ASSESSING THE POTENTIAL FOR REOPENING A BUILDING STONE QUARRY:

KING'S QUARRY, THORNHILL, DUMFRIESSHIRE

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Assessing the potential for reopening a building stone quarry: King's Quarry, Thornhill, Dumfriesshire

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Keywords

King's Quarry, sandstone, quarry, building stone, resources, minerals, petrology.

Front cover

Main Image: Drumlanrig Castle, Thornhill, Dumfriesshire, constructed late 17th century using King's Quarry sandstone. Smaller images (left to right): King's quarry 2009; Masonry wall of Drumlanrig Castle Mains, present day kennels; Detail of 1810 map of King's Quarry; Microscopic thin section of King's quarry sandstone; Geology map of Thornhill area.

Bibliographical reference

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1. INTRODUCTION AND AIMS OF THIS STUDY

The British Geological Survey (BGS) has been commissioned by the Scottish Stone Liaison Group to investigate the potential for reopening a number of former building stone sites from around Scotland under the project 'Scottish Building Stone Resources'. As part of this study, BGS was asked to undertake a general examination of the building stone resources at the King's Quarry, near Carronbridge, Thornhill in Dumfriesshire. The quarry lies within the Buccleuch Estates and is known to have had a long history of operation, having been active around the mid 19th and early 20th centuries, although likely to have produced stone since the 17th century. Today the quarry is periodically worked by the Buccleuch Group, on a small scale mostly for repairs and restoration of existing estate building in the district.

Today there is a growing interest in the use of natural stone in Scotland and throughout the United Kingdom for a range of functions, including the repair of historic buildings, new construction, and stone for public realm works, streetscape improvements and infrastructure projects. An increasing awareness of the distinctiveness of Scottish stone and the importance of selecting appropriate stone that is 'in keeping' with the local stone built heritage has led to an improving market for Scottish stone, in particular stone which has a proven historical reputation. The reopening of three historic dimension stone quarries at Swinton in Berwickshire (2000), Cullalo in Fife (2004) and Pitairlie in Angus (2009) is taken as evidence of this potential resurgence of the Scottish stone industry. These three quarries each produce a different sandstone, each with distinctive characteristics to supply a particular market.

The purpose of this report is to document new and existing and technical and historical information for the King's Quarry sandstone, and to present the information in a form which can be used to help provide an authoritative opinion as to the potential for King's Quarry to supply a wider market in the future, both for restoration/repairs and for new build. The work described in this study follows a short visit to the quarry and a number of estate buildings by Ewan Hyslop and Emily Tracey (BGS Building Stones Team), Colin Tennant, (Scottish Stone Liaison Group), Raymond Shields (Buccleuch Group Property Development Manager) and Mark Coombs (Buccleuch Estate Manager) on 11th December 2009.

This report outlines the geological setting and documented history of sandstone production at King's Quarry, based on archival records and survey maps held by BGS. A number of other published sources were also consulted to provide background historical information. Stone samples were collected during the quarry visit and underwent petrographic analysis in accordance with BS EN 12407:2000 'Natural Stone Test Methods – Petrographic Examination, in order to provide comments on the quality of the stone and suitability for use. It is hoped that the information provided in this report will assist in the assessment of the quarry for continued operation and expansion to supply a wider market. No further standard tests have been undertaken as part of this study, although these are likely to be relevant should the quarry be considered for reopening and commercial supply.

2. LOCATION AND DESCRIPTION OF THE GEOLOGY OF KING'S QUARRY

King's Quarry is located c.1 km to the northeast of Carronbridge and c.3 km north of Thornhill in Dumfriesshire [NX 877985], situated in woodland close to the main Glasgow, Dumfries and Carlisle railway line and c.600m east of the A702 (Fig. 1). The quarry site is of a moderate size with good access and a reasonably large open working area.

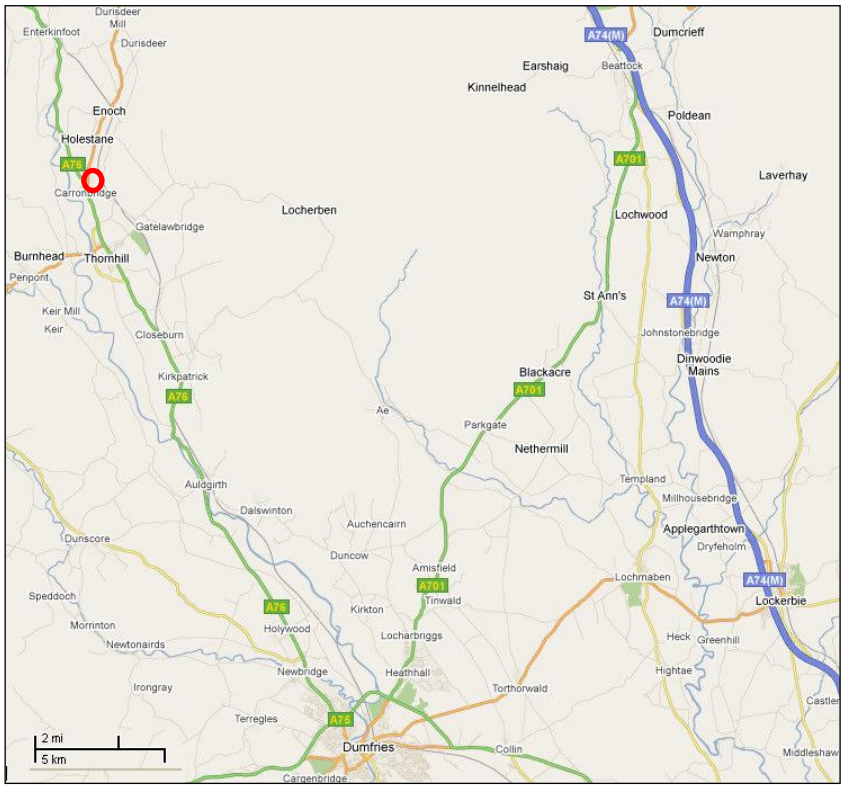


Fig. 1: Location of King's Quarry, near Carronbridge. Quarry site shown by red circle.

