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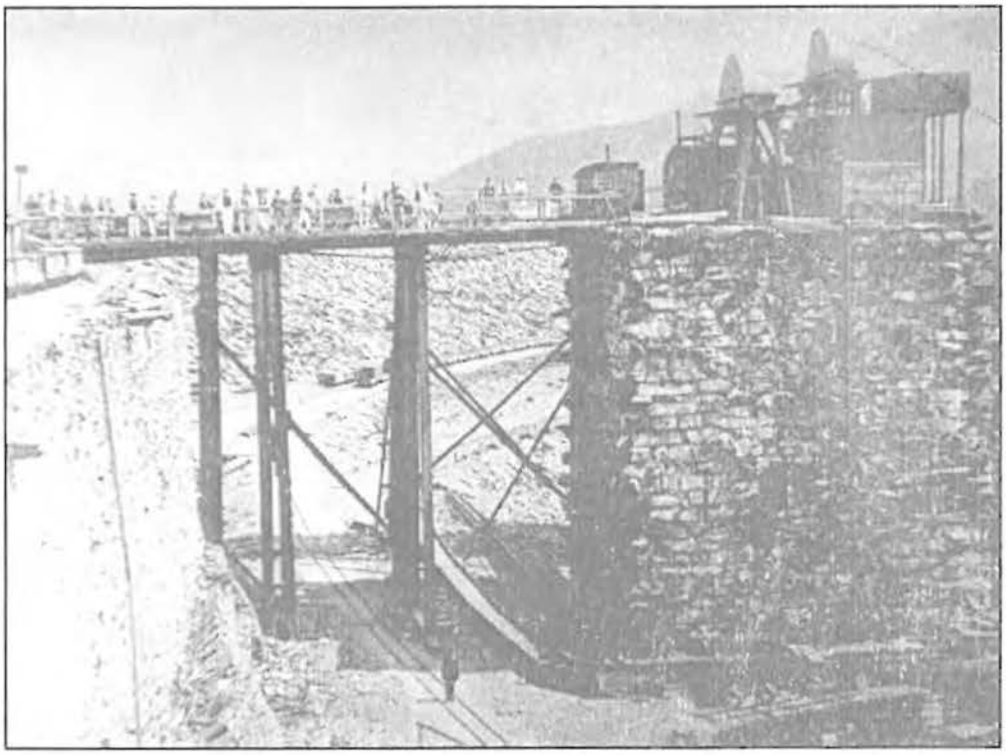
GWYNEDD SLATE QUARRIES

AN ARCHAEOLOGICAL SURVEY
1996 -7



Report No.252

Ymddiriedolaeth Archaeolegol Gwynedd
Gwynedd Archaeological Trust

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AN ARCHAEOLOGICAL SURVEY
1996 -7

prepared for Cadw : Welsh Historic Monuments

March 1997

Gwynedd Archaeological Trust Report No. 252

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Sbwriel a chwarel wedi'i chau - a niwl
Y nos ar y crawiau;
A gwaith dyn fel brethyn brau
Yn braenu rhwng y bryniau

Gwilym Tilsley

Dyma hwrdd o haiarn bwrw
Sydd yn llifio'n mawr ei dwrw;
Ac yn llocio yn ei sgriws
Wrth llifio cerrig Roland Huws

Creiglwyn Fardd

GWYNEDD SLATE QUARRIES

Abbreviations

The following abbreviations are standard:

CDH: *Caernarfon and Denbigh Herald*
CRO: Caernarfon Record office, Victoria Dock, Caernarfon, Gwynedd
DRO: Dolgellau Record Office, Cae Penarlâg, Dolgellau, Gwynedd
IAR: *Industrial Archaeology Review*
JMHRS: *Journal of the Merionethshire Historical and Record Society*
MJ: *Mining Journal*
NLW: National Library of Wales
NWC: *North Wales Chronicle*
SQNW1873: *Slate Quarries of North Wales in 1873* (re-published Penrhyndeudrath 1987)
TCHS: *Transactions of the Caernarvonshire Historical Society*
UWB: University of Wales, Bangor

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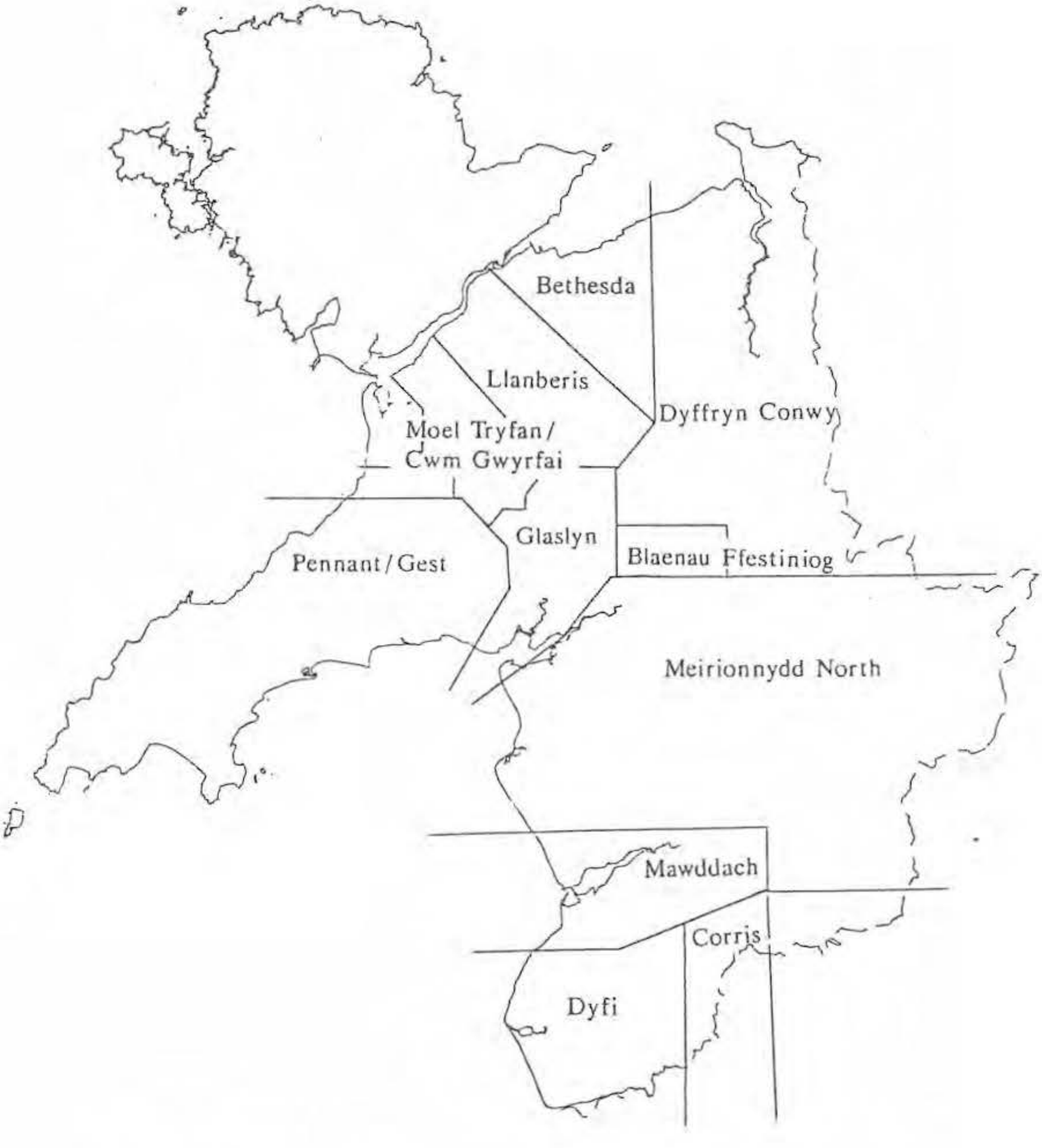
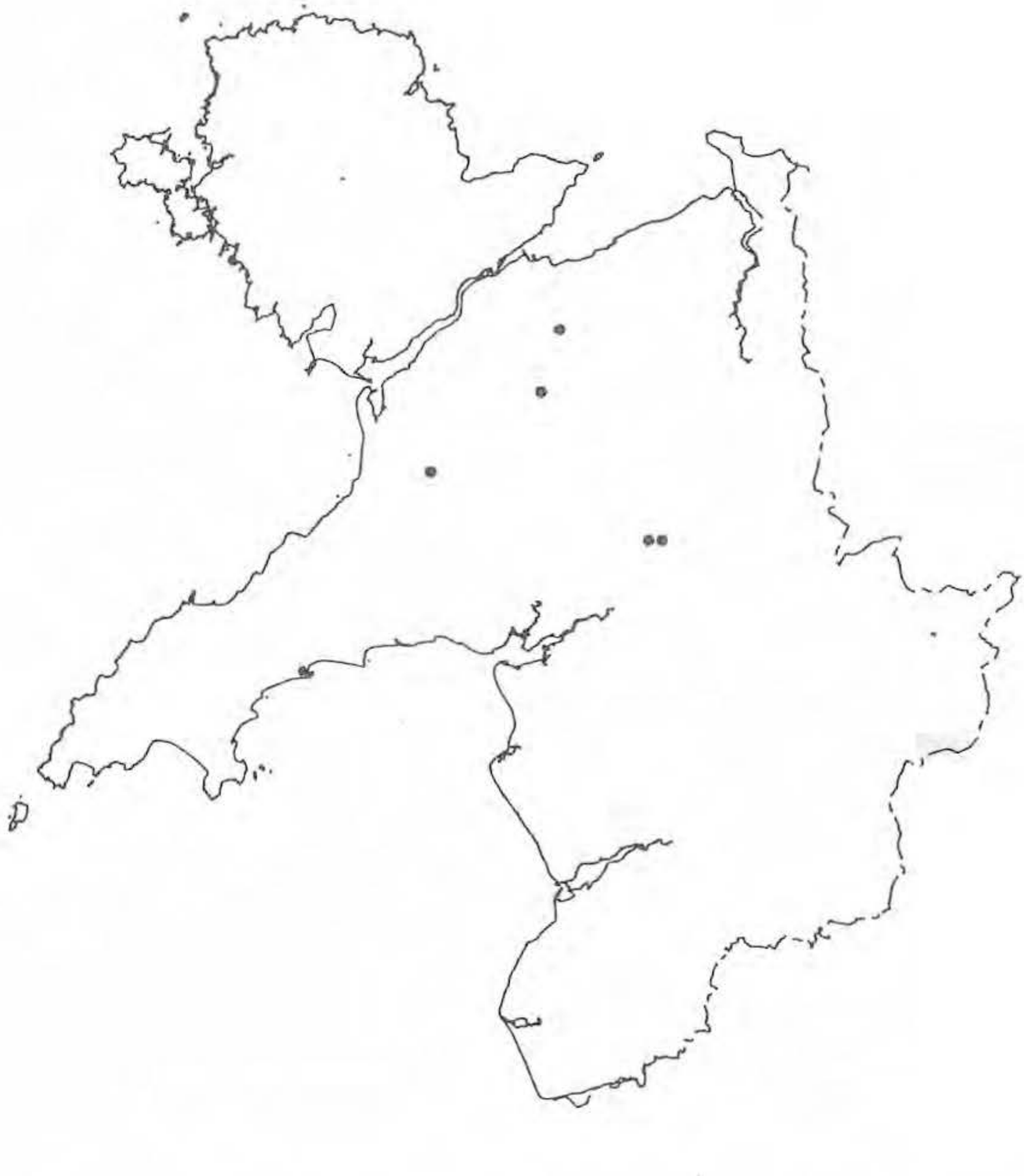
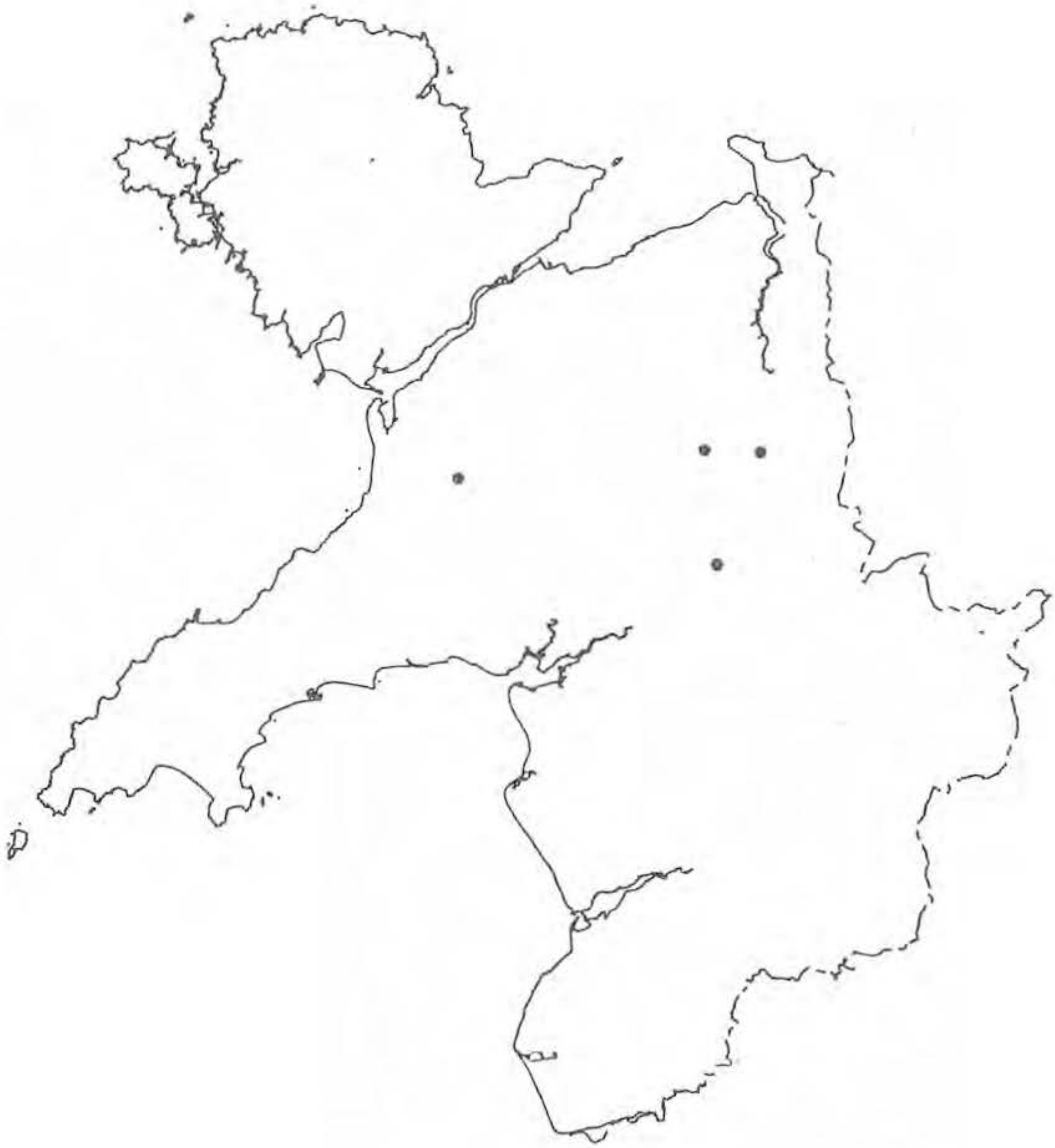


Map 1: slate-quarrying regions of Gwynedd (after Richards 1991)



Map 2a: location of power-features selected for detailed study



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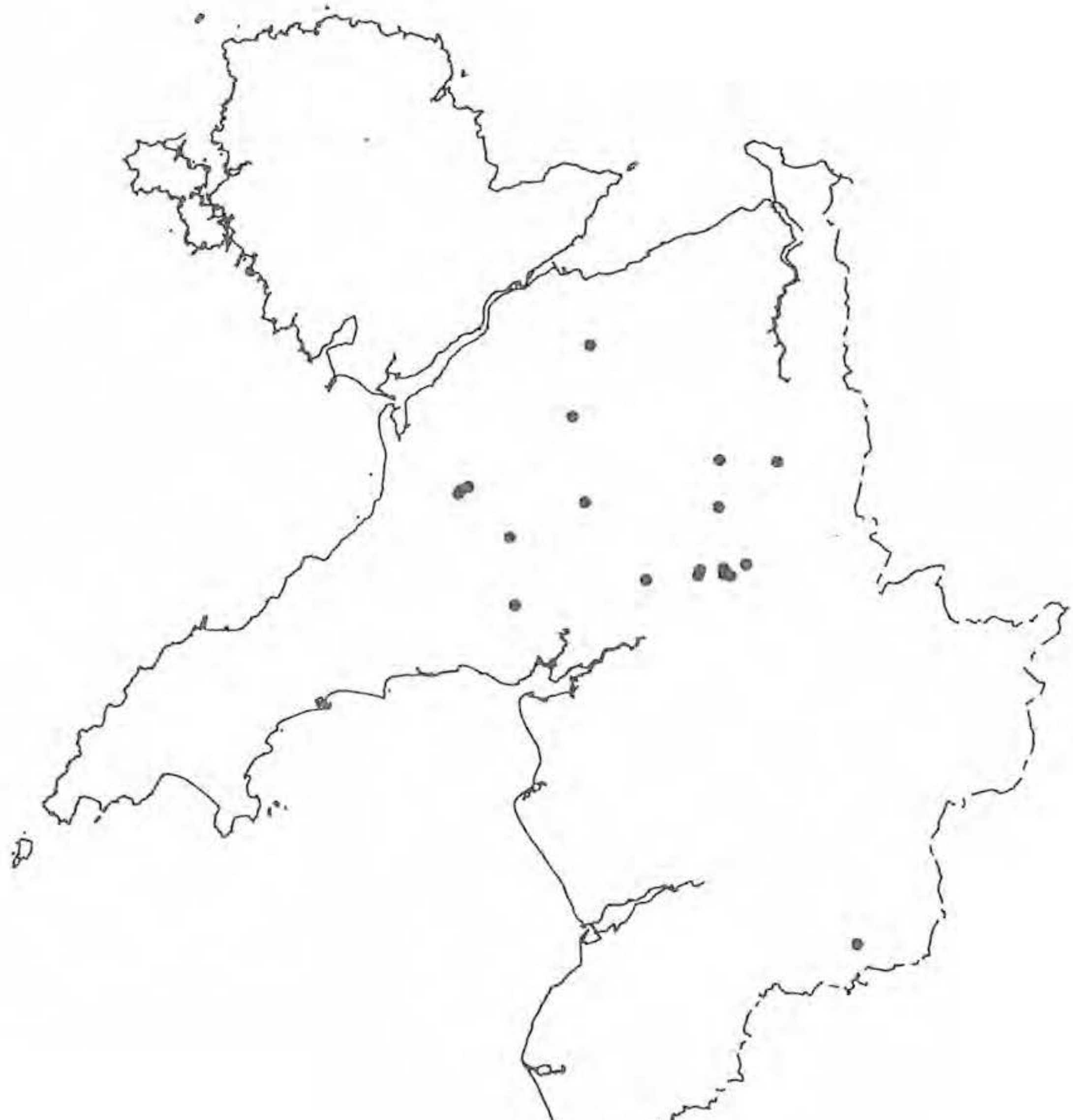

Map 3: location of mills chosen for detailed study

Map 4: location of uphaulage features chosen for detailed study

Map 5: location of barracks chosen for detailed study

1 INTRODUCTION

If output figures from its Victorian hey-day constitute a reliable guide, then the Gwynedd slate industry represents approximately half of the world's archaeological resource for the slate industry and three-quarters of that of the United Kingdom and the Republic of Ireland. Its remains therefore constitute a resource of international significance.

This project has been grant-aided by Cadw: Welsh Historic Monuments and builds on the work previously carried out by the Gwynedd Archaeological Trust with grant-aided from Cadw, towards an assessment of the resource within Gwynedd. The first was the Gwynedd Quarrying Landscapes Project (Report 129) in 1993-4; this identified twenty-five slate quarrying landscapes, which were considered to contain the most significant remains of slate quarrying in Gwynedd.

The second was the Gwynedd Slate Quarries Project (Report 154), which considered the archaeological resource of all Gwynedd slate quarries of any size and a representative sample of smaller workings and trials. 106 sites were visited out of a total of 446, and those features considered to be of national importance were identified.

The methodology of these two projects necessarily imposed a number of limitations. Although by the end of the second project it was possible to suggest the overall survival of particular types of features within sites and within landscapes, the absence of a typology and chronology for some of the most important and frequently-met features made recommendations for scheduling and listing difficult. So far, listing and scheduling of features in the slate industry has emphasised the large-scale and spectacular, such as the Gilfach Ddu workshops and the Ynys y Pandy mill, at the expense of more humdrum but typical features.

It was therefore felt advisable to carry out a detailed study of selected examples of these features in order to determine how they developed, how they replaced other features and were themselves replaced.

It was also considered that work carried out on the archaeology of the Gwynedd slate industry has tended to consider it in isolation, and that it should be considered in the light of technical developments elsewhere, locally and on a broader scale. Increasingly those who study the archaeology of the slate industry have begun to turn their attention to the quarries of the English Lake District, of Cornwall, Scotland and Ireland, as well as to Europe and America, and at the same time various individuals have studied the developments in stone-quarrying. As much as possible, the following report has sought to place the slate industry within its broader context.

