Mineral Resources
Consultative Committee

Mineral Dossier No 17

Sandstone

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Preface

The Mineral Resources Consultative Committee consisted of representatives of interested Government Departments, and specialist advisers. It was set up in 1967 to keep present and future requirements for minerals under review and to identify problems associated with the availability, exploitation and use of mineral resources, both inland and offshore, having regard to competing demands on land use and other relevant factors.

Widespread and increasing interest in the mineral resources of the United Kingdom led the Committee to undertake the collation of the factual information available about those minerals (other than fossil fuels) which were being worked or which might be worked in this country. The Committee produced a series of dossiers, each of which was circulated in draft to the relevant sectors of the minerals industry. They bring together in a convenient form, in respect of each of the minerals, data which had previously been scattered and not always readily available. These dossiers are now being published for general information.

Acknowledgements

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Metric units are employed throughout this document except where otherwise stated. In most cases this has necessitated the conversion of originally non-metric data. The units and conversion factors used are as follows:

millimetres	(mm)	=	inches x 25.4
metres	(m)	=	feet x 0.3048
kilometres	(km)	=	miles x 1.609344r
hectares	(ha)	=	acres x 0.404686
kilogrammes	(kg)	=	pounds x 0.45359237
tonnes (1000 kg)		=	long tons x 1.01605

Contents

Summary

Sandstones are consolidated sandy sedimentary rocks the grain size of which falls within defined limits. Generally they are composed largely of detrital quartz.

Such rocks are widespread in the United Kingdom although their exploitation is largely confined to the central Pennines, Warwickshire, Northern Ireland, parts of Wales, north Devon and southern Scotland.

Traditionally, sandstone was used for building stone and pavements but this outlet has declined over the last fifty years and the material is now used overwhelmingly as crushed stone aggregate. Minor amounts are used in the important industries producing refractories, foundry sand etc. These 'special sands', together with other sources of silica are noted here in passing but will be described in detail in another dossier entitled *Silica.* In general, road surfacing material and good concrete aggregate is produced from pre-Devonian sandstone throughout the country and from pre-Permian sandstone in south-west England and South Wales. The Carboniferous sandstones in northern England in general produce material which meets less demanding aggregate specifications.

In 1973 estimated consumption of crushed rock natural aggregates in Great Britain (limestone, igneous rock and sandstone) was 126M tonnes of which 14M tonnes was contributed by sandstone. Although sandstone is of secondary importance nationally as a source of aggregate, it becomes important in areas where other materials are not readily available or where those varieties with outstanding skid-resistance are exploited for road surfacing.

Sandstone is mainly produced in medium sized quarries few of which exceed 1M tonnes per annum. The growth of the industry in recent years has led to environmental problems which are common to most aggregate producers. These include landscape intrusion, air and ground vibration caused by blasting, noise and dust from processing plant and difficulties in accommodating large volumes of mineral traffic on minor roads.

Definition and properties

Sandstone is a consolidated sedimentary rock consisting mainly of 'sand' grains composed largely of quartz, feldspar or rock fragments. There are several different schemes for size classification of particles and a comprehensive, universally accepted system for all purposes has yet to emerge. However, the grain size of sandstones is generally in the range 2 mm to 0.0625 mm. Finer grained rocks are either siltstone or mudstone, and coarser rocks are conglomerates. In some classifications the term gritstone is introduced to describe a rock with grain sizes between 1 mm and ½ mm; however, this term has been applied to a variety of rocks (for example to those with angular grains) and has no widely recognized single meaning. The spaces or pores may be partly or completely filled by a cement. The interstitial material usually consists of silica, calcium carbonate, clay minerals or oxides of iron, the last generally being the cause of the red, brown or orange colouring which is frequently observed in an otherwise white or grey coloured material.

Sandstones are classified geologically on the basis of their quartz and feldspar content and on the ratio of detrital grains to interstitial matrix. In a commonly used classification (Pettijohn) sandstones are grouped into four major classes; greywackes, lithic sandstones, arkosic sandstones and orthoquartzites (Table 1).

Table 1. Classification of sandstones

<table>
<tr><td colspan="2"></td><td colspan="4">Cement or Matrix</td></tr>
<tr><td colspan="2"></td><td>Detrital matrix over 15%. Chemical cement absent</td><td colspan="3">Detrital matrix under 15%. Voids empty or filled with chemical cement.</td></tr>
<tr><td rowspan="4">Sand or detrital fraction</td><td rowspan="2">Feldspar exceeds rock fragments</td><td rowspan="2">Feldspathic Greywacke</td><td colspan="2">Arkosic sandstones</td><td rowspan="4">Ortho quartzites</td></tr>
<tr><td>Arkose</td><td>Subarkose or feldspathic sandstones</td></tr>
<tr><td rowspan="2">Rock fragments exceed feldspar</td><td rowspan="2">Lithic Greywacke</td><td colspan="2">Lithic sandstones</td></tr>
<tr><td>Subgreywacke</td><td>Protoquarzites</td></tr>
<tr><td></td><td>Quartz content</td><td>Variable usually <75%</td><td><75%</td><td>>75% <95%</td><td>>95%</td></tr>
</table>

