Geology and building stones in the East Midlands

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Abstract. The East Midlands has a diverse heritage of stone buildings reflecting the varied character of the regions geological strata. The principal stones used in the buildings of the area are described and identified and placed in their modern stratigraphic context. This very diversity, however, while providing a colourful backdrop to the villages and towns of the area for all to enjoy, presents an increasing problem to those concerned with conserving these structures, as many of the stones are now no longer quarried.

With the increasingly rapid expansion and development of our cities, towns and villages, by the addition of rather bland, mass-produced brick built housing developments, metal clad factories and glass-fronted office blocks, the end of a millennium is perhaps a particularly suitable time to reflect upon the diverse and colourful use of local building materials in the past.

The East Midlands has a distinctive character which is well expressed in the wealth and variety of vernacular buildings it has produced over the last millennium, many examples of which still survive. It is evident that locally quarried building stone and locally produced bricks have played an important part in moulding this character. The picturesque and attractive gritstone or limestone cottages of the Derbyshire Peak District are familiar to most people through endless images on calendars and in local publications. However, the other counties of the region have equally attractive and perhaps more diverse, though less well publicised, stone built heritages.

This contribution will focus on identifying the many varieties of local building stone used in the area, their distribution and, where possible, the location of their original quarry sources (Fig. 1). By placing these stones in their modern geological context, following the many changes in stratigraphic nomenclature which have taken place over the last few decades, it is possible to avoid perpetuating some of the misconceptions regarding stone sources found in earlier literature. In a study of any aspect of the buildings of the area the books in the series *The Buildings of England*, particularly the later revised editions, are essential reading (Pevsner, 1979, 1992, 1993; Pevsner and Harris, 1995).

Many of the stones described in the following account would probably not pass the stringent engineering tests required for the very different demands of today's building stone market. Many are stones used in limited areas, perhaps only for a few local houses. However, they have all survived several centuries of exposure to the elements and, without the problems of decay caused by modern airborne pollutants, would in many cases probably survive another thousand years.

Publications concerned with the building stones of an area are often focused on their use in the archaeology or conservation of historic structures. However, the building stone industry has never been concerned with providing stone solely for conservation purposes. Today, stone quarrying in the East Midlands area for new building work, such as the Law Courts in Nottingham (Birchover Stone), town centre developments at Bakewell (Stanton Moor Stone) and the new visitor centre at Southwell Minster (White Mansfield Stone), is still an important part of the local economy.

A study of building stones necessarily involves not only an understanding of the stone and its geology, but also some knowledge of a building's history, its building methods and local historical context. It is quite common to find that stone buildings have been restored or extended at different periods in their history, sometimes using stone from the original quarries but in more recent times using stone imported from elsewhere.

In broad terms the stone buildings of the East Midlands can be divided into three types. The first includes high-status buildings in which the use of particular building materials was generally not constrained by proximity to the quarry source or transportation costs; this category principally includes larger buildings constructed prior to the middle of the 18th century, such as castles, stately houses, abbeys, cathedrals and larger churches. The second comprises smaller vernacular houses, parish churches and smaller industrial buildings such as windmills and mine buildings, where local materials would almost certainly be preferred on cost grounds. The third includes larger industrial buildings dating from the end of the 18th century and closely related to the development of canal and, later, the rail networks which markedly increased both the variety and availability of stone for building by dramatically reducing transportation costs. Included in this last category are both the factory buildings in the new industrial centres and the rapidly expanded housing developments for the growing workforces that supported the new industries.

The East Midlands area, which is taken here to arbitrarily include the counties of Derbyshire,

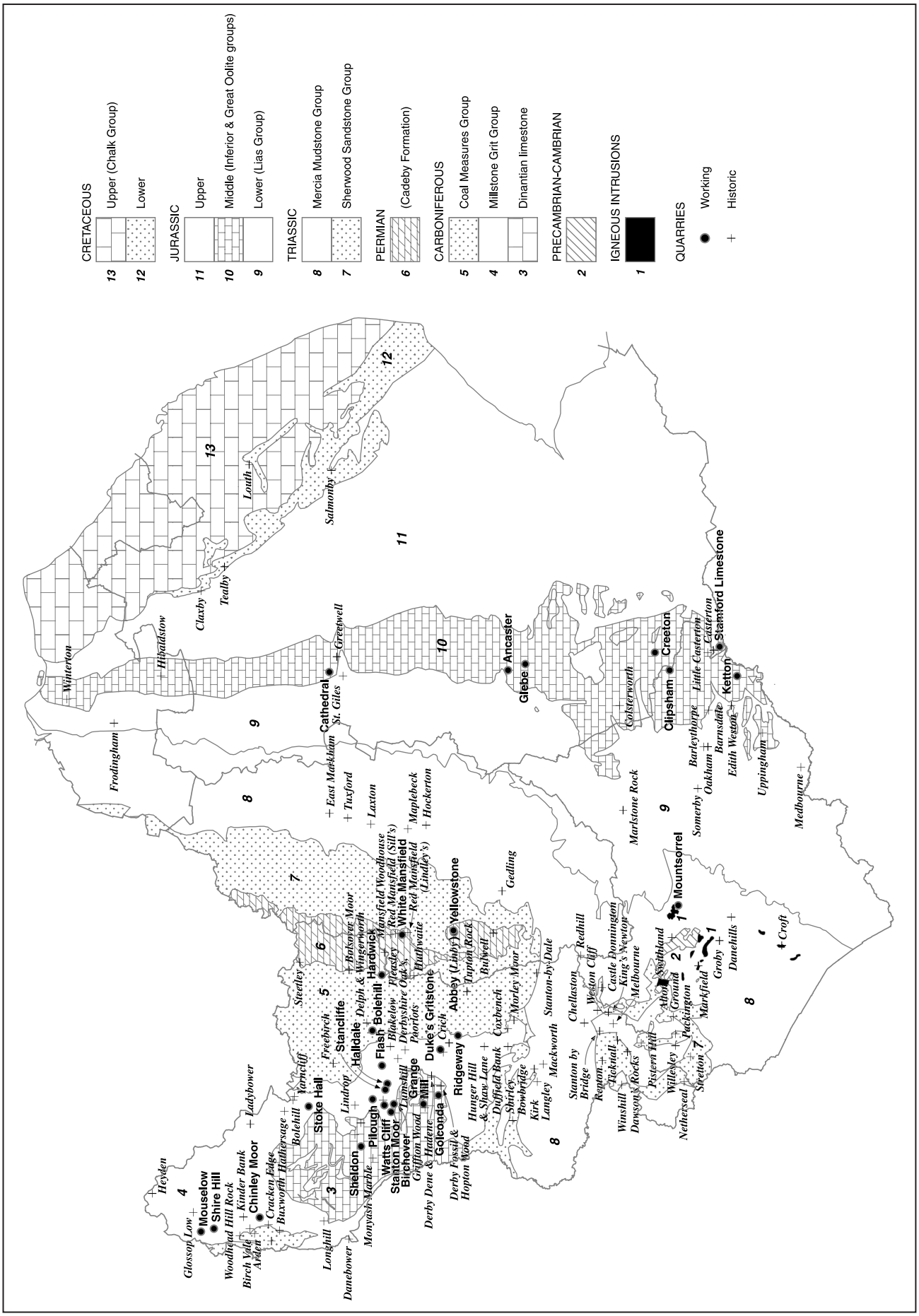


Figure 1. Geological map of the East Midlands, with locations of the main building stone quarries.

Leicestershire (including Rutland), Lincolnshire (including South Humberside) and Nottinghamshire, has long been a significant producer and exploiter of its indigenous stone resources for building purposes. Many of its working quarries are still important building stone sources and exporters in a national context.

Geologically, the East Midlands has a core of mildly metamorphosed Precambrian to Cambrian basement rocks, forming the high ground of Charnwood Forest, surrounded and overlain by a series of more or less conformably dipping sedimentary rock units, ranging from Early Carboniferous to Late Cretaceous in age. In Leicestershire and Derbyshire various igneous rocks have been intruded into this sedimentary cover during the early Palaeozoic and are now also exposed at the surface. The widely contrasting stones used in the buildings across the East Midlands are a product of this geologically varied rock succession.

Precambrian (Charnian) rocks

The rocks of the Charnwood area form a small inlier of folded late Precambrian metamorphosed volcaniclastic rocks – the Charnian Supergroup (Carney, 1999; Carney *et al.*, 2000) cut by Precambrian intrusions of granophyric diorite (Markfeldite – South Charnwood Diorite)) and diorite (North Charnwood Diorite). The geological complexities of the succession are still the subject of debate, but for present purposes the interval comprises the lithologically heterogeneous Blackbrook and Maplewell groups, each of which is divided into a number of formations and members (Table 1).

The Blackbrook Group, forming the core of the anticline, is predominantly a metavolcaniclastic sequence with breccias, sandstones and finer grained

		Group	Formation / Member	Principal Volcaniclastic Lithotypes	Building Stone Quarries
Cambrian		Brand	Swithland	Slate	*Swithland, Brand Groby, Woodhouse Eaves*
			Brand Hills / Hanging Rocks Conglomerate	Pebbly Conglomerate	
Precambrian	Charnian Supergroup	Maplewell	South Charnwood Diorite Intrusions	Diorite	*Groby, Markfield*
			Bradgate	Sandstones	
				Breccia	
			Beacon Hill	Sandstones	
			Charnwood Lodge	Volcanic tuffs	
			Whitwick Complex	Breccia, Porphyritic Dacite	*Whitwick Bardon Hill*
		Blackbrook	Blackbrook Reservoir	Sandstone	
				Breccia	
			South Quarry Breccia	Breccia	
			Ives Head / Lubcloud Greywackes	Sandstone with convolute bedding, lamination, grading	*Ringing Hill Morley*
			Morley Lane Tuffs		
			Morley Lane Volcanics	*Not seen at outcrop*	

Table 1. Precambrian stratigraphy and building stone quarries of the East Midlands.

lithologies. The overlying Maplewell Group is dominated by interbedded fine and coarse-grained, tuffaceous volcaniclastic rocks and breccias. Particularly distinctive units within this latter group are the Whitwick and Bardon Hill intrusive volcanic complexes, which include the coarsely crystalline, green and speckled white (quartz-feldspar crystals) Peldar Dacite.

Precambrian building stones

This relatively small outcrop has one of the most diverse rock successions in the East Midlands area. Many of the lithologies present are properly identifiable only in thin section and their individual recognition in local buildings generally requires a thorough knowledge of the rock succession. However, it is possible to attribute most of the building stone lithologies encountered in and around the area to a generic 'Charnian' suite of rock types. The hard nature of the Charnian metasediments has meant they have principally been used as local building and walling stone and are rarely found outside the immediate area of their outcrop. No single lithological unit from this interval has been systematically worked for building stone and a mixture of litho-types from the succession can commonly be seen in local buildings.

The Charnian rocks used as building stone exhibit a wide variety of colours, lithologies and textures from off-white to dark grey-green and purple with micaceous, fine-grained and coarse-grained textures. They have been used in building construction since Roman times and can be seen in the Jewry Wall in Leicester and in the remnants of Ulverscroft and Grace Dieu priories built in the 12th century (12C). More recently Mount St Bernard Abbey (19C) and Blackbrook Reservoir (20C) were constructed using a variety of Charnian lithologies. Characteristically these hard intractable rocks are seen in buildings as uncoursed, polygonal, random rubble stone and are rarely shaped or sawn (ashlar) block. Examples of the lithological variations that occur and building styles used are displayed in churches in Leicester (St Mark and St. Nicholas churches), Loughborough, Long Whatton and Belton, and in village housing in Osgathorpe (Plate 1A).

The Cambrian Rocks

Overlying the Charnian succession are the finer grained lithologies of the Brand Group. The overlying Brand Group was formerly included in the Charnian Supergroup but has recently been reassigned to the Lower Cambrian (Bland, 1994). The succession includes the greywacke sandstones and siltstones of the Swithland Formation which commonly show a metamorphically-induced, coarse slatey cleavage. They can be split along these irregular cleavage planes into slabs c.100 mm thick.

Cambrian building stones

This succession is perhaps best known as the source of the Swithland Slates, the focus from the early 18th to late 19th centuries of an important local stone industry. The slates are typically purple, dark grey or green-grey in colour and were widely used for roofing but also for wall stone. They are particularly well displayed in the roofs and walls of houses in Woodhouse Eaves (Plate 1B), but scattered examples of their use as roofing slates survive in many of the villages surrounding the original quarries.