2 AIMS

2.1 This project builds on the work particularly of the second project grant-aided by Cadw on the Gwynedd slate industry, which identified eight categories into which features on slate quarry sites were allocated. These are:

1.) **Extraction/tipping**
2.) **Processing**
3.) **Power**
4.) **Transport**
5.) **Structural features**
6.) **Administration**
7.) **Ancillary**
8.) **Domestic**

Of these eight categories, aspects of four were suggested as requiring further work, namely:

2.) **Processing - mills**
3.) **Power-sources and transmission,**
4.) **Transport - uphaulage systems - shafts and ropeways**
5.) **Domestic - barracks**

The archaeological evidence of selected examples of these features has been analysed in the light of archival material in order to determine to what extent it was possible to create a *typology* and a *chronology* of these features.

The project has sought to ensure that differences within the categories of features were adequately reflected in the recommendations for scheduling. A number of changes have therefore been made to the recommendations embodied in Report 154, which are set out in the scheduling forms which accompany the present report.

2.2 Nature of the threat

The threat to slate quarries as sites of archaeological significance comes from a variety of sources.

(i) Working for slate: there are now only five slate quarries working on any scale in Gwynedd, as well as two others employing a handful of men. Features are at risk at all these sites from dumping and quarrying; in the course of the present report Melin Bonc Siafft at the Oakeley quarry was demolished. In the case of Maenofferen, Messrs Greaves may decide to untop the quarry and replace the inclines with tracked vehicles.

(ii) Possible re-opening: planning permission has been granted for the reworking of Rhosydd, dormant since 1929, and others which have been worked more recently may re-open if the trade improves. These include Diffwys Casson, Cwmorthin, Rhiwbach and Braich Goch.

(iii) Re-working of slate tips: slate waste is now less in demand as hard-core for roads than it was a number of years ago, but two sites have been badly affected over last year in particular, Ty Mawr East and Fronheulog (Vronlog), and Dorothea quarry is also known to be under consideration.

(iv) Reclamation of derelict land: a number of slate quarries have already been landscaped, with loss of some or all of their significant features - Pant Dreiniog, Glynrhonwy, Cloddfa Glai, Cilgwyn, Abercwmeiddaw, Braich Goch. Recent work at Fron and Old Braich was preceded by an archaeological survey carried out by the Gwynedd Archaeological Trust, but poor supervision by the local authority resulted in a number of unrecorded features being damaged during stabilisation works. Some landscaping and greening of slate tips is proposed for Penrhyn Quarry.

(v) General deterioration: the majority of quarry buildings are built on slate waste and were designed for short lives. They are often in an unstable condition and prone to natural deterioration. Quarries are also favourite areas of recreation, with the result that vandalism and robbing of structures for building stone are commonplace.

(vi) Leisure and tourism: heritage centres have been proposed for a number of sites.

3 METHODOLOGY

3.1 Extent of the Survey

As with the first and second projects, the present study considers the archaeology of slate quarries within the boundaries of the county of Gwynedd as it existed until March 1996, the present reduced Gwynedd and the western half of the County Borough of Aberconwy. Work has concentrated on the quarries themselves and processing sites, where these were clearly related to the quarries - independent slate mills were not included, nor were transport systems or workers' settlements outside the immediate environs of the quarry. For convenience's sake, the word Gwynedd is here used to mean the pre-1996 boundaries, though the present county is specified where individual features are identified.

The former county of Gwynedd is subdivided according to the quarrying areas identified by Richards 1991 according to place of shipment, namely:

1. Bethesda
2. Llanberis
3. Nantlle
4. Dyffryn Conwy
5. Moel Tryfan/Cwm Gwyrfai

6. Pennant/Gêst
7. Glaslyn
8. Blaenau Ffestiniog
9. Meirionydd (north)
10. Mawddach
11. Dyfi
12. Corris

3.2 Analysis

Within each of the four categories, features were selected according to criteria set out below in sections **3.3**, **3.4**, **3.5** and **3.6**. Features were considered in the light of the known archaeological resource of:

1. the Gwynedd slate industry

2. the slate industry elsewhere in the United Kingdom and in the Republic of Ireland. Occasional reference is made to developments in the slate industry elsewhere in the world.

3. other extractive industries elsewhere in Gwynedd

4. other extractive industries elsewhere in Wales

5. other extractive industries world-wide.

Whether a feature has or has not already been afforded statutory protection was not a factor in selection for detailed study, in that the aim of the present project is to establish the totality of the archaeological resource within its various categories.

Each one of sections **4 Power-sources and transmission**, **5 Mills**, **6 Uphaulage systems - ropeways and shafts** and **7 Barracks** contains two parts. The first consists of a general background to the section in the light of 2 to 5 above. The second contains the results of the survey, based on the analysis of the selected features and of further bibliographic and archival evidence for other features not selected for detailed survey. **Appendix 1** contains the detailed description of the selected features and sites within each category, and a summary of the further bibliographic and archival evidence. **Appendix 2** contains a summary of recommendations and the scheduling forms.

3.3 Power

3.3.1 Introduction: the second report analysed the variety of power-sources and methods of transmission in the Gwynedd slate industry, as well as the uses to which they were put. Whilst it became apparent that the industry remained dependent on water-power to a much greater extent than most comparable industries in Britain, there was also abundant evidence for the use of steam, and it was also clear that the industry was a pioneer in electricity generation.

The present project examines power as it relates both to a site's particular needs and to the topographical and proprietorial constraints within which it operated. This part of the present project is divided into two parts, the first of which examines particular features from selected sites, the second of which looks at four case studies.

3.3.2 Site details: this part examines in detail nine features from five different sites from this category where the machinery survives intact, and includes a written description. Two of these features are Scheduled Ancient Monuments, two are listed Grade II*, two are listed Grade II. Examples were selected for detailed study on one criterion only, namely the survival of machinery intact.

3.3.3 Case studies: the second part consists of a case-study of the type of power generated and used at four separate sites at different periods in their development, and provides a digitised map of each site and a written description. Selection of examples for detailed study was determined by a hierarchy of criteria derived from the database set up in the course of the second project, set out below:

1. The initial criterion was to ensure that the sites selected encompassed all the main types of power-sources. One exception was made, however; the possible Newcomen engine at Tal y Sarn was not included, as not yet confirmed.

2. The second criterion was to ensure that the examples selected encompassed all the main types of power-transmission.

3. The third criterion is the variety of uses to which particular power sources were put, as defined in the report to the second project.

4. The fourth criterion is the extent of archival material; this has been identified as a criterion in that the case-studies will necessarily be period-specific as well as site-specific.

5. The fifth criterion is the extent of past or present archaeological recording and archival research carried out by other organisations. For this reason, Trust officers maintained liaison with the Royal Commission on Ancient and Historic Monuments (Wales), the University of Hull Department of Continuing Education, Snowdonia National Park and Fforwm Plas Tan y Bwlch.

3.4 Mill buildings and related processing areas

3.4.1 Introduction: The second project identified a total of 117 mills. These were divided into a number of types, based on archaeological evidence for transport access, namely **longitudinal**, **transverse**, **radial** and **bay**, depending on where there was evidence for railways having been laid to carry the raw blocks into the mill and for removing waste. Other aspects of these features were also noted where possible within the constraints of the project, such as evidence for (or in some cases, survival of) particular types of machinery, power-sources, line-shafting position and date-stones.

The present project makes a selection of a number of mill buildings and their related processing areas for measured survey.

Where an existing measured survey exists (for instance from the archive of the RCAHMW, Plas Tan y Bwlch, or Amgueddfa Lechi) and permission has been obtained for the project to make use it, this has formed the basis of the detailed study, augmented by a site-visit. Where a plan does not exist, a measured survey was,carried out. In either case, where possible, the report has examined the evidence for process-flow and production methods.

Archaeological evidence, such as mill waste on nearby tips, has been sifted for evidence of the processing machinery used. Where possible the evidence for the prime mover was examined with a view to assessing the power it was capable of generating. Archive material has been examined for information on the processes carried out and dates of construction or modification of all such features.

This section consists of a measured survey amd a written description of each selected feature.

3.4.2 Selection of examples for detailed study: selection of examples for detailed survey has been determined by a hierarchy of criteria derived from the extended database, set out below:

1. The initial criterion ensures that examples of the types identified in the second project, namely longitudinal, transverse, radial and bay be included.

2. The second criterion ensures that the detailed study encompass all the main types of slate-cutting machine, defined as frame saw, circular saw (Greaves type), circular saw (Hunter type), planer and dresser.

3. The third criterion ensures that the variety of different power-sources be surveyed in detail - water-power, whether by waterwheel or turbine, steam power, internal combustion engine or electricity, bearing in mind that many mills were powered by a succession of different types of prime mover.

4. The fourth criterion concerns the form and arrangement of power-transmission.

5. The fifth criterion was the extent of their survival. The second project identified a total of thirty mills as

meriting High Survival (**Report 154 3.2.e**). However, a number of these were not considered appropriate for further examination for several reasons. The tiny mill at Twll Llwyd proved to postdate the second survey's *terminus ad quem* of 1939 (pers. comm. Messrs Alun and Robert Humphries). Some remain in use as slate mills. These include Pen yr Orsedd (20039:41), Maenofferen (20306:29) and Aberllefenni (20487:1). In re-use for other purposes are examples at Glynrhonwy Lower (20075:17), Braich Rhydd (20176:29) Oakeley (20296:12) and Arthog (20375:11). However, a description of Maenofferen mill has been included without a measured survey in the present document, in that it is a listed building. A further example at Oakeley, though identified as being in good condition in the second survey, proved to be a substantial rebuild of a derelict structure using the original trusses (20296:29). Another mill at Oakeley Quarry was demolished in the course of the present survey (20296:5).

6. The fifth criterion was the date of construction, to ensure that a selection represented a chronological cross-section which reflects the construction of mill-buildings as a whole in the industry, as established by desk-top study.

3.5 Transport - uphaulage systems

3.5.1 Introduction: the second report identified a considerable number and variety of features relating to uphaulage of slate and rubble from pit quarries and mines to the processing areas (**Report 154 5.4**). As outlined in the application to Cadw for grant-aid for further work on these features, it was considered that the archaeology of some of these methods in particular was not fully understood, and the opportunity to carry out an archaeological assessment of Penrhyn Quarries in August 1995 (to which access was denied while the first report was being written) confirms that the two water-balance shafts which survive there are indeed likely to be of international importance (**Report 154, 5.4**).

Uphaulage systems were allotted to one of four categories, **vertical haulage**, **aerial ropeways**, **railed inclines** and **cranes**. These last two categories were not felt to merit detailed survey; railed inclines have been studied extensively by the railway fraternity, and their typology is largely understood, and fixed cranes saw little use in the industry. However, two further sections (**6.4** and **6.5**) outlines their role in the chronology of development, especially as they relate to the previously identified categories.

The second section goes on to consider selected surviving examples of aerial ropeways and vertical haulage shafts.

This section consists of a written description of each selected feature.

3.5.2 Selection of examples for detailed study: this has been determined by a hierarchy of criteria derived from the database established as part of the second project, now to be extended, set out below:

1. The initial criterion ensures that examples of the two types selected for further study, namely aerial ropeways and shafts, be included.

2. The second criterion ensures that the variety of power-sources recorded in the second project, namely hydraulic, steam and electricity, be included.

3. The third criterion ensures that the variety of aerial ropeway systems (chain incline, blondin, inclined cableway) be included.

4. The fourth criterion selects the better surviving examples for detailed study. In most cases this means the survival of part or all of the machinery.

3.6 Domestic - barracks

3.6.1 Introduction: archival material has been examined for the dates of construction of all such structures, and secondary works consulted to determine possible relationships between surviving structures within the slate industry and both farm-workers' accommodation and dwellings for workers in other industries. The RCAHMW has been consulted in connection with the barrack accommodation in the Cardiganshire lead mines as the nearest points of comparison.

This section consists of a measured survey and a written description of each selected site.

3.6.2 Selection of examples for detailed study: this has been determined by the criteria set out below:

1. The first criterion ensures that the variety of structures be encompassed.

2. The second criterion ensures the selection the better surviving examples for detailed study.

4 POWER-SOURCES AND TRANSMISSION

4.1. Background

4.1.2 General introduction: mining and quarrying involves the movement and processing of considerable quantities of material. Whilst the physical strength of the miner, whether freeman or slave, was for centuries the only power source known in extractive industries, the expansion of mining in the fifteenth century in particular brought about the gradual introduction of various devices and engines which increasingly freed him from the more simply arduous tasks. This section first examines the historical context of these developments, then goes on to discuss the results of the survey. The references in this second section are all to the site details contained in Appendix 1.

4.1.2 Power-source: for the purpose of the present report, the categories of power-source have been categorised as follows:

Manual			
Wind			
Animal			
Hydraulic	hydrostatic	water-balance	
		Tom and Jerry	
		pressure engine	
	hydrokinetic	waterwheel	overshot
			pitchback
			breastshot
			undershot
			stream
		turbine	impulse
			reaction
Steam	atmospheric		
	double-acting	Cornish type	
		beam rotary	
		Durham type	
		wall type	
		horizontal	
		winch	
Internal combustion	gas		
	petrol		
	diesel		
Electrical	direct current		
	alternating current		

4.1.2.i manual power: this remained important in equivalent extractive industries throughout the nineteenth century. In the extraction process in stone quarries, the hand-operated jumper, a simple tool for boring a hole in the rock for blasting by percussive action, came to be ousted gradually from its task by mechanical drills, both percussive and rotary, from the 1860s onwards (Foster, Cox 192-211), though its use only ceased well into the twentieth. Many examples survive, typically less than the height of a man in length, double-ended, with a swelling in the middle. These were common in extractive industries throughout Europe, though there were minute variations from place to place (Foster/Cox 171).

Other manual tasks involved little or no skill - for instance, pushing a wagon along a length of rail.

4.1.2.ii wind power: windmills saw some limited use in extractive industries, mainly in pumping, where an intermittent power-source would do, generally in conjunction with another power-source; a local example is the five-sailed windmill on Mynydd Parys copper mine (Hope 62-4). The small granite quarries of Jersey were almost entirely drained by wind-power (Foster, Cox 1910 470), and windmills were used at Porthgain and Rosebush Slate Quarries in Pembrokeshire (Tucker 1979 p. 207, p. 212).

4.1.2.iii animal power: the use of animal power in extractive industries does not appear particularly ancient compared to other industrial processes; Agricola in 1556, though he describes a horse-whim operating a rag-and-chain pump, clearly regards it as second-best to hydraulic power (Agricola pp. 192-3). Such a system is known to have been installed at Mostyn colliery in 1675 (Rees p. 117).

The use of horses in extractive industries is first noted underground in Bucksnook colliery in 1716, and rapidly became common elsewhere on Tyneside and the Whitehaven area (Lewis 1970 pp. 310-1), but may well have been preceded by the horse-haulage of sledges in open quarries. The horse-whim for uphaulage begins to supersede the hand-windlass in the course of the eighteenth century (Rees p. 117).

4.1.2.iv hydraulic power: this took various forms. Its simplest was the use of water as a counterweight in uphaulage systems, first recorded at Chatershaugh colliery in 1753 (see **Uphaulage 6.2.2**). Another system which also made use of the weight of the water (as distinct from weight and impulse) was the Tom and Jerry, (allegedly named after a pair of famously noisy roisterers) involved a set of flatrods hinged on brackets, with a bucket at each end, which were alternately filled and emptied and thereby rocked the rods back and forth to operate a pump. These were met with in metalliferous mines, including the copper mines at Llandudno (Bick 1985 96-8).

A more sophisticated type of hydraulic prime mover is the water-pressure engine, which, as its name suggests, operates under the pressure created by a head of water, and were generally used for pumping. These functioned in much the same way as a steam engine - indeed, were developed contemporaneously with them, and often by the same engineers. The first known example was noted at Schemnitz in 1749. A single-acting example was installed by William Westgarth at a lead mine in Allendale, Northumberland in 1765, and a double-acting version was installed by Trevithick at Wheal Druid in Cornwall in 1800. In 1836 Armstrong devised a water-pressure engine, apparently unaware of previous inventions (Cardwell 1965).

Of all hydraulic machines, the waterwheel is by far the most common. The undershot vertical wheel is first noticed by Vitruvius in 30-25 BC in his *De Architectura*, and the overshot slightly later by the poet Antipater of Thessalonica (fl. 20 BC - 20 AD) (Lewis 1993 36). The earliest vertical wheel-site in the British Isles has been dated to the ninth century AD (Syson 18-21), and waterwheels were commonly used for fulling and milling in Wales from the Medieval period (Ellis 1838, Jack 1981). However, between 1700 and 1825 the design and construction of waterwheels went through a radical transformation, in which it ceased to be a millwright's craft and became a scientific technology, through the work of Antoine Parent, Deparcieux and Joseph Smeaton, whose Experimental Inquiry concerning the Natural Powers of Water and Wind To Turn Mills was published in the *Philosophical Transaction of the Royal Society* in 1759. The most telling of Smeaton's conclusions was that the overshot wheel is twice as efficient as the undershot, and though Poncelet as late as 1824 was to devise an undershot wheel which achieved efficiencies of 60%, and was cheaper to install, it appears that few were constructed after Smeaton's researches were published (Cardwell 194-5). Another development of the waterwheel was the substitution of a lightweight all-iron construction, known as the suspension wheel, in place of wooden or composite wheels from the 1820s. The suspension wheel makes use of castings and wrought-iron components whose strength derives from being held in tension; however, it can only operate through rim gearing, and is therefore unsuitable for locations where power need be taken off the main axle (Reynolds 1975). Though these developments in hydraulic technology were undertaken initially with a view to improving corn-milling capacity, substantial waterwheels were operating large textile mills from 1771 (Trinder 1982 63), as well as pumping out mines. Water power operated stone-saws in Derbyshire from possibly as early as 1748 (pers. comm., Dr Michael Lewis), and John Shaw's *Water Power in Scotland 1550-1870* notes that both water and steam were used in the mid-nineteenth century to power cutting machinery in paving-stone quarries, though it says nothing of the Scottish slate quarries (Shaw 534-5).

To this range of hydraulic machines, turbines and peltons were added in the nineteenth century. The inward flow or vortex turbine was devised by James Thomson in 1846 (patent 13,156 of 1850), and the pelton in the goldfields of California (Burstall 1963 p. 329); many examples of both were built by Williamson Bros at Kendal, and their successors from 1881, Gilbert Gilkes and Co. (McCutcheon 1980 pp. 260-1).

4.1.2.v steam power: this had become an accepted power-source in extractive industries from the early eighteenth century, in the form of the Newcomen engine. The series of inventions associated with the name of James Watt from 1765 onwards - the separate condenser, the rotary engine, the double-acting engine - created a more flexible and sophisticated machine which could be used for haulage and operating mills as well as pumping (Dickenson and Jenkins 93, 139, 149). The horizontal-cylinder engine comes into being with Robert Stephenson's incline winder of 1833 for the Leicester and Swannington Railway, and by 1855 the Caernarfon firm of Thomas and DeWinton was capable of producing small stationary steam engines of this sort, of which an example survives, restored to use, at the Glynllifon estate workshops near Llandwrog.

4.1.2.vi internal combustion: internal combustion engines - gas, petrol and diesel - had been a practical possibility from the end of the nineteenth century (Burstall 1963, pp 332-339), and became more commonplace after the first world war, which not only prompted technological development but also made available army-surplus stock to a newly demobilised workforce that had some recent familiarity with them. Some concerns used them to power machinery, but the most consistent use of them was in locomotive form, in which the products of the Motor Rail Company of Bedford vied with those of Ruston Hornsby of Lincoln (Roberts 1996).

4.1.2.vii electrical power: as much a means of transmission as a power source in its own right, electrical power, especially in its hydro-generated form, was being developed concurrently in a number of areas at the end of the nineteenth century - Ulster, by the Traill brothers, Scotland, Canada and the Austro-Hungarian empire - areas where supplies of coal were distant or inadequate. Gwynedd suffered the same problem, and as a mountainous area, appeared to offer similar solutions. In 1891 speed control of d.c. motors was introduced, making possible industrial applications such as winding motors (*Electricity Supply, passim*).

4.1.3 power transmission: for the purpose of the present report, the categories of power transmission method have been categorised as follows:

Mechanical	flatrods	timber
		iron
	ropes	hemp
		wire
	line shafting	
	belt	
Pneumatic		
Hydraulic		
Electrical		

4.1.3.i mechanical transmission: in some respects flatrods constitute the simplest of all the means of transmitting power from its source to the point at which it was to be applied. This system is first attested in 1617 in Löhneis's *GrÜdlicher und AÜsfuhrlicher Bericht*, published at Zellerfeld. They were commonly used in continental metalliferous mines, and their use spread throughout the United Kingdom.

Hemp ropes were used for a variety of mechanical processes in the early industrial period, but was gradually superseded by iron wire ropes, introduced at collieries in Prussia in 1835/6 (Malaws 1996 p. 70) and in use in the Durham coalfield by 1842; they were available in Wales not long after (pers. comm., Dr MJT Lewis).

Endless chains were an accepted method of transmitting power by the beginning of the nineteenth century (Rees A 1821 3 p. 358).

Line-shafting dates from the earliest phase of the factory system in the last decades of the eighteenth century, and methods of construction were improved by William Fairbairn between 1817 and 1818, who used wrought iron instead of cast-iron and timber (Williams and Fairnie 1992 pp. 69-70).

The canvas belt drive was an accepted method of transmitting power by the early nineteenth century (Rees 1821 3 p. 357).

4.1.3.ii pneumatic transmission: the introduction of pneumatic drilling from the 1860s onwards (Morrison 1972 p. 407), common by the early twentieth century, created a need for compressors and lengthy iron piping to carry the air to the rock face.