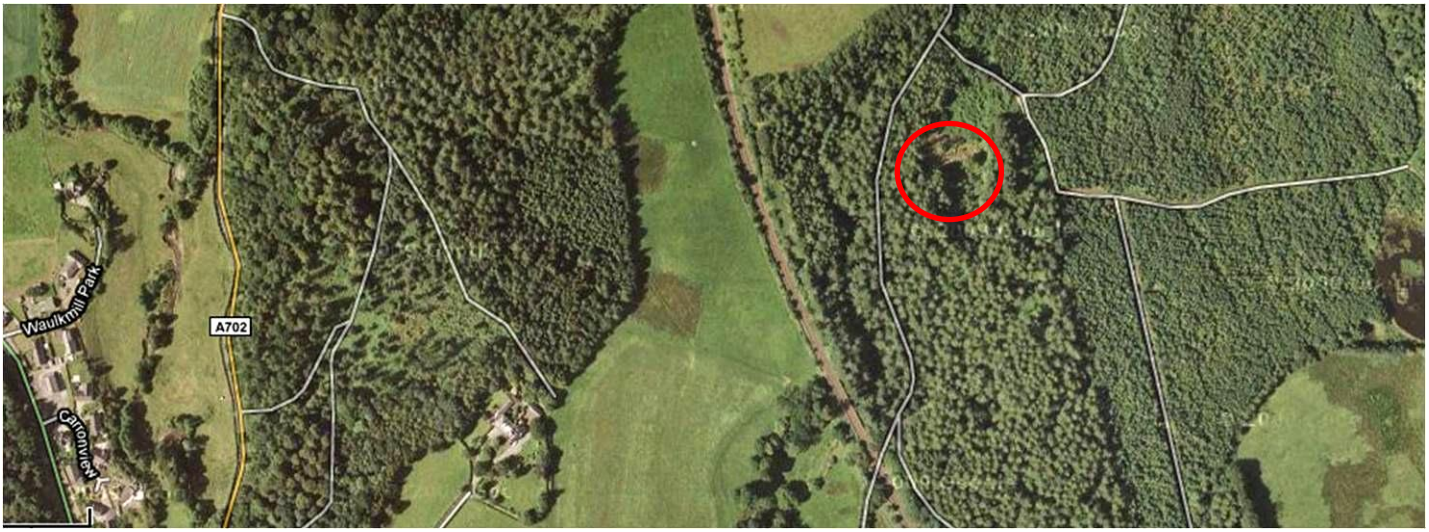


Fig. 2: Location of King's Quarry, sheltered within woodland close to the A702. The main railway line passes just west of the site. Despite proximity to main transport links, the quarry is accessed by small single track roads including a low bridge under the railway line.

Geologically, King's Quarry lies within the Thornhill Basin, a north-south trending geological basin containing sedimentary rocks of Carboniferous and Permian age (dominated by sandstones) with some basaltic igneous rocks of Permian age (Fig. 3). The basin lies within the vast southwest-northeast trending turbiditic sandstones (sometimes known as greywackes) of Ordovician and Silurian age which form much of the Southern Uplands. The Thornhill Basin is approximately 17 km long from north to south and up to 8 km wide near its southern end.

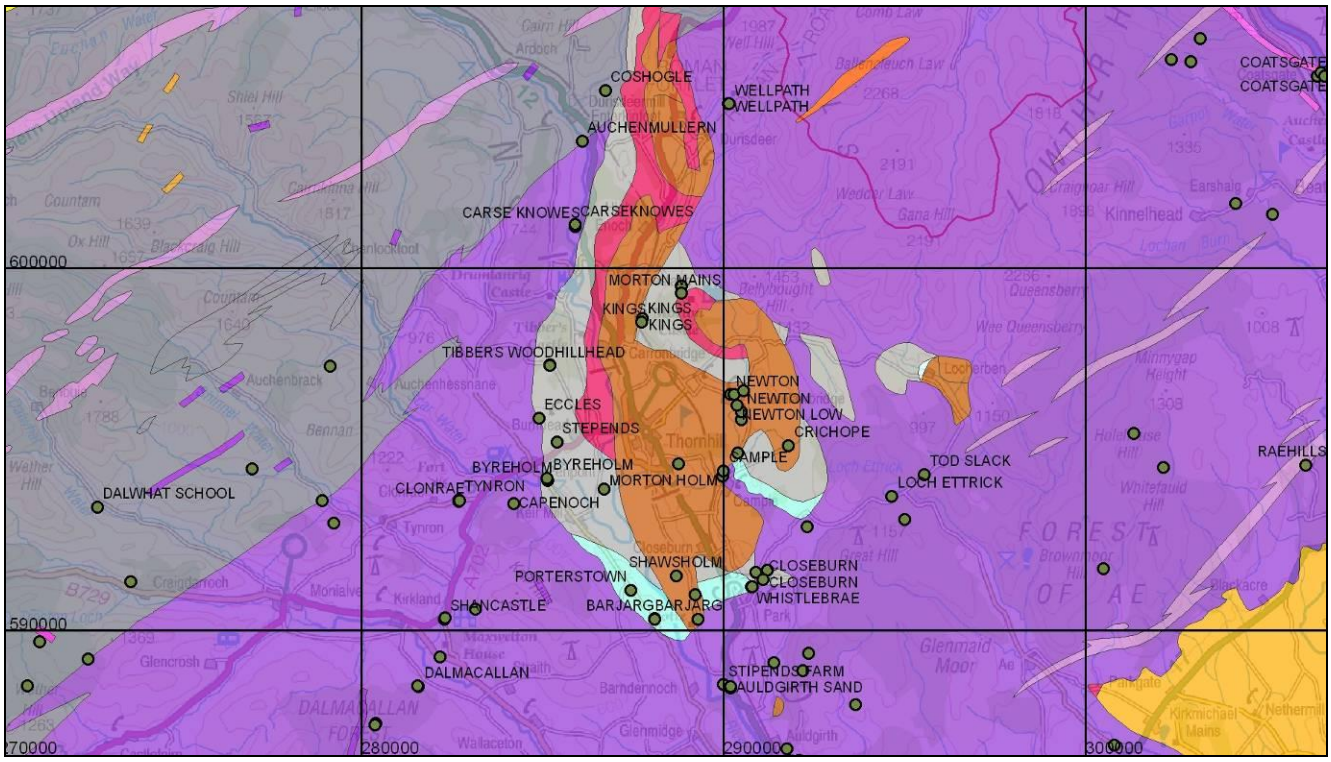


Fig. 3: Geological map of the district, showing Dark Grey: Greywacke 'sandstones' of the Leadhills Supergroup; Purple: Greywacke 'sandstones' of the Gala Group and Hawick Group; Light grey: Carboniferous sandstones and argillaceous rocks (mudstones) of the Coal Measures Group; Red: Lavas of the Carron Basalt Formation (Permian age); Brown: Red sandstones of the Thornhill Sandstone Formation (Early Permian age); Light Blue: Carboniferous limestones of the Closeburn Limestone Formation. Green dots show the sites of recorded quarries (both bedrock and superficial deposits such as sand & gravel), with quarry names where known.

Fig. 4 is a more detailed geological map of the area around King's Quarry, showing the various rock types within the Thornhill basin. The quarry lies towards the eastern edge of a relatively small triangular-shaped outcrop of sandstone, the Towburn Sandstone Member (shown as light yellow), part of the Carboniferous Passage Formation of Namurian to Westphalian age. This geological unit is recorded as consisting of repeated sequences of up to 15m thick of grey, white and pink, poorly sorted, medium to very coarse grained, occasionally pebbly sandstones, with occasional beds of coarser conglomerate. The sandstone is thought to have originated as a fluvial-channel sand, deposited in braided river channels of low-sinuosity.

The sandstone outcrop is bounded to the west and south by red sandstones of Permian age, with the western boundary being a NNW-trending fault. At the eastern edge of the outcrop the sandstone is overlain by Lower Coal Measures mudstones, forming part of a stratigraphic series through rocks of upper Carboniferous to Permian ages, with progressively younger rocks towards the east. The Carboniferous rock sequence at Kings Quarry dips gently towards the east. In detail (Fig. 4b) it can be seen that the east side of the quarry is limited by the presence of the Lower Coal Measures mudstones. Although the sandstones continue to the east beneath the mudstones, they are found under increasing depth of mudstone making quarrying difficult. This explains why the quarry grew in a north-south direction.

