

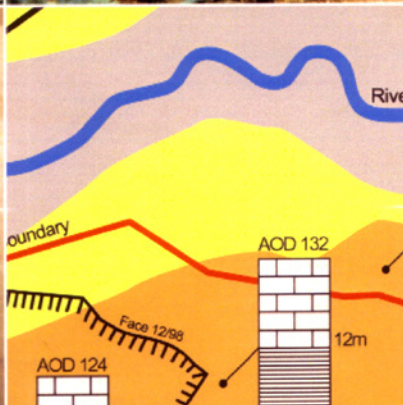
# England's Heritage in Stone

*Proceedings of a Conference*

Tempest Anderson Hall, York  
15 - 17 March, 2005



English Stone Forum





# Field guide to the building limestones of the Upper Permian Cadeby formation (Magnesian limestone) of Yorkshire

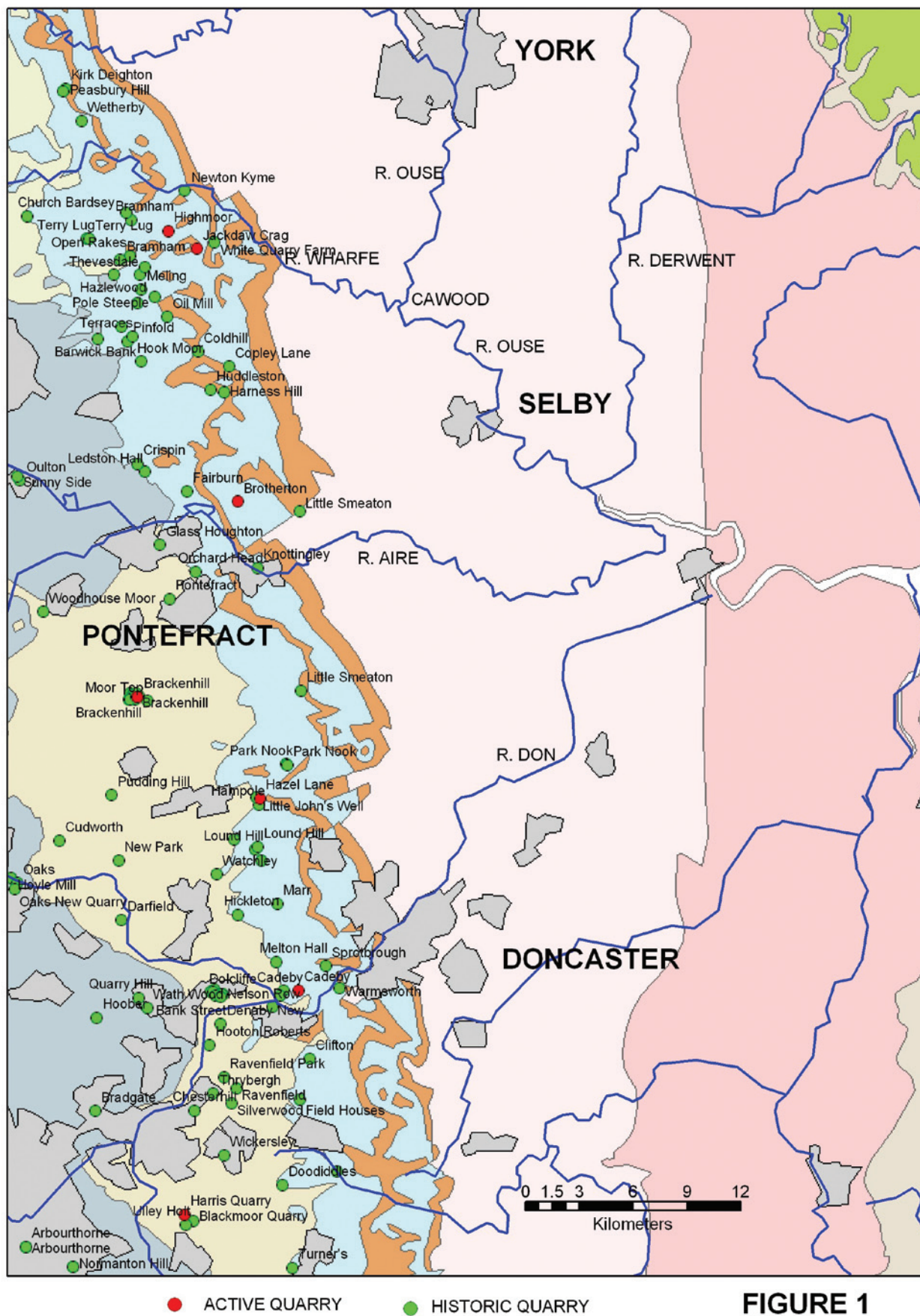
**G. K. LOTT & A. H. COOPER**

The late Permian dolomitic limestones (dolostones), which form an almost continuous outcrop from north Nottinghamshire to the Durham coast at Teeside, have been an important source of industrial minerals for many centuries. They have been quarried extensively for building stone, aggregate and lime for agricultural, industrial and chemical processes (see Buist & Ineson 1992). The limestones, because of their magnesium-rich carbonate mineralogy are perhaps still best known by their former geological name the (Lower) Magnesian Limestone. However, in Yorkshire and Nottinghamshire the limestones are now named, by geologists, the Cadeby Formation (Smith et al. 1986; Fig. 1). Along much of its length, the outcrop is pock-marked by small quarries and lime pits, many now disused and some infilled with waste. Currently there are three quarries producing building stone from the formation in Yorkshire, namely Highmoor, Hazel Lane and Cadeby quarries (Map 1). Many of the most famous quarries of the Tadcaster (Thevesdale) area Smaw's, Jackdaw Crag, Terry Lug, Hazelwood etc have long ceased operations (Fig. 1).