4.1.3.iii hydraulic transmission: though the theoretical basis of hydraulic transmission was established by Blaise Pascal in the seventeenth century, it was in the late eighteenth that it came to be employed for industrial purposes. Joseph Bramah was granted a patent in 1795 for the use of water as a medium for transmitting energy, which included the hydraulic press. Hydraulic transmission was extensively developed in the context of port installations by William Armstrong, who devised the accumulator in 1851, a control device which enabled the use of higher pressures and gave a stored reserve of power (Jarvis 1985 pp. 5-12).

4.1.3.iv electrical transmission: overhead transmission lines in the United Kingdom date from *c.* 1890, and public supply of the three-phase system which made possible electricity distribution over a wide area through a.c. from 1900. The North Wales Power and Traction Company began distribution from Cwm Dyli in 1906, supplying Pen yr Orsedd and Oakeley quarries with three-phase 50Hz (*Electricity Supply, passim*).

4.3.1 power needs: either no attempt was made to calculate power needs in the Gwynedd slate industry on a systematic basis in the nineteenth century, or no results were published, and it seems likely that most engineers relied on rule-of-thumb methods. Whilst extensive research was carried out into hydraulic power at the end of the nineteenth century, when it was taught at university level, and textbooks were available on the subject, it is unlikely that local foundries were much affected. Many power needs would in any case vary tremendously, though in the case of mill machinery some sort of consistent pattern seems clear.

A rotary dresser will need the energy of ¼-h.p. to turn it.

A Greaves-type circular saw table will need 1 h.p.

A planer will need 1½ h.p.

(The foregoing are derived from discussion with Dafydd Price, former manager of Bwlch y Slaters, and Dr Gwynfor Pierce Jones).

Recent research has suggested that each blade of the Hunter saw might require 21 h.p., an extraordinarily high figure which would explain why the saw never became popular (Weaver 1987 p. 4).

A pump's power-needs will depend entirely on the volume of water to be pumped; this was traditionally estimated as the number of pounds of water raised one foot by the consumption of 112 lbs of coal, but this represents a measure of efficiency rather than of power-need (Foster, Cox 1910 p. 506).

4.2 Results of survey

4.2.1 general introduction: the Gwynedd slate industry was found to have used a wide variety of power-sources and transmission-methods, and the old and the new could be seen working alongside each other in many places (see **Appendix 1.1.case-studies 1-4**).

4.2.2 power sources: these are analysed in their separate categories.

4.2.2.i manual power: this is represented in the archaeological resource only in a very slight way - in handles on rubbish wagons to allow for hand-tramming, and in the crude systems of pointwork which are not suitable for locomotive operation. Shot-holes in the rock-face are drilled by a jumper if they are semi-triangular in cross-section rather than the round-section holes that were mechanically drilled. Surviving fragments of the small wooden tripod cranes used in the chambers and levels to raise blocks onto wagons suggest that they were largely hand-operated. A hand-windlass appears in a photograph of Blaen y Cae quarry taken in the 1890s, but no examples have been discovered in the course of the survey (CRO CHS 528 195 15).

There is archaeological evidence for the use of manual power in sawing. The oldest stone saw-bed surviving in Gwynedd, built by Thomas and DeWinton of Caernarfon in 1854/5 (pers. comm., Roy Wakeford) preserved *in* *situ* at the Glynllifon craft workshops, contains a flywheel and a handle for manual operation, even though it has always been rigged up to a steam engine. Though it is not a slate quarry feature, it is likely that the other saws the same foundry turned out would have been similar.

4.2.2.ii wind power: only one windmill is known in the Gwynedd slate industry, at Hafodlas quarry in the Nantlle area. It has left no trace (Lindsay 1974 p. 157).

4.2.2.iii animal power: a horse-whim circle was noted in the course of the second Cadw-funded project at Hendre quarry, which survives as a pivot stone, a circle 12.8m in diameter and part of the retaining wall, surviving to 2.5m at its highest (Lewis, Williams 1988). Hendre was worked from 1838 into the twentieth century and the probability is that this feature dates from the early period (Lewis, Williams 1989 22). Unfortunately, there is no archaeological or archival evidence for the feature it operated, which has been quarried away. In view of the persistence of such features in coal and metalliferous mines from the seventeenth to the twentieth century, it is perhaps surprising that this is the only example to have survived from the Gwynedd slate industry. Otherwise, the only evidence for the use of horses is their stables, which survive at a number of sites, as noted in the second project (**Report 154.5.4**). The slate industry of Gwynedd made consistent use of horses for hauling railed wagons, and they outlasted steam locomotives - horses were used as late as 1968 at Dorothea for internal railway transport.

4.2.2.iv hydraulic power: the present study has amply confirmed the suggestion made in the second report, that Gwynedd slate quarries remained dependent on water-power to a remarkable extent.

The use of water-balances, whether as inclines, evidenced in the case-study at Rhos, or shafts, evidenced in the case study of Pen yr Orsedd, is parallelled elsewhere in the industry. Water-balance inclines were noted at a number of sites and two survive, substantially intact, though out of use, at Aberllefenni Quarry (**Report 154 Appendix 1: 20487**); water-balance shafts at Penrhyn Quarry are discussed in **3.20061**. It therefore appears that the industry made considerable use of this type of hydraulic technology.

Richards 1991 suggests that a Tom and Jerry engine was used at Rhosydd quarry, a possibility on which Lewis and Denton are silent but which seems possible. A possible water beam-engine site at Ty Mawr easy, noted in the second report (**Report 154.5.3.3**) has since been demolished.

No evidence of water-pressure engines was encountered in the course of the second survey. Depending as they do on delivering water at pressure, they were often to be found underground, and it is believed that two were until recently *in situ* at the foot of the Sebastopol shaft at Penrhyn Quarry, where they operated pumps (**3.20061**). The frame of one of these was noted on the main processing level in August 1995, having clearly been cleaned and painted, and liaison is being maintained with Dr Dafydd Roberts of Amgueddfa Lechi, who is negotiating access to the foot of the shafts with the present quarry management to ascertain how much more survives. One source suggests that one of these was built by Easton and Anderson of Erith in 1872 (Lewis 1976 p. 12), another that both these engines were built by the Caernarfon firm of DeWinton and were installed new in 1859; each had a capacity of 30hp and 800 gallons (ex info., Penrhyn Quarry).

Of hydrokinetic machinery, the second project identified wheelpits surviving on a great many locations (**Report 154, 5.3**). It is clear that waterwheels powered the first known purpose-built slab mill, Felin Fawr at Penrhyn, operational by 1803 (**1.20061**) Water-powered mills became common by mid-century throughout the industry; the only region where the second survey found no examples was on the Moel Tryfan uplands, where there was insufficient gathering-ground and fall. The case studies also confirm that waterwheels pumped, uphauled and compressed air. The three surviving waterwheels in the industry (**1.20061, 20091**) are all high-breastshot iron suspension wheels, which may be untypical. The photographs showing Rhos Quarry's wheels in operation make it clear that they were all wooden overshot wheels (**1 case study 3**). It is not clear whether the wheels which operated the mill and the pumping and winding equipment at Pen yr Orsedd were backshot or overshot, or of what construction, but it would not have been possible to use suspension wheels in either place (**1 case study 1**), nor to pump out at Rhiwbach (**1 case study 4**).

What is clear is that the industry remained dependent on the simpler forms of hydrostatic and hydrokinetic energy to a remarkable extent, possibly more so than any comparable British industry; at Rhos Quarry in Capel Curig a waterwheel was installed as late as 1934, and was still at work at the closure in 1951 (Lewis and Williams 1989). In this respect its nearest counterparts are the upland lead mines of Cardigan and the Pennines, which also remained water-dependent for most of their lives, though their hey-day passed early than that of the slate quarries. Slightly further afield, the forges and rolling mills along the River Don resisted the steam engine, and some remained water-powered until the 1950s (Crossley 1995 p. 23).

It is also clear, however, that quarry managers were prepared to look at more advanced forms of hydraulic power. References to turbines were noted as early as 1869 at Hafod y Llan (**2.20255**), and working peltons were noted at Dinorwic (**1.20091**) and Llechwedd (**1.20300**). It is thought that the turbine which replaced the waterwheels at Hafodlas (**1 case study 2**) may survive in use on a farm near Dinas Mawddwy (pers. comm., Dafydd Price), and liaison is being maintained with the members of Fforwm Plas Tan y Bwlch who are hoping to examine the machine.

4.2.2.v steam power: the archaeological evidence for the use of steam power is slightly less than that for hydraulic power; nevertheless, by the turn of the nineteenth and twentieth century steam was making more of a contribution to power-needs in the Gwynedd slate industry than water (Kellow 1907 p. 4). Without a doubt the most impressive steam-power feature in the industry is the Cornish pump engine at Dorothea quarry (**1.20033**), the only surviving example of a type of technology never common in the industry. No steam engines which powered mills survive *in situ*; one survives, dismantled, at Amgueddfa Lechi/Welsh Slate Museum, which formerly drove the mill and possibly also wound a chain incline. This is a vertical wall-engine, a very untypical example (**2.20036**); it is clear from the details of steam-powered mills and uphaulage features that most were horizontal engines, of which no example survives. However, as noted in **4.1.2.v**, the Caernarfon firm of DeWinton was capable of producing steam plant by the mid-1850s, of which an example survives, restored to working order, together with its Lancashire boiler, at the Glynllifon estate workshops. This small but well-built single-cylinder horizontal engine may have been typical of the smaller steam plant used in the slate industry.

Other surviving steam engines are the winch which operated a blondin at Blaen y Cae (**3.20031**), probably typical of blondin engines and possibly similar to the engine which powered the massive chain incline at Cloddfa'r Lôn (**3.20036**), and the single-cylinder horizontal overtype engine which uphauled a waste incline at Cwt y Bugail (**Report 154 Appendix 1 20311**).

There is little evidence for the use of rotary beam engines, except at Tan y Bwlch (**2.20062**), and none for the use of the vertical Durham type. The possible atmospheric engine at Tal y Sarn Quarry (**Report 154 Appendix 1 20025**) remains unconfirmed.

Engine houses for various purposes survive on a great number of sites. The most impressive is perhaps the substantial building erected at Rhiwbach Quarry in 1862 to house the Haigh foundry engine which powered the quarry's uphaulage exit incline, the mill and a shaft (**1 case study 4**).

Steam power did confer a number of advantages over water. While water was cheap, it was not always plentiful, either through frost or drought, and there are many examples in the industry's extensive archive of managers' or workmen's despair when a dry summer threatened their profits (*e.g.*, CRO reports of the British Slate Company [uncatalogued], Shiloh pp. 9-10). Hostile neighbours could interrupt the supply. Furthermore, the siting of waterwheels was a complicated matter, in which various factors had to be balanced against each other, and whereas wheels themselves could be dismantled and rebuilt, their sturdy pits and the extensive leats which served them required considerable capital investment. Steam engines could be moved and re-erected, a considerable advantage in an industrial site which by its nature was apt to change shape.

It would be easy to overstate this advantage. A machine such as the Cornish engine which pumped out the pit at Dorothea was certainly not designed to be moved unless absolutely necessary. In some cases quarries installed a central steam engine and were able to carry on using it even though the quarry developed away from its original focus. The Delabole slate quarry in Cornwall led the way in this respect, where one steam engine powered several haulage ropes and pump-rods (Williams 1991 p. 16), but the same idea can be seen at Rhiwbach, where complex systems of ropes operated shafts, inclines and a mill over some distance.

Steam engines had the further advantages over hydraulic systems for winding in that they were faster, an important consideration in the Nantlle pits and the mines of Meirionydd, where traffic bottlenecks could easily build up on ropeways and inclines.

4.2.2.vi internal combustion: petrol, gas and diesel plant, by virtue of its small size, leaves little archaeological evidence. It is clear that both Rhos and Rhiwbach made use of them (**1 case study 3, 4**), and their comparative cheapness made it possible for such small and struggling concerns to make use of them from the 1920s onwards.

4.2.2.vii electrical power: this became very important indeed in the Gwynedd slate industry, which can fairly claim to have prompted the pioneering development of alternating current by the North Wales Power and Traction company through the work of Moses Kellow, manager of Croesor Quarry. His 1907 lecture to the Institute of Civil Engineers was published as *Application of Hydro-Electric Power to Slate Mining* along with A.H. Preece's *Electrically-Driven Winding Gear and the Supply of Power to Mines* that year. Kellow stated that the bulk of power used in the slate industry was at that stage derived from steam engines, but argued the advantages not only of electrical power but also more particularly of alternating current and three-phase supply. Amongst the many gains he set out were the claim that incline uphaulage could be much more effectively controlled, and that there was less danger of upsetting a finely-balanced trolley carrying a large slab at the foot of the incline or at the pointwork on the intermediate levels (pp. 60-61). He calculated that in a working year of 3,000 hours the total cost per effective horse-power was £2 19/10d with hydro-electricity and £19 15/- with steam (pp. 75-6).

Moses Kellow's pioneering alternating current installation at Croesor (Kellow 1944 pp. 357-358) ceased work in the 1960s and the ironwork was scrapped, but Warren Roberts's direct current power station of 1904 for Llechwedd Quarry survives more or less as constructed and is still in active use. In the absence of any surviving gazetteer of early electrical plant, it is impossible to be certain, but it seems highly likely that the machinery retained in daily use by the Gwynedd slate industry (**1.20300, 20306**) constitutes the best surviving examples of Edwardian hydro-electric equipment in the United Kingdom. Their value is enhanced by the fact that the buildings which house them have been so little changed over the years - at Llechwedd's Pant yr Afon station the sand-bucket bears the wartime utility mark; at Maenofferen the warning notices around the rheostats show a clerk in braces and starched collar giving a shock victim, similarly attired, artificial respiration. Other sites in which electric machinery survives partly or wholly intact include Pen yr Orsedd, with its Bruce Peebles blondin motors of 1906 (**3.20039**). A similar machine, which formerly wound an incline has been reinstated and restored at Oakeley Quarry's Gloddfa Ganol tourist site.

Sites in which the electric motors have been partly or wholly removed but in which their positions and function are clear include the Australia compressor house (**1.20091**) and mill (**2.20091**).

Other sites may have made use of electric motors in a way which is no longer apparent; their comparative lightness meant that they could be attached to roof trusses, as at Pen yr Orsedd (**1 case study 1**) and Cwm Machno (**2.20132**).

The use of a.c. supply meant that the power source itself might now be miles from the quarry - at Cwm Dyli, later Dolgarrog and Maentwrog (Thomas 1989) - and archaeological survivals from this period in the quarries themselves are more likely to be the distinctive converter stations, which were noted at a number of sites, such as Maenofferen (**2.20306**).

4.2.3 power-transmission: the various methods are analysed in their separate categories.

4.2.3.i mechanical transmission: this was noted in a variety of ways. Mills seem most commonly to have made use of wrought-iron or steel line-shafting, generally at truss-height, sometimes waist height as at Australia or below floor level as at Hafodlas, with canvas belt drives to the machines themselves. In some earlier mills it is likely that line-shafting with bevel gears was used to turn the transmission around right-angles rather than belt-drives; this is evident at Coed y Parc (**2.20061:8**), and possibly at Gorseddau (**1 2.20238**). A chain-drive runs from the pelton at Dinorwic's Gilfach Ddu workshops to the line-shafting (**1.20091**).

Few flatrod systems have been identified within the archaeological resource of the Gwynedd slate industry. That at Rhiwbach appears to date from the early 1860s (**1 case study 4**), and is therefore later than those at Cloddfa'r Lôn (1845 - **1 case study 1**) and at Rhosydd (post-1856 - **2.20283**).

The Cloddfa'r Lôn example made use of round iron bars with forged eyes in the end, after the Cornish fashion, several of which survive on site, rather than the timbers which were common elsewhere in Britain and in the centres of continental mining practice. The Cloddfa'r Lôn system probably dates from 1845, when improvements to the quarry were implemented by the Cornishman Gullet, and when the leat which powered it was built (pers. comm., Dr Gwynfor Pierce Jones).

The Rhosydd system pumped the East Twll. It was approximately 400 yards long, and was powered by an extension of the axle on which ran the waterwheel in 3 mill. This feature is later than the mill itself, which dates from 1856 (Lewis and Denton 1974 pp. 36, 51). Some of the rocker bases survive.

Ropes were most commonly used for inclines and cableways; wire ropes were also observed to have been used to power mill machinery at Pen yr Orsedd, where the two power sources in the Bonc yr Offis mill, a 30' waterwheel and a reserve Robey steam engine, also operated a large mill at a lower level. Precisely how the system operated is unclear, owing to the fact that all the ironwork has been removed, but clearly the ropes passed over two intermediate pillars, on the top of which ran horizontal spindles. D.C. Davies describes endless wire rope transmission as inefficient, because rain in the early stages of the night followed by frost made the rope as slippery as glass (Davies 1878 pp. 127-8).

4.2.3.ii pneumatic transmission: compressors were observed to have been driven variously by waterwheel (**1 case study 2**), turbine (**1.20061:123**), internal-combustion engines (**1 case study 2, 4**) and electric motors. Both the horizontal and vertical cylinder variety were noted intact at various points, and at Dinorwic a particularly elaborate set-up was noted on Australia level, which included iron piping, the various junction units and a large cooling tank (**1.20091:61-8**). However, in most sites the iron piping, which lends itself to re-use, had in nearly every cases partly or entirely vanished.

One other use of air-power was noted in the Australia mill (**2.20091:84**), where a vacuum arrangement removed dust from the saw-tables, in order to lessen the risks of silicosis.

4.2.3.iii hydraulic transmission: the remains of an accumulator (a means of ensuring that hydraulic pressure remains constant) to power saws were noted at Pen yr Orsedd Quarry (**1 case study 1**).

4.2.3.iv electrical transmission: the constant upgrading of the local electricity supply systems after the pioneering days of 1906 to 1918 has meant that little survives of the early pole systems from Cwm Dyli. In the absence of the North Wales Power and Traction Company's records, anecdotal and photographic evidence suggests that these were mostly conventional A and H frame poles, giving way to single poles in the quarry premises themselves.

4.2.4 power-needs: a number of facts emerged from the survey which add to the problems of assessing power-needs and output, though they also to some extent cancel each other out. One is the fact that very frequently power-sources were utterly inadequate to operate all the machinery in the mill, and it has to be assumed that very often only a small proportion of the machinery was operational. Another factor is that the machine capacity of many mills was wildly in excess of output. As an example, Cwt y Bugail's two mills, with their twenty-one Greaves saw tables, could produce a theoretical 840 tons a week, compared to the quarry's actual maximum output of 4,000 tons per annum.

5 MILLS

5.1 Background

5.1.1 General introduction: buildings to process slate in Gwynedd quarries are known in Welsh as *melinau*, "mills", though the word *injan* ("machine-house") was used in Blaenau Ffestiniog and Penmachno.

The processing of stone by machinery has been technically possible since at least the fifteenth century, and was a feature of the Italian marble industry in the early modern period. In 1588 Agostino Ramelli depicted a water-powered frame-saw little different from the sort of machinery that could have been seen in, for instance, a Dolwyddelan slate quarry until well into the twentieth century (Ramelli pl. 134, CRO XS 1182 9). More sophisticated versions of such machines (post-war, and therefore not noted in the second survey) remain in use at Aberllefenni slate quarry to this day, as well as in other forms of stone-sawing plant. Unlike the timber saw, it involves horizontal wrought iron blades tensioned in a frame and resting on the block to be sawn, thereby obviating the need for a feed system. Into the cuts created by the blades a paste of sand and water is fed, which then acts as the cutting agent. In unmechanised form this technology was known to the Romans, and had been used on slate blocks in the Mithraeum at Segontium (Boon 1960).

The marble mills set up in Derbyshire and elsewhere at the end of the eighteenth century seem to have made early and consistent use of frame-saws, perhaps also the mill erected in America by Marc Brunel around the same time. It was therefore the obvious choice for processing other forms of fissile stone into rectangular slabs when the slate industry began to be capitalised at the end of the eighteenth century.

Though the frame-saw was nothing exceptional by the time Gwynedd slate quarries began to make use of it, it very much appears that the circular saw, which has by now (1996) largely superseded the frame saw in stone plants, was first applied to sawing stone in Blaenau Ffestiniog. Circular saws were in use to power block-making equipment for the Royal Navy from 1781 if not earlier, and it has been suggested that William Turner of Diffwys Quarry latched on to the idea after travelling to Portsmouth with a cargo of slate sometime between 1801 and 1807 (Turner 1903 pp. 17, 77). At any rate, the gravestone of Suwsanna Pierce of Ffestiniog, who died in 1805, appears to be the first block of stone anywhere to be sawn with a circular saw (pers. comm. Dr Michael Lewis), though the first documentary evidence for the purchase of circular saws by Diffwys Quarry comes in 1815 (UWB Porth yr Aur 30348, 30365).

The pattern for the next sixty years broadly speaking involves both reciprocating saws, which lasted longer in the softer Ordovician slate, and survived longest of all in the quarries of Dyffryn Lledr, and circular saws. The early circular saws involved a fixed blade and a slotted moving table in which the slab was fed onto the saw by a weight on the end of a rope and pulley (CRO Glynllifon 29004, 1823-1828). The earliest surviving example dates from 1855, and is preserved at Glynllifon in Llandwrog; the table is moved by chain operated from the drum axle.

However, the Greaves' patent of 1850 became the standard. Here the slotted table is moved by a worm gear on the saw drive axle driving a ratchet. These were manufactured in their hundreds by Thomas and DeWinton of Caernarfon, John Owen of Bangor, the Glaslyn foundry at Porthmadog and Turners of Newtown, and they were commonly met in slate quarries until the modernisation programmes of the 1960s.