Fig. 5 is a compilation of data from BGS records showing the stratigraphic sequence of different rock types in this part of the Thornhill Basin. It identifies the Townhead Sandstone Member as the principal sandstone unit present, amongst a mixed Carboniferous sequence of siltstones, mudstones, limestones, and subordinate sandstones. In the summary table the Townhead sandstone is shown as a 40 metre thick unit, bounded above and below by siltstones and mudstones.

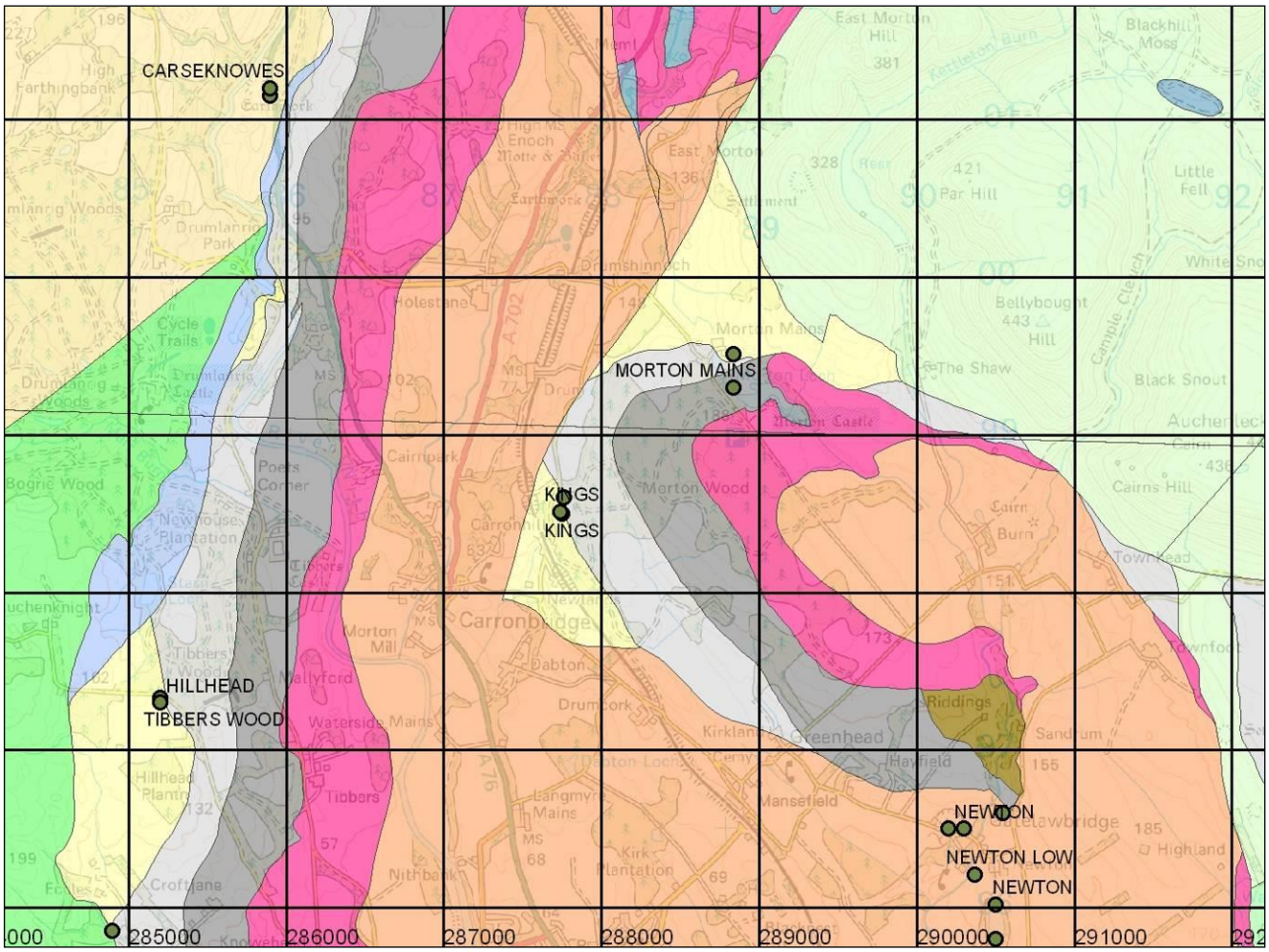


Fig. 4: Detailed geological map of the area around King's Quarry, showing sites of recorded quarries from the BGS database. Pale yellow is the Townburn Sandstone Member from which the King's Quarry sandstone is extracted –seen to outcrop in a number of areas and also quarried to the west at Tibbers Wood/Hillhead and to the northeast at Morton Mains. Other relevant geological units: Salmon pink —Thornhill Sandstone Formation (Early Permian age); Light & Dark grey — Mixed Carboniferous sedimentary rocks of the Lower Coal Measures Formation; Pink —Carron Basalt Formation (Permian age).