The Cadeby limestones, which show subtle colour variations from white to pale yellow, have been used widely over the last millennium to construct some of our most famous historic buildings. The best known examples are the cathedral churches of York, Beverley and Southwell, the castles at Conisborough and Pontefract; the abbeys of Selby, Thorton, Welbeck, and Roche and more recently the Houses of Parliament (1839–52). In addition, the stone has been used extensively in many towns and villages along the outcrop

for the construction of parish churches, local housing (as around Doncaster, Selby, Tadcaster and Wetherby,) and 'stately' homes (such as Huddleston Hall, Monk Fryston, Bolsover Castle and Studeley Park).

In addition to the Cadeby Formation, there is a thinner less well-known limestone in the Permian sequence. This is the Brotherton Formation, which was formerly called the Upper Magnesian Limestone. It is pale grey to pale yellow colour, generally more compact and slightly porcellaneous



**Figure 1.** The Solid Geology of Nottinghamshire and south Yorkshire (Pennine Coal Measures - grey; Cadeby Formation limestones - pale blue; Triassic rocks - pink; Cretaceous Chalk - green).



**Figure 2.** The approximate extent of the Zechstein Sea in Permian times 260 to 248 million years ago when Britain was in subtropical latitudes.

in nature. However, it generally only forms thin and very thin beds rendering it unsuitable for dimension stone. Locally it is used for walling and buildings along the outcrop, especially around Brotherton, where it is currently worked for lime and building stone.

#### **GEOLOGY OF THE CADEBY FORMATION**

The Cadeby Formation consists almost entirely of dolomitic limestones and has been the subject of intensive geological interest for more than 150 years (see, for example, Smith 1974). The best building stones are still quarried from the north Nottinghamshire to Catterick section of the outcrop. North of this area the limestones are largely covered by thick superficial sediments and have not, in general, been worked as extensively for building purposes.

The Cadeby Formation was formally defined by Smith et al. (1986) at Cadeby Quarry, where it comprises a 35m thick succession of dolomitised bryozoan-rich patch reefs and domed algal stromatolites (Wetherby Member) in its lower beds, and cross-bedded oolitic limestones (Sprotborough Member) in its upper interval (Table 1). These two limestone members are separated by a thin sequence of interbedded mudstones and dolomitised oolitic limestones (Hampole Beds). The Cadeby Quarry has been an important producer of building stone for some considerable time and its creamy white oolitic limestone is still commonly used in new build and conservation work (e.g., new Riverside Apartments, General Accident offices, York).

The Cadeby limestone succession originally developed as a series of reefs and ooidal shoals along the western shore-

line of the highly saline late Permian Zechstein Sea, which extended from eastern England into Poland (Smith, 1970, 1989) (Fig. 2). The succession of limestones, dolomites, mudstones and evaporites formed in this sea are collectively termed the Zechstein Group (Table 1).

Understanding, mapping, and exploiting the complexities of the limestone sequence presents difficulties both to the geologist and the quarry owner. Reefal limestone developments, by their very nature, do not generally show a great deal of lateral continuity with individual beds thickening and thinning very rapidly across the outcrop. This can present problems to the quarry operator, as a good stone limestone bed may thin and eventually disappear as the face is worked back. The oolite facies tends to occur either in regularly bedded or massively cross-bedded units. The ooids are like tiny balls of limestone, 0.5–2mm in diameter, that built up in concentric layers as they washed gently backwards and forwards in warm tropical seas. Eventually the ooids were deposited in layers behind and around the reefs, or (especially in the Wetherby Member) as large-scale cross-bedded units as they were washed over the edge of the shallow platform into deeper water. The environment was very similar to the present day Bahamas Grand Banks. Where the ooids became large, or where material was deposited around small shell fragments or other debris, pisoids formed.

Although the reefs themselves can be highly fossiliferous, they are mostly devoid of stratigraphically useful fossils, again making correlation between beds over any distance particularly difficult. To compound these problems the



Groups	Formations	Members	Typical lithology
Zechstein Group	Roxby Formation (formerly Upper Marl)		Calcareous mudstone with gypsum passing into anhydrite with depth
	Brotherton Formation (formerly Upper Magnesian Limestone)		Dolomitic limestone and dolomite
	Edlington Formation (formerly Middle Marl)		Calcareous mudstone with gypsum passing into anhydrite with depth.
	Cadeby Formation (formerly Lower Magnesian Limestone)	Sprotbrough Member (Upper Subdivision) 15-30m Wetherby Member (Lower Subdivision) 14-40m	Dolomite and dolomitic limestone, becoming sandy dolomite in the south

**Table 1.** *The Permian strata at outcrop in Yorkshire and North Nottinghamshire.*

pervasive dolomitisation (magnesium-enrichment) processes which probably took place soon after the formation of the reefs can result in significant changes to the original limestone fabric (a process known as diagenesis). In some parts of the succession the original primary sedimentary structures can be obliterated, to be replaced by a homogeneous crystalline texture of fine to coarse rhombic dolomite crystals. Such factors make correlations along the outcrop tentative, as few beds within the succession are distinctive or consistent enough to be traced over large areas. There are some exceptions, the unit known as the Hampole Beds can be traced from Nottingham to just north of Ripon and enables the southern part of the outcrop to be divided into its lower and upper limestone units, the Wetherby and Sprotborough members respectively as noted above (Smith 1968).

