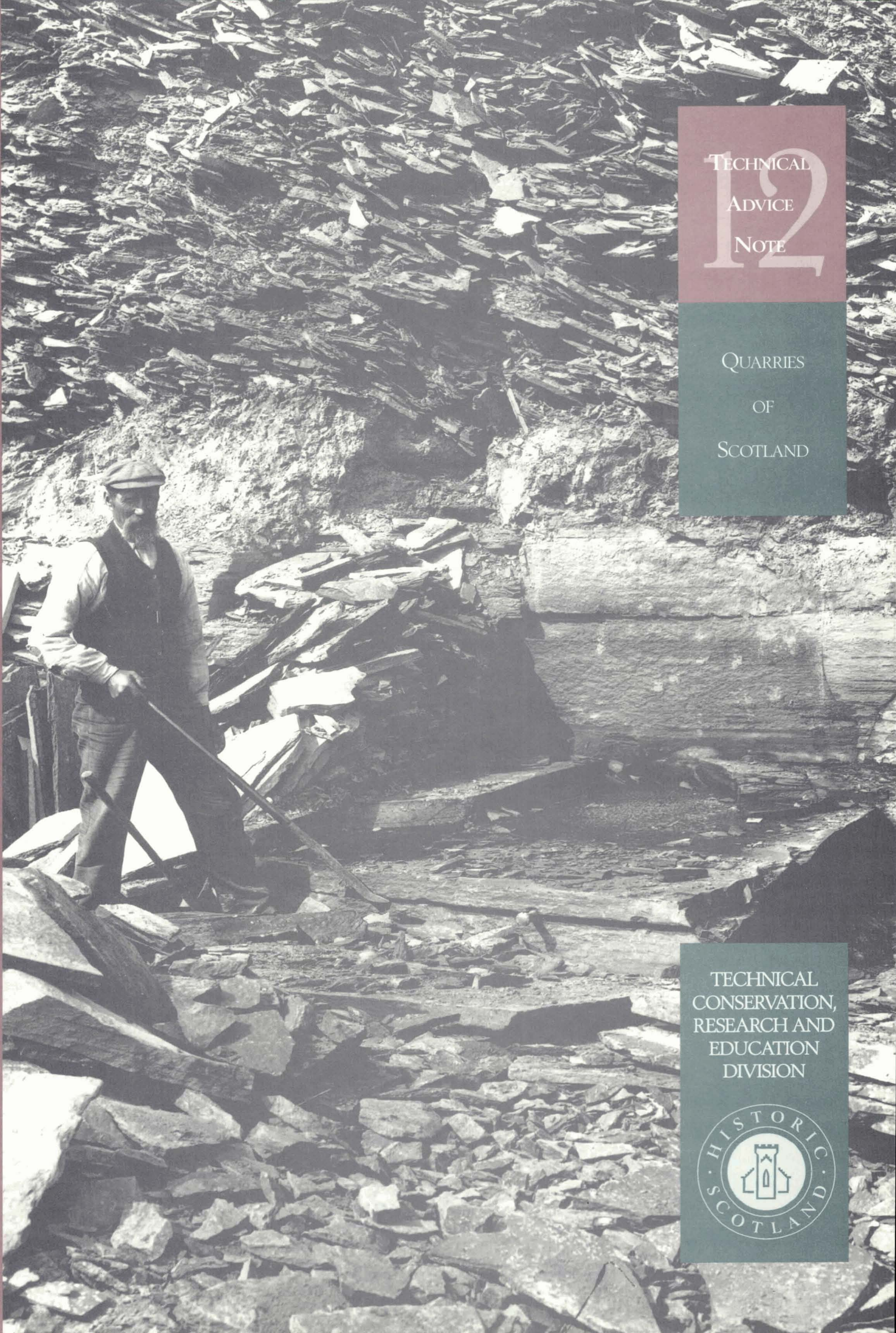
Technical Advice Note 12

Quarries of Scotland



Technical Conservation, Research and Education Division

Historic Scotland

TAN 12

Quarries of Scotland

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TECHNICAL

ADVICE

NOTE

QUARRIES OF SCOTLAND

AN ILLUSTRATED GUIDE TO SCOTTISH GEOLOGY AND STONE WORKING METHODS BASED ON THE BRITISH GEOLOGICAL SURVEY PHOTOGRAPHIC ARCHIVE OF SELECTED BUILDING STONE QUARRIES

by

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with contributions by

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HISTORIC SCOTLAND

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BGS plates are identified either by a Registered Number and caption (see also Appendix 1). Other plates are identified by publisher and source.

FOREWORD

The extensive range of available geological material in Scotland constantly manifests itself in the quality, character and colour of Scottish buildings. No other country can match this unique kind of regional variation. To a great extent, this achievement has been dependent upon the expertise of past quarrymasters and men. Through their endeavours the variety of materials that were won enabled architects, builders and craftsmen, in turn, to exercise their skills and abilities. However, compared to only a century ago, the Scottish building stone quarrying industry is only a shadow of its former self.

This Technical Advice Note, from Historic Scotland's Technical Conservation Research and Education Division (TCRE), looks at the historic perspective of quarrying in Scotland. It covers the characteristics of the various stones and how they were extracted. It draws heavily on the British Geological Survey Photographic Archive to illustrate and typify behind the scenes activities during Scotland's heyday of building in masonry during the late 19th and early 20th centuries.

The selected plates are from a wider collection of material held by the British Geological Survey in Edinburgh. Available for reference by practitioners, this information provides details of all quarrying activities in Scotland, and offers a central archive of geological maps, field surveyors notes, samples and thin sections. Its use by all those working in the field of stone building is to be encouraged.

In recent years a re-emergence of interest in stone as a quality building material has occurred. This is physically manifesting itself in a variety of new buildings, and in numerous hard landscaping schemes being completed throughout the country. The overall benefits in performance and cost-effectiveness is being increasingly recognised and, with it, the awareness of the need to preserve the different character that exists in our cities, towns, villages and individual buildings.

By offering an historic and practical view the TAN aims to provide practitioners, and those involved in education and training, with a greater insight into how the physical geological conditions determine the design, architectural character, and benefits, of using stone. It is one of a number of publications in the TAN series that sets out to present an increased understanding of Scotland's traditional materials, their various working methods and building techniques.

It has been ably prepared by Andrew McMillan, with assistance of Richard J Gillanders, of the British Geological Survey, Edinburgh and complements an associated publication on the Quarries of England and Wales published in 1995. Historic Scotland is indebted to the British Geological Survey for allowing unhindered access to their archive to allow this work to be produced. Thanks are also due to Historic Scotland own Photographic Unit for the production of plates which illustrate Chapters 1 and 3.

INGVAL MAXWELL

Director

Technical Conservation Research and Education

July 1997

PREFACE

BGS sources of information on building stone

The pictorial basis of this technical note is derived from the extensive collection of black and white geological photographs held in the Archives of the British Geological Survey (BGS) at Murchison House, Edinburgh. The full collection of early Scottish photographs (B and C Series) together with more recent photographs may be inspected in the Survey's Library. Copies of prints, subject to copyright agreement (see above), may be ordered from the BGS Sales Desk.

In addition to photographs the BGS holds a large archive of documentary information of use to stone quarrying and working. In addition to 1:10 000 and 1:50 000 geological maps, descriptive memoirs provide details of rock types, physical properties and mineralogy and former quarry workings. The BGS Library holds a wide range of geological books and periodicals of relevance to building stone enquiry. Collections made by geological surveyors include hand specimens of rocks used as building stone and petrographic thin sections which enable detailed mineralogical examination. Geological advice may be sought from the appropriate office of the Survey (see section 7.0).

Acknowledgements

Mr Fergus MacTaggart (Photographic Department, BGS Edinburgh) is thanked for preparing photographic prints from the BGS Collection. Photographs showing the traditional use of stone linked to particular geological settings described in Chapters 1 and 3 are from the Historic Scotland official collections.

Other sources of contemporary illustration include a photograph of Craigleith Quarry taken in c. 1850 by Thomas Begbie from The Cavaye Collection of Thomas Begbie Prints, published in *Thomas Begbie's Edinburgh - A Mid Victorian Portrait* (by Joe Rock and David Patterson; John Donald Publishers in association with the City of Edinburgh District Council, 1992). The print is reproduced here by kind permission of the City Art Centre. The W D Clark photograph of Edinburgh from Craigleith (c.1858) is reproduced by courtesy of Edinburgh City Libraries.

Engravings and sketches are also reproduced from Volume 12 (1834) of the *Transactions of the Royal Society of Edinburgh and The Ichnology of Annandale* by Sir William Jardine (1853).

The Ordnance Survey 25 inch County map extracts of Hailes Quarry (1914) (Figure 8) and Island of Easdale (1899) (Figure 10) are reproduced by permission of the Trustees of the National Library of Scotland.

The simplified geological map (Figure 1) is based on the Institute of Geological Sciences (now BGS) *"10-mile" 1:625 000 Geological Map of the United Kingdom (North)*, 3rd Edition 1979 and on Figure 1.1 from *Geology of Scotland,* edited by G Y Craig, 3rd Edition 1991 (published by the Geological Society, London). Figure 4 is adapted from the Open University Science Foundation Course units 26 and 27 *Earth History 1 and 11* (1971, Open University, Milton Keynes) and Bunyan et al., *Building Stones of Edinburgh* (1987, Edinburgh Geological Society). Figure 5 is adapted from *Geology in south-west Scotland* edited by P Stone (1996, BGS, Keyworth). Slaty Cleavage (Figure 6) and the map of the Easdale Slate Belt (Figure 9) are taken from Richey, J E and Anderson, J G C. 1944. *Scottish Slates.* Wartime Pamphlet No.40. Geological Survey of Great Britain. The illustration of Hand implements (Figure 7) is taken from Merrill, G P. 1910. *Stones for Building and Decoration.* (New York: John Wiley & Sons). Tables 4 and 5 are adapted from *The field description of sedimentary rocks: Geological Society Handbook* by M E Tucker (1982, Open University Press, Milton Keynes).

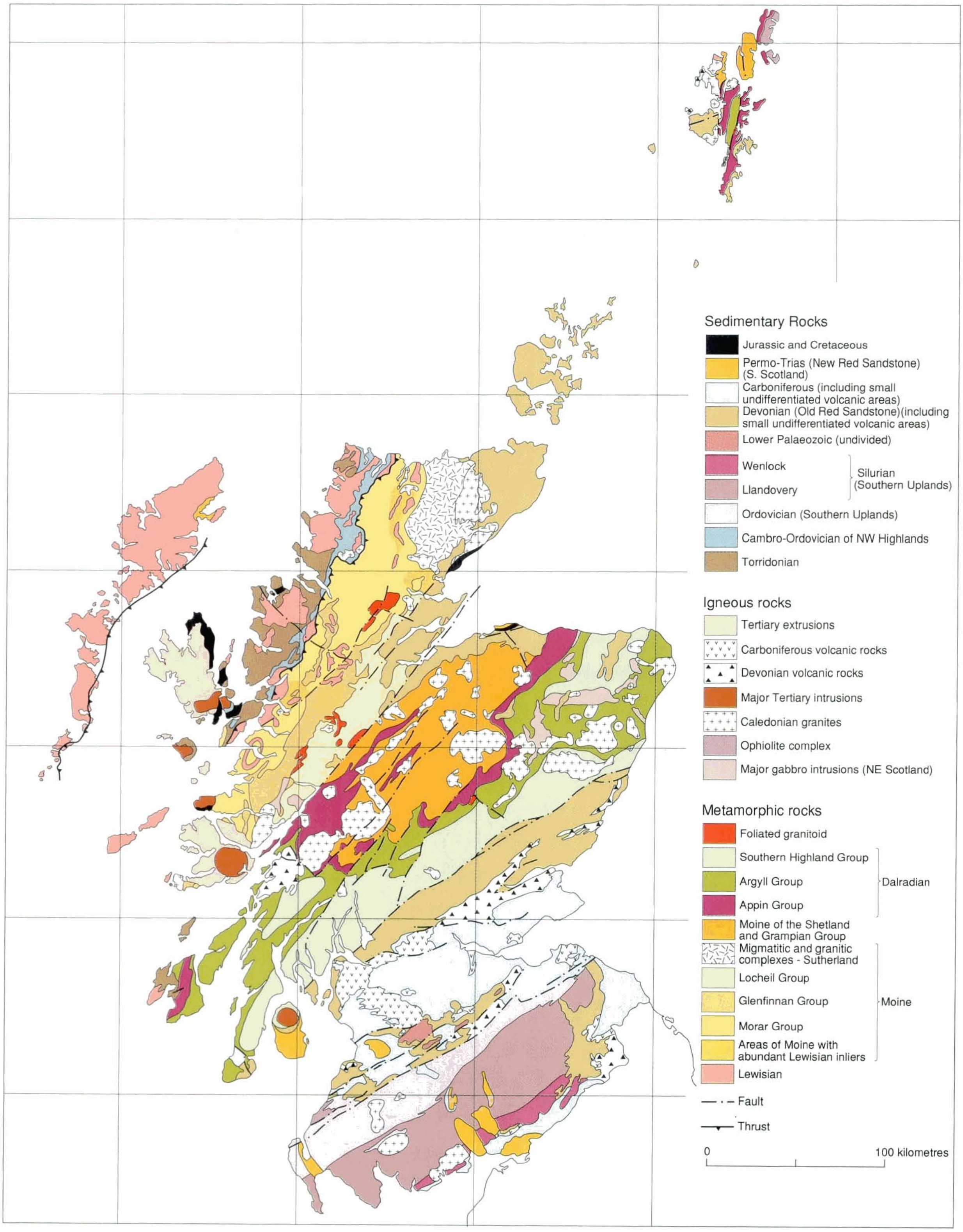


Figure 1 Geological map of Scotland

Based on the Institute of Geological Sciences (now BGS) *"10-mile" 1:625 000 Geological Map of the United Kingdom (North)*, 3rd Edition 1979 and on Figure 1.1 from *Geology of Scotland*, edited by G Y Craig, 3rd Edition 1991, published by the Geological Society, London.

1.00 INTRODUCTION

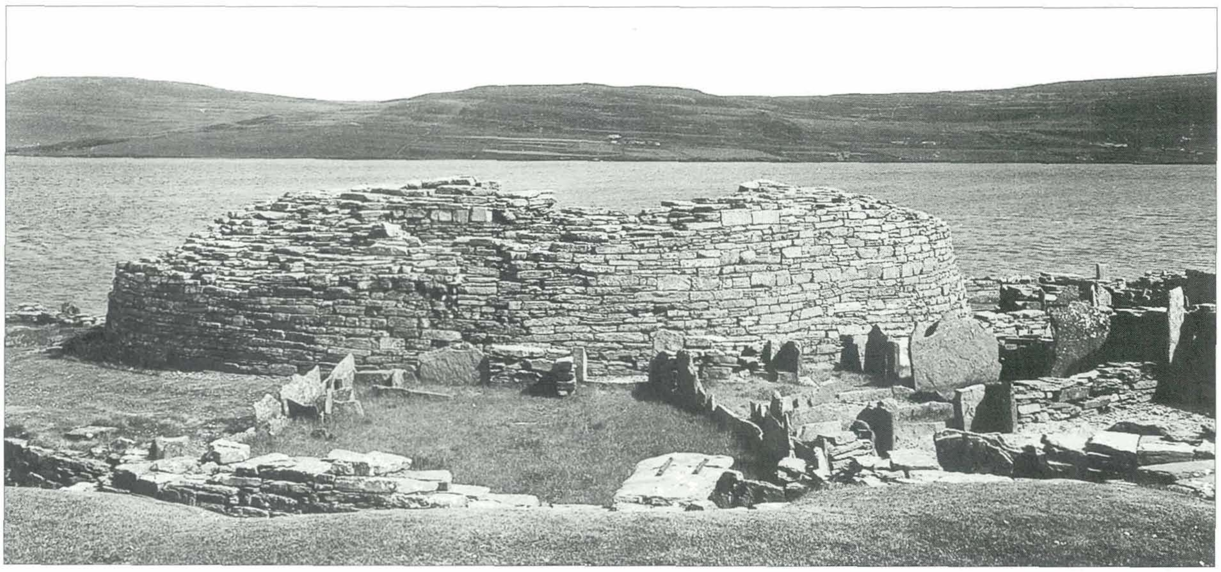
1.01 Quarrying and the use of stone in Scotland

Quarrying is one of man's most ancient activities and the expertise developed over the centuries to work and use stone in buildings was derived from his ability to utilise and exploit the properties of rock. These properties are to a large extent a function of the origin, composition and texture of rock, characteristics which are now understood through the advances in the scientific understanding of the earth and its components. Modern geology is a relatively young science and owes its origins in the late eighteenth century in large part to reasoned thought and observation of scholars of the Scottish Enlightenment, notably Edinburgh-born, James Hutton (1726-1797). Prior to this modern era the use of the earth's stone resources, including stone for buildings, walls, bridges, roads and for monumental and artistic purposes was based on observation and experiment.

1.02 Availability and variety of stone

Scotland has a rich variety of rocks some of which date back to at least 2500 million years. This antiquity of the rocks is matched by an astonishing geological history which has witnessed at various times the opening and closing of oceans, intermittent volcanic activity, the incursion of shallow seas, the development of major river systems and glaciation. Contained within the Scottish landmass is a variety of sedimentary, igneous and metamorphic rocks which rivals that of any similar sized portion of the earth's surface (Figure 1). It is not surprising therefore that man has sought to use these materials either directly or as raw components over many centuries for construction of all sorts.

Nature, through the action of successive, relatively recent ice sheets (which covered the landmass at intervals during the last 2 million years) and the processes of rivers and seas, has assisted in the excavation of the bedrock to provide raw materials in ready supply at the surface. Thus the early days of construction of walls and dwellings often utilised fieldstones and boulders gathered from the land or from the bed of rivers and along the coastline. The products of deglaciation such as glacial sands and gravels, lake clays and marls also supplied the needs of early builders.



Aikerness Broch, Gurness, Orkney

Standing to a height of 3 metres the central broch tower is surrounded by later buildings and a deep ditches. The site was the centre of the local communities, and was used from the Iron Age to Viking times. The masonry construction utilised the natural properties of the thin-bedded all red sandstone slabs to great advantage. The broch and external buildings contain architectural features composed of vertical slabs in addition to well constructed walls which display considerable fluidity in their conception and construction.

1.03 Geological influences on the early use of stone

In the early days of building, stone was extracted from the most easily exploited sites to provide building material. Much of this material was used with little, if any further dressing to form random rubble walls. Stone gathered manually from the land as part of field clearance work during the late eighteenth and early nineteenth centuries was set aside to make for easier use of ploughs and other equipment. There was thus a ready source of rounded weathered boulders suitable for the building of field drains, enclosures and march dykes. The character of the dykes very much depended on the geological nature of the stones. Particularly in western Scotland weather-worn, rounded field boulders of a range of rock types were utilised to produce ill fitting constructions which withstood gales because they were riddled with holes which allowed the wind through. This may be contrasted with the use of Old Red Sandstone flagstones of Caithness and the Northern Isles which were set in the ground on edge to produce a tight fitting fence arrangements. When laid horizontally these parallel sided, regular shaped, flagstones with slab height to length ratios of between 1:4 and 1:8 produced a brick-like wall.

In the Lowlands early eighteenth century buildings utilised mainly glacially rounded, weathered sandstones and igneous rocks retrieved from the fields with exposed face height to length ratios of 1:1 or 1:2. These required the use of thick mortar beds and levelling up slip-stone pinnings to course the wall's construction. Galloway dykes used mainly hard greywacke sandstones (traditionally referred to as 'whin' or 'whinstone') of irregular shape and size. Inward inclining double walls were stabilised using small stones in the middle hearting which enabled free use of the irregularly shaped face stones. Quarried greywacke sandstones of the Southern Uplands typically have a face dimension height to length ratio ranging from 1:3 to 1:5. The irregular profile of such material demanded highly skilled mason work for effective coursing. Tightly packed small face slip-stones and pinnings were commonly used to make up course bed height.

In areas where suitable rock cropped out, small quarries were developed and stone became established as the local building material. Local stone was extracted not only for domestic and farm use but also for larger buildings. Medieval castles, for example, were mainly rubble-built constructions of stone derived from locally available materials. The size of available stones, determined by the geological factors such as bedding and joints in the original rock, affected the form of the building. The relatively small dimensions of available stones dictated that walls were mainly constructed with small openings, a feature suited for the purpose of defence. The availability of large stones determined the whether wide openings could be spanned. Thus large blocks of dressed stone were often transported from further afield for use as lintels and corbels of window and door openings. The form, colour and design of a building was therefore determined by the use of geologically different stones. Stones used for tombstones and slabs, crosses and effigies also utilised local stone of metamorphic and sedimentary origin which could be easily worked and sculpted.

1.04 Geological influences on the use of stone in the last 200 years

As villages and towns grew from early settlements so the requirement for building materials increased and large numbers of local quarries were developed. In the centuries before mechanised transport the local sources of stone were utilised almost to the exclusion of materials from farther afield except for the most important buildings and monuments. This continued to be the case well into the 19th Century. Not only was it costly to transport large quantities of building materials over large distances but often the local sources yielded abundant, good quality stone. Not surprisingly therefore, many of the buildings in major Scottish cities and towns were built of local stone. In the Lowlands, a major resource was good quality sandstone suitable for constructional and monumental purposes, particularly, but not exclusively, from the Carboniferous period. Stone for both ashlar and rubble work was in great demand and could often be supplied from the same quarry. The Lower Carboniferous Craigleith Sandstone from the many famous quarries in west Edinburgh, for example, supplied the finest 'liver rock' (massive, non-laminated sandstone) for ashlar.

Broken residual material from dressed down blocks together with more thinly bedded sandstone was used for rubble-built walls thereby ensuring fullest use of the stone resource. Hailes Quarry, on the other hand yielded primarily thinly bedded, laminated sandstones which although unsuitable for ashlar was in much demand for squared rubble and also for stairs and landings. Glasgow and Dundee had similarly excellent local sources of sandstone which could be used for a variety of purposes. Roofing slates were however transported from Argyllshire and paving stones from the Old Red Sandstone flagstone beds of Angus and Caithness. The city of Aberdeen, the "Granite City", and other towns in Aberdeenshire, built wholly of granite exemplified the use of these locally available igneous rocks.

North side of Charlotte Square, Edinburgh 1795. Craigleith sandstone.

An example of high quality ashlar work which exploits the fine characteristics of this stone.

With the development of the road, canal and railway networks, it became economic to use a variety of stones from further afield for general domestic, industrial and commercial use. During the middle of the nineteenth century, the famous Stirlingshire, West Lothian and Angus sandstone quarries came into their own, supplying much stone both for prestigious buildings as well as houses and tenements. Soon Permian red sandstone became popular, and by the turn of the century stone from Dumfriesshire, Ayrshire and Arran sources was in much demand as a source of good ashlar. The sandstones were often slightly softer and easier to work than the Carboniferous stone. Utilising the different sedimentary characteristics and the striking colour contrasts, Glasgow, in particular became a principal recipient of these stones. Stone, too, started to be imported from northern England, as local supplies of good quality building stone became scarce or more difficult to provide. Recently English Carboniferous quarries have supplied much stone for use as cladding and as matching material for repairs to buildings constructed of local stone now no longer available. However whereas some Scottish quarries worked out most of the stone suitable for building, others still have available resources. In recent years, the re-opening of old quarries for short periods (known as 'snatch-quarrying') has been successfully applied to supply specific orders either for stone repair or new build.

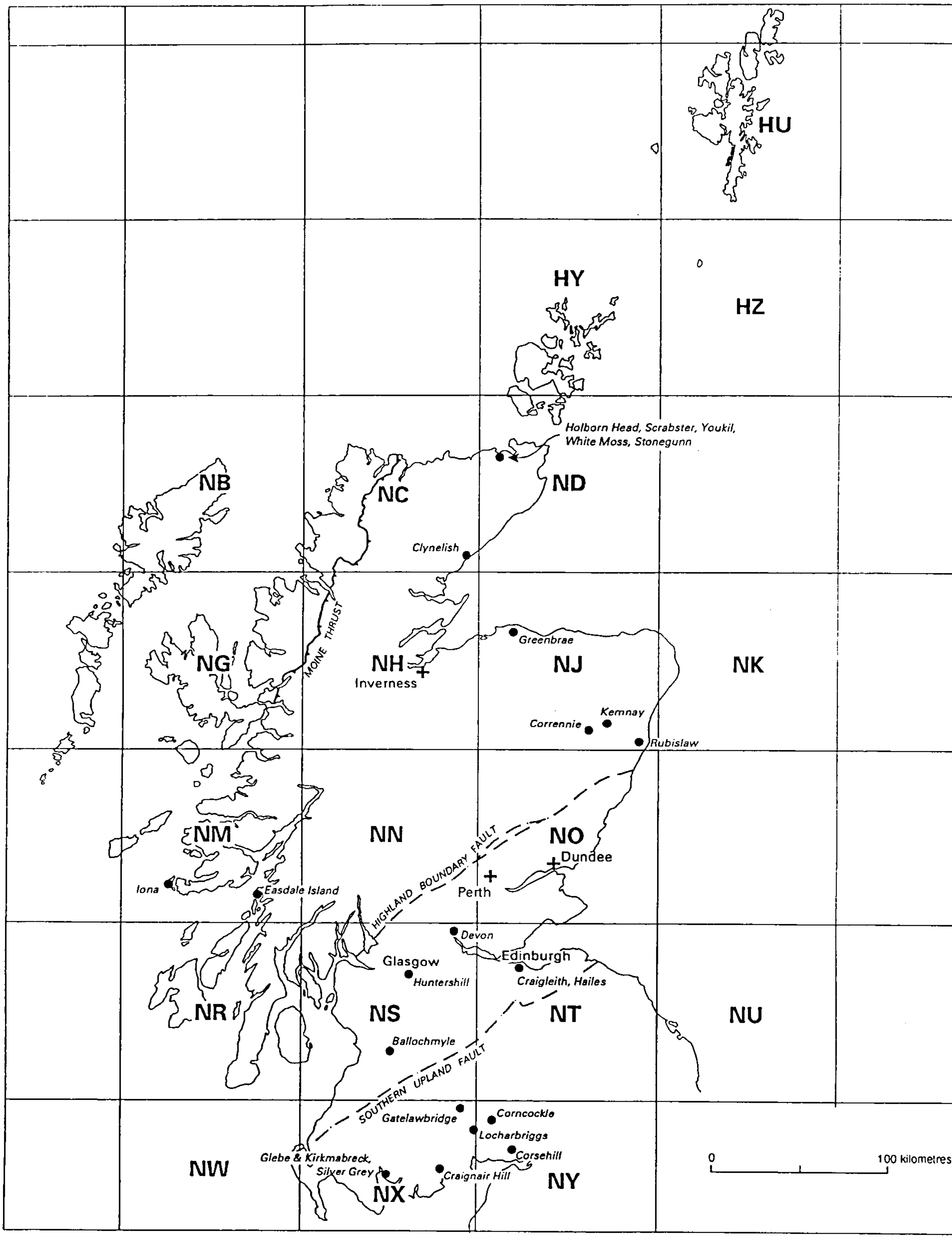


Figure 2 General locations of building stone quarries illustrated in the report

2.00 THE BRITISH GEOLOGICAL SURVEY PHOTOGRAPHIC ARCHIVE

Photography was recognised by the Geological Survey in the late 19th century as an important method of recording geological features and scenery and the collections were built up to provide for both reference and publication in descriptive memoirs. Prior to about 1940 photographs were taken with Linhof plate cameras using full glass plates. The photographs selected here (listed in Appendix 1) from the B and C Series (the A Series, housed at BGS Keyworth, covers England and Wales) date from the early days of Survey photography in the 1890s up till 1939 (one D Series photo of the 1960s is also included) and have been chosen to illustrate methods employed in building stone quarries, the men who worked them and the geological features of different rock types. The general location of the quarries is shown in Figure 2. Coverage is far from comprehensive and many famous quarries are not recorded in the photographic collections. Nevertheless, the photographs are a valuable resource, illustrating as they do scenes from quarries long since abandoned and in many cases completely obscured through secondary use as landfill.

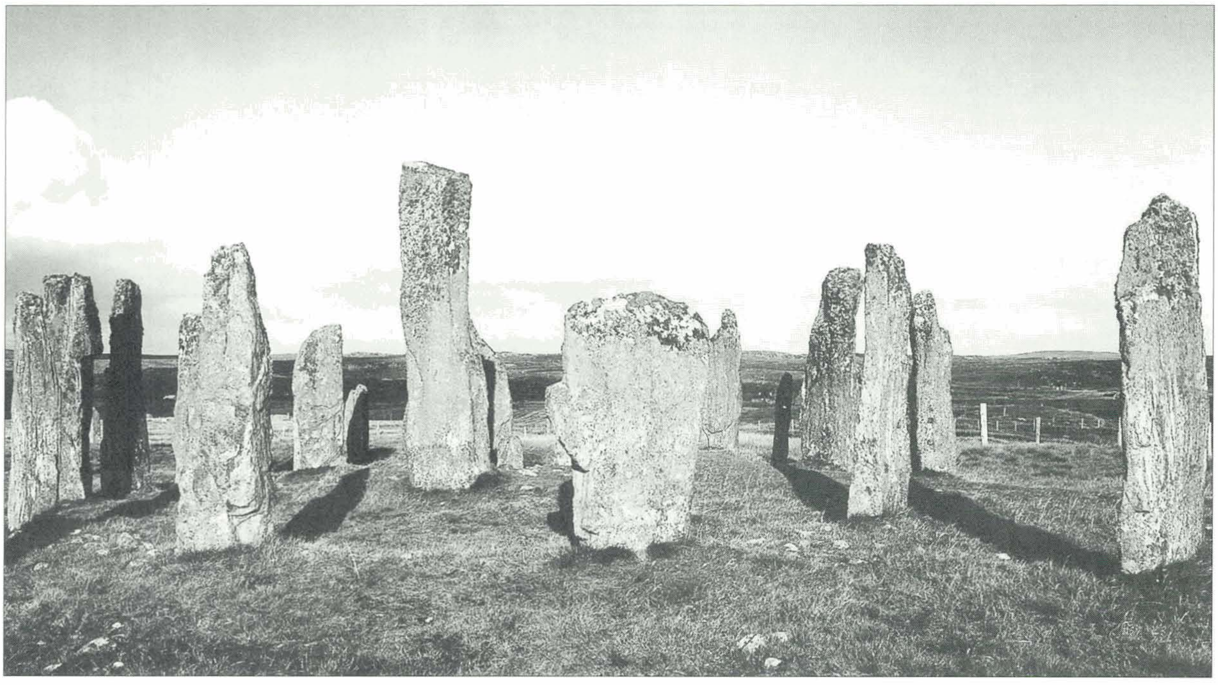
The earliest Survey photographs were taken by Robert Lunn, born in 1861, who combined his photographic expertise with geological knowledge acquired during his years working for the Geological Survey to produce technically superb compositions. Lunn joined the Geological Survey as a boy porter, aged 14, in 1874. He was recruited because a man could not be found to act as porter for the annual salary of £27. He was later appointed to General Assistant and in 1891 started taking geological photographs in the field. The oldest registered photographs published in this volume were taken by Lunn in 1899 (C238-239), some 4 years before the date of the earliest registered photographs in the England and Wales collection. Lunn was appointed Superintendent of Maps in 1901 and retired in 1921. Other photographers whose work is published here include David Tait, William Manson, MBE and W D (Bud) Fisher. Tait (1869-1943) was appointed Fossil Collector in 1897 and made many notable contributions to palaeontological research. He took the opportunity to photograph quarries as part of his official duties which included the examination and recording of new rock excavations. Manson (1891-1973) joined the Survey in Edinburgh during 1908 initially as a draughtsman. After naval service during the First World War he returned as a Fossil Collector, under the tutelage of David Tait and pursued a distinguished career, until his retirement in 1960, researching the stratigraphy and palaeontology of the Scottish Carboniferous rocks. Photographs of the 1930s presented here were taken by Bud Fisher who joined the Survey in 1927 and retired in 1970.

3.00 THE GEOLOGICAL CHARACTER OF SCOTLAND

3.01 Geological history and outline of stone types and origins

The diversity of the geological environment and the immensity of the time span covered by the rocks which underlie Scotland explain why it became the focus for modern geological studies during the latter part of the 18th century. Long before this new awakening in the significance of Scottish geology, the indigenous population exploited the geological properties of a wide range of available resources.

Much of Scotland is underlain by ancient crystalline igneous and metamorphic rocks which can be linked with those in Greenland and the Appalachian Belt of North America, which formed the ancient continent of Laurentia. These include, in particular, the metamorphic rocks (some greater than 2500 million years old) known as the Lewisian Gneiss of the Outer Hebrides and the north west mainland (Figure 1). Appropriately enough, it is in Lewis that some of the oldest uses of stone are preserved in the form of standing stones composed of gneiss. On the Scottish mainland, the ancient worn down, irregular terrain of Pre-Cambrian rock formed the floor for sedimentary rocks of the Torridonian and Cambrian periods (Table 1). Remnants of these strata can be seen in various parts the north west highlands forming the spectacular mountains of Torridon and monadnocks of Assynt.



Callanish Standing Stones, Isle of Lewis

Dating to around 3000 BC, this outstanding cross-shaped setting of standing stones is unique in Scotland.

The builders used large irregular slabs of gneiss, possibly from a source of free surface slabs a few kilometres to the east. The largest stones were used for the central monolith and the stone circle; another large stone was later used to mark the northwest end of the avenue.

Geological System	Age of base in millions of years	General distribution	Typical Scottish building stone types
QUATERNARY	2	Throughout Scotland	Various glacially-derived materials, both of local and far-travelled origin
TERTIARY	65	Inner Hebrides, Arran, Tertiary dykes in Western, Central and Southern Scotland	Basalt lavas, gabbro and other igneous rocks including basalt dyke swarms; Arran granite and dykes
CRETACEOUS	140	Remnants on Mull, Skye, Lochaline	Sandstone
JURASSIC	200	Moray Firth Coast and pockets in Inner Hebrides	Sandstone
TRIASSIC	250	Moray Firth Coast	Sandstone
PERMIAN	300	Dumfries and Galloway, Mauchline, Arran	Red sandstone
CARBONIFEROUS	360	Midland Valley, Solway coast, Berwickshire	Sandstone; basalts and other volcanic rocks
DEVONIAN	410	Angus and southern parts of Midland Valley; Caithness, Northern Isles; granites of Southern Uplands and Grampian Highlands	Sandstone, notably Flagstone; major granite intrusions; Andesite lavas and other igneous rocks
SILURIAN	440	Southern Uplands	Greywacke, siltstone (locally used as 'slate')
ORDOVICIAN	510	Southern Uplands	Greywacke, siltstone (locally used as 'slate')
CAMBRIAN	570	North-west Scotland	Quartzite, Durness Limestone
PRE-CAMBRIAN			
DALRADIAN	850	Grampian Highlands, Argyll, Islay, Jura	Slate, quartzite, schist, metamorphosed igneous rocks
TORRIDONIAN	1000	Skye and Applecross to Laxford; parts of Cape Wrath	Arksose (Feldsarenite)
MOINIAN	1200	Northern Scotland and northern part of Grampian Highlands	Schist, quartzite
ARCHEAN	*Oldest Scottish rocks c.3000*	North-west Highlands and Outer Hebrides, Coll and Tiree	Gneiss, schist, quartzite, marble

Table 1 Geological timescale and distribution of Scottish rock types used as building stone

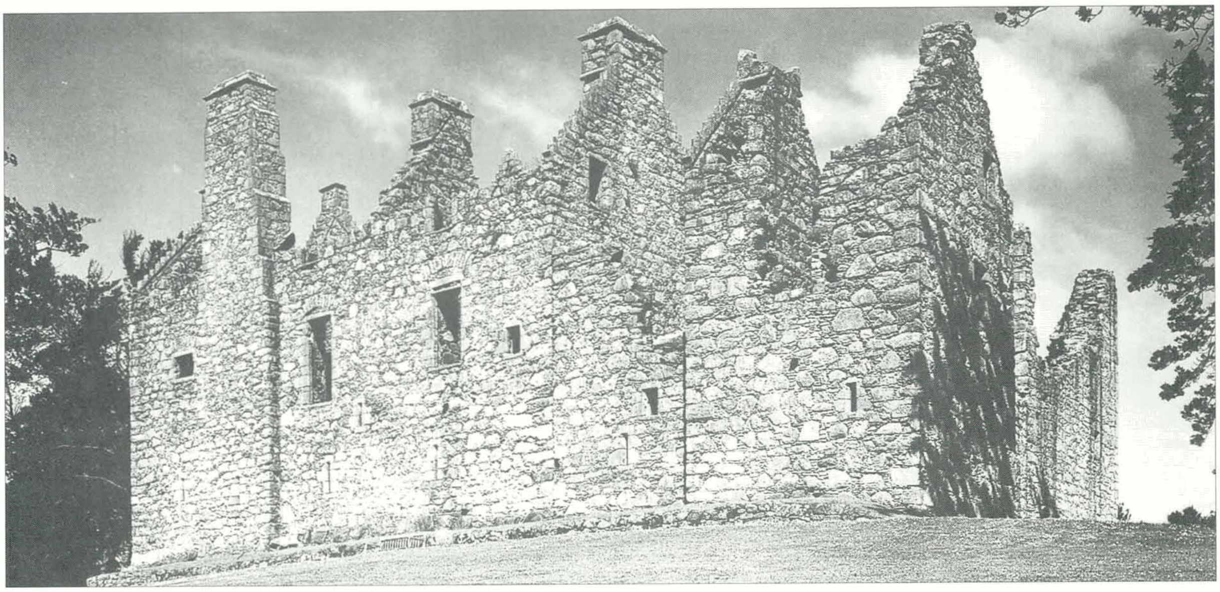
The classic Moine Thrust Zone (Figures 1-2), identified first by the early geological surveyors during the latter part of the 19th century, separates these sedimentary rocks from Moine and Dalradian metamorphic rocks of similar age which occupy much of the rest of the Northern Highlands and most of the Grampian Highlands. North of the Great Glen Fault, a major fault which was intermittently active over many millions of years, the Moine sediments probably accumulated on the margin of the Laurentian - Greenland continent about 1200- 600 million years ago. During this time span the rocks were metamorphosed and then recrystallised during a mountain building episode between c.470 and 400 million years ago known as the Caledonian Orogeny. South of the Great Glen Fault, the Dalradian rocks were metamorphosed at about 590 million years (during the Grampian Orogeny) and also during the later Caledonian Orogeny. Amongst the varied metamorphosed sediments of the Dalradian are the slates of Argyllshire, long used as a valued resource for roofing, together with schists, quartzites and metamorphosed limestones and igneous rocks.