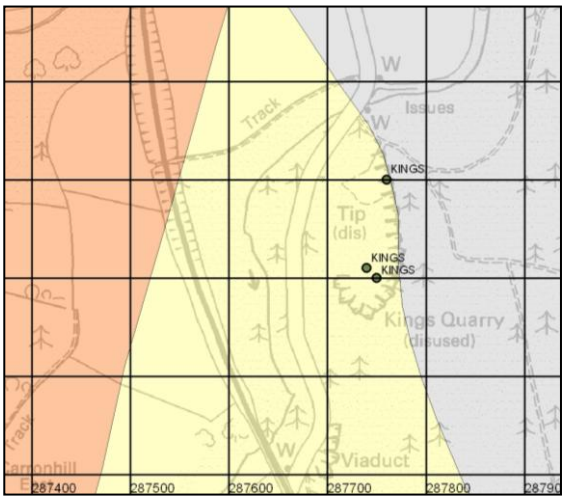
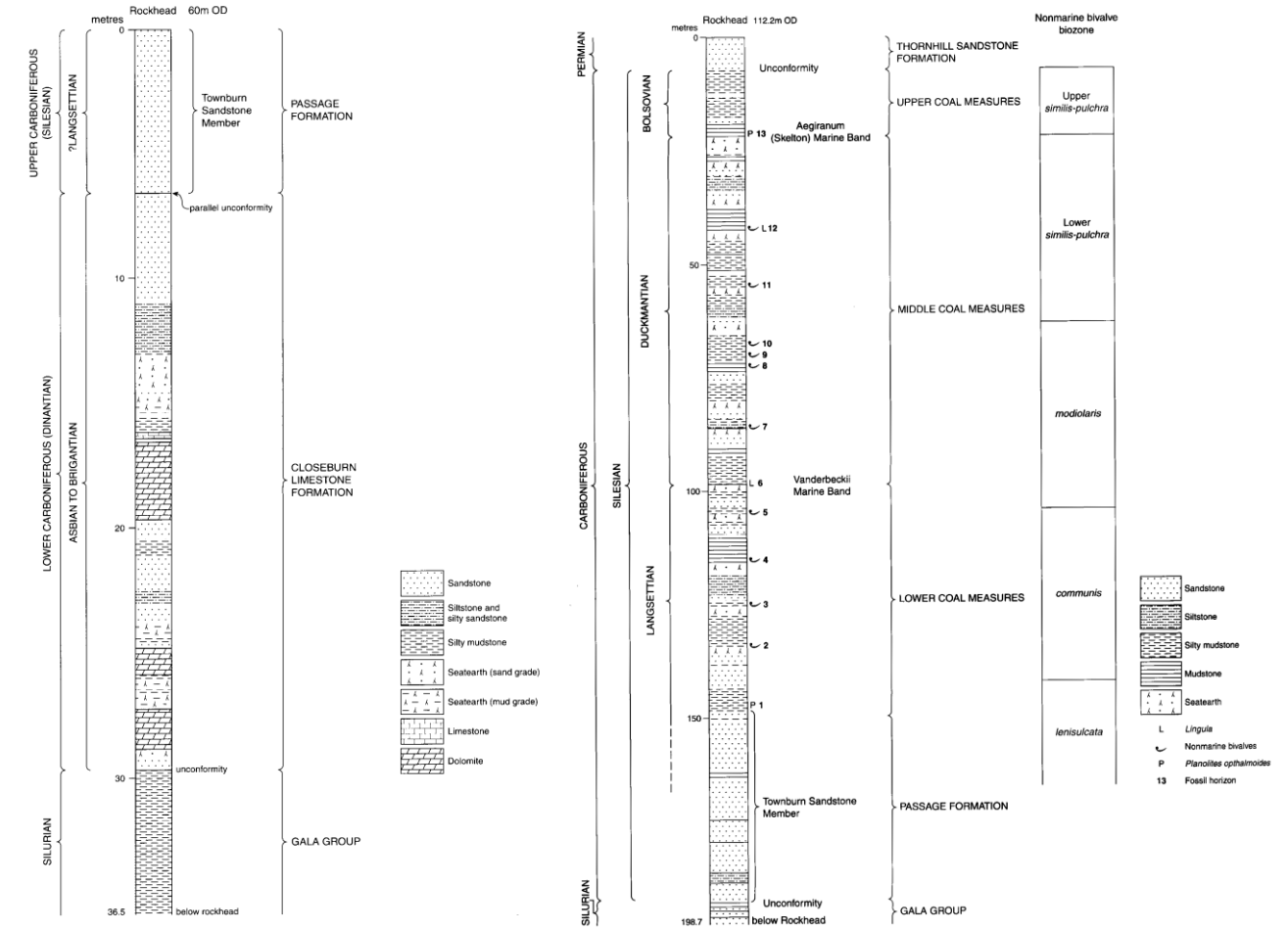


Fig. 4b: Detailed geological map of King's Quarry, showing current extent of the quarry. The sandstone (shown as yellow) is limited to the east by the presence of mudstone (grey colours). To the west, the quarry is limited by the road and railway. Continued expansion southwards appears possible and would continue to exploit the Townburn Sandstone Member.



		SOLID LITHOSTRATIGRAPHICAL FORMATIONS	*Lithology*	*Thickness m*
PERMIAN		**Dumfries Basin**		
		LOCHARBRIGGS SANDSTONE FORMATION	red, dune-bedded sandstone	c.1400
		DOWEEL BRECCIA FORMATION	red breccia with clasts of wacke sandstone, microdiorite and granite	> 200
		Thornhill Basin		
		THORNHILL SANDSTONE FORMATION	red, dune-bedded sandstone	200
		LOCHERBEN BRECCIA FORMATION	red breccia with clasts mainly of wacke sandstone	50
		DURISDEER BRECCIA FORMATION	sandstone and red breccia with clasts mainly of basalt	50
		CARRON BASALT FORMATION	thin basalt flows and interbedded breccia	20
		Unconformity		
CARBONIFEROUS	SILESIAN	**Thornhill Basin**		
		UPPER COAL MEASURES	sandstone, siltstone and mudstone	15
		MIDDLE COAL MEASURES	sandstone, siltstone and mudstone, mussel bands	75
		LOWER COAL MEASURES	sandstone, siltstone and mudstone, mussel bands	50
		PASSAGE FORMATION Townburn Sandstone Member	sandstone	40
		Unconformity		
	DINANTIAN	ENTERKIN MUDSTONE FORMATION	mudstone, siltstone and sandstone	25
		CLOSEBURN LIMESTONE FORMATION	limestone, calcareous shale and sandstone	>25
		Unconformity		

Fig. 5: Stratigraphic sections from BGS records showing the geological sequence in the King's Quarry area. Two nearby borehole logs (Closeburn Borehole to left-hand side; Crichope Linn borehole to right hand side) show the variability of the Carboniferous rock sequence, with the Towburn Sandstone Member identified as the most significant sandstone present amongst a mixed sequence of principally siltstones, mudstones and limestones. The table shows a summary of the overall rock sequence with the Townburn Sandstone identified as a 40 metre thick unit bounded above and below by siltstone/mudstone dominated rocks.

3. HISTORICAL INFORMATION RELATING TO KING'S QUARRY

King's Quarry is shown on Ordnance Survey maps from 1861 to the present (Fig. 6), specifically identified as a sandstone quarry in 1861 with an apparent working area at the southern end of the site and a possible face aligned north-south along the east side of the quarry. The 1900 map shows that the extraction has expanded considerably, with both the entire east face and extraction at the southern end moved eastwards (Fig. 7). Subsequent maps show the quarry as disused and record much of the quarry floor area being used as a tip. It is apparent that the eastern face of the quarry has been worked up to the geological boundary with the adjacent mudstone unit, as discussed in the previous section.

King's Quarry was already of considerable size by the time of the 1861 map, and it is likely that the quarry was being worked much earlier than this. According to the publication on Dumfriesshire by Hewison (1912): *"the grey calcareous sandstone of King's Quarry and Auchennaight, Nithsdale, affords massive material for edifices such as Morton and Drumlanrig Castles."* It is therefore probable that King's Quarry supplied building stone for the late 17th century construction of Drumlanrig Castle (a castle had existed on the current site since 1429, but much of the old house was demolished in 1675). By 1684, 31 masons were contracted to the project, and it is clear that large quantities of stone would have been required at this time (Gifford 1996).

It is recorded that in Thornhill during the 1790s the villagers were in no short supply of building materials for their homes (Brown 1791-99). According to the Statistical Accounts of Scotland (written at this time by Rev. Alexander Brown of the Parish of Morton), an "*abundance of free-stone is to be had in the neighbourhood, and the other materials for building at no great distance."*

The expansion of King's Quarry seen on the OS maps between 1861 and 1900 suggests that the quarry was in operation at this time, most likely supplying building stone locally. The contemporary Geological Memoir of 1877 (Sheet 9, Kirkcudbright & Dumfriesshire) states:

> *The grey Calciferous Sandstones of the Thornhill basin furnish excellent building material. They have been largely quarried South of Drumlanrig [Auchenknight Quarry] and near Carronbridge [King's Quarry] and in the case of one or two recent local buildings, they have been preferred to the well-known Gatelawbridge stone.*

Other documented sandstone quarries in the area exploiting the Townburn Sandstone Member are Auchenknight Quarry (also known as 'Hillhead' and 'Tibberswood' Quarry) c.3km west-southwest of King's Quarry [NX852973] and Morton (or Morton Mains) Quarry, c.1.3km northeast of King's Quarry [NX888993] (Fig. 3. It is possible that a number of other smaller (probably unnamed) quarries also exploited the sandstone for more local use. The "Gatelawbridge stone" referred to above is Permian red sandstone, exploited in a number of quarries to the south (e.g. Gatelawbridge, Newton), and is discussed further below.