The extent of the Late Permian limestones was first shown in the county maps of William 'Strata' Smith (1815–24) (Lott and Richardson 1997; Smith was one of the four Commissioners who selected the Cadeby limestone for the Houses of Parliament). Probably the best and the earliest geological description and interpretation of the sequence was that of Adam Sedgwick (1829). Sedgwick's work has been followed by a plethora of other studies including those by Smith 1844, Aveline (1861, 1862); Hull 1869; Sherlock (1911) and the many memoirs and maps of the Geological Survey (e.g., Edwards et al. 1950; Eden et al. 1957; Smith et al. 1967, 1973; Cooper & Burgess 1993) which have provided detailed information about the unit over much of its outcrop. The lithological

and sedimentological aspects of the limestones have been extensively described and discussed by Smith (1970, 1974, 1986), Harwood (1986) and Kaldi (1986). Together, these publications provide a comprehensive source of geological information on most aspects of the limestone succession and the reader is referred to them and their comprehensive bibliographies for further detailed information. The evolution of the lithostratigraphical nomenclature of the unit is summarised in Table 2.

### LITHOLOGICAL AND FACIES VARIATIONS IN THE CADEBY FORMATION LIMESTONES

The term facies can be defined in a number of ways, but is used in the following text to describe those lithological units with primary sedimentary features intact, representing deposition in distinct sedimentary environments – marine, lagoonal or reefal settings for example. In some parts of the outcrop, however, the Cadeby Formation limestones, as noted above, may have lost part of their primary fabric through the dolomitisation process, thus preventing placement of the limestone beds within normal sedimentary facies units.

The local changes in depositional facies that occur in these basin margin marine limestones are reflected in their many variations in colour, lithology and fabric. In gross mineralogical terms the composition of the limestones is quite consistent (see next section). However, the limestones can show a spectrum of colours from orange-brown to creamy white, principally because of very small changes in their iron content. The limestones show a wide range of sedimentary, diagenetic, tectonic and weathering structures that can be readily identified in the buildings in the area. The primary sedimentary include features such as ooids, pisoids, algal stromatolites, brecciation, lamination, bedding, cross-bedding and clay seams. The diagenetic features developed textures such as dolomite crystal rhombs and cellular fabrics and 'vuggy' cavities, which may be either open, or partly to fully filled with crystals of carbonate. Diagenetic and tectonic features due to the depth of burial can also generate stylolites (intricate and irregular suture-like

Sedgwick 1829	Aveline 1880	Mitchell et al 1947
Yellow Magnesian Limestone	Magnesian Limestone	Lower Magnesian Limestone

**Table 2.** *Previous nomenclature of the Cadeby Formation*

bedding layers caused by differential dissolution) and fractures commonly sealed with coarsely crystalline carbonate. Later alteration due to weathering can also change the rock, developing cellular fabrics, water-dissolved joints, Liesegang rings (coloured rings of leached chemicals) and black speckling (manganese). All these colour and fabric variations can have consequences in terms of determining the likely durability of a particular limestone and in understanding its decay patterns.

### MINERALOGY OF THE CADEBY FORMATION LIMESTONES

The mineralogy of the Cadeby Formation limestones is relatively well known because of its strategic importance as an industrial mineral resource. A comprehensive review of its mineralogy has been provided by Rendell, Palmer & Triton (1988) and more recently by Buist and Ineson (1992). Mineralogically the limestone has a mean composition of 54.35 per cent (CaCO<sub>3</sub>) and 45.65 per cent (MgCO<sub>3</sub>), this defines it as a dolomitic limestone, or dolostone, in most modern rock classification schemes. There are some local variations, however, and perhaps the most distinctive is the development, at the southern end of the outcrop, of a significant component of detrital siliceous sand grains (up to 80 per cent by volume). This sandy facies of the limestone is best developed around the Mansfield area where it has been worked for many centuries as a building stone. It was commercially produced as the Mansfield Red and White stone, but the last quarry in the area closed in 2004. The presence of the fine detrital, siliciclastic sand grains in the limestone has helped to produce a particularly durable stone which was used extensively for the external and internal ashlar fabric of Southwell Minster, parts of the Houses of Parliament, as well as Newark and Mansfield town halls, to name just a few examples.

Interest in the mineralogical composition of the Magnesian Limestone dates back to 1839 when, as part of the selection process for choosing a building stone for constructing the present Houses of Parliament, detailed analyses of these limestones and others was commissioned (Barry et al. 1839; Daniell and Weston 1839; Table 1). They eventually selected, from 102 stones, the Lower Magnesian Limestone from the Bolsover quarry as the most suitable stone for their purpose, apparently after admiring its durability on a visit to Southwell Minister. An erroneous assumption as the Minster is, as noted above, constructed of Mansfield White Stone (Smith 1840; Lott and Richardson 1997). In fact the Bolsover Quarry could not meet the considerable demands placed on it by the project and most of the original Magnesian Limestone eventually came from quarries at Anston.