The Caledonian Orogeny was associated with the closure of a large ocean, the Iapetus Ocean, which brought together crust of Avalonia which underlies most of England and Wales with that of Laurentia. The folded and deformed ocean floor greywackes (impure lithic sandstones), siltstones and cherts of Ordovician to Silurian age (Table 1) which form today's Southern Uplands (Figure 1) and parts of Ireland and Newfoundland are the principal remnants of this long-closed ocean. Greywackes have been used traditionally for many centuries in the building of walls, houses and castles.

Smailholm Tower, Kelso

Dating from the 15th and 16th centuries, this small rectangular tower is perched on a natural rocky outcrop and set within a stone barmkin wall.

The corners, skews and windows and doors are made from dressed sandstone blocks whilst the general body of the rubble wall is constructed of a variety of stones, the squarish size and coursing of which is determined by the local heavily geological cross bedded stone.



Tolquhon Castle, Grampian

Built for the Forbes family, Tolquhon has an early 15th century tower to which a large quadrangular mansion was added between 1584 and 1589.

Employing the standard medieval building technique of using the best quality stone for window and roof dressings, the general rubble walling also displays a sense of care and attention to detail - with the tightly packed pinnings set around the larger rough granite rubble blocks to produce a well bedded structure of considerable strength.

During late Silurian to Devonian times, large bodies of granitic magma were emplaced in the crust both in the South of Scotland and in the Grampians. Both regions have supplied exploitable building resources of granites which have had a wide range of uses in buildings, bridges, monuments and for ornamental purposes.

Two other major crustal dislocations, the Southern Upland Fault and the Highland Border Fault (Figures 1-2) were active at this time and continued to control sedimentation in the newly formed Midland Valley of Scotland. During the Devonian, large bodies of river sands and gravels accumulated whilst lake sediments (principally flagstones) formed in large lake basins in Northern Scotland and the Northern Isles. During the subsequent tropical Carboniferous period, active volcanicity punctuated the deposition of thousands of metres of coal-bearing, strata, in which sandstones, mudstones thin limestones, coals, ironstones were laid down in subsiding basins. Periodic inundation by the sea is illustrated by the limestones and other marine fossil-bearing horizons. The proportion and thickness of these component lithologies varied according to the conditions under which they were deposited.

By Permian times, desert conditions prevailed and the latitude of northern Britain was probably similar to that of today's Sahara. New Red Sandstones, unlike the Carboniferous sandstones, were deposited mainly in desert environments. Evidence for this is shown by sedimentary structures including aeolian (wind-blown) dune-bedding. These sandstones occupy small basins in Dumfries and Galloway and Ayrshire. In Morayshire Permo-Triassic buff and white sandstones were also laid down in an aeolian environment but close to the margin of a sea, conditions which effected unusual stone characteristics including convolute bedding and patchy silicification.

Thin, dominantly marine sedimentary sequences of Jurassic age crop out on the Moray Firth coast and in small isolated outliers of the Inner Hebrides. These are the onshore representatives of extensive and thick Jurassic, oil-bearing sequences of the North Sea.

The development during Tertiary times of the major volcanic centres of Mull, Ardnamurchan and the Inner Hebrides represents the final stages of the opening of the Atlantic Ocean. A significant and lengthy period of denudation preceded the development of ice sheets across Scotland during the Quaternary (Table 1). These have left their mark in a variety of way including 'U shaped' glens and till deposits (stiff, clay-bound mixtures of boulders, pebbles and smaller fragments). Meltwaters carved drainage channels and left strings and sheets of glacial sands and gravels. As the ice sheets melted changing global sea-levels have combined with local rebound of the earth's crust (responding to the diminishment of the ice-load) to produce sharply defined raised beach platforms and deposits bordering the present coasts of east and west Scotland. Particularly in the highlands, these raised coastal features together with the alluvial floors of geologically modern rivers provided both fertile land and level foundations on which settlements developed.

4.00 GEOLOGICAL CLASSIFICATION OF ROCKS: FACTORS AND CONSTRAINTS AFFECTING WORKING AND USE OF STONE

The characteristics of the wide variety of stones which have been quarried in Scotland are related to their modes of geological origin. Rocks may be divided into three principal categories: sedimentary, igneous and metamorphic.

4.01 Sedimentary Rocks

Sedimentary rocks are formed by the accumulation of sediment, undergoing natural compaction, dewatering and cementation over a long period. The process of sedimentation may take place in a variety of depositional environments, for example in rivers, lakes and seas to form conglomerate, sandstone, siltstone, mudstone and coal, and in deserts to form sandstones. Sedimentary rocks also include salts formed by the process of evaporation of lakes and shallow inland seas, and limestones formed by the accumulation of marine, calcareous organic remains. Sediments may vary in grainsize from clay and silt particles (less than 1/32mm) to boulders (greater than 64mm) (Table 2).

They may be derived from previously existing rocks, organisms and vegetation. Changes in the environment during deposition and variations in the incoming sediment produce layers or beds (Table 3) of rocks of differing characteristics.

Phi units	Clast or crystal size in mm log scale	Sedimentary clasts		Volcaniclastic fragments	Crystalline rocks Igneous, Metamorphic or Sedimentary
		boulders	GRAVEL	blocks & bombs	very-coarse grained
-8	256	cobbles			
-6	64	pebbles		lapilli	
-4	16				coarse-grained
-2	4	granules			
-1	2				
0	1	very-coarse sand	SAND	coarse-ash grains	medium-grained
		coarse sand			
1	0.5 (1/2)	medium sand			
2	0.25 (1/4)	fine sand			fine-grained
3	0.125 (1/8)	very-fine sand			
5	0.032 (1/32)	silt	MUD	fine-ash grains	very-fine-grained
8	0.004 (1/256)	clay			

Table 2 BGS Grainsize Scheme (based on Wentworth, 1922)

Bed thickness: geological definition		Architectural use	Notes
	Very thickly bedded	Ashlar and sculpture	Beds suitable for building may contain internal thinly bedded or laminated structure
1 metre			
	Thickly bedded		
0.3 m			
	Medium bedded		
0.1 m			
	Thinly bedded	Sculpture panels	
0.03 m			
	Very thinly bedded	Flagstones for pavement and roofs	Individual laminations unsuitable for building
10 mm			
	Thickly laminated		
3 mm			
	Thinly laminated		

Table 3. Terminology of bed thickness and typical architectural use

Minerals taken into solution by surface and ground water, are redeposited as precipitates or crystals, cementing the grains or fragments of sediment together.

Progressive burial produces compaction in the sediment which eventually becomes lithified into rock. Shrinkage of the drying sediments and movement of the earth's crust create joints perpendicular to the bedding planes which separate the layers of rock. Thus the constructional properties and characteristics of sedimentary rocks depend upon the particles, the cements and the spacing of the bedding planes and joints. The combinations of these widely varying factors produce a wide range of sedimentary rocks, many of which are unsuitable as constructional stone for building but may have other applications. For example some shales and mudstones provide the raw material for brick making.

(i) Sandstones

Sandstones originate as unconsolidated loose grains of sand deposited on the sea bed, in coastal and desert dunes, on beaches or by rivers. The grainsize of sandstone ranges in diameter from about 1/32mm to 2mm (Table 2). The composition of the grains reflects the composition of the source rocks and the physical and chemical resistance to weathering of constituent minerals.

The texture (grain shape - Table 4, and sorting - Table 5) of sandstones is affected by the mode of transportation of the grains, for example by water or wind.

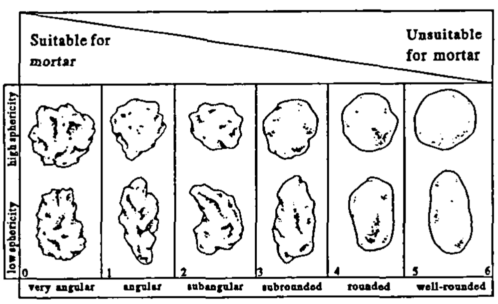


Table 4 Categories of roundness for sediment grains and suitability for mortar

Adapted from *The field description of sedimentary rocks: Geological Society Handbook* by M E Tucker (1982, Open University Press, Milton Keynes).

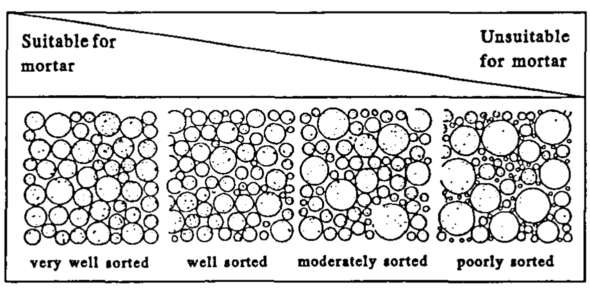


Table 5 Degree of sorting and suitability for mortar

Adapted from *The field description of sedimentary rocks: Geological Society Handbook* by M E Tucker (1982, Open University Press, Milton Keynes).

The geological characteristics of shape and sorting apply equally to unconsolidated sediments and to their lithified (rock) equivalents. Wind is often a good agent for sorting the sand, so that the range of particle sizes (Tables 2 and 5) is small: the best sorted sands tend to be those which have been transported and deposited by winds in deserts. These sands are also characterised by well-rounded grains. Note, however that a geologically well sorted sand is commonly considered to be poorly graded in quarry operator's terminology. When considering the suitability of sand for mortar it is important to assess both particle shape and degree of sorting. Generally angular, moderately sorted sands are best (Tables 4 and 5). A moderately sorted sand is considered to be well graded (i.e. with a normal particle distribution and median grain size of about 0.5 - 0.6 mm).

Compositional maturity of a sandstone is defined by the constituent minerals which are determined by the source and agent of transport of the sand. Sands which are rich in chemically stable minerals such as quartz (silica) are said to be mature. Sands with a wide range of mineral constituents, including a high proportion of clay minerals (complex silicates), are both texturally and compositionally immature. Sandstones suitable for use as building stone commonly consist of strong, chemically stable, colourless or light buff or pink particles of the minerals quartz or feldspar. However the presence of particles of weaker minerals is not uncommon. An example is the flaky silicate mineral, mica, each flake reflecting light and giving a lustre to the fresh stone.

Bedding Characteristics

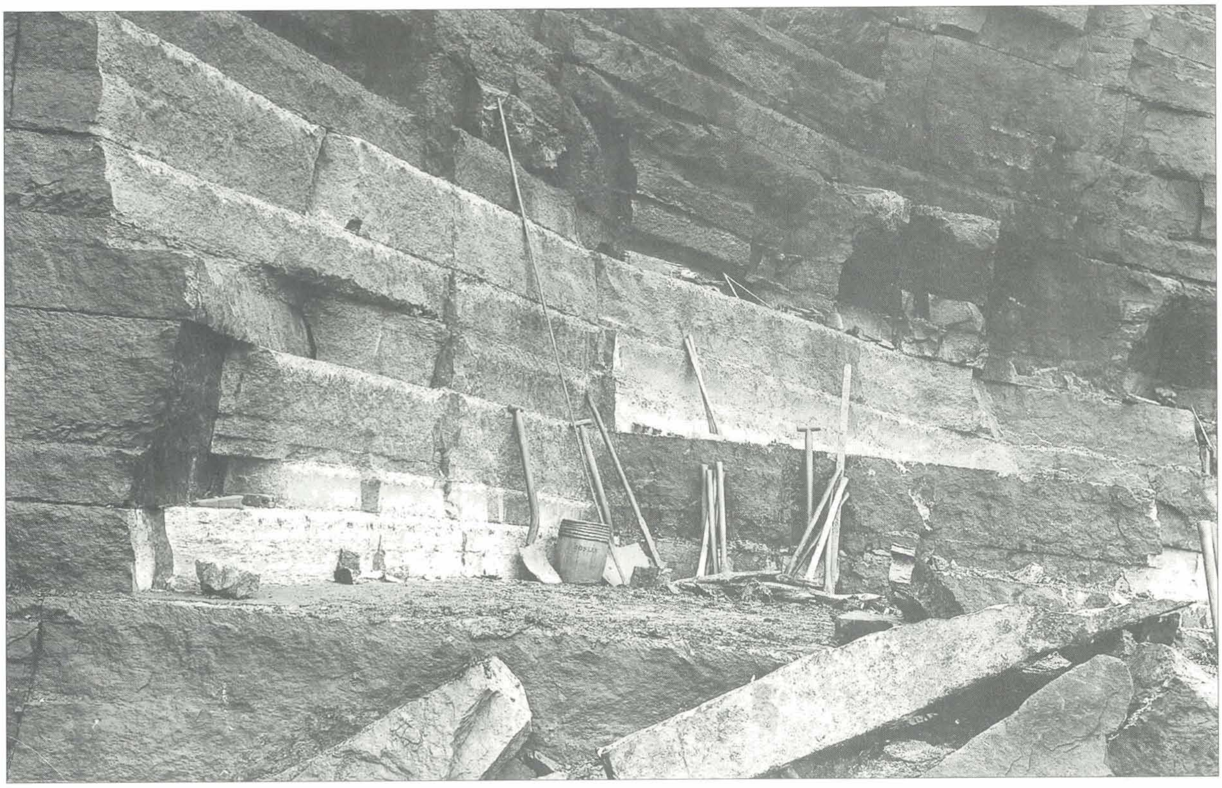
The natural sequence in which sediments are deposited results in the youngest layer lying at the top and the oldest at the bottom (the 'principle of superposition'), providing the sedimentary pile is not disturbed or overturned by some external force. In building works it is often desirable to simulate this natural arrangement of sediment layers by laying stone 'in bed' and the 'right way up' because the stone is not only better equipped to take imposed loads at right angles to its natural bed but also has the potential to weather better. There are circumstances, in the building of arches and corbels, where this arrangement is also desirable for structural reasons. Examples include edge bedded arch blocks in which the planar edge forming the length of each block is aligned parallel to the natural bedding. Each block is rotated a few degrees to form a curved arch. End bedding where the block is laid 'on cant' with vertical bedding on the exposed face, for example in parts of columns, may erode more quickly. Face bedding where the exposed face is parallel to the bedding may suffer from de-lamination.

During the formation of the sandstone, the lapse of time between one layer of sediment being laid down and another is represented by a lateral discontinuity in the structure, known as a bedding plane, separating one bed of rock from another. Each bed can be subdivided into smaller units and the thickness of the unit to be described as a bed may depend upon the context in which the term is used. Beds may be many metres in thickness but below an arbitrary lower limit of 1cm thickness, the units are known as laminations (Table 3). Some medium- to thick-bedded sandstones have internal lamination which may render them unsuitable for polished ashlar but suitable for squared rubble work (eg Hailes Quarry, **BGS Photograph C3114**).

Flagstones are beds of uniform thickness up to 3cm which have internal lamination. They have mainly been quarried, for example in the Northern Isles, Caithness and Angus for use as paving stones or roofing slabs. A freestone is a massive, medium- to thick-bedded sandstone in which no internal lamination is apparent and which can be worked with equal ease in all directions. Historically this was frequently referred to as 'Liver Rock'. Often, but not necessarily, the stone has a uniform appearance. The best unstratified stone from Craigleith, Edinburgh was, for example, described as 'Liver Rock'. However, it was a hard sandstone, difficult to excavate and dress.

Water- or air-borne particles are subject to physical laws which determine how they are transported and deposited. In a river, for example, cobbles and pebbles (the bedload) may be rolled or bounced along the floor of a channel. Finer sediments including sands may be transported partly as the bedload and partly in suspension. The finest sediments such as silts and clays will be carried in suspension. It follows that if the velocity of the current carrying the particles in suspension is high, only the larger and denser particles will settle; as the velocity drops successively smaller and less dense particles settle. Assuming that the current wanes uniformly, the resultant sediments will exhibit graded bedding, the particles in the bed grading from coarse at the bottom to fine at the top. Features such as graded bedding observed in sandstones indicate that depositional processes millions of years ago were the same as those today. Comparisons can be made with many easily observed modern sedimentary structures. For example, ripples, similar to those seen on beaches today, are seen preserved in ancient sandstones and their wavelike structures can be seen in vertical section as well as on exposed bedding planes.

Waveforms on a larger scale occur in river channels and windblown sands, giving current-bedding (cross-bedding) (Figure 4) and dune-bedding (Figure 5, **BGS Photograph C2913**).



Hailes Quarry, Slateford, Edinburgh (C3114), c.1926

The fresh surfaces of rock clearly demonstrate characteristic wispy, black, carbonaceous, ripple laminae, a feature frequently seen in buildings constructed of this stone. The tools used included picks and wedges. The latter have been driven vertically into 'back' joints at the back of a bed.

Photograph courtesy of the British Geological Survey.

(a) Flowing water carries sediment particles in suspension and these are deposited out on the lee side of the slope, where the velocities are lower.

(b) Due to deposition on its lee side, the slope 'moves' forward producing 'layers' of the form indicated so producing a cross-stratified unit.

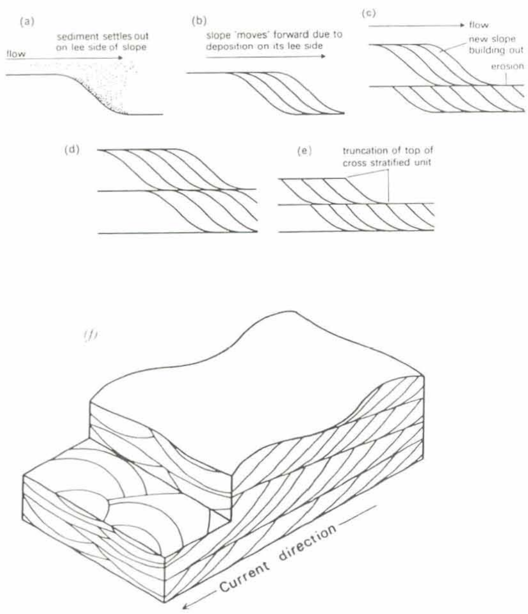
(c) After the formation of one cross-stratified unit, its top is eroded, and another formed above it.

(d) Two units of cross stratification formed without any erosion occurring.

(e) Two units of cross stratification produced by deposition and erosion, so that their tops are truncated.

(f) Three dimensional block illustrating the form of trough cross bedding shown in (e).

(g) The surface characteristics of a finished ashlar block cut from the sandstone beds shown in (f).



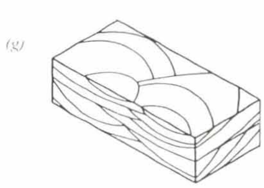


Figure 4 Sedimentary structures: the development of cross bedding in a water flow

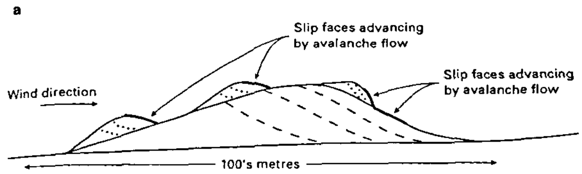
Adapted from the Open University Science Foundation Course units 26 and 27 *Earth History I and II* (1971, Open University, Milton Keynes) and Bunyan et al., *Building Stones of Edinburgh* (1987, Edinburgh Geological Society).

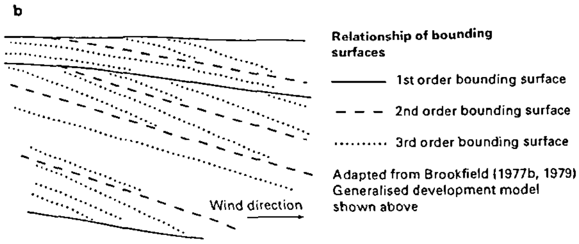
Figure 5 Sedimentary structures: section through an idealised large wind-blown dune

Adapted from Brookfield, 1977, 1979 and *Geology in south-west Scotland* edited by P Stone (1996, BGS, Keyworth).

The figure illustrates the formation of a dune and shows the relationship to dune beds in Permian red sandstone formerly exposed in Ballochmyle Quarry, Mauchline (BGS Photograph C2913 and sketch).

The gently dipping side of the dune faces into the wind and sand grains are being continually moved upwards towards the crest (Figure 5a). The steep side of the dune is the site of successive avalanche flows as the dune migrates down wind. The large-scale cross -beds are the preserved foresets on the steep side of the dune. The wedge-shaped beds represent individual avalanches, each formed as a single event. Each dune was stabilised, then overtaken and eroded during the deposition of the subsequent dune, resulting in trucation at the top of the dune and the development of a 1st order bounding surface (Figure 5b).





The development of cross-bedding is shown in Figure 4a-e. The tops of the waves are often eroded by the current which eventually deposits the succeeding layer, giving the waveform a truncated appearance (Figure 4e). This enables the orientation of the stone to be determined because the individual sand layers will tend to become parallel to the base of the bed and truncated at the top. The three dimensional appearance of commonly occurring trough cross-bedding is shown diagrammatically (Figure 4f) and in a finished ashlar block (Figure 4g). Sometimes worm burrows are apparent, the 'tunnel' being filled with material which contrasts in texture and colour with the surrounding stone. Dewatering and slumped structures which are commonly manifested as disturbed or convolute bedding may occur where quicksand conditions existed. In dune bedding the development of different orders of bounding surfaces (Figure 5, **BGS Photograph C2913**) together with the joint spacing determines how the stone may be worked. The largest dimension of block which can be removed from the quarry platform is determined by the thickness of strata lying between bounding surfaces. In turn this thickness is determined by the size of the successive sand avalanches involved in the formation of the dune.

Examination of sedimentary structures in many of the pale white, yellow and brown sandstones used for building construction in the Lowlands reveals that the majority from the Old Red Sandstone (Devonian) and Carboniferous periods originated as river sands. Finely laminated Old Red Sandstone flagstones in Northern Scotland accumulated in freshwater lakes. Red sandstones from the New Red Sandstone (Permian) of the South of Scotland were mainly formed as desert dunes. Fossiliferous sandstones of Jurassic age are of mainly marine origin.

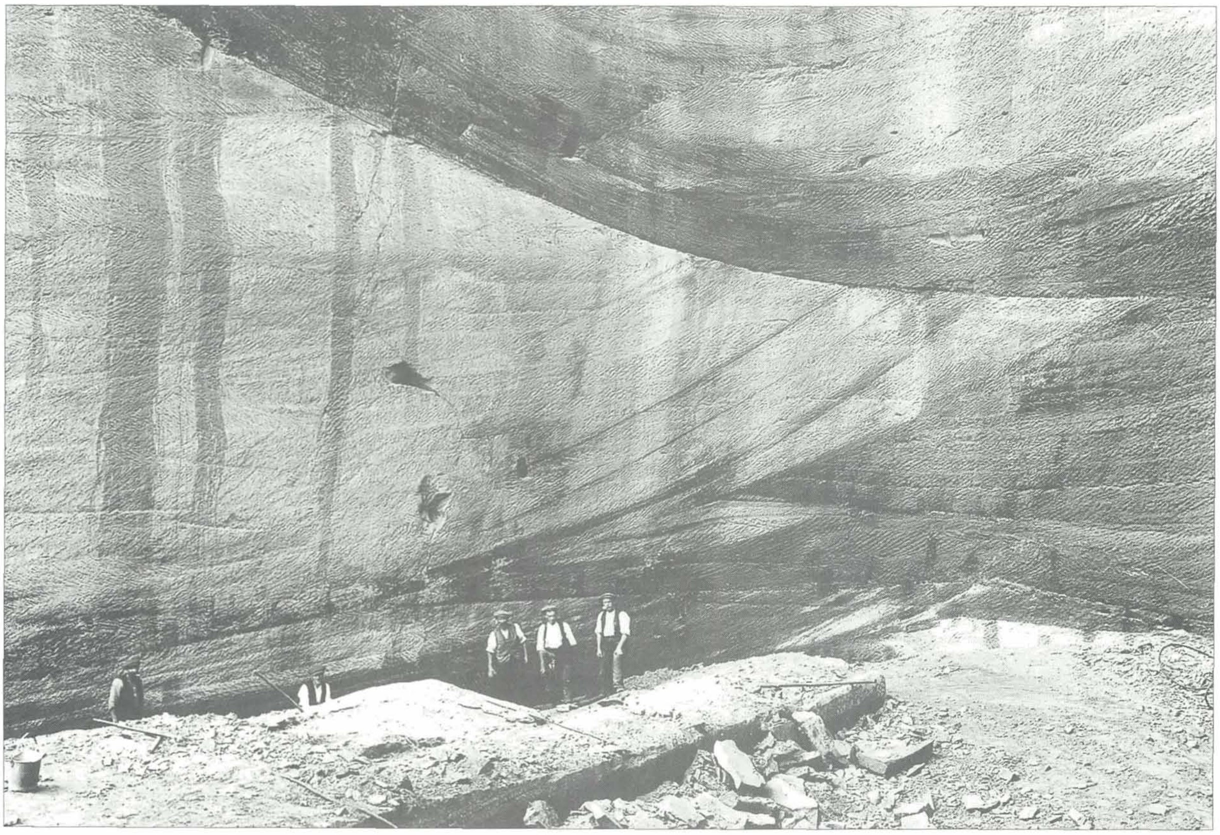
Joints

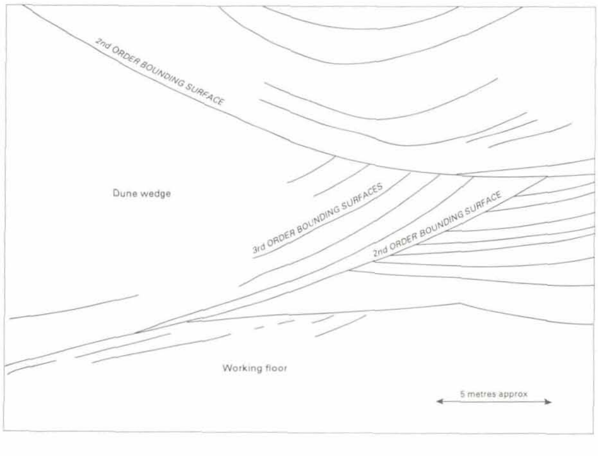
The tendency for well-bedded sandstone to split along natural bedding planes is exploited during quarrying operations. In addition to bedding planes the rock often has two systems of joints or cracks almost at right angles to each other. One set of joints usually runs roughly parallel to the dip direction of the strata. In quarries which usually work to the dip of strata, these joints typically cut into the face of the quarry and are known as cutters. The other joint system roughly follows the strike (i.e. at right angles to the dip of the strata) and its planes lie parallel to the quarry face. These joints are known as backs. Dip joints (cutters), strike joints (backs) and bedding planes give three natural planes of division approximately at right angles to each other by which blocks of stone can often be wedged out using a crow bar only. When the rock is very tough or the joints are very far apart, more powerful tools have to be used but even then backs and cutters usually define the shape of excavated blocks and the mode of development of a quarry.

The geological jointing together with the bedding characteristics determine the size of block which can be quarried and dressed. In turn this dictates what size of stone block can be successfully used in a building. Thus the geology of the stone must be fully appreciated and employed in the ultimate build design.

Grain and cement composition and the classification of sandstones

The appearance (colour and texture) of a sandstone in a building is dependent upon the mineralogical composition of the stone. The mineralogy of both the constituent grains and pore cement should be a prime consideration when planning cleaning operations. For





Ballochmyle Quarry, Mauchline (C2913), c.1921 and sketch

The view in Photograph C2193 and interpretative sketch represents a small part (left of centre) of the working face shown in Photograph C2912, Chapter 5. It is part of a former very large dune composed of smaller migrating dunes. The three large wedges are bounded by 2nd order bounding surfaces (Figure 5b). The surfaces represent a period of time when the underlying dune was eroded, prior to deposition of the next dune. Within each wedge fainter laminations, 3rd order bounding surfaces (best seen in the middle wedge), converge downwards. These 3rd order bounding surfaces dip at angles in excess of 35° and flatten out as they curve towards the base of the unit. The size of sandstone block which can be hewn depends on the the position from which the block is taken. For example thick beds may be worked from the near the top of each major wedge defined by the 2nd order bounding surfaces.

Photograph courtesy of the British Geological Survey.

example the use of acidic treatments may etch grains, destroy pore cements and have a serious irreversible detrimental effect on the colour of the 'cleaned' stone.

Characteristics of sandstone which are observable with a hand lens both in the field and in blocks of a building enable a classification of based on the mineralogy of the detrital grains. The classification is defined by the relative proportions of quartz, feldspar and rock fragments (Table 6). The basic categories include Quartz arenite, Feldsarenite, Litharenite and Greywacke. Qualifiers based on the cement composition may also be used and commonly sandstones are described as siliceous (silica cement), calcareous (calcite - ie calcium carbonate cement) or ferruginous (iron-rich cement). A sandstone with high clay content may be referred to as argillaceous. Sandstones with a coal (organic) content are often described as carbonaceous.

Specific rock name	Mineralogical characteristics	Bedding & Colour	Building and sandstone characteristics
Quartz-arenite	Dominantly quartz. Fluvial and marine sandstones: sub-rounded to sub-angular quartz grains; qualifiers define the cement content of the sandstone: Siliceous Sandstone (silica), Ferruginous Sandstone (iron-rich cement), Calcareous Sandstone (calcite or Calcium Carbonate cement). Argillaceous sandstones have a high clay content. Carbonaceous sandstones have a coal (organic) content.	May be massive (unbedded) or parallel bedded, planar and trough cross-bedded or laminated; micaceous, laminated sandstones are referred to as flagstones; some sandstones are soft on working and harden on exposure; sandstones with calcite and silica cements are white or pale grey; ferruginous sandstones are brown and yellow; Argillaceous and carbonaceous sandstones and flagstones are grey and brown	Massive sandstone hard to work, may produce durable ashlar; bedded sandstones, particularly laminated stones including flagstones may split easily; micaeous, carbonaceous laminae may enhance delamination especially if blocks laid on cant; iron-rich impurities may produce yellow and brown patterns; iron or carbonate nodules may give the stone a non-uniform appearance.
	Desert sandstones: rounded quartz grains, coated with haematite	Prominent dune bedding; often thickly bedded; shades of red; sometimes black laminae and streaks of manganese oxide may be present	Spacing between bounding surfaces determines thickness of block; often soft to work, these sandstones may be cut to produce ashlar block which hardens on exposure
Feldsarenite (arkose)	Quartz with >5% feldspar grains	Medium to thickly bedded; pink and red	Joints and bedding may be exploitable to produce blocks; hard to dress
Litharenite	Dominantly lithic (rock) grains	Colour dependant on constituent rock fragments	Loss of surface skins and veneers may occur in sandstones with high clay content
Greywacke	Angular lithic (rock) grains with quartz, feldspar and other silicate minerals; >15% matrix (grains <30μm)	Greywackes often show graded bedding; rocks fracture irregularly; dark grey	Hard to work and dress; normally used as rock-faced blocks

Table 6 Geological and building characteristics of sandstones

Quartz arenites are mature sandstones composed only of quartz grains cemented either with quartz or calcite. Typically, these monomineralic sandstones are white or pale grey, although aeolian quartz arenites are often red through the presence of finely disseminated haematite which coats the grains. The Old Red and New Red sandstones owe their colour to each sand grain being coated with haematite, this being a reflection of the oxidising regime of the semi-arid conditions of deposition. Only 1-2% iron is enough to produce strong colours. Arkoses (feldsarenites) such as the Torridonian Sandstone have a high percentage of feldspar grains which impart a pink or red colour to the stone. A proportion of feldspar grains may be altered to kaolinite (a white clay mineral). Litharenites, composed of lithic (rock) grains are variable in composition. Their colour depends on the rock fragments present. Varieties of litharenites with high clay mineral contents are prone to failure through the loss of surface skins or veneers. Greywackes are hard, dark grey rocks composed of principally of feldspar and lithic grains with a high percentage of matrix. Greywackes owe their hardness and strength to low grade metamorphism which has affected the strata. Such hard, dark stone has been commonly referred to as "whin" in the north of England and Southern Scotland. Although whin is not used as a petrological classification, it was formerly employed by geologists as a field description of dark compact, igneous rocks such as basalt and dolerite (see Chapter 4.02).

The strength of a sandstone is dependent largely upon the pore cement which binds the grains together. Generally, during the process of sedimentation the pores (spaces) between the grains become partially or wholly filled by silica, calcite, clay minerals or iron oxides. In siliceous and calcareous sandstones silica and calcite respectively form strong bonds, although carbonate cements are liable to corrosive weathering, particularly in town atmospheres. Argillaceous sandstones cemented wholly by clay minerals are generally too weak to use as building stone. Sometimes the sand grains remain virtually uncemented and the rock may be crushed in the fingers. In the Southern Uplands, Lower Palaeozoic greywackes, used in many Border towns, can be strong and durable but fracture irregularly.

Weathering

The definition of weathering varies according to its usage in geological or masonry description. However the geological make-up of the stone including its texture and grain and cement composition are important factors to be considered in both the natural environment and the built setting. These characteristics may be observed both in a hand specimen and in larger structural units, for example quarry faces or ashlar masonry.

In the ground, a rock may undergo a series of weathering changes which can be classified according to the degree to which the strength of the material and the rock's mineral constituents are altered. Both physical disaggregation and chemical alteration may take place. The rock may be affected by changes in climate, burial, temperature and percolating solutions either from the surface or from depths in the earth's crust. The groundwater regime of circulating salt-bearing waters is critical. Movement of groundwater facilitates the transfer of chemicals in solution which in turn may interact with the rock constituents, affecting the strength and chemical composition of pore cements. Such processes may have acted on the body of rock for time spans of millions of years or over much shorter periods.

In the field, the relative hardness of interbedded sedimentary rocks can be observed in natural sections or quarry faces. Concentrations of flaky minerals such as micas on particular planes in the rock or variations in grain-size may reveal the natural layers or bedding formed during deposition which in turn may be exploited in winning the stone. Equally internal planes or laminations within a single bed may more prone to erosion. This may produce differential weathering of rock surfaces in quarry faces, natural sections and in masonry stone faces, particularly if stone is laid with beds 'on cant'(with bedding vertical).

In the built environment, stone is removed from its place of origin and regional groundwater setting and placed in an artificial position, either on the ground surface or at higher elevations. Freshly quarried stone is generally wet and full of 'quarry sap' and it is usually necessary to allow it to dry and season before it is used in a building. Sometimes it is considered desirable to dress freshly quarried stone which is generally softer than its seasoned equivalent. The hardening which seasoning brings to a stone is caused by the fact that the 'quarry sap' contains, in solution or suspension, small amounts of siliceous, calcareous, clay or iron-rich material which is drawn to the surface by capillarity and deposited when the 'sap' evaporates. The deposited material is thought to produce a kind of skin on the exterior of the seasoned stone affording some protection against weathering. Although one stone type is often used, stone of different origin, texture and composition can be employed in wall courses. However the potential for chemical interaction between stones thus placed and between stone and mortar also needs to be considered in assessing the likely performance. Commonly occurring weathering of building stone includes the development of granular dissolution where surface grains become detached to effect a loss of sharpness in tooled faces and polished ashlar. Erosion patterns around edges of the stone may develop if there is interaction between the stone and lime mortar. Delamination may occur where stone is laid 'on cant' due to the development of sub-surface salt crystallisation or clay mineral expansion. Sub-surface salt crystallisation is particularly noticeable in stones subjected to total saturation where zones of salt precipitation efflorescence develop on drying out. Surface veneers and contour scaling may occur irrespective of the natural bed alignment.

(ii) Limestones

Limestones are used as building stone in some parts of Britain. In England, south of the Humber, Jurassic limestones occur in thick beds and have been extensively worked for dressed stone in the Cotswolds, the Bath area and Isle of Portland. In Scotland, beds are generally too thin to be used as constructional stone but have had a long history of usage, in the Lowlands and parts of the Borders and Highlands, as lime for agricultural purposes, in mortar and as a flux for iron smelting. Limestone was occasionally used in rubble construction with sandstone dressings on vernacular buildings in limestone areas (eg. Keith, Aberdeenshire and Lismore Isle). Limited ornamental uses of Scottish black limestones are recorded. An example includes the "Cambuslang Marble" (strictly a shell-rich, limy ironstone) found in the Glasgow area, once much favoured for polished stone fireplaces.

Limestones are formed by the accumulation of shells or the calcareous hard parts of marine organisms, or by the precipitation of calcium carbonate as calcite, or the evaporation of water rich in minerals, depositing crystalline calcium or magnesium carbonate. The Carboniferous strata of the Midland Valley of Scotland record deposition in subsiding sedimentary basins which were periodically invaded by shallow seas. Thin limestones formed at times of marine inundation of the land area. Typically the limestones and associated marine mudstones are fossiliferous, making these rocks valuable for stratigraphical correlation.