The main quarries were at Brand, Groby, Swithland Wood and Woodhouse Eaves, but are long abandoned and flooded. In its heyday the Swithland Quarry was worked to a depth of 55 m and the stone blocks had to be raised to ground level by crane for splitting, cutting or polishing. Evidence for the long exploitation of Swithland Slates is found in their usage as roofing material on Roman buildings in Leicester (*Ratae*) and at Margidunum near East Bridgford, Nottingham. The recorded production figures from the industrial minerals survey carried out by Hunt (1860) provide some indication of the scale of the industry. At that time (figures for 1858) annual production from the slate quarries at Groby and Swithland Wood was 1000 and 2000 tons respectively. By comparison annual production was 10,000 tons at the Burlington slate quarries at Kirby in Cumbria, and about 90,000 tons at the Dinorwic quarries in North Wales. It is easy, therefore to see why, after the development of the railways, the Swithland quarries quickly went into decline. The last Swithland slate quarry had closed by about 1888 (Crocker, 1981).

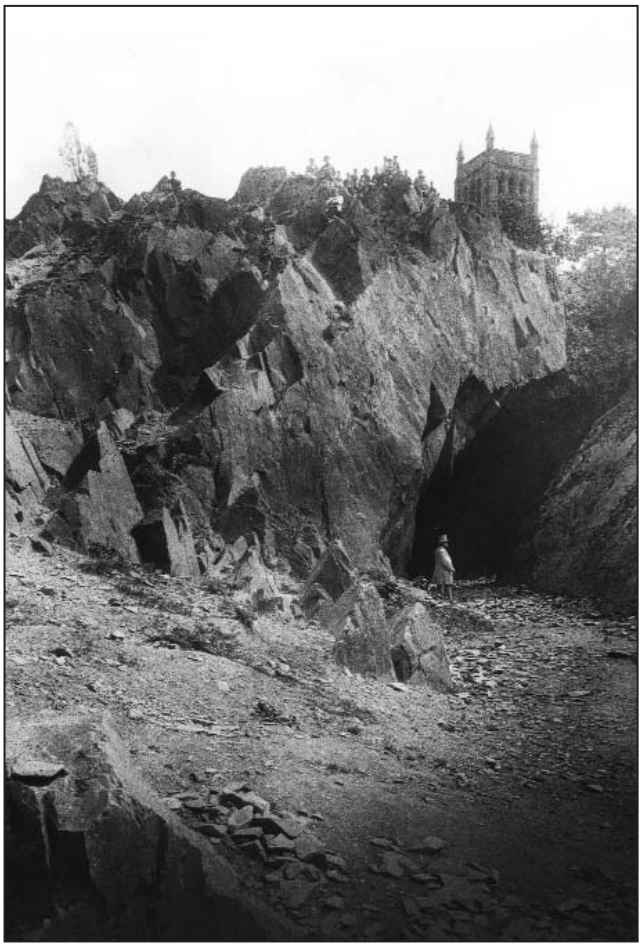


Figure 2. Swithland Slate quarry at Woodhouse Eaves, Leicestershire in 1894 (British Association photo #938).

The other important use for Swithland Slate was for intricately lettered and carved headstones or memorial plaques, many of which survive in the churches and graveyards of Leicestershire, Rutland, south Nottinghamshire and west Lincolnshire (Barley, 1948; Burgess, 1954; Herbert, 1945). The Swithland slates headstones can be distinguished from the later Welsh imports, some of which can be similar in colour, by the characteristic natural undulations on the unpolished back surface of the slabs.

Intrusive igneous rocks

The Precambrian-Cambrian succession of Charnwood and adjacent areas was extensively affected by igneous activity both during the Precambrian and Lower Palaeozoic. Most of the resulting exposed intrusive igneous bodies are currently being exploited for construction materials. These coarse-grained rocks, often described in early literature as syenites, are in fact a much more varied rock suite. Compositionally the Lower Palaeozoic intrusions are a complex mixture of diorite (dark coloured, containing no potassic-feldspar and little or no quartz), granodiorite (containing quartz, pink potassic-feldspars and grey plagioclase) and tonalites (dark coloured, with no potassic-feldspar, and low quartz). Their outcrops are concentrated in three areas that are compositionally distinct (Worssam and Old, 1988).

In south Leicestershire, the Lower Palaeozoic diorites crop out around Enderby (dark purple grey with pink feldspar), Yennards and Barrow Hill (dark grey, porphyritic, microdiorites with feldspar phenocrysts 2 mm long), Huncote and Croft (coarse pink and dark greenish brown) and Stoney Stanton (dark medium to coarse quartz diorite). In south Charnwood Pre-Cambrian diorites have been quarried at Groby (coarse-grained, purple and green mottled) and Markfield (granophyric textures; coarse-grained, pink and greenish grey feldspars, with some silica and darker green ferromagnesian minerals). The feldspar crystals are characteristically tabular and equant. In north Charnwood the Precambrian diorites are coarse-grained but darker in colour (dark grey) than the southern Markfieldite varieties. Probably the most readily recognised of these intrusive rocks is the Ordovician Mountsorrel granodiorite. This is pink to grey in colour, coarsely crystalline and silica-rich with both pink potash and grey plagioclase feldspars.

Igneous building stones

All the igneous rocks can be identified in local buildings in the area. Few, however, achieved any real individual success as building stones and they usually occur within a mixture of lithologies in walls or buildings. The exception is perhaps the red Lower Palaeozoic granodiorite of the Mountsorrel quarries. Most famous, perhaps, for the production of kerbstones and setts which were exported to cities and towns across the country from the early 19th century, it was used long before then as a local building stone. A very hard and intractable stone, it was commonly used as large irregular rubble stone blocks in the walls and houses of older buildings in villages around the quarries. In the 19th century numerous local churches and houses were constructed or 'restored' using large blocks of dark red Mountsorrel granodiorite. Many examples can be seen in churches and houses in Leicester (St. Paul) and at Mountsorrel, Quorndon, Barrow-on-Soar and Hoton. The distinctive green coloration of the coarse-grained diorite of the Markfield quarries is also readily identified in the walls of buildings in and around Groby and other examples of its use include 19th century wall buttresses at Diseworth church. Rothley church includes diorite from quarries at Stoney Stanton.

The Carboniferous rocks

The oldest unmetamorphosed sedimentary rocks that crop out in the East Midlands are of Upper Palaeozoic age and are restricted to the western part of the area. They comprise the early Carboniferous (Dinantian) limestone-dominated succession of western Derbyshire, the famed White Peak area, together with the isolated limestone inliers of north-west Leicestershire. Conformably overlying this limestone succession are the important sandstone resources of the Namurian (Millstone Grit Group) and Westphalian (Coal Measures) successions, largely concentrated in the equally famous Dark Peak area and the south Derbyshire-Leicestershire coalfield. The stratigraphy of the Carboniferous sequence is summarised in Tables 2 and 3.

Stone buildings occur extensively throughout the Derbyshire Peak District. The stones used in the higher status or country houses of the 'gentry' have been exhaustively documented by Craven and Stanley (1991). In their research they also identified a number of the larger building stone quarries in the area. However, many more local quarries supplied stone for village houses, farms and moorland barns and later for the housing demands of the new industrial towns. The harsh climate of the moorland areas of the Peak District also demanded a particularly good roof covering and the local fissile sandstones were extensively worked for thick roofing slates. These 'grey slates' were generally used within the county and only rarely appear farther afield.

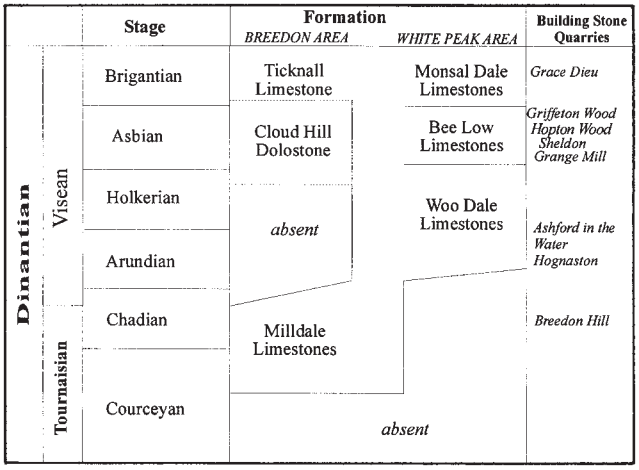


Table 2. Lower Carboniferous stratigraphy and building stone quarries of the East Midlands.

The earliest survey of the building stone quarrying activities of Derbyshire was carried out by Farey (published 1811). He listed 180 freestone quarries in operation at the time. Of these, two were working Carboniferous limestones and 143 Carboniferous sandstones. The remainder included 24 quarries working sandstones of Triassic age, 11 the Permian Magnesian Limestone and two in Pleistocene tufa deposits. Currently, there are 22 Carboniferous sandstone quarries and four limestone quarries producing building stone in Derbyshire.

Lower Carboniferous building limestones

The geology of the limestones of the White Peak is now known in some detail and mapping has defined clear lithological changes across the outcrop. These variations have been related to changes in depositional environments, most specifically to marked difference in water depths across the sedimentary basin (e.g. Harrison and Adlam, 1985; Miller *et al.*, 1987). The pale grey, fossiliferous limestones, often termed *Mountain Limestone* in older literature and typical of the White Peak outcrop, were principally formed in high energy shallow water, reef and shelf environments. Good examples of their use as building stone can be seen in Matlock and in village housing at Tissington and Carsington (Plate 1C). Adjacent to this main shelf limestone development, deeper water limestones were deposited which are finer grained, laminated and characterised by layers of siliceous chert. Limestone blocks containing these dark brown to black, layered chert bands are a common feature in the wall fabrics of houses in Hognaston village (Plate 1D), lying to the south of the main shelf limestone outcrop area. They can also be seen in buildings in Ashford-in-the Water, which lies to the east of the main shelf limestone area.

Despite the relatively few building limestone quarries identified by Farey (1811), it is evident from the older housing stock of the outcrop area that

the local limestone is the primary building material. The building styles and date-stones present suggest that quarrying has been important in the White Peak area since at least the 17th century. In village housing the grey, coursed limestone wall fabrics often contrast with brown Carboniferous sandstone ashlar blocks which were used for window and door surrounds, as at Bonsall and Parwich (Wright, 1985). Haddon Hall provides another fine example of this early polychromatic building technique. Numerous disused quarries can be identified throughout the area, but many probably yielded products other than building stone, namely agricultural and building lime. Each village, or indeed any sizeable house or farm in the area, is likely to have had its own local building limestone quarry source.

The Carboniferous limestones of the Derbyshire area have also long been famous for their decorative stone production. Commonly termed 'marbles' by the trade, due to their attractive colours and varied internal fabrics, and because their hardness allowed them to take a high polish, they were quarried in a number of localities. These 'native marbles' included Ashford Black, Bird's Eye (black with white crinoid fragments), Coralline (grey mottled), Derby Fossil (grey, crinoidal), Rosewood (pink layered), and Duke's Red (deep red with shades of yellow) (Farey, 1815; Ford, 1958). None of these stones is now produced, but their former local importance is evident from their extensive use as decorative adornments in many of the Great Houses of the Derbyshire area such as Chatsworth, Hardwick, Haddon and Bolsover Castle. Derbyshire marbles were recorded in the early 18th century as part of the trade goods carried along the Don Navigation to the Humber Estuary ports (Hey, 1980).

The more coarsely fossiliferous crinoidal and coraliferous limestone beds, representing original shallow shelf, reefal developments, have commonly been quarried for decorative use. Formerly the Derby Dene and currently the Once-a-Week quarries near Wirksworth produce pale grey, polished crinoidal limestone slabs. Decorative crinoidal limestones slabs, probably sourced from the Derbyshire quarries, can be seen in churches throughout the area, e.g. St. Peter's and St Margaret's in Nottingham. Polished limestones are still produced from the Bee Low Limestone Formation at the Hopton Wood and Griffeton Wood quarries. The original Hopton Wood Stone, which is a pale buff coloured limestone, spotted by white crinoid fragments, has been used in many major buildings including the Bank of England and the city halls of Manchester and Sheffield. On a more sombre note the Hopton Wood quarry provided the headstones marking the overseas graves of tens of thousands of British and Commonwealth troops who fell in the First and Second World Wars, and was also frequently specified for war memorials throughout Britain.

South of this main limestone outcrop, several small, fault-bounded Dinantian limestone inliers occur in north Leicestershire, stretching from Ticknall southwards through Breedon to Grace Dieu. Though extensively quarried in the past for lime at Ticknall, and today for aggregate at Breedon, they were also used locally as building stone sources. The limestones are variably dolomitised and show a range of colours from reddish brown to grey. Examples of their local use can be seen in the fabrics of the churches and houses at Osgathorpe, Breedon-on-the-Hill and in surrounding hamlets. The hard limestone is commonly used in randomly coursed rubble style giving some buildings a distinctive polygonal wall fabric. Adjacent to the former abbey at Grace Dieu is the small quarry from which stone for parts of the Abbey fabric was obtained. In the surviving wall remnants, the local Milldale Limestone, notable for the large brachiopod fossils present, is mixed with a variety of Charnian lithologies.