### PETROGRAPHY AND DIAGENESIS IN THE LIMESTONES OF THE CADEBY FORMATION

Petrographically the limestones of the Cadeby Formation show a wide range of textures varying from highly porous, weakly cemented limestones to hard, non-porous lithologies with a distinctly crystalline texture. The crystalline nature of the limestones may vary markedly with some varieties consisting of quite coarsely crystalline porous

fabrics and others of less porous finely crystalline types. In other limestones the original bioclastic texture, though dolomitised, is still partially preserved and ooids, pisoids, bryozoan, coral and shell fragments can all be recognised, e.g., Cadeby. Particularly noticeable in the Tadcaster area is the development of a distinctive highly porous, cellular texture that appears to represent an original very finely peloidal or ooidal fabric in which the cores of the spheroidal framework grains have been leached out. In general the porosities of the best building limestones range between 19–25 per cent (Table 3)

Stone	Porosity	Fabric
Mansfield White	19.7	crystalline
Steetley	23-25.8	crystalline
Roche	19.9	crystalline
Cadeby	20.1	peloidal
Huddleston	20.2	crystalline
Smaws	28.4	cellular
Jackdaw Crag	22.4	cellular
Terry Lug	25	cellular

**Table 3.** Typical porosities in Cadeby Formation limestones (BGS archive data 1931)

The conditions that lead to the dolomitisation of the Cadeby Formation limestones are still the subject of scientific debate, as also is the precise mechanism of magnesium enrichment (Harwood 1986). However, the effects of diagenesis on the limestone are so significant in terms of its durability that it is necessary to have at least some understanding of what changes have occurred to produce the limestones we now use for building.

One particular possible mechanism, favoured by many geologists, is termed seepage reflux. This theory suggests that during or soon after its formation the reef structure, which still formed a highly porous, biogenic framework of calcium carbonate mineralogy, was transgressed and infiltrated by the magnesium-rich waters from the adjacent hypersaline main basin. This process or something similar was ultimately responsible for the complete dolomitisation of the whole late Permian limestone succession.

Such wholesale diagenetic changes to the original limestone fabric are clearly likely to affect the durability of the limestones for building purposes. In particular there are noticeable differences in the porosity of the limestones across the outcrop. Recrystallisation of the original fabric resulted in large volume changes and led to a fundamental redistribution of the original primary porosity. One notable consequence of this redistribution is, for example, the common occurrence of large open or carbonate crystal-lined cavities or vugs in the limestone fabric.

### THE BUILDING STONES OF THE CADEBY FORMATION

The Cadeby Formation limestones have been used for building in the Yorkshire area since Roman times and there is ample evidence of its use in villas and forts from the many

Quarry	Date
Thevesdale (Tadcaster)	1225-1423
Huddleston (Sherburn-in-Elmet)	1423-1544
Stapleton (Pontefract)	1399-1403
Doncaster	1400-16
Bramham	1419-22
Hampole	1512-30

**Table 4.** *Medieval stone quarries supplying limestone to the Minster at York (after Gee 1981)*

Roman sites along its outcrop, for example, Doncaster, Castleford and Tadcaster. The importance of the Bramham-Tadcaster (Calcaria) area as a source of medieval building limestone is evident from its use in substantial quantities in the City of York since the twelfth century (Brook 1976; Gee 1981). Many of the early quarries in the area were originally under the control of the De Percy and Vavasour families who donated stone to York Minster (Table 4).

As the Vale of York lacks any building stone resources of its own, any stone used had to be transported along one of the many river courses which cross-cut the area. Stone from the 'Thevesdale' (Hazelwood) and Bramham quarries east of Tadcaster would first need to be carted overland to the Wharfe and then along the river to Cawood, its junction with the Ouse, and then upriver to St Leonard's Landing in the City. The Huddleston Quarry stone was originally transported using the now long disused canal known as the Bishop's Dyke, carrying the stone to the wharves near Cawood.

In York, the City walls, Norman Minster and numerous medieval parish churches as well as Selby Abbey, Beverley Minster and Hazelwood Castle have all been constructed using these Tadcaster stones. These river navigations also allowed access to the sea via the Humber estuary, opening further opportunities in the south of England. Tadcaster stones were used in the early fabric of the Tower of London, Windsor Castle and Eton College, for example.

Transport of stone from quarries at Stapleton (Pontefract) and around Doncaster would initially have required overland transport to the Aire or Don rivers, via which they could use the Ouse to reach Selby and Cawood. The Hampole Quarry stone reached York via Doncaster.

#### **DECAY IN THE BUILDING LIMESTONES OF THE CADEBY FORMATION.**

Studies of the decay characteristics of the Cadeby dolomitic limestones date back to the construction of the Houses of Parliament in the mid-nineteenth century. Almost before the building had been completed the Anston Stone was showing marked signs of decay in the damp, heavily polluted London atmosphere. As a consequence perhaps the most intensive studies of a single stone type ever to be carried out then commenced and have continued on the building ever since. Many of the seminal studies of stone decay by, for example, Schaffer (1932) and his colleagues at the Building Research Establishment were based initially on research into the problems of decay in the 'magnesian limestones'.