The term marble, traditionally used for any decorative stone which will take a polish, is geologically restricted to recrystallised limestones in which new minerals have formed in response to burial and heating of the rock at depths of several kilometres in the earth's crust (see Chapter 4.04).

4.02 Extrusive igneous rocks

Igneous rocks are formed from hot molten source material, magma, which cools to form essentially crystalline rocks. Extrusive igneous rocks are the product of volcanic or fissure eruption in which magma emerges through a weakness in the earth's crust, producing lavas that cool relatively quickly in contact with the earth's surface and atmosphere, into irregular layers of rock. Good Scottish examples of ancient lavas, poured out on the earth's surface can be seen in various parts of the Midland Valley including Devonian andesites of the Pentland Hills and the thick Carboniferous basalts of the 'Clyde Plateau' in Renfrewshire, Lanarkshire and Stirlingshire. Remnants of volcanoes such as Arthur's Seat, Edinburgh are familiar sites, important in the history of early geological research. Younger basaltic lavas of the Tertiary Province are spectacularly exposed on Skye.

Not all magma reaches the earth's surface before solidifying. Some cools in pipes which feed volcanoes, forming plugs. Erosion of the earth's crust over millions of years exposes such rocks at the surface. The crag on which Edinburgh Castle is built is an example where the surrounding sedimentary rocks have been eroded to deeper levels by icesheets. Magma also intrudes into natural planes of weakness within the existing rocks of the crust, forming sheets that are known as sills and dykes. Stirling Castle crag stands on a sill, an intrusion which lies parallel to the bedding planes of the sedimentary rocks which lie above and below it. Dykes are planar bodies of igneous rock which have intruded across the principal bedding planes of the preexisting rocks. When exposed by erosion, they often form wall-like features and are commonly relatively narrow features, only a few metres thick. Rapid cooling produces closely spaced joints, a characteristic which enables easy extraction but which limits the potential for using these rocks for dressed stonework. Such rocks are typically hard and intractable and thus are difficult to dress.

Typically basalt and dolerite of the Midland Valley are dark grey to black rocks composed of very small interlocking crystals comprising feldspar and magnesium- and iron-rich silicate minerals. Such rocks yield tough but aesthetically uninteresting stone, quarried extensively in the past for use as setts for paving carriageways and in modern times for roadstone aggregate, providing rough-wearing surfaces. Andesite although similar in texture to basalt, varies in colour from pale pink to red. The widespread use of stone of volcanic origin in rubble walling testifies to its abundance and availability throughout the Lowlands. On the west coast, too, it proved a valuable source of material as can be seen in rubble walls of many buildings.

4.03 Intrusive igneous rocks : granites

Large bodies of magma also cool at depth in the crust.

Relatively slow cooling permits growth of large interlocking crystals of minerals which form rocks such as black gabbro and red and grey granite. Although a wide range of medium- to coarse-grained igneous rocks, including imports from overseas, have been used in Scottish buildings, particularly in recent years as cladding to concrete structures, it is the indigenous granites which have had a particularly long and notable history of use in Scotland. Their distribution (Figure 1) where it coincided with populated and accessible areas, has dictated the principal location of the granite quarrying industry. Thus Aberdeenshire and, to a lesser extent Galloway, have provided the bulk of the best material. A general (geologically *sensu lato*) definition of granites embraces all medium to coarse-grained, light-coloured igneous rocks with at least 5% quartz. Individual crystals should be discernable with the naked eye. Compositionally, granites contain between 55 to 75% silica. The mineralogy of the granite group comprises quartz and silicate minerals including orthoclase and plagioclase feldspar, muscovite (white) mica, biotite (black) mica and amphibole.

The crystal size has a direct bearing on the purpose to which the stone will be used. Thus fine-grained varieties may be more suitable for roadstone and may weather better and be less liable to spalling in monumental and building work than coarse grained types. Porphyritic textures, in which large crystals, usually of feldspar, occur in a fine-grained groundmass tend to be of less value for setts and roadstone but can be used to striking effect in ornamental work. The large crystals display the variation in the natural colours of the rock's constituent minerals, a characteristic utilised to advantage in monumental work and for decorative purposes in buildings. Colours vary from grey to pink according the proportion of pink feldspar in the rock. The dark minerals amphibole and biotite mica give a variegated appearance. There are also rare occurences in Scotland of 'black granite' such as the kentallenite (found near Ballachulish, and used as a handsome polished dark monumental and ornamental stone) which owes its colour to the presence of olivine, pyroxene and large plates of biotite.

In granites the cohesive texture of interlocking crystals which prevents the plucking out of grains during polishing enables a brilliant finish to be achieved. This contrasts with the matt finishes of 'polished' sandstone ashlar in which grains are more likely to be dislodged. The capability of granite to withstand large loads and ability to weather well has been utilised in the construction of plinth courses and for functional works such as bridges and docks.

The working of granite in the quarry to some extent utilises the visible natural breaks (fractures or joints). These joints are planes in the rock, often approximately vertical in orientation, which are related to the way in which the rock has cooled. They are widely spaced, rendering the rock more difficult to split in the quarry but enabling large blocks and relatively thin flat sheets, free from natural fractures, to be won. Quarrymen in Scottish quarries used the terms 'reed' ('rift' or 'first way') and 'hem' ('grain' or 'second way') to describe planes along which the rock would split. 'Reed' was the direction of easiest splitting. At right angles to the 'reed', the 'hem' provided the second easiest splitting direction. These directions frequently, but not always, coincide with the directions of jointing. At right angles to the 'reed' and 'hem' the rock is often difficult to split and this direction was referred to as the 'hard way', (tough way' or 'head') and produced more uneven surfaces.

The preferred directions of splitting of granites can be related to the mineral orientation in the rock, for example in a foliated granite where the mica and amphibole minerals are aligned in one direction, but this is not always the case. There may be other factors, such as minute hairline cracks, aligned to fluid-filled cavities in quartz crystals, in the rock which will facilitate splitting. Compared with many sandstones the geological structural and textural characteristics of granites enable a wider range of block size to be worked. This in turns provides a greater freedom in the ultimate use of the stone.

4.04 Metamorphic Rocks

When rocks are subjected to high temperatures and stresses deep within the earth's crust their physical characteristics may be changed. This process, known as metamorphism, produces crystalline rocks containing new minerals and exhibiting new textures. Although the rocks are often tougher and stronger than the previous material they may be more brittle than the original rocks and are susceptible to fracture in subsequent folding. A wide range of metamorphic rocks can be formed according to the depth of burial in the earth's crust (in the order of tens of kilometres) and temperatures (up to 900 degrees C) to which rocks are subjected. Although the texture and mineralogy of a metamorphosed rock are used to determine the degree (grade) of metamorphism, the mineralogy of the original material also has to be considered.

(i) Quartzite

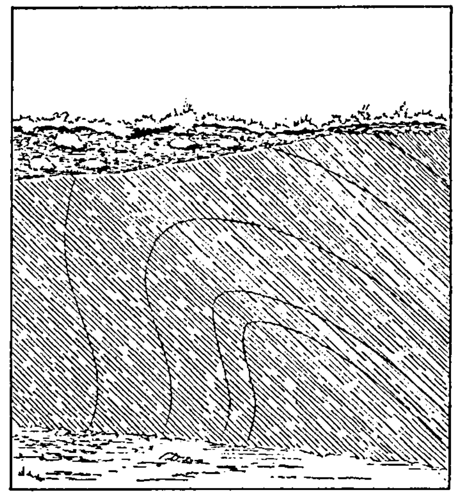
Relatively low grade rocks include quartzites (metamorphosed quartz-rich sandstones) which occur within the Dalradian sequence of the Grampians and Cambrian strata of the north-west Highlands. These recrystallised white, quartz arenite sandstones often display primary natural bedding and this feature together with vertical joints often produces naturally formed, approximately square blocks which can be utilised as building stone. Because the strata have been hardened during metamorphism such blocks may less easy to dress compared with sandstones. Block height to length ratios similar to those of the Southern Uplands greywackes (1:3 to 1:5) are seen walls constructed of quartzite.

(ii) Slate

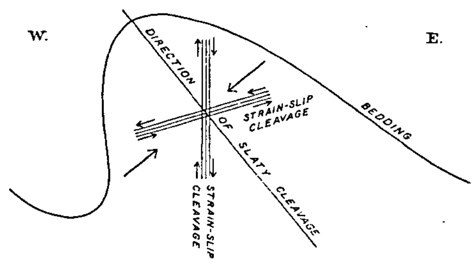
Slates are the most commonly used low grade, fine-grained metamorphic rocks. They commonly occur in varying shades of purple, grey and green. They originated from mudstones (fine-grained sediments, which possessed natural bedding and lamination). When the mudstones are subjected to lateral compression and folded, new minerals, usually mica and chlorite form along planes normal to the direction of the compression and parallel to fold axes to develop slaty cleavage (Figure 6).

Slates usually split or cleave easily along this direction and sometimes the new minerals impart a sheen to the freshly cleaved faces. The process of metamorphism imparts a strength to the rock and the slaty cleavage, although rendering the material quite unsuitable for use as dressed stone, enables thin slabs to be split for roofing. Not all slates require to be cut to the same size and, in Scotland, a common practice was to use slabs of diminishing size on a roof, thus more fully utilising the available resource. A broader non-geological definition of slate has been used in the past to include fissile siltstones such as those from parts of the Southern Uplands. However the fissility is due to the close-set nature of original bedding planes and the siltstones, being weaker than true slates, have to be split into relatively thick, heavy slabs.

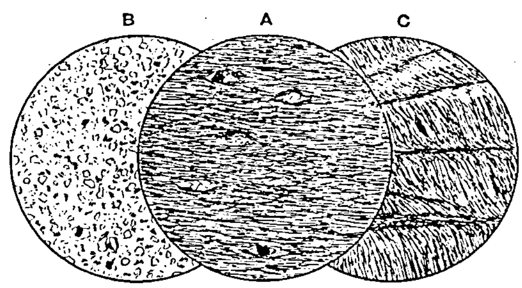
Geological factors which may affect quarrying of slates include dykes and larger masses of igneous rock which may intrude the slate beds. In these circumstances, the heat from the igneous rocks may effect the development of close-set joints in adjacent slates and destroy the slaty cleavage. Strain-slip cleavage (closely spaced fracture planes) which is also frequently developed at wide angles to the slaty cleavage (Figure 6b) can be a serious problem, rendering the slate difficult to work. The development during metamorphism of cubic pyrite crystals within some beds of a slate belt can also affect the quality of the material but provided the crystals are not large and decomposed, they tend to split in two and stay in place when the slates are made.



(a) —DIAGRAM SHOWING RELATION OF SLATY CLEAVAGE TO FOLDING.



(b) .-DIAGRAM SHOWING RELATION BETWEEN BEDDING, SLATY CLEAVAGE AND STRAIN-SLIP CLEAVAGE.



(c) —MICROSCOPIC SECTIONS OF SLATE
A, at right angles to the cleavage
B, parallel with the cleavage
C, strain-slip cleavage
(Quoted, with permission, from fig. 17, p. 280, 'The Geology of Building Stones' by J. Allen Howe, 1910.)

Figure 6 Relation of slaty cleavage to folding

Reproduced by permission of the Director, British Geological Survey.

From Richey, J E and Anderson, J G C. 1944. *Scottish Slates.* Wartime Pamphlet No.40. Geological Survey of Great Britain.

(iii) Schist

Higher grade rocks include schist in which concentrations of new recrystallised minerals are aligned to produce a banded effect known as schistosity. Owing to the high proportion of constituent micas, schists have variable weathering characteristics and some disintegrate mechanically relatively easily. Harder wearing schists are suitable for sculpting. The mineralogically distinctive 'greenbeds' of calc-chlorite-albite schist from the Loch Sween district of Argyll have been used throughout the west coast of Scotland and Outer Isles as a source for medieval crosses and grave slabs. Intricate well preserved carving may suggest that the stone was soft when first quarried but hardened on exposure.

(iv) Gneiss

At the highest temperatures and pressures the original rock may be totally recrystallised as in gneiss. These rocks are generally very hard to work and exhibit colour banded foliation composed of concentrations of the recrystallised minerals. Gneiss, being locally readily available in the North-western and Northern Highlands and Outer Hebrides has often been used for wall and house construction. As an external construction stone, it is almost invariably rock-faced.

(v) Marble

Other forms of metamorphic rock used for building stone, particularly for interior finishes include marbles. These rocks originate from limestones and their colour, mineralogy and texture are dependent on the composition of the original rock. In Scotland marbles have been quarried on a small scale for ornamental and decorative purposes. 'Marble' has been used traditionally by quarrymen and stone masons to describe some limestones which are comparable as building materials to marbles, particularly in their ability to take a polish. True marbles are limestones which have been subjected to sufficiently high temperatures within the earth's crust to crystallise the rock, producing a tough, fine-grained stone which can be sawn and polished, providing an impervious and decorative surface. Metamorphism of impure limestones has commonly resulted in the development of coloured marbles in which colourful silicate minerals such as serpentine minerals are present. Marble composed of serpentine and calcite, the rock known as ophicalcite, was formerly quarried on Iona (the Iona Marble). Coloured marble is currently worked at Ledmore near Lairg (Ledmore North Quarry is operated by Ledmore Marble Ltd). Some of the marble at Torrin is also coloured (Skye Marble). The commonly occurring yellow, green and blue colour mottling of such marbles may be controlled by the movement of mineral-rich fluids along small discontinuous joints. In the quarry block size is determined by the larger more continuous joints and slabs can be cut to dimensions of a few metres making the material suitable for panel work and interior floors.

(vi) Serpentinite

Metamorphism of igneous rocks of ultra-basic composition (very low in silica content) such as dunites or peridotites commonly produces a rock composed mainly of serpentine group minerals. Such serpentine-rich rocks are termed serpentinites. Whereas serpentinites are commonly rather drab, dark coloured rocks, they are also locally found with attractive colouring and/or patterning. Small masses of serpentinite have been worked as ornamental stone at various places. Perhaps the best known is the serpentinite formerly worked as 'Portsoy Marble' in Banffshire. Similar serpentinites occur at Girvan in Ayrshire. A dull greenish grey serpentine-rich rock (a talcose-epidiorite) was used in the construction of Inverary Castle where the sharpness of the arrises indicate that the stone, although soft and easy to work, is durable.

5.00 QUARRIES: A PICTORIAL RECORD

The photographs, mainly from the BGS Collection, illustrate building stone quarries and working methods. Links are made between the geological characteristics of the worked stone and ultimate use to which the stone is put. Rock types discussed include sandstones, granites, slates and marbles. Figure 2 illustrates the general quarry locations and Appendix 1 lists the photographs presented. Of the quarries described only about four are currently (1996) working building stone. Currently working Scottish quarries supplying building stone (including flagstone) number in the order of 20 (Figure 3, Appendix 2). This figure is variable depending on whether quarries operated on a "snatch" basis (Chapter 1.04) are included.

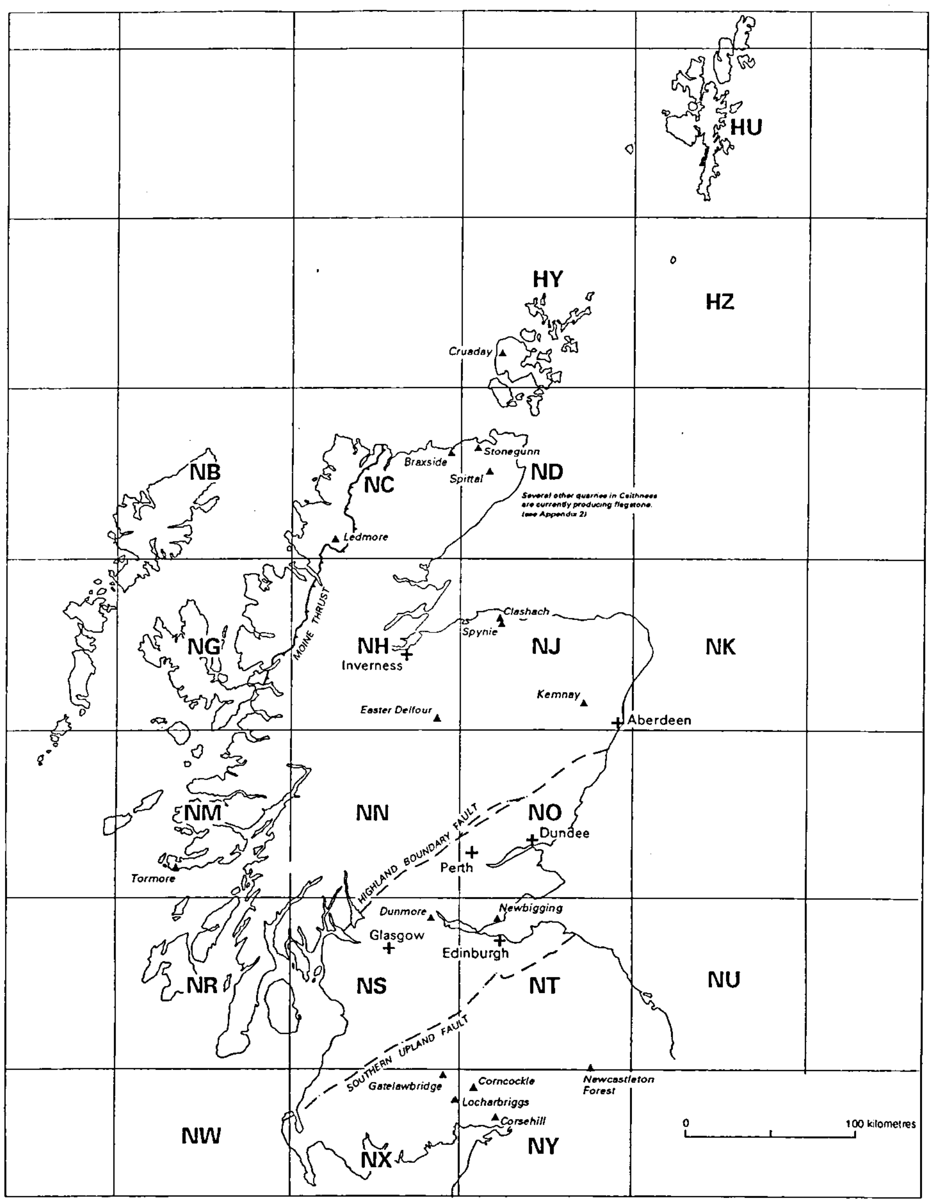


Figure 3 General locations of quarries currently (1996) producing building stone

Many sandstones ranging in age from Devonian (Old Red Sandstone) to Jurassic have been quarried in Scotland. The photographs illustrate not only the variety of sandstones worked in Scotland but also the quarrying equipment and methods. These have changed surprisingly little over the centuries. Some of the commonly used quarrying hand tools are illustrated in Figure 7.

Mattocks, hoes, shovels, rakes and spades were used for uncovering the stone and removing the overburden or 'tirr' as it was called. Hammers of various shapes and weights were used to shape the stone or to drive in the drills. Crowbars, wedges or picks were often employed to lever the stone off the bed so that it could be lifted with a crane. The main modern development has been in the use of mechanical equipment for

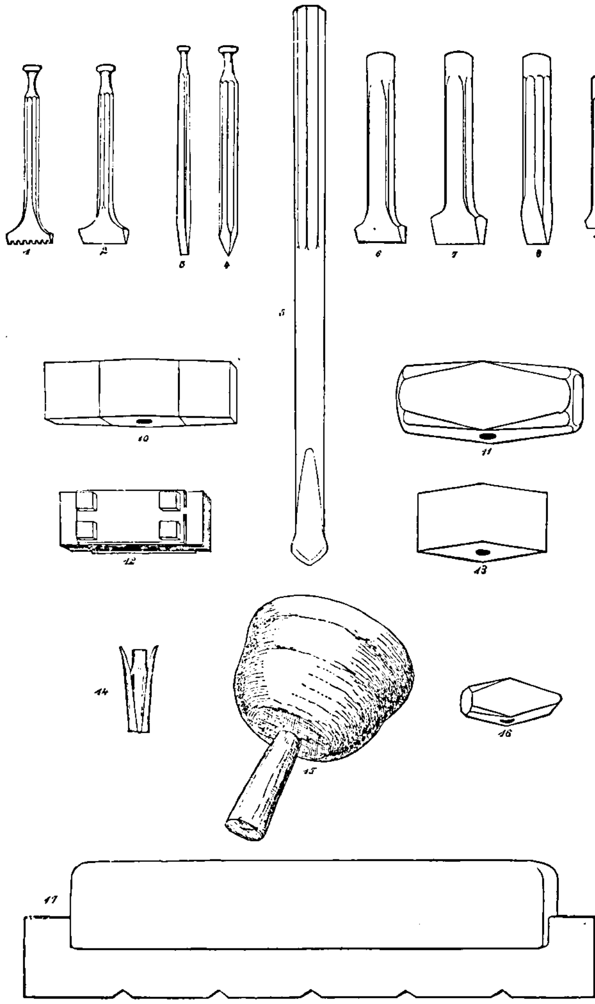


Figure 7 Hand implements used in stone working

Adapted from Merrill, G P. 1910. *Stones for Building and Decoration.* (New York: John Wiley & Sons)

1. Tooth chisel used on soft stone

2. Chisel or drove

3. & 9. Chisel used on soft stone and driven with wooden mallet

4. Point, cutting end in form of a pyramidal point

5. Hand drill or jumper used for making holes for 'plug & feather' splitting

6. & 7. Point for use on hard stone

8. Splitting chisel for splitting and cutting of hard stone such as granite

10. Face hammer, square-faced, for roughly shaping blocks

11. Sledge or striking hammer used in driving large wedges for splitting stone

12. Patent or bush hammer with deeply grooved faces

13. Ax or pean hammer with two opposite cutting edges

14. Wedge (plug) and feather used in the process of splitting (up to 8cm long); long wedges (30 cm) for splitting off large blocks

15. Mallet, wooden, cylindrical head, used in cutting of soft stone

16. Hand hammer, smooth-faced, for hand-drilling, pointing and chiselling hard rocks

17. Grub saw for cutting stone by hand

moving stone. From the earliest times cranes were used, first operated by muscle-power (human or horse) then powered by steam, diesel and electricity. Mechanical methods of stripping the overburden, either glacial drift or useless strata were introduced during this century.

Good quarrying practice ensured that stone was carefully handled during and after quarrying. Dropped or knocked stones, for example, may develop unseen small scale fractures at the site of the shock which may open up when the stone is exposed to weathering. Large charges of explosive are rarely used when regularly shaped building stone is required. The use of excessive explosive produces minute cracks in the rock which may jeopardise the use of the stone for building purposes. Coarse-grained black powder is preferred to other blasting agents (e.g. dynamite) since it acts more slowly and less shattering is produced. Sometimes a small charge of black powder was used to split a stone. A tool called a reamer is used to cut a groove down each side of a previously drilled shot hole in the direction of the desired break and the elongated hole is then charged and fired. Manual methods of splitting blocks, for example using plug and feathers (Section 5.06), are best employed for producing good quality stone.

Geological characteristics to a large extent determine the dimensions of quarried blocks which in turn dictate the character of the ultimate build. The geology should also determine proper use of stone in modern buildings and it is important that the building design does not over-specify the requirements. Thus specification of excessive dimensions of some sandstones may fail to recognise the geological constraints on block size and may result in buildings which are both aesthetically unattractive and structurally unsound. With sandstones, the key determining factors are bedding, jointing and composition. The lateral continuity of a bed and uniformity of bed thickness are also important. Thus large intact blocks can only be hewn if the bed of sandstone is itself intact. Generally, massive, siliceous, sandstones with little or no internal lamination and widely spaced vertical joints will yield large blocks although the extracted stone may be difficult to split and cut. Such stone is typically used in ashlar and pillars. Finely bedded or laminated sandstones, with concentrations of mica flakes on the laminae, will split naturally along bedding planes, yielding material more suited to steps, plats and foundations and inner walls of houses. Flagstones, laminated fine-grained sandstones, split into thin beds which are of sufficient strength to be used as pavement.

5.01 Caithness Flagstones

Flagstone is so named on account of the thinness of beds which split easily into flat, parallel sided paving stones or slabs. The strata were laid down originally as muddy, fine-grained silts and sands within large freshwater lakes during Devonian (Old Red Sandstone) times. One such lake "Lake Orcadia" extended across much of what is now Caithness and beyond to Orkney and Shetland. Working of the flagstones particularly in the 19th Century yielded fine specimens of Old Red Sandstone fossil fish.

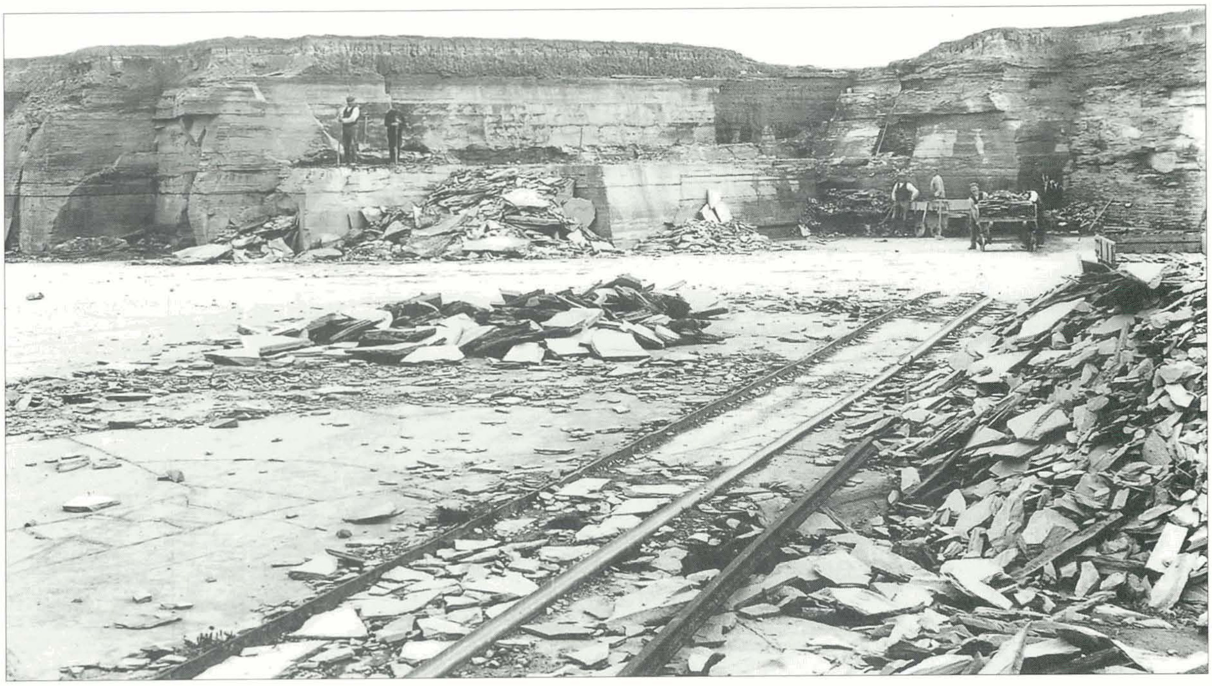
The flagstone industry has had a long history in Caithness, Orkney and Shetland and also in parts of Angus. In Caithness, flagstones are currently worked at quarries at Spittal, Watten by A & D Sutherland and Caithness Stone Ltd; at Stonegunn, Castletown by Caithness Stone Ltd; at Weydale, Thurso by Caithness Flagstones Ltd; and at Achavrole, Calder by Scotstone Ltd (Appendix 2). In the Orkney Isles, flagstone is worked at Cruaday, Sandwick by Orkney Builders Ltd.

The continuity and uniform thickness and fissility of the beds has utilised to good effect and the principal uses of the stone were in paving and roofing. Stone for these purposes was in much demand during recent centuries for cities and towns. Flagstone has been used locally over several thousand years until the present for construction of dwellings and other purposes including field boundaries.

The colour of flagstones varies considerably. The interbedded carbonate-rich siltstones and silty, micaceous, laminated sandstones of Caithness are generally grey. In Orkney and Shetland, both red and grey brown flagstones occur commonly within the Old Red Sandstone succession. Both these and more thickly bedded sandstones have been used locally for building purposes. The famous Carmyllie Quarries of Angus yielded much grey flagstone for paving and the flooring of buildings.

The thickness of stone which can be specified is determined by the spacing of bedding planes of the flagstones. The thin natural laminations of stone found in Shetland, Orkney and Caithness produce a natural height to length ratio of between 1:4 and 1:8. This determines the characteristic horizontal appearance of buildings seen to good effect in early dry stone builds such as the 5000 year old Maes Howe Chambered Cairn of Orkney. Larger stones were used for monolithic lintels, sills and jamb doors. Modern farm buildings in this material also exhibit the same horizontality.

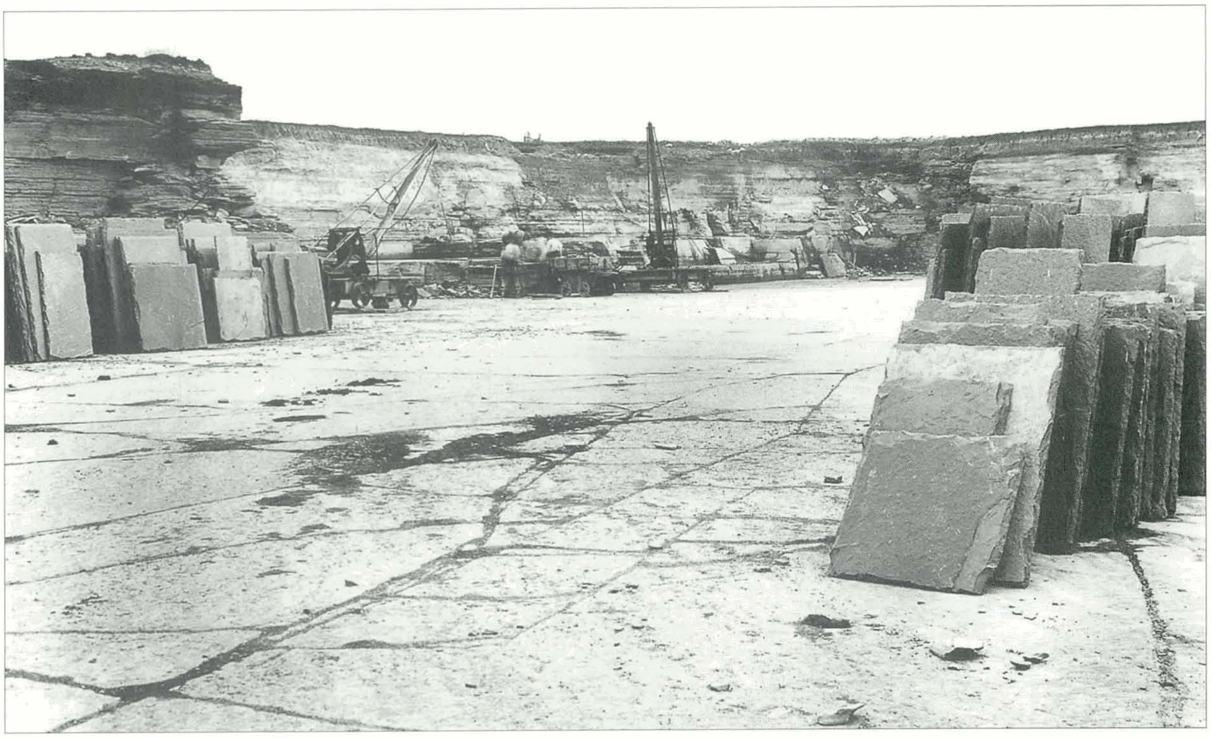
BGS photographs of Caithness quarries taken in about 1910 illustrate the working of flagstones and their geological characteristics.



Holborn Head Quarry, Thurso (C1534), c.1910

This photograph shows the working face and workmen removing the 'tirring' (superficial deposits and inferior flagstones) from the marketable rock. Often the flagstone bedding is horizontal, the strata having been little affected by post-depositional earth movement and folding. This has made for easy working and transportation either by cart or on a railway to the cutting shed. Spoil is seen piled on the floor of the quarry ready for possible local use in rubble walls.

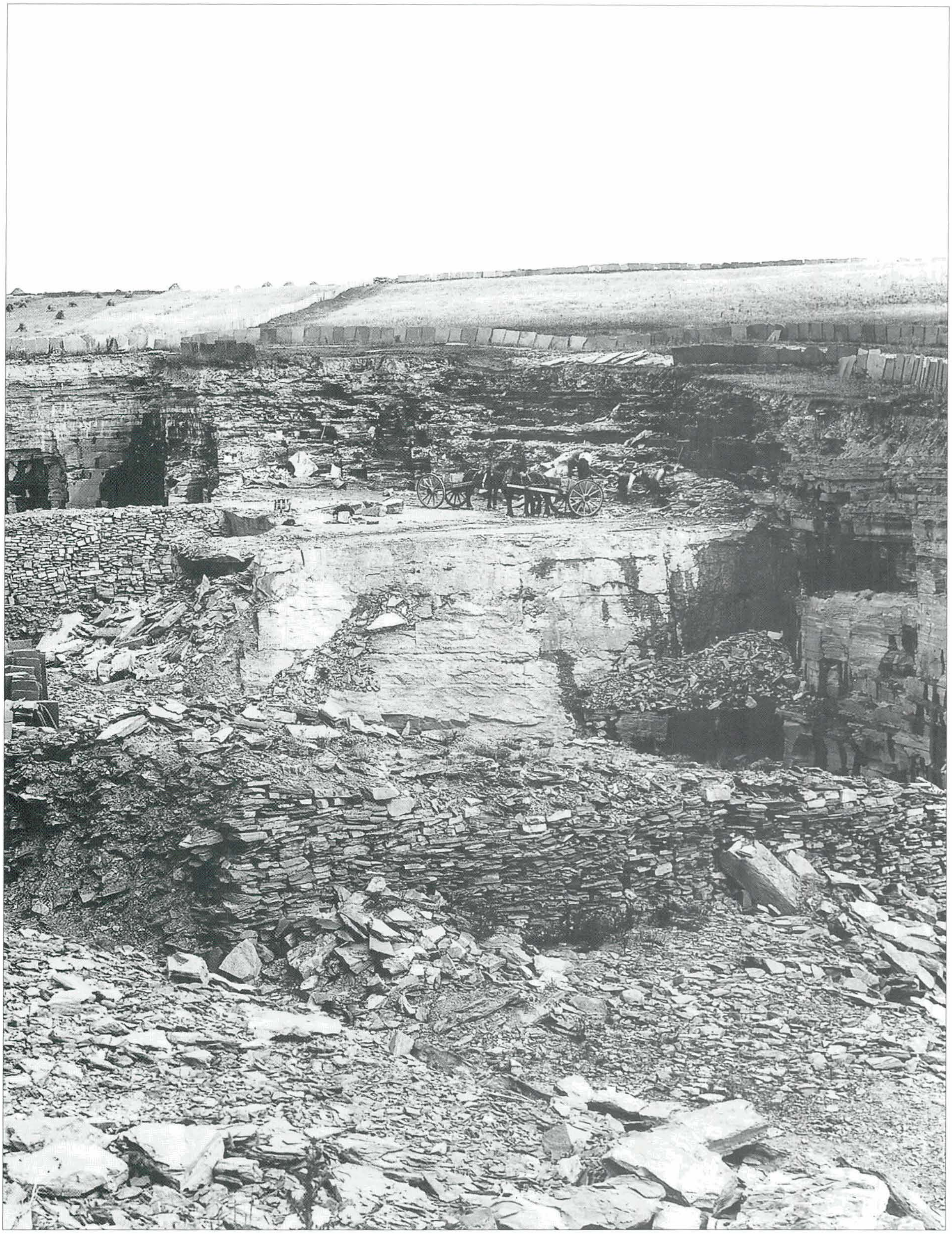
Photograph courtesy of the British Geological Survey.



Holborn Head Quarry, Thurso (C1533), c.1910

The floor of the quarry is along a bedding plane of inferior quality which also reveals the square pattern of vertical joints utilised during the working of the stone. Squared flagstones ready for removal to be sawn are piled on the clean flat floor.