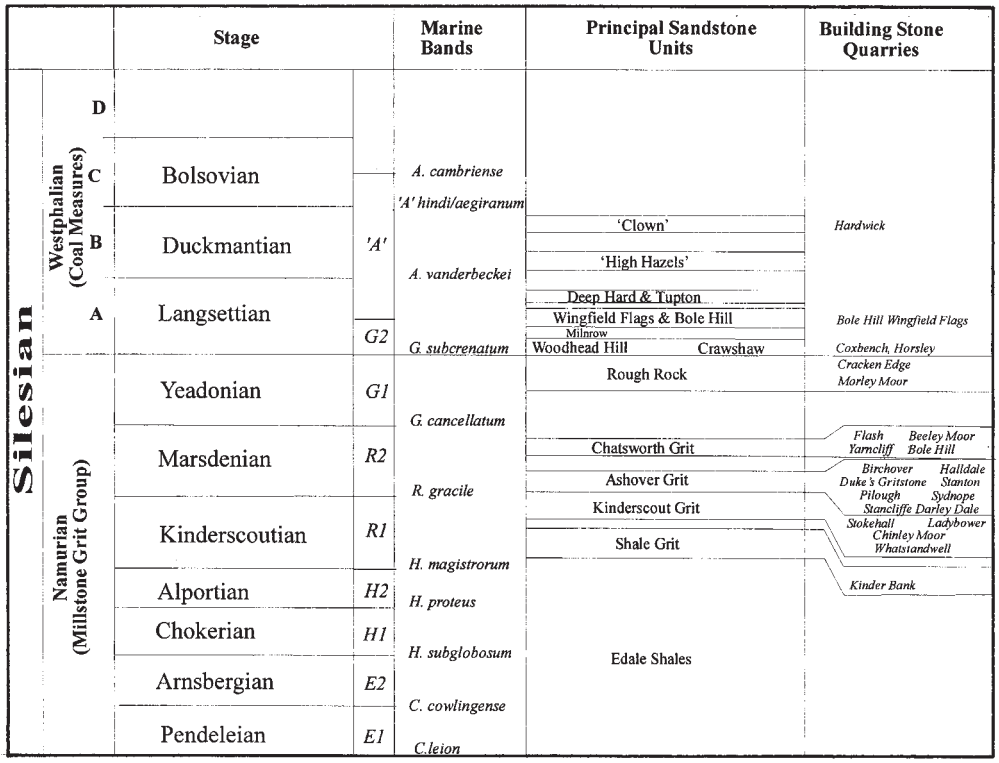
Namurian building sandstones

The sandstone beds of the Millstone Grit Group have been widely quarried for building stone in Derbyshire and to a lesser extent in north-west Leicestershire (Table 3). The fluvio-deltaic succession is characterised by thick, massive-bedded, channel sandstones, thinly bedded sandstones and mudstones. The hardness and resistance to weathering of the sandstones are clearly evident in the steep gritstone edges that dominate the local scenery.

Petrographically the sandstones range from quartz arenites (quartz-rich) to arkoses (feldspar-rich), but beyond the fact the stones quarried for building purposes are all sandstones, there is no 'typical' Millstone Grit lithology. Different quarries in the county have worked beds of varied colour, lithology and thickness. The thinly bedded varieties were extensively exploited for flag or roofing stone in the past while the more massive beds were favoured for high quality sawn stone lintels, mullions etc. and ashlar block. Today few quarries work the fissile beds for roofing 'slate' and new sources are being sought out. The block stone industry, however, is still thriving and supplies builders throughout Britain, where the Carboniferous sandstones are often known collectively as York Stone.

The sandstones used in buildings show a wide variety of colours, commonly from grey to brown to buff, but the variable iron content produces yellow or reddened varieties in some areas. Lithologically they vary from fine grained, well sorted sandstones to coarser, poorly sorted, quartz pebble-rich varieties. Some sandstone blocks show pronounced cross-bedding or horizontal lamination, while others appear to be more homogeneous in character. It is these changes in the sandstones that provide subtle differences in the character of local buildings across the outcrop.

Table 3. Stratigraphy of the Upper Carboniferous, and its quarries sites for building stone within the East Midlands.



In the Derbyshire Peak District, the exploitation of the Namurian sandstones has a long history and the area is pockmarked by old sandstone quarry workings. All the major sandstone beds have been quarried locally, the majority for local building use, but a number have attained national importance for the quality of their stone (Farey, 1815; Stevenson et al., 1971; Smith et al., 1967). Many of the smaller abandoned quarries, particularly in the north east of the county and across the border into Yorkshire, probably relate to the production of the famed 'Peak Millstones', dating back to medieval times (see below).

In the High Peak area of north Derbyshire, sandstones have been extensively worked in the past from the Shale Grit at Kinder Bank, the Kinderscout Grit at Chinley Moor, Lady Bower and Stokehall, the Heyden Rock at Thornseat, the Ashover Grit at Combs, Ridge Hall and Longhill), the Chatsworth Grit at Birch Vale, Buxworth, and the Rough Rock at Cracken Edge.

The most important areas of sandstone quarrying in Derbyshire, however, lie along the Derwent and Amber valleys and the hillsides between. Here, the Namurian sandstones are exposed in the valley sides from Hathersage to Belper. Quarries have long worked the Kinderscout Grit at Hayfield and Whatstandwell, the Ashover Grit at Duffield Bank, Darley Dale, Birchover, Pilhough, Duke's and Stanton Moor) and the Chatsworth Grit at Yarncliff, Grindleford, Beeley Moor, Lumshill and Millstone Edge.

The Stancliffe Darley Dale Stone (Ashover Grit) was famed for its durability and quality and has been widely used in surrounding towns and cities (e.g. Derby Cathedral; St. George's Hall, Liverpool; Royal Exchange, Manchester; the Town Hall, Birmingham). The Ashover Grit used in the buildings in the village of Kirk Ireton is stained pinkish red from the percolation of groundwaters through the former Triassic red-bed cover (Frost and Smart, 1979). The Shale Grit sandstone at Bolehill Quarry was used for the Kinder reservoir, and Stoke Hall Stone (Ashover Grit) from the Grindleford quarries for the Howden and Derwent reservoirs and Sheffield Town Hall. Large sandstone quarries once worked the Rough Rock at Morley Moor.

One of the characteristic features of the Derbyshire Peak District are the large stone roofing slates that once covered almost every stone built house. Today these original stone slate roofs are much harder to find as they have been replaced by Welsh slates and even clay and concrete tiles. Stone slates were once quarried extensively throughout the county and Farey (1815) lists about 46 slate quarries in operation. Most were small-scale producers but some later become quite large operations e.g. Glossop Low and Goytsclough. The 'slates' were obtained from both Namurian and Westphalian sandstones, and quarries were concentrated from Glossop southwards to Whaley Bridge, along the Derwent valley around Hathersage and between Matlock and Chesterfield. The main stone slate quarries have been documented by Hughes (1996).

Farther to the south, separated from this main Carboniferous outcrop by Triassic strata, are the Millstone Grit and Coal Measure rocks of the Derbyshire-Leicestershire Coalfield. There, the

Namurian sandstones, though no longer quarried, have been used for building stone for centuries. The imposing Norman church at Melbourne is a fine example of its local use. The Chatsworth Grit was worked in the past around Melbourne and Stanton-by-Bridge and the Rough Rock around Dawson's Rocks (Fox-Strangways, 1905).

Sandstones interpreted on their lithological character as being from the Millstone Grit Group, appear sporadically in 10th and 11th century church buildings in north Lincolnshire, along the southern shore of the Humber Estuary (e.g. Alkeborough, Whitton church); the long and short Saxon stonework of the tower at St. Peter's Church, Barton on Humber). Evidence from archaeological research suggests that these sandstone blocks were probably recycled from earlier Roman buildings in south Yorkshire (Stocker, 1990). The precise quarry provenance for these sandstones is still unclear but their considerable size and distribution pattern along the estuary testify to a fairly sophisticated system of local river transportation at the time.

Coal Measures building sandstones

In Derbyshire, the sandstones of the Coal Measures have been used locally for building since Roman times (e.g. the site at Ockbrook). Generally finer in grain-size than the Millstone Grit sandstones, petrographically they are very similar, consisting of both quartz arenites and sub-arkosic sandstones. Numerous small quarries once existed but no large-scale sandstone exploitation has taken place except in the Crawshaw Sandstone and Wingfield Flags (Table 3).

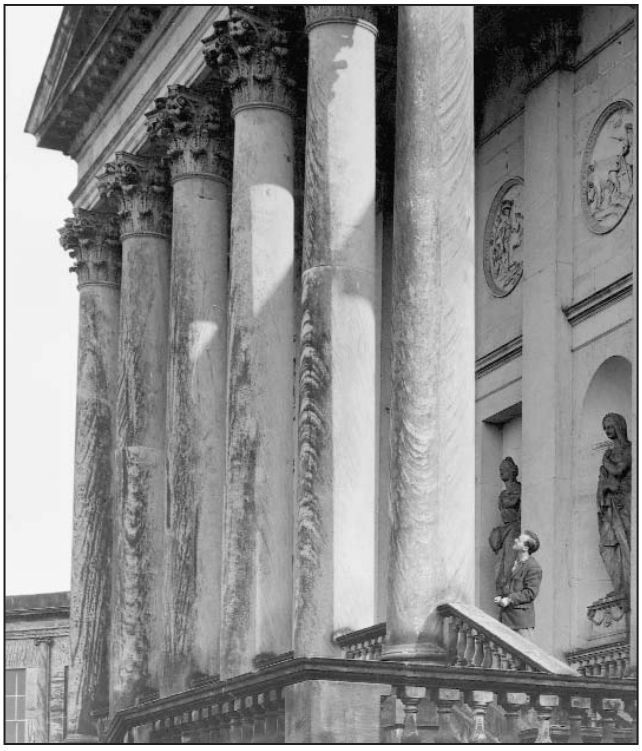


Figure 3. Kedleston Hall, Derbyshire, built 1759-63: north portico with massive columns of cross-bedded sandstone quarried from the Crawshaw Sandstone at Horseley Castle (BGS photo #L892, 1966).

In the High Peak area the Woodhead Hill Rock and the Milnrow Sandstone have been worked around Whaley Bridge. Farther to the south and east the Crawshaw Sandstone was extensively worked in the Holymoorside, Alton and Woolley areas. Large quarries formerley exploited the Wingfield Flags (locally known as the Greenmoor Rock) for building stone, paving and roofing slates at Freebirch to the west of Chesterfield. The flags continue to be worked at Bole Hill Quarry, Wingerworth. The 15th century manor house at South Wingfield was built with Wingfield Flags sandstone quarried from Crich Moor. Stone for houses in the village itself, was presumably worked from local sandstone outcrops, although grander houses are of ashlar blocks, probably from the same quarries as the manor (Plate 1F).

Some quarries, like the one operating within the estate of Hardwick Hall, were opened solely to supply stone for the hall and estate buildings. The original and 'new' halls, which sit on Permian strata, were built with Middle Coal Measures Hardwick Sandstone (Chisholm, 2001, *pers comm*.) that crops out beneath the Clown Coal seam in the low escarpment just southwest of the present hall. One of the characteristic features of this sandstone is the presence of liesegang rings in many of the blocks, a result of iron precipitation from fluids flowing through the pore space of the rocks. Current conservation requirements for the hall are, however, being met from a different sandstone below the High Hazels Coal exposed in a quarry northeast of the hall.

Farther south, the Westphalian Coal Measures are best known for their coal reserves, but they also contain prominent sandstones, which in the past have been quarried extensively for local building stone. Few of the sandstone units in this part of the coalfield area have been formally named on Geological Survey maps, making reference to specific sandstone units difficult. Sandstone quarries for building stone are known to have operated along the eastern side of the Erewash Valley around Trowell. Gibson *et al.*, (1908) suggest, however, that the general '*absence of quarries is due to the lithological composition of the sandstones*', dominated by micaceous, laminated varieties with only a few massive beds, which '*renders them unsuitable for building and other purposes*'. In older buildings in the area it is evident that the local stones were widely used for building purposes as at Beauvale Priory and Dale Abbey. Large sandstone quarries once worked the Crawshaw Sandstone at Stanton-by-Dale and Kirk Hallam (Stanley, 1990). The same sandstone from the Coxbench or Horsley quarries was also used extensively for the construction of Kedleston Hall and buildings in Derby and elsewhere (Gibson *et al.*, 1908, 1913).

