm Pennant a few miles from Portmadoc, is being prepared for the Museum's Industry Gallery. Ore was raised from the mine intermittently from about 1828 to the end of the nineteenth century.

**THE THIRD PERIOD**

The last two centuries - climax and decline

**VIII. COPPER MINES**
The Giant-Power from earth's remotest caves Lifts with strong arm her dark reluctant waves,
Each cavern'd rock and hidden den explores, Drags her dark coals and digs her shining ores,
Now his hard hands on Mona's riven crest, Bosom'd in rock, her azure ores arrest.

Erasmus Darwin, in The Botanic Garden
(The Economy of Vegetation, 1792).

Although some of the lead mines yielded ores of copper in sufficient quantity to justify separate dressing, the modern era of mining for copper, as such, in Wales did not begin until after the pioneer period that has been under review. Since then copper ores have been raised in most of the Welsh counties that have yielded non-ferrous ores, but it is not necessary to mention all the mines; they are adequately listed in other publications, and a few examples will serve to illustrate the extent and character of the operations. With one exception the output has not been great. The exception is the composite mine on Parys Mountain near Almwhc in Anglesey which by 1768 was producing ore yielding about 3,000 tons of metallic copper yearly. Because of its importance it will be convenient to consider this group of mines last, although their history began earlier than that of most of the others.

In 1828 the total annual output of copper ores from Wales was about 3,500 tons, most of it from Anglesey. By 1845 it had risen to 68,000 tons, after which it fell rapidly to about 50,000 tons in 1847 and continued to fall irregularly so that the total amount produced during the whole of the next 65 years was not much more than 50,000 tons. During fifty years prior to the first world war some 6,000 tons of ore were raised from mines otherwise worked for lead and zinc in Montgomeryshire and Cardiganshire. It came mostly from two deep mines - Esgair Fraith, about 11 miles, and South Darren, about 8 miles, from Aberystwyth.

Relatively small amounts of copper ore were obtained from the lead and zinc mining areas of Flintshire and Denbighshire, and from workings in the Carboniferous Limestone on Mynydd y Garreg near Kidwelly in Carmarthenshire, whilst larger amounts were raised from several mines in Caernarvonshire. Here, mines in the Nantlle Valley produced about 14,000 tons of ore in sixty years (1853-1913). Of this more than 80 per cent. came from two mines -Drws-y-coed near Pen-y-groes and Tal-y-sarn near Llanllyfni. The formler was worked intermittently from the early part of the 19th century by means of levels, some above and some below the mouth of the hoisting shaft which was 480 feet deep. The water was removed by Cornish pumps. The mine was abandoned just before the First World War. The Tal-y-sarn shaft was deeper - about 540 feet - and the mine was not abandoned until the end of the war.

A mine on a precipice overlooking Glaslyn high on the eastern side of Snowdon - Britannia Mine - produced ore intermittently from 1889 to 1915, and other small mines were also active in the neighbourhood during the second half of the 19th century. The decomposition products of copper ores are usually blue or green and the green colour to which Glaslyn owes its name was due to the detritus discharged into the lake as a natural product of erosion or from very early mine workings. Pennant recorded that in his time the black waters of the lake were quite green at the edges and in 1897, when ores were crushed and dressed on the shores of Llyn Llydaw, the waters of that lake also assumed for a time a greenish hue.

Several levels were opened in Nant Ffrancon and in Cwm Ceunant on its western side, but none of them seem to have been successful. A mine near Portmadoc - Bron y Gadair - was worked in the early part of the 19th century by the father of Samuel Holland who had taken a lease of the slate quarries at Blaenau Ffestiniog. The Cambrian Mining Company took it over in the early 1830's and installed a twelve horse-power pump to drain it but met with no success. Work was discontinued in 1844 although small scale operations continued at intervals for some years after that. Rather more than 8,000 tons of copper ore were obtained between 1870 and 1892 from two of a group of mines near Llanengan in the Lleyn Peninsula that were better known for their yields of zinc ores and silver-bearing lead ores.

More productive as a single mine was that opened to work lodes traversing the Carboniferous Limestone of Great Orme headland, Llandudno. In 1869, after producing nearly 14,000 tons of ore in fourteen years the mine had to close because the workings were suddenly flooded by water from the sea. Every fissure that could be found was filled with cement but the main feeder was never found. The winding and pumping engines used at the mine were purchased by the Broughton Coal Company of Wrexham, and installed at a colliery at Brymbo. The winding engine was later removed to Broughton Colliery where it remained until it was broken up in 1921.
Several mines in the neighbourhood of Dolgellau in Merionethshire yielded copper ore, usually in small quantity, and there were more substantial outputs from the Glasdir and Clogau mines which, although started for copper, were later worked mainly for gold.

The ore at Glasdir mine, about a mile north of Llanfachreth, does not occur as a true lode but as an impregnation of the country rock in a zone about 50 feet thick. Produced at first from large opencast workings the ore was subsequently obtained from levels driven from a shaft extending 620 feet below the level of the adit cut for drainage. Between 1872 and 1914 it yielded about 10,000 tons of ore, but the metallic content was less than 2 per cent of the material mined.

The Clogau mine eventually had about nine miles of levels and the deepest workings were about 540 feet below the surface. A mine at Dol Frwynog near Llanfachreth, which flourished for about 25 years from 1824 produced about 75 tons per annum but the other mines in the region together yielded only about 125 tons of ore in 65 years from 1848.

The mines already described were worked on traditional lines by methods applicable to ores that occur in lodes, but a mine of an unusual kind was worked at Dol Frwynog where peat on the floor of a small valley had been impregnated with copper bearing solutions. The bog received the drainage of a hill on the southern side of the Mawddach valley, and included two beds of peat consisting largely of decomposed grass and decayed wood, separated by a thin layer of stones.

The body of the peat was richly impregnated with carbonate of copper, whilst leaves, fragments of wood, and nuts had been largely replaced by metallic copper. The peat, or turf as it was called, was cut in the usual way and after being dried by exposure to the air was burnt in heaps. As the pile smouldered fresh material was added, care being taken to prevent the peat from bursting into flame lest the heat should result in the formation of slag from which the metal could not be readily extracted. After 8 to 10 days the ashes were sent to Swansea to be smelted. In one year 2,000 tons of ashes valued at £20,000 were recovered from the "Turf " mine. Parts of the lower layers of the peat were so richly impregnated with copper salts that they were cut into blocks and sent away for smelting with no more treatment than air-drying to reduce the water content.

Extensive search was made, without success, in the hope of finding a rich lode from which the copper had been derived, but the peat rests upon slaty rocks that contain small crystals of iron pyrites and specks of copper pyrites and it is more likely that, instead of being derived directly from a lode like that which has been worked in the small Dol Frwynog mine about half a mile away, the metalliferous compounds in the peat were carried in water that percolated through the local rocks and rose as springs feeding the rivulets that drained into the bog.

The discovery that the peat contained copper was, according to Walter Davies (Gwallter Mechain), made by a certain Mr. Parry. Observing heaps of peat ashes outside cottage doors he chided the occupants for not putting them to use on the land and was told that the effect of doing so was to make the ground more sterile. Being, as Davies put it, of a "mineralogical turn," Parry found by chemical tests that the ashes contained copper, employed men to cut the peat, constructed kilns for burning it and shipped the ashes to Liverpool.

Parys Mountain near Amlwch in Anglesey is said to derive its name from Robert Parys, Chamberlain of North Wales at the time of Henry IV. Its ores were known to the Romans, and Pennant recorded seeing, in 1780, "Vestiges of antient operations, carried on by trenching, and by heating the rocks intensely, then suddenly, by pouring on water so as to cause them to crack or scale, awkwardly supplying the use of gunpowder." Whether or not these were the remains of Roman workings cannot now be determined, but there are no records of subsequent interest in Parys Mountain until late in the 16th century, and then it was not the prospect of mining copper ore that attracted attention.

Writing in 1607 Sir John Wynn recorded that " the heat of summer causes copperas [iron sulphate, not, as its name might be thought to imply, copper sulphate] to grow in the chinks," i.e. caused the evaporation of the solutions containing salts dissolved from the rocks, and said that there were great stores of brimstone which could be dug out with ease. He added that the water of the mine contained 'alome ' as well as copperas, but that much skill was required to extract more of the former than of the latter. It was, indeed, the mineral content of the water that excited curiosity and he referred to " a great
mineral work " from which in 1579 a Mr. Hedley obtained " a mineral water " that made " alome and
copperas and transmuted iron into copper." This is the-first dated reference to copper at Parys
Mountain.

Wynn said that the experiment was made in the presence of the Lord Treasurer Burleigh and other
Lords of the Council, members of the Society of Mineral and Battery Works that had been incorporated
in 1568. In one of his letters he professed to have forgotten "the particularities" of the process, but in
another he described it in some detail.

Iron, beaten to powder, was put into boilers made of lead together with water from the mine and
subjected to an "exceedinge hot fire of turf," and then allowed to cool. Three substances were formed,
or as he put it, congealed - at the top there was copperas, in the middle ' alome,' and at the bottom a
yellowish earthy sediment. This was laid upon charcoal and smelted like lead, producing cinders and
copper, the latter amounting to about one tenth of the whole. The Lords of the Council were of the
opinion that the work would "not quite cost " and it was discontinued.

Nearly 150 years later, all that Lewis Morris could say about the mountain in the notes that
accompanied his charts of the Welsh coast, completed in 1748, was that " there is plenty of reddish
ochery earth " superior to Spanish brown for making paint. He made no mention of copper, and it was
not until about 1757 that further serious attempts were made to exploit the ores.

Of the circumstances in which the new developments took place and the persons responsible for
them it is sufficient for our present purpose to say that the first were connected with the use of copper
sheathing for warships and the establishment of smelting houses near Holywell, and that the second
included Sir Nicholas Bayley (part owner of Parys Mountain and proprietor of an old lead mine at
Penrhyn Du on the south coast of the Lleyn Peninsula), and the Revd. Edward Hughes, a country
clergyman who came into possession of part of the mountain through marriage. Hughes secured the
interest of Thomas Williams, a farmer's son who later became the leading figure in the copper industry
and with the aid of a London banker named Dawes they formed the Parys Mine Company and began to
exploit the western side of the mountain.

The country rock consisted of shales of Ordovician and Silurian ages with a thick layer (sill) of
felsite near the junction between them. Felsite is an igneous rock forced, when in a molten condition,
into the position it now occupies. During the volcanic episode, which occurred at the end of Silurian
times, magma was injected into hundreds of fissures where it cooled and consolidated. Before the
vulcanity ended the strata were thrown into folds, and heated waters were forced amongst them taking
into solution large amounts of silica. This, as soon as the water cooled, was deposited as minutely
granular quartz in the pores of the rocks, converting the once fissile shales into hard flinty substances.
Towards the end of the process the water brought sulphur compounds of copper, iron, lead and zinc,
which, especially those of copper, crystallised on a large scale, giving rise to zones of maximum
mineralization in a generally mineralised mass rather than to true fissure lodes. The minerals, of which
copper pyrites and bluestone (a dark blue grey finely granular intergrowth of blende and galena with
scattered particles of copper pyrites) are the most important, include iron pyrites, blende, and galena.
Bluestone was the principal ore in the mine at Morfa Ddu about a mile west of the Parys Mine.

What subsequently became known as the Great Lode was discovered in 1768 and a few years later
the combined output from this and the workings on the eastern side of the mountain, operated by the
Mona Mine Company and also managed by Thomas Williams, yielded about 3,000 tons of metallic
copper yearly. This was larger than the output of any other copper mine in Europe and gave
employment, when in maximum production, to about 1,500 men.