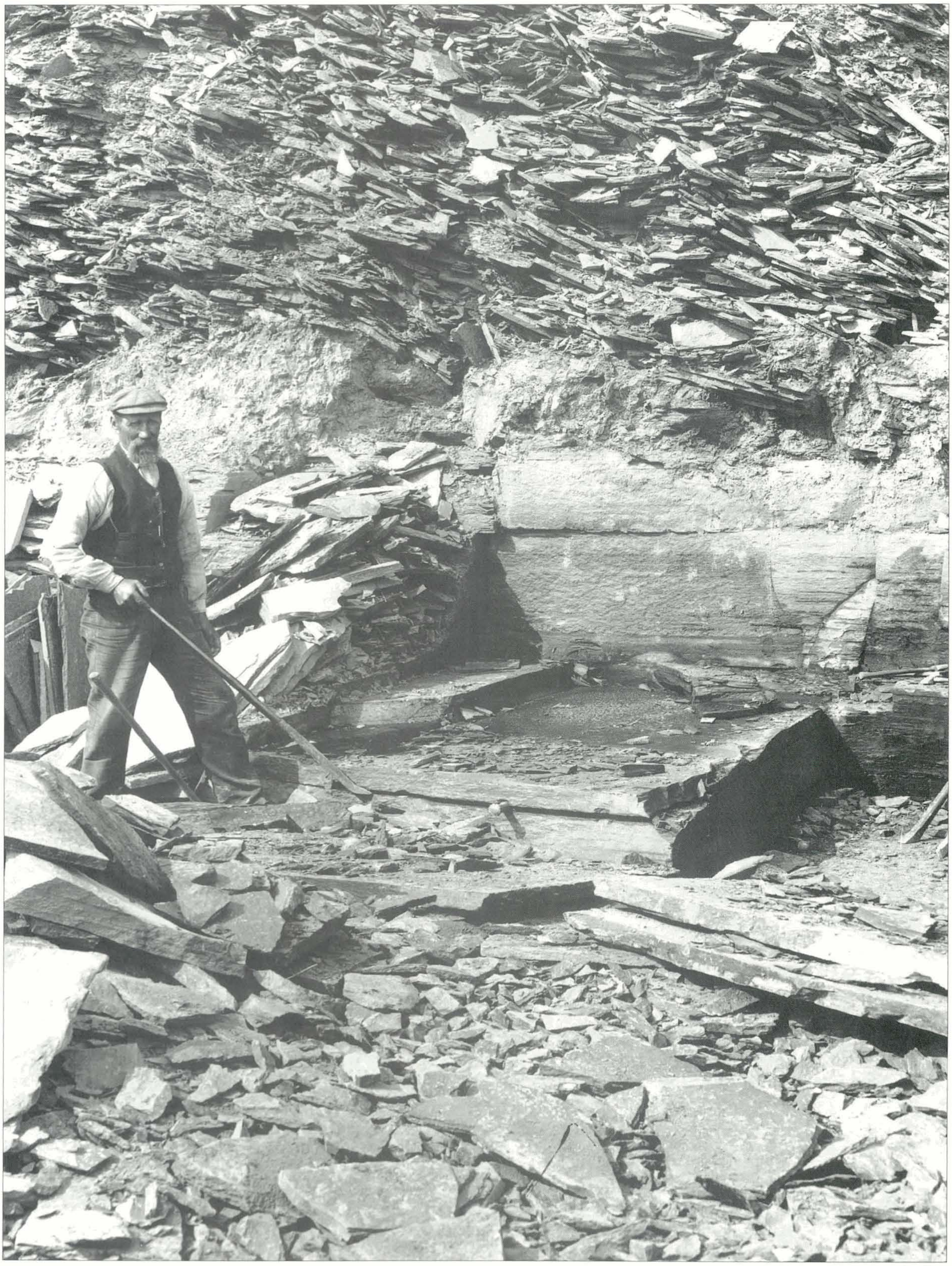
Photograph courtesy of the British Geological Survey.



Youkil Quarry, Hilliclay, Thurso (C1552), c.1910

Note the use of ponies, harnessed to two wheeled carts for transporting stone. A cartway is supported by retaining rubble walls. Large quantities of spoil are held back by rubble walls. Some squared flagstones are seen on the left of the photograph. In the background, slabs placed vertically form a fence beyond which harvested stooks can be seen.

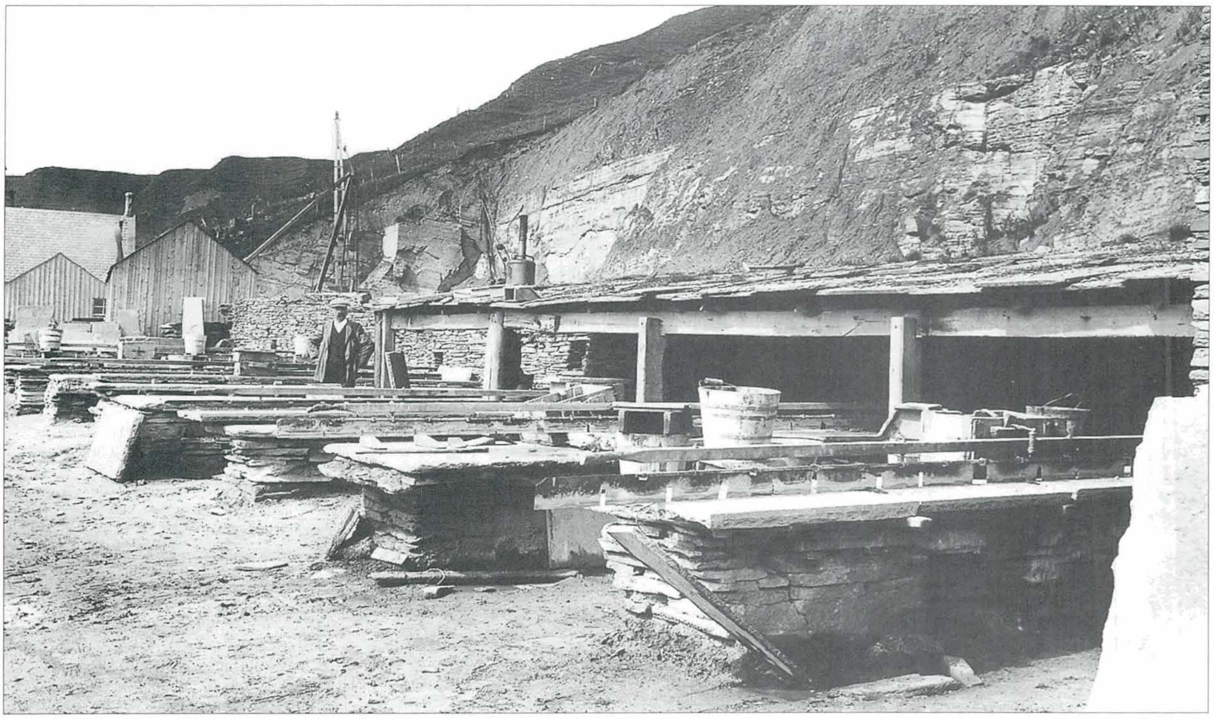
Photograph courtesy of the British Geological Survey.



Stonegunn Quarry, Thurso (C1555), c.1910

The method of levering the flagstone is shown well in this photograph. Each bed is split with the use of sledge and chisel and then levered off its bedding plane with a crowbar.

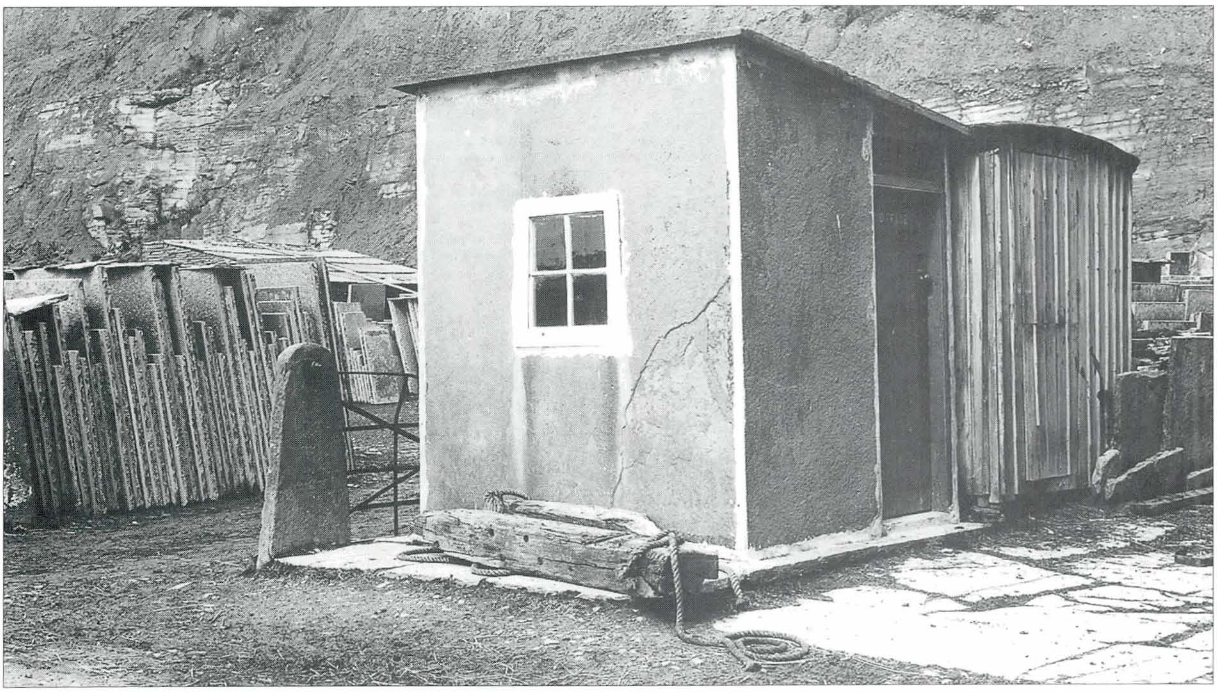
Photograph courtesy of the British Geological Survey.



Scrabster Quarry, Thurso (C1543), c.1910

Photographs of Scrabster Quarry illustrate how much of the local material had an immediate use on site. Flagstones were used for the cutting tables and the roofs of the adjacent sawing sheds. In the background is a steam-driven crane. Slabs are laid "on bed" in walls. Working has ceased on this face of the quarry where the strata are overlain by a thick overburden of till.

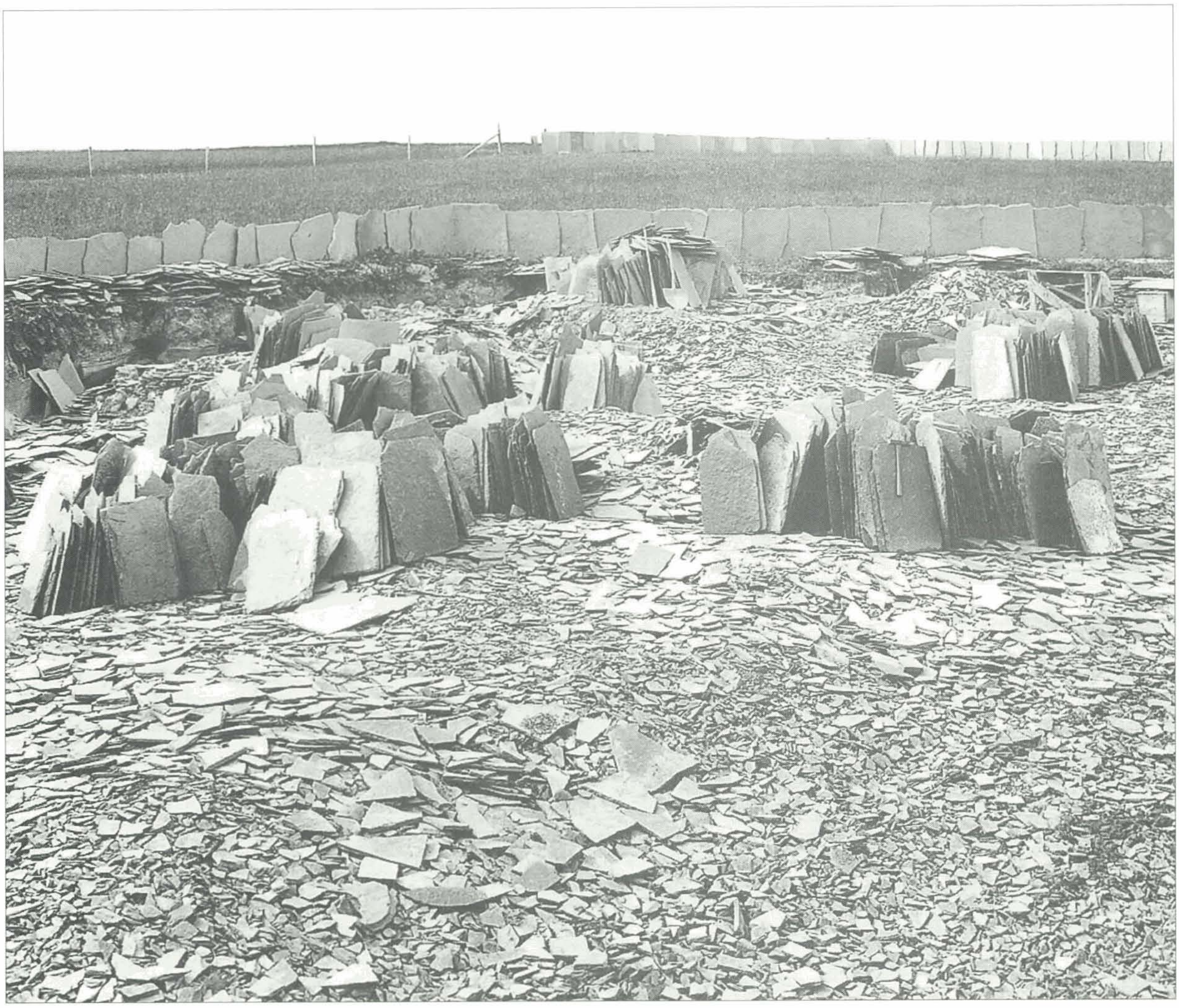
Photograph courtesy of the British Geological Survey.



Scrabster Quarry, Thurso (C1544), c.1910

The roof and walls of the office and gate post were also constructed of flagstone from the quarry, illustrating the large dimensions of slabs which can be obtained. Small buildings could often be roofed with 3 or 4 large slabs.

Photograph courtesy of the British Geological Survey.



White Moss Quarry, Thurso (C1554), c.1910.

Thin flags, used as green ornamental stone-slates are piled ready for export. In the background is an example of a characteristic Caithness 'flag fence' (field wall) with slabs set in the ground on edge in a tight fitting arrangement.

Photograph courtesy of the British Geological Survey.

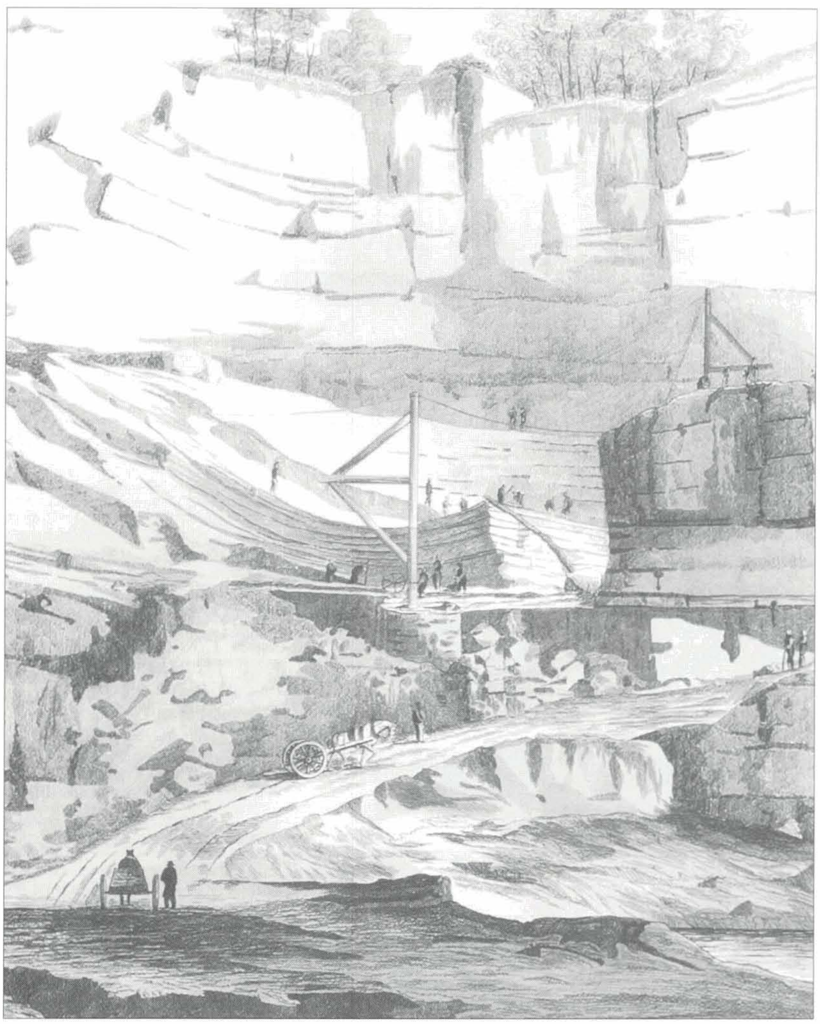
5.02 Carboniferous Sandstones of the Midland Valley of Scotland

Widely distributed beds of sandstones laid down mainly as river sands during the Carboniferous are present in the Midland Valley of Scotland. They supplied by far the largest proportion of constructional stone in central Scotland. Often quarries would supply a variety of material from the best constructional stone, traditionally referred to as 'liver rock', for ashlar as well as more thinly bedded stone suitable for rubble work in walls. The best quarry sources supplied a flourishing export market to other parts of Britain and abroad. Many of the once famous quarries around the cities of Edinburgh and Glasgow ceased operations several decades ago and have been used subsequently as landfill sites. A selection from early engravings and prints and the BGS photographic archive illustrate this once thriving quarrying industry.

(i) Craigleith Sandstone

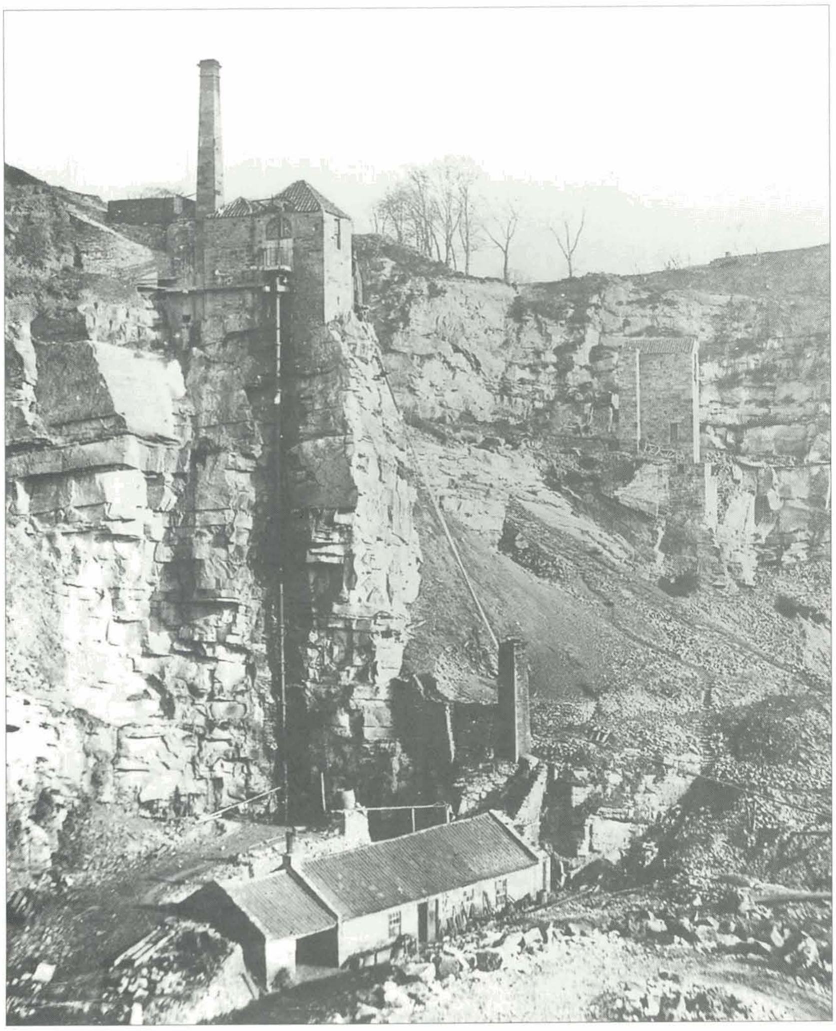
In the Edinburgh area three principal stratigraphic horizons within the Lower Carboniferous were once worked, namely the Craigleith, Ravelston and Hailes sandstones. The Craigleith Sandstone attains a maximum thickness of over 100m and comprises in the main a highly siliceous, close-textured, fine-grained, grey sandstone. Beds vary from a few centimetres to 4m. The stone was described as 'well nigh imperishable' and was used extensively as ashlar in Edinburgh, particularly parts of the New Town, as well as in London, Europe and the United States. The largest beds supplied stone for monolithic pillars. It was worked at many quarries notably Craigleith, Ravelston, Craigcrook, Maidencraig (Blackhall) and Granton (Sea and Land) quarries.

At Craigleith, the quarry face was said to have been 110 m deep of which 104 m was solid rock. It is now infilled and only the top few metres are exposed and preserved, courtesy of Sainsburys plc, as a Regionally Important Geological Site, a reminder of the once famous workings. A second quarry to the north and separated from the main Craigleith Quarry by a fault was worked intermittently during the first forty years of the 20th Century. Latterly stone was worked for rubble and aggregate.



Craigleith Quarry, Edinburgh (Engraving, Transactions of the Royal Society of Edinburgh), 1834

An early 19th Century engraving illustrating a paper by H Witham shows the extent of working at the time of the building western extension of the New Town. The engraving shows one of the large specimens of fossil trees (*Pitus withami*) which were discovered, an example of which may be seen at the Royal Botanic Gardens, Edinburgh.



Craigleith Quarry, Edinburgh (Thomas Begbie), c.1850

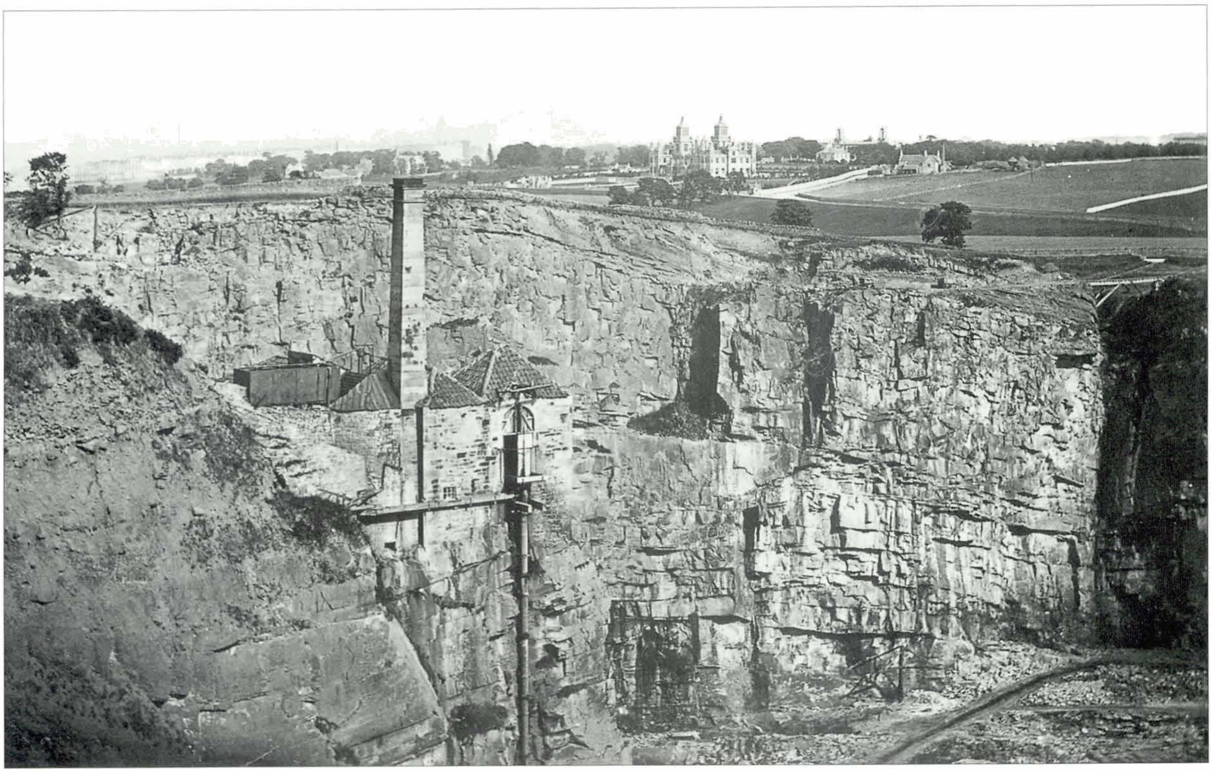
This dramatic photograph shows the quarry at a time when the stone was becoming too expensive to work. The quarry is partially infilled with spoil. Thick massive beds of sandstone are exposed in the face beneath the pump engine house.

Reproduced by permission of the City Art Centre, Edinburgh.

Craigleith Quarry, Edinburgh (W D Clark), c.1858

Taken at about the same time, this photograph, looking east, places the quarry in its setting on the western fringe of the city. Stewarts Melville College, built 1849-55 mainly of Binny Sandstone from West Lothian, is seen beyond the quarry with Edinburgh Castle and Arthur's Seat in the background. Contrast the thickly bedded massive sandstone at the base of the quarry with thin overlying strata.

Reproduced by courtesy of Edinburgh City Libraries.



(ii) Hailes Sandstone

The Hailes Quarry, now completely infilled, exemplified the variability of the building stone and the utilisation of the available resource for a variety of purposes. In 1892 the quarry was said to have been in operation for 300 years. The extent of pre-World War I workings can be seen in an extract (Figure 8) from the Ordnance Survey 25 inch County map (Edinburghshire Sheet III.13 & 14, 1914 edition).

Different parts of the quarry yielded white, greyish or blue, and pink stone.

The blue and pink sandstones were ripple laminated with irregular micaceous, carbonaceous wisps (see Photograph C3114, Chapter 4). The 'pink' sandstone was tinted red by iron oxide.

The geological characteristics, in particular the laminated structure and thinly bedded nature of the Hailes Sandstone determined usage predominantly as plats and steps, in foundations and for squared rubble work. Unlike the 'liver rock' of Craigleith, it was not used as a source of sawn ashlar on external walls of buildings or for window openings and door jambs.

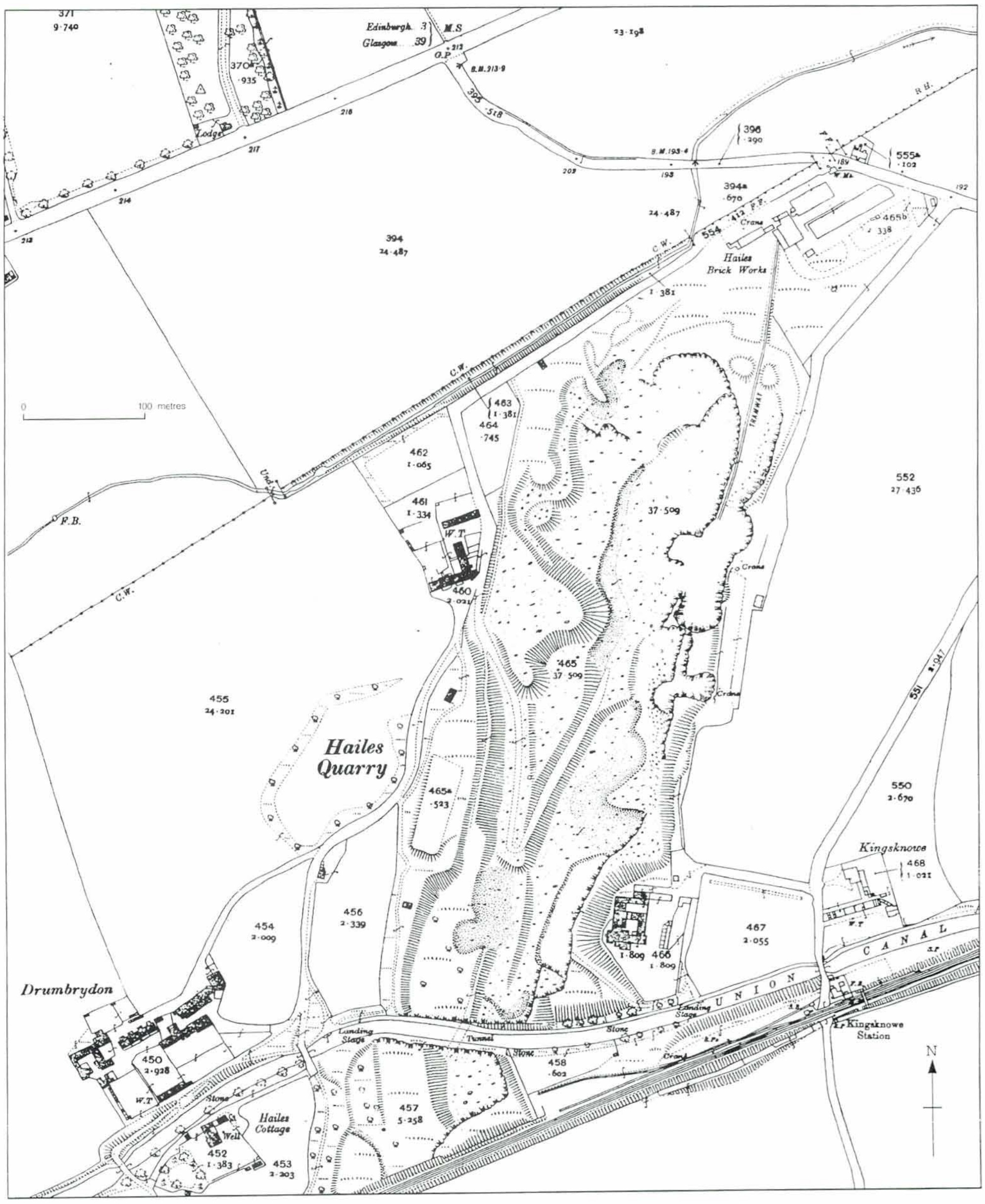
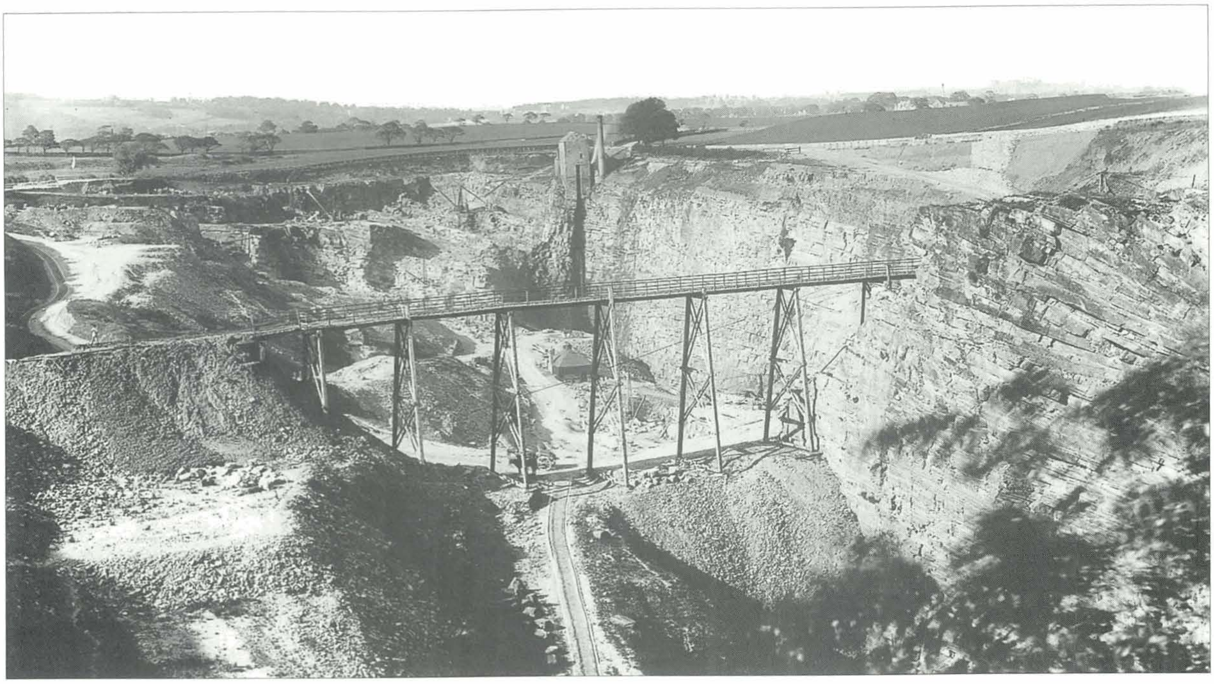


Figure 8 Hailes Quarry: Extract of the Ordnance Survey 25 inch County Map Edinburghshire III.13 and III.14 (1914 edition)

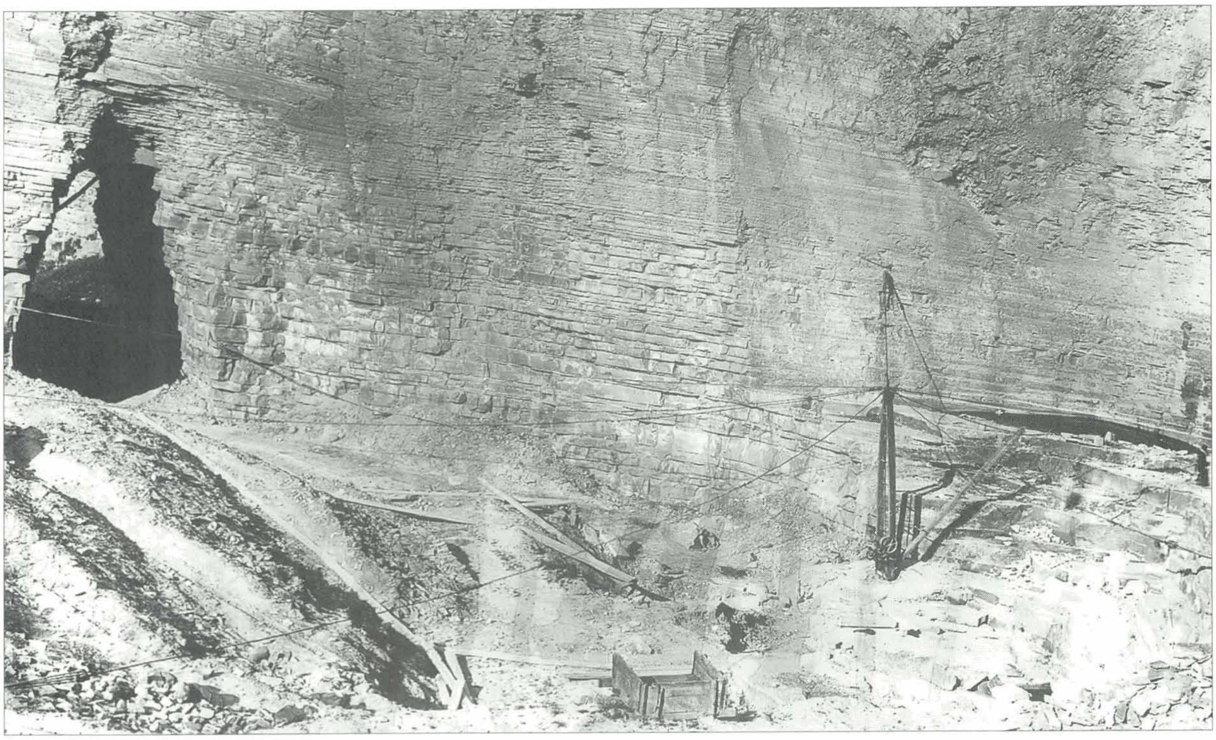
Note scale is reduced



Hailes Quarry, Slateford, Edinburgh (B932), c.1913

This photograph shows the general view of the quarry looking north, with the tramway bridge (not shown on the Ordnance Survey 25 inch County map, 1914 edition) and steam pumping engine in middle distance. Corstorphine Hill and Donaldson's Hospital are in the background. At this end of the quarry, the blue stone was more of a 'liver rock' in which lamination was not discernable.

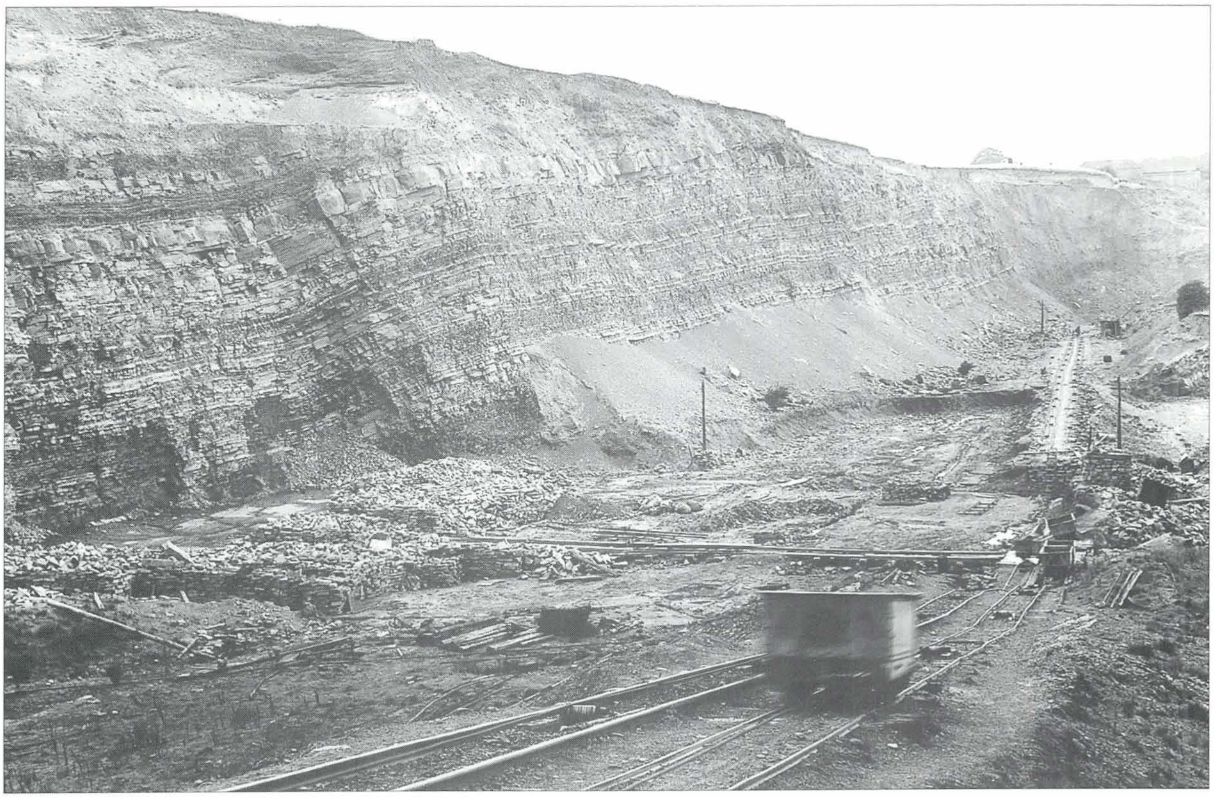
Photograph courtesy of the British Geological Survey.