A development of the 1860s for which high hopes were entertained was the Hunter saw, with its renewable tip blades. Developed in the freestone workings of Arbroath, it was made in diameters up to 15', for cutting breakwater stone. Though not the answer its patentees claimed it was, examples remained in use at a number of Gwynedd slate quarries into the twentieth century (CRO ZS 45 16), and it was also used at Delabole Quarry in Cornwall (Stanier 1995 p. 116).

Planers for slab production appear by 1839 (*CDH* 23 Nov. 1839).

Until the 1850s the production of roofing slates, as distinct from slabs, remained entirely unmechanised, and it is only in this period that the integrated mills, where all the processes were carried out under one roof, began to appear. The guillotine dresser for trimming the edges of the split laminae was patented in 1850 by Nathaniel Matthews (patent 13019) but was less successful than the Greaves rotary dresser (patent no. 2347 of 1860) which quickly replaced it (Williams 1985 53-54), but has never entirely replaced hand tramming with a knife in the Arfon quarries. It appears that originally mechanically-sawn blocks from mills were taken to gwaliau to be made into roofing slates, but that gradually the waliau came to be incorporated into the structure of the mills themselves.

Nevertheless, by the 1860s and 1870s the various pattern of mill buildings seems to have been established, and remained more or less standard until diamond saws came to be used, from the 1920s onwards, and more particularly until the modernisation programmes of the 1960s onwards not only caused the replacement of many of the old-fashioned saw tables with much bigger machines but also led to the replacement of the narrow-gauge railway as a means of access by fork-lift trucks. Of the four nineteenth-century mills which were noted by the second survey as being in use, only Maenofferen is still served by a railway.

5.2 Results of Survey

5.2.1 general introduction: mills were found on all but the very smallest sites, and encompassed a considerable variety of structure-types.

5.2.2 chronology: it is clear from the archives of the slate industry that large structures such as mills were often built over a period of several years, the extreme example being Dorothea, where the large mill was built over a period of eighteen years, and the small mill over no less than twenty-eight years. In this case the reason is said to be that the quarry wished to avoid paying rates on them, and classified them as incomplete for this reason. They were built in a way that lent credence to this claim, with line shafting and machines in the open air (pers. comm., Gwynfor Pierce Jones).

Equally, there was reason why some quarries should suggest that mills had been built when they were still under construction, or to exagerrate the number of machines in them in order to placate shareholders. Company prospectuses, letters to the *Mining Journal* and newspaper advertisements are therefore not always entirely reliable.

Within these limits, the present report has been able to produce a chronology of mill-construction encompassing most of the mills recorded in the second report. Of mills which can be confidently dated to a decade, the following dates are indicated:

1840-1849 - 2
1850-1859 - 11
1860-1869 - 32
1870-1879 - 9
1880-1889 - 9
1890-1899 - 6
1900-1909 - 0
1910-1919 - 2
1920-1929 - 2

Of the examples chosen for detailed study, the following dates are indicated:

1840-1849 - 1
1850-1859 - 3
1860-1869 - 11
1870-1879 - 3
1880-1889 - 2
1890-1899 - 1
1900-1909 - 0
1910-1919 - 1
1920-1929 - 2

The numbers correspond to the expansion and contraction of the slate industry, with the increasing investment of the 1850s leading to the extraordinary burgeoning of the period 1860 to 1866, the financial collapse of March of that year, and the slow revival thereafter. Even though 1877 is frequently taken to represent the end of the expansionist period, the industry was still buoyant until the turn of the century, and there was some investment after the first world war. This pattern is necessarily obscured by the fact that small mills were often built in the 1860s and subsequently extended.

The present report has largely confirmed the findings of the second, that documentary evidence makes it clear that mechanical processing of raw slate blocks into architectural slabs in powered mills begins near simultaneously at the turn of the eighteenth and nineteenth century at Ffatri Rhyd y Sarn near Blaenau Ffestiniog and Felin Fawr, near Penrhyn Quarry (CRO Glynllifon unlisted [map of May 1802], PQ 22 1 [entry for June 1803]). Conversely, the processing of blocks into roofing slates in the so-called integrated mills only begins in a limited way, probably as early as the 1840s, certainly from the late 1850s, but it soon became an established feature of the important Nantlle and Ffestiniog districts, though only became common in the Penrhyn and Dinorwic Quarries in the early years of the present century.

However, the earliest identifiable sites of which any archaeological evidence remains at all date from the 1840s. These include Portreuddyn (20241:1), which has been extensively altered to form two large cow-sheds, and Diffwys Quarry's off-site Pant yr Ynn mill, which opened its doors in 1846, and which was converted into a woollen factory by 1879 (CRO BJC X647, DRO DCH 3 77, 84, NLW John Thomas CC66).

The mill at Minllyn Quarry (20449:6) is a different matter; believed to have been constructed before 1843, apparently as an integrated mill whose process flow was very little different from that at the Australia mill in Dinorwic quarry (20091:84)), the most recent structure considered in the present report - longitudinal railway access and a transverse process flow from saw-table to a hand-processing area, geared to the production of roofing slates.

Whether because the remoteness of the site or the very limited commercial success of Minllyn Quarry in this period, the example does not appear to have been copied or followed for a number of years.

5.2.3 typology: a typology of mill buildings is more problematic.

The second report divided mills into four separate categories according to the way in which they were accessed by their railway systems. These are:

longitudinal - in which railways to deliver and remove material enter and leave through gables and run parallel to the main longitudinal walls

transverse - in which railways to deliver and remove material enter and leave through the opposite longitudinal walls

bay - in which railways to deliver and remove material enter through one longitudinal wall

radial - in which a single railway to deliver and remove material enters through one wall and machinery is served by railways radiating off a central turntable.

The longitudinal mill encompasses both the earliest and the latest mill chosen for detailed study, namely Minllyn of pre-1843 and Dinorwic's Australia mill of 1921. In each case, though the railway access is longitudinal, the process flow is likely to have have been transverse, with raw blocks being barred off wagons onto a saw-table, then to a hand-processing and dressing area. This might be in semi-integral *gwaliau* as at Minllyn or Rhos, in booths within the building, as at Maenofferen and Australia, or there might be no attempt made to provide a separate area for the splitters, as at the Pen yr Orsedd mills.

The transverse mill first appears at Rhosydd in 1856, then at Prince of Wales (1864), Penrhyn Quarry (1865), Cwt y Bugail (1867), Arthog (1868) and Cwm Machno (c. 1921). It is suggested below (**2.20061** and **20221**) that Prince of Wales, the two Penrhyn mills and perhaps Arthog are all the work of John and Thomas Francis. However, the design was clearly a popular one, and as Cwm Machno demonstrates, such mills were still being erected in the twentieth century. The process flow in a transverse mill follows the railways across the mill from saw-table to hand-processing area.

The bay mill appears mainly to have been used for the processing of raw blocks into slab for architectural purposes. Though Rhiwbach's main mill has been defined as a bay mill, in that its railways do not go right through the mill, it is much nearer the transverse mill, with finished roofing slates being hand-carried to a stackyard outside. The bay mill as represented by Hafodlas appears to be essentially a machine house, in which the whole process is carried out mechanically. Even in the case of a tiny structure like the mill at Pompren Fedw this appears to hold good, with raw block being loaded onto a single frame-saw through an open longitudinal side.

The radial mill also appears mainly to have been designed to turn out slabs. The clearest example here is Gorseddau, where recent excavation has confirmed central turntables giving access to saw-tables and planers arranged along the centre of the mill.

One other possible pattern is exemplified by the mills at Hafodlas, Rhosydd and Croesor; in each case a double bay mill powered by a waterwheel either between the two bays or externally forms the original building, with a transverse or longitudinal mill constrcuted later as a lateral extension. The common factor may be CE Spooner of the Ffestiniog railway, who was certainly involved in the design of Hafodlas and Croesor mills (**2.20156**, Morrison 1972 p. 406).

The construction of slate mills at such a furious rate from the late 1850s onwards makes a typology difficult to establish, except in the limited case of the mills which share some architectural similarities noted above. More likely that quarry managers experimented with various types of structures and arrangements, that each was aware of what his neighbour was building, and that by the 1870s at the latest there was a considerable variety of types which could be erected, depending on rail access and the site itself, and possibly on managerial whim as much as anything else. They certainly seem to have been more anxious to impress their fellows than to hide their technological expertise under a bushel, as when Alan Searell unveiled his new saw at Cwmorthin in front of a gathering of big-wigs including Francis of Penrhyn, Mathew of Rhiwbryfdir, Casson of Diffwys, Samuel Holland, Greaves of Llechwedd, Dixon of Bryn Hafod y Wern, and Spooner of the Ffestiniog Railway (*MJ* 1852 198), or when Moses Kellow demonstrated his new planer at Croesor which leapt off its mountings, demolished the mill wall and fell to a stream below (Isherwood 1988 p. 11).

The working quarryman himself may also have exerted a profound influence on the design of the mills. The semi-integral *gwaliau* or separate booths for hand-processing may reflect managerial acknowledgement, however grudging, of the quarryman's traditional self-image as a contracted *bargeinwr* who would deeply resent the implications of being considered a mere factory hand. His loyalty was to the other members of the bargain, some of whom would be working far away, rather than to the authority of a mill foreman.

Very little evidence survives for the process by which a mill came to be built; only in the case of the Bonc yr Offis mill at Pen yr Orsedd (20039:20) do plans survive, in this case from DeWinton's Union Ironworks at Caernarfon (CRO Pen yr Orsedd 381), and there are very few examples of a contract to build a mill. Whatever discussions of arrangements and process-flow took place between managers and engineers seem to be beyond recovery. It is therefore difficult to say to what extent DeWinton's or other local engineering concerns would have worked to rule-of-thumb methods or to scientific principles, whether to ad-hoc decisions or to calculated process-flow. Certainly the principle of the rational factory workplace was understood well before the mechanisation of the slate industry, being reflected in such huge establishments as the Carron ironworks in Scotland, yet the only attempt to calculate process-flow on any careful basis for which archival evidence survives dates from 1962, when Dinorwic Quarry was contemplating the programme of modernisation for their existing mills which would have replaced railway access with dumper trucks and conveyor belts (CRO: XDQ 2249).

If the directors of quarries were slow to respond to the call of scientific management, men were actively hostile. A time-and-motion expert sent to one of the Nantlle quarries ended up being placed in a barrel and rolled down an incline for his pains. The slate-quarrymen of North Wales had, and have, their own decided views as to the best way of doing things.

There was, in any case, little need for an entirely rational process-flow for much of the industry's history; whatever ideas may have informed deliberations in the drawing offices of the local foundries when these structures were being erected in the boom years of the 1860s and 1870s, the relentless decline in the industry since then meant that few mills would be working at anything like capacity. As an example, the case of Cwt y Bugail's mill (20311:7) had a theoretical maximum output of 840 tons a week, yet the known maximum output was 4,000 tons a year (Plas Tan y Bwlch report). Doubtless as saw tables broke down or needed repair, the men would move to another one, and although photographs of mills at work in the late nineteenth century give an impression of bustle and noise, many can not have had more than a handful of men at work in them. It is hard not to resist the analogy of the nonconformist chapels of Wales, built for congregations which never materialised.

There is no evidence of influence from other slate-producing area within Britain and Ireland; such influence as there was is likely to have been in the other direction. Delabole Quarry in Cornwall, whence came the chain incline (Kent 1968 p. 321), seems in matters of processing to have followed Gwynedd, making use of DeWinton-built Hunter saws (Stanier 1995 pp. 115-116). The important Burlington Quarries in the Lake District had Welsh managers from *c.* 1852 to 1937 (Geddes 1975 pp. 258-9), and the substantial slate-sawing plant built *c.* 1839 at Valentia Quarry in County Kerry, an important early source of slabs, has no obvious parallells with any feature in the Gwynedd slate industry, despite other evidence of Gwynedd-inspired technology and a manager from Llandygái (Gwyn 1995, *passim*).

There is little apparent influence from other stone-processing plant in the United Kingdom. The common plan of a stone-works, with a bank of saws along one side of a rail access, and masons' booths along the other, with an overhead gantry crane between them (Powis Bale 1884, p. 17, Stanier 1995 p. 79) has no close parallel in Gwynedd, even though it combines the elements of mechanical and hand-processing which is a distinctive feature of the slate industry.

6 UPHAULAGE - AERIAL ROPEWAYS AND VERTICAL SYSTEMS

6.1 Background

6.1.1 General introduction: wherever the processing point in a mine or quarry lies above the workings, some form of uphaulage system is required - in Western Europe, in the Post-medieval period at least, it was only in the poorest and least-capitalised concerns that the mineral made its way to the surface by hand, without any mechanical assistance at all. The coal-mine pit-head gear became not only the most distinctive surface feature of the industry but also a symbol of the collier and his labour.

Yet this was only one of a number of means by which coal, ore or stone were brought to the surface, and this technical diversity is reflected in the slate industry of Gwynedd. The following section therefore concentrates on **vertical** and **aerial ropeway** systems, as set out in the original project submission for grant-aid to Cadw, but it also considers the development of other uphaulage systems in order to gain a fuller understanding as to why some systems were used in preference to others, and why some replaced others at particular sites.

6.1.2 Vertical uphaulage: this category consists of uphaulage methods in which the process is accomplished by means of a vertical rope depending from a power source at or near its head. It has been divided up into two, namely **platform**, in which the rope runs from a platform projecting over the lip of an open pit, and **shaft**, in which the rope runs down an enclosed shaft, further subdivided into **water-balance** and **steam**.

6.1.2.i platform: the use of projecting cantilevered platforms over the edge of a pit supporting a drum or windlass from which a haulage rope depends was established practice in opencast working by the end of the eighteenth century. The earliest illustrations of uphaulage systems in slate quarries are in Diderot's *Encyclopédie*, which shows the systems in use in French slate workings in the eighteenth century, where horse-whims and hand-windlasses wound vertical hempen ropes from platforms on the edge of open pits or up shafts which raised kibbles to the processing areas (Diderot: Mineralogie: Ardoises d'Anjou planche 1 numéro 4). By the beginning of the twentieth century the important quarries of Angers in France were still making use of broadly similar systems, though now steam- and electrically-powered, in which blocks were raised vertically from open and underground extraction points by means of headgear constructed on huge timber stagings on the lip of the pit (CRO XS 1072 158).

Prints of Mynydd Parys copper mines from this period show both hand- and horse-powered systems pulling up kibbles containing not only the ore but workmen as well, on the end of hempen ropes which depend from flimsy wooden platforms or which descend shafts (Rowlands pl. 6).

They are first recorded in the slate industry of Britain in 1761, when they were introduced at Delabole Quarry in Cornwall, operated by horse-whims. More were added in 1803 (Kent 321). They were also a feature of the coastal slate quarries of Cornwall, small and poorly-capitalised concerns (Sharpe 1990, *passim*), and it is possible that the remains of two stone piers at Summerton Slate Quarry in Pembrokeshire may be connected with such a system (Tucker 1979 pp. 212, 220-1). The payload of a hand-windlass is 6cwt and a horse-whim 12 cwt (Pierce Jones 1980 113).

6.1.2.ii shaft: the use of enclosed vertical shafts to reach either an underground mine-face or an open pit is of great antiquity, though the majority of mines throughout Britain and continental Europe were accessed by horizontal drifts until the eighteenth century. Shafts operated by windlasses hauling a kibble were known in Gwynedd's lead mines by the eighteenth century (Bick 54).

The use of **hydraulic** and **steam** power (described below) instead of manual and animal power to operate shafts enabled the iron cage held steady by guide-rods and carrying complete loaded wagons to be substituted for the kibble. This method was first introduced at South Hetton colliery in County Durham in 1834 (Malaws *et alii* 69), and had the great advantage that as well as enabling much heavier loads to be lifted, there was no need to transship material at the top and bottom of the shaft. Iron wire ropes were introduced at collieries in Prussia in 1835/6 (Malaws *et alii* 70) and were in use in the Durham coalfield by 1842; they were available in Wales not longer after (pers. comm., Dr MJT Lewis).

Hydraulic shafts are first attested in their simplest form in 1753, when Chatershaugh Colliery on the River Wear used a simple system whereby a bucket of water raised a lighter kibble of coal. The introduction of the cage system allowed a more sophisticated double-acting version to be introduced, with a tank underneath each cage. At the end of the journey the tank at the foot of the shaft is emptied and that at the top filled, and the process is reversed. It was in the coal industry of South Wales that the water-balance method became common, and over sixty were in use in Glamorgan alone by mid-nineteenth century, before they gradually yielded to steam winders. Surviving examples include the water-balance from the Bryn Pwllog Colliery, Blaencarno in the Rhymney valley dating from *c.* 1830 which was acquired by the National Museum of Wales in 1935 (accession number 35.348) and which became part of the holding of the Welsh Industrial and Maritime Museum when it was set up in 1957. It is now to be seen, re-erected, at Big Pit, Blaenavon (pers. comm., Miss Caroline Charles, Welsh Industrial and Maritime Museum, Malaws *et alii*, pp. 65-8, 76, 161).

Steam-operated shafts raised cages containing one or more wagons by means of a rope passed over a headframe at the shaft-head, an arrangement typical of collieries. The South Wales engineer Powell, killed in an accident in 1783, had devised rotary atmospheric engines to wind coal in pits between Landore and Morriston even before Watt's engine was first applied to winding in 1784 with the introduction of the crank (Malaws *et alii* p. 69, Dickenson and Jenkins 249). A Trevithick high-pressure engine was installed in the Llanelli coalfield in 1804 (Malaws *et alii* 69), and, in conjunction with the cage-shaft, such machines held sway for many years.

6.1.3 Aerial ropeway uphaulage: this category consists of uphaulage methods which involve a ropeway from the bank to the bottom of a pit. Three categories were identified, the **catenary ropeway**, the **chain incline** and a later version known as the **inclined cableway**, and a ropeway stretched across the pit from which a mobile uphaulage rope depends, commonly known as the **blondin**.

6.1.3.i catenary ropeway: ropeways stretched across the pit from which a further rope depends appear to be unique to the slate industry. They are first evidenced in John Smith's painting of Glynrhonwy dated *c.* 1820 (National Museum of Wales). An engraving of Killaloe Slate Quarry in County Tipperary dated 1845 shows an apparently similar form of ropeway in some detail. It involves a rope stretched across the pit from which a further rope depends by means of an eye through which the cross-rope is threaded. The dependent rope is trailed across the bottom of the pit, and is attached at its other end to a horse-whim on the processing area. This, when wound, not only raises the rope, to which a block of slate or a loaded kibble (but not, probably, a loaded wagon) has been attached, but pulls it in to the landing point. To repeat the process, the rope is unwound off the whimsy drum, and the catenary section of the cross-rope allows the eye to slide back to a central point above the pit.

6.1.3.ii chain incline: this appears to originate at Delabole Slate Quarry in Cornwall. They were introduced there by Thomas Avery, who was working the quarry by 1833 and sold out in 1847 or 1848, and steam-powered chain inclines are attested there by 1850, with a sliding landing platform (Kent 1968 p. 321).

The chain incline consists of a chain running from a headframe on the lip of the pit an angle to a fixed point in the pit. On this ran a traveller carriage to which a wagon was attached, and which was powered by winding rope which passed over the headframe to a power-source. By paying this rope out, the carriage could by lowered at the angle of the chain until it reached a stop-block, at which point it began to travel vertically down to the pit floor where the empty wagon would be removed. The process was reversed for a wagon loaded with blocks or rubble, which would be removed at a landing stage underneath the headframe and wheeled to the processing areas or to the tips. Commonly two chains ran parallel to each other, and operated in tandem from the same winding drum, one uphauling while the other one downloaded.

6.1.3.iii the blondin: the blondin ropeway, named after Charles Blondin who walked across Niagara falls on a tightrope in 1852, was developed in the Scottish stone quarries in the 1870s. John Fyfe installed a blondin at Kenmay Quarry in Aberdeenshire in 1872, but they made comparatively little impact, and as late as 1886 only two other quarries in Aberdeen were using them, assisting derrick cranes. They had a lifting capacity of three tons (Donnelly 233). In 1896 Henderson's of Aberdeen patented a form of cableway which quickly became popular in Gwynedd and elsewhere. Known throughout the world as a blondin (except at Penrhyn quarry, where they were called Jerry Ms), they made use of the newly-available steel ropes, in place of the iron ropes or chains (Pierce Jones 1985 30). There were differences in detail between those used in the granite quarries of Scotland on the one hand and those used in Gwynedd slate quarries and at Delabole on the other (Foster and Cox 1910 pp. 432-4). Their use was not confined to extractive industries; they were employed on the construction of Calstock viaduct in Devon from 1904 to 1907 (Parkhouse nd.), and possibly on other large-scale engineering projects.

All had in common the fact that the rope was stretched across a pit between two masts, along which ran a traveller, known locally as the ceffyl ("horse"), from which in turn depended a haulage rope. Both the lateral movement of the ceffyl and the vertical movement of the haulage rope were controlled from a power source on or near the processing area.

6.1.4 railed incline planes: railed incline planes, in which rails are laid on a steep gradient and wagons are hauled by a rope from the summit, fell into two broad subdivisions. One is the **counterbalance incline** type, in which the weight of loaded wagons pulls up empties on an adjacent track by a rope passed over a drum at the summit. The other is the **powered uphaulage incline** in which the load has to be hauled against the gradient. It is this second type which is discussed here.

Though the origins of the incline have been traced back to *c.* 1430, powered examples have only been used in extractive industries since the late seventeenth century. One was installed at Humboberg copper mine in Dalarna, Sweden in 1698, powered by a water-wheel (Lewis 1970 pp. 42, 53). One such, powered by a horse-whim is attested on the Llandygái railway of 1798/9, part of Penrhyn Quarry's exit system from 1800/1801 (Cadw ref: 42/A/143 [Index]).