The most recent geological reference to stone quarrying in the area is the 2002 BGS Memoir which states: "*Limited resources of Carboniferous sandstone, formerly used locally, are potentially workable around Carronbridge*" (McMillan 2002).

The proximity of King's Quarry to the railway line does not seem to have impacted on the production of stone. Despite the opening of the Carron Bridge Station (later renamed Carronbridge Station) c.3km north of quarry in 1850 there was never a direct link between the quarry and the railway and, although the quarry is positioned alongside a local road, it is unlikely that significant transport of stone to the station was ever made. This implies that the stone from King's Quarry was for local use and is unlikely to have ever been exported outside the district.

In summary, published documentary evidence suggests that the sandstone at King's Quarry is likely to have been quarried since the 17th century, and certainly into the 18th and 19th centuries. It is likely to have been one of a number of local quarries which supplied stone for the construction of Drumlanrig Castle as well as many other local buildings within the Estate. Despite this, there is little published evidence documenting the use of the stone. According to the Statistical Accounts of Scotland (Brown, 1791-9), only 4 masons were working in Morton Parish during the mid 18th century, yet 100 years previously 31 masons were recruited alone for the construction of Drumlanrig Castle. Furthermore, although the quarry is situated close to a major railway line there is no evidence that the stone was exported outside the district. It is therefore considered likely that King's Quarry was worked exclusively for local building and mostly for properties on the estate. It seem clear from the buildings in the local area that the pink coloured gritstone has been used much earlier than the mid-19th century, implying that King's Quarry and the other quarries exploiting similar stone in the area have probably been active for several centuries.

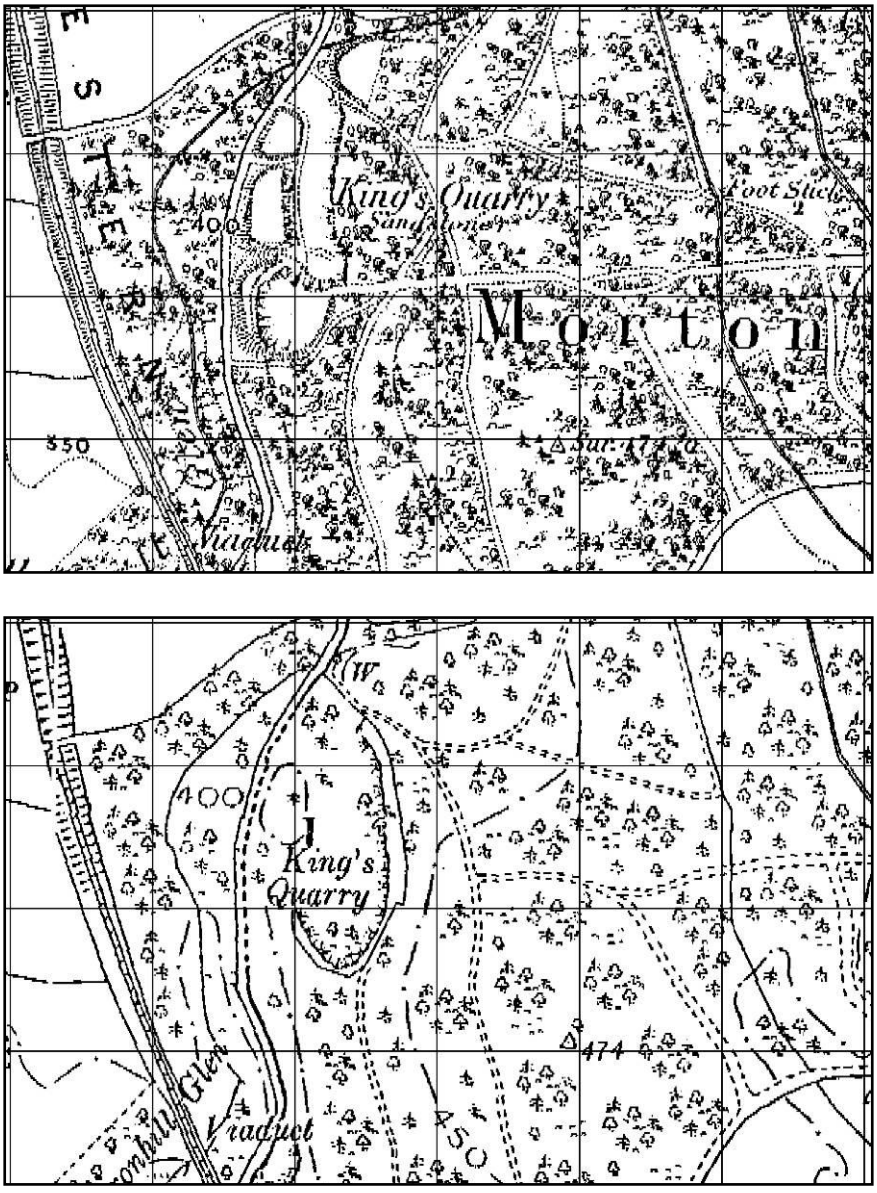


Fig. 6: Top: 1861 OS survey map showing the King's Quarry as a sandstone quarry of considerable size. **Bottom**: The 1900 OS map showing the quarry at a more developed stage, the individual areas connected together. The east side of the quarry is limited by the adjacent mudstone unit; hence the quarry grew in a north-south direction.

Fig. 7: Hand-annotated geological field slip based on the 1861 OS survey map, probably representing an early geological field survey of around 1900. Exposures of sandstone along the eastern face of the quarry are marked by dip-arrows indicating the strata is dipping ENE, annotated by the surveyor as *"pale reddish-grey & white sandstone"*. The comment *"B.clay on top of sandstone"* refers to the layer of superficial boulder clay which overlies the sandstone.

The Geological Memoir of 1877 describes the Permian red sandstones as: *"By far the finest building stones are obtained from the Permian sandstones of Dumfries and Thornhill. The red sandstones vary considerably in quality, but at Gatelawbridge and Locharbriggs they have long been worked."* The quarries at Newton (also known as Gatelawbridge), Closeburn (and Locharbriggs further to the south) expanded rapidly following the arrival of the railways, the stone being exported in considerable quantities to the Central Belt of Scotland. Gatelawbridge (Newton) quarry was first recorded as early as the 17th century, but by the early 20th century (1905) was employing 108 men. It is clear that the Permian red sandstones were exploited on a much larger scale than the Carboniferous sandstones, probably due to the relatively restricted outcrop and variable nature (e.g. coarse grained, gritty) of the Townburn sandstone compared to the extensive deposits of uniform fine grained Permian red sandstone in the southern part of the Thornhill Basin.

4. DESCRIPTION OF SITE VISIT

The site was briefly visited in December 2009 when a visual examination of the quarry was undertaken, in particular former faces along the east side of the quarry, and the results of more recent excavations at the south end. A number of large blocks of stone stockpiled close to the active face were examined and a number of small hand samples taken for further examination.