Hailes Quarry, Slateford, Edinburgh (B933), c.1913

At the south end of the quarry, faces exposed beds which became progressively thinner upwards. Note the wire rope stays for the crane. To the left, a tunnel under the Union Canal (Figure 8) connected with another part of the quarry to the south.

Photograph courtesy of the British Geological Survey.



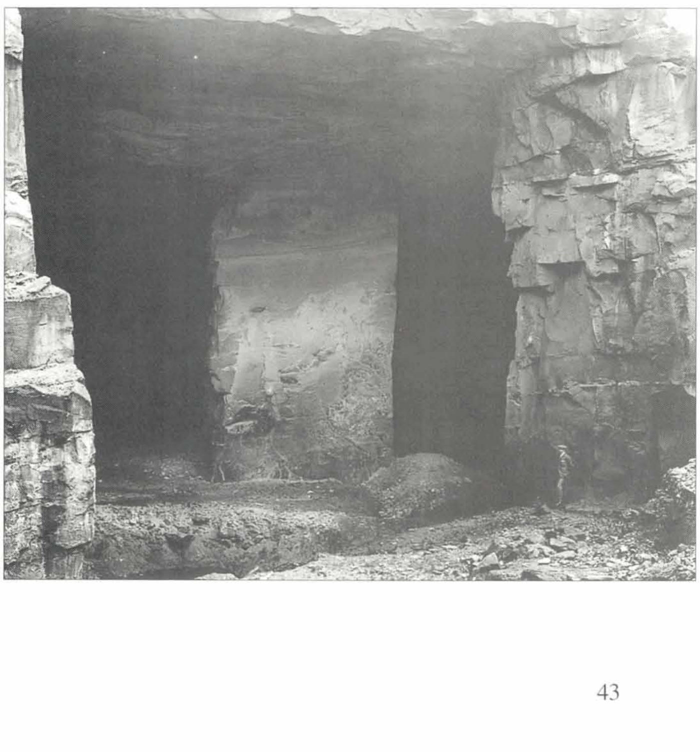
Hailes Quarry, Slateford, Edinburgh (C3536), 1935

The easterly dip of the strata determined that stratigraphically higher beds were worked on a bench on the east side of the quarry. This photograph taken looking south to Kingsknowe Farm (Figure 8) shows the strata dipping into the face They were dominantly thinly bedded mudstones worked for brickmaking. The sandstones were stockpiled on the floor of the quarry ready for transport and use in rubble work. In the foreground is a continuous wire cable tramway on an incline. Note the thick overburden of glacial sand and gravel.

(iii) Sandstone of the Upper Limestone Formation

A significant group of building stones used in Glasgow and, to a limited extent, Edinburgh is found in strata of the Carboniferous Upper Limestone Formation of west-central Scotland. Currently sandstone is worked at Dunmore (New) Quarry by Scottish Natural Stones Ltd. (Appendix 2). Thick sandstones, named the Bishopbriggs or Kenmure Sandstone, which occur between two marine horizons (the Index and Calmy Limestones), were once worked extensively in Glasgow. The sandstones are considered to have been laid down as river channel sands derived from the west or north-west on top of pre-existing deltas.

The characteristics of the sandstones vary considerably. South of the River Clyde the Barrhead Grit (the approximate stratigraphical equivalent of the Bishopbriggs Sandstone) is a coarse-grained, locally pebbly, sandstone. Although worked on a small scale, the material was often unsuitable as a building stone. At Bishopbriggs, the rock is a thickly bedded, fine- to medium grained, sandstone, suitable for ashlar. The whole of the rock was white except for the uppermost few feet, which was yellow and reputedly weathered better in buildings. The thickness of some beds, together with the absence of joints, made it possible to obtain large blocks. Ashlar 12' x 6' and other sized blocks were dressed at the quarry for local use.



Huntershill Quarry, Bishopbriggs (C2417- 2418), c.1908

The Bishopbriggs Sandstone was quarried and mined at Bishopbriggs in Huntershill Quarry where it is developed as two units, the lower 18m thick and the upper part 14m. Mining by the stoop and room (pillar and stall) commenced in the 1850s as the overburden of poor quality strata and till increased in thickness. The process of quarrying was started by a special set of 'miners' who drove horizontal mines near the top of the post (bed). Quarrymen then wrought downwards from these mines, a few feet of solid sandstone being left to support the roof. Mining continued until about 1907 when a serious roof fall killed 5 men. The thickness of the beds and the dimensions of the stoops (pillars) are well seen in both photographs. The galleries were some 15 m high.

Photographs courtesy of the British Geological Survey.

(iv) Coal Measures Sandstones

The Coal Measures of the Midland Valley have also yielded good sandstone for building purposes. Recently Deer Park Quarry, Hamilton, was re-opened to supply suitable stone for the renovation of Chatelherault Hunting Lodge, Hamilton.

Devon Quarry, Alloa, (C3061), 1926

Working massive, thick-bedded, red sandstone (Devon Red Sandstone) from the Coal Measures (Upper Carboniferous), Devon Quarry was already becoming overgrown with vegetation on spoil. Workings are of some antiquity and there are references to quarrying at the turn of the 18th Century. In one corner the new extension of the quarry was probably worked by cutting deep parallel vertical grooves using picks, a method known as channelling. Note the access to the platform was by ladder. The photograph also shows a hand winched crane adapted to operate with a vertical steam boiler.

Photograph courtesy of the British Geological Survey.

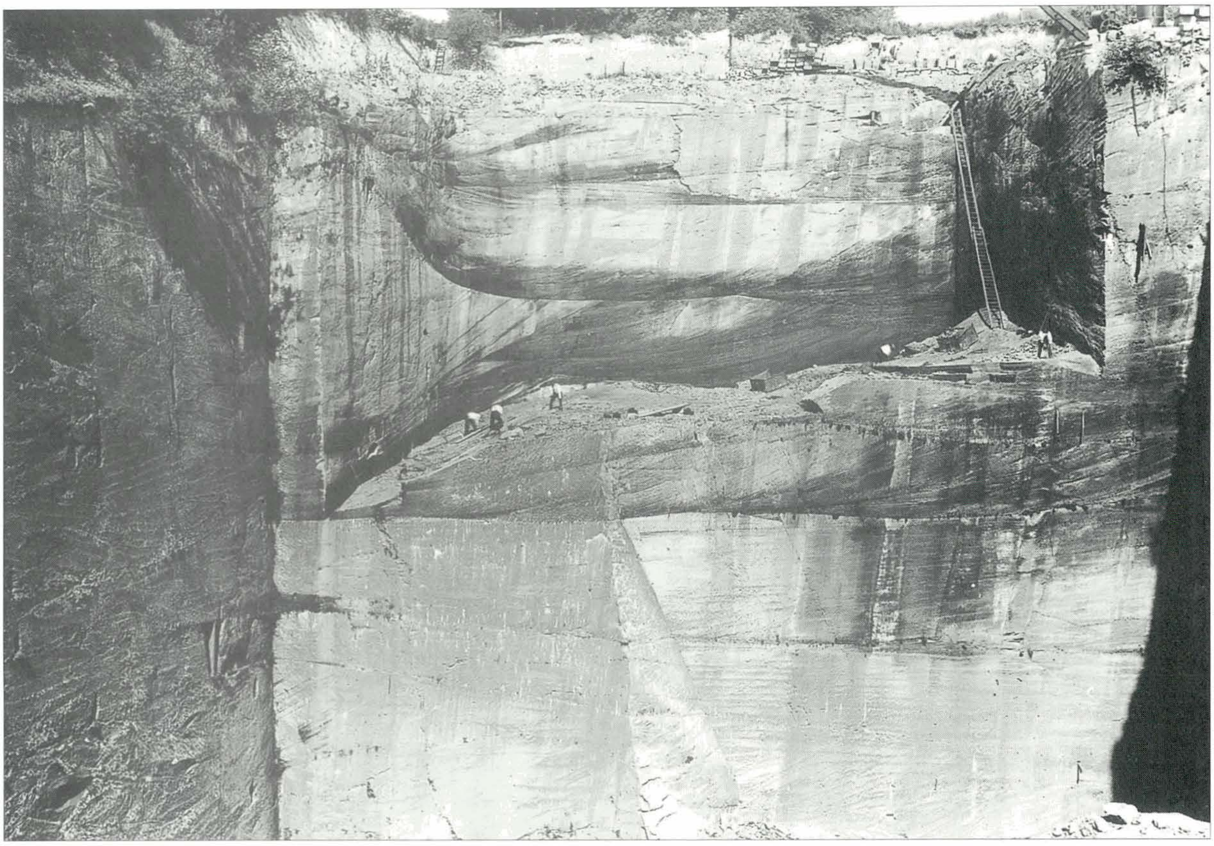
5.03 New Red Sandstone of the south of Scotland

Sandstones of the New Red Sandstone (Permian and Triassic age) are found in a number of sedimentary basins in southern Scotland (Figure 1). Distinctive characteristics of the Permian red desert sandstones of Dumfries and Mauchline include large scale aeolian (windblown) dune-bedding. They are petrologically and texturally distinctive, usually showing a high degree of sorting with a high proportion of rounded, frosted, quartz grains. The grains are coated in haematite (iron oxide) giving them their distinctive colour. In contrast Triassic red sandstones of the Annan area, currently quarried at Corsehill, do not exhibit distinctive curved aeolian cross bedding and are considered to be of fluviatile origin. Texturally the sandstones are less mature and they are interbedded with red silty mudstones.

The Dumfriess-shire Permian red sandstones have long been quarried at Gatelawbridge (Thornhill), Locharbriggs and Corncockle (Lochmaben). Stone has been widely used as sawn and polished or rock-faced ashlar. The curved dune-bedding is often well displayed in polished ashlar faces but such dune bedded stone can be prone to granular dissolution particularly if the pore cement is weak.

(i) Mauchline Sandstone Formation

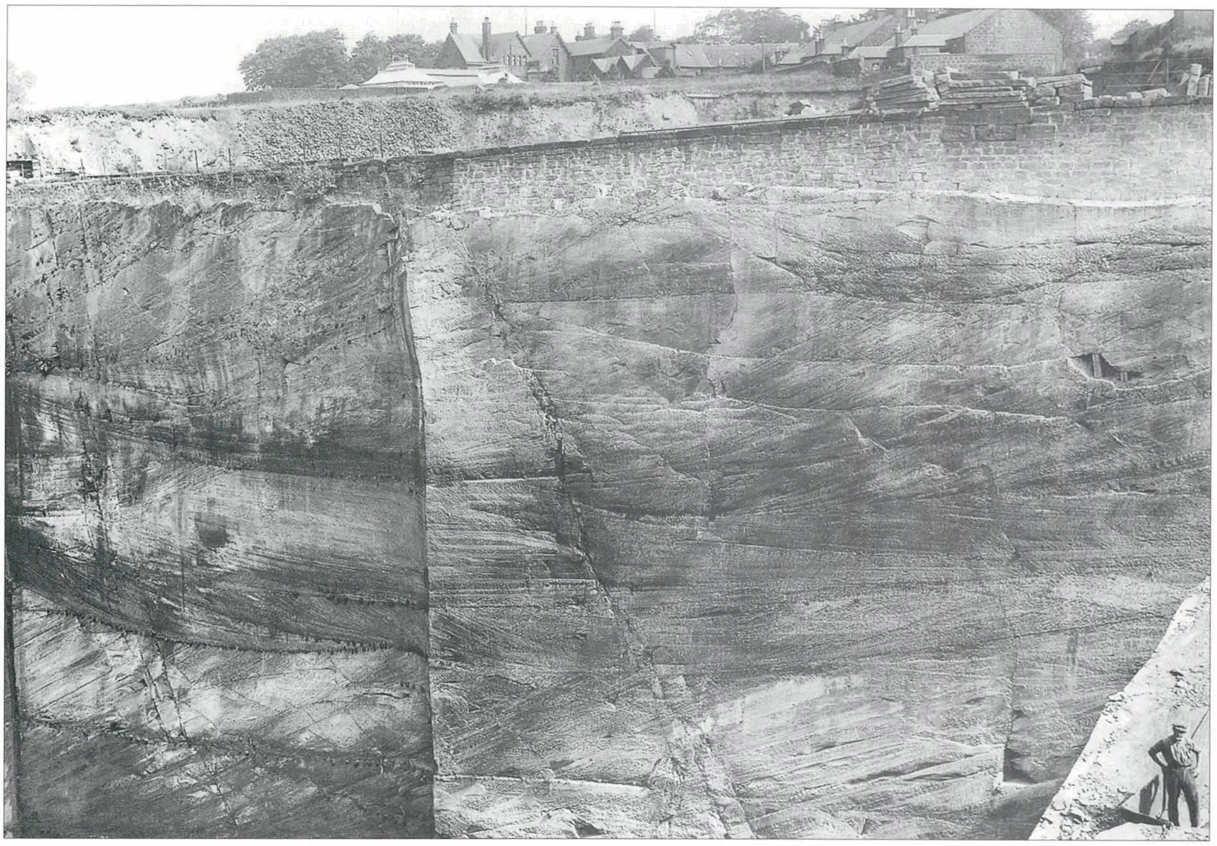
In the Mauchline Basin, over 450m of large scale cross-bedded, well-sorted, bright red, fine-grained, aeolian sandstones form the Mauchline Sandstone Formation. Red sandstones of Permian age were quarried for building stone over many centuries and were worked in several quarries including Mauchline (Ballochmyle), Barskimming and Failford. Stone was much used for houses, halls, churches, monuments and bridges in Glasgow, Paisley, Ayr and Kilmarnock particularly at the turn of the century. It was also used for construction of buildings in many smaller local towns and villages. The sandstones from these quarries varied from hard, compact varieties suitable for making grindstones, much used by the Clyde shipbuilding yards, to soft friable rock.



Ballochmyle Quarry, Mauchline (C2912), c.1921

Depths of the workings exceeded 64 m. Ladders were used as a means of accessing the working part of the vertical faces. Prominent pick marks in fishbone patterns made by the quarrymen can be seen on the vertical faces. The method of working was by channelling in which deep vertical cuts or grooves, some 6 m long and 3 m deep, were cut manually by pick. A crane driven by a vertical steam boiler was used for lifting large blocks. (A close-up of part of the face is seen in Photograph C2913, Chapter 4).

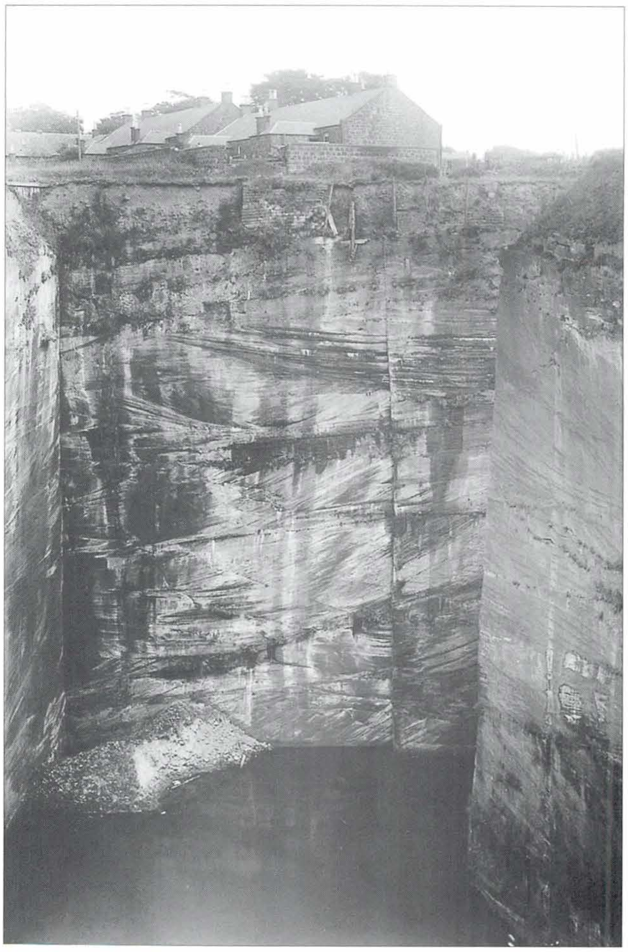
Photograph courtesy of the British Geological Survey.



Ballochmyle Quarry, Mauchline (C2914), c.1921

This eastern part of the quarry was separated from the western working (C2915) by a road.

Photograph courtesy of the British Geological Survey.



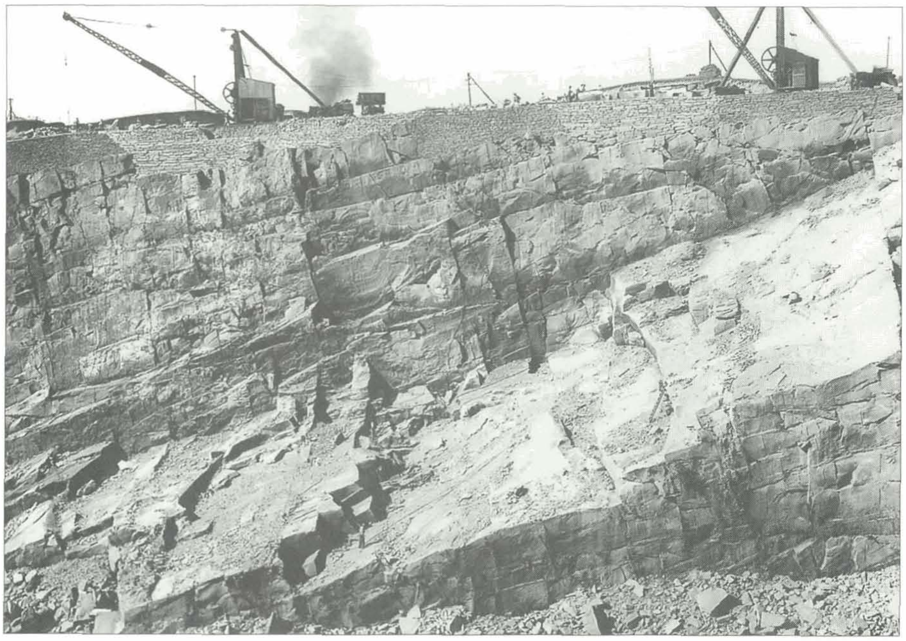
Ballochmyle Quarry, Mauchline (C2915), c.1921

This view shows the abandoned western quarry with water-filled hole. 1st order bounding surfaces, dipping at low angles from right to left, extend across the whole face.

Photograph courtesy of the British Geological Survey.

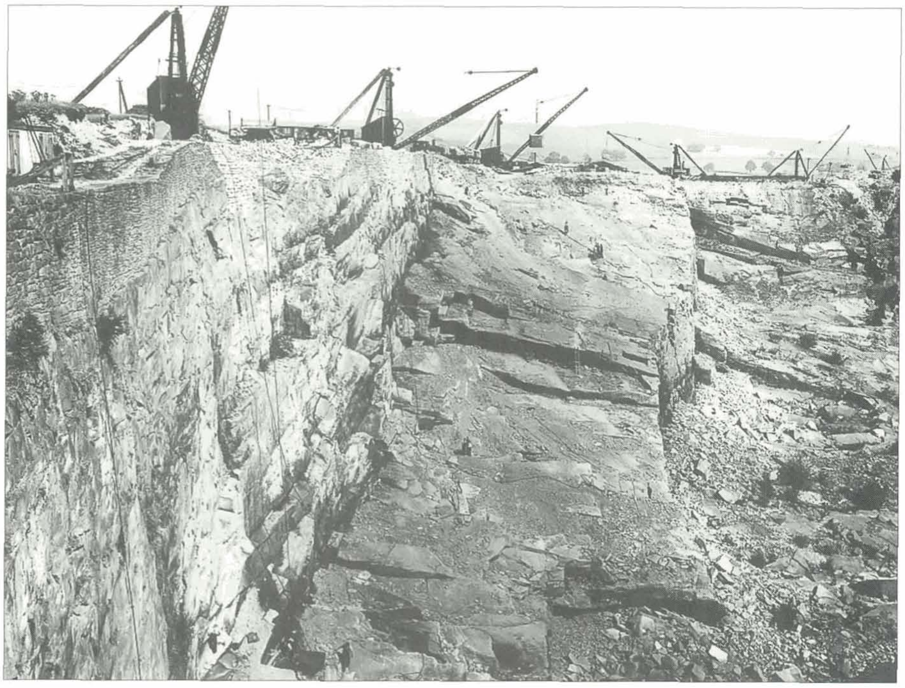
(ii) Locharbriggs Sandstone

Quarrying of red sandstone flourishes today in workings operated by Baird and Stevenson Ltd on the outskirts of Locharbriggs (Figures 2 and 3, Appendix 2). This is a good illustration of small scale sandstone quarrying which can satisfactorily coexist in proximity of habitation. Situated in the Dumfries basin the Locharbriggs Sandstone Formation has been worked for hundreds of years. It is estimated that the formation is at least 700m thick and geophysical evidence suggests it may attain a thickness of up to 1km in total. The sandstone shows aeolian dune-bedding arranged as wedge-shaped and planar tabular foresets, between 0.5 and 2.0m thick, dipping between 10° and 30° south-west. The rock is medium to fine-grained red quartz arenite, very well sorted, and consists of sub to well-rounded quartz grains, coated with iron oxide and weakly cemented by silica. Some feldspar is also present. Footprints of reptiles have been found preserved on bedding planes. Baird and Stevenson Ltd were the operators at Locharbriggs in 1937 when the photographs were taken. The illustrations demonstrate the efficient use of traditional quarrying techniques which have changed little over the years.



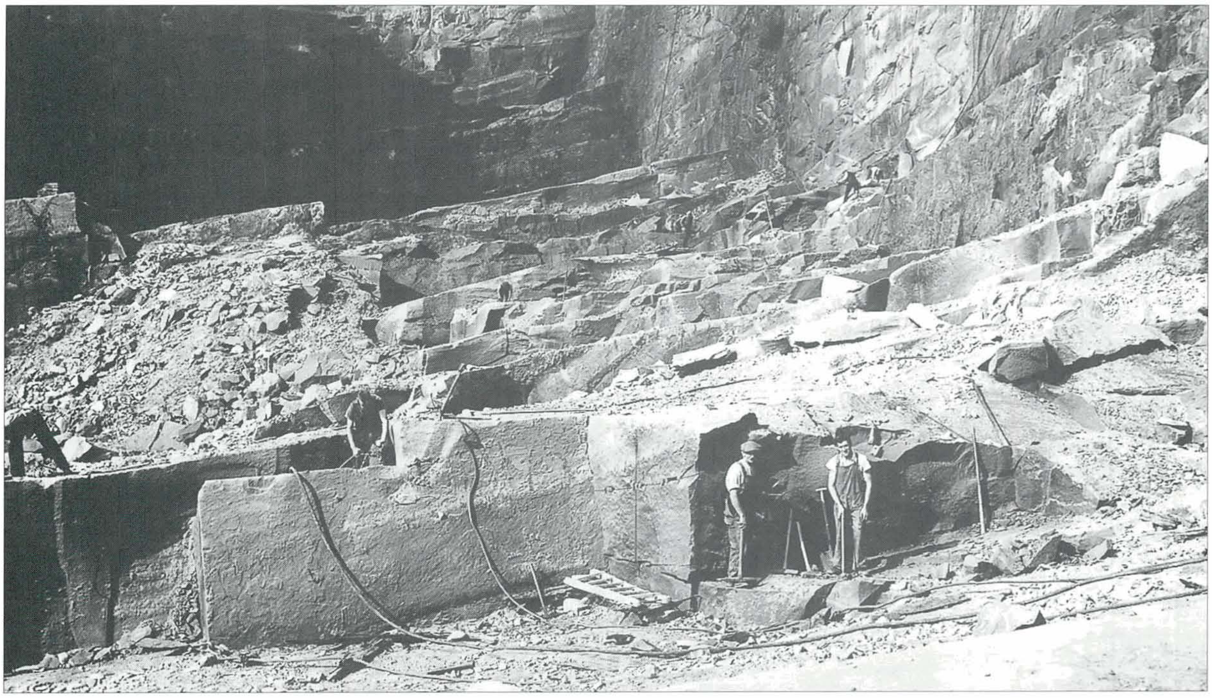
Locharbriggs Quarry, Dumfries (C3596), 1937

This photograph shows a general view of the working face. The sandstone was worked 'against the dip'. Situated at the top of the quarry a regiment of modern electric-powered cranes with steel lattice jibs capable of lifting up to 150 cu. feet of stone. Blocks 12' x 6' on their natural bed could be lifted to the top of the quarry ready for cutting and dressing.



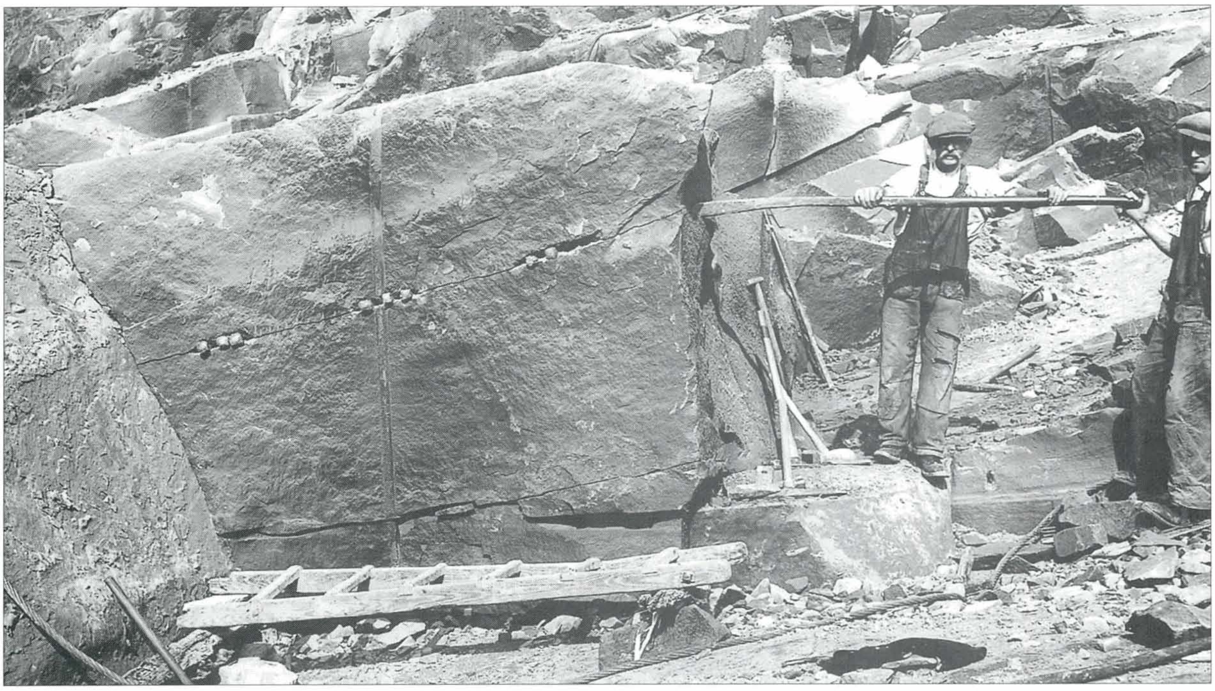
Locharbriggs Quarry, Dumfries (C3598), 1937

In the foreground a block of stone is ready to be raised to the surface. An LMS wagon can just be discerned in the background, a reminder that stone was transported by railway directly from the quarry.



Locharbriggs Quarry, Dumfries (C3600), 1937

A general view of the working face at the base of the quarry. Pneumatic drill hoses are draped over the beds of sandstone.

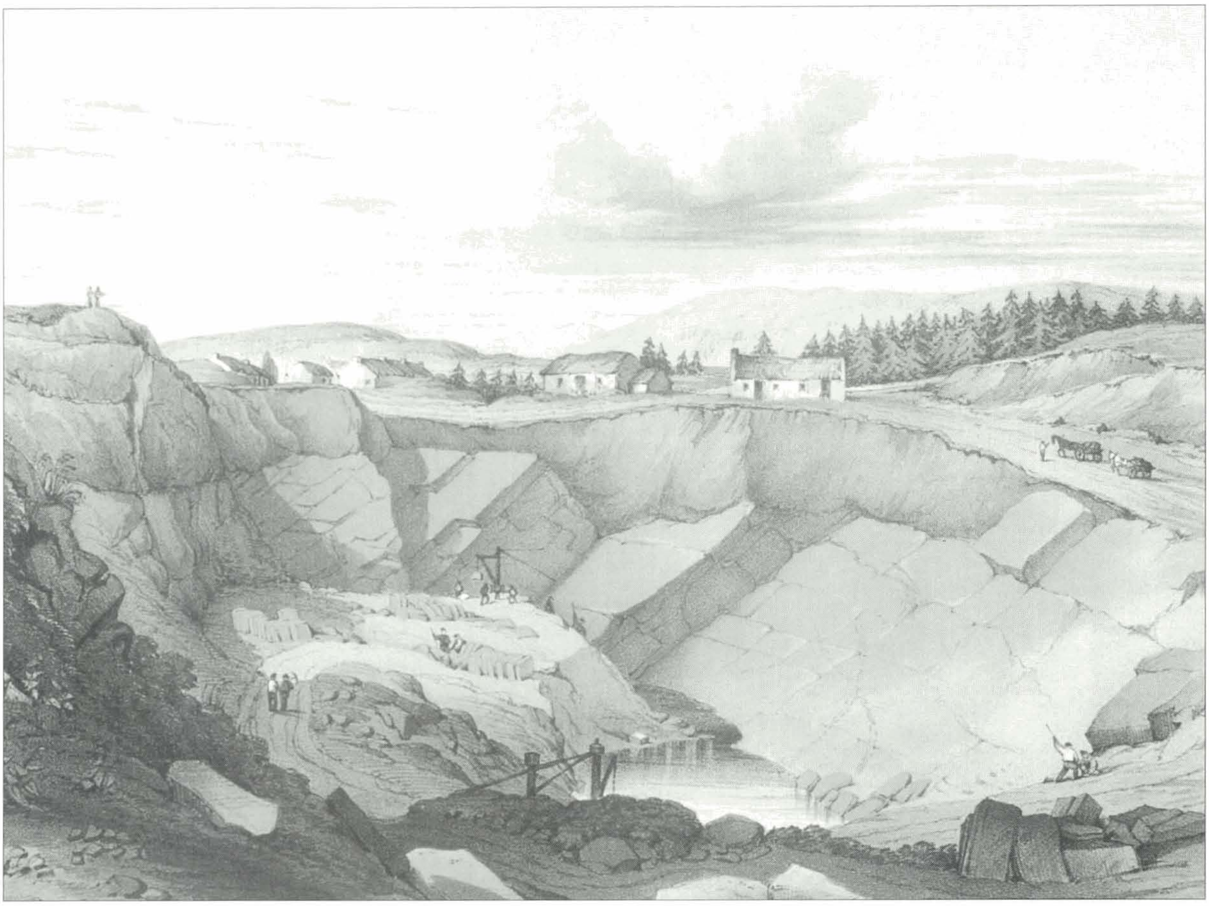


Locharbriggs Quarry, Dumfries (C3601), 1937

The quarrymen make sparing use of black powder which is placed in widely spaced vertical drill holes. A drill hole is seen in this photograph which demonstrates the 'shot grove and chisel wedge' method of working. Once the block is dislodged, the sedimentary characteristics of the stone, in particular the principal bedding, as planes of weakness are exploited using chisel wedges.

(iii) Corncockle Sandstone

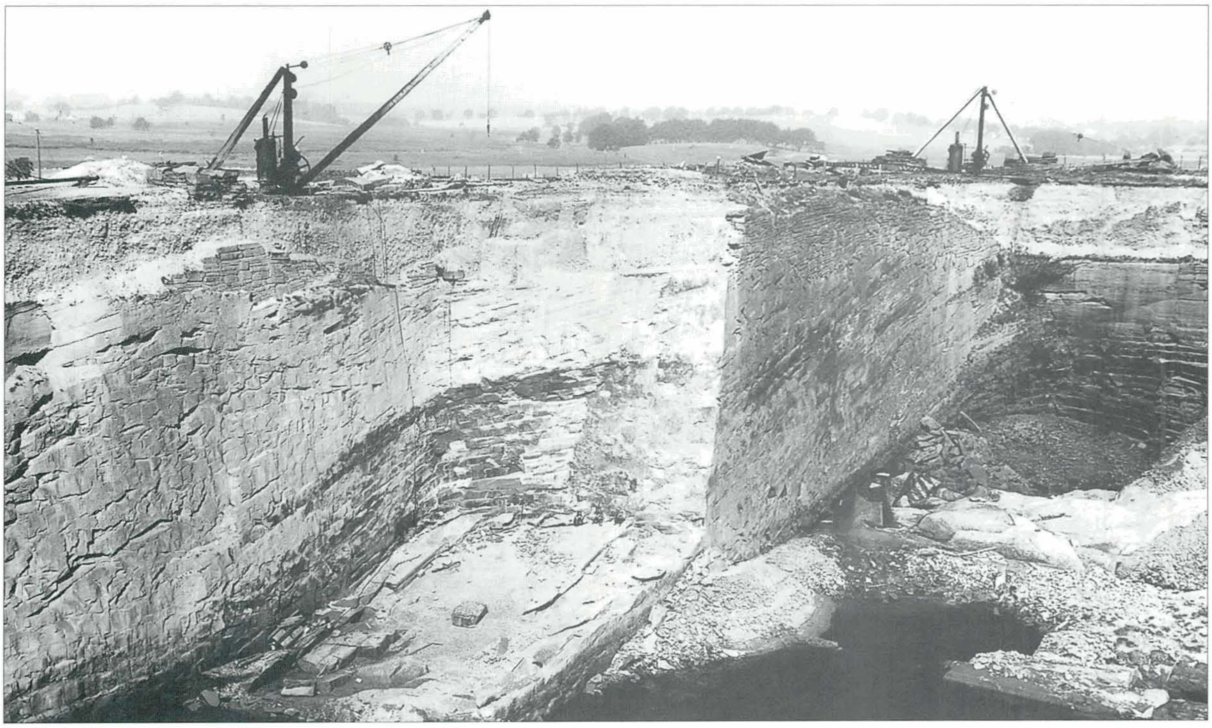
The Lochmaben Basin lies to the east of the Dumfries Basin and is separated from it by older (Lower Palaeozoic) rocks. Corncockle Quarry (Figures 2 and 3, Appendix 2), is currently operated by the Dunhouse Quarry Company Ltd. Here, the Corncockle Sandstone Formation comprises fine- to medium-grained, well-sorted, red sandstone, composed of quartz with minor amounts of feldspar. The grain size of the sandstone was a little finer than the stone worked at Locharbriggs and Gatelawbridge. At the type section in Corncockle Quarry sedimentary structures include large scale aeolian crossbedding and tabular foresets which dip up to 40° southwest. The vertical face of the quarry exposes up to 30m of stone. As at Locharbriggs, the uniform dip of the cross-lamination indicates that the prevailing winds which transported and deposited the sands came from the east-north-east.



Corncockle Quarry, Lochmaben (Sir William Jardine, The Ichnology of Annandale), 1853

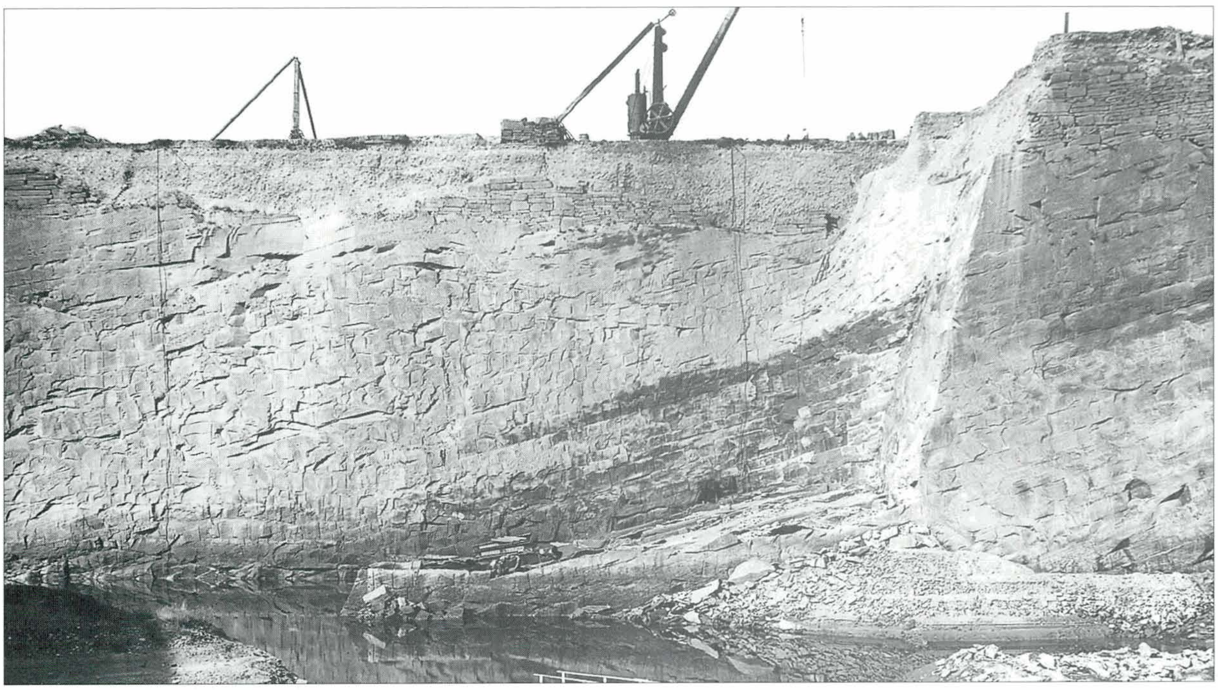
Early workings revealed abundant fossilised reptilian labyrinthodont footprints. This drawing by Sir William Jardine shows footprints preserved on an inclined bedding plane to the right of the flooded area.