Millstones and grindstones

It would be difficult to leave the subject of Upper Carboniferous sandstones, particularly those of the Millstone Grit Group, without at least a brief mention of their importance locally and nationally as sources of millstones and grindstones. Primarily known as a source of millstones for grinding flour and corn in water and wind mills from at least the 13th century (Polak, 1987), they were also used as pulping stones in the paper industry and in the paint-making industry (Radley, 1963). The sandstones were also a major source for grindstones and played an essential part in the growth and development of the tool and cutlery trade of Sheffield and the needle producing industry in Hathersage.

Important millstone quarrying areas included Stanage Edge, Hathersage Moor (Millstone Edge and Burbage), Froggatt to Baslow (all working Chatsworth Grit). From Hathersage the millstones were transported overland to the river port of Bawtry, for onward shipment to Hull and beyond (Radley, 1963; Polak, 1987). To understand something of the scale of the industry, even at a late stage in its history, it is only necessary to take a short walk over the moors between Longshaw and Hathersedge, where hundreds of partly finished millstones lie abandoned following collapse of the industry in the late 19th century.

The grindstone trade in Derbyshire (and south Yorkshire) had requirements different from that of the millstone trade (Radley, 1963). Grindstones for tool sharpening were generally finer and more even-grained and came in all shapes and sizes. Farey (1811) listed 17 Derbyshire grindstone quarries scattered across the county, using Namurian (at Beeley Moor and Ashover), Westphalian (around Bolsover, Belper, Stanton by Dale and Stanley) and Triassic (at Darley Moor) sandstones. This trade was eventually destroyed by the introduction of manufactured abrasive stones in the late 19th century.

Formation	Former Names	Building Stone Quarries
Roxby Formation	Upper Marl	
Brotherton Formation	Upper Magnesian Limestone	
Edlington Formation	Middle Marl	
Cadeby Formation	Lower Magnesian Limestone	*Bolsover* *Bulwell* *Linby* *Strelley* *Mansfield White* *Mansfield Red*
Permian Basal Breccia		

Table 4. Permian stratigraphy and building stone quarries of the East Midlands.

The Permian rocks

Rocks of this age unconformably overlie the Coal Measures. The heterogeneous succession can be subdivided into a lower unit of breccias and shales, a middle unit of orange-brown or buff-coloured dolomitic (or magnesian) limestone (the Cadeby Formation), and an upper interval in which red clays (often termed marls) and sandstones predominate (Table 4). Of these lithologies, the dolomitic limestone unit, which forms a narrow outcrop and prominent west-facing escarpment along much of the Derbyshire-Nottinghamshire border, is the main source of building stone both in the past and today.

Cadeby Formation building limestones

The Cadeby Formation, formerly known as the Lower Magnesian Limestone, is the most important source of building stone in Nottinghamshire. These limestones were once quarried extensively in the Bulwell, Cinderhill, Linby and Mansfield areas and farther north around Steetley (Metcalf, 1894). Numerous other smaller quarries along the outcrop produced local stone for building. Lithologically the limestones are very varied, ranging from coarsely crystalline dolomites and sandy (quartz-rich) dolomites in the south, to bioclastic (shell- and bryozoan-rich), oolitic and pisolitic varieties farther north. Each of these lithological varieties can, with a little care, be identified in buildings all along the outcrop.

At the southernmost limit of the outcrop around Nottingham, the Bulwell and Linby quarries dominated production. These yellow-brown to orange, coarsely crystalline limestones with thin, discontinuous, pale greenish-grey clay seams were much in demand in the past for housing, churches, schools and factories in Nottingham. The original Bulwell (Golden) Stone quarries appear in documents as far back as the 16th century. The workings were extensive in the late 18th and 19th centuries, but today are obscured by modern industrial development. The stone is still seen in a wide variety of buildings, most notably in many of the much-restored churches of the north Nottingham suburbs e.g. St. Leodegarius, Old Basford and St Andrew's. Most are constructed of rock-faced, ashlared blocks of Bulwell Stone usually with quoins, mouldings and spire in paler, contrasting Lincolnshire Limestone. Bulwell Stone appears to have been a firm favourite of local Victorian architects and was used to good effect in St. Andrew's Presbyterian Church in Nottingham, with contrasting string courses of pale grey Lias and mouldings of Lincolnshire Limestone. It does not appear as a rule to have been used far outside the present City suburbs, but there are rare exceptions. St. Anne's Church at Radcliffe-on-Trent was built of yellow-brown Bulwell Stone, with grey skerry sandstone and Lias string courses, and buff Lincolnshire Limestone for all mouldings and carved work.

The Linby quarries supplied stone for Newstead Abbey in medieval times. Today they provide much of the material needed to conserve surviving Bulwell Stone buildings in the Nottinghamshire area. The stone was also used in many of the older villages near the quarries e.g. Linby village (Plate 1G) and at Annesley Hall and Church. Northwards, older houses at Kirby and Sutton-in-Ashfield are all built of locally quarried Cadeby limestones. Stone from the present Linby quarries can be seen in the newly built flood defence walls along the Trent at Wilford.

The local importance of the Cadeby Formation limestones for building is evident in other parts of this southern outcrop. The church at Strelley is built of a red-brown, highly ferruginous variety quarried within a hundred metres of the church. In general the more ferruginous varieties of the limestone, like the Strelley stone, appear to be less durable, and parts of the church fabric are severely decayed.

Farther north in the Mansfield area, the Cadeby Formation includes two sandy dolomitic limestone varieties known as the Red and White Mansfield stones. These are the only building stones from Nottinghamshire to have achieved any kind of national status in terms of their use and wide geographical distribution. Lithologically they are dolomitic limestones with a high quartz sand content (up to 50% siliciclastic sand grains) and are in consequence very durable. The limestones are commonly cross-cut by green grey clay seams similar to those seen in the Linby and Bulwell varieties. The Mansfield stones are good freestones, easily worked, and were therefore favoured for decorative carved work, such as is commonly seen in local churches and exemplified by the foliage carved on the capitals of the 13th century Chapter House of Southwell Minster.

These two Mansfield stones proved particularly popular with local builders and architects in the 19th century. Mansfield White is extensively use in Mansfield town, most notably for the town hall, but also in the large railway viaduct that dominates the town centre. Other examples include the 18th century town hall at Newark and pre-eminently the Norman Minster at Southwell. At nearby Mansfield Woodhouse the quartz sand content of the limestone has all but disappeared, but the stone was still widely quarried and there are many examples of its use in the older houses of the town (Plate 1H)

The Mansfield Red variety, now long worked out, was popular for decorative work. It was extensively used by the local Nottingham architect Watson-Fothergill in his 19th century city centre buildings, and is common as small, decorative columns in some of the larger Victorian villas of the Nottingham suburbs. It can also be seen in the large pillasters that front the 18th century Shire Hall (now the Galleries of Justice Museum). Elsewhere it can be seen in the quoins of the Castle Brewery, Newark, and was even used for a bank frontage in St Alban's in Hertfordshire. Nationally the stone was show-cased in the magnificent Midland Hotel at St Pancras, in London which was designed as a showpiece of the Midland Railway Company and built completely from materials obtained from quarries on the route of the line. The building includes Mansfield Red and Ancaster stonework, which contrasts with the red 'Gripper' bricks from the Mercia Mudstone brickpits of Mapperley in Nottingham. Originally the building also had a Swithland Slate roof, sadly replaced in later renovations by green Cumbrian slates. Perversely, the red sandstone used in Clumber Church was not the local Mansfield Red, but was Triassic sandstone imported from the Runcorn quarries in Cheshire by the Duke of Newcastle.

The earliest geological descriptions of the Mansfield Red quarries were provided by Sedgwick (1829). '*On the east side of the glen, which descends to Mansfield, is a quarry which lays bare a system of beds, about 50 feet thick, of very extraordinary character. The bottom beds are about 20 in number and vary from less than 1 to 3 or 4 feet in thickness; but the planes of separation are extremely irregular, and not continuous. They are of dull red colour, and might, without close examination, be mistaken for New Red Sandstone. The thin beds are much used in building, and the thickest are hewn out into large troughs and cisterns, and in that state are conveyed into all the neighbouring counties*'

In 1856 the first national survey of quarrying carried out by the Geological Survey listed three Mansfield building stone quarries owned by Charles Lindley (Hunt, 1860). The Mansfield Red Stone was then produced at '*9d per cube foot for random sized blocks*.' The average annual production of the quarry was '*5,000 cube feet*'. The stone was used in the '*Terrace at Trafalgar Square, also for altar steps, pavings etc., for interior of several churches. Large and small cisterns are made from this stone*.' The Mansfield White Stone was priced the same. The average annual production of this quarry was '*10,000 cube feet*'. The stone was used in the '*Town-Hall of Mansfield; several public and private buildings*' (Hunt, 1860). By 1861, three quarries were in operation at Chesterfield Road and Rock Valley (both owned by the Lindley family) and at West Hill, Chesterfield Road. Mr Gilbert Scott (subsequently Sir George Gilbert Scott), one of the principal architects of the Victorian period, described the Mansfield Stone as '*one of the best building stones in the kingdom*' (Aveline, 1861).

Stevenson (1866) refers to the Chesterfield Road red sandstone quarries of Mr William Sills and to quarries at Mansfield Woodhouse and Mansfield (Rock Valley Quarries). By 1930 there were nine building stone quarries in the Mansfield area, but only six were still active. The Rock Valley Quarries were then disused, and Lindley's White Mansfield was the major stone producer. Today the only survivor from this long tradition is the White

Mansfield Quarry (or Gregory Quarry), now owned by the Rare Stone Group.

North of Mansfield, most of the older houses and churches along the outcrop are constructed from Cadeby Formation limestones (e.g. Bolsover Castle, Welbeck Abbey, dressings of Thoresby Hall, Carlton in Lindrick, Worksop and Blyth priories and many village houses). The limestones, though dolomitized, have commonly retained much of their original fossiliferous fabric. They vary from white to pale yellow brown, and from finely crystalline to coarsely fossiliferous limestones. Houses in the Scrooby-Maltby area, close to the Yorkshire border, have been constructed from coarse-grained pisolitic lithologies. It is likely in the distant past that many different quarries were in operation supplying local building stone needs. However, by the early part of 20th century most quarries in the area were working the stone for crushed rock aggregate and lime rather than for buildings.

Cadeby Formation limestone is also extensively used in churches located beyond its immediate outcrop. In north Lincolnshire a lack of suitable alternative local stones has meant that the Cadeby limestones were extensively imported. Churches at Thurgarton, Retford, Clarborough, Gringley on the Hill, Walkeringham, and Misterton, each built of white Cadeby Formation limestone, provide typical examples. Several churches along the Humber Estuary have also used the limestone for their fabrics, e.g. at Barton on Humber. Cadeby limestone is also used with local Lincolnshire Limestone, ironstones and even some chalk block stonework in buildings in north Lincolnshire.

A number of large building stone quarries once operated in the Cadeby Formation close to the Nottinghamshire-Yorkshire border. These included the quarries adjacent to Roche Abbey (finely crystalline lithologies), at North Anston (bioclastic) and at Cadeby (oolitic and bioclastic). The quarries at Cadeby itself are still a major supplier of building stone for new buildings and for conservation work, including York Minster.

The Triassic rocks

The Palaeozoic rocks of the East Midlands area are succeeded eastwards and southwards by a thick, easterly-dipping Mesozoic (Triassic to Cretaceous) sequence. The Triassic red-beds consist of fluvial sandstones and non-marine mudstones. The succession in the East Midlands is subdivided into a lower unit of variegated sandstones with occasional pebbly horizons, the Sherwood Sandstone Group (formerly the Bunter sandstones and pebble beds), and an upper unit dominated by red mudstones termed the Mercia Mudstone Group (formerly the Keuper sandstones and marls). The upper unit also includes a basal sandstone unit, the Sneinton Formation, in the Nottingham area, and a series of thin but extensive sandstone beds (skerries) in its upper part. The recently revised Triassic litho-stratigraphy, is summarised in Table 5 (Warrington et al., 1980; Charsley et al., 1990).

In Nottinghamshire the Sherwood Sandstone Group is divided into the Lenton and Nottingham Castle Formations, neither of which have provided significant stone for building purposes (Table 5). The Nottingham Castle Sandstone Formation, despite its prominent exposure in the high cliffs below Nottingham Castle is too poorly cemented to produce durable block stone. However, the friable

Figure 4. Lindley's Mansfield Red Quarry, at Mansfield: hand-working the dolomitic red sandstone of the Cadeby Formation. (BGS photo #A5053, 1930).

nature of the sandstones was exploited in other ways, notably to excavate the many caves and storage rooms that underlie the city centre of Nottingham (Waltham, 1996).