The eastern side of the quarry is defined by a subvertical face several metres high in massive sandstone (Figs. 8 & 9). The face is defined by a number of subparallel joint planes forming part of a consistent local joint pattern. The sandstone appears to be consistent and, although containing bedding planes, remains as large massive blocks. This suggests the stone is competent and unlikely to fragment in small slabs along the bedding. The upper part of the eastern face shows a sharp geological boundary where the sandstone passes eastwards into mudstone and shale. Although the sandstone continues at depth eastwards it is unlikely to be economic to quarry in this direction.

Fig. 8: View of part of the eastern face in the quarry showing several metres of continuous sandstone. Note the scarcity of both horizontal bedding planes and vertical fractures (joints) indicating the sandstone is present in large blocks several metres in size.

Fig. 9: View looking northeast at the eastern face of the quarry, showing sandstone beds partially overgrown by vegetation. The top of the face is the boundary with the adjacent mudstone/shale unit that continues eastwards. This eastern face of the quarry is aligned north-south and marks the eastern limit of the sandstone outcrop at surface, although it will continue at depth eastwards below the mudstone/shale deposits. The ramp at the left-hand side of the image is composed of shale/mudstone from the overlying deposits to the east.

The southern end of the quarry has been more recently worked and exposes a face of thick (metres-scale) sandstone beds with a series of consistent parallel steeply dipping joint planes (Figs. 10 & 11). Together, these produce large blocks of sandstone which are commonly of metres-scale, suitable for masonry production. The nature of the stone is such that it is competent enough not to split too readily along bedding planes, and the joint spacing is sufficient to preserve large lengths of unfractured stone. Extraction of the stone is likely to be relatively easy, probably largely possible with the use of a digger without the need for explosive splitting. Occasional particularly large blocks which are too large to handle may need to be split, although compressed air systems would eliminate the need for explosives. Most of the block sizes appear ideal for transportation to a processing facility for primary sawing and masonry block production.

In detail the sandstone in the exposed blocks appears to be competent and suitable for masonry production. Despite the presence of bedding planes and variable grainsize (sometimes gritty) the stone appears to be able to be produced in large block sizes. The sandstone is typically a pale purple to lilac-pink colour, although localised patches of grey are present (Figs. 12 & 13). This represents the presence of reduced iron minerals (i.e. not in an oxidised state) and is likely to only affect the colour of the stone—the internal properties will be unaffected.

Fig. 10: South-eastern part of the quarry showing the thinner bedded mudstone/shale deposits overlying the sandstone, with several metres of superficial boulder clay above. Any expansion of the quarry in an easterly direction will encounter such overburden.

Fig. 11: Typical block recently extracted from King's Quarry showing coarse grained sandstone with a strongly bedded character. Some beds are particularly coarse grained (gritty). The colour is mostly a pale pinkish-purple/lilac, although pale grey patches are common (caused by localised reduction of iron oxides).

Fig. 12: Typical recently extracted sandstone blocks from King's Quarry showing pale purple pink colour and bedded character. Note the grey coloured patches in the block, which represent areas where the iron oxides minerals are less oxidised—this is unlikely to affect the property of the sandstone which will be consistent despite the colour changes. Blocks of sandstone of this size are suitable for transportation to a processing facility for primary sawing and production of masonry blocks.

Fig 13: View of the southern end of the quarry (most recently worked face) showing sandstone beds typically several metres thick, with widely spaced steep angled planar joints, producing large unfractured extracted blocks of metre-scale dimensions. From visual inspection the sandstone and jointing continue in a consistent pattern towards the south, suggesting that further resources of large block are available.

5. DESCRIPTION OF THE STONE AND PETROGRAPHIC ANALYSIS

5.1 Introduction

A number of small samples of sandstone were collected during the site visit, intended to be representative of the range of grainsize and composition present in the quarry. Two samples were selected for petrographic analysis in order to characterise the stone and provide information relevant to its use as a building stone. The two samples analysed are given in the table below and illustrated in Fig. 14:

BGS Sample Number	Date Collected	General Description	Macroscopic analysis	Microscopic analysis
ED10659A	2009	Medium to coarse grained, banded reddish pink to lilac sandstone.	●	●
ED10659B	2009	Coarse grained, irregularly banded reddish pink to lilac sandstone.	●	

Fig. 14: Samples of sandstone from King's Quarry, showing the typical reddish pink to lilac colours and the typical bedded texture. (ED10659A left; ED10659B right).

5.2 Methodology

The two samples were examined visually using a binocular microscope (macroscopic description below). Colour was determined using a standard Munsell® Colour Rock Chart (Geological Society of America). Sample ED10659A then underwent detailed microscopic analysis, selected as being representative of the range of characteristics shown by the King's Quarry sandstone (microscopic description below). Thin sectioning was carried out at the University of Edinburgh thin section laboratory; the sample impregnated with blue dye resin in order to highlight porosity. The section is supplied on a glass slide measuring 75 by 25mm. The thin section was cut perpendicular to the bedding orientation. It was examined using a petrological microscope (Zeiss Standard WL polarizing microscope) following the procedures given in BS EN 12407:2000 'Natural Stone Test Methods – Petrographic Examination'. The stone type is defined in accordance with European Standard prEN 12670:1997.

5.4 Macroscopic Description

Fine to coarse grained, pink to lilac banded sandstone. The various thin bands are given by both combinations of differences in grainsize and amount of iron oxides/hydroxides. Grainsize appears to vary greatly, from generally fine to coarse, but from the quarry visit it has been observed that grainsize can reach pebble size (up to 8-9mm). Munsell colour code (when dry) mostly ranges between to 7.5R 7/1 to 6/1; *light reddish grey to reddish grey*. No reaction to 10% HCl indicating absence of carbonates. A water bead test indicates moderate permeability. Both samples obtained from the quarry appear competent.

5.5 Microscopic Description

'Fine' to 'coarse' grained, poorly sorted sandstone, with relatively abundant clay minerals (Figs. 15 &16).

Framework grains are generally angular to subrounded, grainsize ranging from 0.1-1.5mm, average approximately 0.25-0.45mm. Grains have a certain fabric (orientation of elongated grains) with their long axis parallel to the bedding. Dominated by quartz (c.65-70%), generally monocrystalline, with some larger grainsize polycrystalline grains. Characteristically, these quartz grains often have undulating extinction and can appear broken/cracked. A moderate amount of feldspar (c.10-12%) is present, both twinned (plagioclase, microcline) and untwinned varieties, appearing both fresh and slightly altered into clays, occasionally as relict grains with skeletal texture, sericitized into clays. Minor amounts of lithic grains (c.2-3%), of different origins, some metamorphic (microquartzite), with others of uncertain origin (possible volcanic and chert). Both feldspar and lithic grains can appear in large sizes. Minor amounts (c.2%) of moderately oriented, white mica (muscovite) is present as short, often broken plates. A small percentage of iron oxides/hydroxides, c.2-3% appear both as small irregularly shaped grains, stretched and/or mobilized into other pore spaces and as very thin coatings around some of the grains, giving the reddish colour to the stone. Moderately sized tourmaline appears as an accessory mineral.