The deepest excavations in the mountain eventually reached 570 feet below sea level and the
highest surface from which a shaft was sunk was 480 feet above it so that the vertical range of the
workings was about 1,050 feet.

At first the ore was worked from shafts, of which hundreds are said to have been sunk in a single
year, and from levels, but when miners who had been refused fresh leases removed the pillars that had
been left to support the roof there was a great collapse and opencast working was resorted to. Water
which accumulated in the pit was removed by wooden pumps bored out of large oak trunks because
iron cylinders could not be used owing to the acidity of the water. The pumps were activated by a
windmill that was built on the windy summit of the hill and remained in use long after the introduction of steam-driven pumps.

The Great Opencast on the west eventually reached a length of 620 yards and an area of 12 acres, but (early in the nineteenth century) after some ninety million cubic feet of rock and ore had been extracted the fortunes of the mine began to decline, as too did those of the Hillside Opencast of the Mona Mine which was less extensive. In 1839 when W. R. Bingley prepared a new edition of his father's *Tour round North Wales performed during the Summer of 1798* he had to say that "the mines are but a wreck of what they formerly were, the veins of ore being so exhausted that not more than 300 persons are employed." The decline in Anglesey coincided with growing activity in some Caernarvonshire mines e.g., Drws-y-coed, which provided work for some of the redundant miners, including the women, *ledis copor*, copper ladies as they were called locally.

Contemporary records enable us to envisage the mines in their heyday. A. Aikin, who visited them in 1796, noted that "the bottom of the pit is by no means regular but exhibits large and deep burrows in various parts where a richer vein has been followed in preference to the others." [95] Thomas Pennant writing a few years earlier described the mine as "a hollow in the solid ore, open to day." Excavations in the faces were, he said, supported by vast pillars and magnificent arches from which caverns meandered underground. The sides of the hollows were, he added, "mostly perpendicular and on the edges of the chasms are wooden platforms which project far, and on them are windlasses by which the workmen are lowered to transact their business ... There suspended, they work in mid-air, pick a small space for footing, cut out the ore in large masses and tumble it to the bottom with vast noise." In such situations, he said, they formed caverns in which they could shelter during the explosion of gunpowder whilst blasting was in progress, and "be safely lodged until ropes were lowered to convey them up again."

These verbal descriptions are vividly supported by some water-"Colours in the National Museum of Wales painted by J. C. Ibbetson about 1785 (see Plate IV) and although some lines in Wordsworth's *Evening Walk* (1788-9) relate to slate quarries they might equally well have been inspired by the Parys Mountain operations---

Some, hardly heard their chisel's clinking sound, Toil, small as pigmies, in the gulf profound Some, dim between th'aerial cliffs descry'd, O'erwalk the viewless plank from side to side These, by the pale blue rocks that ceaseless ring, Glad from their airy baskets hang and sing.

Before the mines were closed the winding appliances illustrated by Ibbetson had been replaced by others in which the ropes passed round a large drum revolving about a vertical axis as in the horse-driven whims. Two ropes were used, separated by a fillet of wood round the middle of the drum, and so wound that when one bucket was being drawn up another was being let down.

The dislodged masses of ore were broken with sledge hammers and the fragments hoisted in baskets to ground level by means of precariously placed windlasses as described by Pennant. Here they were further broken on iron anvils into smaller pieces, mainly by women and children, or by old and feeble folk whom the company thought it charitable to employ. Women who did some of the heavy work were locally known as *Morwynion y Parys* and gained the reputation for making indifferent wives. When sufficiently reduced in size the metalliferous fragments of ore were roasted (in the early days in open piles and later in coal-fired kilns) in order to remove some of the sulphur. The escaping sulphurous fumes contributed largely to the destruction of vegetation and the desolation of the hillsides.

The kilns consisted of two parallel walls of brick, varying from 20 to 50 yards in length and about four feet high. The ore and fuel were packed between them, rising higher than the walls, and were covered with flat stones closely luted with clay, the whole being covered with a "general integument of clay." Later kilns had brick arches over the ore, and shortly before Pennant's visit attempts were made to prevent the sulphur from" flying away" by conducting the fumes through brick flues so that they "could strike the roof and condensing, fall to the bottom as brimstone."

The best ores were sent to Lancashire or to South Wales to be smelted, and, writing in 1810, Walter Davies recorded that 20 small vessels were formerly employed in conveying the ore, returning with coal and culm for the kilns in which the ores were roasted and the furnaces in which some of the poorer ores were smelted. There were, he said, at one time 32 reverberating furnaces in two smelting houses at
Amlwch. Other lower grade ores, after roasting, were placed in shallow brick tanks where they were soaked in water for from 12-16 hours, during which time soluble copper salts (copper sulphate) were dissolved. The contents of the tanks were discharged into a large basin where the valueless sediment they carried was deposited whilst the liquid was conducted to another series of tanks containing scrap iron, brought from Coalbrookdale and other places. This metal, having a greater affinity than copper for sulphuric acid, dissolved to form iron (ferrous) sulphate, which passed into solution, leaving the copper to be thrown down as a dark muddy precipitate.

From time to time the copper deposit was removed from the tanks but the iron solution ran to waste and found its way into the sea at Traeth Dulas. The oxidation of the ferrous sulphate, due to contact with air, produced red ferric hydrate which, being insoluble, was deposited in the stream, suggesting the name, Afon-goch (Red River) by which it is known, although when mining operations ceased it began to lose its colour. Chemical knowledge had advanced since Sir John Wynn's time, and a better understanding of the process involved in what he thought was transmuting iron into copper was to play an important part in prolonging the life of the mine.

Once commenced, the decline in the fortunes of the mine was never arrested: as the depth increased the ore bodies tended to become more restricted and poorer in quality whilst the cost of raising the ore increased. These factors, together with the falling price of copper and competition from foreign ores brought operations to an end in the Parys Mine in 1871 and the Mona Mine in 1883. Although recent surveys have shown that there are considerable reserves at greater depths than have hitherto been worked, the low grade of the ore and the costs of raising it make the prospect of renewed mining problematic.

By an adaptation of the process operated to recover metal from the water in which low grade roasted ore had been soaked it was possible to continue the production of copper after mining had ceased. Water pumped to the top of the hill was allowed to flow into the old workings, flooding them to the level of the floor of the west pit. There it acted upon the fine particles of copper ore that were disseminated through the rock and became charged with copper sulphate. After a time it was conducted into tanks constructed of cement and brick in which wooden partitions caused the water to flow by a circuitous route from the point of entry to the outlet. Scrap iron placed in the tanks, and from time to time turned over and scraped, changed places with the copper and when the exchange had proceeded as far as possible the water, now a solution of ferrous sulphate, was not, as formerly, discharged into the sea and wasted, but pumped into pits - called ochre pits - passing over an artificial waterfall on the way. Combining with oxygen from the air the iron sulphate changed to iron (ferric) hydrate which was precipitated as ochre that found a use in the purification of coal gas and for making paint such as Venetian Red. The copper deposit was removed at regular intervals until work was interrupted by the First World War, to be resumed intermittently in later years.

TX. GOLD MINES

The earth does not conceal metals in her depths because she does not wish that men should dig them out, but because provident and sagacious Nature has appointed for each thing its place.

Georgius Agricola, De Re Metallica (1556)

The most important mines producing gold in Britain in modern times were situated on the south-eastern flank of the high ground sloping down from the mountains of Rhinog, Diphwys, and Garn in Merionethshire. The auriferous tract, known for many years as the 'Dolgelly gold belt,' lies west and north-west of the Mawddach River and its estuary. It is from one to three miles wide and extends for about ten miles from near Bont-ddu to beyond Tan-y-groes.

It has been suggested that gold obtained from his silver-lead mines provided some of the wealth that Bushell made available to Charles 1 and the absence of records to that effect has been explained by supposing that it was not in the interest of either party to say anything about it. This is an unlikely story and it was not until 1843 that the presence of gold in North Wales in paying quantity was publicly announced by Mr. Arthur Dean, who, finding the metal in the debris from the Cwm Eisen lead mine, reported his discovery at the York meeting of the British Association in 1844.
The announcement was quickly followed by claims that others already knew of the existence of the metal, but, believing gold to be a perquisite of the Crown, had made no attempt to open mines. The ensuing gold rush does not, however, favour the view that anyone with the necessary knowledge would have failed to take advantage of it, and when Dean confirmed the presence of the metal in other parts of the 'belt' local proprietors lost no time in searching for it. Although some of the mines were highly productive the potentialities of the area were greatly exaggerated and almost every vein of quartz was opened up in the hope that it might prove to be auriferous, but, as T. A. Readwin, who was familiar with the circumstances wrote, in a paper to the British Association a few years later (1861), "much current gold of the realm was expended, and very little bullion obtained by smelting."

Most of the adventurers were new to gold mining and there were more failures than successes, largely because it was not at first realised that the lodes were only productive when certain geological conditions were fulfilled. Moreover, mines that might have yielded profit if worked on a small scale did not produce enough ore to pay for the elaborate and costly machinery erected to treat it on a large scale.

About ten mines were successfully worked for a number of years but there are more than 150 old shafts, levels, and trial excavations. The first rush lasted for about 20 years and then, except for intermittent working at the Clogau and Vigra (Figre) mines in the south-west, and the Gwynfynydd mine near the northern end of the 'belt,' there was very little activity for the next 20 years. The Clogau mine was originally worked for copper but after the discovery, about 1862, of gold in what appeared to be paying amounts interest in the copper ores in this and the Vigra mine declined.

Gold was noticed in the lead mine at Gwynfynydd, near the junction of the rivers Gain and Mawddach, in 1864, but little interest was taken until 1888 when the discovery of a rich lode resulted in the mine producing, during the next four or five years, nearly all the gold recorded from Merionethshire.

In 1899 the St. David's Gold and Copper Company was formed to exploit the Vigra, Clogau- and St. David's lodes at levels considerably below the earlier workings and the productive 'era lasted until about 1910. The Company's machinery was sold by auction in 1914. Ventilation was provided by a method then in common use i.e., by the action of a centrifugal fan, driven by a small Pelton Wheel (a water driven turbine) that drew foul air out of the adits so that fresh air could flow in to take its place. Bushell, it will be remembered, forced air right to the working face through a pipe fed by a bellows, a method that ensured more even ventilation than when the air was 'sucked out,' as Agricola put it, when describing the use of bellows and fans.

Compressed air drills were used for boring the rock, the compressor being driven by a second Pelton Wheel. By storing water behind a dam built at the head of the valley and using it when the water in the streams was low, it was possible to run both wheels for nine months of the year. The ore was removed by overhand stoping and very little timbering was necessary because the country rock was strong and quite large chambers could be safely left without support. In 1934 another company extended an adit until it reached what appeared to be a downwards continuation of the principal lode (or lodes) of the old copper mine, but the ore did not contain gold and the amount of copper was not sufficient to encourage further work.

Records show that for the area as a whole the output of gold was not inconsiderable. A. R. Andrew, who described the mining region in 1910, gave the value of the gold produced in Merionethshire between 1861 and 1907 as £400,000, and a recent computation puts the value of the total up to the time the mines were abandoned - there has been no recorded output for about 20 years - as about £486,000.