Reproduced from *The Ichnology of Annandale* by Sir William Jardine (1853).



Corncockle Quarry, Lochmaben (C3605), 1937

The general view of the quarry shows the steam-driven cranes along the working platform and the general dip of the strata. As at Locharbriggs, the stone was 'removed against the dip'. Cranes were operated using vertical steam boilers. It is lunchtime and the men are enjoying their piece at the foot of the working face.



Corncockle Quarry, Lochmaben (C3604), 1937

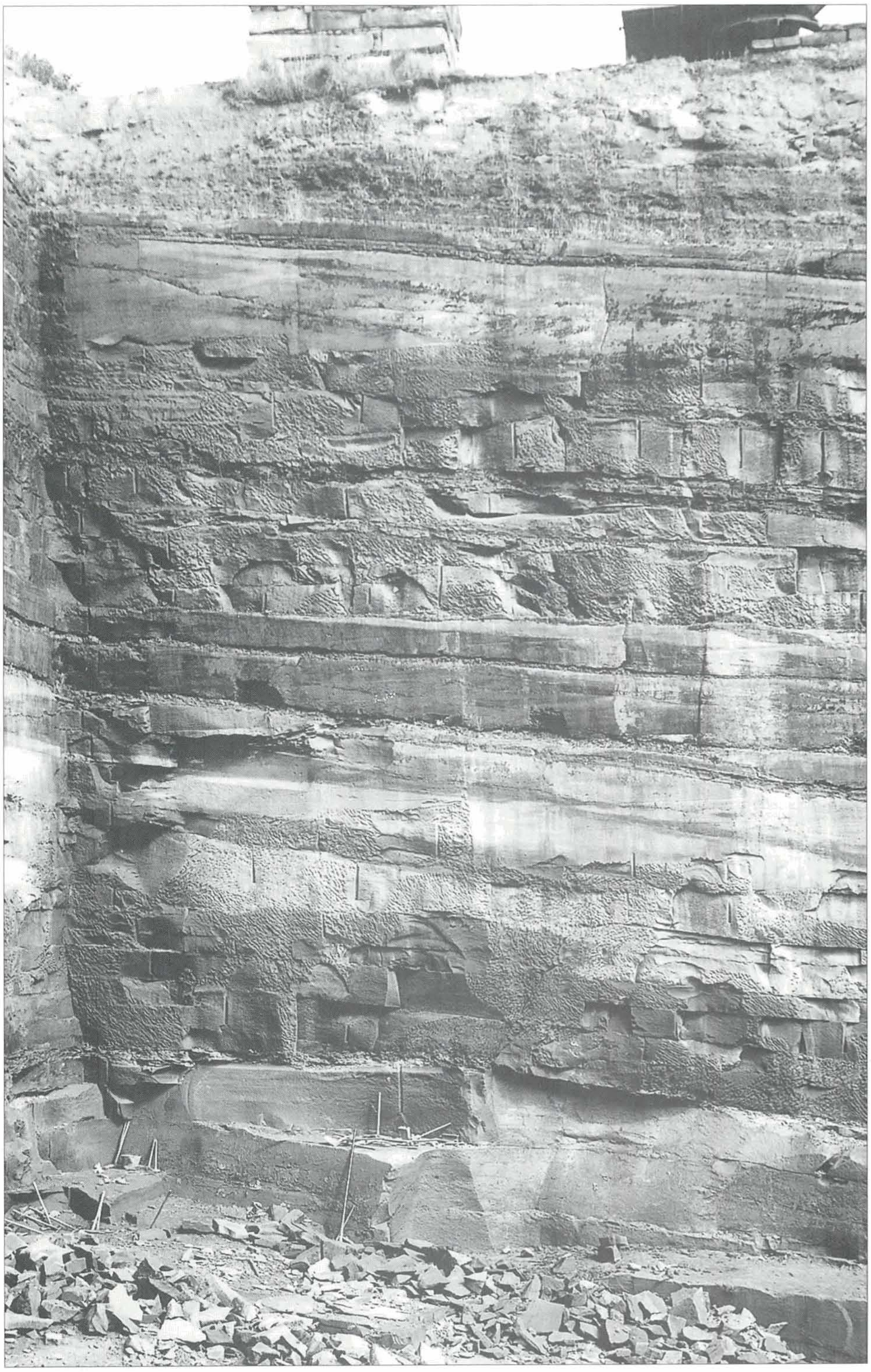
The floor of the quarry is flooded. Vertical drill holes can be seen on the face.

Corncockle Quarry, Lochmaben (C3606), 1937

The close up shows use of the chisel wedge method to split the stone to the required dimensions.

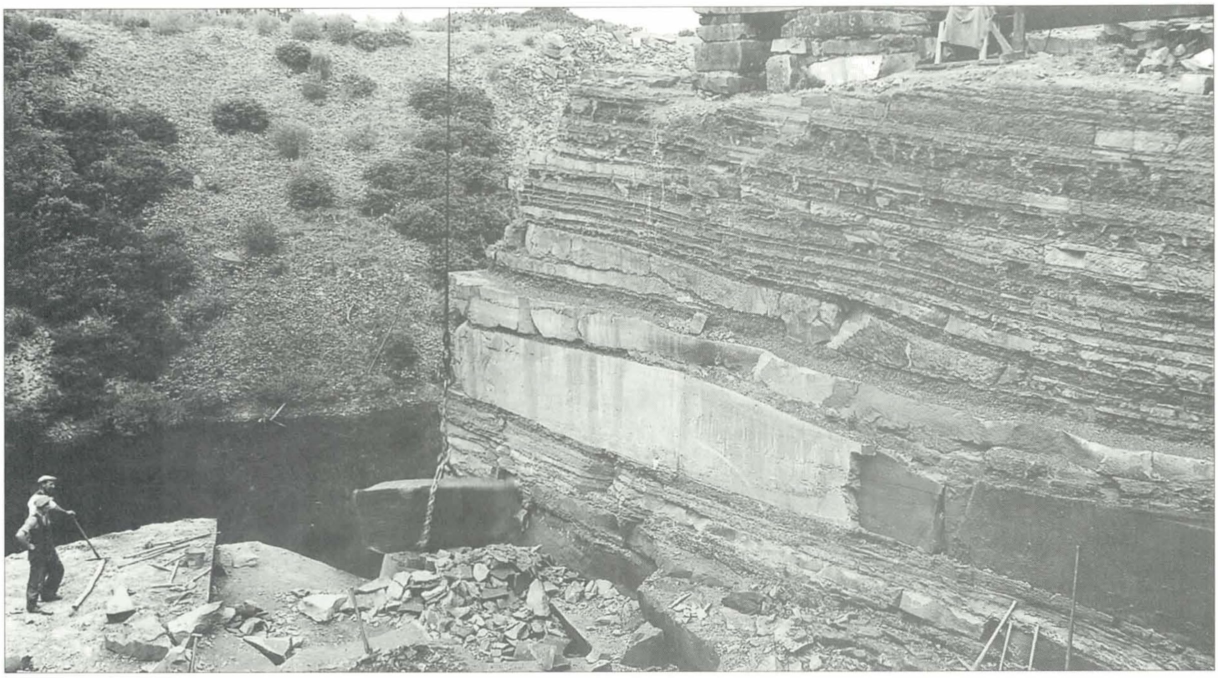
(iv) Corsehill Sandstone

Early Triassic rocks crop out in the Annan Basin in the Annan and Gretna district and form part of the sequence of strata extending southwards into the Carlisle Basin and Vale of Eden. Around Annan they are represented by unfossiliferous water-laid, fine-grained, sandstones. Stone from this sequence has been worked at Corsehill Quarry (Figures 2 and 3) for many years and currently the Dunhouse Quarry Company Ltd continues to supply stone (Appendix 2) for both the home and overseas market. The depth of the quarry in the early 1900s was of the order of 30 m. Being fine- to very fine-grained and capable of carrying a sharp arris the stone has traditionally been used for all kinds of inside and ornamental work and carving, and is noted for its use not only as a construction stone but also for monuments, panels, quoins and plinths.



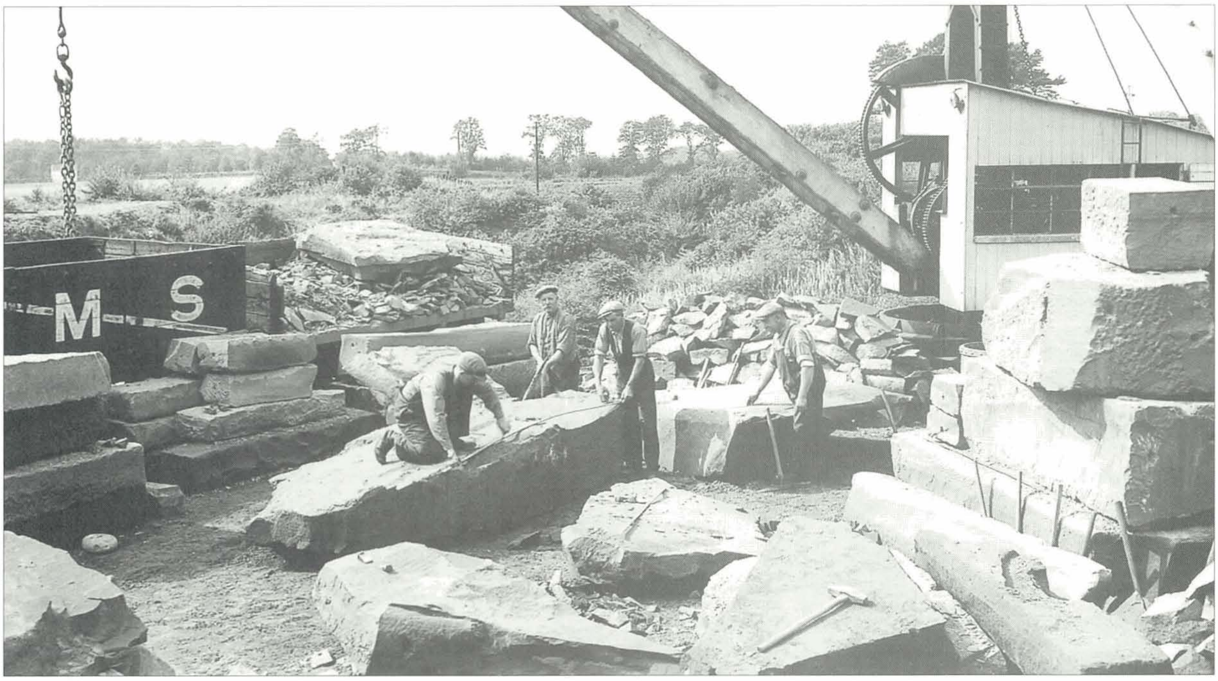
Corsehill Quarry, Annan (C3609), 1937

A view of the working face of the quarry illustrates the very different characteristics of the strata compared with the Permian desert sandstones. Beds are generally thinner, but are laterally continuous. Internal cross-bedding within some beds is discernable but is much smaller in scale and less prominent than in the desert sandstones. Drill holes are clearly seen. Tool marks on some beds may indicate that the stone was squared up while still in the face. The overburden of till is up to 5 m thick.



Corsehill Quarry, Annan (C3608), 1937

In a new section, the interbedded fine-grained rocks (generally silty mudstones), being softer than the sandstones are weathered back in the face. In places towards the top of the section, the mudstones are injected with strings of sandstone. These structures originated during loading as the sediment, which was once saturated with water, dried out. Loosened blocks are shown being raised to the surface by a chain sling just after a blast. The blocks at the top of the face support the crane stay.



Corsehill Quarry, Annan (C3602), 1937

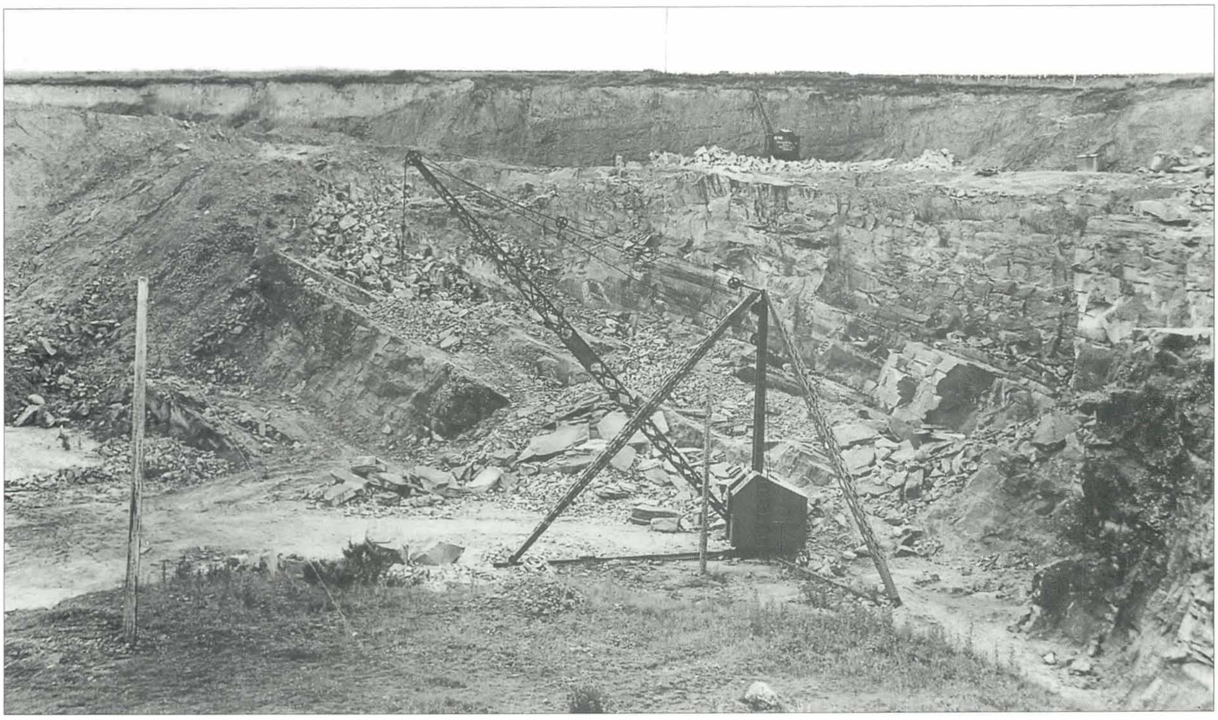
At the surface, a block is being measured up and made ready for the dressing yard. The LMS wagon, again shows the use of railways as the principal and efficient mode of transport. Also in the background is a block, bedded on small stones on a bogie.

Corsehill Quarry, Annan (C3603), 1937

In the dressing yard masons are shown at work using mells (wooden mallets) and chisels on the stone. Note that many of the blocks were sawn and that the small holes cut in the faces were used for gripping the block with dogs and chain sling (see block in the foreground).

5.04 Permo-Triassic Sandstone of Morayshire

The Permo-Triassic sandstones of the Moray Firth have long supplied fine building stone and roadstone. Strata of the New Red Sandstone worked in quarries of the Elgin district were famous for yielding reptilian fauna. Quarries which worked sandstones of Upper Permian age included those at Cuttieshillock and Rosebrae. On the Moray coast, the sandstones of Hopeman Sandstone Formation (considered to be equivalent in age to those of Cuttieshillock) are currently worked at Clashach (Hopeman) Quarry by Moray Stone Cutters. Greenbrae quarries have also supplied stone in recent years. These sandstones are typically yellow to buff coloured, laminated and composed of well rounded quartz grains with feldspar. Large scale cross-bedding is taken as an indication of dune formation although locally, water-laid pebbly sandstones are also present. Upper Triassic fine-grained, siliceous, buff sandstone worked at Spynie is currently worked by Moray Stone Cutters.



Greenbrae Quarry, Hopeman (D692), 1963

The most recent photograph (taken looking south) in this selection shows the dip of the beds assigned to the Hopeman Sandstone in the long established Greenbrae Quarry. The strata are overlain by thick till. An electrically powered crane is used. The sandstones are yellow to buff coloured laminated and composed of well rounded grains of quartz and feldspar of high sphericity, with only a little mica. This together with the dune-bedding suggests they were deposited under desert conditions although locally there is evidence of water-laid deposits. Fossil reptilian footprints used to be commonly found during quarrying operations. The variable cementation of the sandstone which locally has hard siliceous and ferruginous patches affects both the coloration and weathering properties of the stone. This illustrates some of the difficulties in predicting the availability within a single quarry, of geologically uniform strata which may be worked as building stone.

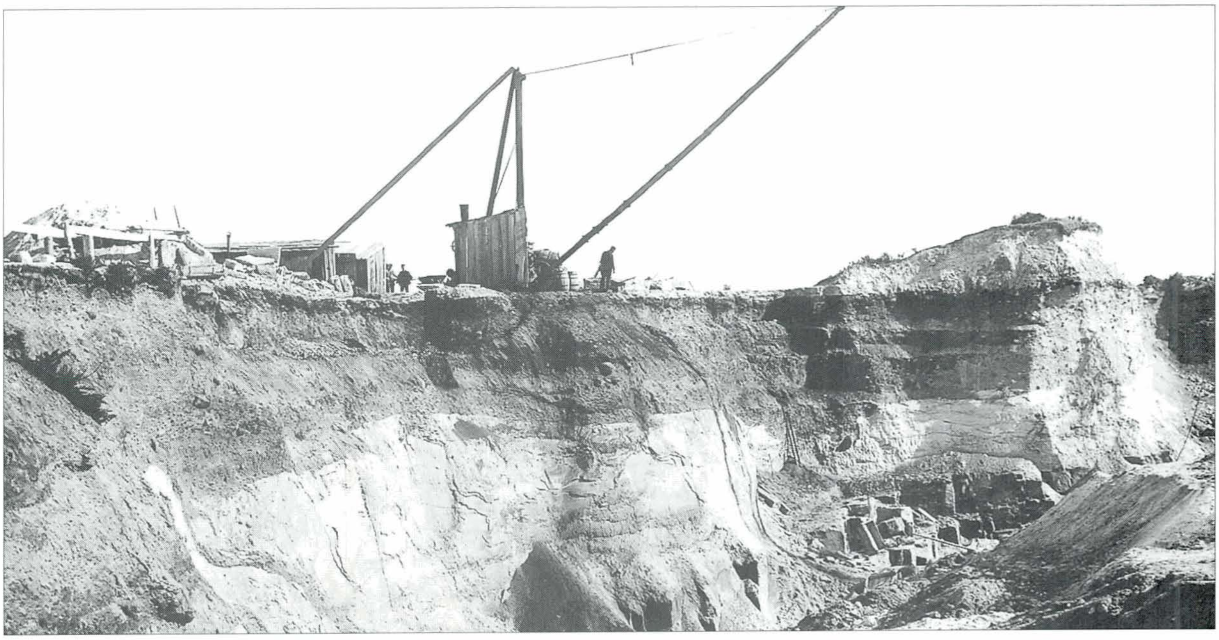
5.05 Jurassic Sandstone of the north of Scotland

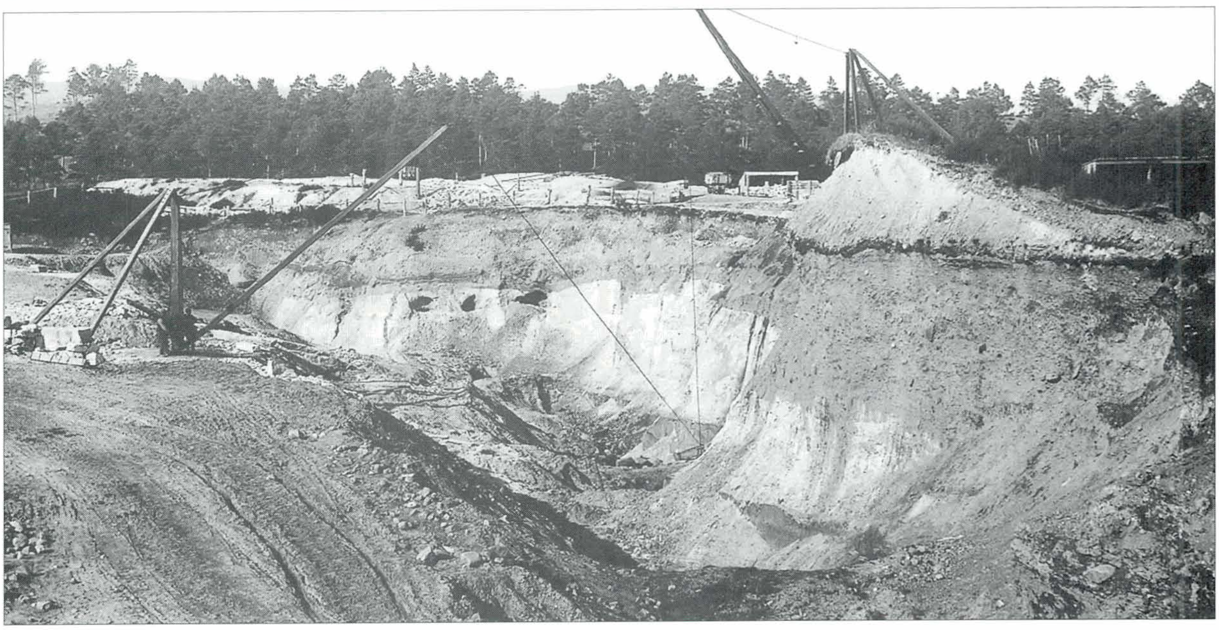
Jurassic sedimentary rocks are found on the Moray Firth coast and in small isolated outliers of the Inner Hebrides. Sandstones which could be easily worked and sculpted such as those at Carsaig, Mull have been worked in medieval times. More extensive quarrying took place in the Clynekirkton Sandstone Formation (Upper Jurassic) at Brora.

Clynelish Quarry, Brora (C238-239), c.1899

Some of the earliest photographs in the BGS collections illustrate the working of fine-grained, siliceous, white sandstones, known as 'Clynestone', of the Clynekirkton Sandstone Formation. The Quarry Register of 1899 records the quarry owner, Andrew Murray employing 16 men "inside" and 14 "outside". When worked the sandstone was relatively soft, parts of it could be crushed between the fingers, but upon exposure it became hard and tough, a quality which made it valuable as building stone. The top 3 m or so of the sandstone at the quarry are silicified and the rock resembles a fine-grained quartzite.The quarry yielded many important marine fossils during the 19th century. From the photographs it is noticeable that a large thickness of overburden comprising boulder clay (till) on sands was present. Sandstone blocks were retrieved by a manually operated crane and dressed at the surface.

Photographs courtesy of the British Geological Survey.



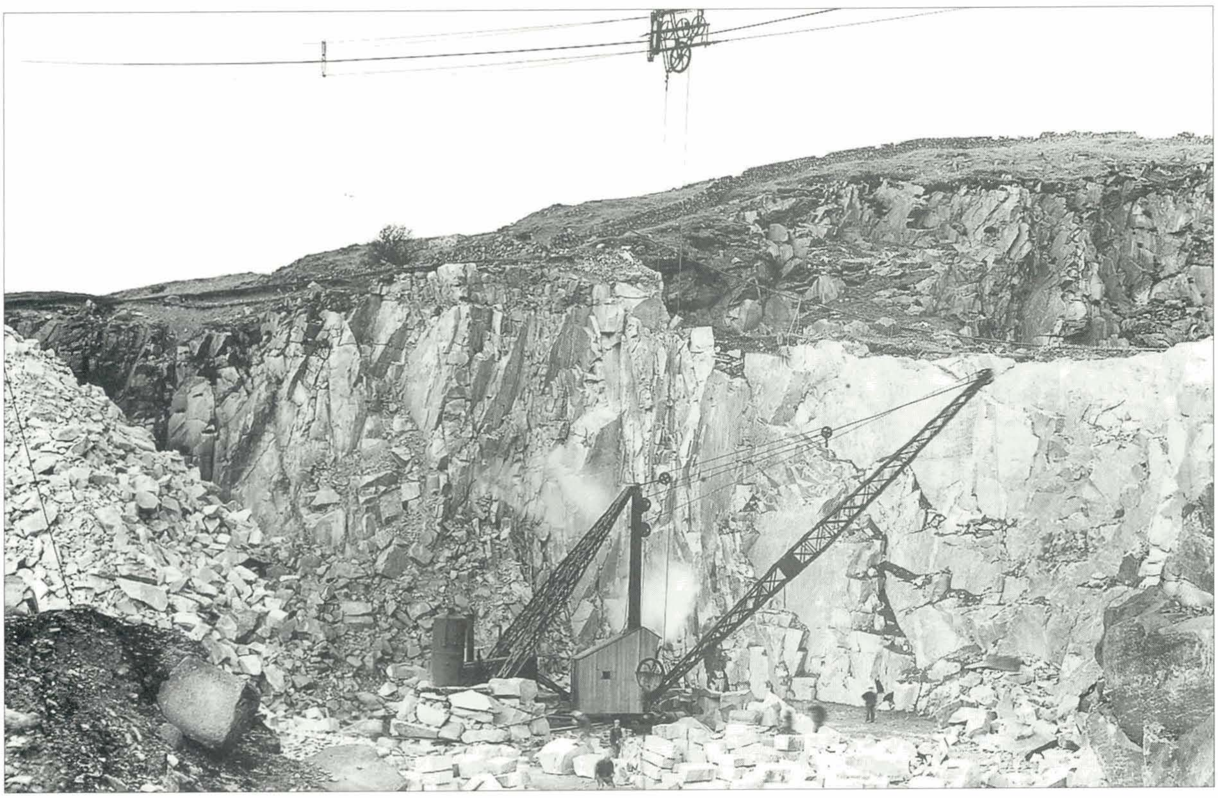


5.06 Granites

Granite and granodiorite have been worked in many parts of Scotland for monumental and building stone as well as kerbs and setts. The principal area of working where quarrying methods were developed was Aberdeenshire although the granites of Galloway and Ross of Mull have also supplied much stone. Granite building stone is worked today by John Fyfe Ltd at Kemnay; by Scottish Natural Stones Ltd at the Ross of Mull Granite (Tormore) Quarry; and by Alvie Trust at Easter Delfour, Kincraig, Inverness-shire; and (Figure 3, Appendix 2). Diorite (a more basic igneous rock) is worked for building stone at Braxside, Reay by G H Minter. Other quarries which formerly supplied building stone continue to work granite for road and concrete aggregate.

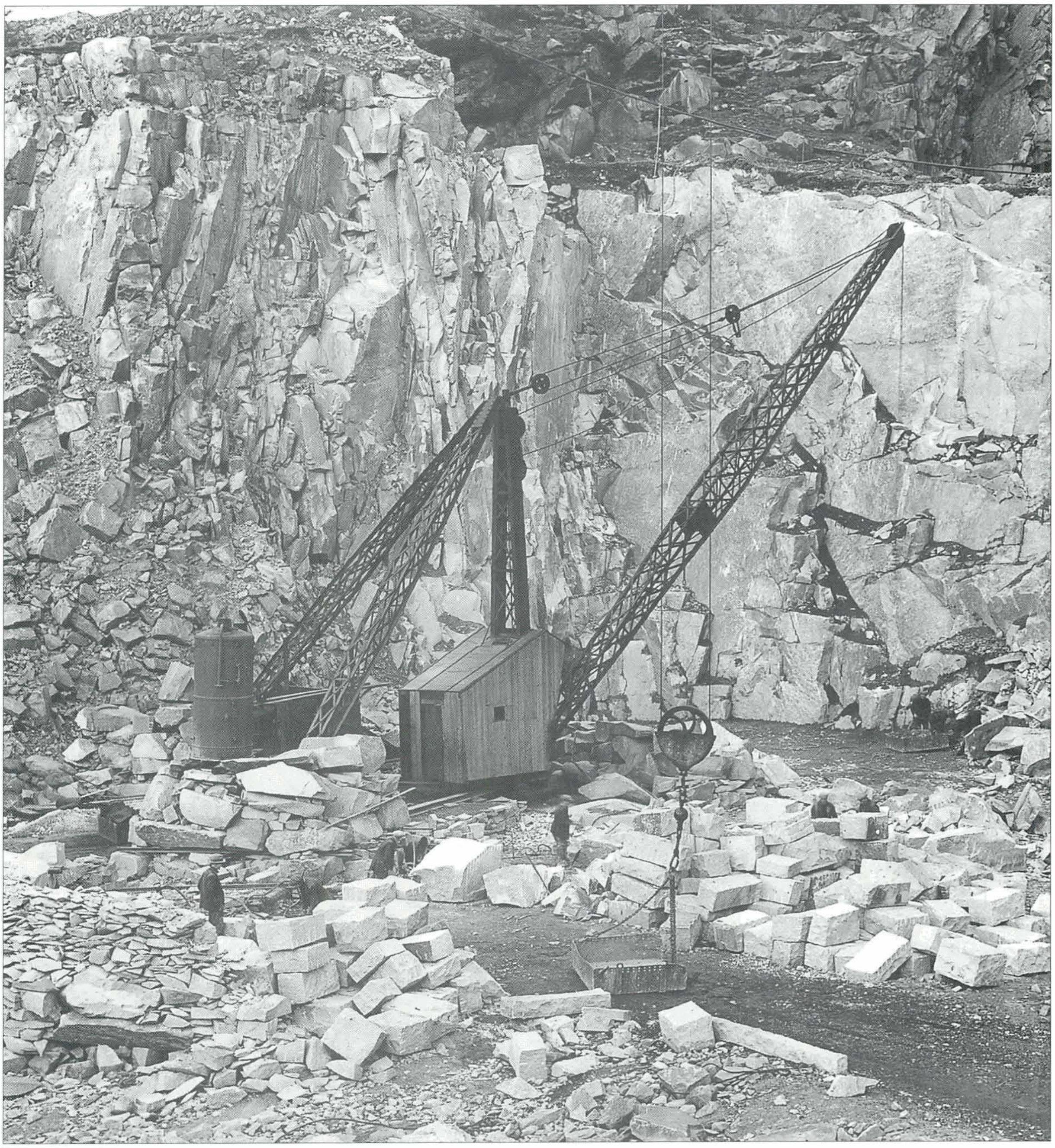
(i) Galloway granite

The principal workings were at Creetown and Dalbeattie. Photographs of these quarries were taken in 1939. The Creetown quarries originally worked grey granite for monumental and building materials, setts and kerbs. Little crushed stone was produced in the 1930s. Quarrying was initiated by the Liverpool Dock Trustees in about 1831. Kirkmabreck Quarry, Creetown is currently operated by Tarmac Roadstone (Scotland) Ltd. At Craignair Hill, Dalbeattie, quarries were opened in coarse-grained, grey granodiorite of the Criffel mass. Quarrying began on a large scale in 1824 and was carried out by the Liverpool Dock Trustees. Initially the Urr Water was navigable for light vessels to Craignair Bridge, west of the town, which enabled transport of stone by sea. Subsequently transport was by railway and road. The stone was supplied for major dock works and bridges. In the 1930s the quarries were operated by Improved Road Constructions (1934) Ltd for dimensioned stone, setts, kerbs and chippings. Six large openings were made at different levels on Craignair Hill.



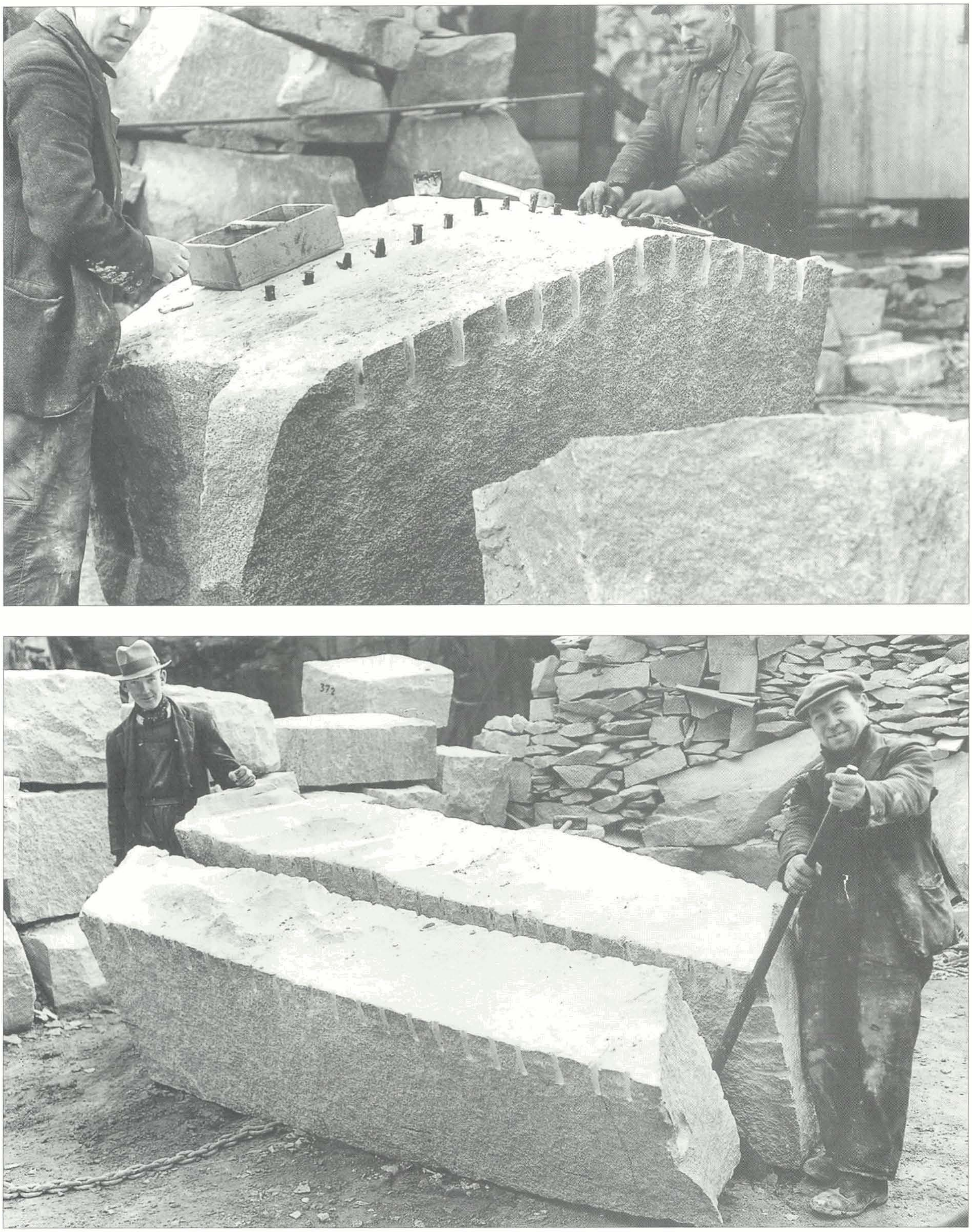
Silver Grey Quarries, Creetown (C3735), 1939

A general view of one of several openings shows the jointed granite face. The stone was handled by means of crane and 'blondin'. The crane was powered by a vertical steam boiler. Above the quarry was a 'blondin', a pulley system arranged on wires stretched across the quarry which enabled loads to be hoisted and transported out of the quarry. This was particularly useful in deep quarries. Two fixed wire ropes, supported on standards, were employed, one for the outward journey, the other for the return. On these the carriers, supporting buckets, were drawn by a light rope which was wound on a driving drum at one end of the course and on a tension drum at the other end.