Matrix minerals are relatively abundant, constituting c.12-15% of the stone. These consist of abundant complex associations of primary (original) and secondary (due to weathering) clay minerals present, partially infilling most of the porosity throughout the stone.

Grainsize distribution is in alternate layers of finer and coarser grainsizes, giving the macroscopic planar bedded aspect. Often the finer grainsize beds contain more abundant iron oxides/hydroxides. The overall porosity total is estimated at c.15-17%, moderately communicated. The abundant clay content partially reduces the amount of open porosity by infilling the pore spaces and conduits, although some of the clays may be hydrophilic. The sand grains are moderately to well cemented by an irregularly distributed but occasionally thick silica overgrowth, with some extra cementation relying on the weak matrix minerals (clays). Contacts between grains are punctual, long and occasional pressure-solution and interlocked contacts, making this a moderately well compacted sandstone. The rock type is classified as an **impure arkosic arenite sandstone**.

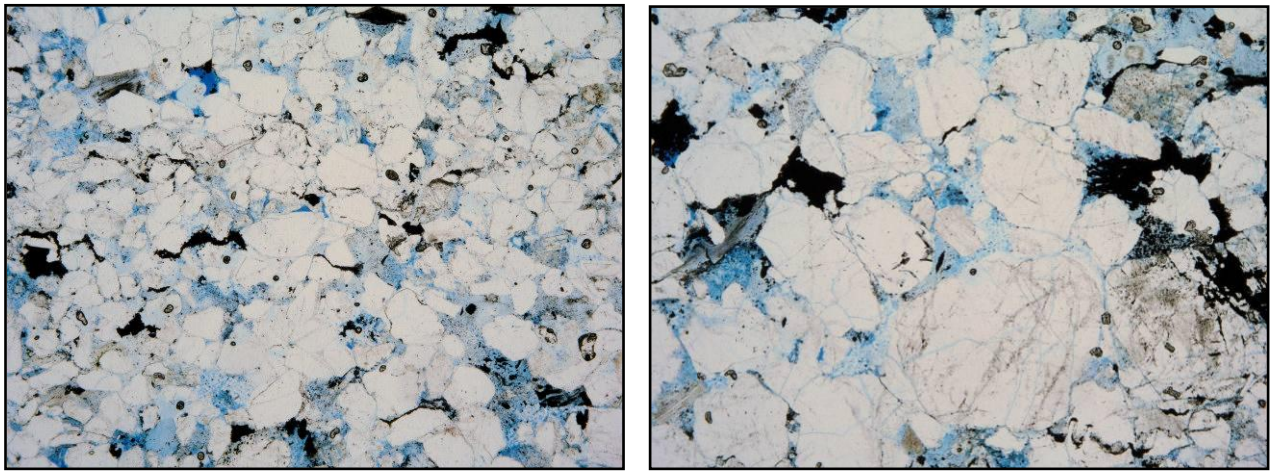


Fig. 15: Microscope images of King's sandstone (sample ED10659A) in thin section; to the left the finer grained fraction, to the right the coarser grained, as it appears in different beds. Images are c.3.3mm wide, taken under plane polarised light. Porosity is highlighted by blue dye resin.

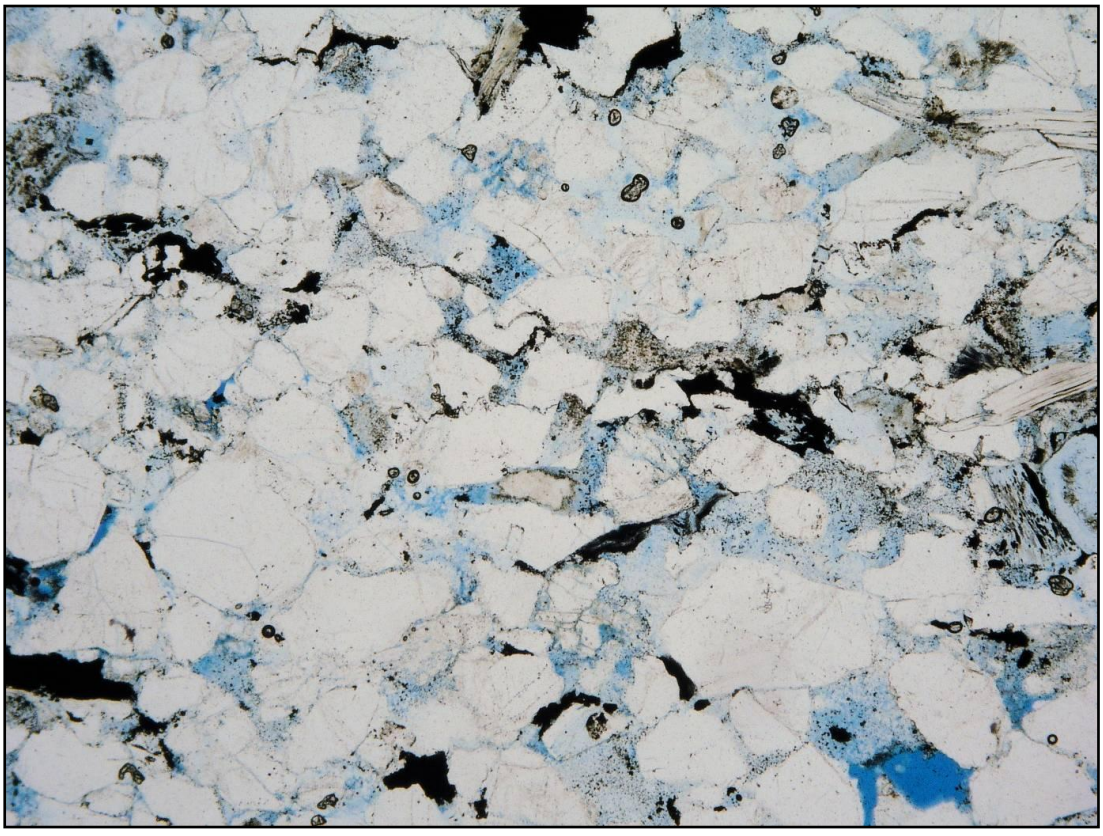


Fig. 16: Microscope image of King's sandstone (sample ED10659A) in thin section. To the right side of the photo can be seen some mica flakes as well as some altered feldspars. Black areas are iron oxides/hydroxides. Dark blue is an open pore space, while light blue colour indicates the pore spaces are partially infilled with clay minerals. The rest of white/light grey grains are quartz, feldspar and lithic grains. Some of the quartz grains (left side) appear occasionally broken. Image is c.3.3mm wide, taken under plane polarised light. Porosity is highlighted by blue dye resin.

6. DISCUSSION AND CONCLUSIONS

6.1 Quality of the stone

The petrographical analysis indicates that King's Quarry sandstone is of relatively high quality in terms of a building stone. It has a relatively stable mineral composition, dominated by quartz and minor feldspar. It is moderately compacted and well cemented which suggests it has good cohesion and indicates good strength and durability. There are no carbonate minerals or other components which could be unstable or particularly prone to weathering. The relatively high content of clay minerals (both within pore spaces and as partial breakdown of feldspar) does indicate that the stone may be susceptible to weathering in the presence of excess water. The variable grainsize and bedded nature of the stone may also limit its use as a building stone, for example it is likely to be unsuitable for high quality polished ashlar and carved details. These factors suggest that the stone is at least suitable for traditional rubble walling and possible as dressed stone. It should be noted that these comments are based purely on a petrographic analysis, and that other standard tests such as strength should be undertaken. The suitability of the stone for use as cladding would also need to be assessed using the appropriate tests.