There is, however, considerable variation in the reported outputs for different mines and over different periods, those given during the preparation of the Final Report of the Royal Commission on Mining Royalties (1893) being (understandably) lower than those quoted for commercial purposes. Although certainly substantial the yield did not cover the working costs of the ventures taken as a whole. Indeed, in evidence given at an enquiry instituted by the Mines Department in 1930 at the request of the Merioneth Mining Development Committee, the spokesman for the Committee admitted that"more gold had come into the district than had been taken out of it." The situation had not improved since Readwin referred to it some seventy years before!
The auriferous quartz veins range from a mere thread to a few inches in thickness, occasionally swelling to two or three yards. The gold occurred where the veins passed through the Clogau Slates and was most plentiful where the veins intersected another series containing ores of copper, with sometimes lead and zinc as well. The fine-grained black Clogau Slates constitute one of the divisions of the Cambrian strata hereabouts and are usually associated with greenstone, an igneous rock, probably intruded in Ordovician times. The slates are rich in pyrites and it may be that the products of the decomposition of that mineral were responsible for the deposition of the gold. The precious metal was visible to the naked eye and was of deeper yellow hue than the pyrites with which it was associated.

The earlier work was undertaken in advance of knowledge of the limits of the distribution of the auriferous ores - the Clogau Slates account for only about 300 feet in some 6,000 feet of Cambrian strata - and although such knowledge increased as the operations were extended it was only fully available when it was too late to be of much use. Not only did the lodes vary in thickness with no way of determining where concentrations of gold were likely to occur, but rich pockets were sporadic in distribution and were usually separated by considerable stretches of barren lode.

Special investigations - made in 1921 on behalf of the Commissioners for Crown lands, the owners of a large part of the gold 'belt,' and on behalf of the Department of Mines in 1930, led to the conclusion that whilst gold is undoubtedly present in the region its uneven and unpredictable distribution make search for it speculative, and whilst bonanza finds are possible, as they have been in the past - it is, for example, recorded that on one occasion 130 oz. of ore taken from the St. David's lode yielded 116 oz. of gold - the potentialities were not such as to encourage the setting up of a permanent industry. It is, however, safe to assume that the area will, from time to time, attract optimistic prospectors, and unwise to predict that none of them will be successful.

Attempts have been made to obtain alluvial gold from the bed of the River Mawddach. The gold occurs in small grains associated with the sulphide minerals that occur with it in the lodes, and owing to the presence of small air-filled cavities its specific gravity is lower than that of vein-gold. The first recorded attempt was made in 1862, and good results were obtained in 1870 when the level of the river was unusually low. The gold was found all along the course of the river from Rhaeadr Mawddach to Cymmer Abbey, the grains becoming finer on the way, which, together with their composition, suggests that they were derived from the wearing away of the Gwynfynydd lode.

There were also gold mines outside the Dolgellau 'belt.' One at Castell Carndochan near Llanuwchlynn, the discovery of which was reported to the British Association at Newcastle in 1863, was worked spasmodically for the next 40 years or so and produced nearly 900 oz. of gold. Unlike those around Dolgellau the lode traversed sediments and volcanic rocks of Ordovician -age.

In the Prince Edward Mine near Trawsfynydd, lodes consisting of quartz with metallic sulphides occurred along the junction between sedimentary rocks of Cambrian age and a sill of diabase. They followed the inclination and trend of the strata and had the sedimentary rocks beneath, with the diabase forming the hanging wall of the workings. Most of the gold was intimately associated with the pyrites, but some of it was, visible. The mine continued in production until 1935, but interest in the gold potentialities of North Wales was revived in the following year when it was reported that the metal was present in volcanic ash that occurs on Moel Siabod in Caernarvonshire. The whole of the rock over a large area and to a depth of 300 feet was presumed to be gold-bearing and capable of being worked as an open quarry, without the expense of providing shafts and tunnels. The company formed to exploit the discovery anticipated, from the conclusions of an Austrian diviner who tested the area “that the mountain will prove to be the most valuable gold producing area in the world” but the extravagance of the claim is a measure of the credulity of those who entertained it!

The temporary success of gold-mining ventures in Merionethshire inspired attempts to exploit again the gold-bearing deposits at Dolaucothi which had been neglected since the departure of the Romans. About 5 ounces of gold are said to have been won between 1889 and 1891 and in the early part of the present century a shaft was sunk and machinery installed to crush the ore. Some 90 ounces of gold were recovered, partly from mined ore and partly from debris left by earlier miners. Later attempts met with varying success and in 1938 about 200 men were employed in the Roman Deep Holdings Company's mine, but work was abandoned in 1939 after boreholes had shown that the bands of ore continued to contain small quantities of gold at the depth to which they were carried by the
inclination of the strata. Whether deeply buried low-grade ore could be profitably worked is a matter for speculation.

X. LEAD AND ZINC MINES

This extraordinary Bounty of Nature [lead and silver ore in Cardiganshire] has been so much neglected and overlooked by us that we chose to rummage the East and West Indies for Mines, rather than to go fifty or a hundred yards under ground in our own Island, where, with Proper Management, we may find the very Thing we so much strive for.

Lewis Morris, in the notes accompanying his Plans of the Harbours, Bays and Roads in St. George's Channel, 1737-48, written during a period of comparative inactivity in the mines.

Ores of lead are more widely distributed in Wales than those of other metals. They occur and have been mined on widely varying scales in all the Welsh counties, especially in Cardiganshire, Montgomeryshire, Flintshire, Denbighshire, and Caernarvonshire.

Vigorously pursued in the 17th century, lead mining continued to engage attention in the 18th, but for Cardiganshire its most flourishing modern period began in the early part of the 19th. Activity rose to a climax in the third quarter of that century and then declined rather rapidly, partly due to a fall in the price of lead resulting from the discovery of large and easily worked deposits in other countries, and partly because the known reserves were approaching exhaustion and the mines had been regarded mainly as a source of wealth, too much of the profit being distributed and too little used for the exploration and development necessary to ensure future production. In addition, in many instances, too much had been spent on elaborate machinery before the capacity of the mines to supply ore in sufficient quantity had been proved. For a time mining for lead and the associated ores of zinc and copper was the most profitable local occupation and the decline of the industry contributed much to the depopulation of the regions concerned.

In the north of Cardiganshire and the adjacent part of Montgomeryshire the productive lodes occur in a roughly triangular area covering about 400 square miles, with the Dovey estuary, Llanidloes and Strata Florida at its extremities. In this region there are records or the remains of over 130 mines, of which the majority, about two thirds, were short-lived, operating for less than ten years, whilst the life of the remainder averaged about 30 years. Amongst those which operated longest were Cwrnystwyth, 61 years, Fron-goch, 59 years, and the Van mine in Montgomeryshire, 51 years. Some plans of mines in Cardiganshire are preserved in the National Library of Wales; two of them date from the middle of the eighteenth century and the remainder to the latter half of the nineteenth.

The abundance of abandoned mines attracted attention as long ago as 1848, and Warington W. Smyth, was constrained to write, "The wanderer who pursues his winding way by the beautiful valley of the Rheidol . . . is often struck with surprise to find himself ... close to the mouth of a gallery, perhaps long ago abandoned, which opens in the midst of a wood of oaks ... where the light tint of the pile of excavated rubbish offers a marked contrast to the verdure of the surrounding landscape."

From about 1840 until mining ceased, during the first quarter of the present century, nearly 480,000 tons of lead concentrates and more than 150,000 tons of zinc concentrates had been produced in the area. The most productive lodes are associated with faults that run in a generally E-W direction and they occur in strata of Ordovician and Silurian ages. They are usually from 20 to 30 feet thick but occasionally thicker and are made up of fragments of the country rock cemented together by non-metallic minerals, of which quartz is the most abundant, with local concentrations of the ore minerals. The same lode has been worked for more than one ore, partly because one tended to replace another - zinc replacing lead for example - as a mine grew deeper, and partly because of variation in the price or the demand for one ore or the other.

The lodes in Cardiganshire are most productive where they traverse strata of the Fron-goch formation (one of the subdivisions of the Silurian System, named after an important mine near Devil's Bridge) and nearly three quarters of the mines occur in that formation, but in the Cwmystwyth district the richest lodes occur in strata of the Cwrnystwyth formation which rests upon the Fron-goch.
The character of the rocks affected the richness of the ores, for where the faulted zone passed through relatively hard rocks like grits and mudstones the shattered debris was more permeable to the mineralising solutions than where it traversed shales, the fragments of which, being softer, tended to be squeezed together giving little facility for the deposition of mineral matter in the spaces between them.

Owing to the hilly nature of the country the ore, like that of copper, could be reached by means of adits, but when shafts became necessary in order to reach ores below the level of the adit it was necessary to introduce pumping machinery. Water power was available and leats were made to conduct water to water-wheels, usually of the overshot type. Some of the leats were so planned that the water, after use at one mine, could be conducted to others at lower levels and used again. Steam engines were in consequence not generally installed in Cardiganshire as they were in Cornwall. In 1848 one small engine was in use for winding ore at Llangynog (in Montgomeryshire) and in 1854 George Borrow, passing what his guide identified as "Level Fawr, a mining establishment " on his way to Ysbyty Ystwyth, saw "immense works of some kind " where "engines were clanging and puffs of smoke were ascending from tall chimneys." A company founded in 1860 to re-work the Imperial Mine erected an engine to permit working at 25 fathoms below the original adit and to provide power for the mills, but the cost of the steam was such that the project had to be abandoned. A similar fate befell a steam engine installed at the Llwymnaelas mine south of Bron Caradoc, because water power proved inadequate. The engine was too costly to work and the mine had to be closed.

The first mine in Cardiganshire to make extensive and successful use of water-driven machinery was East Darren. One of the richest - it had been the source of some of Myddleton's wealth - the new pumps made it possible to extend the workings to an eventual 124 fathoms below the old adit, but water-wheels were not always successful. At the Tynewydd mine, for example, a 40-foot wheel was erected about 1870 with a view to working the mine at greater depths but it was never put to work. The owners could not pay for it and the contractors took it away. Some mines failed because of a superabundance of water in the workings and others because there was insufficient surface water to work the machinery. The deficiency was often quite serious because the supply was apt to fail in dry weather when there was a limited rainfall, and in winter because the water, although abundant, froze in exposed places.

Some of the 19th century workers turned their attention to mines that had been abandoned by their predecessors. In 1830, for example, at Allt-y-crib mine which had been worked by Bushell, an adit was driven above the level of the old workings in order to provide ventilation and give access to ore that the old miners had not been able to reach. Attempts were also made e.g., at Gellireirin about 1850, to recover ore from the debris of mines that had been worked before efficient machinery was available for the crushing and dressing plant.

The Van Mine near Llanidloes in Montgomeryshire was one of the most prolific in the central Welsh area, producing over 96,000 tons of lead ore, nearly 800,000 oz. of silver and over 28,000 tons of zinc ore during its working life. The lodes occur in the Van formation, of Ordovician age - a little older than the strata of Cwmystwyth and Fron-goch - and the mine provides the only important exception in the mid-Wales region to the rule that only when they traversed fractured rocks were the lodes worth working, for rich ores were found in the massive grits that constitute the lower part of the Van formation.

The ore-bearing lode - the Van lode - was a true fissure vein cutting across the bedding and cleavage of the strata in which it occurred. Its average dip was about 74' towards the south, and as the ore part was unusually wide, sometimes reaching 48 feet, it was necessary to modify the method usually employed for working thinner lodes: fortunately we have an adequate contemporary description of the mine at a time when it was in maximum production.

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an important part in the development of the mine. Flucan corresponds with the Cornish flookan, meaning a comparatively soft clay rock which, when it ran parallel to the lode, as in the Van mine, was called cross-flookan.