The magnesium-rich mineralogy of the carbonate does not inherently appear to make the limestone more vulnerable to decay, as there are many examples where such limestones have survived well. It is, however, clear that the magnesian limestones do not fare as well as some calcitic varieties in polluted urban settings. In purely chemical terms it has long been established that the calcium salts are generally less soluble than magnesium rich varieties. It is also notable that the volumetric expansion within pore spaces of a magnesian sulphate, derived by reactions with acid rain, as distinct from a calcium sulphate (gypsum) bi-product is considerably greater (e.g., Richardson 1971). The decay features that develop are well documented by Schaffer (1932) and many other workers. Typically they include surface discoloration, efflorescence, blistering and ultimately severe surface exfoliation.

The varied textures and fabrics encountered in the limestones from different quarries in the outcrop make any generalisations about the causes and mitigation of decay problems risky without detailed petrographic characterization. Each stone needs to be assessed fully before remedial work is undertaken. Clearly the replacement of one magnesian limestone with another from a different quarry, which may have quite different textural and porosity characteristics, should also be an important consideration during any conservation programme.

#### **FIELD EXCURSION STOPS**

**Selby Abbey [SE 461 332]** The Abbey was founded by the Benedictine community in 1069 and construction of the church took place from 1097-1123. The (Parish) church is 91.5m long and comprises a Norman to Early English nave of 8 bays, Norman transepts and a Decorated chancel of seven bays. In 1690 the central tower collapsed. Restoration work was carried out by George Gilbert Scott in 1871-73 and by his son Oldrid Scott in 1889-90. In 1906 fire damaged the whole fabric. The crossing tower was rebuilt by Oldrid Scott in 1908. The south transept was rebuilt in 1912. All the associated monastic buildings have completely disappeared.

Originally the stone used for the Abbey came from the magnesian limestone quarries at Hazelwood-Thevesdale near Tadcaster with probably some from Huddleston Quarry. More recent restoration work has used stone from the Smaws Quarry (1906) and even possibly Clipsham Stone (Middle Jurassic limestone) in the 1950's. Currently the stone being used in the Purcell, Miller and Triton conservation project is magnesian limestone from the Highmoor Quarry, Tadcaster.

#### **Sherburn in Elmet, All Saints Church [SE448 433]**

Given as a thanksgiving offering to the Archbishop of York in 938 AD by King Athelstan, the manor of Sherburn became the seat of the Archbishops of York until the middle of the fourteenth century. The original Saxon church was rebuilt in the twelfth century. Although much modified, evidence of its Norman origins can be seen in the nave and north aisle. The church is constructed of local stone from the adjacent Huddleston Quarries