In south Derbyshire and Leicestershire, the Sherwood Sandstone Group is divided into three formations of which the youngest, the Bromsgrove Sandstone Formation (formerly the Lower Keuper Sandstone of Hull, 1869) is the only one of importance in terms of building stone production (Table 5). This has an outcrop extending from south of the Trent northwards towards Ashbourne and westwards into Staffordshire and Warwickshire (Fig. 1). The pale red to grey-green and occasionally the more highly prized white, sandstones were once extensively quarried for building in the area of Norbury, Cubley, Calke and Kirk Langley (Hull, 1869). Close to the Derbyshire–Staffordshire border, important building stone quarries have worked the Hollington Sandstone, also a part of the Sherwood Sandstone. These, and the Grinshill Quarries in Shropshire, are the only quarries still active in the unit, producing purple, red or mottled sandstones for buildings in Staffordshire and south Derbyshire (Craven and Stanley, 1982, 1984).

South of Derby, the Bromsgrove sandstones form an irregular outcrop around the margins of the Derbyshire-Leicestershire coalfield. They have been extensively worked in the past for local building stone at Repton, Bretby, Pistern Hill, Netherseal, Chilcote, Willesley and Alton Grange (Farey, 1815; Hull, 1869). Large quarries also operated along the Trent at Kingsmill and Castle Donnington and at Weston Cliff along the Leicestershire - Derbyshire border (Hull, 1869).

The basal sandstone unit of the overlying Mercia Mudstone Group is now termed the Sneinton Formation (formerly the Lower Keuper Sandstones or Waterstones). The Sneinton sandstones though relatively soft, were once an major source of building stone for Nottingham. Lithologically they are similar in character to the Bromsgrove sandstones, but are interbedded with subsatantial amounts of mudstones and siltstones. In the past, the two formations were mapped as one unit, the Lower Keuper Sandstones (Hull, 1869), but current stratigraphic practice places the Bromsgrove Sandstone in the Sherwood Sandstone Group and the more mudstone-rich Sneinton Formation in the Mercia Mudstone Group.

	Formation		Former Names	Building Stone Quarries
Mercia Mudstone Group	Blue Anchor			
	Cropwell Bishop		Siliceous 'Skerry' Sandstone	*Windmill 'Skerry'*
	Hollygate Sandstone Member		Keuper Marl	*Dane Hills Sandstone* *Hollygate 'Skerry'*
	Edwalton			
	Cotgrave Sandstone Member		Dolomitic Skerry' Sandstone	Cotgrave 'Skerry'
	Gunthorpe			*Plains, Maplebeck, Tuxford Laxton, Kneesall & Clarborough 'Skerries'*
	Radcliffe			
	Sneinton		Keuper 'Waterstones' Keuper Basement Beds	*Gedling Sneinton*
Sherwood Sandstone Group	Bromsgrove Sandstone	*absent*	Keuper Sandstone	*Weston Cliff Kingsmill Repton Norbury many local quarries*
	Polesworth	Nottingham Castle Sandstone	Bunter Sandstone	
	Moira Fm.	Lenton Sandstone		

Table 5. Triassic stratigraphy and building stone quarries of the East Midlands.

Bromsgrove and Sneinton building sandstones

Hull (1869) stated that 'the sandstones of the Lower Keuper Series are the most economically valuable of all which the Trias produces. In the central counties it is from them exclusively that the only good building stone can be procured'. The fine-grained, relatively soft nature of these sandstones, together with their occurrence in moderately thick beds, has meant they were a prime source of large ashlar block stone.

Sandstones from the Bromsgrove Sandstone Formation of South Derbyshire and Leicestershire were widely used in local churches and houses. They can be seen in houses at Castle Donnington (Plate 1I), Kingsmill and in churches at Hickling, Gotham, Radcliffe-on-Soar, Trumpton, Breedon on the Hill, Bunny and Keyworth. In south Derbyshire the Bromsgrove Sandstone was extensively used for larger houses either as block stone or as dressings for brick-built structures such as Sudbury Hall (Craven and Stanley, 1982). Further examples of its use for building include Calke Abbey, Elvaston Castle, and churches and houses at Bretby, Norbury, Cubley and Bentley. In these rural settings, without the discoloration caused by pollutants, the variegated greenish grey to reddish brown colours are more commonly seen in the building fabrics

The Sneinton Formation crops out along the south and east side of Nottingham but is only exposed between Sneinton and Gedling where it was quarried fairly extensively in medieval times (Charsley et al., 1990; Alexander, 1995). Little evidence of this quarrying survives, which are now large suburban housing estates. The greenish grey sandstones principally occur in church fabrics in the Nottingham area, where large, ashlared, sandstone blocks up to 1 m across and 0.3 m deep are commonly visible. Typically these fine-grained

sandstones show prominent cross-bedding and convoluted soft sediment deformation structures. Clay pebbles or intraclasts are commonly present along the sets but are often eroded away to form small cavities in the blocks. The sandstone was particularly widely used for church tower and steeple construction, and outside the main urban areas has generally survived well (e.g. Gedling, Burton Joyce, Shelford, Epperstone churches). In the more polluted city centre sites, however, such as St. Peter's Church in Nottingham, the stone is considerably blackened. The Sneinton sandstones do not appear to have been used far from their outcrop area.

Skerry sandstones

Although the Mercia Mudstone Group is dominated by red-brown mudstone and siltstone it also includes, in its upper part, thin beds of hard, grey-green, fine-grained sandstone, known locally as skerries (Smith, 1910, 1913; Elliott, 1961). The term appears to be derived from the old Norse skaerr or Swedish skär meaning thin or fine (Arkell and Tomkieff, 1953). Its local use may therefore date from days of the Danelaw.

Stratigraphically the skerries can be divided into sandy (very fine-grained) dolomites in the lower part of the group and silica-cemented sandstones in the upper part (Lamplugh *et al.*, 1911). They range from isolated, discontinuous layers a few centimetres thick to more continuous and thicker sandstone beds that can be traced across much of the outcrop. In general the siliceous skerry beds are much more thinly developed than the dolomitic varieties. At some stratigraphic levels several beds may be concentrated into 'skerry belts', but individual sandstone units rarely attain more than 600 mm in thickness (Lamplugh *et al.*, 1911). An exception is the Dane Hills Sandstone in Leicestershire that may reach 7 m thick . In north Nottinghamshire, a unit of the 'skerry-rich beds', the Clarborough Beds, is also distinguished.

The dolomitic skerry comprise very fine, angular, silt-grade, quartz/feldspar grains in a microcrystalline dolomitic cement. The upper siliceous skerry beds have larger amounts of coarser detrital quartz and feldspar grains and a pervasive silica cement giving them an almost flint-like hardness. Common in many skerry sandstones are ripple marks and elaborate, convoluted, soft sediment deformation features – ball and pillow or flame structures. Exposed skerry surfaces commonly show cube-shaped moulds representing former halite crystals.

Skerry building sandstone

Beds of skerry sandstone crop out in the Triassic sequence throughout the East Midlands. Their occurrence within an extensive area of mudstone outcrop, which lacked a good alternative building stone, meant that in early buildings the skerry stone was widely used for rubble walling material including the Roman fort of Margidunum at East Bridgford (Oswald, 1927), the Bishops Palace at Southwell and village houses at Car Colston, Elston, Thurgarton and Maplebeck (Plate 1J).

Quarrying, or at least small-scale surface digging of the skerry sandstones has taken place all along the Trent valley at Hockerton, Tuxford, Laxton, Maplebeck and East Markham, but its widespread use in local buildings suggests that numerous other small pits were probably opened along the outcrop (Lamplugh et al., 1911). In these areas small, flat skerry stones commonly form debris in fields and would have been easily gathered for local building purposes. Although locally important, the skerry sandstones do not appear to have been used far from their outcrops.

Varitions in thickness and lithology of the skerries has meant that, in general, two types of stonework can be commonly identified in the buildings of the area. The thinner, siliceous skerry were generally too

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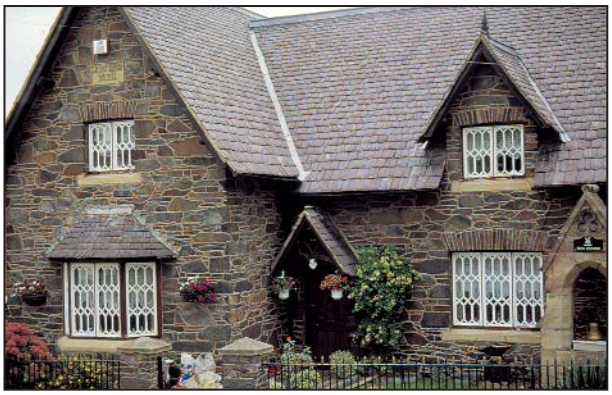
Plate 1 (on following pages). Buildings of the East Midlands showing a selection of the wide variety of local building stones that have been used.
A. Osgathorpe, Leicestershire, 18C house; rubble walling of various Charnian lithologies.
B. Woodhouse Eaves, Leicestershire, 19C house; rubble walling and roofing slates both of variegated Swithland Slate.
C. Ashford in the Water, Derbyshire, 18C house; grey Monsal Dale Limestone with contrasting Millstone Grit Group sandstones for quoins and window surrounds.
D. Hognaston, Derbyshire, 18C house; Woodale Limestone with prominent dark chert bands.
E. Appleby Magna Moat House, Leicestershire, medieval; local Coal Measure Group sandstones.
F. South Wingfield, Derbyshire, 18C house; ashlar walling of local Wingfield Flags.
G. Linby, Nottinghamshire, 18-19C houses; Linby Stone from the nearby quarries.
H. Mansfield Woodhouse, Nottinghamshire, 16C and early 17C houses; slightly ferruginous limestones from the local Mansfield Stone quarries.
I. Castle Donnington, Nottinghamshire, 18C houses; large, greenish-grey, cross-bedded, ashlar sandstone blocks from the local Kingsmill Stone quarries.
J. St Radegund Church, Maplebeck, Nottinghamshire, medieval with later restorations; sandstone blocks of Maplebeck Skerry with soft sediment deformation structures.
K. Holwell, Leicestershire, 19C house; large blocks of ferruginous sandstone and ironstone of the Sandrock Member and Marlstone Formation.
L. South Scarle, Nottinghamshire, 18C house; yellow-brown and grey, coursed Lias limestone blocks.
M. Ketton, Rutland, 17C house; Colleyweston Slate roof, and Ketton Stone wall blocks.
N. Winterton, Lincolnshire, 18C house; small coursed blocks of locally quarried Lincolnshire Limestone.
O. St Mary's Church, Horncastle, Lincolnshire, medieval with later restorations; Spilsby Sandstone with original dressings and later inserted blocks of pale yellow Lincolnshire Limestone.
P. Wootton, Lincolnshire, 17-18C house; white Ferriby Chalk blocks with red brick quoins and tumbling.

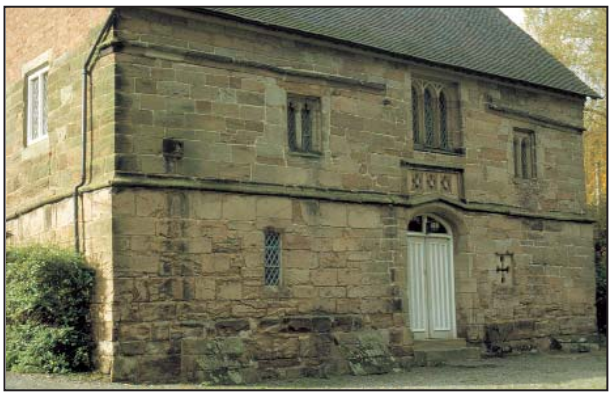
A. Osgathorpe (Charnian) © G K Lott



B. Woodhouse Eaves (Swithland Slate) © G K Lott

C. Ashford-in-the-Water (Dinantian Limestone) © G K Lott

D. Hognaston (Woodale Limestone) © G K Lott



E. Appleby Magna (Coal Measures Sandstone) © G K Lott

F. South Wingfield (Wingfield Flags) © G K Lott

G. Linby (Linby Stone) © G K Lott

H. Mansfield Woodhouse (Mansfield Stone) © G K Lott

I. Castle Donnington (Kingsmill Stone) © G K Lott

J. Maplebeck (Maplebeck Skerry) © G K Lott

K. Holwell (Marlstone/Sandrock) © G K Lott

L. South Scarle (Lias Limestone) © G K Lott

M. Ketton (Colleyweston Slate) © G K Lott

N. Winterton (Lincolnshire Limestone) © G K Lott

O. Horncastle (Spilsby Sandstone) © G K Lott

P. Wootton (Ferriby Chalk) © G Lott

hard to cut and dress and are used for randomly coursed, rubble walling. They commonly form footings or part-walls to more substantial brick or timber framed buildings (in East Bridgford, Flintham, Elston, Diseworth). In contrast, the thicker skerry sandstone beds are softer and could be dressed into rough blocks (Coach and Horses Public House and houses at Thurgarton, and Kelham Church). Exceptionally large blocks were sometimes quarried from locally thickened beds, as can be seen in the church tower at Normanton-on-Trent. The Dane Hills skerry quarries, now lost in the suburbs of north Leicester, supplied pale grey sandstone block for much of the local area. A few remaining examples of its use include the Roman Jewry Wall and the nearby tower of St. Nicholas's Church in Leicester.