Although it was intended to remove only the main lode, except where the bastard lode was rich enough, the resulting excavations would have been dangerous if left open, partly because the hanging wall would not be the hard slate of the country rock but the weaker material of the bastard lode, and partly because the empty space left after the removal of the ore would have been too wide to be spanned by timber supports in the usual way. In the circumstances it was decided to fill up every cavity immediately after the removal of the ore.

A vertical shaft (D in Fig. 4i) was sunk on the south side of the lode to a depth of about 880 feet from the surface. From this shaft - the engine shaft, so called because the rods of the pumping engine passed down it - cross-cuts were driven at vertical intervals of about 90 feet to meet the lode (Fig. 4iE). There were nine cross-cuts and the lowest part of the shaft was in the lode itself. The section along the lode (Fig. 4ii) shows how the ore was worked from levels driven from each cross-cut, the operation extending to lower levels as the upper part of the lode was removed.

The method of winning the ore can be best illustrated by describing the operations after a cross-cut had reached the flucan (Fig. 4iv). From each side of the cross-cut a level was driven in the flucan itself, to serve as a primary level (F). The flucan was chosen for this level because its softer rock permitted more rapid excavation and in consequence more rapid access to the ore-bearing part of the lode. The next step was to drive cross-cuts (G in Fig. 4iii and 4v) from the primary level towards the main lode (depicted in section in Fig. 5vi and in plan in Fig. 4iii). These were from 120 to 150 feet apart and from their ends the first level in the lode (H) was driven, usually as close as possible to the foot-wall.
The next process consisted of stoping away the lode from both sides of the level, filling the empty spaces so produced with 'deads' - waste material from the lode, rock set free from other levels, and slate sent down from the surface in a manner to be described. A working level was maintained in the middle of the deads (I in Figs. 4v and 5vii), supported by timbers and a covering of small poles to prevent loose debris from falling into the roadway. This level was provided with a tramroad. The excavation made in the lode by the process was filled to within 18 inches of the roof (Fig. 5vii), except at one end where it was proposed to begin stoping.

When the working level in the lode had been completed the level in the flucan was abandoned except where parts were kept open for conveying waste material for stowing and to assist in ventilation.
Whilst the preparation of the working level in the lode was in progress, winzes (J) from the level above and from 120 to 150 feet apart were sunk in the flucan (Fig. 5viii), or in the lode itself (Fig. 5ix) if the thickness of the intervening material was too great. These served for ventilation and as shoots, called passes, for the waste material needed to fill the excavations. They were 6 feet by 3 feet inside the supporting timbers and were divided into two unequal parts by a partition about one-third of the way along the long axis. The larger part was completely encased in timber and served as the shoot for rubbish while the smaller part was maintained as a passage-way.

It was at this stage that the overhand stoping of the prepared part of the lode began. The height of the stopes varied from 2 to 6 feet according to the character of the roof and each one was carefully packed with deads, passes being left, down which rubbish could be shot for filling the trams. The ore passes were timbered in the same way as the winzes and were of the same size. (K on Fig. 5ix.) In order not to lose ore amongst the rubbish used for stowing, a layer of flucan a few inches thick was spread over it. This, when the lode had been stoped away to the required height, was shovelled into one of the passes and sent to be treated with the ore. It was cheaper to treat a few extra tons than to lay sacks or boards to form a floor to catch the ore.

The stoping continued until only about 12 feet of lode separated the top of the working from the floor of the one above (Fig. 5x). The last stope was then packed tightly with rubbish up to the roof, a new level (L) was made in the remaining part of the lode and the ore removed from each side of it, the empty spaces being filled with rubbish in the usual way. When the lower half of the 12-foot slice of lode had been removed another level (M, Fig. 5xi) was driven in the remaining part and the process repeated. The packing used to replace the ore that had been removed was then continuous with that relating to the lode that had been worked from the level above, and a block of lode some 90 feet high and 120 feet long had been removed and its place taken by rubbish. As the filling followed immediately upon the removal of ore there was at no time danger from the walls falling in, and as no lofty cavities were formed loose rock could be removed from the roof before it fell upon the miners.

Whilst stoping was in progress the permanent level at the bottom of the block was pushed forwards in order to provide a road for conveying the deads to winzes communicating with other workings beneath. The lode itself provided enough waste to fill about one third of the excavated space and additional material became available as levels were driven in the flucan and across the bastard lode, but much more was needed to fill all the space left by the removal of the ore. This was obtained from a quarry near the mine and was taken to one of the two rubbish shafts (0 in Fig. 4ii), shot down to the adit level (P in Figs. 4i and 4ii), along which it was carried by tramroad to other shafts (shoots) leading to lower levels and to places where it was needed. The shoots were so placed that the bottom of one was conveniently near the mouth of another, reducing to a minimum the distance over which the rubbish had to be conveyed by tram.

The Van mine, as previously mentioned, is one of the few metalliferous mines in Wales in which explosive gas was encountered. Methane was met with in the adit and at every level below it when first entering the lode. The gas was described as rushing out with a great noise and as always coming up from below, which suggests that it originated in the rocks and not from the decomposition of mine timbers. Occasionally there were slight explosions, when men's hair and whiskers were singed. The methane was sometimes associated with sulphuretted hydrogen in greater amount than would have been expected in the smoke of gunpowder used for blasting; it resulted no doubt from the decomposition, of pyrites in the lode.

Minor quantities of galena have been raised from eight mines near Llangynog, also in Montgomeryshire, where the lodes occur in shales and mudstones interbedded with volcanic rocks that extend from the upper part of the Ordovician formation into the lower part of the Silurian. Other mines have been worked on a small scale in the upper part of the Elan Valley in Radnorshire and in the Abergwesyn area of Breconshire.

Lead and zinc ores have been worked in Caernarvonshire - in the neighbourhood of Llanrwst in the east and near Llanengan in the Lleyn Peninsula. In the former area, which lies eastwards of the Conway Valley and extends from the valley of the Llugwy to Trefriw, the ores occur in lavas and beds of tuft associated with shales in the upper part of the Ordovician System (Bala Series). They were mined for about 90 years from 1838, producing both lead and zinc ores, the latter in slightly larger amount (14,000 tons as against 13,000) than the former. The Pare mine near-Llanrwst was reopened in 1952, and although it was necessary to undertake much exploratory work, de-water old workings, and
make a new level about a mile and a half long, nearly 8,000 tons of concentrates were produced in about three years, but due to practical and economic difficulties the mine has now been closed.

The most important lead and zinc mining region in Wales lay in Flintshire and eastern Denbighshire, where ores occur in the Carboniferous Limestone and the overlying Cef'n y Fedw Sandstone, and where, as in Cardiganshire, the zinc ores tended to become more abundant as the mines increased in depth. In the 94 years following 1845 the mines produced nearly a million tons of lead and zinc concentrates.

Both in Cardiganshire and north-eastern Wales the lead and zinc compounds were brought up by ascending waters but whilst in the former region they were deposited where they passed through Ordovician and Silurian rocks, conditions in the latter were unfavourable for deposition in the older strata and the mineral-laden waters rose until they reached the Carboniferous rocks before depositing their burden, usually in fissures associated with faults and joints. Some of the mineralised waters reached the top of the Limestone, and in places where shales - the impermeable Holywell Shales that occur at the base of the Coal Measures - rest upon it and prevent further upward movement, the water spread out along bedding planes and joints, forming irregular masses known as pipes or flats but not lodes cutting steeply or vertically through the strata. Gas was encountered in some of the mines where the workings approached the Coal Measures and gave rise to an explosion in the Milwr Mine.

Mining areas occur on either side of the Vale of Clwyd. On the west the ores have been worked mainly in the north, but on the east a much larger, nearly continuous, and highly productive region extends from Prestatyn and Dyserth in the north to Llandegla in the south, with a smaller but highly important area extending from Minera towards Llangollen.

The principal mining regions in the west are near Abergele and at Bodelwyddan. The ancient workings, e.g., at Ffos y Bleiddiaid, have already been mentioned, and others in the same region, e.g., at Caer Gwaith and Tyddyn Morgan, were highly productive in the latter half of the last century. Caer Gwaith is reported to have yielded masses of galena weighing several hundredweights, but, as with many of the other mines, the methods of drainage then available could not cope with the influx of water.

Two veins crossing the hill Cef'n yr Ogof have also been exploited. The northern one was reached by a level commencing at Tynewydd, with shafts sunk at intervals along its course, and the workings in the southern one extended as far as Gwrych Castle. The mine at Bodelwyddan, which derived its ore from two veins, had several shafts and an adit. It was worked at intervals from 1828 until 1859 when it closed because, owing to its low elevation it could not be further drained by adits, and pumps were not installed.

Talar-goch mine, with its Roman associations, occurs at the northern end of the eastern mining region. It was worked at intervals for many centuries and became the deepest mine in Flintshire-reaching 400 yards, but reliable records of output only begin, as they do for most mines, about 1848 when the Geological Survey established a Mining Records Office, the functions of which were taken over by the Home Office in 1882. In 40 years after records began more than 100,000 tons of lead and zinc ores were produced, the lead predominating, but between 1885 and 1898 the output had fallen to less than 2,700 tons, of which nearly seven tenths was blende, and in 1904-5 to only 346 tons, all of it blende.

An unusual kind of mine was developed at the base of the gravelly glacial deposits that lay on the limestone containing the veins worked at Talar-goch. Scattered on the surface of the limestone and covered by the gravel there were large quantities of water-worn lumps of galena that had mingled with the material picked-up by the ice. Known as "gravel ore" it was mined by driving tunnels in all directions after the water with which the gravel had been saturated had drained into the mine-workings in the limestone beneath.

Other mines in this region occur at Dyserth, Talacre, and Axton (near which were the Trelogan and West Trelogan mines). The former was producing ore in 1848 and continued to work until 1909. Its output followed the usual pattern: of about 10,000 tons of ore raised between 1859 and 1873, about 74% was zinc, and of about 18,000 tons produced between 1898 and 1909 nearly 90% was zinc. There were larger and more important mines in the neighbourhoods of Holywell, Halkyn, and Minera, where the surface is often scarred with trial holes, surface workings, and shallow pits, made in search of or to work the ores. The early mines were opencasts or shallow underground workings, but the
modern mines had vertical shafts sometimes fitted with cages in addition to ladders that gave access by means of inclines and levels to all parts of the mine. Ponies were sometimes used for underground haulage. In some mines the ore could be got with picks, after light blasting, and in others the latest types of compressors and rock drills were used. An example of the magnitude of the workings is provided by the Great Halkyn Lode which was stoped to an average height of 110 yards above the tunnel that gave access to it.

The productive mines are too numerous to be described in detail, but for the most part their history has been similar - periods of successful working followed by abandonment (because of inability to keep the workings free from water rather than on account of exhaustion of the ore), and renewal of activity when the market improved or on the installation of more efficient means of drainage.

In its drainage problems the area east of the Vale of Clwyd is unique amongst the mining regions of Wales. The Limestone in which most of the ores occur is divided into blocks by faults and joints, in many of which the lodes have been formed. The area, has been compared with a child's box of bricks in which some of the adjacent faces are cemented together whilst others are not. If such a box were tilted and water poured into the upper corner it would make its way by zigzag routes to the lower corner. The pattern is not quite as simple as this because in the Limestone the water can also move horizontally along bedding planes, and pass by means of open vertical joints from one level to another. Consequently, pumping from one mine might draw water from others, and a mine that pumped vigorously would be spending money for the advantage of competitors. In the Minera district, prior to 1845, when several undertakings were amalgamated, it was not unknown, when any individual company appeared to be especially prosperous, for a jealous rival to stop pumping and so drown its neighbour's workings.