Figure 3. New Micklefield in 1850

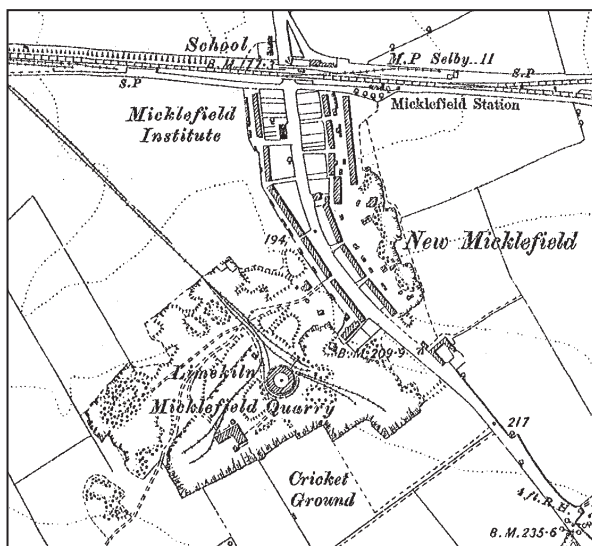


Figure 4. New Micklefield in 1892

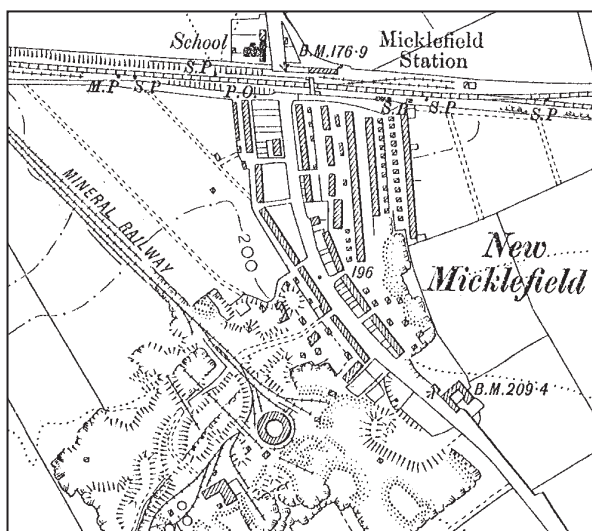


Figure 5. New Micklefield in 1908

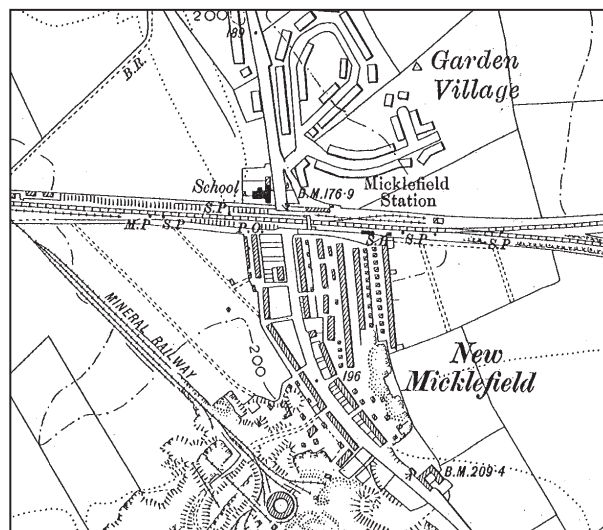
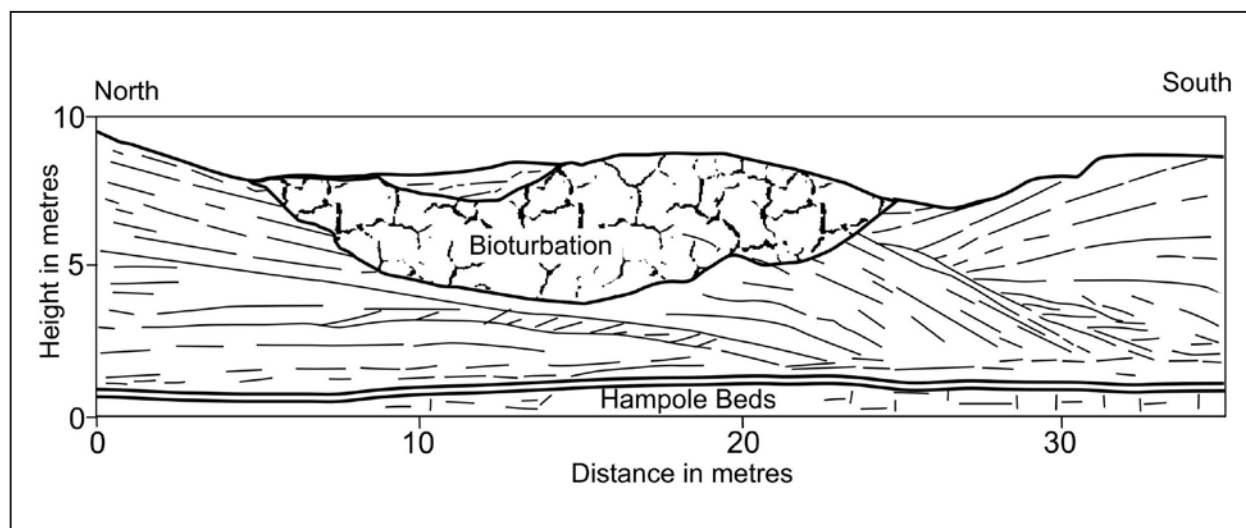


Figure 6. New Micklefield in 1938

**Micklefield Quarry [SE 445 325]** The Micklefield Quarry is situated at the south end of New Micklefield Village. It lies within the triangle bounded to the west by the old Great North Road, to the east by the A1 dual carriageway and to the north by the Leeds-York/Selby railway line. The quarry has a history of being worked for lime and building stone going back to before 1850. The east face is now preserved as an SSSI with easy public access. Historical maps show how the area developed for quarrying and indicate that the preserved face was in existence in 1850, with most of the subsequent quarrying taking place to the west of the Great North Road (Figs. 3 – 6). The old maps show coal mining activity in the area and numerous circular structures in the quarry. These are almost certainly limekilns. The historical six-inch to one mile Ordnance Survey maps also suggest the approximate ages for some of the housing.

The section in the quarry shows the Hampole Beds and the overlying Sprotbrough Member of the Cadeby Formation. The lower sequence comprising the Wetherby Member was formerly exposed, but was concealed when the quarry was partially filled in. The lower part of the sequence may have been the better building stone because it would have contained the algal stromatolite layers and the better-laminated and bedded rock. The now concealed Wetherby Member comprised reef and back-reef facies as noted above. The Hampole Beds represent a time when the sea level fell and the seabed became dry or only partially inundated in a peritidal environment. This change caused the erosion of partly lithified limestone and the deposition of ripped-up material in a porous mesh (strongly fenestral) texture that typifies the Hampole Beds (Smith 1968, 1995). Interbedded with the upper parts of the Hampole Beds there are common thin mudstone beds and laminae that extend for considerable distances along the outcrop of the Cadeby Formation. The upper part of the sequence comprising the Sprotbrough Member shows massive cross-bedding on a scale of 5-10 metres. The lithology of the rock was originally mainly ooids and these were deposited on the fronts of large-scale ripples in shallow water in a similar way to





**Figure 7.** Sketch of the southern part of the main face at Mickelfield Quarry, showing the cross-stratification in the Sprotbrough Member of the Cadeby Formation and the position of the Hampole Beds. Slightly modified from Kaldi 1980 and Smith 1995.

the ooid banks being deposited at the present time in the Bahamas Grand Banks. Some areas of the oolite banks are considerably altered in structure due to bioturbation and pervasive dolomitisation. These effects give the rock a much more massive homogeneous texture (Fig. 7)

**Smaws Quarry [SE461 430]** Access to the Smaws Quarry is not possible at present as it is part of an active landfill site. However, the general succession of the Magnesian Limestone can be viewed from a vantage point outside the quarry boundary. Smaws Quarry has long been owned by the Smith family, Tadcaster brewers since 1758. Brook (1976) relates the quarry's history as follows 'According to an 1888 trade Directory, stone from Smaws was used for the repair of York Minster and York City walls. In 1903 Smaws stone was used at Bramham Church, and 1000 cubic yards were sold to Anleys who were restoring Clifford's Tower that year. Others sources mention Smaws stone used for repairs

to cathedrals at Beverley and Ripon, and also for rebuilding of Selby Abbey after the fire of 1906. But the triumphal monument to Smaws stone is not ecclesiastical but rather more commercial and convivial. It is the massive rock-faced John Smith's Brewery (1883, Scammell and Collyer) which is the chief landmark of Tadcaster (Fig. 8.). Behind this mammoth Victorian brewery is a sleek, modern, one storey brewery building built for conditioning lager for Samuel Smiths (by Gillinson and Barnett). Completed in 1976 this is the first building faced with Highmoor Stone from the newly opened quarry one-mile west of Smaws.'