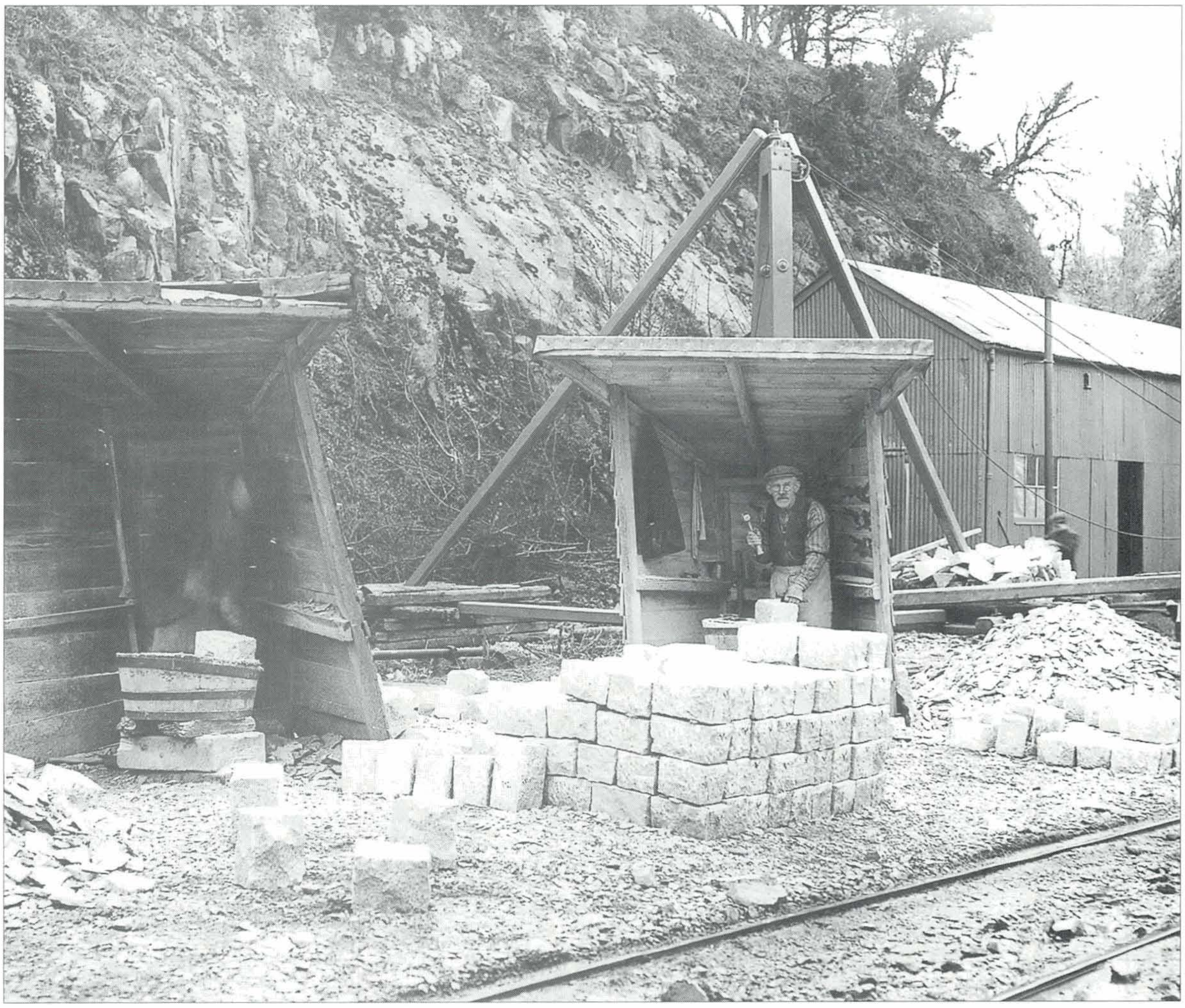
Silver Grey Quarries, Creetown (C3734), 1939

This photograph shows the detailed scene of the quarry face and floor. The pattern of joints was exploited at time of extraction. The 'reed' (direction of easiest splitting) was approximately horizontal. Blocks were blasted off the steeply inclined 'cross-reed' joints, the orientation of which coincided approximately with the 'hard way'. On the floor, blocks are split and roughly cut to sizes which could be handled by the cranes and 'blondins'.



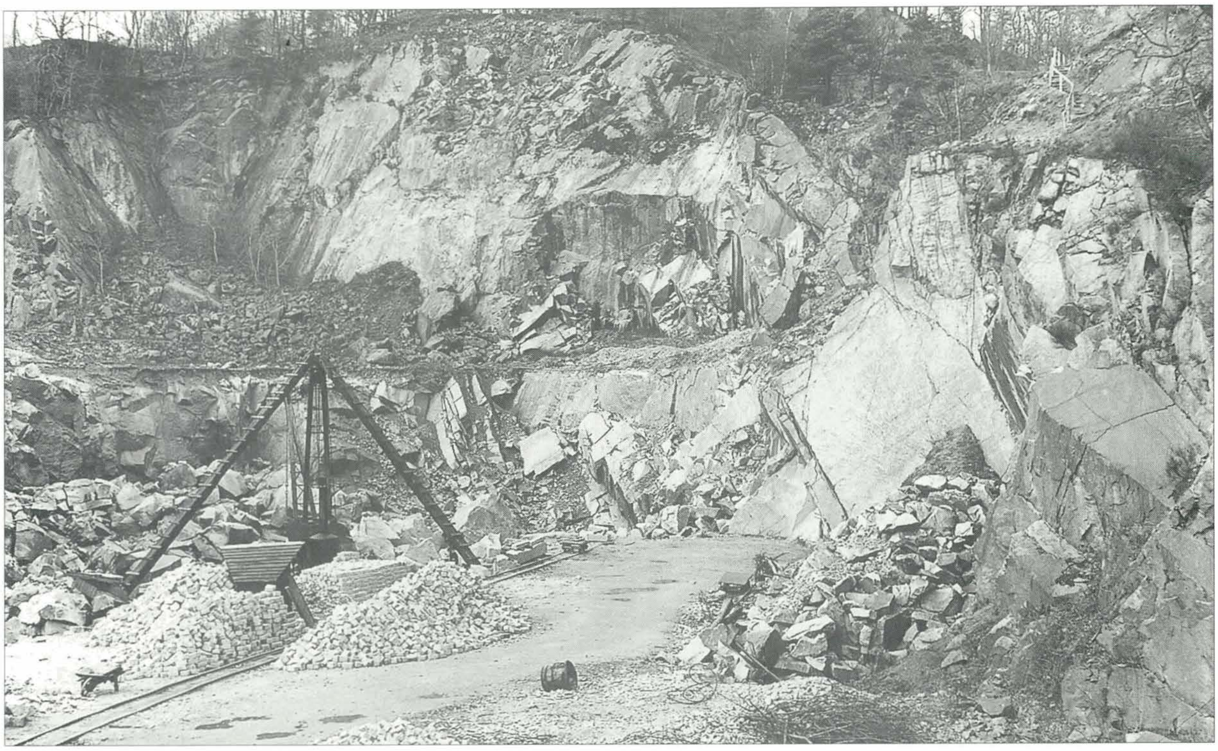
Silver Grey Quarries, Creetown (C3736-3737), 1939

Working on the quarry floor large blocks were split using "plug and feathers". This involved the drilling of a series of narrow holes a few inches apart on a selected line by means of a pneumatic drill. The "feathers", two half cylinders of steel were placed in each hole. Between them was inserted a steel wedge-like "plug" (Figure 7, No.14). A series of hammer blows delivered on the plugs in succession wedged them into the feathers and produced a straight split in the block (C3737).



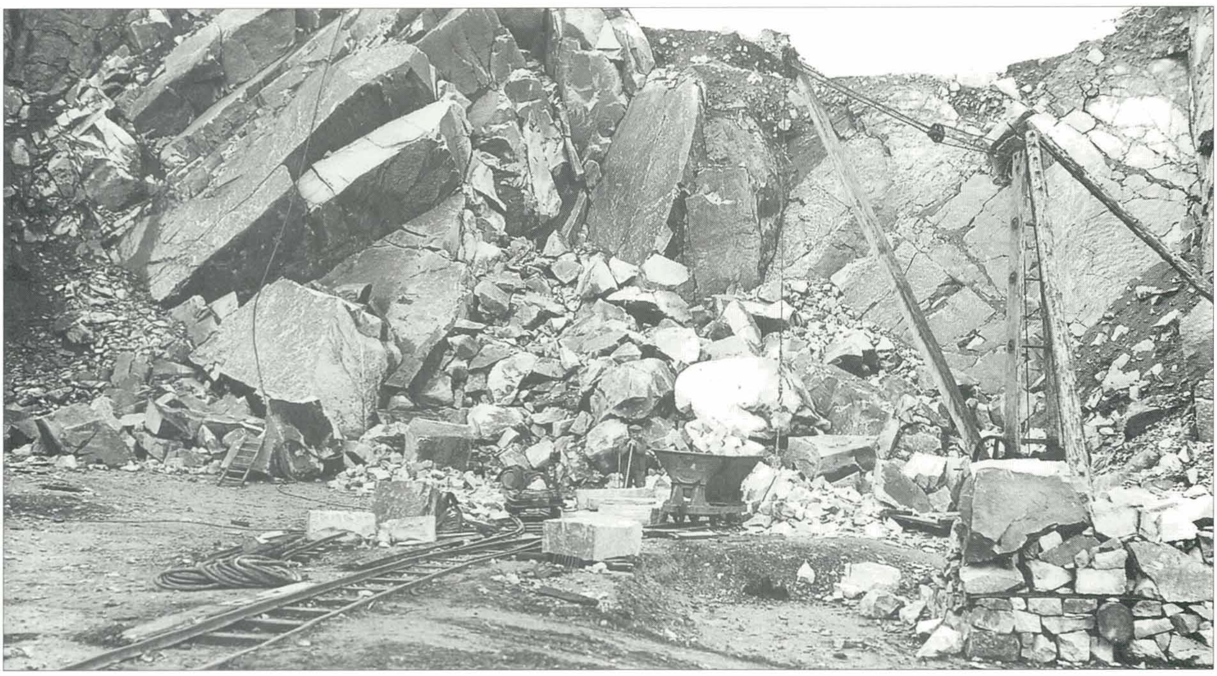
Glebe and Kirkmabreck Quarries, Creetown (C3726), 1939

At Glebe (lower) and Kirkmabreck Quarry operated in the 1930s by the Scottish Granite Co. Ltd, blocks were roughly hewn on the quarry floor before being prepared as squared setts on barrels filled with sand. Note the waste fragments which may have had multiple uses. Traditionally small elongate slivers of rock generated in the production of setts might have been used as pinning stones in walls. Use in the construction of paths, particularly in the practice known as horonising, where fragments are set tightly on edge, is another possibility. A light railway ran from the quarry across the road to storage bins and a pier on the Wigtown Bay shore.



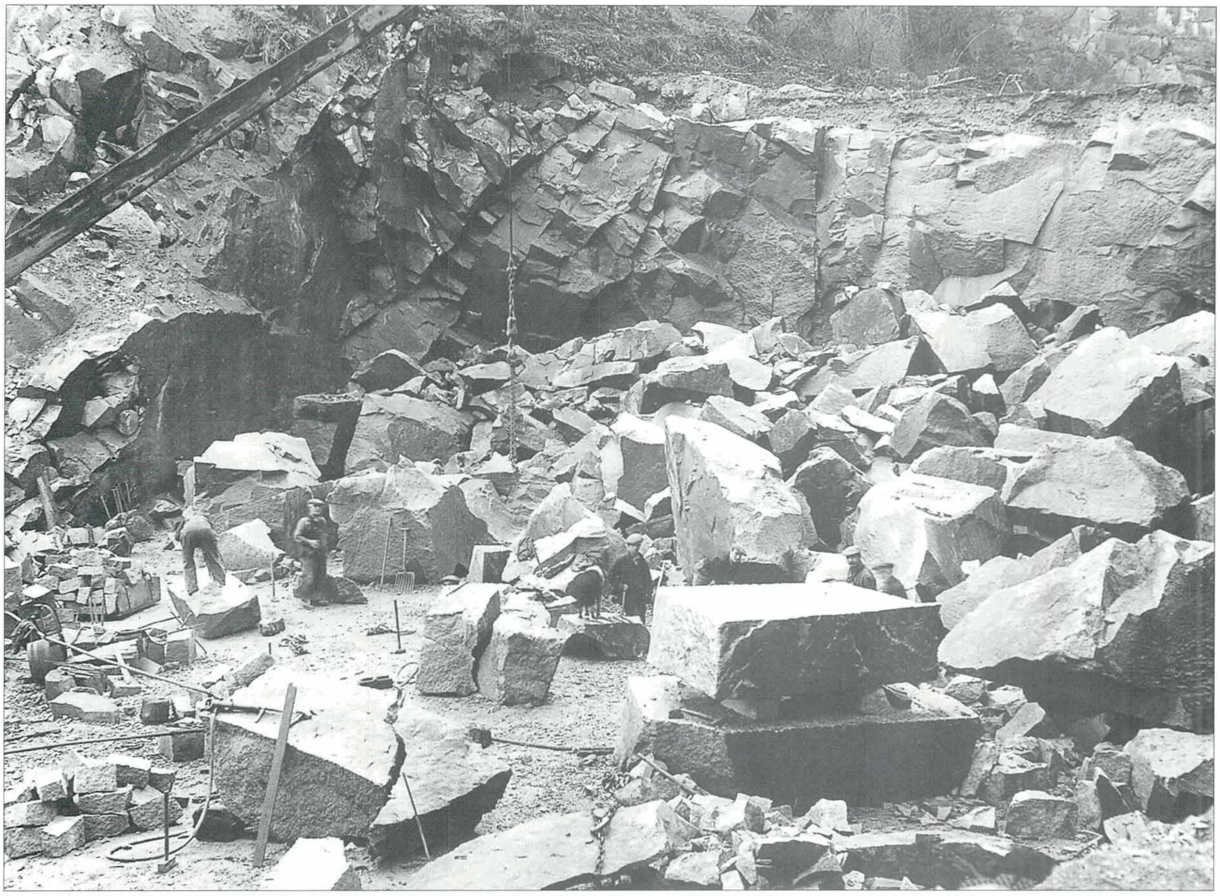
Craignair Hill Quarry, Dalbeattie (C3727), 1939

A general view of one of the quarry faces shows the remnants of a previously worked bench. High angle joint planes are strongly developed in the face. Next to the steam-driven crane stockpiles of setts, produced in the quarry, await transport on small bogies. The wheel barrow has seen better days!



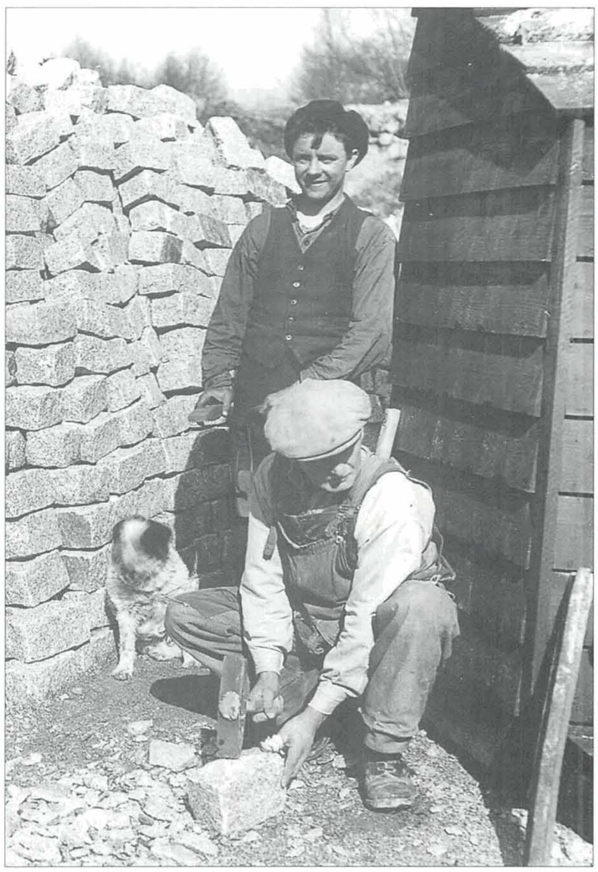
Craignair Hill No.2 Quarry, Dalbeattie (C3733), 1939

At Craignair No.2 Quarry a hand winch-operated crane with stays anchored by stone blocks is situated beside a light railway (note the side-tipping bogie) which ran to a crushing plant at Craignair Bridge. Inclined joint faces in the granodiorite are well exposed.



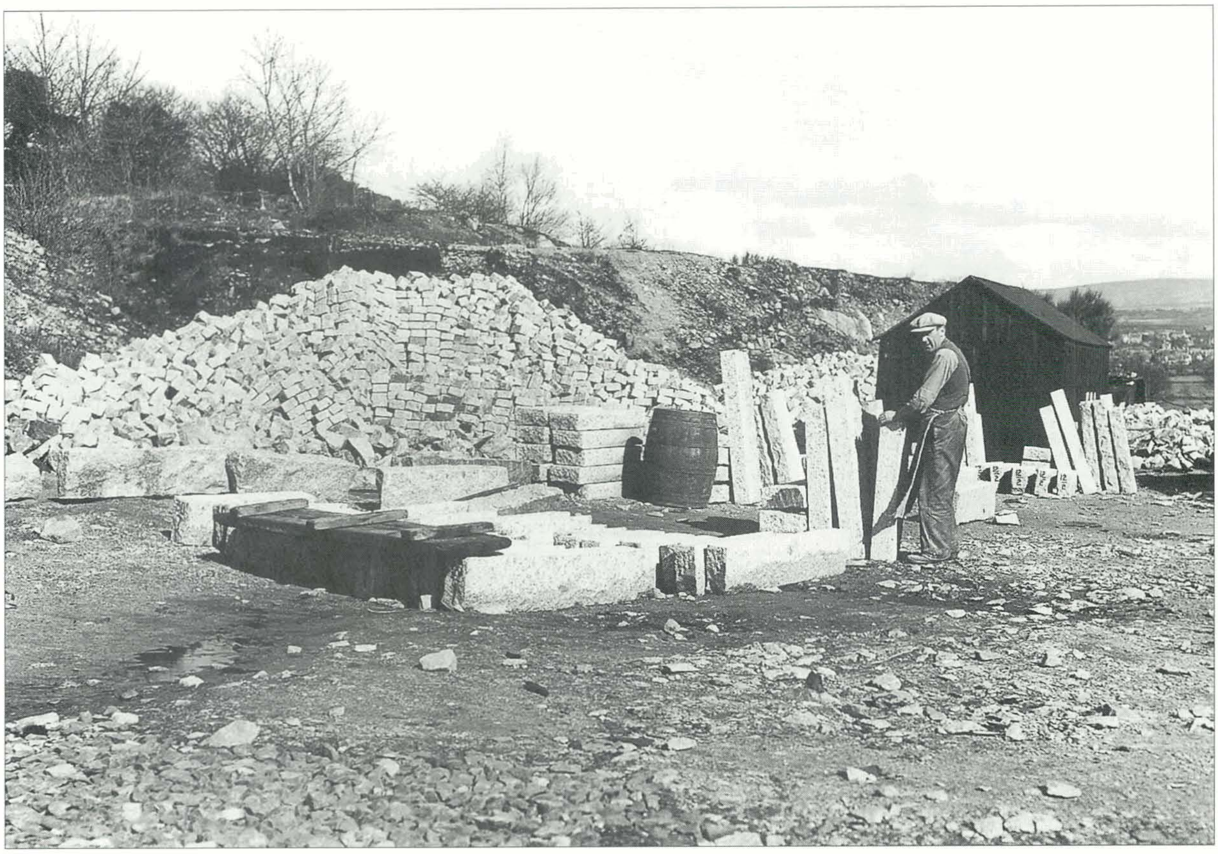
Craignair Hill Quarry, Dalbeattie (C3728), 1939

At the working face blocks are removed along joints by blasting with powder. Blocks were split by plug and feathers roughly to size at the quarry.

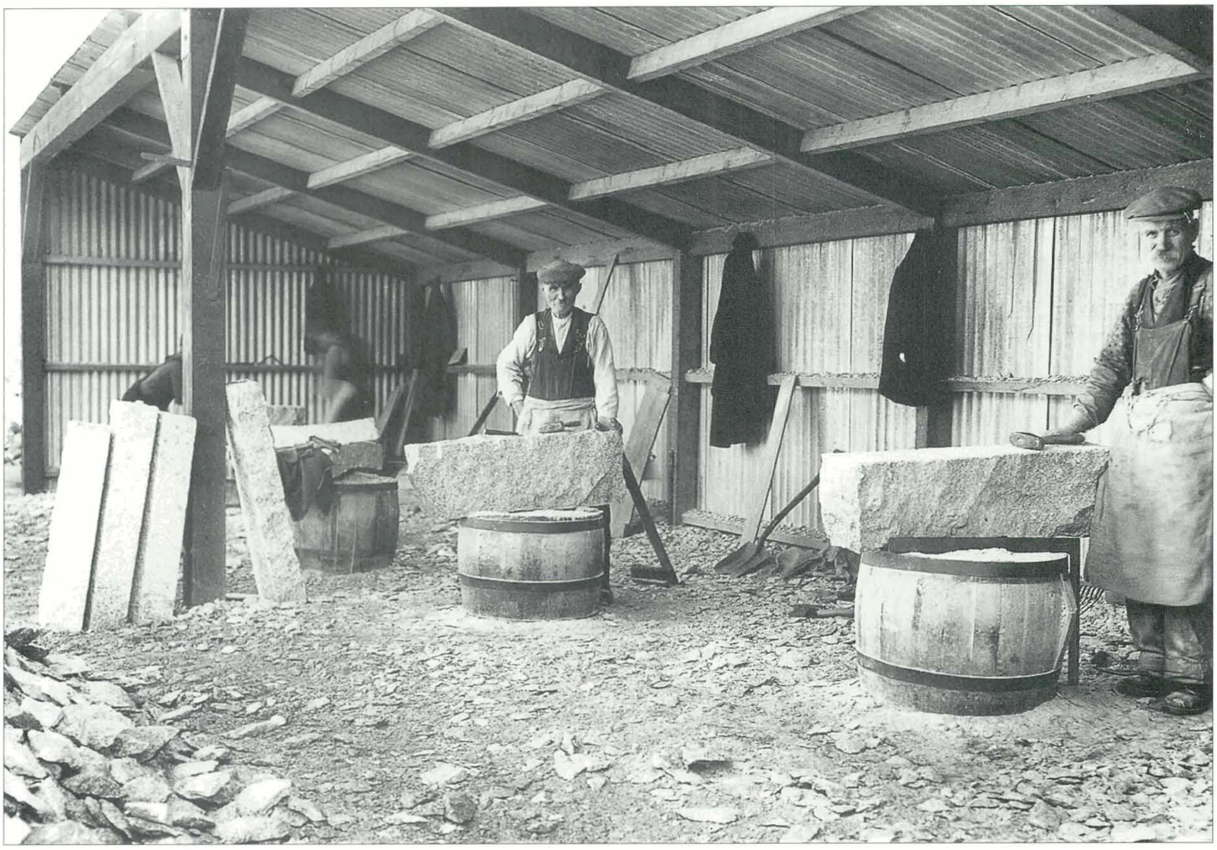


Craignair Hill Quarry, Dalbeattie (C3729, 3730, 3732), 1939

Sett, kerb and lintel making was also carried out at the yard. Stone was dressed either on the ground (C3732) or on barrels filled with sand (C3730).



(C3729)



(C3730)

(ii) Aberdeenshire granite

The principal area in Scotland for granite building stone was Aberdeenshire. Both grey and pink granites were worked. Photographs shown here of Rubislaw, Kemnay and Corrennie Quarries were all taken in 1939. Perhaps the most famous granite quarry ("the deepest hole in Europe") Rubislaw was one of many working the Aberdeen Granite Mass. It supplied Aberdeen and the world with building and monumental stone. The grey, muscovite-biotite granite was also used for setts, kerbs and as chips for concrete. Opened in 1741, it takes the form of a huge oval pit with a smaller pit on the floor. This form was typical of many of the Aberdeenshire workings due mainly to the thickness of the overburden and poor qualities of the surface layers of rock. Thus, after sufficient area was opened up, expansion of quarries took place downwards. This led to the development, more than in any other part of the country, of cableways, or 'blondins' to bring the rock to the surface. Blondins were invented by John Fyfe and first used at his quarry at Kemnay (see below) in 1873. Legend has it that he was inspired to design the 'blondin' having seen a ropeway which carried mail across the River Dee at Abergeldie Castle. He named his invention after Charles Blondin the alias of the French tight-rope-walker, Jean François Gravelet (1824-97). The Kemnay Quarries also worked grey granite which was used in dock works and major buildings. Kemnay No.1 Quarry was started in 1858. Adjacent to it and at a higher level, No.2 was opened in 1868. Building stone, setts and kerbs were produced beside the quarry but the best quality material was sent to Aberdeen for cutting and polishing for monumental work. Corrennie Quarries worked two colours of granite, the pink variety providing large blocks for buildings, ornamental and monumental use. The grey granite was used more for crushed stone.

Rubislaw Quarry, Aberdeen (C3740), 1939

This photograph shows the pit-like form of the quarry which, in 1939, was 122m deep. Three 'blondins' were employed at Rubislaw: 'blondin' wires can be seen stretched across the opening. The most powerful was capable of handling 20 tons.

Rubislaw Quarry, Aberdeen (C3742), 1939

The west wall shows prominent west-south-westerly running joints. On the floor is material brought down by blast. The rock was blasted from the main joint planes by means of black powder placed in holes drilled pneumatically to a depth of about 6 m.

Rubislaw Quarry, Aberdeen (C3746), 1939

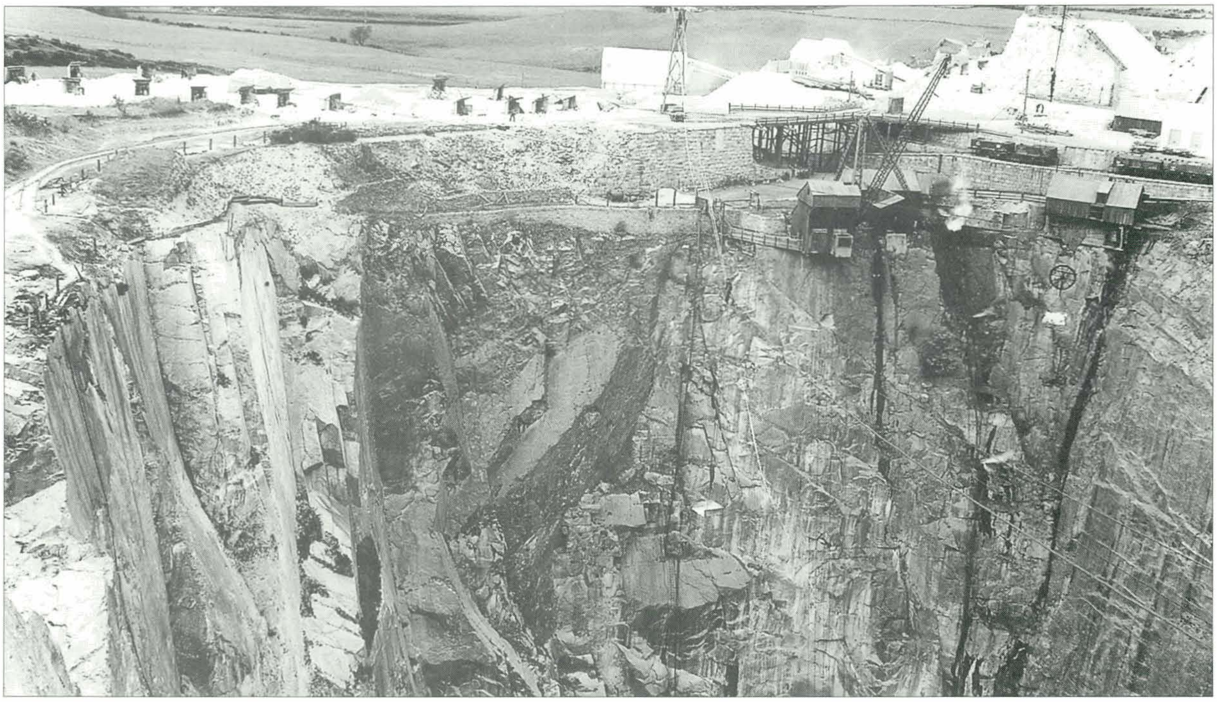
A close-up at the base of the quarry shows the dimensions of the recently blasted blocks (with men and ladders for scale).

Rubislaw Quarry, Aberdeen (C3744, 3748), 1939

Views at the surface show blocks being dressed for building stone. The stone was used mainly for building and monumental purposes.

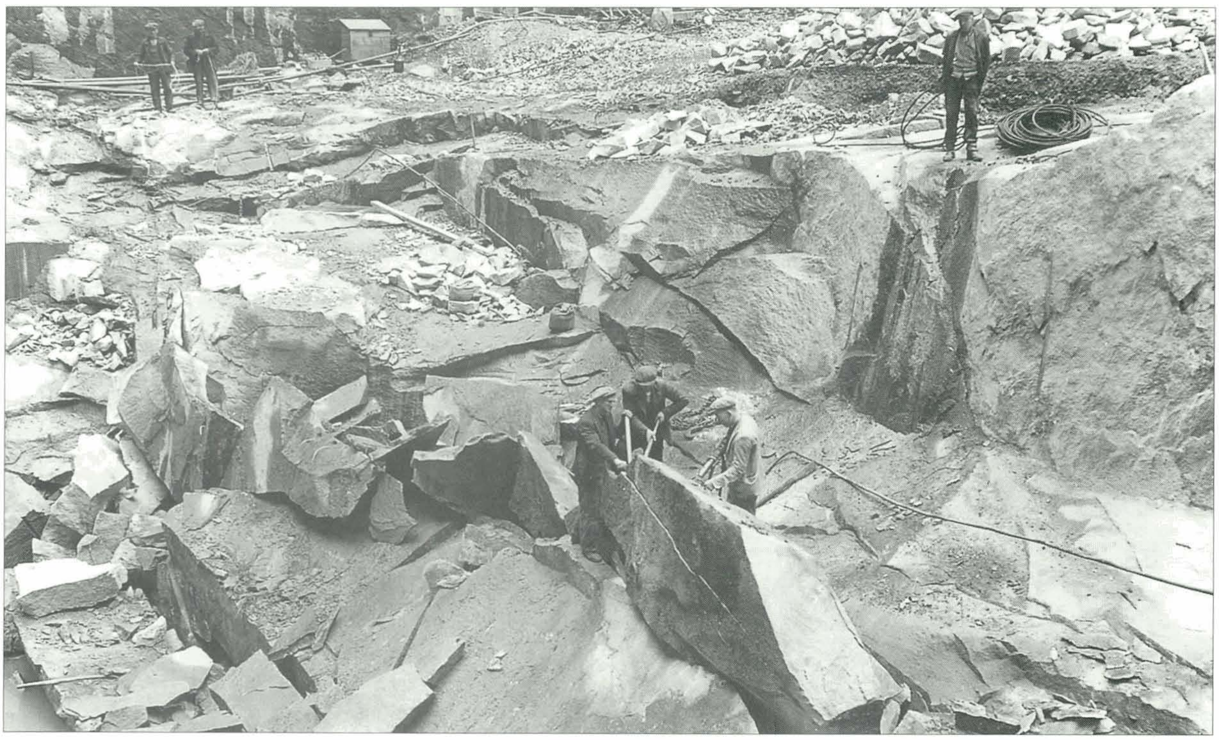
Rubislaw Quarry, Aberdeen (C3749), 1939

A portable pump is lowered to the floor for clearing the quarry of water.



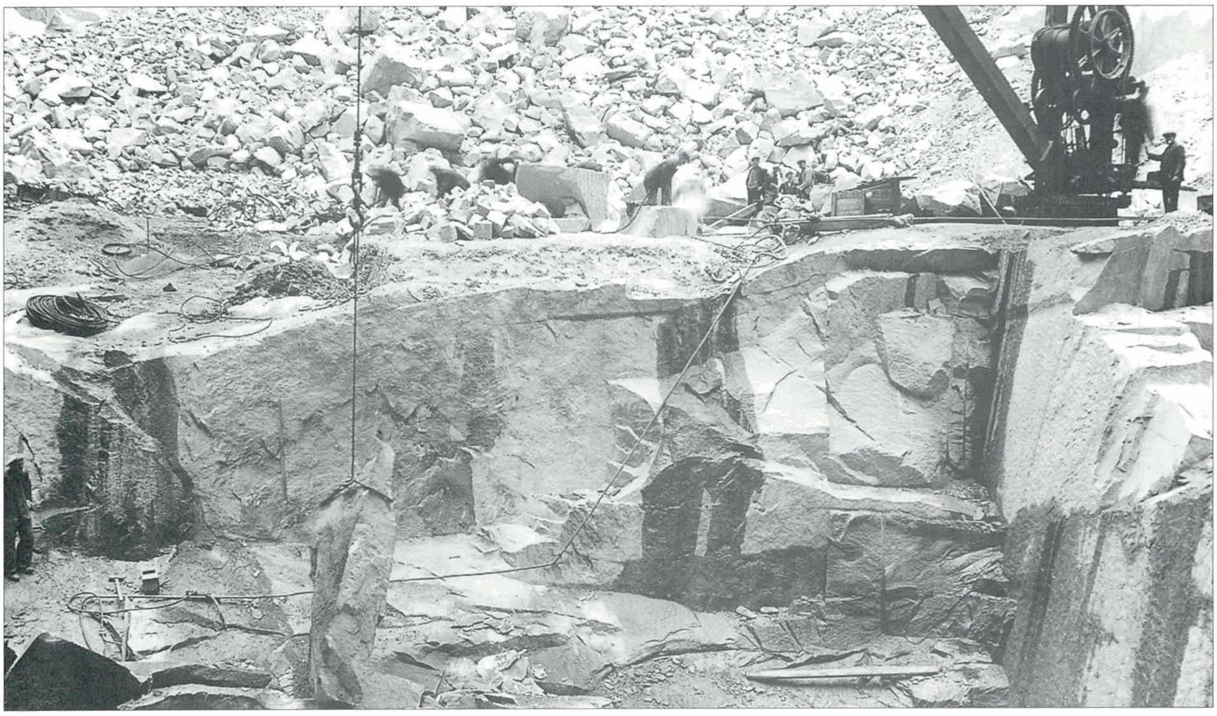
Kemnay Quarries, Aberdeenshire (C3750), 1939

The deep Kemnay quarries also worked a grey granite. This general view shows the scale of working (the quarry was 122m deep) and the vertical nature of the pit walls. 'Blondin' cables and pulley are clearly seen. Left of the large steel crane on the edge of the quarry is the embarkation point of the 'hutches', the means by which men were lowered to the quarry floor. Scathies (huts) for sett-making are situated in the background.



Kemnay Quarries, Aberdeenshire (C3756), 1939

Blocks broken and split by blast.



Kemnay Quarries, Aberdeenshire (C3757), 1939

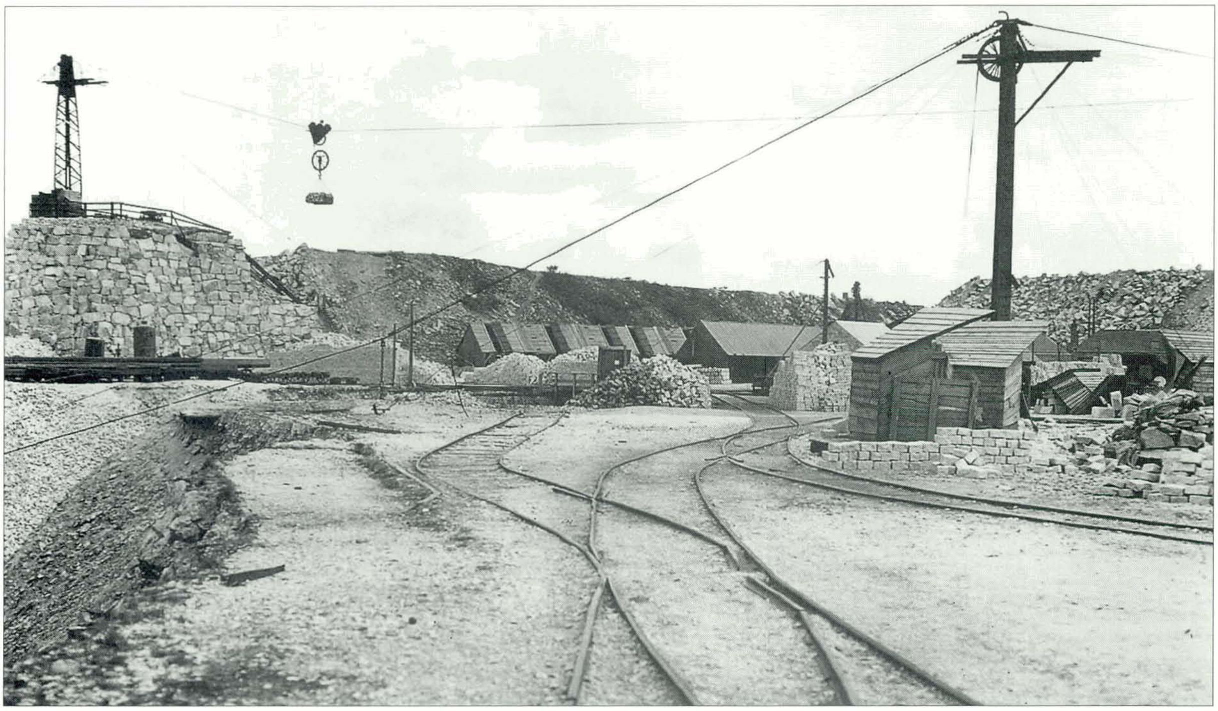
This photograph shows a block being raised by crane.

Kemnay No.2 Quarry, Aberdeenshire (C3755), 1939

The view of Kemnay No.2 Quarry floor shows a steam-driven crane with stays anchored by stone blocks. Dressed blocks of varying sizes await transport out of the quarry.