The Jurassic rocks

A prolonged period of marine sedimentation then followed the Triassic continental environments, and dominated deposition throughout the Jurassic and Cretaceous. Jurassic deposition commenced with the grey, calcareous mudstones, clay-rich limestones and yellow-brown to grey-green ironstones of the Lower Jurassic (Lias Group) (Table 6). Oolitic and shelly carbonate deposition characterises the succeeding Middle Jurassic succession that forms the pronounced high ground of the Lincolnshire Edge limestone escarpment, extending from the Humber Estuary southwards into Northamptonshire. A brief return to non-marine conditions was then followed by the re-establishment of fully marine conditions producing a mudstone-dominated Upper Jurassic succession, most of which is concealed beneath a cover of Pleistocene superficial deposits.

		Formation	Member		Building Stone Quarries
Upper		Spilsby Sandstone			See Table 5
	Ancholme Group	Kimmeridge Clay	'Elsham Sandstone'		locally quarried
		Oxford Clay			
		Kellaways			locally quarried
Middle	Great Oolite Group	Cornbrash			
		Blisworth	'Snitterby Limestone'		locally quarried
		Rutland			
	Inferior Oolite Group	absent			*Hibaldstow Clipsham Scawby Heydour Silver Beds Casterton Ancaster Stamford Wilsford Ketton Colleyweston Wittering Pendle*
		Lincolnshire Limestone	'upper' Hibaldstow Limestone; 'lower' Kirton Cementstones Santon Oolite	numerous local quarries	
		Grantham			
		Northampton Sand			locally quarried
Lower	Lias Group	Whitby Mudstone			
		Marlstone Rock	'ironstone'	numerous local quarries	*Branston Holwell Ab Kettleby*
		Dyrham	'sandrock'		*Wycombe Tilton*
		Charmouth Mudstone			
		Scunthorpe Mudstone	Foston	Frodingham Ironstone	locally quarried
			Beckingham		
			Granby	'Granby Limestones'	locally quarried
			Barnby		
			Barnstone	Blue Lias 'limestones'	locally quarried
Triassic	Penarth Group	Lilstock	Cotham		locally quarried
		Westbury			

Table 6. Jurassic stratigraphy and building stone quarries of the East Midlands.

Within the Jurassic sequence there are various sources of building stone that have been widely exploited for local building. The 'Lias', notably in its lower part, is characterised by thinly interbedded, grey, argillaceous limestones and calcareous mudstones. Two locally developed, but lithologically distinctive, 'ironstone' dominated units occur – the 'Lower Lias' Frodingham Ironstone (Lower Sinemurian) and 'Middle Lias' Sandrock/Marlstone Rock (Pliensbachian). The Middle Jurassic succession of the East Midlands is divided into a lower interval termed the Inferior Oolite Group and an upper interval named the Great Oolite Group (Table 6). The Inferior Oolite comprises a lithologically varied sequence of ferruginous and calcareous sandstones, ironstones, oolitic and shelly limestones, silty limestones and occasional mudstones. The Northampton Sand and Lincolnshire Limestone (Table 4) are two of the major sources of local building stone.

Lower Lias building limestones

The pale grey to yellow-brown (when weathered), fine grained limestone beds of the Barnstone Member, formerly the Blue Lias (Table 6), were once a very important local source of building stone and appear in numerous older buildings in villages along the outcrop. From the 18th to early 20th centuries, these limestones also became the basis of an important hydraulic cement industry around Barrow-on-Soar, Barnstone, Granby, Cotham and Coddington (Woodward, 1893). These limestone beds extend across the whole of the East Midlands and beyond to Dorset, South Wales and the Yorkshire coast.

The large number and geographic extent of the surviving buildings constructed using these limestones suggests that quarrying was from a large number of small pits, most of which have long since degraded, but can still be seen, for example, in the valleys around Barrow-on-Soar and Widmerpool. The individual limestone beds are rarely more than 250 mm thick and need to be carefully selected because they do not weather well and in many instances tend to split (or shiver) along thin clay laminae. The limestone/mudstone sequence is commonly fossiliferous and was the source of the famous Barrow 'Kipper' (a 5 m

plesiosaur skeleton). The thinly bedded, blocky nature of the limestone has meant that very little dressing or cutting was necessary to produce the small blocks used in wall construction. The limestones were also commonly used for wall footings, chimney stacks and internal floor slabs in some brick built houses of the area.

Good examples of Barnstone Member limestones in buildings can be seen all along the outcrop, in village houses, grand halls and parish churches at Barrow-on-Soar, Barnstone, Costock, Long Bennington, Staunton-in-the-Vale, Dry Doddington, Fenton, Collingham, South Scarle (Plate 1L) and Newark. Although these beds are no longer locally worked for building stone, there are several quarries producing comparable limestone from the basal Lias in Somerset.

Lower Lias building ironstones

The Lias Group succession of north Lincolnshire includes a thick localised deposit of grey-green (unweathered) to yellow-brown, commonly coarsely fossiliferous, calcareous, oolitic ironstone known as the Frodingham Ironstone (Member). Petrologically, the ironstones are generally highly calcareous with abundant shell debris, and distinctly oblate ooliths of berthierine (green iron silicate) and geothite set in a matrix of calcitic or muddy sideritic (Gaunt *et al.*, 1992). This ironstone unit, originally cropping out from Coleby southwards to the Ashby area, has been worked as a source of iron since Roman times. The ore formed the focus for the iron and steel industry that developed in the Scunthorpe area in the mid-19th century, and continues today. Long before this, however, the evidence of many churches and some houses in the surrounding area indicates that the ironstones were a locally important source of local building stone in earlier times. Around Scunthorpe, it is used as thinly bedded blocks, characterised by abundant large Gryphaea, in many local houses and churches, notably at Scotter, Messingham and Bottesford (Scunthorpe). St John the Evangelist Church in Scunthorpe is a fine example of the use of dark brown, coarsely fossiliferous and oolitic Frodingham Ironstone, with pale 'streaky' limestone (probably from Ancaster) as dressings.

Middle Lias building ironstone

'Ironstones' clearly form some of the more distinctive of the region's vernacular building stones. Those of the Middle Lias Marlstone, though superficially similar to the Frodingham ironstones, include a wider range of lithologies, with fossiliferous and ferruginous sandstones, limestones and oolitic ironstones. The names that once described this 'iron-bearing' succession, of the Leicestershire-Lincolnshire area have changed many times since the earliest research 200 years ago (Table 6). Traditionally, the Marlstone was divided into an upper unit of iron-rich beds, the 'ironstone' proper, and a lower unit of ferruginous sandstones, known as the Sandrock. Together these units formed the Marlstone Rock Bed. Recent mapping by the BGS, together with a better understanding of regional stratigraphic relationships (Berridge *et al.*, 1999) now places the lower Sandrock beds into a newly defined unit called the Dyrham Formation (formerly the Middle Lias Silts and Clays). The 'ironstone' beds alone, therefore, comprise the whole of the unit now termed the Marlstone Rock Formation. Petrologically the Marlstone Rock ironstones are sideritic-berthierine (chamositic) limestones. Siderite (iron carbonate) and berthierine (a green, iron-silicate), both oxidise to yellow-brown limonite/geothite during weathering. The ironstones contain abundant fragmental shelly material and sporadic fossiliferous horizons. Fresh ironstone blocks are commonly termed 'blue-hearted' where the core of the block has been protected from weathering and oxidation effects.

The widespread use of both the Sandrock and Marlstone Rock stones in the fabrics of older buildings all along the outcrop indicates that quarrying of the stone for building purposes was once extensive. Although this activity has a long history, little is known about this early quarrying industry. Building stone was probably obtained from a large number of local pits or quarries and some may even have been opened to supply stone for a single structure. Unfortunately, subsequent workings for iron ore, in the late 18th and early 19th centuries, have removed most traces of earlier building stone quarries, but local names such as Stonepit Spinney, near Ab Kettleby, give some clue as to their possible locations. There is also documentary evidence that 'ironstone' beds were quarried for building stone at Branston, Holwell, Wycomb, Ab Kettleby and Tilton (Woodward. 1893).

Quarrying of the ironstone as an ore dates from about 1856, but the real expansion in the industry accompanied the development of local rail networks, enabling the ore to be shipped to existing smelting furnaces in Yorkshire and Derbyshire. Local furnaces, such as those at Asfordby, were not established until as late as 1881 (Wright, 1982).

The highest grades of ore come from the Marlstone Rock Formation. As building stones, however, these darker, red-brown stones, though locally common in some wall fabrics, are in general less durable and were rarely used. The harder, yellow-brown, ferruginous and calcareous sandstones of the underlying 'Sandrock' have generally been preferred for building (Lamplugh *et al.*, 1920). They are well displayed in the walls of Belvoir Castle and Harlaxton Manor, and also in houses and churches in numerous villages along the outcrop, including Wartnaby, Ab Kettleby, Holwell (Plate 1K), Barrowby, Redmile, Marston, Barkston, Easton, Muston, Oakham, Lyddington and Belton-

in-Rutland. The local buildings commonly include some particularly distinctive stone blocks containing concentrations or 'nests' of fossil brachiopod shells (Hallam, 1961). These shelly beds were described by the quarrymen as 'jacks' and provided harder, very well-cemented building blocks which are commonly seen to stand proud in the weathered wall fabrics. In Caythorpe, in Lincolnshire, 'ironstone' is decoratively interbanded with paler Ancaster Stone in the walls of the buildings.

The sandstones and ironstones have been used both as irregularly shaped rubble stone and as squared, cut ashlar block in the local buildings. They are only rarely used for carved stonework because they are generally too soft, but are occasionally used in window and door mouldings as in the church at Eaton-on-the-Hill. In most instances pale, buff-coloured oolitic and shelly Lincolnshire Limestone ashlar blocks were preferred in such situations where greater strength was required. This contrast between the local yellow-brown ironstone wall fabric and quoins, window and door surrounds in the paler Lincolnshire Limestone is a characteristic feature of the buildings in the area.

Today there are no quarries producing ironstone in the local area, and recent conservation work has to rely on replacement stone from the 'Marlstone Rock' quarries at Hornton and Wroxton in the South Midlands or from the Northampton Sand Formation (Middle Jurassic) in Northamptonshire.

Northampton Sand building stones

The orange-brown to green-grey, ferruginous Northampton Sand Formation, with its outcrop from Lincoln south to Towcester, is widely used for building stone throughout Northamptonshire (Hudson and Sutherland, 1990). The formation is very poorly developed north of Grantham, but to the south was commonly quarried for building purposes and can be seen in local houses and churches. The Marlstone Rock Formation also crops out in this area and, as these two units yield building stones similar in colour and lithological character, they need to be carefully distinguished.

The Northampton Sand Formation was formerly quarried for building stone around Barnsdale, Whitwell and Uppingham. Buildings along the main street of Uppingham have fine and varied examples of the use of this local ironstone. Along with Barrowden and Glaston, Uppingham also has houses with polychromatic interbanding of the Northampton 'ironstone' with paler Lincolnshire Limestone.

Lincolnshire Limestone building stone

In the whole East Midlands the most important sources of building stone are the upper and lower divisions of the Lincolnshire Limestone Formation, which have been worked since Roman times (Table 6). The formation is restricted to the East Midlands with a continuous outcrop from Kettering to just north of the Humber (Sylvester-Bradley and Ford, 1968; Ashton, 1975). It comprises a lithologically diverse succession of pale yellow, cream, reddish or buff limestones (when weathered) which are blue-grey or blue-hearted when freshly quarried from beneath the weathered zone. The limestones may be coarsely shelly, oolitic or finely micritic and silty in character. They have been extensively worked for building stone under a plethora of local quarry names, including: Weldon, King's Cliffe, Barnack, Colleyweston Slate, Wittering Pendle, Ketton, Edith Weston, Stamford, Casterton, Clipsham, Heydour, Ancaster, Cathedral, Hibaldstow, Newbold and Cave Oolite. Most of the older buildings in villages along the outcrop, the 'Cotswolds' of the East Midlands, are constructed of Lincolnshire Limestone. Houses and cottages of lower status are commonly constructed of uncoursed rubblestone while the more substantial houses are built of finely cut ashlar block. It is likely that the rubblestone was obtained from numerous local pits whereas the sawn, ashlared stones were probably supplied by a few better established local quarries.