The partitions in the rock were not equally watertight at all levels so that there were instances where the water stood higher in one block than in others adjacent to it and was not affected by pumping in them. All in all; conditions were such that pumping costs were always high and the results uncertain. It was apparent that the only way to continue working was to drain large areas by means of adits at low levels, and the history of the mines from the early part of the, 19th century is a record of the results of driving longer and lower drainage tunnels.

The magnitude and complexity of the problems are indicated in Richard Warner's account of his tour in North Wales in 1798, which also includes a vivid description of an adit driven to de-water a mine, and of the workings to which it gave access. The Pen y Fron mine near Mold was, he said, drained by a steam engine and a waterwheel working five pumps in the same shaft. Two other pumps raised water from lower workings to the main level that communicated with the engine shaft, but, "with all this power Mr. Ingleby is scarcely able to get to the bottom of his works, except the weather be particularly dry." Of the neighbouring Llyn y Pandy mine, owned by John Wilkinson, the Bersharn ironmaster, he wrote, "The mine contains so much water that he is under the necessity of erecting four vast engines of Messrs. Boulton and Watt's construction upon the promise to drain it."

The largest undertaking he saw was the Holywell mine, where, from the bottom of the hill in which the veins occurred, an adit 6 feet high and 4 feet wide had been driven for 1,700 yards. A stream of water nearly 3 feet deep flowed from the passage in which long narrow boats, sharp at each end, were propelled by workmen pushing their hands against the sides of the tunnel. The adit was commenced about 1774 and after penetrating 600 yards a vein yielding about 80 tons of ore was encountered, but during the next four years the tunnel was extended for another 500 yards without meeting with sufficient ore to cover the cost of driving it. At this point another vein was struck which was still productive at the time of Warner's visit. Six men were constantly employed to extend the tunnel, using gunpowder to blast the rock.

Sitting in one of the boats, Warner and his guides (with lighted candles in their hands) proceeded along the level for about 1,100 yards and then entered a large natural cavern from one side of which a passage branched off into the mountain. Here they met two miners coming out of the mine, each wearing a fur cap and carrying a lighted torch. When they reached the end of the level "it was necessary for us to ascend several vertical shafts or perpendicular passages ... which pursue the ore in all its ramifications as well as admit air to the workmen. For the first twenty yards we performed the ascent without any difficulty being assisted by a rude kind of staircase." After this they had to "encounter a shaft properly so called. This is a vertical pit about four feet square and of uncertain depth, sometimes boarded and often instead having only pieces of wood fixed to the sides of the rock,
one above another and at a distance of two feet apart, so that the position of a person ascending, with his legs and arms stretched to the utmost, is much the same as if he were extended on a Greek cross."

After climbing for forty or fifty yards and scrambling through a horizontal passage giving access to another large cavern, the side of which was encrusted with spar, they reached the place where "those laborious beings who are content to sacrifice health and safety for the scanty gain of about twenty pence per day, are busied in their horrible employ.--- Emerging from the tunnel after about four hours in the mine Warner was assured that he had not visited a tenth part of the excavations.

Pennant described a similar excursion into the mine with his two sons during the course of which they saw "a small but elegant cascade which ... served to augment the water in the tunnel, which was also increased by several strong springs rising from the sides and bottom with strong ebullitions." He thought that the water might be one of the feeders of St. Winifred's well as the spot was "nearly in a descending line with it a speculation that, as will appear later, proved to be correct.

The first of the major drainage schemes was commenced in 1818, when a level - the Halkyn (Deep Level) Tunnel - was driven at about 200 feet O.D. from the side of a stream at Bryn Moch near Coed y Cra. This cut into an important lode - the Deep Level lode - at about 570 feet beneath the surface. In 1875 a new company - the Halkyn District Mines Drainage Company Ltd. -was formed with a view to continuing the tunnel, meeting the cost by levying a rate on the various mines that would benefit by it. This company extended the tunnel along the Deep Level lode for about four miles, meeting several shafts on the way and affecting mines between the Halkyn Mine in the north and the Llyn y Pandy Mine in the south. As it progressed it made possible the re-working of mine after mine that had been derelict and revealed new lodes as well. Most of the lodes were worked down to the level of the tunnel, and by pumping, below it, but regional drainage to a still lower level was necessary if deeply buried ores were to be economically worked.

In 1896 the Holywell - Halkyn Tunnel Company was formed to de-water lodes in the Holywell district, a region in which mining had almost ceased because, although many of the mines were equipped with expensive machinery, even pumping simultaneously in several shafts could not deal with the volume of water that was involved. This tunnel was known as the Milwr Tunnel from the name of one of the mines it drained, and the Sea Level Tunnel because it began near sea-level at Bagillt on the estuary of the Dee. By 1908 it had been driven as far as the boundary of the Halkyn Mines drainage areas, a distance of some 3 miles.

An incident towards the end of the driving of this part of the tunnel emphasised the water-hazards of mining. Early in 1917 the tunnel broke into a large fissure-like cavern about 4 feet wide, 60 feet long, and rising to a height of over 20 feet near its centre. The cavern was filled with sand and water which rushed out and swept loaded tubs along until they were jammed and partly choked the tunnel with sand. The break-through demonstrated the facility with which water could move for long distances in the region concerned, and confirmed the opinion expressed by Pennant more than a century before, for the flow from St. Winifred's Well, nearly three miles away, decreased and about 11 hours later failed altogether. The water-supply of Holywell was also affected, but both were restored by pumping from workings below sea-level.

It had already been realised that in the area affected by the Halkyn drainage scheme the ores above the level of the tunnel were nearly exhausted, and in 1913 the Halkyn District Mines Drainage Company obtained powers to extend the Milwr Tunnel and drain mines in the Halkyn area to a further depth of 190 feet. When, during the first world war, lead and zinc ores were urgently needed and it was apparent that the Milwr Tunnel would be a long time reaching its objective, a Government sponsored scheme was introduced with a view to giving access to greater depths by pumping, but it was abandoned at the end of the war, just as it was nearing completion. The southwards extension of the tunnel was continued, until, when mining ceased in 1958, it was more than ten miles long. The excavation of the underground passages and shafts resulted in the production of large quantities (from 50,000 tons to 100,000 tons a year) of high grade limestone, the sale of which helped to meet the expense of the exploratory work that was necessary for the continuation of the metalliferous mining.

In some of the mines the ore occurred as 'pipes' and 'flats.' A flat originated as a number of pipes or caverns hollowed out in the limestone and running in various directions, each pipe following a joint and coming to an end where the joint closed up or died out. As a result the ore did not occur as steeply
inclined lodes but as irregular beds associated with crystalline calcite and clay or, if the enclosing rock was calcareous sandstone, with sand.

Flats worked in the Prince Patrick Mine on Halkyn Mountain occupied a fissure in the Limestone that had been widened by solution into a long oval-sectioned cavity. The lower part was filled with clay containing irregular layers of massive calcite, while the upper part contained crystalline calcite. The galena occurred in the lower part as a series of "runs." In one flat there were vertical ribs and in another a horizontal bed, recalling the appearance of a coal seam in a coal-level. Opened in 1872, the mine was worked for about 15 years but produced less than 3,000 tons of ore.

At Parry's Mine near Halkyn the ore in a flat was reached from a shaft 110 yards deep. It was followed for about 250 yards, at which distance it was about 140 yards beneath the surface. After this the ore thickened out as the rock closed in on all sides. In the North Hendre Mine near Rhyd y Mwyn there were flats of considerable extent and up to three feet in thickness, as well as irregular pockets of ore running upwards into the overlying shales. One such pocket contained 2,000 tons of ore.

There were also highly productive mines in the Llanarmon district near the southern end of the main ore-field, and workings in the Westminster lode (named after the Duke, whose land it traversed and whose family, the Grosvenors, had taken an active part in local mining for many years) are said to have produced ore to the value of £3,000,000.

Ores in the Minera district, where there were about twelve lodes, may have been worked by the Romans. By 1921, after many years of high productivity, the largest of the mines were idle on account of water difficulties, which had, as in the region farther north, always been acute. The orefield is almost completely separated from the main mineral-bearing tract by a geological fault - a branch of the Bala Fault that extends across North Wales, interrupting the continuity of the strata from the neighbourhood of Caergwrle by way of Bala Lake to the sea near Towyn. As a consequence the strata in which the ores occur are not continuous with those farther north and were not affected by the major drainage schemes undertaken there. The Minera group of mines in the eastern part of the region was de-watered by a level commenced about 1766, and by 1815 water from them made its way, through an open fissure associated with one of the veins, into the deeper parts of the western workings and although large sums were expended in installing and running pumps it was only in dry weather that the bottoms of the workings could be reached.

In 1845 the Minera Mining Company commenced a deep level which, by 1849, connected the eastern and western mines and drained the whole Ore-field some 70 yards lower than before. Pumping ceased in 1909 when the lodes were becoming less productive and the price of lead was low, and eighteen months afterwards the workings below the level were full of water. The peak year of production was 1864, when nearly 6,900 tons of lead ore and nearly 1,200 tons of zinc ore were raised.

The lead and zinc ores of South Wales were of less importance than those farther north but like them occur both in the Ordovician and Silurian series of rocks and in the Carboniferous Limestone. Between 1845 and 1938 nearly 48,000 tons of lead concentrates were produced from mines in the older rocks of Carmarthenshire, mainly from the region around Rhandirrhwyrn, where there was considerable activity in the middle part of the eighteenth century and some 400 men are said to have been employed in Lord Cawdor's mine. This figure, like many others cited in similar circumstances, has to be accepted with caution and probably means no more than a 'good many.' It was given by an old miner to Walter Davies in 1815. He also said that four miners and three labourers raised 45 tons of ore in three weeks, which represents a little over 2 tons per man per week, so that the output of from 900 to 1,200 tons per quarter, quoted by Davies, represents the result of the work of only a little more than 40 men!

The workings had become extensive when Davies wrote, some 60 years after the mine had started. There was a level entering the western side of the hill and serving for some distance as a canal for the passage of small boats; an incline of about 70 feet led to another level which continued until it reached the eastern side of the hill, nearly a mile away. There were also small mines near the Pembrokeshire border and one producing silver-bearing lead ore at Llanfrynach in the north-east of that county.

Veins in the Carboniferous Limestone have yielded ore in Carmarthenshire, near Mynydd y Garreg, and farther east in Glamorgan where they were worked mostly about a century ago. What Walter Davies described as a "belly or ore" was worked near Bishopston in Gower, whilst in the Vale of Glamorgan there are shafts and levels at Pentre near Llantrithid, and the remains of more extensive
workings between St. Hilary and New Beaupre where there are about eighteen shafts from 60 to 70 feet deep and from 50 to 140 feet apart. They are connected along their bottoms by a level entered from the hillside and appearing to represent a natural fissure widened for the purpose. Explorations by members of the South Wales Caving Club show that the roadways extended for about 600 feet and opened here and there into small natural caverns.

The galena was associated with calcite in narrow vertical veins, and a simple form of overhand stoping appears to have been employed in working it. Small logs were wedged across the narrow rift, formed as the ore was excavated, in order to provide a crude staircase enabling the miners to reach the roof, which grew steadily higher as the veinstuff was removed and was in some parts about 25 feet above the floor of the level.

Near Cefn y Pare south east of Llantrisant there are levels and shafts made in search of galena which occurs in small discontinuous veins and scattered pockets in limestone representing the Triassic basal conglomerate. Walter Davies said that the Park mine, as he called it, was unique in that it was the only one in the region where lead ore occurred in limestone above the coal - a correct observation, for the Carboniferous Limestone with its lead bearing veins lies beneath the Coal Measures, whilst the Triassic deposits rest upon them.