Water-balance inclines worked on a slightly different principle to the water-balance shafts described above, in that the load was raised by a wheeled tank on a parallel track, which when filled with water pulled up the load by virtue of its superior weight. An example was noted in use at Whitehaven in 1765 (Lewis 1970 p. 323).

Outside Gwynedd, railed uphaulage inclines were used in the pit slate quarries of Ireland (OS County Tipperary XIX 8/12, County Kilkenny LXXII 2/10), possibly because of Welsh influence, and an impressive four-track steam incline was installed in Delabole in the 1860s, which seems to have replaced the chain inclines. Uphaulage inclines were used at Honister in the Lake District (Tyler 1994 pp. 98-99).

6.1.5 cranes: primitive forms of derrick crane are known to have been used in quarries since Medieval times at least (Moorhouse *passim*) and by the nineteenth century they were a standard form of uphaulage in open pit-quarries working minerals and useful earths other than slate (Stanier 1996 *passim*).

Large derrick cranes were a feature of slate quarries elsewhere in Britain and Ireland; one was noted at Curraghbally in County Tipperary, and a photograph survives of one at Easdale in Argyll (Tucker 1976 plate XVIII). Gantry cranes such as were used at Valentia in County Kerry appear to be unique to this site (Gwyn 1995). However, many stone yards made use of large gantry cranes to lift the blocks from machine-sawing areas to masons' booths and on to railway wagons (Powis Bale 1884, p. 17, Stanier 1995 p. 79).

6.2 Results of survey

6.2.1 Introduction: evidence for uphaulage systems were found in the following slate quarrying regions of Gwynedd as defined by Richards 1991 - Bethesda, Llanberis, Nantlle, Dyffryn Conwy, Moel Tryfan/Cwm Gwyrfai, Ffestiniog and Dyfi. Evidence of the use of vertical uphaulage systems was encountered in the Bethesda area, and to a limited extent in Nantlle and Ffestiniog regions - all areas where the processing took place above the point of extraction. Use of ropeways was encountered in the Bethesda, Llanberis, Nantlle, Dyffryn Conwy, Moel Tryfan/Cwm Gwyrfai and Dyfi regions - all areas which include pit quarries.

6.2.2 Vertical uphaulage: no archaeological evidence was encountered for unenclosed vertical haulage from platforms, though there is some documentary and visual evidence for their use. One source suggests that Penrhyn had at least one horse-whim by 1760 on the evidence on an old print, but the print itself has not turned up (*The Penrhyn Quarry* 5). Robert Williams' autobiography speaks of hand-powered *tyntris* ("turntrees") pulling up a kibble on a chain at Nantlle in the 1820s (Williams, Hunangofiant Chwarelwr *Cymru* XIX 109 87), and there is evidence that this method remained in use until well into the nineteenth century. A hand-windlass on the edge of the pit is shown, apparently in use, as late as the 1890s on a photograph of Blaen y Cae Quarry in Nantlle (CRO XCHS 195 15).

So far as is known, only hand and animal power was used on these systems; an advertisement in the *NWC* on 12 June 1828 offering for sale the effects of the Hafodlas Quarry in Nantlle (now completely buried by tipping, not to be confused with Hafodlas in Dyffryn Conwy) implies that the 8 hp steam engine was used for pumping, and that horse-whims, possibly also waterwheels, hauled the buckets and kibbles.

Enclosed vertical uphaulage through shafts is attested in the Gwynedd slate industry from 1829 at Tal y Sarn Quarry in the Nantlle region, by a group of workers which included Robert Williams, who claimed it as a first (Hunangofiant Chwarelwr *Cymru* XVI 90 p. 57). Sylwedydd includes a brief description of its operations; it involved two shafts, one for the wagon to be raised and the other for the water tank; a mechanism calculated the weight of the load and thereby regulated the amount of water to be fed into the tank, thus enabling it to function as a weighing machine as well as an uphaulage device (p. 21).

The hydraulic shafts at Penrhyn Quarry (20061:58, 20061:82) represent a much more sophisticated double-acting version of this method, and the two surviving cast-iron headframes also represent an advance on the South Walian examples, the crude timber pit-head gear at Cwmbyrgwm Colliery, and on the comparatively more sophisticated iron frame from Brynpwllog Colliery.

Other examples were noted from the same period at Oakeley (20296:6) and slightly later at Pen yr Orsedd (20039:63), though neither preserve their headgear.

Water-balance shafts were only suitable where a number of particular factors operated. For raising blocks from pit quarries set on the slopes of hills they were in some respects ideal, since a gently-inclined adit from the sump could drain both the pit and the cage-tanks. However, the sinking of shafts was an expensive business, and needed skilled workmen, like the Salts and the Twiggs of Bethesda; only a comparatively confident or spendthrift management was likely to install them. Once installed they were cheap to run, but suffered from the disadvantages of all hydraulic machinery, aptness to freeze in winter and to dry up in summer.

Though it is clear that the Welsh slate industry made little use of hydraulic shafts, shafts in which steam engines raised and lowered the cages are only recorded at three places, at Tan y Bwlch, near Bethesda, at Ty Mawr East in the Nantlle area and Rhiwbach in the Ffestiniog area. D.C. Davies devotes some space to this method, which he claims is the most expensive, and suggests that it is particularly adapted to a slate bed overlain by hard rock, and that it should strike the bed at the deepest point. He recommends a shaft measuring 16' by 9', equipped with one pair of 25 h.p. steam engines. He states that sinking a shaft costs £15 a yard, and the equipment and its housing £3,240 (p. 102-8).

6.2.3 Ropeway uphaulage: the catenary ropeway has left no visible remains. Within a Gwynedd context it is only attested at Glynrhonwy, in the form of a painting by John Smith of *c.* 1820, now in the National Museum of Wales, and in the context of the slate industry as a whole it is only otherwise recorded at Killaloe, where they may have been introduced by emigré Welshmen (dehóir *passim*, pers. comm., Griffith Parry of Dolgarrog).

If the catenary ropeway was devised in the quarries of Arfon, it seems clear that the **chain incline** was introduced directly from Cornwall by Delabole quarrymen working in Nantlle (Pierce Jones 1985 17). Robert Williams' autobiography "Hunangofiant Chwarelwr" describes a Mr Gullet coming to Cloddfar' Lôn with fifteen Cornishmen, where he built a steam engine to raise wagons and drain the pit. Sylwedydd states that the steam engine was for a chain incline, and that this was the first example. He describes the first chain incline engine as a massive affair with two flywheels, each of which alone required five horses to drag it from Caernarfon (p. 56). This would have been after April 1841, when Gullet's predecessor Searell was still there (Beddgelert census 1851, date and place of children's birth); Gullet remained as manager until 1844 or later (*CDH* 24 August 1844).

Though they became a distinctive feature of the Nantlle industry, evidence for their use was noted at Glanrafon in the Cwm Gwyrfai area, at Rhos and possibly at Rhiwgoch in Dyffryn Conwy and certainly at Bryneglwys near Tywyn. Power was generally steam, which allowed for higher winding speeds, but water-powered examples are met in a number of locations. No examples are known from outside the slate industry.

The introduction of **blondin ropeways** at the end of the nineteenth century represents another example of the Gwynedd slate industry borrowing from outside the area, in this case from the Scottish stone industry, as it did with the Hunter saw in the 1860s. Their use spread from Pen yr Orsedd Quarry, where they were first installed in 1898, to the other quarries of Dyffryn Nantlle and of the Moel Tryfan/Cwm Gwyrfai region and to Penrhyn in 1912, where they were known as Jerry Ms after the winning horse in the Grand National of that year (Carrington 56-7).

The inclined cableways found at Dinorwic combine certain of the features of the chain incline with those of the blondin (the name by which, confusingly, these systems were known at Dinorwic). Like a chain incline, the main rope ran at an angle rather than on a shallow catenary, so the ceffyl was rhombus-shaped. Like a blondin, it made use of a wire rope, rather than a chain.

6.2.3 railed inclines: these were a distinctive feature of the Gwynedd slate industry until the 1960s and 1970s, in which wagons were hauled up or down steeply-graded railways by means of a rope, either on their own wheels or on transporter wagons. Gradients were anything between 1/9 and near-vertical, though 1/4 seems to have been common. It is thought that a water-balance was operational in Holland's quarry in the Blaenau Ffestiniog area, later part of the Oakeley site, from at least 1848 (Isherwood *Rhiwbryfdir Fawr*, 22), though there may have been earlier ones in the area.

Water-wheel powered inclines were to be found in the Ffestiniog area from 1836, when the Ffestiniog Railway constructed one as a temporary expedient to cross the Moelwyn spur (Boyd 1975 p. 27). Water-wheels rather than water-balances probably operated the hydraulic inclines known to have been in existence at Penrhyn Quarries in 1849 (*CDH* 1 Sept 1849), and probably much earlier, since they were shortly to be replaced by the water-balance shafts. This newspaper account is short on detail, but implies a central water-wheel or wheels operating a number of remote inclines.

Steam power was first applied to railed inclines in 1803 on the Lancaster Canal, followed by a high-pressure Trevithick engine in the Cynon Valley in 1805 (Hughes 153). Within the Gwynedd slate industry it was first applied to inclines in the Ffestiniog area in 1854 when Mathews built the large Rhiwbryfdir haulage incline, and a permanent engine bed may have been installed there two years later (Isherwood *Candles to Caplamps* 36-37, *Rhiwbryfdir Fawr* 28). A steam engine was installed on an existing incline at Dorothea Quarry in 1854, the first incline engine in the Nantlle area (Pierce Jones 1980 p. 113). Their use elsewhere in the Gwynedd slate industry is very limited.

Electricity was applied to incline uphaulage from 1904 (at Llechwedd), and its use spread once the North Wales Power and Traction Company began the sale and supply of electricity from 1906 (Weaver 1990).

The railed incline for uphaulage was once common in the Dyffryn Nantlle district, but they were largely superseded by cableways in the course of the nineteenth century. There were two reasons for this; the small surface area of a Nantlle quarry meant that there were physical limits on the extension of an incline, whereas both chain inclines and blondins could be moved. Secondly, the slate strata at Nantlle are near-vertical; therefore an incline often had to constructed on workable rock. At Ffestiniog underground chambers opened at one specific adit point, and the vein dips at 30°, so inclines could be built through the unworkable "hard". The railed incline remained the dominant uphaulage system in the Ffestiniog area until the closures and modernisation programmes of the late twentieth century, being used at Oakeley until 1969 and at Llechwedd until *c.* 1982. It is in the Ffestiniog area that two powered uphaulage inclines continue in use, at Maenofferen Quarry, one originally steam-operated but equipped with an electric motor from 1900, one operated electrically from the start. In the Nantlle area, they had begun to yield to the chain incline from the 1840s, though one was constructed at Dorothea in 1852 (Thomas O 1874 p. 697), and others were to be constructed there from the 1870s for second level winding (Pierce Jones 1985 21) - in other words, the creation of tipping areas above the processing area, as distinct from lifting from the pit.

6.6.4 Cranes: these saw very limited use in Gwynedd slate quarries.The remains of one survive at Hafodlas, and smaller fragments at Cae Abaty, and bases at Minllyn. A Chaplin steam crane was used at Cwt y Bugail, possibly only for development work (*Baner ac Amserau Cymru* 7 Awst 1867). Small tripod cranes were commonly used in the extraction areas to load wagons, and their remains were met at a number of sites in the second project.

7 BARRACKS

7.1 Background

7.1.1 general introduction: for the purpose of this and the previous study, a barracks was defined as domestic accommodation within a slate quarry, but not including houses clearly built for a manager. In English these have traditionally been called "barracks". The Welsh word is *barics*, for which the plural is *baricsod*, though variants are noted; the Penmachno Shiloh essayist of 1912 notes: "I call a lodging a barigs, and lodging-houses Barigsus, as quarrymen do." (*"Yr wyf yn galw lluest [barrack] yn 'Barigs', a llust-dai, yn Barigsus', yn ol arfer y* *chwarelwyr*" [Shiloh 40]). The verb meaning "to stay in a barracks" is *baricsio*. Whilst their derivation from soldiers' barracks suggests that these formed dormitory accommodation for men, the word encompasses dwellings both for quarrymen only and for entire families. Similarly in England, there is evidence that the word comprehended both sorts of accommodation; the barracks of the Shropshire coalfield were single-storey rows of houses (Trinder 1981 p. 193).

Barrack accommodation was known in other extractive industries elsewhere in the United Kingdom. In the lead mines of the Pennines, barracks or lodging shops were known where the men were accommodated during the working week; in 1842 such a building near Stanhope was described as a plain sandstone building about eighteen by fifteen feet, with a door and two windows and a large fireplace. Lockers and rows of hooks were provided for the forty-eight miners who stayed in the building, and there was a large box to keep the clothes the mine owners put on when they visited the mines. Beds were crammed in close beneath the roof of a first-floor sleeping room (Trinder 1982 p. 190).

In the Cardiganshire lead mines, purpose-built accommodation for workmen is recorded from as early as the sixteenth century (pers. comm., Stephen Hughes), and though comparatively few examples survive on the mine sites themselves (Dyfed Archaeological Trust Metalliferous Mines Report), others have been recorded within walking distance of the workplace, such as Pen y Bryn near Cwm Ystwyth, built *c.* 1835 (Lowe 1989 p. 10), *crog-lofftydd*, like the slightly earlier barrack block at Drws y Coed copper mine in Gwynedd (Lowe 1989 p. 10-11). Elsewhere in Gwynedd barracks are noted at Cwmdwyfor (SH541505), Snowdon (SH616547) and Clogwyn Goch copper mines (SH603556) (Bick 1985 pp. 32, 79, 84). Barrack accommodation was provided at temporary construction sites in Gwynedd as elsewhere, as for instance, the rows of two-room single storey dwellings built for men working on the Britannia Bridge (Hawkins 1849).

It became clear in the course of the present study that the word can also be used to mean a rudimentary lodging-house for quarrymen in a town or village. An example is known in the village of Nantlle (CRO Pen yr Orsedd 1873), but they appear to have been most common in the Ffestiniog quarrying region (*Report of the Departmental Committee of Enquiry*, evidence of Dr R. Jones). A photograph of one in Lord Street, Blaenau Ffestiniog, dating from as late as the 1920s, appears in Jones E, 59. These buildings were not selected for detailed survey.

There is also anecdotal evidence of men living perhaps only semi-permanently, in workshops; there was at one time accommodation in the Gilfach Ddu complex at Dinorwic Quarry (pers. comm., Dr Dafydd Roberts).

There are remarkably few accounts of life in barracks, and such as exist describe all-male communities within the quarries themselves. Of literary sources, Emyr Jones' *Canrif y Chwarelwr* and *Bargen Dinorwic* paint a possibly idealised picture of the frugal and communal life lived in y dre' newydd at Dinorwic - though he does also commit to print the unkind jokes made at the inhabitants' expense by locally-resident quarrymen, and there is evidence to suggest that there was a strong distinction between those who lived nearby and the *pobl y ffordd bell*, those who came to work from outside the community, whether they commuted by the day or by the week (Jones RM 22-24). Emyr Jones's account draws on the memory of men who lived in the last of them, and details the simple wooden furniture, the Welsh-language newspapers and games of dominoes, Ludo or Snakes and Ladders with which they whiled away their leisure moments, as well as the bibles, hymn-books and denominational magazines on which they nurtured their faith.

In similar vein, the bard Tegfelyn praises the community of the barracks at Rhosydd, a sober crowd whose reading was the *Athrawiaeth yr Iawn*, but Ioan Brothen, writing of the same place, complains of filth and hardship (Lewis and Denton 96). Ifor E Davies, recalling in his old age a visit to the barracks at Melynllyn hone quarry, describes the men setting off from Llanbedr y Cennin on a Monday morning with their *walats* (a form of shoulder-bag), the hams hung from the ceiling out of the way of mice, and the intense cold which made them wake up with ice on their beards (Davies IE 1974 p. 85). Doubtless the same could have been said of many a small local slate quarry barracks as well.

The most detailed of official sources is the report of the *Departmental Committee of Inquiry into the Merionethshire Slate Mines*, published by HMSO in 1896. This makes it clear that the Local Board of Health was prepared to intervene to regulate conditions. Dr R. Jones stated that four now slept where six slept before, and that the men now had a separate place to eat, but that most were in an insanitary condition (4). All were inspected periodically and a quarterly report presented to the Board of Health. All were entered on the register of lodging houses, but certificates of approval were not given in every case. They were exempted from a clause which forbade men sharing a bed, since those sleeping together were generally members of the same family. Beds were only fixed at Rhosydd, but the Board had insisted that these be removed and partitions erected between the sleeping and eating rooms. The bedsteads were generally home-made with flock beds but sometimes the ticks were filled with straw. Originally the Board had considered 250 cubic feet per man essential but by 1894 this had been modified to 300 cubic feet (120).

Certainly, by the end of the nineteenth century barrack accommodation was considered a distinctive and typical feature of the Welsh slate industry. Sir Clement LeNeve Foster's standard textbook, *Ore and Stone Mining* (London 1910), after discussing the ambitious barrack accommodation erected at the Mechernich lead and Mansfeld copper mines in Germany, with their reading-rooms, dining-halls and skittle-alleys, goes on to observe:

"The barrack system is also found in Great Britain, especially in North Wales, but not on so large or so sumptuous a scale as in Germany. In Wales the men often sleep two in a bed upon straw mattresses, and as a rule, there is not a separate eating-room, nor are there arrangements for supplying meals ... Sometimes bunks are prepared for 21 men in a room without a window or a chimney, and containing only 2200 (sic - *recte* 220) cubic feet of space - *i.e.* about one-third of the smallest amount which sanitarians would consider requisite." (712)

Average air-space at Eisleben, one of the Mansfeld barracks, was between 350 and 400 cubic feet (711-712). Other contemporary writers largely concur with Foster's strictures, and there was clearly a running battle between the Local Board of Health and the Inspectors of Mines on the one hand and the quarry owners on the other; in 1896 an Inspector stated bluntly that the barracks in the Ffestiniog area, in which a total of 350 men then lived, "do not give the accommodation which .... a respectable working man may expect to receive" (Jones RM 28-29).

7.2 Results of survey

7.2.1 General introduction: the second report identified barrack dwellings in the Nantlle, Llanberis, Dyffryn Conwy, Moel Tryfan/Cwm Gwyrfai, Glaslyn, Blaenau Ffestiniog and Corris areas. The present report has selected examples from each of those areas, apart from Corris, where the one known example is too badly ruined.

7.2.2 Chronology: of barracks which can be confidently dated to within a decade, the following dates are indicated:

1840-1849	1
1850-1859	4
1860-1869	9
1870-1879	3

Of the examples chosen for detailed study, the following dates are indicated:

1840-1849	1
1850-1859	1
1860-1869	7
1870-1879	2

7.2.3 Function: surviving barrack dwellings in Gwynedd slate industry make it clear that the barracks represent various different types of structure, and that their function and development has to be seen in relation to the development of housing for slate quarrymen and their families as a whole.

Firstly, it is clear that by no means all barracks were on-site dormitories for workers, as those in the lead mines of the Pennines appear to have been. Some clearly did fulfil this role, such as, perhaps, Glanrafon, Hendre Ddu, Hafod y Llan and Rhosydd, though analysis of the first four of these is hampered by the comparatively short working lives of the quarries, which means that little information is available from the census.

It is also clear that barrack accommodation of this type was also available in at least one slate quarry town, Blaenau Ffestiniog (*Report of the Departmental Committee of Inquiry into the Merionethshire Slate Mines*, HMSO 1896) and that they were open to the same sort of objections as those in the quarries. Those in the town were run mainly as private ventures. A photograph of one in Lord Street, a small one-storey dwelling, was published in

1985 (Jones 1985), but the building itself has since been demolished, as have all the other examples. The considerable size of some of the houses in Blaenau Ffestiniog, which often reach three or four storeys, opens the possibility that many quarrymen's households took in lodgers on a scale that made many of them practically boarding houses.

Some on-site barracks, though understood to have been built purely for workmen, contain subdivisions which make them effectively cottage rows. Such are y dre' newydd, the Anglesey barracks, at Dinorwic, where each unit is a two-room cottage, and the Prince of Wales barracks where each unit consists of three rooms, accessed by a central doorway in the middle room, and with doorways in the gable walls giving access to the rooms on either side. The most probable explanation is that each unit housed the members of a particular bargain, and since in many cases, though not all, these would be made up of a father and his sons, perhaps an uncle or a nephew, these were effectively family dwellings.

The need for these settlements is in some cases obvious; Rhosydd is a remote plateau, a thousand feet above the nearest settlements at Tan y Grisiau, Blaenau Ffestiniog and Croesor. Hafod y Llan, Prince of Wales and Rhiwbach are equally remote.

On the other hand, even after the quarry towns and villages sprang up, often within easy walking distance of the workplace, many quarrymen refused to make the move, preferring to commute by the week. In this respect, the development of the local railway network in the 1860s and 1870s, while it did not call barracking into being, helped ensure that it outlasted the boom years, just as the Crosville 'bus company helped do away with it in the 1930s. Many quarrymen employed in Blaenau lived as far away as Garn Dolbenmaen or in the northern Conwy valley. Similarly there were many Dinorwic men living as far away in Brynsiencyn on Anglesey, and, in the 1860s, Penrhyn men in Beaumaris. Whether they refused to make the move for longer than a working week at a time because of family connections, a fondness for their own *milltir sgwar* or because of a smallholding or a shop or a pub which their wives could manage in their absence, lies beyond the scope of the present study, though a combination of these factors seems highly probable. There is ample evidence of quarrymen having an alternative source of income, generally a smallholding, in the Nantlle and Llanberis quarrying areas in particular (Barnes 1970, Jones RM 1982 pp. 19-23). Whatever the reason, they could be seen in their hundreds early on a Monday morning clambering onto their cramped wooden railway carriages, clutching their *walats* stuffed with store for the week. These were the men who made barrack accommodation a long-standing feature of the Gwynedd slate industry.