#### SELECTED REFERENCES

Aveline, W.T. 1861. The Geology of the Country around Nottinghamshire and Derbyshire. Memoir of the Geological Survey of England and Wales, HMSO.

Aveline, W.T. 1862. The Geology of the Country around Nottingham. Memoir of the Geological Survey of England and Wales, HMSO.

Aveline, W.T. 1880. The Geology of parts of Nottinghamshire, Yorkshire and Derbyshire. Sheet 82 NE. Memoirs of the Geological Survey of England and Wales, HMSO.

Barry, C., de la Beche, H.T., Smith, W. and Smith, C.H. 1839. Report on the Selection of Stone for Building the New Houses of Parliament. HMSO.

Brook, C. 1976. The Stones of York. Diploma in Conservation Studies. York University.

Buist, D.R. and Ineson, P.R. 1992. The Magnesian Limestone in the UK. Quarry Management, April 1992.

Cooper, A.H. and Burgess, I.C. 1993. Geology of the country around Harrogate. Memoir of the British Geological Survey, Sheet 62 (England and Wales), HMSO.



**Figure 8** Smaws Quarry has long been owned by the Smith family, Tadcaster brewers since 1758. The town's chief landmark and triumphal monument to Smaws stone is their massive rock-faced brewery.

- Daniell, and Weston 1839, in Report on the Selection of Stone for Building the New Houses of Parliament. HMSO.
- Eden, R.A., Stevenson, I.P. and Edwards, W. 1957. The Geology of the Country around Sheffield. Memoir of the Geological Survey of Great Britain, Sheet 100 (England and Wales). HMSO.
- Edwards, M.A., Mitchell, G.H. and Whitehead, T.H. 1950. Geology of the district north and east of Leeds. Memoir of the Geological Survey of Great Britain, Sheet 70 (England and Wales), HMSO.
- Gee, E. 1981. Stone from the medieval limestone quarries of south Yorkshire. *Collectanea Historica: Essays in Memory of Stuart Rigold*. Kent Archaeological Society.
- Harwood, G.M. 1986. The diagenetic history of the Cadeby Formation carbonate (EZ1) Upper Permian, eastern England, 75-86 in Harwood, G.M. and Smith, D.B. (Editors). *The English Zechstein and related topics*. Geological Society of London, Special Publication, No. 22, 244pp.
- Harwood, G.M. and Smith, D.B. 1986 (Editors). *The English Zechstein and related topics*. Geological Society of London, Special Publication, No. 22, 244pp.
- Hull, E. 1869. The Triassic and Permian rocks of the Midland Counties. Memoir of the Geological Survey of England and Wales, HMSO.
- Kaldi, J. 1980. Aspects of the sedimentology of the Lower Magnesian Limestone (Permian) of eastern England. Unpublished Ph.D. Thesis, University of Cambridge.
- Kaldi, J. 1986. Diagenesis of nearshore carbonate rocks in the Sprotbrough Member of the Cadeby (Magnesian Limestone) Formation (Upper Permian) of eastern England.
- Harwood, G.M. and Smith, D.B. (Editors) (pp 87-102 in). *The English Zechstein and related topics*. Geological Society of London, Special Publication, No. 22, 244pp.
- Lott, G.K. & Richardson, C. 1997. Yorkshire Stone for the Houses of Parliament. (1839–c.1852). *Proceedings of the Yorkshire Geological Society*, 51, 265-272.
- Miller, J.S. and Gee, E. 1983. The Bishop Dyke and Huddleston Quarry. *The Yorkshire Archaeological Journal*.
- Mitchell, G.H., Stephens, J.V., Bromehead, C.E.N. and Wray, D.A. 1947. The Geology of the Country around Barnsley. *Memoirs of the Geological Survey of Great Britain*, HMSO.
- Rendell, Palmer and Triton, 1988. Outline study of the Magnesian Limestone in the UK.
- Richardson, B.A. 1971. Choosing Stone for the Minster. *Stone Industries*. March–April, 1971
- Sedgwick, A. 1829. On the geological relations and internal structure of the Magnesian Limestone, and the lower portions of the New Red Sandstone in their range through Nottinghamshire, Derbyshire, Yorkshire and Durham, to the southern extremity of the Northumberland. *Transactions of the Geological Society of London*, 3, 37-124.
- Schaffer, R.J. 1932. *The Weathering of Natural Building Stones*. HMSO.
- Sherlock, R.L. 1911. The relationship of the Permian to the Trias in Nottinghamshire. *Quarterly Journal of the Geological Society of London*, 57, 75-117.
- Smith, C.H. 1844. *Lithology or Observations on Stone used for Building*. Royal Institute of British Architects.
- Smith, D.B. 1968. The Hampole Beds – A significant marker in the Lower Magnesian Limestone of Yorkshire, Derbyshire and Nottinghamshire. *Proceedings of the Yorkshire Geological Society*, 36, 463-477.
- Smith, D.B. 1970. The palaeogeography of the British Zechstein. 20-23 in Rsu, J.L. and Dellwig, L.F. (Editors). *Third symposium on salt*. Northern Ohio Geological Society, 474pp.
- Smith, D.B. 1974. Permian in Rayner, D.H. & Hemingway J.E. (Editors) *The geology and mineral resources of Yorkshire*. Yorkshire Geological Society.
- Smith, D.B. 1989. The late Permian palaeogeography of north-east England. *Proceedings of the Yorkshire Geological Society*, 47, 285-312.
- Smith, D.B. 1995. *Marine Permian of England*. Geological Conservation Review Series. Joint Nature Conservation Committee. Chapman and Hall. London.
- Smith, D.B., Harwood, G.M., Pattison, J. and Pettigrew, T. 1986. A revised nomenclature for Upper Permian strata in eastern England. 9-17 in Harwood, G.M. and Smith, D.B. (Editors). *The English Zechstein and related topics*. Geological Society of London, Special Publication, No. 22, 244pp.
- Smith, E.G. Rhys, G.H. and Eden, R.A. 1967. The Geology of the Country around Chesterfield, Matlock and Mansfield. Memoir of the Geological Survey of Great Britain, Sheet 112 (England and Wales). HMSO.
- Smith, E.G. Rhys, G.H. and Goosens, R.F. 1973. The Geology of the Country around East Retford, Worksop and Gainsborough. Memoir of the Geological Survey of Great Britain, Sheet 101 (England and Wales), HMSO.