When water difficulties were encountered, he said, a level was cut through the coal-bearing strata to serve as a drain. He also said that, about 1770, the mine gave employment to 500 miners, but the writer has found no other authority for such a claim, and the geological indications are that no considerable amount of ore either has been or will be obtained from these workings. Small veins and scattered crystals of galena in the Carboniferous Limestone, Trias, and Lias in other parts of the Vale of Glamorgan and the country adjacent to it have invited attempts at exploitation but the operations were short lived and seldom remunerative.

Farther east along the border of the coalfield, between Rudry and Machen in Monmouthshire - a region in which as already mentioned Roman coins were found in association with ancient lead workings there are shallow opencasts and shafts leading to underground excavations from which lead ore was being obtained about a century ago. The ore is said to have been washed in Draethen Brook near Cwm Glesyn and the remains of hearths discovered at a brickworks near Farm Furnace 111 wrn at the western end of Caerphilly Common are presumed to mark the site of the smelting furnaces.

XI. IRON AND MANGANESE MINES

As touching mines of iron ore … wheresoever any such be, they are easily discovered, for the very leer of the earth, resembling the colour of the ore, betrayeth where they lie.

Pliny the Elder, *Natural History.*

Three quite different kinds of iron ore occur in Wales - in the Cambrian and Ordovician strata of Anglesey, Caernarvonshire, and Merionethshire; in the Carboniferous Limestone of north-eastern Wales and Glamorgan; and in the Coal Measures of the South Wales and North Wales Coalfields. Each has its own history in relation to industry.

The iron ores of north-west Wales are sediments interbedded with the strata in which they occur. From time to time during the last century they made useful contributions to the home supply of iron but their present interest lies mainly in the problems associated with their origin, for the optimistic forecast of the writer (J. E. Thomas) of an essay that gained a prize in the "Bangor Royal Eisteddfod" in 1874 has not been realised. Of Caernarvonshire he wrote, "In many parts of the county we find rich bands of pisolithic iron ore that has not as yet been sufficiently opened to the commercial world, but which, bye and bye, as railways hre constructed through the country will be busy centres of industry."

The ores are usually dark purplish in colour or black, and the richest of them consist largely of rounded grains or oval pellets varying from the size of a pin's head to, that of a pea or bean, i.e., they exhibit the structures known as oolitic (resembling fish roe) and pisolithic (like peas). The average iron content is about 45 per cent but some may contain as much as 52 per cent whilst others, in which the rounded particles are scattered in a matrix of dark mudstone, have so much less that they have not been worth exploiting. It was once thought that the ores had resulted from the alteration of oolitic and pisolithic
limestones, but it is more likely that they were deposited as iron ores, perhaps by bacterial action in waters that were deficient in oxygen.

The ore beds vary from about 4 feet to 15 feet in thickness and were worked in quarries or shallow trenches, or in short levels driven from the faces of the open workings. They have been too much affected by folding and faulting for deeper mining to have been economically feasible, especially as the ore became harder when followed downwards and contained greater amounts of deleterious impurities (compounds of silica, sulphur and phosphorus) that had to a large extent been removed by weathering from the more superficial layers.

In Caernarvonshire the ores are present in the Lingula Flags division of the Cambrian System and have been worked at Betws Garmon near Caernarvon, Llandegai near Bangor, and Llanengan in the Lleyn Peninsula. They also occur at Pen-yr-allt near Penrhyndeudraeth in Merionethshire, and have been reported (in rocks of Ordovician age) from about fifteen localities in Anglesey. There, however, they are of low grade and attempts at exploitation have not been successful. On the northern slopes of Cader Idris, at Cross Foxes, and by the side of the ancient Ffordd-ddu the ores are associated with lavas and volcanic ashes of Ordovician age.

Many mines were opened in Caernarvonshire, especially in the latter half of the 19th century, but the output was restricted by their remoteness from smelting centres and by inadequate road and rail communications. The quality and quantity of the ores were not such as to justify the cost of improving transport facilities.

Although there are no contemporary records of output the ores at Betws Garmon were worked early in the nineteenth century because on the 1841 edition of the Ordnance Survey map old ironstone quarries are indicated at nearby Ystrad, but for the most part the workings belong to the latter part of the century and the first two decades of the next. Reference to the Ystrad mine first appears in Home Office statistics in 1911. The ore was excavated from open cuttings or won by overhand stoping in short levels with an occasional pillar of ore or rock left to support the roof. The mine at Llanengan near Abersoch, where the ore was associated with manganese, was worked as a quarry. At Pen-yr-allt the ore was worked about 1840 and again about 1880, but on a limited scale. Tests made more recently showed that it contained too much sulphur to be suitable for present day needs. The Penrhyn mine near Llandegai, which was opened in 1913 and yielded ore from openworks and levels, illustrated the difficulties with which many of the mines in rural surroundings had to contend. The ore was first conveyed in tubs running on rails down an incline about 150 yards long, the full tubs pulling up the empty ones. The tubs were then drawn about 500 yards along a level tramway to the Bangor-Bethesda road where the ore was transferred to carts which conveyed it another 200 yards to a siding on what was then the L. & N.W. Railway.

Information regarding mines in the neighbourhood of Cader Idris is disappointingly meagre, but they seem to have been worked much earlier than those farther north for there can be little doubt but that they provided the ore for the furnace built in 1717 at Dolgyn about 2 miles west of Dolgellau by Abraham Darby of Coalbrookdale. [1401 The power for the blast and for the hammers to work the forge was provided by the nearby river and the fuel was charcoal from the neighbouring woods. As in other mining regions charcoal was difficult to obtain in sufficient quantity and the average length of time the furnace was in blast was about 15 weeks in a year. The most successful blast lasted for nearly 37 weeks and yielded 446 tons of iron, but it took nearly four years to accumulate the necessary fuel. After about ten years the use of the local ores declined and haematite ore was imported from Lancashire. The ores were worked again in the early part of the 19th century because iron mines are indicated near Cross Foxes on the Geological Survey Maps of 1850-1856. They were narrow open trenches the depth of which varied from about 20 feet on one side to about 40 on the other where the strata were steeply inclined, but were of more uniform depth where the beds were nearly vertical.

A mine at Drws-y-nant near Dolgellau was also worked as a deep open trench at least as early as 1838, because the name Tyllau-mwn, meaning mine shafts, appears on the Ordnance Survey maps of that date. It was worked again about 1880. The output of pisolithic ore from all sources reached its highest figure in 1857 when it was 80,000 tons. For a few years after 1908 it varied between 10,000 and 14,000 tons but by 1925 all the mines had closed.
The iron ore in the Coal Measures is the so-called clay ironstone that is interbedded with shales associated with coal seams. It is essentially a hard clay-rock containing carbonate of iron (chalcybite) in such quantity as to yield from 25 to 35 per cent of iron. Normally the colour ranges from light to dark brown but it may be almost black, due to the presence of so much carbonaceous matter that the ore can be roasted (as a preliminary to smelting) without the use of fuel. It is then called black-band.

The ore may occur in continuous beds a few inches in thickness, or as more or less rounded lumps or nodules distributed in layers within the shales. It was known as 'mine,' the nodules being 'balls of mine' and the beds 'pins of mine,' whilst the shale in which the ore occurred was known as 'mine ground.'

Clay ironstone owes its origin to the conditions which resulted in the formation of coal seams. Most rocks contain a small amount of iron which normally passes into solution as the rocks are weathered, and, together with other products of denudation, finds its way into the waters of rivers. In the swamps in which the Coal Measures accumulated, and on which were established the forests that provided the material for coal seams, there were many temporary shallow lagoons in the often stagnant water of which there was much decaying vegetation which acted as a reducing agent and prevented oxidation, so that an appreciable amount of the iron remained in solution. This, deposited as iron carbonate as the solution became concentrated, mingled with the mud or other sediment that was settling out of the water and gave rise to the ferruginous clay that now constitutes the ironstone.

In South Wales clay-ironstone occurs principally in the Lower and Middle Series of the Coal Measures which also contain most of the important coal seams. It is best developed and was most extensively worked between Pontypool and Merthyr, but when traced to the west, although the individual beds tend to become thicker they also become poorer in iron. As a result they were not exploited to the same extent as in the east, although they were worked, amongst other places, along the south side of the Amman valley near Brynamman and in the neighbourhood of Ponthenry. It was also mined at Maesteg and Cwmavon, and ore associated with a small seam of anthracite was worked both opencast and by tunnelling in the cliffs between Amroth and Saundersfoot in Pembrokeshire it was smelted at Stepaside.

At first the ore in the principal regions of production was obtained by picking the nodules from the beds of streams, where they tended to accumulate on account of their superior weight and hardness whilst the associated softer shales were disintegrated and washed away. When these supplies were exhausted the nodules in beds exposed in cliffs and artificial excavations were worked. One method of separating the ores from the much more abundant shales was to make a pond (about 20 yards square and 3 or 4 feet deep) at a suitably high level by damming a stream and then allowing the water (controlled by a sluice gate) to rush suddenly down the hill, washing away the shale and leaving the heavier nodules to accumulate at the bottom of the slope. The streams were called races, but the process, which was called 'scouring' tended to block watercourses with debris, causing floods that destroyed valuable land and led to expensive lawsuits.

As the demand increased the ores were obtained from quarry-like excavations along the outcrop. These were known as 'patches' or patchworks and the debris left the surface very irregular with fan-shaped mounds that were gradually covered with vegetation. Plate V illustrates a mid-nineteenth century patchwork known as the Elled Patch, situated on the shoulder of a hill between Nant-y-glo and Beaufort. Below a thin layer of soil and stones there followed in turn, a (dark in the illustration) layer of poor quality ironstone, then shale with abundant ironstone nodules, a seam of coal - the Elled Coal - and more shales separating other thin seams of coal.

By the beginning of the 19th century the ore was obtained from levels driven into the hills by a method resembling the 'pillar and stall' system used for working coal seams. From main roadways intended for transport a number of tunnel-like cuttings (stalls) were driven into the seam or strata to be excavated, with pillars left between them to support the roof. This operation released a considerable part of the available ore, and then, after cutting or 'holing' through a pillar at its far end from one stall to another the material of the pillar was removed, the ore sent to the surface in trams and the unsupported roof left to collapse into the space that remained after the miners had stowed away as much of the discarded shale debris as was possible. The amount of debris was considerable because although the workings had to be about 6 feet in height the ironstone beds - two or three in number and from less than two inches to about six inches thick - accounted for only a small proportion of the material that had to be excavated, and even when as much as possible had been stowed back in the
emptied space there was still a considerable quantity to be brought to the surface through roadways maintained within the debris. This amounted to as much as five or six trams of rubbish to one tram of ore. A model of the neighbourhood of Ebbw Vale made by Thomas Sopwith in 1840 when the ore was still in great demand is preserved in the Museum. It illustrates the distribution and effects of patchworks and the plans of some pillar-and-stall workings in both ironstone and coal. When underground mining for the ore first commenced there was a tendency, as there had been in earlier mining ventures, to adopt methods that seemed likely to yield most profit most quickly, without taking into account the desirability for planned working with a view to ensuring that the removal of ore at one level did not increase the labour and cost of working at other levels.

Before ironstone mining ceased the pillar-and-stall method was in large measure replaced by 'long wall working' - also a system applied in coal mines - by which all the ore-bearing shale was removed at one operation, no supporting pillars being left for subsequent removal. The shale was mined along a continuous face or 'wall' that moved farther and farther away from the entrance to the mine. The roof of the space immediately in front of the working face was supported by timbers which were moved and re-erected as the face advanced, allowing the roof to collapse on the debris which had been stowed in the emptied workings. Communication with the exit was maintained by building thick stone walls from floor to roof on either side of a road, thus providing a passage through the fallen debris which became more and more tightly packed as the overlying strata settled down upon it.