However, some of what were known as barracks were intended for, and inhabited by, whole families. To this category belong dwellings at Cloddfa'r Lôn, Pen yr Orsedd, Rhos, possibly Cwt y Bugail and Blaen y Cwm, certainly Rhiwbach, which is effectively a self-contained village. In the case of Clodda'r Lôn, an existing farm settlement became the nucleus for two rows of dwellings at a time when the nearby village of Tal y Sarn was coming into being. In the case of Pen yr Orsedd, the quarry company was also building accommodation, of a remarkably high standard, for its workers, in an existing but recent community, the village of Nantlle, and it is here that the one surviving off-site barrack settlement is to be found, consisting of a row of single-storey dwellings facing a courtyard on the far side of which is a cowshed and a stable. Aberllefenni in the Corris area is another examples of such a company village, built so near the quarry itself that no recognisable barracks buildings were noted. Only slightly further removed from the workplace is Abergynolwyn, in the Dyfi quarrying area, also built by the quarry company.

The need to create these industrial villages is itself telling; the sparsity of pre-industrial settlement in these areas underlines the vital importance of accommodation for the quarrymen and their families, and explains some apparently incongruous locations for dwelling places. The row of houses known as bythynod Harry Williams on the main processing level of the middle quarry in the Oakeley complex may appear strange in their industrial setting to Gloddfa Ganol's visitors, but when they were constructed in the 1840s the actual workings lay still some way away, and the town of Blaenau Ffestiniog had not yet come into being. These might have been the nuclei of settlements that never took root, of which there are other examples from the industrial period in Gwynedd - Treforys at Cwmystradllyn, Drws y Coed in Dyffryn Nantlle.

In the case of Rhiwbach, as well as the village in the quarry itself, the 1860 company built a row of houses in the village of Cwm Penmachno, which barely existed in 1852 (CRO: X Plans R 154), but which by 1880 had become a sizeable settlement with two chapels. a schoolroom, a church and a post office (Williams VP 1996 *passim*).

7.2.2 Typology: Cwm Machno as a community illustrates the changes in the architecture of Gwynedd slate communities from the vernacular styles of the first half of the nineteenth century to the standard working class housing of the second half. The earlier structures are an immediate lineal descendant of the *crog-lofft*, in that there is a loft on both sides of the house but only one cross wall, whereas the buildings put up by the Rhiwbach company *c.* 1870 are standard two-up and two downs laid out on a planned street grid (SH750473 - Cadw listing ref: 41/B/10-19 [inclusive] 3). This architectural shift, which can be parallelled in Bethesda (Lowe 1989) is represented also in the quarry barracks, though some other patterns are also evident.

Two room, single-storey dwellings are evident at y dre' newydd, Dinorwic, and a three-room variant at Prince of Wales. *Crog-lofftydd* are evident at Cloddfa'r Lôn and at Rhiwbach, where an additional two-storey range has been tacked on to them, and in both bythynod Harry Williams and the Rhos barracks the single cell construction is divided into two rooms downstairs and into two attic bedrooms by the use of timber partitions. A simple two-cell dwelling at Cwt y Bugail has been further by the use of internal stone-built partitions to give eight rooms, around two cross passages, whilst the barracks at neighbouring Blaen y Cwm consists of four separate units each of two rooms.

The use of two-storey structures is evident at Rhiwbach, where the substantial range which once housed the shop differs little from the sort of building that might have been put up elsewhere in the Bro Machno in the second half of the nineteenth century. At Hafod y Llan in the Glaslyn quarrying area, a two-up and two-down range differs from similar domestic structures in having few and comparatively small windows, suggesting both the problems of insulating a building in such a remote location and that it was crammed with beds.

One building derived from a purely industrial tradition is the dual row at Glanrafon, a type of building common in South Wales and elsewhere in the United Kingdom, but not otherwise recorded in Gwynedd (Lowe 1989). As yet, it is unclear why this pattern should have been followed by locally-based entrepreneurs leasing the site off the Vaynol estate.

Another building which has no local parallells but which appears to derive from no known vernacular or industrial model is the barracks at Hendre Ddu in the Glaslyn quarrying district. Here the three of the eight units follow the same pattern of a very tall doorway (4m+) in one longitudinal wall which has no other doors or windows, and a varying pattern of windows and doors in the far wall. Whilst the doors may been surmounted by a fanlight, there is no other evident influence of polite architecture, though such a thing might well be possible on the Bryncir estate, noted for its architectural whimsies and follies.

There is little evidence of architectural embellishment on these buildings. The two storey range at Rhiwbach has a pattern of slab drip mouldings over the doors and windows, similar to many other buildings in Cwm Machno and Penmachno, and which tend to be a feature of quarrying districts where there is a big slab output - as at the Blue Cottages near Aberllefenni (Lowe 1989 p. 24).

The one major exception to this is the barracks on Bonc yr Offis at Pen yr Orsedd, which not only has a patterned slate roof but also a pattern of vari-coloured slate hangings on the walls. More like a contemporary villa than a workmen's dwelling, its use of different-coloured slates resembles other buildings in the area, such as the former Riley slate company offices at the junction of Victoria Road and County Road in the village of Pen y Groes in the Nantlle quarrying district, where ornate patterned slate roofs called attention to the variety of the company's slates. Yet there is no evidence that the Pen yr Orsedd structure was ever anything other than a dwelling.

The provision and continued use of barracks in the slate industry of Gwynedd is one of its remarkable and distinguishing features, and forms an essential part of its archaeology. At the same time, their development can only be understood within the broader patterns of the development of other types of industrial settlement in the area, the particular rhythms of the quarryman's life, bound as he continued to be to the soil in many ways, and in the development of transport.

8 SUMMARY

The present project has concentrated on four aspects of the archaeology of the slate industry of the former (pre-1996) county of Gwynedd, namely power systems, mills, uphaulage features and barracks. It has presented detailed studies of selected examples of each of these.

The project has confirmed that the industry saw massive investment, beginning in the 1850s, increasing in the following decade, and tailing off in the '70s, in machinery and workers' accommodation, and that these are reflected in the archaeological resource. It has confirmed also that there was modernisation in the first two decades of the twentieth century, as the industry faced an ever-more competitive market, and that this is reflected in the surviving electrically-powered plant in many quarries. It has become clear that the archaeological resource reflects an industry which looked to its own local resources in many respects, but which also was prepared to learn from, and adapt the best practice of the wider world. The technological innovativeness of the slate industry is not confined to its earliest phases of mechanisation but continues into the twentieth century with the development of electrical power.

The archaeological information upon which sections **4.2**, **5.2**, **6.2** and **7.2** are based is given in **Appendix 1** following. From the information presented therein, and the conclusions drawn from them, as well as from the work carried out in the first two Cadw-funded projects, recommendations as to features likely to be of national (Welsh) or international significance appear in **Appendix 2**.

9 BIBLIOGRAPHY

Agricola G: *De Re Metallica Libri XII* Basle 1556, trans. HC Hoover and LH Hoover, New York 1950
Abbott R: Chronicles of a Caernarfon Ironworks *TCHS* 17 1856
Barton DB: *The Cornish Beam Engine* Exeter 1989
Bick D: *The Old Copper Mines of Snowdonia* The Pound House, Newent, 1985
-- The Beam-Engine House in Wales *IAR* XII 1 Autumn 1988 84-93
Barnes FA: Settlement and Landscape Change in a Caernarvonshire Slate Quarrying Parish, in *Geographical Essays in Honour of KC Edwards* Nottingham 1970
Boon GC: The Temples of Mithras at Caernarvon - Segontium *Arch. Camb.* CIX 1960 171.
Born A: Blue Slate Quarrying in South Devon: An Ancient Industry *IAR* XI 1 A 1988 51-67
Boyd JIC: *The Festiniog Railway* Oakwood 1975
-- *Narrow Gauge Railways in North Caernarvonshire vol. 2 The Penrhyn Quarry Railways* Oakwood 1985
-- *vol. 3 The Dinorwic Quarry Railways* Oakwood 1986
-- *The Talyllyn Railway* Wild Swan 1988
Bradley VJ: *Industrial Locomotives of North Wales* Birmingham 1992
Burstall A: *A History of Mechanical Engineering* London 1963
Cameron A: *Slate from Coniston* Cumbria Amenity Trust Mining History Society 1996
Cardwell DSL: Power Technologies and the Advance of Science, 1700-1825 *Technology and Culture* vol. 6, no. 2 Spring 1965
Corris Railway Society: *A Return to Corris* Weston-super-Mare 1988.
Crew P: Ynys y Pandy CBA *Archaeology in Wales* 25 1985 53.
Crossley D: *Water Power on the Sheffield Rivers* University of Sheffield Division of Continuing Education and Sheffield Trades Historical Society 1989.
Davies DC: *Slate and Slate Quarrying* Crosby Lockwood and Co., 1878
Davies IE: The Manufacture of Honestones in Gwynedd *TCHS* 37 (1976)
Diderot D: *L'Encyclopédie Diderot et D'Alembert: Arts des Mines Inter-Livres*, n.d.
Donnelly T: Structural and Technical Changes in the Aberdeen Granite Quarrying Industry 1830-1880 *IAR* III 3 1979 228-238.
Eardley-Wilmot J: *Thomas Assheton Smith, The Reminiscences of a Famous Fox Hunter* London 1859
Electricity Supply in the United Kingdom: A Chronology Electricity Council 1982
Ellis H: *Registrum Vulgariter nuncupatum The Record of Caernarvon* London 1838
Fairweather B: *A Short History of the Ballachulish Slate Quarry* Glencoe and North Lorn Folk Museum nd.
Fenton R: *Tours in Wales (1804-1813)* Cambrian Archaeological Association supplemental volume 1917
Ffestinfab: *Hanes Plwyf Ffestiniog a'r Amgylchoedd* Jones and Roberts, Blaenau Ffestiniog 1879
Foster C le Neve and Cox SH: *Ore and Stone Mining* London Charles Griffin 1910
Geddes RS: *Burlington Blue-Grey: A History of the Slate Quarries, Kirkby-in-Furness* Barrow 1975
Gloddfa Ganol: *Guide* Blaenau Ffestiniog nd
Gwyn DRh: *Dolgarrog: An Industrial History* Caernarfon 1989
-- Valentia Slate Slab Quarry *Journal of the Kerry Literary and Historical Society/Cumann Seandálaíochta is Staire Chiarraí* 24 1995 (for 1991) 40-57.
Gwynedd Archaeological Trust: *Penrhyn Quarry Archaeological Assessment* 1985
Hawkins G: *Britannia Bridge: General View of Works, September 1848*, London 1849
Hay G and Stell G: *Monuments of Industry* Royal Commission on the Ancient and Historical Monuments of Scotland 1986
hóir, S de: A Welsh Quarryman's Grave at Castletown Arra, Co., Tipperary *North Munster Antiquarian Journal/Irisleabhar Seandáluíochta Tuadh-Mhuman* 30 1988 35-8.
Holmes A: *Slates from Abergynolwyn* Caernarfon 1986
Hope B: *A Curious Place: The Industrial History of Amlwch (1550-1950)* Wrexham nd (1994)
Hughes HD: *Hynafiaethau Llandegai a Llanllechid* Bethesda 1866 (ailgyhoeddwyd gan Gyhoeddiadau Mei, Y Groeslon, 1979)
Hughes S: *The Archaeology of an Early Railway System: The Brecon Forest Tramroad* RCAHMW 1991
Harries PL Notes from an Auction Catalogue *Festiniog Railway Heritage Group Journal* 12 Winter 1987-8
Hughes I: *Chwareli Dyffryn Nantlle* Cyhoeddiadau Mai, Y Groeslon 1980
Isherwood G: *Rhiwbryfdir Fawr, 1800-1879: A History of the Oakeley Slate Quarries* (ts in DRO)
-- *Candles to Caplamps: The Story of Gloddfa Ganol* nd, np.
-- *Slate from Blaenau Ffestiniog* Leicester 1988

Jack RI: Fulling-Mills in Wales and the Marches before 1547 *Arch. Camb.* CXXX 1981 pp. 70-130)
Jarvis A: *Hydraulic Machines* Princes Risborough 1985
Jones E: *Blaenau Ffestiniog in Old Picture Postcards*, Zaltbommel 1985
Jones E: *Bargen Dinorwic* Denbigh 1972
Jones GR: *Chwarel Blaenycwm* (ts) 1991
-- *Rhiwbach Slate Quarry, Cwm Penmachno* (ts) nd
-- *Hafodlas Slate Quarry* forthcoming
Jones IW: *Slates and Slatemen of Llechwedd* Blaenau Ffestiniog 1975
-- *Llechwedd Slate Caverns* Blaenau Ffestiniog 1995
Jones RM: *The North Wales Quarrymen 1874-1922* UWP 1982
Joyner P: *Dolbadarn: Studies on a Theme* Aberystwyth 1990
Kellow M: *Application of Hydro-Electric Power to Slate-Mining* London 1907
-- The Autobiography of the late Ex-Alderman Moses Kellow *Quarry Managers' Journal* 1944
Kent JM: The Delabole Slate Quarry *Journal of the Royal Institution of Cornwall* new series 5 part 4 1968
Lewis MJT: *Early Wooden Railways* London 1970
-- *Llechi/Slate* Caernarfon 1976
-- Quarry Feeders *Festiniog Railway Heritage Group Journal* 13 Spring 1988
and Williams MC: Foel Quarry CBA *Archaeology in Wales* 26 1986 66-67
-- Hafodlas Slate Quarry CBA *Archaeology in Wales* 27 (1987) 74-5.
-- Dolwyddelan Quarries CBA *Archaeology in Wales* 28 (1988) 87.
Lindsay J: *A History of the North Wales Slate Industry* Newtown Abbott 1974
Lowe J: *Welsh Industrial Workers' Housing 1775-1875* Cardiff 1989
McCutcheon WA: *The Industrial Archaeology of Northern Ireland* HMSO 1980
Malaws B: *Collieries of Wales* Cardiff 1995
Malchow HL: *Gentlemen Capitalists* Macmillan 1991
Moorhouse S: The Quarrying of Stone Roofing Slates and Rubble in West Yorkshire during the Middle Ages in Parsons D: *Stone Quarrying and Building in England AD43-1525* Phillimore/Royal Archaeological Institute, Chichester 1990, 126-145
Morgan Rees D: Some Aspects of Industrial Archaeology in Wales *Transactions of the Honourable Society of Cymmrodorion* Session 1970 Part II, London 1971
-- *The Industrial Archaeology of Wales* Newton Abbot nd.
Morrison TA: The Story of the Croesor United Slate Company Ltd *JMHRS* 6 1972
Nicholson Ch: Easdale Island, Argyll *IAR* V 2 Spring 1981 163-4.
Owain S ab: Llên Gwerin *Llafar Bro* 1984
-- *Geirfa'r Mwynwyr* Cyfres Llyfrau Llafar Gwlad 1988
Penrhyn Quarry: Over 150 Years of Progress Bangor nd (?1937)
Parkhouse N: Building Calstock Viaduct *Archive* 2 n.d.33-54
Parry J: Y Barics *Caban* Rhagfyr 1961
Pierce Jones G: A Panoramic View of the Slate Quarries in the Nantlle Valley (CHS 528/195/15) *CRO Bulletin* 4 1971 26-29
-- Dorothea Slate Quarry (UWB MA thesis) 1980
-- The Slate Quarries of the Nantlle Valley *Stationary Power* 2 1985 13-41
-- The Gwernor Slate Quarry, Nantlle *TCHS* 48 1987 47-73
-- A Plateway in a Nantlle Slate Quarry *Gwynedd Diwydiannol/Industrial Gwynedd* 1 1996 30-33
Plas Tan y Bwlch: typescript reports of IA courses, 1974 to date
Pritchard D: *The Industrial Situation of Snowdonia* London 1948
Ramelli A: *Le Diverse et Artificiose Machine* Paris 1588; Dover Press ed. by Gnudi NT, New York 1994
Rees A: *Manufacturing Industry* London 1821
Rees W: *Industry Before the Industrial Revolution* University of Wales Press 1968
Report of the Departmental Committee of Inquiry into the Merionethshire Slate Mines HMSO 1896
Reynolds TS: *Stronger than a Hundred Men: A History of the Vertical Water Wheel* Baltimore and London, 1983
Richards A: *A Gazeteer of the Welsh Slate Industry* Capel Garmon 1991
-- *Slate Quarrying in Corris* Capel Garmon 1994
-- *Slate Quarrying in Wales* Capel Garmon 1995
Roberts D: Moses Kellow a Chwareli Cwm Croesor *Journal of the Merionethshire Historical and Record Society* IX 2 1982.
-- Technoleg Draddodiadol yng Ngilfach Ddu - Hanes yr Olwyn Ddwr *TCHS* 47 1986 97-107
-- Ruston Hornsby 175414 *Gwynedd Diwydiannol/Industrial Gwynedd* 1 1996 pp. 26-29.

Roberts E: *Stiniog* Blaenau Ffestiniog 1991
Roose-Williams J: *Quarryman's Champion: The Life and Activities of William John Parry of Coetmor* Denbigh 1978
Rowlands J: *Copper Mountain*, Llangefni 1988
Scourfield E: *A Directory of Agricultural Machinery and Implement Makers in Wales*, National Museum of Wales, Welsh Folk Museum nd
Shaw J: *Water Power in Scotland 1550-1870* Edinburgh 1984
Sharpe A: *Coastal Slate Quarries Tintagel to Trebarwith* Cornwall Archaeological Unit, 1990
Shiloh: *Traethawd: Chwarelau Machno; - hanes eu dechreuad; a'u cynnydd ynghyd a byr hanes o'r goruchwylwyr* (Pref destyn Eisteddfod Gwyr Ieuainc Shiloh [W.] Cwm Penmachno, Mai 4, 1912) (ms in private possession)
Stanier P: Granite Quarry Cranes of Cornwall and Devon: Vanishing Industrial Archaeology *The Journal of the Trevithick Society* 19 1992
-- *Quarries of England and Wales* Truro 1995
Sylwedydd *Chwarelau Dyffryn Nantlle a Chymdogaeth Moel Tryfan* 1889
Thomas D: Historical Notes on Hydro-Electricity in North Wales *TCHS* 50 1989 87-110
Thomas O: *Cofiant y Parchedig John Jones Talsarn* Wrexham 1874
Trinder B: *The Industrial Revolution in Shropshire* London and Chichester 1981
-- *The Making of the Industrial Landscape*,London 1982
Tucker DG: The Slate Quarries of Easdale, Argyllshire, Scotland *Post-Medieval Archaeology* 10 1976 118-130.
Thomas WG: Preservation of Industrial Relics *Amgueddfa* 10 Spring 1972)
Tucker G and M: The Slate Industry of Pembrokeshire and its Borders *IAR* III 3 Autumn 1978 203-227
Turner Ll: *Memories* Caernarfon 1903
Tunzelmann GN von: *Steam Power and British Industrialization to 1860* Clarendon Press, Oxford 1978
Tyler I: *Honister Slate: The History of a Lakeland Slate Mine* Caldbeck 1994
Weaver R: report on Hendre Ddu unpublished t.s., 1974
-- letter in *Festiniog Railway Magazine* 103 (Winter 1983-4) pp 37-8, discussing phtograph of eastern Blaenau Ffestiniog in *Festiniog Railway Magazine* 102 (Autumn 1983) pp. 17-19.
-- Thoughts on Saws unpblished t.s., 1987
-- The Oakeley BS90S *Festiniog Railway Heritage Group Journal* 23 Autumn 1990 15-19
Williams D: *Chwareli a Chloddfeydd yn y Pennant* Caernarfon 1986
Williams GJ: *Hanes Plwyf Ffestiniog o'r Cyfnod Boreuaf* Wrexham 1882
Williams J: *Digest of Welsh Historical Statistics/Crynhoad o Ystadegau Hanesyddol Cymru* vol. 2 Aberystwyth 1986
Williams JLl a Jenkins DA: Dwr a Llechi ym Mhlwyf Llanllechid, Bethesda - Agweddau ar Ddatblygiad Diwydiant yn Nyffryn Ogwen *TCHS* 54 1993 29-62
-- Tair Chwarel ym Mhlwyf Llanllechid, Bethesda Rhan I *TCHS* 56 1995 47-70, Rhan II *TCHS* 57 65-84
Williams M: An Early Matthews Dressing Machine in the Ffestiniog Quarries CBA *Archaeology in Wales* 25 (1985) 53-4
-- *The Slate Industry* Princes Risborough 1991
Williams M with Farnie DA: *Cotton Mills in Greater Manchester* Preston 1992
Williams R: Hunangofiant Chwarelwr, *Cymru* XVI 90 15 Ionawr 1899, XVII 90, 55-59, XVIII 107 330, XIX 109, NLW Lls 8412