**Appendix 1: Buildings using Magnesian Limestone****1. Listed in Barry et al. (1839)**

Beverley Minster (twelfth–fourteenth centuries): limestone from Bramham Moor and Oolitic variety from Newbold.  
St Mary's Church, Beverley: also from Bramham and Newbold.

Bolsover Castle, local quarries.

Doncaster Old church (fifteenth century)

Hemingborough Church (fifteenth century)

Howden Church (fifteenth century) in part

Huddleston Hall (fifteenth century): local quarry.

Knaresborough Castle (twelfth century)

Conisborough Castle (eleventh–twelfth centuries)

Ripon Cathedral (eleventh–thirteenth centuries), in part

Robin Hood's Well (1740)

Roche Abbey (twelfth century): local quarry

Selby Church (Abbey) (eleventh–fourteenth centuries)

Southwell Church (Minster) (tenth century)

Spofforth Castle (fourteenth century)

Studley Park (nineteenth century?)

Thorpe Arch Village: local quarries

Thorpe Salvin Manor House (fifteenth century)

Tickhill Church (fifteenth century)

York Minster Jackdaw Craig Quarries; St Mary's Abbey (twelfth century); St Denis's Church (Norman Doorway);

St Margaret's Church (fifteenth century); Walls of

York City

Worksop Church (thirteenth century)

**2. From Oswald (1959)**

Sawley Abbey: from Thevesdale Quarry

Hazelwood Castle: from Thevesdale Quarry

Howden Church

Thornton College, Lincolnshire

Drax Abbey

Sherburn in Elmet Church: Huddleston Quarry

St Stephen's Chapel, Westminster: Pontefract Quarry

Windsor (1344): Stapleton Quarry

Rochester Castle (1368): Stapleton Quarry

Westminster Hall, Marr Quarry

Syon Abbey

Eton College: Huddleston and Taynton

King's College, Cambridge: Huddleston and Weldon

**3. From Elsdon and Howe (1923)**

Houses of Parliament

Temple Bar Memorial; Claridge's Hotel; Burlington House; the Hippodrome, Cranborne St; St Pancras Hotel; several London & County Bank Buildings; the Cross, Charing Cross Station; flags on terrace opposite National Gallery, Trafalgar Buildings: all Mansfield Red

**4. From Brooke (1976)**

All Saint's, North Street, twelfth–fifteenth centuries

All Saint's Pavement, fourteenth century

Holy Trinity, Goodramgate, twelfth century

Holy Trinity, Micklegate, thirteenth century

St Andrew, St Andrewgate, fourteenth century

St Cuthberts, Peasholme Green: Frosterley Marble, Hopton

Wood

St. Denys, Walmgate, thirteenth century

St. Edward, Tadcaster Road, Dringhouses (1847)

St. Helen's, thirteenth–fifteenth centuries

St John, Micklegate, fifteenth century

St Lawrence, Medieval Tower

St. Margaret: Walmgate (plus Caen stone?)

St. Martin cum Gregory, Micklegate, twelfth–fourteenth centuries

St Mary's Abbey (1089), part

**5. From Arkell (1977)**

Martyr's Memorial: Mansfield Woodhouse

Balliol College, University Museum, Christ Church

Meadow buildings: Red Mansfield courses

**6. From Robinson (1985)**

Shafts Law Courts, the Strand: Mansfield Red

Trafalgar Buildings: Red Mansfield columns

**7. Others**

Newstead Abbey

Welbeck Abbey

Roche Abbey

Mansfield Town Hall

Newark Town Hall

Annesley Hall

Thoresby Hall: Steetley