The most famous and productive of the many quarries in the region were those in the Stamford and Ancaster areas. South of Stamford, the famous Colleyweston 'slates' have been worked for centuries from the lowermost silty limestone beds of the 'lower' Lincolnshire Limestone. At the Neville Holt inlier, near Medbourne, Leicestershire, beds equivalent to those found at Colleyweston were also quarried for roofing slate. The characteristically graded roof of Colleyweston-type slates, largest at the eaves and smallest at the ridge, is still a common sight in the villages of the Leicestershire-Lincolnshire border area (Plate 1M) (Walton, 1975). This lower unit is also the source of the Wittering Pendle, a compact buff, silty (siliceous) limestone variety that was widely used in and around Stamford for building purposes and can be distinguished by its thinly bedded courses (Ireson, 1986).

The more massively bedded, oolite-dominated limestone succession of the 'upper' Lincolnshire Limestone has been extensively quarried at Ketton, Casterton, Ponton and Clipsham. The Ketton Quarries produce what has been described as Britain's most 'perfect' freestone (Arkell, 1947). No other Jurassic limestone in Britain, with the possible exception of some beds of Casterton Stone, shows the same well-sorted, fine-grained, oolitic structure. The fine, even-grained fabric has meant that the stone has always been sought after for the most delicate decorative carving on buildings and tombstones.

Throughout the earliest history of the quarries (16-18C), Ketton Stone was mainly taken south to markets at Cambridge and beyond, and is rarely seen in the East Midlands (Purcell, 1967; Best *et al.*,

1981). By the 19th century, improvements in transport saw a more widespread use of the stone, notably for conservation work, as in Westminster Abbey, the Palace of Westminster and Ely Cathedral. Locally it can be seen in the quoins and decorative mouldings of St. Bernard's Abbey in Charnwood Forest, where it contrasts with the dark Charnian rocks of the main wall fabric.

Although the Ketton Stone is distinctive, the other 'upper' Lincolnshire Limestones are less easily distinguished one from another. The quarries in the Barnack area produced block stone which appears to vary from a distinctive hard, coarsely shelly variety (ragstone), which was widely used, for example in the 'long and short' Saxon stonework of Barnack church and in some of Stamford's churches (Dawn, 1993), to finer, more even-grained, oolitic and shelly block stone. Stone from the King's Cliffe quarries appears to show similar variations in character and relating the provenance of the stones to individual quarries therefore relies largely on documentary evidence (Purcell, 1967). The importance of the Barnack quarries, particularly for ecclesiastical buildings (Ely and Peterborough cathedrals; Crowland, Sawtry, Thorney and Bury St. Edmunds abbeys) has been documented by Salzman (1967), Jope (1964), Purcell (1967) and Ireson (1986). Perhaps the pre-eminent examples of the use of stone from the quarries near Stamford is the Norman Cathedral at Ely (Barnack Stone, with modern Clipsham restorations) and the 16th century Burleigh House (King's Cliffe, Barnack and other stones) (Eric Till, *pers comm*., 1995). Further afield, the famous 15th century 'Stump' of St Botolph's parish church in Boston was built of coarse shelly and oolitic Lincolnshire Limestone, probably sourced from the Barnack area.

North of Stamford the 'upper' Lincolnshire Limestone is still worked in large quarries at Clipsham. Here the limestone may be coarsely shelly, peloidal or oolitic in character depending on the beds being worked. The quality, durability and availability of the Clipsham Stone has meant that it has been widely used to replace weaker limestones in many historic structures. A prime example is the Houses of Parliament, where many of the original magnesian limestone (Cadeby Formation) blocks from the Anston Quarries of south Yorkshire, have decayed badly and been replaced using Clipsham Stone. Though texturally and petrographically different, it is durable and reasonably similar in colour. Many other examples of replacements by Clipsham Stone, not always to the best advantage, occur throughout England, including Windsor Castle (14C); more recently Ely Cathedral, Eton College, York and Southwell Minsters and extensively, in the last century, colleges at Oxford (Arkell, 1947).

Farther northwards along the outcrop in the Wilsford-Ancaster-Leadenham area the 'upper' Lincolnshire Limestone has been worked as a freestone since Roman times (Purcell, 1967; Alexander, 1995). In most of the villages along this part of the outcrop, including Ancaster, Fulbeck and Leadenham, limestone is used almost exclusively in the older buildings. At Caythorpe the limestone is used with contrasting courses of ironstone from the Marlstone Rock Formation. Most of the impressively tall church spires, for which Lincolnshire is justly famous, were built of Lincolnshire Limestone, much of it from the quarries of the Ancaster-Wilsford area; these incude spires at Grantham, Brant Broughton, Louth, Newark and Bottesford.

Lincolnshire Limestone was very much the stone favoured for the great country houses of this part of the East Midlands. Belton House (late 17C) was constructed of Lincolnshire Limestone from quarries at nearby Heydour, while Wollaton Hall in Nottingham (late 16C) is documented as built of Ancaster Stone. Most villages along the outcrop have smaller halls or manor houses built of locally quarried Lincolnshire Limestone; Sudbrook, Caythorpe and Leadenham Halls are just a few such examples.

North of Ancaster, the limestone edge which dominates Lincoln has been quarried to provide

Figure 5. Thompson's Ancaster Stone Quarry, Wilsford Heath, Ancaster, with 4.5 m of Rutland Formation clays and sands overlying thickly bedded Ancaster Stone of the Lincolnshire Limestone (BGS photo #A6333, 1933).

stone for the Norman castle and cathedral and presumably for many lesser properties in old Lincoln such as the 12th century Jew's House. The original quarries, aptly named Dean and Chapter or Cathedral quarries, have remained under the control of the cathedral authorities and are still extant. They lie within the city limits close to the cathedral and work the limestone unit, known locally as the Silver Beds, from the 'lower' Lincolnshire Limestone (Jefferson, 1992). The limestone is typically a grey to buff, variably oolitic and shelly limestone, and is still primarily used to maintain the fabric, despite a brief dalliance with less durable foreign limestones.

When traced further along the crop into north Lincolnshire the oolitic and shelly nature of the limestones begins to change. In the Kirton in Lindsay and Hibaldstow areas a lower interval of oolitic limestone, locally termed the Santon Oolite Member, has been quarried for local building stone, together with the overlying fine-grained, micritic limestones of the Kirton Cementstone and Hibaldstow members. The main oolitic beds, characteristic of the 'upper' Lincolnshire Limestone farther south, are much reduced in this area where they are known as the Hibaldstow Beds. The fine, even grained oolite has been quarried for freestone and its use can be seen in houses in Redbourne, Hibaldstow and most notably at Winterton (Plate 1N). Northwards, across the Humber, the equivalent limestone unit is known as the Cave Oolite, which has also been widely used as a local building stone.

Great Oolite Group building limestones

Unlike the equivalent beds in southern England, which include the thick oolitic limestone developments of Bath and the Cotswolds, the Great Oolite Group of Lincolnshire and Leicestershire is a relatively thin, fine-grained, clastic sequence of sandstone and mudstone with only poorly developed limestone beds. It is divided into three formations, Rutland, Blisworth and Cornbrash, that only have local significance as building stone sources (Table 6).

The sandstone beds are generally too poorly cemented to have had any importance as a building stone. The thin pale grey, micritic, fossiliferous and non-oolitic limestones have, however, been worked for building stone in some localities. These limestones are the equivalent of the Blisworth Limestone (Table 6) which is developed and used as a building stone in the Northamptonshire area (Hudson and Sutherland, 1990). A thin development of the limestone extends into south Lincolnshire, but the presence of easily accessible quarries in the Lincolnshire Limestone has reduced its importance as a building stone. The equivalent bed in north Lincolnshire is a flaggy, fine grained limestone known as the Snitterby Limestone, which had limited local use for building and rough walling in villages close to the outcrop, including Snitterby and Waddingham (Gaunt *et al.*, 1992).

The thinly developed Cornbrash Formation, marking the top of the Middle Jurassic succession, is a fossiliferous limestone known to have been used for rough building work north of the Humber at South Cave (Gaunt *et al.*, 1992). No unequivocal examples of its use have been observed along its Lincolnshire outcrop.

Upper Jurassic rocks

The thickly developed but poorly exposed Upper Jurassic succession of the East Midlands is dominated by mudstones and siltstones, and is termed the Ancholme Group (Table 6). The group, which includes the Oxford and Kimmeridge Clay formations, has been worked locally for brick clay, but seldom for building stone. The possible exceptions are the thin basal sandstone beds of the Kellaways and the locally developed Elsham Sandstone, within the Kimmeridge Clay. No unequivocal examples of the use of Kellaways 'sandstone' have yet been found in the area. The Elsham Sandstone, however, has a moderately thick development around Elsham where it has been has been quarried. The local church and houses possibly include Elsham Sandstone in their fabric, but petrographic study is needed to confirm this.

The Cretaceous rocks

In the steep-sided valleys of the south Lincolnshire Wolds, the oldest rocks of the marine Cretaceous succession are exposed. They comprise a basal sandstone unit, the Spilsby Sandstone Formation, which spans the Jurassic-Cretaceous boundary, and a thin but lithologically and stratigraphically complex succession of interbedded sandstones, mudstones, ironstones and limestones (Table 7). Capping the valley sides and forming a second escarpment, are the white chalks of the Upper Cretaceous succession (Table 8), extending from the Humber coast southwards to the Wash and continuing eastwards offshore beneath the southern North Sea. Chalk is only well exposed along the edge of the escarpment, and the long dip-slope to the east is largely masked by thick Pleistocene deposits. The Cretaceous beds have yielded a few building stones for local use, but none has been distributed beyond the outcrop area.

Lower Cretaceous building stones

As with other successions in the East Midlands area, only the harder, well-cemented beds within the sequence have been worked for building stone, and each appears to have its own local sphere of influence. The basal sandstone unit, the Spilsby Sandstone Formation, crops out only in south Lincolnshire but, based on its widespread

occurrence in local buildings, was probably the most important of the Cretaceous building stones of the area. The Spilsby Sandstone is a poorly cemented, greenish grey, ferruginous, fine-grained, spordically pebbly, glauconitic sandstone. It was once extensively worked for building stone along the Calceby Beck at Salmonby, Ashby Puerorum and Harrington Carrs (Jukes-Brown, 1887). Churches, farm buildings and the lowermost stone courses of many buildings in the villages around this quarrying area are built of this sandstone. Despite its relatively soft nature it was evidently widely favoured for building purposes and can be seen in churches at Horncastle (Plate 1O), Fulletby, Tetford, South Thoresby, Alford, Cumberby, Donnington on Bain, South Willingham and as far north as Grimoldby. There are no quarries working the sandstone today, posing a problem for the conservation of the many buildings made of it. There are many cases where unsuitable stones, such as buff Lincolnshire Limestone have been inserted into the green sandstone fabric.

Farther north in Lincolnshire, the Spilsby Sandstone is gradually replaced by ironstone as the principal building stone. The ironstone mainly used comes from the Lower Cretaceous Claxby Ironstone Formation (Table 7). This is commonly pale yellow-brown but may include orange-brown to purple-red varieties. It is a muddy, calcareous ironstone, sparsely oolitic and often with large thick-walled bivalves (Gaunt *et al.*, 1992). The ooliths are distinctly spheroidal and ferruginous, often giving the rock an 'ironshot' appearance. The ironstone has been exploited as an ore since Roman times (Squires and Russell, 1999) but was also widely used in buildings along its outcrop at Claxby, Market Rasen, Cadney, Ulceby, Swallow, Cuxwold, Rothwell and Caistor. Cottages in the picturesque village of Nettleton are mainly built from the local Claxby Ironstone.

	Stage	Formation	Member	Previous Terminology	Building Stone Quarries
Upper Cretaceous	Cenomanian	Ferriby Chalk		Red Chalk	
		Hunstanton Chalk			
Lower Cretaceous	Albian	Carstone Grit		Carstone	
	Aptian	'Sutterby Marl' 'Skegness Clay'		Sutterby Marl Skegness Clay	
	Barremian	Roach		Fulletby Beds	
	Hauterivian	Tealby	Upper Tealby Clay	Tealby Beds	*Locally quarried at Tealby*
			Tealby Limestone		
			Lower Tealby Clay		
		Claxby Ironstone	Upper Claxby Ironstone	Claxby Beds	*Claxby*
	Valanginian		Lower Claxby Ironstone		
	Ryazanian	Spilsby Sandstone	Upper Spilsby Sandstone	Spilsby Sandstone Beds	*Salmonby Ashby Puerorum Harrington Carrs*
Upper Jurassic	Volgian/ Portlandian		Lower Spilsby Sandstone		

Table 7. Lower Cretaceous stratigraphy and building stone quarries of the East Midlands.

The Tealby Formation, which overlies the Claxby Ironstone, is a sequence dominated by mudstones, with a thin and distinctive grey, micritic limestone, the Tealby Limestone Member, which crops out only in the Tealby-Walesby area (Gaunt *et al.*, 1992). It has been used as a rough walling stone in Tealby village.