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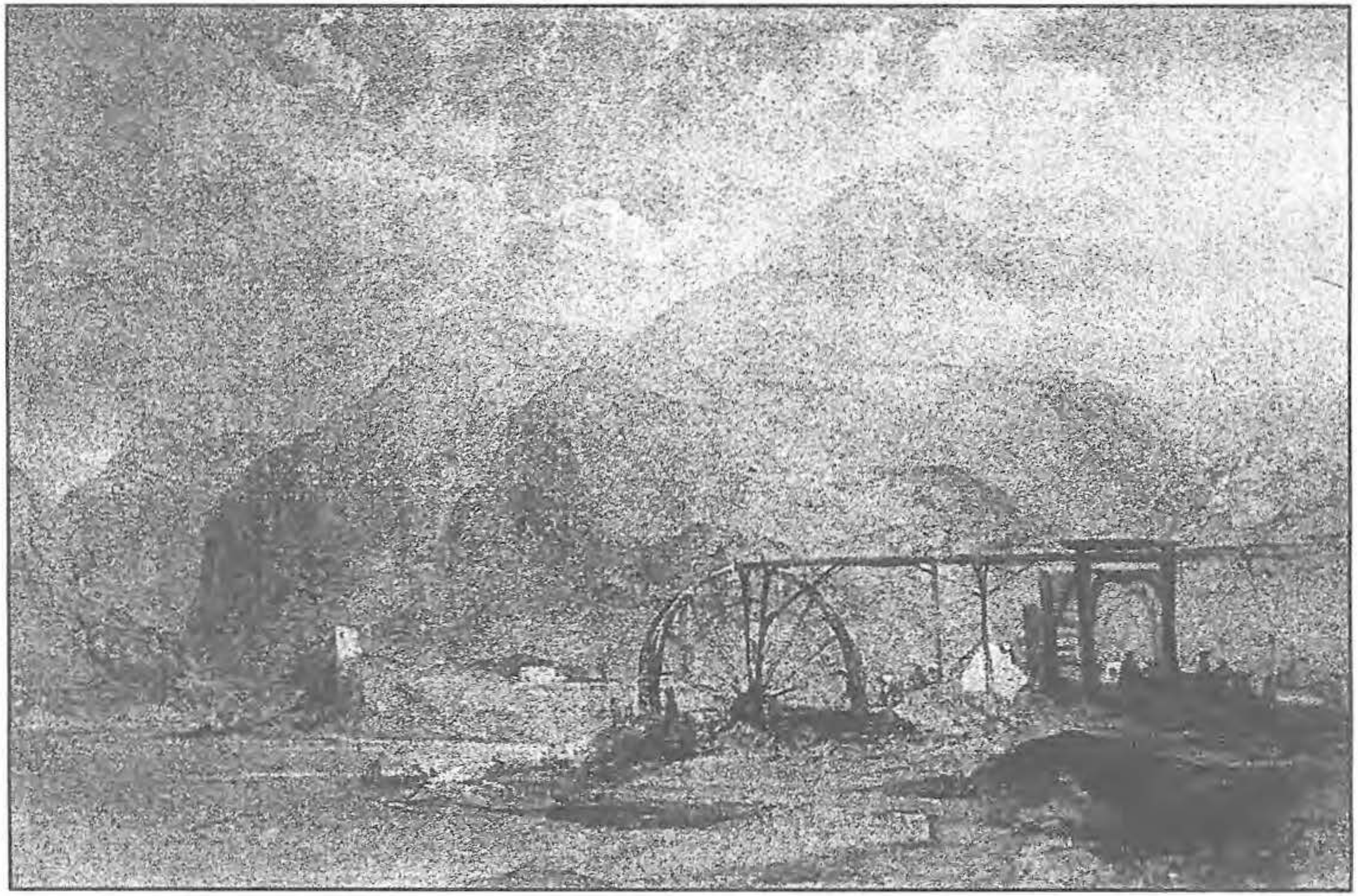


Illustration 2 John Campion's painting of a waterwheel and sand-saw at Glynrhonwy Quarry.

Illustration 3 A water-pressure engine at Penrhyn Quarry

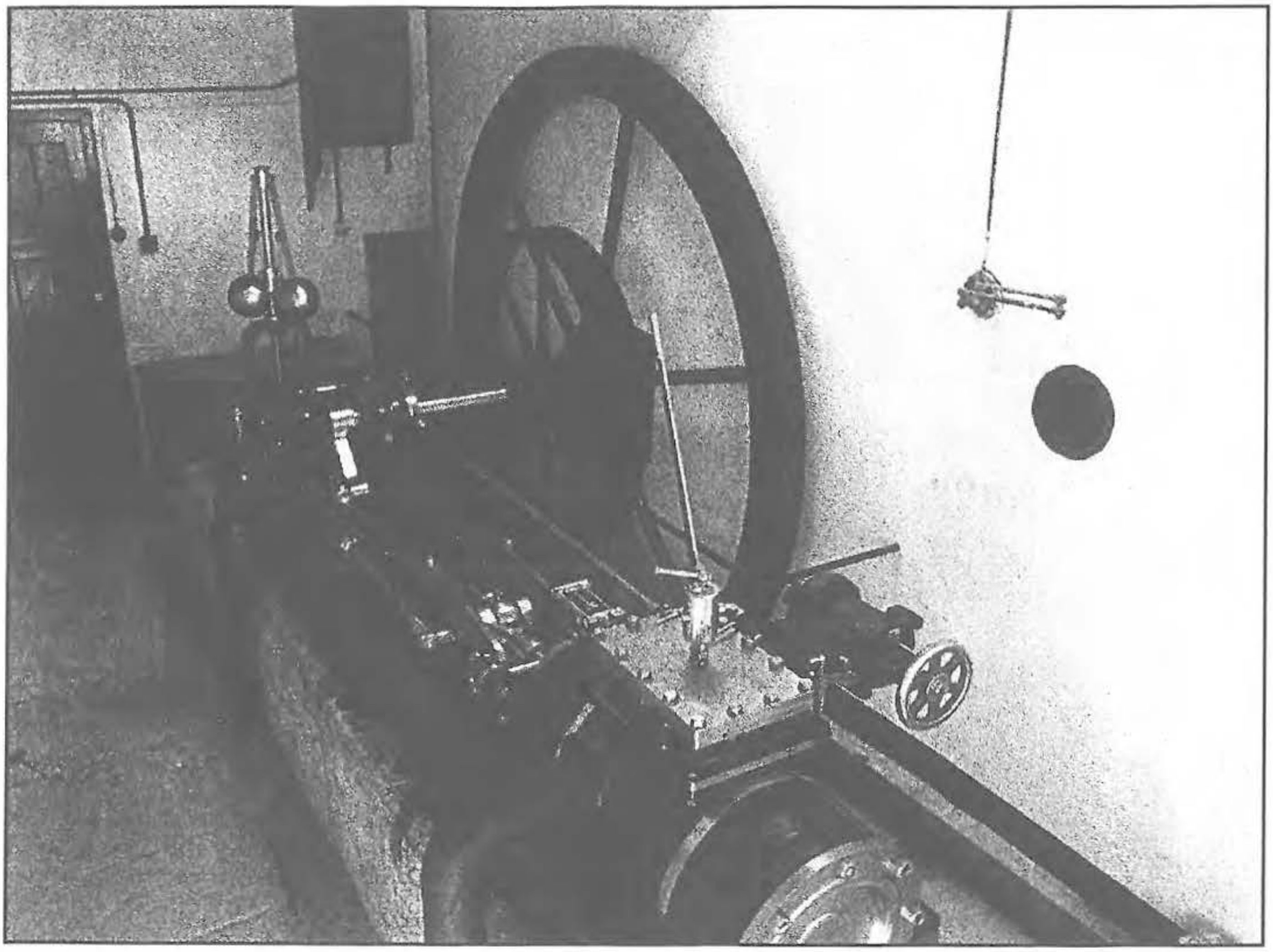


Illustration 4   A DeWinton stationary steam engine at Glynllifon workshops

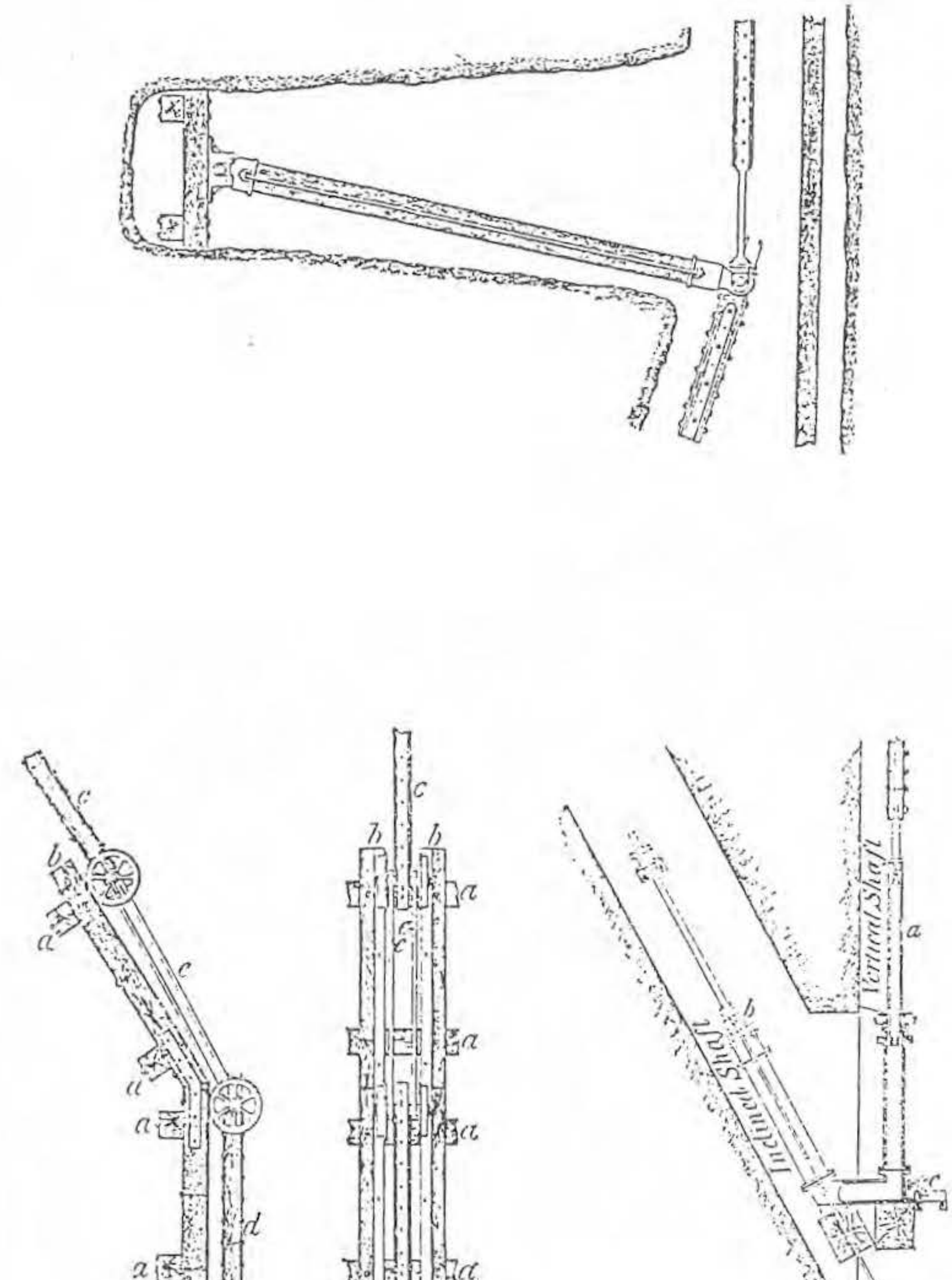


Illustration 5 Flatrod systems

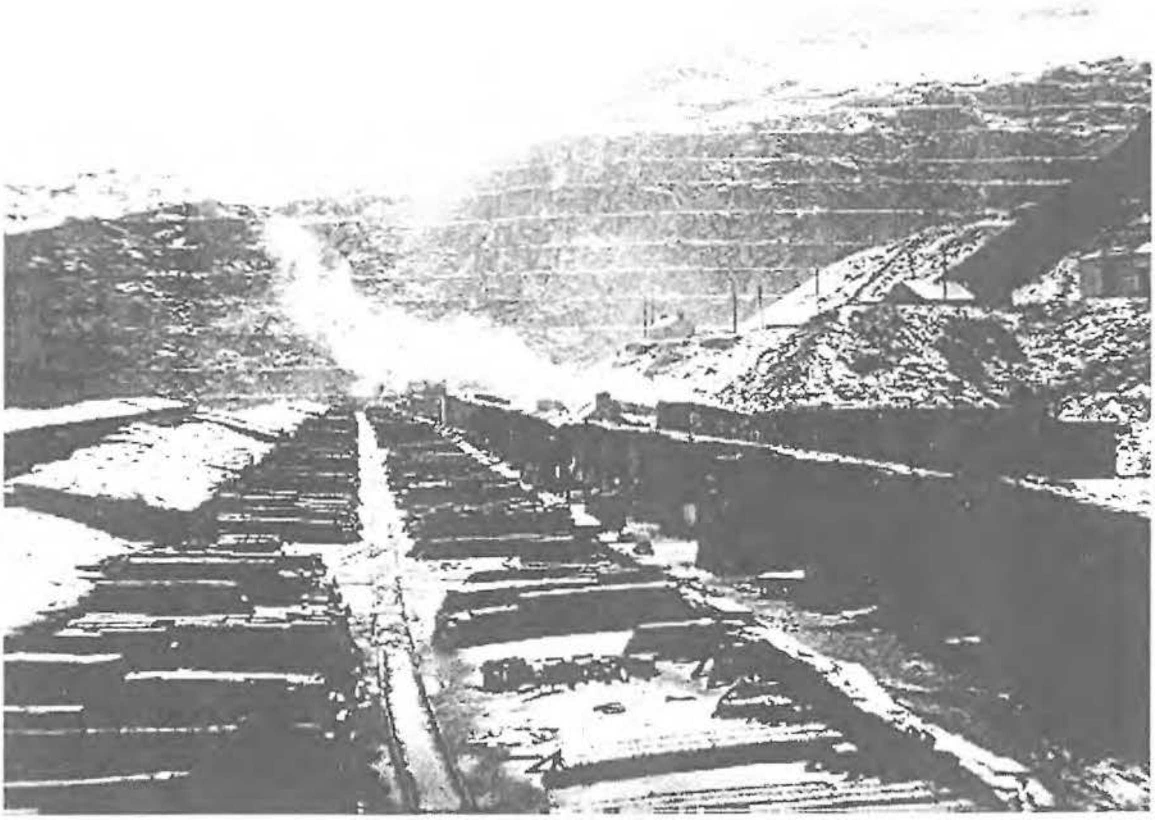


Illustration 6 *Gwaliau* at Penrhyn Quarry

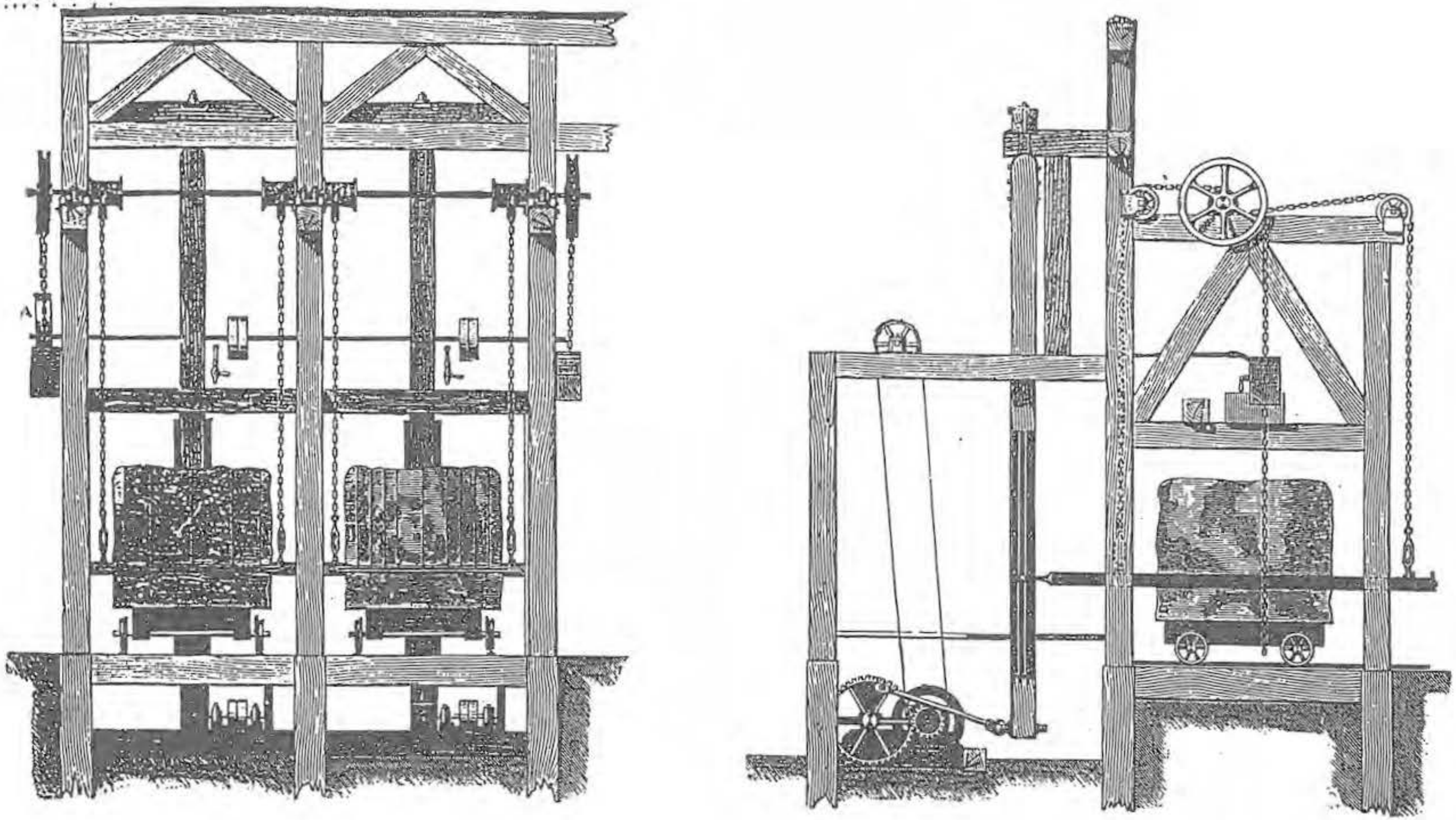


Illustration 7 Sand-saws

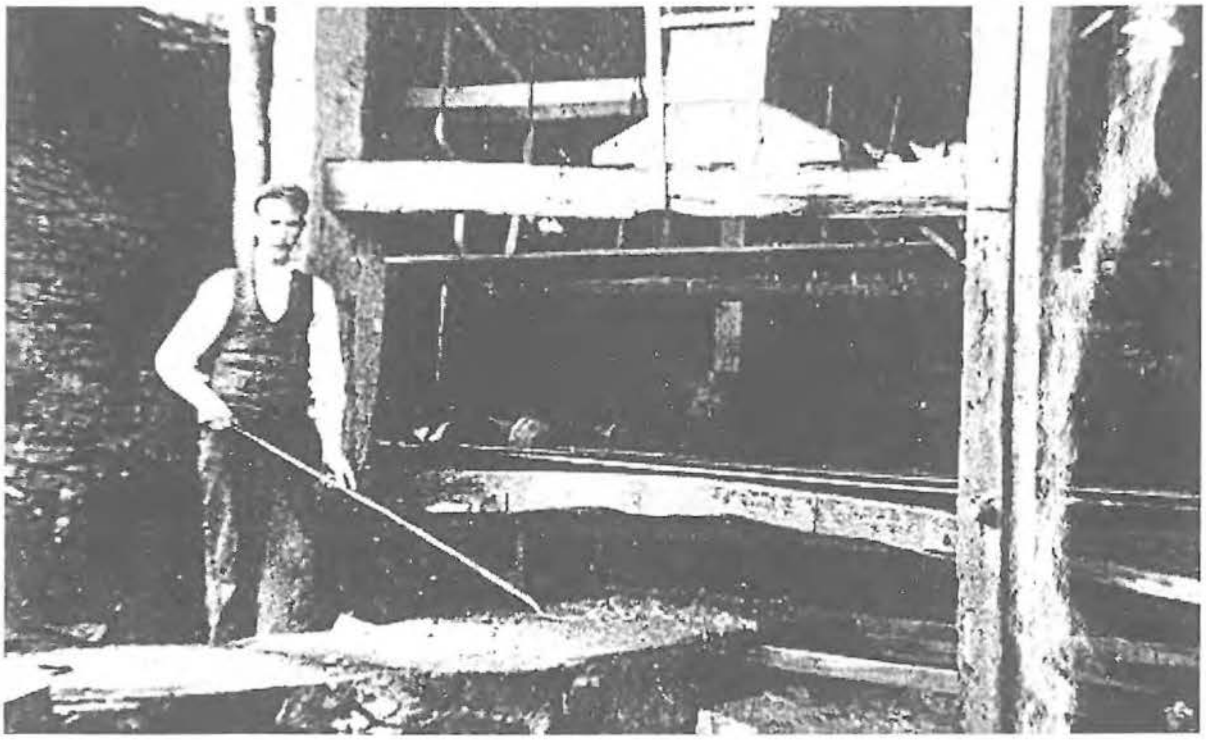
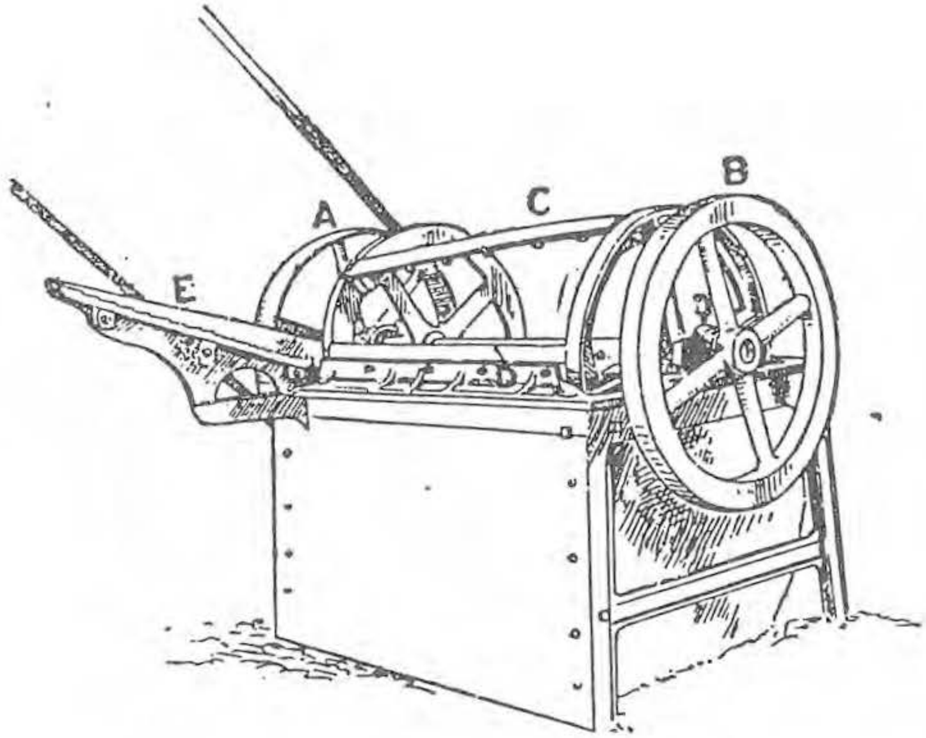