Large scale production of clay ironstone in South Wales began during the 17th century when the exhaustion of timber for smelting in the ore-fields of England made it necessary to find new sources of supply. Advantage was taken of the occurrence, especially around the north-eastern rim of the coalfield, of timber, iron ore and limestone - the essential materials for iron making. By 1740, however, the industry became nearly extinct because of growing scarcity of local timber for making charcoal. Ore was then taken on the backs of ponies or mules as far away as Brecon, where supplies of fuel were still to be obtained.

The industry revived again in 1765 when Anthony Bacon began to use coal for smelting at Merthyr. By the middle of the 19th century clay ironstone accounted for nine tenths of the home supplies of iron ore and an article in the Illustrated London News in 1854 referred to it as "the true material of England's greatness, of which South Wales furnishes 700,000 tons," i.e., about one third of the British output at the time. In 1856 the output from Wales was over 1,700,000 tons, after which it fell to less than half as much in 1860 and no more than 20,000 tons by 1900.

The use of the ore declined rapidly after 1855, when Sir Henry Bessemer introduced his new process for making steel, a process for which the clay ironstone was unsuitable. Its place was taken by foreign ores, by the lower grade but more easily worked ores that had been discovered in the Jurassic rocks of England, and by the haematite ores that occur in the Carboniferous Limestone, the greatly increased demand for which led to the opening of new mines. By the end of the century most of the ironstone that was still being raised came from coal mines, for when it became necessary to drive through 'mine ground' in order to reach a coal seam it was worth while to preserve for sale the iron ore in the rock that was removed. In 1920 a small amount was raised at Ebbw Vale and sent to Staffordshire but none has been recorded from any locality in South Wales since 1930.

Very large quantities of ore still remain in the coalfield - one estimate gives 15,000,000,000 tons - but even if changes in metallurgical processes should create a new demand for it, and there are no reasons for anticipating such changes, only a small proportion could be economically worked.

Clay ironstones also occur as thin beds or as nodules in the shales of the Middle Coal Measures of Denbighshire. They contain from 20 to 30 per cent. of iron and are usually so closely associated with coal seams as to have been mined together with them after the local iron works began to use coal, but, as in South Wales, they were first exploited when charcoal was still used in smelting. At Ponkey, near Ruabon, for example, shallow pits, 'bell pits,' sunk for ironstone, passed right through a coal seam - the coal being then of no value in the ironworks.

Bell pits began as shallow shafts sunk to reach shales containing ironstone (or a coal seam) that lay not far beneath the surface in more or less level country where the driving of adits was not possible. Upon reaching the ironstone (or coal) the bottom of the shaft was widened in all directions and when the mineral had been removed for as far as was safely possible the pit was abandoned and filled with waste material excavated from a new one sunk close by. The pits varied in size according to the depth
of the mineral to be reached and the stability of the strata to be penetrated, but an average size was 5 feet in diameter at the top, widening to 12 feet at the bottom and from 15 to 20 feet deep. The name derived from the bell-like shape of the excavations, which suggested also an alternative name, 'beehive pits.' The method was very wasteful because it meant leaving behind a great deal of mineral that could not be recovered by subsequent operations.

A collection of specimens shown at the Great Exhibition in 1851 indicated that at least 7 layers of ironstone were then being worked in the Ruabon district. The ore was also raised in the neighbourhood of Brymbo, and in Flintshire at Mostyn, Coed Talon and Leeswood, but not to any great extent. Furnaces at Leeswood were using it in 1854.

The output from this coalfield rose and fell as it did in South Wales and for similar reasons. It reached a maximum in 1865 when it was over 97,000 tons and declined in a fluctuating manner to less than 25,000 tons in 1881, 2,700 tons in 1887, since when it has never reached 1,000 tons in a year. It ceased in 1911 when only 341 tons were raised.

*Haematite ores.* Reference to the iron ores that occur in the Carboniferous Limestone has been left until last because, although the Limestone is an older rock than the Coal Measures that contain the clay ironstone, the ores within it were not deposited contemporaneously but were introduced long after the materials of the rock itself accumulated and are the youngest of the iron ores that have been mined in Wales.

The ores were, as we have seen, used by Iron Age man and the Romans and again in Tudor times, but the modern era of their exploitation commenced when changes in the metallurgy of iron and steel created a demand for them in place of the clay ironstones that had previously been so extensively used. Their mode of occurrence is illustrated in Figure 6 from which it will be seen that they occur as irregular and often very large masses within the Limestone, especially near the top of the formation where (in Glamorgan) shales of the overlying Millstone Grit Series or the more recently formed Triassic deposits rest upon it; but one important mass, at Taffs Well, occurs in the main body of the Limestone. Where the overlying strata had all been denuded away the ore appeared at the surface and could be obtained from shallow excavations.

The ores, which are now oxides of iron, some with and some without combined water, resulted from the replacement of Limestone, and perhaps also the filling of pre-existing cavities within it, by compounds of iron introduced by percolating waters. One view concerning their origin takes into account the fact that the Triassic strata accumulated under and desert-like conditions. They include the red marls seen in the cliffs at Penarth and in some inland brick-pits, and the conglomerates and breccias that occur at the base of the formation where it rests upon Carboniferous Limestone. In the circumstances in which the Triassic strata were formed iron compounds present in the rocks that were undergoing denudation were not carried away by streams to the sea but were retained in the accumulating debris, and were deposited on and between the particles of what subsequently became the Triassic rocks, giving them their characteristic red tint. In due course percolating waters dissolved some of the iron compounds and carded them downwards until, on reaching the Carboniferous Limestone, a rock soluble in natural ground water and in which there were fissures and caverns where the water could accumulate, chemical action took place, the Limestone being in part replaced by the iron compounds which either originally were or subsequently became for the most part the oxides known as haematite and limonite. The former has a rich dark red colour, seen especially when the mineral is scratched or powdered, whilst the latter, into the composition of which water enters, is rust coloured.
An objection to this view is that, since the red material in the Triassic rocks is a dehydrated form of iron (ferric) oxide that is almost insoluble in water, it is difficult to see how it could have passed into solution to the extent required by the amount of ore that is present in the underlying Limestone. An alternative and on the whole more likely explanation is that the source of the material responsible for the red staining of the Triassic rocks and the deposition of ores in the Limestone was the iron-bearing substances - clay ironstone and pyrites - that occur in the Coal Measure shales. These deposits were undergoing denudation during the period of uplift that brought the Carboniferous Period to a close, and the mineralised solutions resulting from the decomposition of the ferruginous rocks and minerals could well have been responsible for both the red staining of the Trias and the concentration of iron.
compounds in the Limestone. A third view, not yet fully elaborated in published works but discussed in an unpublished thesis by Mervyn Williams of the Department of Mining, Imperial College, London, is that the ores were deposited from iron-rich solutions rising upwards from an unspecified source, probably during or soon after the earth-movements that, during Tertiary times, gave rise to the faulting and folding seen in the local strata of more recent age than the Carboniferous. An evaluation of these varying views would involve excursions into fields quite outside the scope of the present work, but whichever may ultimately receive the greatest measure of support the essential features of the distribution and occurrence of the ores will remain the same.

In South Wales haematite ores are found around the rim of the coalfield between Taffs Well near Cardiff and Llanharry about 6 miles to the west, and also to a small extent in a few other localities. At Taff's Well, where the ore occurs in the main body of the Limestone beneath beds of dense dolomitic limestone that set an upper limit to the strata that were affected by the ferruginous replacement a mine - Garth Mine, from the name of the hill in which the ore occurs - was opened before the middle of last century but records of output do not begin until 1859. By the time it closed in 1884 it was estimated to have produced about 1,000,000 tons of ore.

The ore was first worked from the surface downwards giving rise to a vast open pit, but when this became too deep and unsafe for further working an adit was driven from the side of the hill to a point near the bottom of the pit, cutting into it where it was about 240 feet deep. From the adit, when it reached the ore, a shaft was sunk that eventually extended to a depth of over 180 feet, giving access to more deeply buried ore bodies. The ore from these was raised by means of an engine erected near the end of the adit. The walls of the cavities produced as the ore was removed were sufficiently firm and secure for timbering or other means of support to be unnecessary.

A contemporary description gives a vivid picture of the conditions obtaining at the mine during its hey-day. After traversing the long adit to reach the bottom of the open pit, "Close by, a powerful engine is in motion to pump up the water and raise the minerals. Men and boys, horses and trams, are seen flitting about and a hum of voices and the sound of hammers greet the ears ... In the quick descent [of the shaft] may be noted, in passing, a blacksmiths' shop that looks as if it were suspended in mid-air, where the tools of the workmen are sharpened. Below, numerous lights are seen: they are the candles of the miners engaged in blasting the rock ... Far above a glimmer of light insinuates itself through tortuous passages that communicate with the great outer pit ... Around, the men are making tubular orifices in the hard rock to receive a charge of powder to rend it in pieces." After the mine was abandoned the lower workings filled with water up to the level of the adit, whilst those above it formed an extensive lofty cavern.

During the latter half of the last century three mines were active near Pont-y-clun - the Mwndy and Bute mines about a mile to the east and the Trecastle mine about as far to the west. In this area the ore bodies occur in the topmost beds of the Carboniferous Limestone and their upper limits are determined in part by the shales of the Millstone Grit which succeeds the Limestone and in part by the basement beds of the Trias. Where these deposits had been denuded away before the Ice Age the ore-bearing Limestone lies directly beneath a covering of Glacial gravels.

The Mwndy and Bute mines lay east and west respectively of the road from Cardiff to Llantrisant. Some old workings at the Bute mine were reopened in 1854 whilst the Mwndy mine began production shortly afterwards and their combined workings extended over about a mile and a half. At first the ore was reached by the removal of the material (overburden) resting on it, and this, due to the inclination of the strata in which the ore occurred, steadily increased in thickness, much of it being conglomerate which had to be blasted and would have provided a good roof for underground workings. Somewhat belatedly inclines were driven along the dip of the strata and small shafts were sunk from which roadways were cut to reach the ore pockets.

The Trecastle mine was opened about 1878 and continued to be active until 1891, some years after the other mines in the neighbourhood had closed down. All the ore (about 120,000 tons) was obtained from one large pocket. It was won by means of a shaft sunk some distance away from the outcrop, with levels driven from it to meet at the ore. The removal of the ore gave rise to large cavities and when one became inconveniently lofty a small opening known as a 'pass' was driven upwards to the gravel or shale, whichever lay above, so that through it the chamber could be filled with rubbish to a height convenient for renewed working. The ore subsequently obtained from the chambers so treated was
thrown down to a haulage road through a 'pass', either in the debris, kept open by means of timber, or in one of the pillars of ore left between the chambers.

The ore of the pillars was subsequently removed by means of small headings, for the gravel, which was always more or less wet when filled into the chambers, settled down to a compact mass capable of supporting the roof when the pillars were removed. The Bute Mine was worked in a similar manner, except that shale rather than gravel was mostly used to raise the floors of the working places. It was sufficiently incoherent in the neighbourhood of the ore to run freely without having to be excavated. Difficulties were created by water in the deeper parts of the mine, and where the roadways passed through shale flooding was apt to cause the roof to collapse.