6.2 Resources in the King's Quarry

There appears to be reasonable future resources of sandstone remaining in the quarry, assuming that the site can be expanded to the south. The eastern side of the quarry has been worked up to the boundary with the adjacent mudstone unit (the sandstone will continue eastwards beneath the mudstone, though quarrying would be difficult). The western and north sides of the quarry appear to contain spoil and are ultimately limited by the presence of the road. The currently exposed faces at the southern end of the quarry show large size block of good quality stone with widely spaced regular joints. There is no evidence to suggest that this will not continue to the south, implying that there are further resources available in this direction. It should be noted that because of this restricted outcrop and direction of working in the quarry, it is unlikely that the quarry will ever be a major producer of stone. Should substantial expansion or investment be planned it is recommended that more detailed site investigation such as shallow drilling be carried out to confirm the nature of the resource to the south.

6.2 Use of the King's Quarry sandstone: past and future potential

Traditionally, the sandstone from King's Quarry has been used in local buildings, mostly for the estate (cottages, farm buildings, etc.). The stone has been mostly used as squared rubble walling and simple dressings (windows and door surrounds, quoins, etc.) and appears to have performed well over a long timescale (Fig. 17). Visual examination of the masonry at Drumlanrig Castle (built c.1675-97 and thought to have been constructed using stone from King's Quarry amongst others) shows that the sandstone is generally performing well. Many blocks retain their 'sharpness' in terms of masonry detailing, and detailed carved elements are in many cases in excellent condition (Figs. 18, 19 & 20). This is despite of the variable bedded nature and coarse grainsize which would normally make sculptural work difficult. The main vulnerability of the stone appears to be in areas of high water penetration, where the relatively high clay content has cause the stone to deteriorate. It is apparent that good detailing and routine maintenance is essential in order to keep the masonry in a 'healthy' state—factors that are also important for many other stone types.

In recent time the quarry has been periodically worked on a small scale to extract stone for repairs to local buildings and for extensions, boundary walls, etc. that are in keeping with the character of the local historic built environment. The stone appears to have performed well and is amenable to modern quarrying, processing and masonry techniques. It is apparent that King's Quarry is a significant asset

to the local area in terms of supplying local stone. It is considered that the stone may well have a wider appeal and potential market beyond the local area. Firstly, several parts of the British Isles have similar pinkish sandstones which were used for local buildings, and the King's Quarry sandstone could be a useful substitute stone for the local quarries which are (in most cases) closed. Examples of areas where traditional buildings used a similar stone are: Auchinleck and district in Ayrshire, parts of Berwickshire, and Cheshire. Sandstones of Carboniferous age outcrop in many parts of the northern British Isles and have been used extensively as building stone, so that other potential markets are likely. Secondly, the unusual and attractive appearance of the King's Quarry sandstone (particularly its pink-lilac colour and banded appearance) makes it particularly attractive such that it could have potential for new build applications. Architects are increasingly seeking stone with 'lively' visual characteristics for new projects, and it is possible (subject to testing for technical suitability) that the stone could find a use in modern construction such as cladding panels. The stone bears similar characteristics to a number of currently available sandstones quarried in the UK, such as Dukes Sandstone/Gritstone, Wattscliffe Lilac (both Derbyshire), Cloudside Gritstone (Cheshire) and Brownieside sandstone (Northumberland).

6.3 Conclusion

King's Quarry has operated for several hundred years, mostly supplying stone for local domestic and agricultural buildings, although it apparently supplied high quality masonry stone for the construction of Drumlanrig Castle. Despite proximity to major transport networks, the stone does not appear to have been used widely and the quarry remained small-scale, unlike the nearby red sandstone quarries at Gatelawbridge (Newton) and Locharbriggs.

The stone is an impure arkosic arenite sandstone, meaning it has a mixed composition which, although dominated by quartz, also contains a number of other mineral constituents including feldspar, rock fragments and clay minerals. This, together with the variable (bedded) and often coarse grained texture of the stone, is likely to have made it unsuitable for high quality ashlar work and detailed carving work. Despite this, the presence of such high quality masonry at Drumlanrig shows that, given the resources, it is still possible to use the King's Quarry sandstone to produce very high quality masonry. The sandstone is well compacted with a natural silica mineral cement and considered to be of good quality in terms of weathering and durability. The presence of clay minerals however, means that it may be vulnerable to damage from continued water penetration, such that correct masonry detailing and routine maintenance are important factors for the longevity of the stone. This potential vulnerability is not unique and it found in many other currently available stone types. The unusual pink-lilac colour of the stone is caused by the presence of iron oxide minerals.

The quarry site itself is constrained on three sides by the presence of a road and a geological boundary. Despite this, the presence of good quality block with large joint spacing suggests that expansion to the south is possible. Given these constraints it seems unlikely that the quarry will ever operate on a large scale, but could provide a useful source of distinctive sandstone suitable for local use in several parts of the United Kingdom, with the potential for use in larger new-build projects. Successful large scale quarries need to able to produce stone that is versatile in order to supply a range of uses, and the high value products (e.g. large volumes of thin-cut cladding) are particularly demanding in terms of testing and consistency. If considerable investment or expansion of the quarry to the south is planned, it is recommended that a programme of shallow drilling is undertaken to confirm continuation of similar stone to the south.

Fig. 17: Recently refurbished former stables building in Drumlanrig estate grounds (now used as kennels). The distinctive local Carboniferous sandstone, likely sourced from King's Quarry, has been used for rubble for walling as well as for dressed masonry (quoins, window and door surrounds, etc.). The stone is generally in good condition.

Fig. 18: Drumlanrig Castle: Detail of an ashlar block showing both the good condition of the stone (with minor repairs at the bottom), and the typical appearance given by the bedded nature and the coarse grained (gritty) texture of the stone.

Fig. 19: Drumlanrig Castle: detail of the main façade showing high quality masonry as ashlar blocks, detailing and carvings. The overall condition of the stone is very good given the age of the building.

Fig. 20: Drumlanrig Castle. Detail of part of the intricate carvings present on the building, still retaining sharp detailing despite the age of the building, testifying to the quality of the local sandstone used for construction.

7. TERMS AND CONDITIONS

Geological observations and interpretations are made according to the prevailing understanding of the subject at the time. The quality of such observations and interpretations may be affected by the availability of new data, by subsequent advances in knowledge, improved methods of interpretation, and better access to sampling locations.

Raw data may have been transcribed from analogue to digital format, or may have been acquired by means of automated measuring techniques. Although such processes are subjected to quality control to ensure reliability where possible, some raw data may have been processed without human intervention and may in consequence contain undetected errors.

Detail which is clearly defined and accurately depicted on large-scale maps may be lost when small-scale maps are derived from them. The most appropriate techniques for copying original records are used, but there may be some loss of detail and dimensional distortion when such records are copied.

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8. REFERENCES

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