Greywacke

The term *greywacke* was first applied to rocks in the Hartz Mountains of Germany. Greywackes have been defined as sandstones in which a high proportion (over 15 per cent) of the matrix consists of detrital material, normally clay, and in which there is no chemical cement. They are divided into feldspathic and lithic subgroups dependent on the proportions of feldspar and other rock fragments, although there is disagreement on the boundaries between greywackes and the other rocks into which they grade. Greywackes are normally characterised by 25 per cent or more of sand-sized grains of a varied assemblage of unstable materials, including feldspar and rock fragments, together with 15 per cent or more of an interstitial matrix taking the place of the cement which is characteristic of other sandstones.

Orthoquartzite

Sandstones in which at least 95 per cent of the grains consist of quartz are normally classified as orthoquartzites. The cement usually consists of silica as a secondary overgrowth, or silica together with carbonate. The volume of secondary silica may vary from the minimum necessary for grain adhesion to a complete infilling of the voids.

Orthoquartzites are usually clean white sandstones often characterised by the excellence of the sorting and rounding of the detrital quartz.

Lithic sandstone

Lithic sandstones are those in which there are more rock fragments than grains of feldspar. If the detrital quartz content falls below 75 per cent, the rock is described as a subgreywacke, and if the quartz content lies between 75 and 95 per cent it is a protoquarzite.

Subgreywackes are the most common type of sandstone. A substantial proportion of the grains are not quartz and they usually contain more voids or mineral cement than detrital matrix. Subgreywackes are notably better sorted than greywackes, and tend in consequence to have higher porosity.

Arkosic sandstone

Arkosic sandstones consist predominantly of quartz and feldspar. A true arkose should contain at least 12.5 per cent feldspar and up to 75 per cent quartz. If the quartz content is 75 to 95 per cent and feldspar is the next most important phase, the rock is described as subarkose or feldspathic sandstone.

Arkoses are typically coarse, and are generally pink or light grey, sometimes resembling granite, being quite unlike the dark grey of greywackes. Porosity may be high due to good sorting or incomplete cementation, and although bedding is commonly obscure, arkoses usually show some stratification and may be coarsely cross-bedded.

Tuffs and tuffaceous sandstone

Rocks comprising material of the appropriate size range which has been ejected aerially from a volcanic vent, and has subsequently been deposited in water, are defined in some classifications as a special type of sandstone.

Rocks composed of volcanic ejecta are usually classified into agglomerates or breccias if the particle size is greater than 32 mm diameter, lapillic tuff if the particles are from 4 mm to 32 mm diameter, tuff if the particles are from 0.25 mm to 4 mm and fine tuff if the particles are smaller than 0.25 mm.

The fragments comprising a tuff may consist of either glass, crystal fragments or rock particles. Mixtures with non-volcanic arenaceous material produce hybrid rocks which, if the other material predominates, are termed tuffaceous sandstones.

Other varieties

Sandstones are sometimes cemented by important secondary minerals which give rise to such types as calcareous, ferruginous, or occasionally cupriferous sandstone with calcite, hematite or copper minerals as the cement. Calcareous sandstones are fairly common and with increasing calcite content grade into sandy limestones. Ferruginous sandstones are brown or green in colour depending on the state of oxidation but the iron content is seldom high. Cupriferous or other sandstones cemented by less common minerals are rare.

Commercial terms

There are differences between geological descriptions of sandstones which are based on detailed petrography and the more generalised trade terms, which are based on properties, end use or, often, tradition. Quarries supplying material to British Standard specifications are required to describe their product in terms of the groups given in BS 812: 1975 (Granite, Basalt, Gabbro, Porphyry, Quartzite, Flint, Schist, Hornfels, Gritstone and Limestone). Sandstones, as defined geologically, are included within both the Gritstone and Quartzite groups:

Gritstone group	*Quartzite group*
Agglomerate	Ganister
Arkose	Quartzitic sandstone
Breccia	Recrystallised quartzite
Conglomerate	
Greywacke	
Grit	
Sandstone	
Tuff	

Some rocks are misnamed in the trade - eg 'Ingleton Granite' is a greywacke, as frequently is 'Welsh Granite', and 'Nuneaton Granite' is usually a quartzite with varying amounts of igneous material. The term 'whinstone', generally used for dark compact igneous rock, may on occasion be used to describe greywackes. This may give rise to errors in official statistical returns. Furthermore, quarries working quartzites with minor igneous intrusions may return their whole output as quartzite, and quarries supplying sandstone for fill may also sell associated shales and other inferior material, all of which may be returned as sandstone.