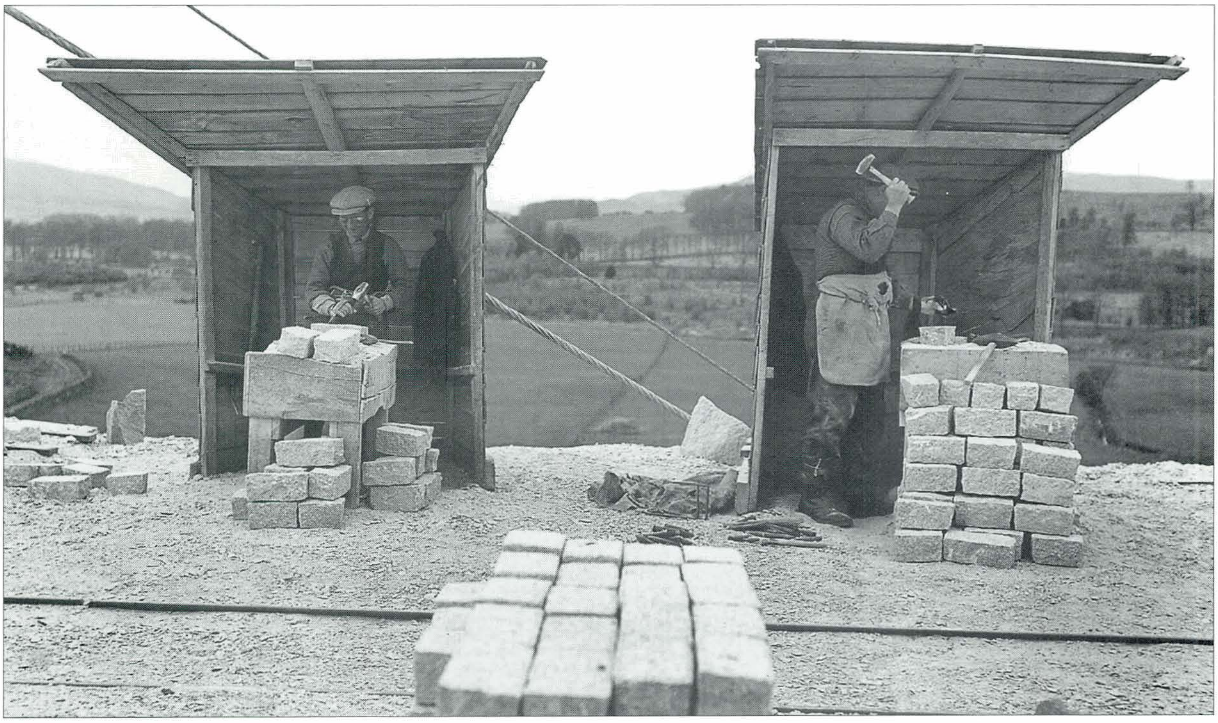
Kemnay Quarries, Aberdeenshire (C3753) 1939

Setts (cassies) and kerbs stockpiled next to the railway which crosses a bridge over an access road. A 'blondin' lifting cable is also seen. No. 2 Quarry is on the far left.



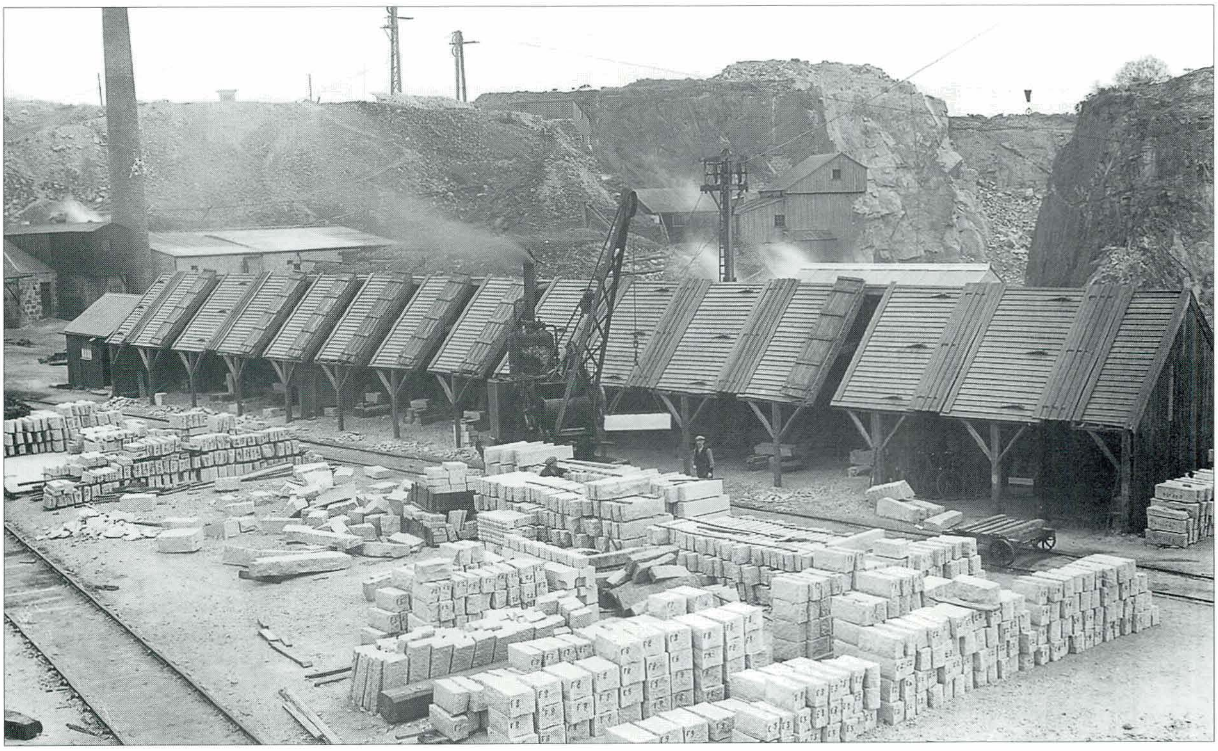
Kemnay Quarries, Aberdeenshire (C3758), 1939

This view across the railway bridge shows a 'blondin' in action, transporting setts above the yard with the masons' sheds in the background.



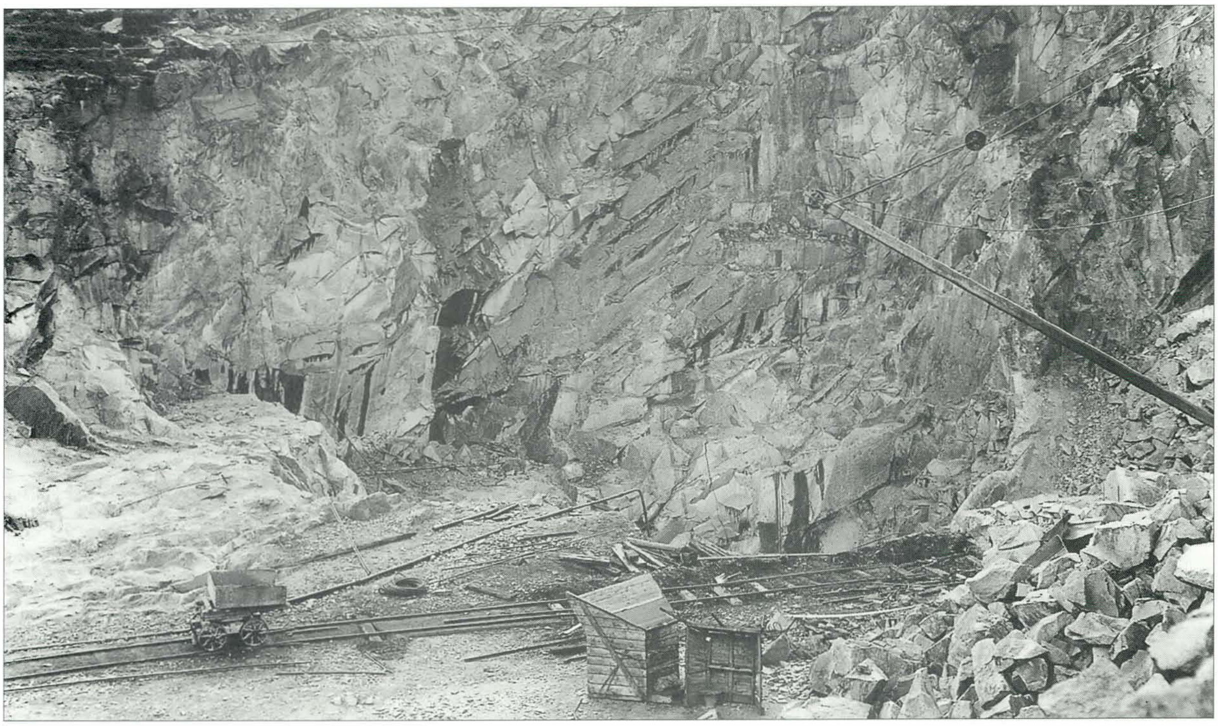
Kemnay Quarries, Aberdeenshire (C3759), 1939

Sett-makers are hard at work in their scathies (huts).



Kemnay Quarries, Aberdeenshire (C3760), 1939

Part of the orderly yard with stockpiled dressed stone labelled according to size. A travelling steam crane is operating in front of the masons' sheds. 'Blondins' and part of No.2 Quarry can be seen in the background.



Corrennie Quarry, Tillyfourie, Aberdeen (C3771), 1939

This quarry, some 76 m deep, yielded pink quartz-rich granite with subordinate bands of grey quartz diorite. On the quarry floor is a sett-maker's hut and railway with bogie.

5.07 Slates

Slates are metamorphosed mudstones which possess a well-developed cleavage along which the rock will split. There are several slate belts developed in the Dalradian rocks of the Grampian Highlands. In addition to Ballachulish, Loch Lomond and Birnam, one of the principal regions supplying slate for many centuries was Easdale, Argyllshire (Figures 9 and 10).

Figure 9 Map of the Easdale Slate Belt.

Reproduced by permission of the Director, British Geological Survey.

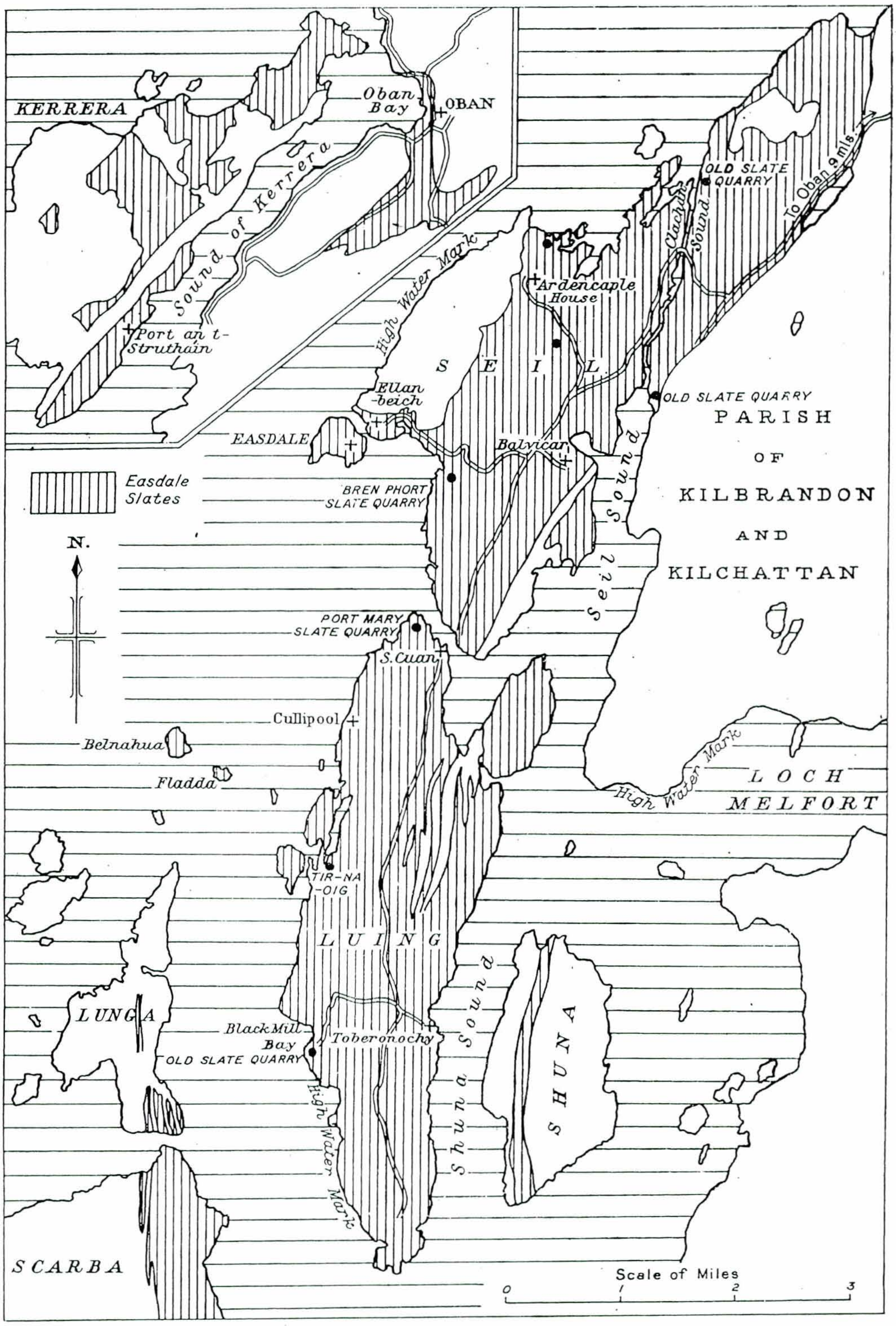
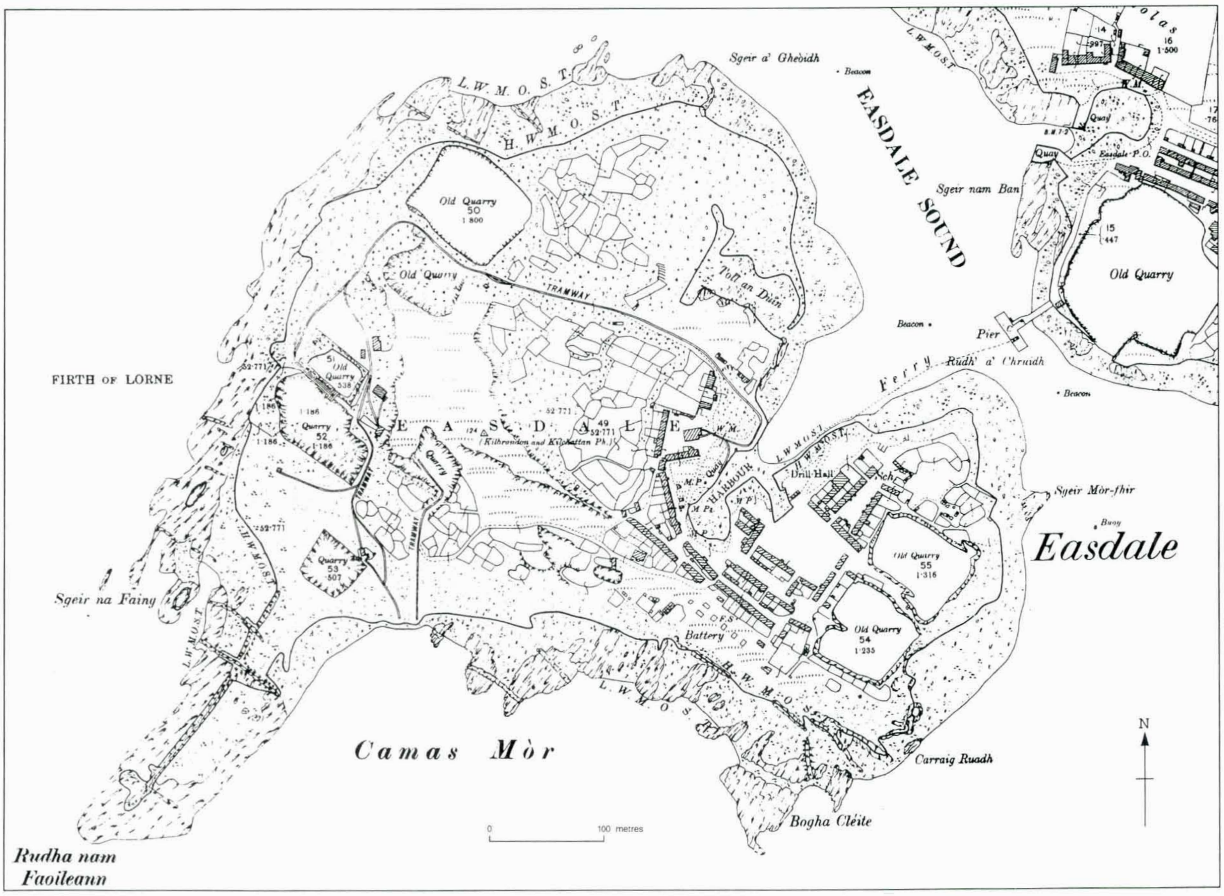


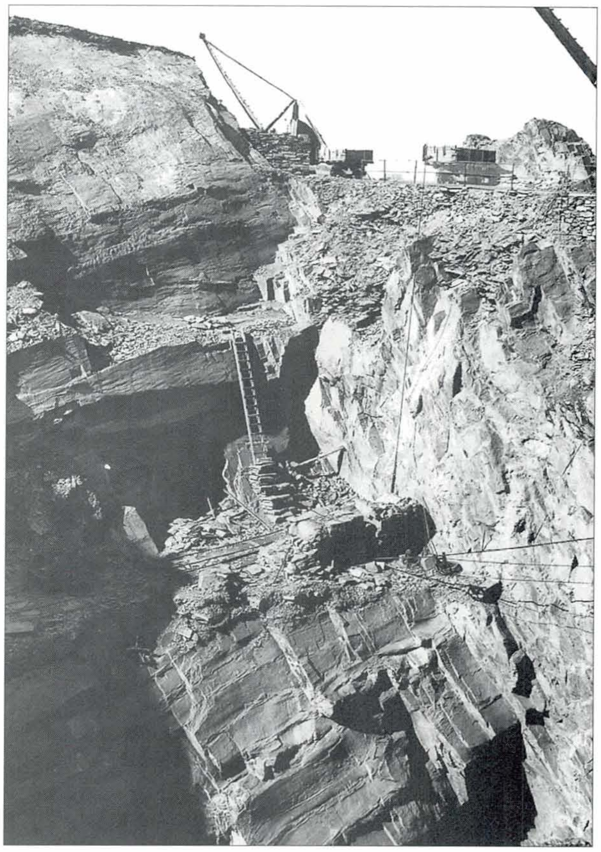
Figure 10 Island of Easdale: Extract of the Ordnance Survey 25 inch County Map Argyllshire CXXI.6 & 10 and CXXI.7 (1899 edition)

Note scale is reduced



(i) Easdale Island Slate

Some of the oldest workings were on Easdale Island. The 1899 edition of the Ordnance Survey 25 inch County Map (Figure 10) shows the extent of workings. In this district the quarrymen applied Gaelic names to the various parts of a fold. A working along a gently inclined limb, where cleavage and bedding nearly coincide was said to be on the sgriob (pronounced skreep). On a highly inclined limb, the beds were said to be on the beul (pronounced byel). At the fold hinge, the beds are said to be on the bonn (pronounced bown). Cubic iron pyrites crystals found within the slates were said to be fresh and unoxidised. They tended to cleave in two when the slates were cleaved and did not pull out to leave holes.



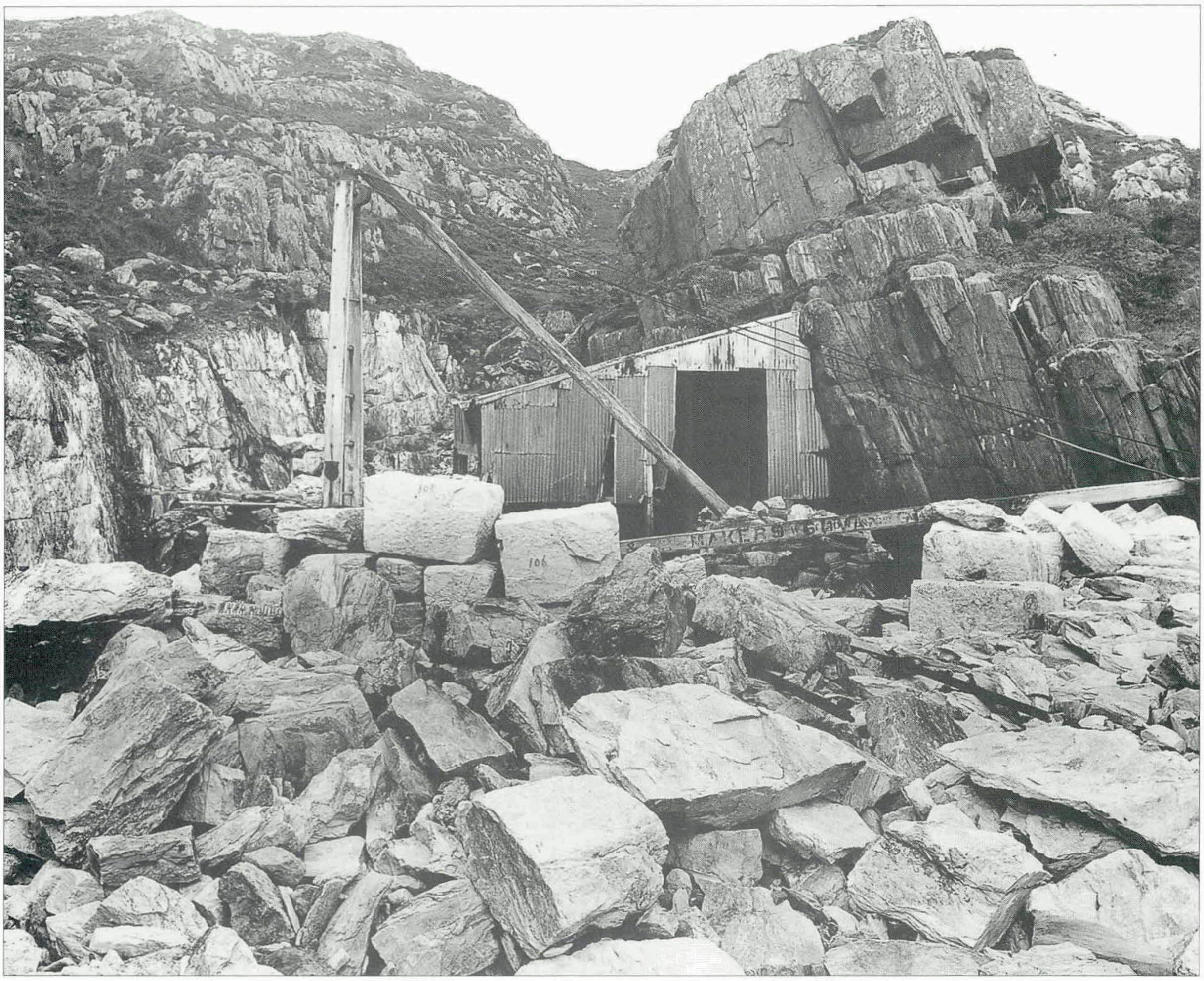
Easdale Island Quarries, Argyllshire (C1087, 1089), c.1904

The Easdale Island slate quarries worked slates of the 'Black Slate Group'. Slaty cleavage dips steeply from left to right and bedding is almost indistinguishable. The wrinkling is due to incipient strain-slip cleavage. The photographs show the rail at the top of the quarry and ladder supported at its foot by what appear to be precarious steps constructed of piles of slates!

Photographs courtesy of the British Geological Survey.

5.08 Marbles

Serpentine-rich, coloured marble, the rock known as ophicalcite, is characteristic of the Iona Marble, some of the Skye Marble worked at Torrin and the Ledmore Marble worked near Lairg. Use for ornamental purposes and interior work is encouraged by geological properties of the marble, notably the relative softness of the rock which aids cutting and the mineralogy which enables the rock to take a polish. At Torrin, white marble is the principal product used as stone chipping on roughcast blocks. Ledmore is the only marble dimensioned stone quarry in the UK (Appendix 2) yielding blocks of a variety of mottled colours.



Marble Quarry, Iona (C2769), c.1920

The coastal Marble Quarry at An-t-Ard, Iona worked an Archean (Pre-Cambrian) coloured marble (a serpentine-bearing carbonate rock) which occurs as lenticles in the Lewisian gneiss. The foliation in the gneiss dips steeply from left to right. After an ancient history of intermittent working, the quarry was re-opened during the period 1907 to 1914. The BGS photograph shows a hand-winched crane in front of the cutting frame used for moving blocks and slabs. The crane maker was D Watson & Co., Govan, Glasgow. Another crane was situated on the nearby quay from which the stone was shipped. To the left of centre is a stone with several thin parallel cuts presumably to provide small slabs for ornamental purposes.

Photograph courtesy of the British Geological Survey.

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8.00 GLOSSARY

Only a brief selection of geological, quarrying and architectural terms is given. For further guidance the following references are recommended:

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Amphibole Family of rock-forming minerals, mainly silicates of calcium, magnesium and iron. A common constituent of some igneous and metamorphic rocks.

Andesite Fine-grained volcanic rock consisting of feldspar and an iron-magnesian silicate mineral.

Ashlar Hewn blocks of masonry finely dressed to size and normally laid in regular courses.

Basalt Dark coloured, fine-grained, basic igneous rock consisting of silicate minerals including feldspar, pyroxenes and iron oxides.

Bedding Natural layers formed during deposition of sediments.

Blaes Mudstone or shale, not containing much bituminous material.

Cladding Thin slabs of stone used as external, non-load-bearing covering to building structure.

Conglomerate Sedimentary rock consisting of water-worn pebbles bound together in a sandy matrix.

Corbel Stone or series of stones projecting from a wall used for support.

Course Continuous layer of stones of uniform height.

Coursed Stones laid in courses (usually) to correspond with quoin and jamb stones.

Cross-bedding A series of inclined bedding planes having a relationship to the direction of current flow (also current-bedding).

Dimensioned Stone Ashlar or measured stone.

Dip Inclination of strata to the horizontal.

Dolerite Medium-grained basic igneous rock.

Dressed With any kind of worked finish.

Dune Bedding Large-scale cross-bedding typical of sands deposited in desert and beach dunes.

Dyke Sheet-like body of igneous rock which cuts across the bedding of the country-rock - e.g. sedimentary rock.

Fault Fracture in rock along which there has been an observable amount of displacement.

Feldspar The most important single group of rock-forming silicate minerals including silicates of sodium, potassium and calcium.

Flagstone Fissile, micaceous, laminated sandstone used for pavements or roofing.

Gabbro Coarse crystalline basic plutonic rock consisting of feldspar, pyroxene and sometimes olivine.

Granite Coarse-grained igneous rock consisting of quartz, feldspar and very commonly mica.

Greywacke Fine- to coarse-grained, hard sandstone consisting of mainly angular rock fragments.

Joint A fracture with no displacement. Joints often occur in two sets, more or less vertical and at right angles to each other.

Lithology Character of rock in terms of composition,structure and grain size.

Liver Rock A massive sandstone without discernible bedding which can be worked in all directions (also freestone).

Metamorphic Rock derived from pre-existing rocks by action of high temperature and/or pressure in the earth's crust.

Mica Flaky complex hydrated silicate mineral.

Olivine Group of rock-forming, iron and magnesium (Ferro-magnesian) silicate minerals.

Plug and Feathers Steel wedge or chisel (plug) with half-round steel strips (feathers) on either side, used for splitting stone in a series of holes drilled into the stone (Figure 7, No.14).

Pyroxene Group of rock-forming, iron and magnesium (Ferro-magnesian) silicate minerals.

Quartz Common rock-forming glassy mineral, silica.

Quoin Stone at external angle of wall, usually bonded with tails extending, alternately, onto both faces.

Random rubble Walling of irregular unsquared stones not laid in courses.

Rubble Uncut stone of variable and irregular shape and size which was traditionally laid in rough courses.

Sandstone Sedimentary rock composed of detrital sand grains naturally cemented. Sandstones can be classified according to grain mineralogy (Table 6). The basic categories include Quartz arenite, Feldsarenite, Litharenite and Greywacke. Qualifiers based on the cement composition may also be used and commonly sandstones are described as siliceous (silica cement), calcareous (calcite - ie calcium carbonate cement) or ferruginous (iron-rich cement). A sandstone with high clay content may be referred to as argillaceous.

Sett Stone roughly squared for paving.

Sill A sheet of igneous rock intruded along the bedding planes of earlier rocks.

Squared rubble irregularly formed stones, roughly worked to a more consistent shape so that they can be coursed more readily.

Stoop and room Method of mining which involved leaving pillars of the material being mined to support the roof (also known as Pillar and Stall).

Till Mixture of clay and stones, deposited by ice (also boulder clay).

Tirr Material removed as overburden, including glacial till, sand and gravel and poor quality strata unsuitable for building.

Tooled Dressed stone with hewing mason's tool markes evident on the surface. A wide range of textures can be produced.

APPENDIX 1
LIST OF BGS PHOTOGRAPHS

Print No.	Quarry	Grid reference	Rock type	Year	Photographer
C02912	Ballochmyle Quarries, Mauchline.	NS50002600	Sandstone	c.1921	W Manson
C02913	Ballochmyle Quarries, Mauchline.	NS50002600	Sandstone	c.1921	W Manson
C02914	Ballochmyle Quarries, Mauchline.	NS50002600	Sandstone	c.1921	W Manson
C02915	Ballochmyle Quarries, Mauchline.	NS50002600	Sandstone	c.1921	W Manson
C00238	Clynelish Quarry, 1.3 km. WNW of Brora.	NC88000400	Sandstone	c.1899	R Lunn
C00239	Clynelish Quarry, 1.3 km. WNW of Brora.	NC88000400	Sandstone	c.1899	R Lunn
C03605	Corncockle Quarry, Lochmaben.	NY08608700	Sandstone	1937	WD Fisher
C03606	Corncockle Quarry, Lochmaben.	NY08608700	Sandstone	1937	WD Fisher
C03604	Corncockle Quarry, Lochmaben.	NY08608700	Sandstone	1937	WD Fisher
C03771	Corrennie Quarry, Tillyfourie, Aberdeen.	NJ64301200	Granite	1939	WD Fisher
C03602	Corsehill Quarry, Annan.	NY20607000	Sandstone	1937	WD Fisher
C03603	Corsehill Quarry, Annan.	NY20607000	Sandstone	1937	WD Fisher
C03608	Corsehill Quarry, Annan.	NY20607000	Sandstone	1937	WD Fisher
C03609	Corsehill Quarry, Annan.	NY20607000	Sandstone	1937	WD Fisher
C03727	Craignair Hill Quarry, Dalbeattie.	NX81006000	Granodiorite	1939	WD Fisher
C03728	Craignair Hill Quarry, Dalbeattie.	NX81006000	Granodiorite	1939	WD Fisher
C03729	Craignair Hill Quarry, Dalbeattie.	NX81006000	Granodiorite	1939	WD Fisher
C03730	Craignair Hill Quarry, Dalbeattie.	NX81006000	Granodiorite	1939	WD Fisher
C03732	Craignair Hill Quarry, Dalbeattie.	NX81006000	Granodiorite	1939	WD Fisher
C03733	Craignair Hill No. 2 Quarry, Dalbeattie.	NX81006000	Granodiorite	1939	WD Fisher
C03061	Devon Quarry, 3.2 km. North of Alloa.	NS89809590	Sandstone	c.1926	W Manson
C01087	Easdale Island Quarry.	NM73001700	Slate	c.1904	R Lunn
C01089	Easdale Island Quarry.	NM73001700	Slate	c.1904	R Lunn
C03726	Glebe and Kirkmabreck Quarry, Creetown.	NX48005650	Granite	1939	WD Fisher
D00692	Greenbrae Quarry, Hopeman	NJ13806920	Sandstone	1963	WD Fisher
C03536	Hailes Quarry, Slateford, Edinburgh.	NT20807050	Sandstone	1935	WD Fisher
B00932	Hailes Quarry, Slateford, Edinburgh.	NT20807050	Sandstone	c.1913	R Lunn
B00933	Hailes Quarry, Slateford, Edinburgh.	NT20807050	Sandstone	c.1913	R Lunn
C03114	Hailes Quarry, Slateford, Edinburgh.	NT20807050	Sandstone	c.1926	D Tait
C01533	Holborn Head Quarry 4.0 km. NE of Thurso.	ND10007100	Flagstone	c.1910	R Lunn
C01534	Holborn Head Quarry 4.0 km. NE of Thurso.	ND10007100	Flagstone	c.1910	R Lunn
C02417	Huntershill Quarries, Bishopbriggs, Glasgow	NS60806950	Sandstone	c.1908	R Lunn
C02418	Huntershill Quarries, Bishopbriggs, Glasgow	NS60806950	Sandstone	c.1908	R Lunn
C02769	Iona Marble Quarry, An T-Ard	NM26002100	Marble	c.1920	W Manson
C03750	Kemnay Quarries, Kemnay, Aberdeen.	NJ73701700	Granite	1939	WD Fisher
C03753	Kemnay Quarries, Kemnay, Aberdeen.	NJ73701700	Granite	1939	WD Fisher
C03755	Kemnay No. 2 Quarry, Kemnay, Aberdeen.	NJ73701700	Granite	1939	WD Fisher
C03756	Kemnay Quarries, Kemnay, Aberdeen.	NJ73701700	Granite	1939	WD Fisher
C03757	Kemnay Quarries, Kemnay, Aberdeen.	NJ73701700	Granite	1939	WD Fisher
C03758	Kemnay Quarries, Kemnay, Aberdeen.	NJ73701700	Granite	1939	WD Fisher
C03759	Kemnay Quarries, Kemnay, Aberdeen.	NJ73701700	Granite	1939	WD Fisher
C03760	Kemnay Quarries, Kemnay, Aberdeen.	NJ73701700	Granite	1939	WD Fisher
C03596	Locharbriggs Quarry, Locharbriggs, Dumfries.	NX99008100	Sandstone	1937	WD Fisher
C03598	Locharbriggs Quarry, Locharbriggs, Dumfries.	NX99008100	Sandstone	1937	WD Fisher
C03600	Locharbriggs Quarry, Locharbriggs, Dumfries.	NX99008100	Sandstone	1937	WD Fisher
C03601	Locharbriggs Quarry, Locharbriggs, Dumfries.	NX99008100	Sandstone	1937	WD Fisher

Print No.	Quarry	Grid reference	Rock type	Year	Photographer
C03740	Rubislaw Quarry, Aberdeen.	NJ91000500	Granite	1939	WD Fisher
C03742	Rubislaw Quarry, Aberdeen.	NJ91000500	Granite	1939	WD Fisher
C03744	Rubislaw Quarry, Aberdeen.	NJ91000500	Granite	1939	WD Fisher
C03746	Rubislaw Quarry, Aberdeen.	NJ91000500	Granite	1939	WD Fisher
C03748	Rubislaw Quarry, Aberdeen.	NJ91000500	Granite	1939	WD Fisher
C03749	Rubislaw Quarry, Aberdeen.	NJ91000500	Granite	1939	WD Fisher
C01543	Scrabster Quarry, 2.4 km. NW of Thurso.	ND08007000	Flagstone	c.1910	R Lunn
C01544	Scrabster Quarry, 2.4 km. NW of Thurso.	ND08007000	Flagstone	c.1910	R Lunn
C03734	Silver Grey Quarry, Creetown.	NX48605680	Granite	1939	WD Fisher
C03735	Silver Grey Quarry, Creetown.	NX48605680	Granite	1939	WD Fisher
C03736	Silver Grey Quarry, Creetown.	NX48605680	Granite	1939	WD Fisher
C03737	Silver Grey Quarry, Creetown.	NX48605680	Granite	1939	WD Fisher
C01555	Stonegunn Quarry, 4.8 km. SE of Thurso.	ND15006500	Flagstone	c.1910	R Lunn
C01554	White Moss Quarry 4.8 km SE of Thurso	ND15006500	Flagstone	c.1910	R Lunn
C01552	Youkil Quarry, Hilliclay, 4.0 km. SE of Thurso.	ND15006500	Flagstone	c.1910	R Lunn

APPENDIX 2
LIST OF QUARRIES CURRENTLY WORKING BUILDING STONE

Quarry Name	Location	National Grid ref.	Operator	Rock type	Age
Achavrole	Calder	ND098594	Scotstone Ltd	Sandstone	Devonian
Braxside	Reay	NC950639	G H Minter	Diorite	Reay Diorite
Clashach	Hopeman	NJ162701	Moray Stone Cutters	Sandstone	Permian
Corncockle	Lochmaben	NY086870	Onyx Contractors	Sandstone	Permian
Corsehill	Annan	NY206700	Onyx Contractors	Sandstone	Triassic
Cruaday	Sandwick	HY247217	Orkney Builders Ltd	Sandstone	Devonian
Dunmore	Airth	NS860881	Scottish Natural Stones Ltd	Sandstone	Carboniferous
Easter Delfour	Kincraig	NH843087	Alvie Trust	Granite	Monadhliath Granite
Gatelawbridge	Thornhill	NX902965	Scottish Natural Stones Ltd	Sandstone	Permian
Kemnay	Kemnay	NJ737170	John Fyfe Ltd	Granite	Kemnay Granite
Ledmore	Ledmore	NC253136	Anglo European - Ledmore Marble Ltd	Marble	Cambro-Ordovician
Locharbriggs	Dumfries	NX990805	Baird and Stevenson (Quarrymasters) Ltd	Sandstone	Permian
Newbigging	Burntisland	NT211864	Scottish Natural Stones Ltd	Sandstone	Carboniferous
Newcastleton Forest	Newcastleton	NY495840	Baird and Stevenson (Quarrymasters) Ltd	Sandstone	Carboniferous
Spittal No 1	Watten	ND172540	A. and D. Sutherland	Sandstone	Devonian
Spittal No 2	Watten	ND166545	Caithness Stone Ltd	Sandstone	Devonian
Spynie	Elgin	NJ222657	Moray Stone Cutters	Sandstone	Permian
Stonegunn	Castletown	ND157659	Caithness Stone Ltd	Sandstone	Devonian
Tormore	Ross of Mull	NM305239	Scottish Natural Stones Ltd	Granite	Ross of Mull Granite
Weydale	Thurso	ND153650	Caithness Flagstones Ltd	Sandstone	Devonian