Illustration 8   A sand-saw at work in a Dolwyddelan quarry



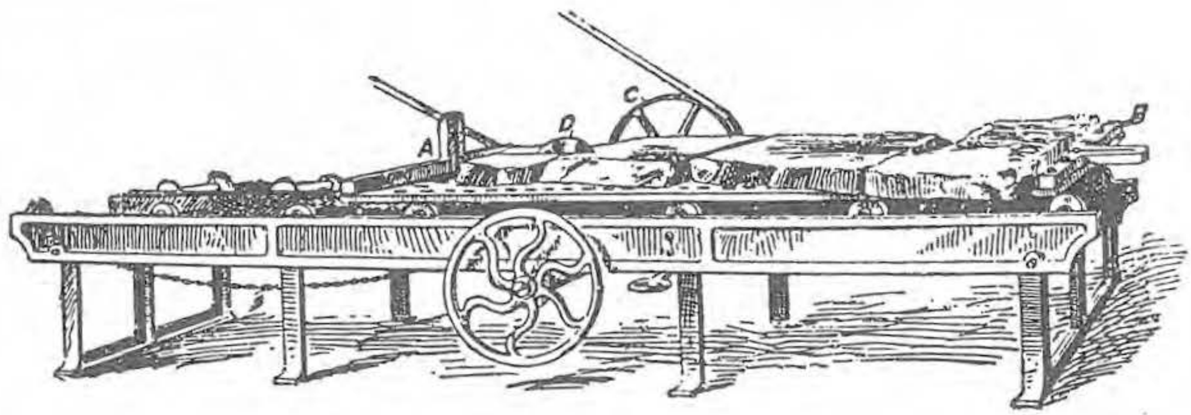


Illustration 9 A slate dresser and a circular-saw table

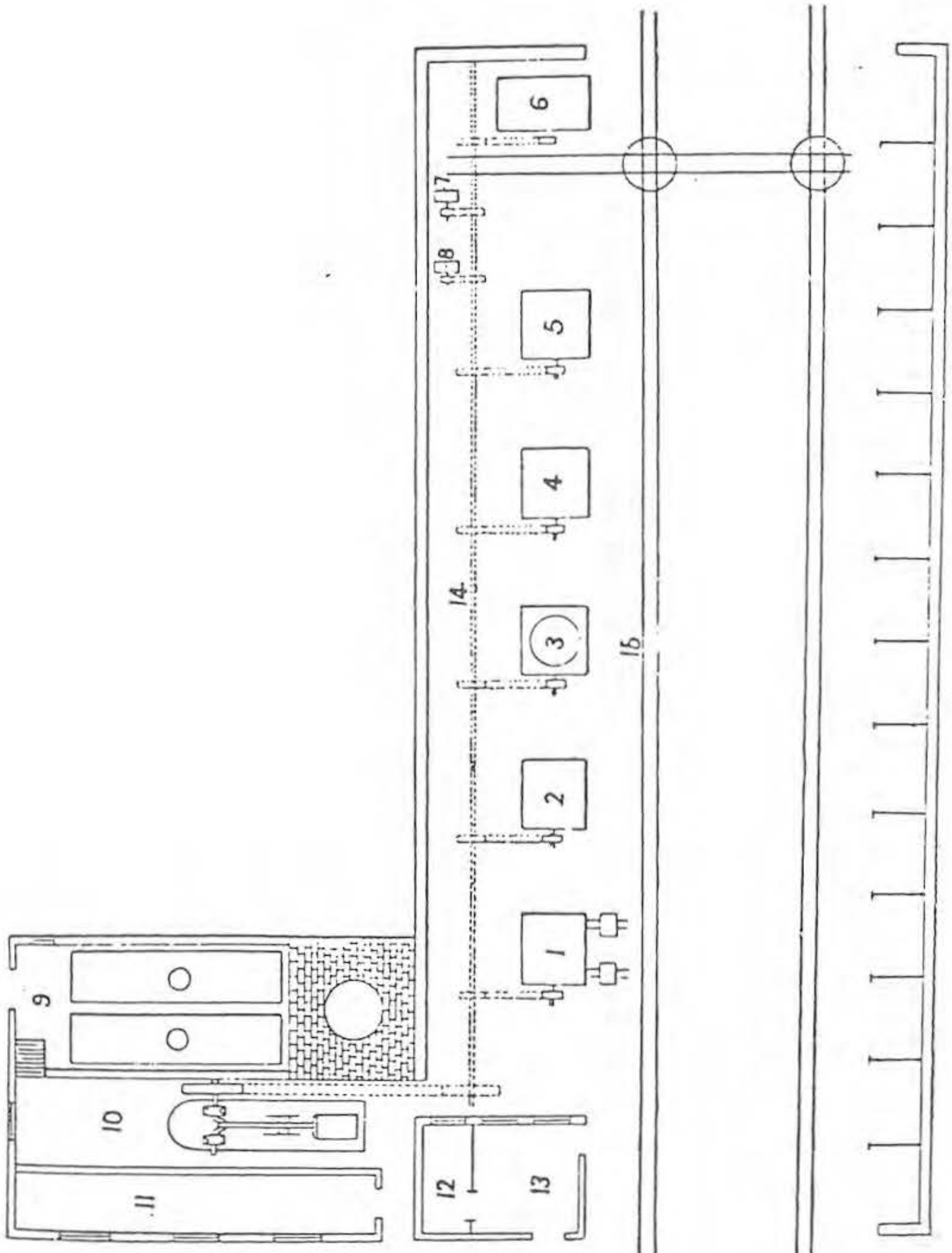
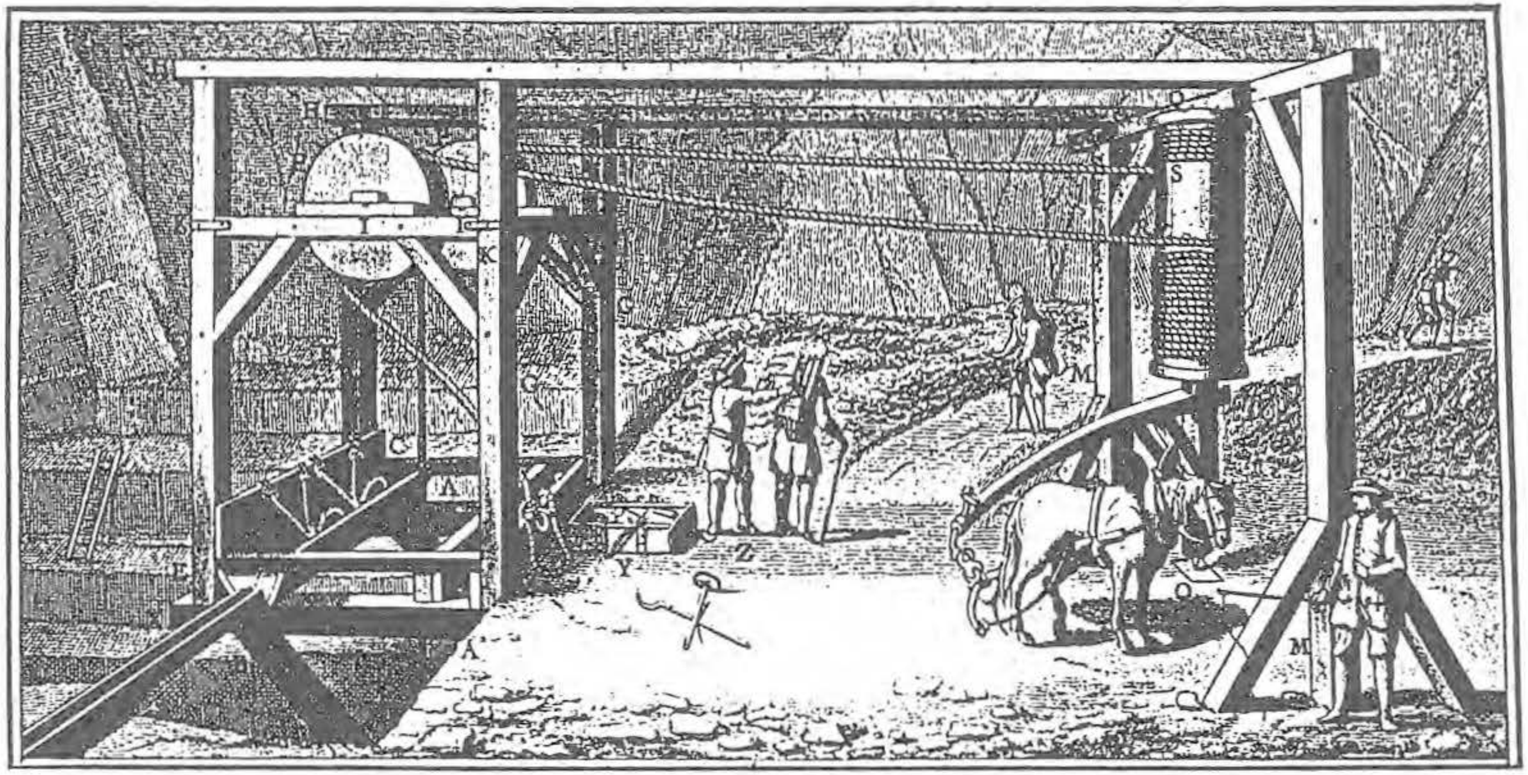


Illustration 10 A typical stone-sawing plant



COMMISSION DES ARDOISIÈRES D'ANGERS (LARIVIÈRE & Cie)
Les Ardoisières d'Angers au XVIIIe siècle, d'après une gravure de l'époque (Extraction et Epuisement).

Illustration 11 A horse-whim operating a vertical haulage system in a French slate quarry

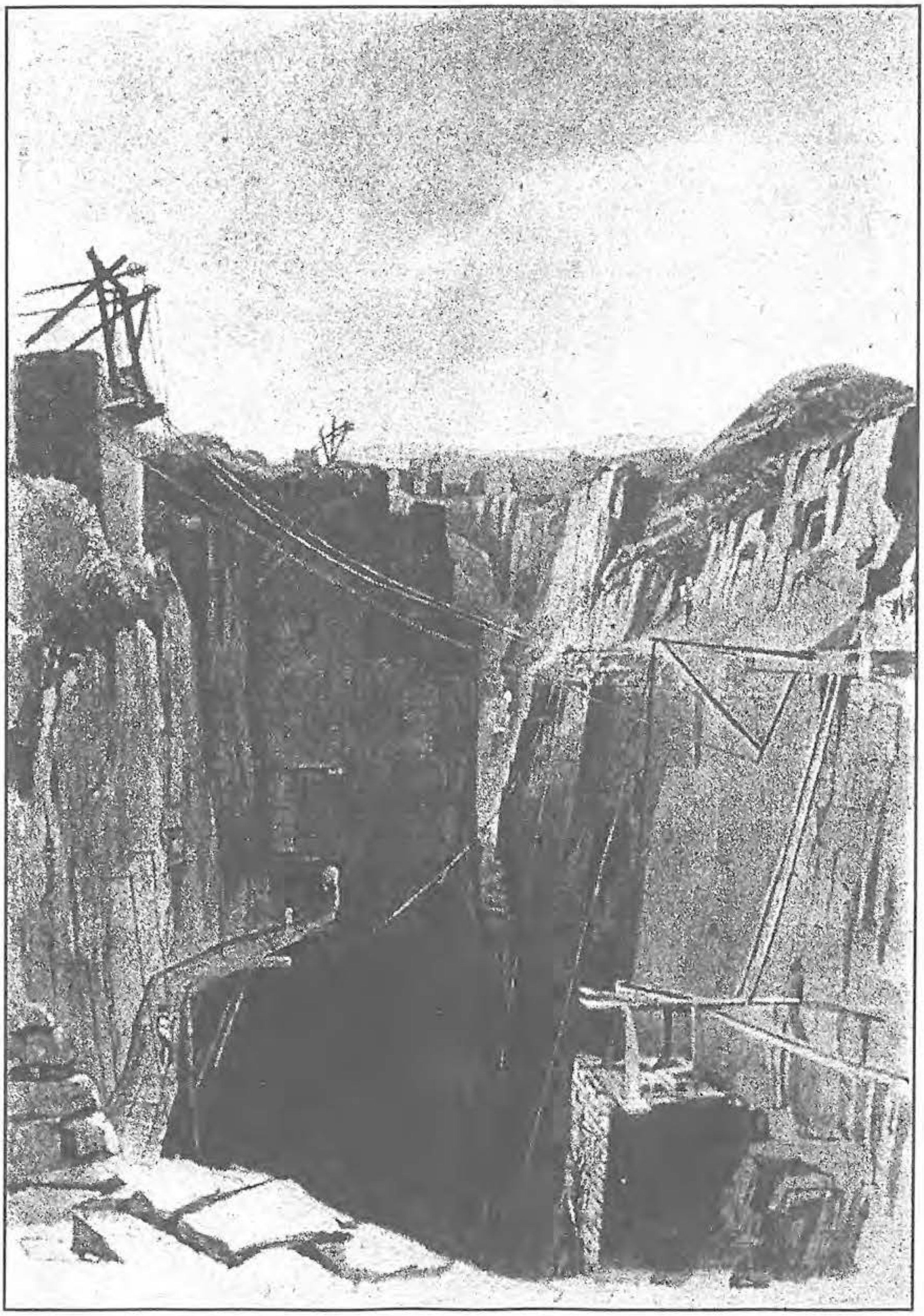


Illustration 12 John Smith's painting of catenary ropeways at Glynrhonwy Quarry.

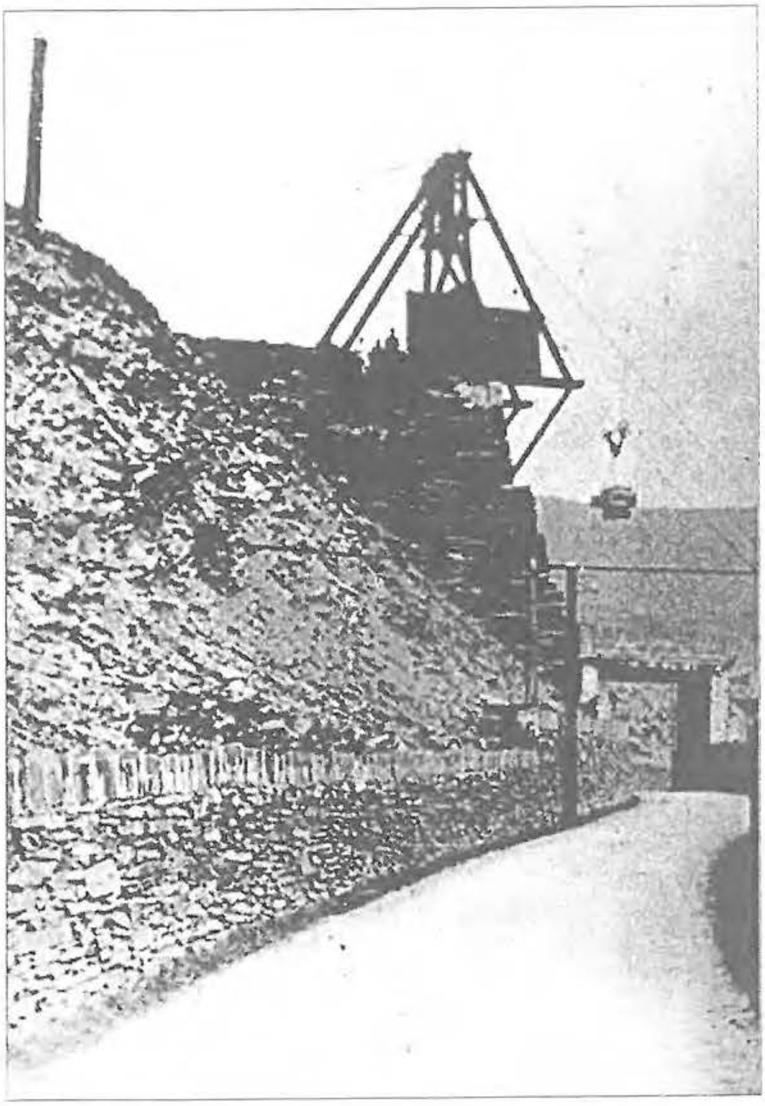


Illustration 13 A chain incline in the Nantlle quarrying area

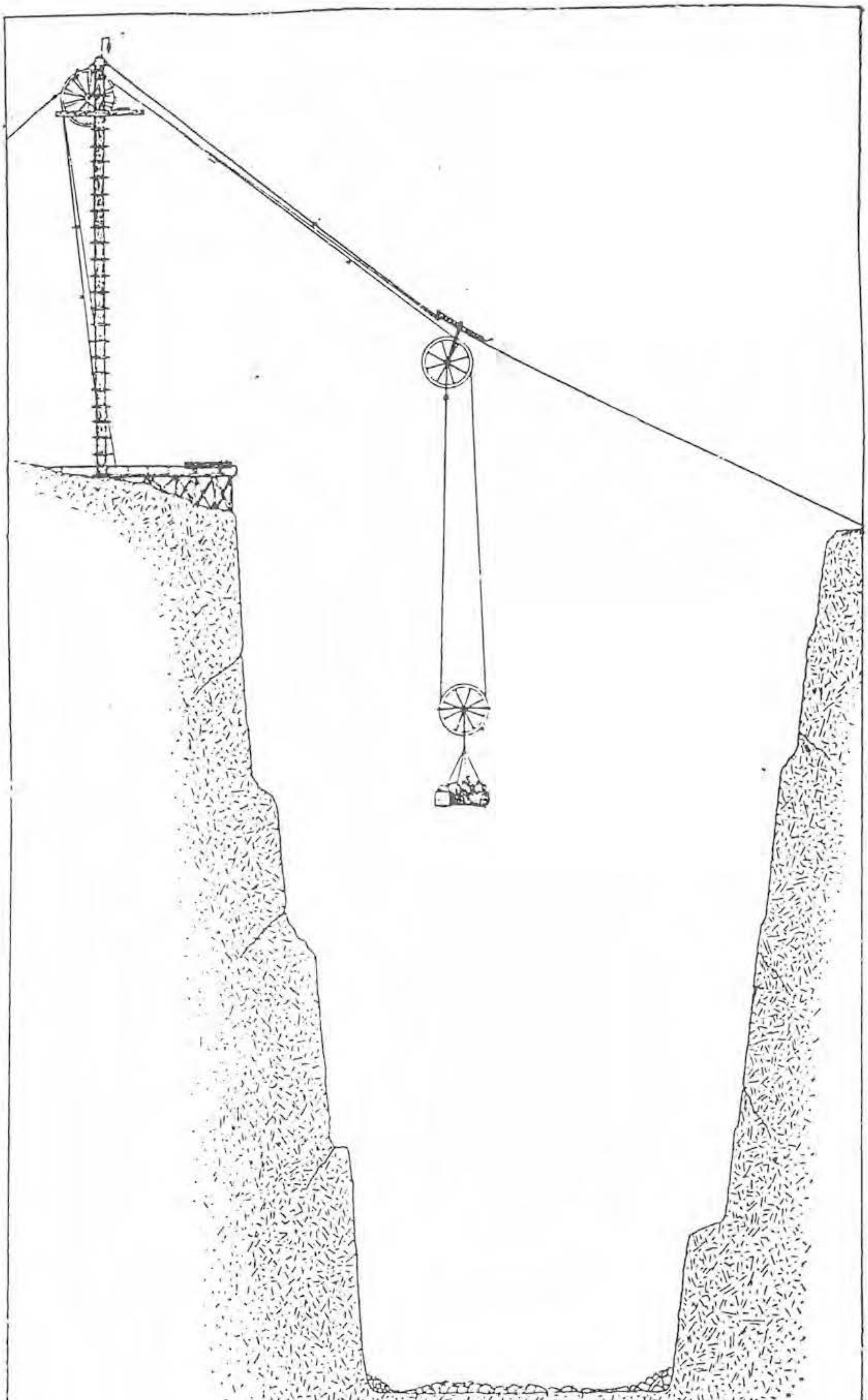


Illustration 14 Arrangement of a blondin cableway

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