The three mines near Pont-y-clun and their associates had all closed down by 1891 and a mine between Llechau and Llanharry, opened about 1885, produced a small quantity of ore before it was abandoned in 1899. The pumps used for dewatering these mines were actuated by steam conveyed from the surface, an uneconomic method that resulted in considerable loss due to condensation, and the mines suffered also from increasing competition from foreign ores.

No further ore was raised in South Wales until 1910 when the mine now operating at Llanharry was opened. During the Second World War the output from this mine rose to 200,000 tons in some years, after which, for a decade, it fluctuated between 90,000 and 130,000 tons, with a tendency to increase in recent years.

The ore is amongst the best produced in Britain, picked ore averaging 54 or 56 per cent of iron with only traces of phosphorus and sulphur, an important factor in the production of high-class iron. The general dip of the strata is about 30° to the north, and here, as at the Mwndy group of mines, shales that represent the Millstone Grit sometimes form the hanging wall of the ore-bodies; there may however be as much as 80 feet of limestone between the shales and the top of the ore. There are two shafts which have been recently deepened to 705 feet. Winding takes place from the 520 feet level, and inclines in the limestone run from this level to 780 feet. Ore extraction is proceeding downwards from the 520 feet level to 705 feet, with development in progress to still greater depths.

Horizontal roadways have been driven at four levels in the limestone, with subsidiary roadways between them. The main levels and subsidiary roadways are connected by vertical shafts or 'raises,' which serve the same purpose as winzes but are driven upwards from a lower to a higher level instead of from a higher to a lower one. From these raises, which are generally in the limestone, horizontal roadways twelve feet apart vertically are driven into the ore-bodies. These and branch roadways from them are about 10 feet wide and 6 feet high, leaving 6 feet of ore between the roof of one roadway and the working above from which the ore has been extracted. Pillars of ore are left between adjoining roadways, which are driven to the hanging wall of the ore. Retreating from the hanging wall the six feet of roof-ore is removed, together with the ore of the pillars that had been left to support it. The roof collapses as the workings retreat until the whole of the twelve feet thickness of ore has been removed. The operation is repeated at successively lower levels separated by 12 feet intervals. Pit ponies drawing small trains of trams are used on the subsidiary roadways, with electric and compressed air haulage on the inclines, and then endless rope haulage to the bottom of the shaft. The writer is indebted to Mr. W. Brymnor Davies for recent information about this mine.

The fissures and caverns in the Carboniferous Limestone often carry much water that makes its way downwards from the surface for considerable distances, being discharged into springs or providing supplies for wells. That which makes its way into the Llanharry workings necessitates continuous pumping at an average rate of 200,000 gallons an hour under normal conditions. The proved reserves at the mine are sufficient to maintain existing output for several years and there are reasons for believing that other ore-bodies may occur outside the limits of the region already exploited. But as the ore is almost entirely non-magnetic it is difficult to locate by magnetic surveys whilst other geophysical methods have not proved successful.

In the Hendy mine, opened in 1919 immediately east of Pont-y-clun, the occurrence of the ore and the method of working it resembled those of the neighbouring mines but the output was not great and the life of the undertaking was short. Water from the abandoned Bute mine, tapped by the main level, and involved the pumping of about 30,000 gallons an hour and occasionally as much as 60,000 gallons.
Other less important ore-bodies occur in the limestone at Fforest Fawr on the eastern side of the Taff near Taff's Well and at Cwrt y-ra l a near Wenvoe. At the former, a hill corresponding to the Little Garth with its once important mine on the other side of the river, the removal of the ore resulted in a large irregular chamber leading to three caves sloping down with the bedding of the rock, whilst another chamber was reached by an adit through the Limestone.

Between 1859 and 1864, whilst the other mines in the region were active, a small amount of ore was raised from a mine near Wenvoe, south-west of Cardiff, and between 1868 and 1876 unsuccessful attempts were made to work an ore body about half a mile east of Rudry near the road from Caerphilly to Newport. Iron ore representing a crinoidal limestone largely replaced by haematite occurs near the base of the Carboniferous Limestone at Rhiwbina, north of Cardiff. It was, as we have seen, known to the Romans, and a trial level was made some time before 1861 but the ore is not present in sufficient quantity to be economically important by modern standards.

Veins and small irregular bodies of haematite, similar in mode of origin to those of South Wales, occur here and there in the Carboniferous Limestone of north-eastern Wales, mostly at the northern end of the Vale of Clwyd (Abergele, Dyserth, Caerwys, and also near Bodfari) but although several small mines were opened in the latter half of the 19th century and the early years of the 20th none was active for more than a short period. [44] In a small mine near Dingle at the head of the Vale of Clwyd the ore-bearing rock was first quarried and then obtained from a large level, but it was of poor quality and did not pay for working, especially as haulage was expensive.

Haematite was also obtained from a mine on Foel Hiraddug near Dyserth that in one respect was unique in Wales, for it yielded cobalt ore. The vein or lode was the clay-filling of a steeply inclined water-worn fissure in Carboniferous Limestone that varied in width from nothing to 8 or 10 feet. It was worked to a depth of 240 feet by means of winzes and irregular passages. The red clay matrix contained loose fragments of limestone that had fallen from the walls of the fissure and the metalliferous bodies were small lumps of manganese dioxide (wad) and cobalt oxide (earthy cobalt ore or asbolane) either in grains or as nodules as large as walnuts or hen's eggs. The asbolane was black and soft enough to mark paper. Much of the clay was barren and the ore-bearing parts were detected by using the blade of a knife to draw some of it over a piece of unglazed porcelain when the asbolane produced a series of black shining streaks. This was an on-the-spot application of a test used in the identification of minerals, many of which yield a characteristic 'streak.' The output of cobalt ore was not considerable, being about 240 tons (valued at nearly £1,800) in the three years (1878-1880) for which records are available.

MANGANESE

Manganese ores occur in Merionethshire and Caernarvonshire for about fifty years the principal sources of supply in Britain—but none have been mined since the second world war. Many manganese compounds find important applications in industry but there are no everyday uses for the metal as such. It is, however, an important constituent of many alloys, particularly manganese steel, which is hard, tough, and almost non-magnetic, and Ferro-manganese which is of supreme importance as a deoxidiser and de-sulphuriser in the iron and steel industry. It was the realisation that certain desirable qualities of some of the steel made in Germany were due to the manganese present in the ores that led to experiments which resulted in the deliberate and controlled use of the metal in steel-making and encouraged the exploitation of the Welsh sources of supply.

A bed of ore from 10 to 15 inches thick is inter-bedded with the grits and shales that constitute the Harlech Beds division of the Cambrian System in Merionethshire. The ore appears to have been deposited in a partially enclosed sea basin under hot climatic conditions that gave rise to intense weathering of the rocks on the surrounding land and led to a concentration of manganese and iron in the water in which the sediments were accumulating. It is essentially a mixture of manganese carbonate with clay and siliceous material and has a fine-grained flint-like texture. The layers of which it consists are predominantly reddish in colour but some are purple, yellow, or bluish black.

Near the surface, and where intersected by strong joints into which air could penetrate, the ore has been partly converted into black dioxide of manganese (pyrolusite) which, containing from 20 to 30 per cent. of manganese, was the richest ore available and at first the only part that was mined. The mode of occurrence of the ore called for mining methods different from those employed in working the lodes that yielded lead in Cardiganshire. The workings began as narrow opencasts along the outcrop of the
bed and were continued underground by means of levels (adits). Owing to the small thickness of the ore-bed some of the overlying rock had to be excavated as well and the ore was removed from the floor and sides of the adits.

The extent of the workings was limited by the cost of removing the unwanted rock and the steep inclination of the strata - often more than 30' - that carried the ore rapidly to considerable depths. For these reasons, although there are extensive reserves, renewed working is unlikely as long as ample supplies of richer ore are forthcoming from other sources, or until some new industrial processes create a demand for low-grade ore. Records of output from the mines in west Merionethshire began in 1892 and continue until 1928, with an interruption between 1909 and 1913, and the total amount produced was about 44,000 tons from 17 small mines in the region between Barmouth and Bont-ddu in the south and Harlech and Trawsfynydd in the north.

The failure of supplies from Russia during the Russo-Japanese war (1905) gave fresh impetus to the Welsh mines, but this time the greatest contribution came from the neighbourhood of Rhiw, at the western end of the Lleyn peninsula. In this region irregular bodies of ore, situated between a massive sill of dolerite below and a lava flow above, occur in some mudstones in the Arenig division of the Ordovician System. The mudstone, being softer than the associated igneous rocks was greatly disturbed - folded and shattered - during a period of mountain building movements, so that the ore-bed was broken into many separate bodies, the content of which varies from as little as 10 tons to as much as 30,000 tons. The thickest masses were about 30 feet thick, having been built up by the distortion of a bed originally from 8 to 10 feet thick, but as they were steeply inclined they appeared, in shafts driven vertically through them, to be twice as thick as they really were.

There were two groups of mines, a southern group including the Nant mine near Llanfaelrhys, not far from Aberdaron, and a northern group about a mile away, including the Rhiw and Benallt mines. Ore was being raised as early as 1894 and before the last of them (Benallt) closed in 1945 they had produced over 196,000 tons of ore. At first only a few hundred tons a year were raised, but between 1905 and 1907 the output rose to more than 20,000 tons a year. For the next few years most of the ore was obtained from levels driven from an incline at the Nant mine - the most in any one year being about 9,300 tons in 1918. The mine has been inactive since 1925. The ore, which was worked from levels driven off a main incline, came all from one ore body.

The Benallt mine was found to have a particularly complex geological structure, due to folding and faulting, and the ore bodies occurred in a disconnected manner. The character of the original sediments was changed by mineral solutions that invaded the rock as a concomitant of the volcanic activity, and the ore consists mainly of manganese silicates with oxides of manganese and iron, whilst manganese carbonate, so characteristic of the other mines, is present only in insignificant quantity.

The ore was obtained from opencast workings until, due to the inclination of the strata, the amount of overburden became excessive and inclines were driven into the ore-bearing beds. Eventually several shafts were sunk, one of which was deepened in 1941 from 60 to 130 feet, and the ore was obtained from headings driven from the shaft at three levels : it was allowed to gravitate to the lowest level and from this was hoisted to the surface. Exploratory work shortly before the mine closed in 1945 produced negative results although, having regard to the nature and distribution of the ore bodies, this does not preclude the possibility that they may occur at greater depths.

During the latter half of the 19th century black manganese ore was obtained from shallow open cuts and levels near Arenig, e.g. on the western slopes of Mynydd Nodol. The ore filled joints and irregular fissures that occasionally swelled out into small pockets. About 1880 a mine was opened in the Carboniferous Limestone at Nant Uchaf near Abergele, where manganese ore occurred in association with haematite, but it was short lived and produced little more than 500 tons of ore.
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Geol. Mag. Geological Magazine
Journ. Chester Journal Chester and North Wales Archaeological and
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PLATE IV

Park's Mountain Mine, Anglesey, c. 1785

The opencast workings, from a water colour drawing by J. C. Repton, now in the National Museum of Wales. See page 63.

PLATE V

"Patchworks" (For iron ore) Beaumaris, Mon., c. 1858

(from The Geologist, vol. 1 [136])

Workings in clay ironstone and a series of coal seams; for description see page 89.
PLATE VI

SHAFTS, ADITS, AND CROSS-CUTS
(from D. C. Davies [90]; for description see page 52)
Reproduced by courtesy of Metasa. Crosby Lockwood and Son, Ltd.
PLATE VII

OVERGAND STRIPPING IN A MINE, C. 1888
(from D. C. Davies, [00] ; for description see page 53)
Reproduced by courtesy of Messrs. Crosby Lockwood and Son, Ltd.