A return to more ferruginous lithologies occurs in the succeeding Roach and Carstone formations. The thin, calcareous, fossiliferous sandstone and oolitic ironstone unit known as the Roach Formation is variegated in colour, ranging from greenish grey to yellow-brown in its more weathered state. The Roach is similar to the overlying ferruginous Carstone beds, making their identification difficult. The Roach Formation outcrop is restricted and as yet no examples have been unequivocally identified of the stone being used for building, despite its local potential.

The Carstone Formation represents a final phase of clastic deposition before the onset of Upper Cretaceous chalk sedimentation. This yellow-brown, fine to coarse, pebbly ferruginous sandstone is thinly developed over most of the area and unconformably overlies earlier formations (Gaunt *et al.*, 1992). It has been used extensively for vernacular building south and east of the region in Norfolk (Gallois, 1994) and around Ely (Ashurst and Dimes, 1990) but it is not seen in buildings in Lincolnshire, perhaps because of its softer, more friable nature.

Upper Cretaceous building stones

A thick succession of fine-grained, white to pale grey, chalky limestones, now termed the Chalk Group, constitute the Upper Cretaceous rocks of the area (Table 8). The basal interval of the chalk succession, is characterised by a distinctly reddened chalk lithology interval, the 'Red Chalk' or Hunstanton Formation. These red chalks have been extensively used for vernacular building stone near the outcrop in north Norfolk, but lack of suitable exposure of the unit appears to have precluded its use in Lincolnshire.

The overlying white chalk succession, has an outcrop extending from Norfolk across the Lincolnshire Wolds into Yorkshire and is subdivided into four lithostratigraphic units (Wood and Smith, 1978). Within Lincolnshire only the three lower divisions are known to occur, namely the Ferriby, Welton and Burnham formations (Table 8). Of these only the Ferriby and Welton formations can be seen

at outcrop as the Burnham Formation is buried beneath a thick cover of Quaternary deposits. Perhaps an unlikely source of building stone at first sight, chalk lithologies, particularly the harder beds, are widely used in the area (Judd, 1867). It is also notable that across the Humber, in the Wolds of East Yorkshire, vernacular chalk buildings were once a very common feature and many examples still survive (Hayfield and Wagner, 1998).

The chalk of the Lincolnshire Wolds is typically white to off-white, very fine-grained and hard. Chalk blocks are used in a number of buildings across the outcrop, most notably including the remnants of the 12th century Louth Abbey and Legbourne church. The rock at outcrop around Louth is part of the Ferriby Chalk, and a hard unnamed chalk interval, stratigraphically equivalent to the better-known Totternhoe building stone of Cambridgeshire, is believed to have been the principal stone source (Judd, 1867).

Farther north along the outcrop there are many examples of chalk being used for local building stone both in external and internal walling. Farm buildings at Elsham and older houses at Croxton and Wooton are built of a colourful mix of squared chalk blocks with red brick quoins (Plate 1P). The church at Horkstow is constructed entirely of ashlar chalk, and in the abbey ruins at Thornton internal walls were at least in part lined with chalk blocks, some of which have large grey flints still embedded in them. Some quoins of chalk buildings are blocks of the Claxby Ironstone that have weathered quite badly.

The Upper Cretaceous Chalk successions south of Lincolnshire were important sources of flint, and flint-faced buildings are common throughout Norfolk, Essex, Kent and Sussex. The siliceous flints, which in their best-known natural form are irregularly shaped nodules, were used either as rubble-fill for walling or were carefully broken and shaped (knapped) for wall facings. The black flint varieties were particularly sought after for this latter purpose. Although flint is common in some parts of the succession across the Lincolnshire Wolds (Mortimore and Wood, 1983), there appears to be little evidence of its use as a building material. Of the few examples of flintwork seen in the area, the best known is the flint-faced church at Sutton Bridge, close to the Lincolnshire-Norfolk boundary. The reason for this lack of use is not clear, although it is evident that the character and form of the Lincolnshire flints, which commonly occur as large tabular masses, differ from the nodular varieties of the southern Chalk outcrops. The Lincolnshire flints are typically pale grey and lie within a harder chalk matrix, and it may be that the hardness of the matrix was also a deterrent to the development of a local flint mining industry.

Stage		Formation		Building Stone Quarries
Upper Cretaceous (Chalk Group)	Santonian	Upper Chalk	Flamborough Chalk (flintless)	*(not exposed at surface)*
	Coniacian		Burnham Chalk (with flints)	
	Turonian	Middle Chalk	(with flints)	*Thornton*
	Cenomanian	Lower Chalk	Welton Chalk (flintless)	
			Ferriby Chalk (flintless)	*Ferriby Louth*
Albian		Hunstanton Chalk (red chalk)		

Table 7. Lower Cretaceous stratigraphy and building stone quarries of the East Midlands.

Quaternary building stones

Extensive tracts of unconsolidated Pleistocene fluvio-glacial sediments (sands, gravels, glacial tills and clays) blanket much of the ground over the eastern part of the region, particularly along the main river courses. Although appearing an unlikely source of building stone there are in fact several sites in the area where larger, lithologically varied pebbles and cobbles from these deposits have been used to provide a utilitarian walling material. Good examples include the Anglo-Saxon churches at Waithe, Holton le Clay, Scartho and Clee (the latter three with Claxby Ironstone). Wall fabrics at Wysall and Stanton on the Wolds churches also include cobbles from the local fluvio-glacial deposit.

Another distinctive Quaternary building stone in some parts of the East Midland area is calcareous tufa (or travertine). The tufa is precipitated as calcium carbonate around springs discharging from limestone and was originally found on many of the limestone areas of the East Midlands. As a building material it has a long history. It was particularly favoured by the Romans, perhaps because of its common usage in many important buildings in Rome itself, and later was much prized by Norman builders. It is easily worked, strong, highly porous and therefore light. These properties made it a suitable choice for use in vaulting of churches and

Figure 6. Marl Cottage, Via Gellia Valley, Derbyshire, constructed of large blocks of calcareous tufa quarried from the hills behind (BGS photo #A9125, 1957).

cathedrals. Tufa from the Carboniferous limestones of Derbyshire has been used on a small scale in walls and buildings in Derbyshire, most notably in Marl Cottage beside the Via Gellia road (Fig. 6). Thick deposits formerly occurred around Matlock Bath, where it was commonly used as walling stone, and extensive deposits are still found in Lathkill Dale and Monsal Dale (Pedley, 1993; Pentecost, 1999). Tufa deposits have been recorded on the Jurassic and Cretaceous limestone outcrops of the area but there is no evidence that any of the accumulations were large enough for significant exploitation as building material (Gaunt *et al.*, 1992).

Overview

The primary source for information on the early history of the building stone industry lies in the correct geological identification of the stones used in surviving buildings, and then matching them with potential quarry sources. Sometimes this process may be simplified by access to documentary evidence; however, this is usually only available for high-status buildings, principally those constructed by the Church or Crown. Alexander's wide-ranging study (1995) of major medieval buildings in the East Midlands, including Lincoln, Peterborough and Ely Cathedrals and Southwell Minster, has provided numerous examples, mainly from the 11th to 15th centuries, where documents detailing their construction can be used to establish the location of many early East Midlands quarries. Her work, following the trail blazed by Knoop and Jones (1933, 1938), Arkell (1947), Saltzman (1967) and Purcell (1967), has provided yet more evidence of the importance of the Lincolnshire Limestone quarries in particular to both the early building history and economy of the East Midlands area. However, documents are commonly incomplete or provide ambiguous data, in which case the researcher must turn to geology to identify the stones.

The smaller stone-built vernacular houses, of which the East Midlands still has many, rarely provide useful documentary evidence and correct geological identification of the stone becomes the only viable starting point. The precise provenance of every stone is not always identifiable, as stone can vary significantly in character from bed to bed and quarry to quarry. Problems may also arise where, over time, the names of some stones, such as *Mansfield* or *Barnack*, because of their quality and reputation, were applied indiscriminately to quarries which had no real link to the original stone source. It should however be possible to recognise most stones in the smaller buildings of the East Midlands to at least a generic level (e.g as Charnian rocks or Lincolnshire limestones), and it is hoped that this article goes some way to providing the data to make such identifications.

A factor of considerable importance to understanding where building stones were quarried and how they were distributed is the development of transportation networks. The majority of the East Midlands quarries were up until the end of the 18th century, only able to supply local building needs. Heavy and bulky stone could not easily be moved by cart or packhorse even after the establishment of the first metalled turnpike roads. Successful early quarries were, therefore, those situated near a navigable waterway or near the coast. Good examples were the Lincolnshire Limestone quarries at Stamford, Ancaster and Lincoln, which all developed their access to navigable rivers as far back

as Roman times. The Barnack quarries used the Nene and Welland rivers to supply building stone to south Lincolnshire, Norfolk and Cambridgeshire (Purcell, 1967; Alexander, 1995). The Lincoln and Ancaster quarries could send stone both west to the Trent via the Fossdyke canal and east to the coastal port of Boston via the River Welland.

In Leicestershire and Nottinghamshire, the early quarries at Repton, Weston on Trent and Kingsmill could use the Trent to supply the Triassic sandstones to the many medieval churches along its banks, such as at Barton-in-Fabis, Thrumpton and Ratcliffe-on-Soar. In north Derbyshire and south Yorkshire, Carboniferous sandstone quarries used the rivers Trent and Don as links to the Humber, allowing wider distribution of their millstones and other stone products. Mountsorrel granodiorite and Swithland slates were despatched via the River Soar.

From the end of the 18th century the development of the canals network transformed the stone industry by offering a relatively inexpensive means of transport. A useful overview of stone transportation and its costs was provided for the early part of the 19th century by the survey to identify stone sources for the new Palace of Westminster, built in 1839-1852 (Barry *et al.*, 1839). In this nationwide survey of 102 building stone quarries, the proposed mode and cost of transport to London were described and several quarries from the East Midlands were included (Table 9). Those eventually selected included Mansfield White and Bolsover, but most of the construction was carried out using Anston Stone from just over the border into South Yorkshire. Transportation of stone from the North Anston quarry was via the nearby Chesterfield Canal to the rivers Trent and Humber and then by sea to London (Lott and Richardson, 1997).

Quarry	Probable transportation route	Cost (quarry)	Cost (London)
Ancaster	By land to Grantham; by canal to Boston and by sea to London (*with no canal from Grantham to Boston this is surprising*).	9d	2s 6d
Barnack Mill	By land to Wansford, canal to Sutton Bridge, and then by sea to London	1s	2s 3d
Bolsover	By land to Chesterfield Canal at Worksop; by canal to Stockwith; by the Trent and sea to London	10d	2s
Cadeby	By land to the Don Navigation; on to Thorne and the Ouse/Humber; by sea to London	not given	1s 10d
Duffield Bank	Not specified	1s 1d *	not given
Dukes	By canal to Leicester (*unspecified*); by Grand Junction canal to London	7d	2s 8d
Haydor (Haydour)	By land to Sleaford; through Boston by sea to London	8d	2s 4d
Hopton Wood	By land to Cromford wharf; by canal to London (*unspecified*)	3s to 4s	4s 10d to 5s 10d
Ketton	By land to Stamford; to London via Wansford? (*unspecified*)	1s 9d	3s 4d
Lindrop	By land to Cromford Canal; by canal (*not specified*) to London	not given	not given
Morley Moor	By land to Little Eaton; by canal (*unnamed*) to London.	10d	not given
Mansfield White and Red (Lindley's)	By land to railway wharf at Mansfield; to Pinxton by rail; to Gainsborough by boat using the Trent and Irwash and then by sea, *presumably via the Humber*, to London	8d	2s 2d to 2s 6d
Shaw Lane, Belper	*Not specified*	1s 1d *	not given
Stancliffe Darley Dale	By land to Cromford; thence to London (*route unspecified*)	1s 5d	3s 3d

Table 9. Potential building stone sources for the Palace of Westminster (after Barry, 1839). Costs are per cubic foot, at the quarry and delivered to London. s = shillings, d = pence. * costs for white stone; stone that was half brown and half white cost 9d.

With the development of the national rail and road systems, particularly in the second half of the 19th century, the building stone quarrying industry expanded dramatically. In the East Midlands, the Carboniferous sandstone quarries of Derbyshire developed into a major national resource and supplied stone to most major cities. The downside of this expansion was of course the decline in the need for smaller local stone quarries, and coupled with the expansion of the brick industry, quarrying of the many vernacular stones of the area ceased to be an economic proposition even for local markets.

Today's stone industry in the East Midlands is mainly concentrated along the Derwent valley, but with small but important production remaining around Ancaster and Stamford. Many stones are now no longer produced. There is no current production of Swithland Slate, Triassic sandstone, Lias limestone, Marlstone and Frodingham 'ironstones', Spilsby and Chalk building stone from quarries in the area - posing a significant problem for building conservation.

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