The rocks described within this dossier mostly fall within the composition limits defined in Table 1. However, the definitions are not rigidly adhered to and other arenaceous rocks are not necessarily excluded because they do not fall within precise size limits. Thus some of the deposits referred to here may produce material more correctly described as siltstone or conglomerate.

There is an important industry centred in the Midlands which extracts pebbles from poorly consolidated Bunter conglomerates for sale as gravel. As these are now usually regarded as part of the sand and gravel, rather than the sandstone, industry, they are covered by Mineral Dossier No. 4 *Sand and Gravel as Aggregate.*

Sandstones of economic importance for refractory purposes because of their high silica content are known as silica stone or ganister. Rocks in these categories are usually within, or close to, the quartzite composition range. The term ganister, originally used to describe fine grained siliceous seatearths occurring in the Lower Coal Measures near Sheffield, is now used to cover similar material occurring elsewhere in the Carboniferous. However, the term is also used commercially to describe siliceous fireclays containing as little as 85 per cent SiO_2. The term ganister is also widely applied to synthetic mixtures of clay and silica used for refractory purposes.

Engineering properties

The mechanical properties of sandstones, in common with other materials, are important for many of their end uses. Probably the most important property is shear strength, or resistance to crushing. Where the rock is used in block form, as in building or paving stone, strength is determined by testing single small blocks to the point of failure, but the strength of coarse aggregates is tested by subjecting a closely sized sample to known crushing forces in a standard container for a fixed time. The result, the Aggregate Crushing Value (ACV), is expressed as the percentage of material which has been reduced to below a given size. Alternatively a series of such tests can be performed under varying loads and the results extrapolated to determine the load under which ten per cent of the weight of the sample is reduced to below a standard particle size. This quantity is known as the '10 per cent fines' value and is measured in tons. The test, which was introduced because ACV measurements tend to be unreliable in weak rocks, is more time-consuming but can be applied universally with confidence.

In another test, otherwise similar to the ACV test, a shock load is applied, to determine the resistance of aggregates to impact, giving the Aggregate Impact Value (AIV).

The Polished Stone Value (PSV) is of importance in assessing the resistance of aggregates to polishing and hence their suitability for use as road surfacing material. To obtain this value a standard surface, made up of aggregate, is exposed to the wear of a rubber-tyred wheel in the presence of loose abrasive. After a given time the frictional resistance of the aggregate surface is measured and the results expressed by the coefficient of friction, as a percentage.

Resistance of aggregates to surface abrasion is measured by submitting a standard sample to an abrading wheel for a fixed time. The percentage loss in weight resulting from this test is then the Aggregate Abrasion Value (AAV).

Other physical properties of stone of practical importance include the water absorption and porosity, which are useful in assessing resistance to damage from frost and the effect of crystallisation of soluble salts.

These practical tests, described in BS 812: 1975 are designed to assess the suitability of a material for a particular end use. ACV and 10 per cent fines values measure the shear strength of the material in a way which should exclude many of the anisotropic effects of structural weaknesses such as bedding planes or joints, but there may be other weaknesses from incipient fractures caused by the crushing process which produced the aggregate. The AIV measures a combination of impact resistance and shear strength and for many materials is numerically similar to the ACV, which depends largely on the strength of bonding between the constituent particles of a rock and is consequently related to the shear strength. However in glassy or other highly stressed materials, which shatter on impact, a relatively low AIV can be expected.

Resistance to polishing depends on mineralogical factors and on the ease with which particles are abraded from the surface. In consequence, a high PSV tends to be associated with low abrasion resistance and therefore with low strength. There is difficulty therefore, in finding rocks which combine the high strength and high PSV necessary for road surfacing.

Many of these properties are dependent on each other and recently a statistical relationship has been derived between each property and the apparent saturated moisture content of the rock. The saturated moisture content (i_s) is defined as the ratio of the weight of water in the voids of a rock (W_w) to the weight of the dry rock (W_s). The parameter (W_s) is determined after oven drying for 12 hours at 105°C and (W_w) is determined after a 12-hour soaking or until the soaked sample reaches a constant weight. The value of i_s, usually expressed as a percentage, is thus dependent on the porosity which in turn tends to have an inverse relationship to the strength of the rock, since a high void content usually implies poor bonding and therefore low rock strength. The relationships are given below:

$$\text{Ten per cent fines value} = 4.18 - 3.55\,(\log_{10} i_s)\ (\pm 1.4)$$

$$\text{ACV} = 2.93\, i_s + 12.61\ (\pm 8.2)$$

$$\text{AIV} = 5.32\, i_s + 15.72\ (\pm 10)$$

$$\text{AAV} = 11.69\, i_s - 1.18\ (\pm 12.5)$$

Uses

The main uses of sandstone have always been in the construction industry; traditionally, sandstones have been used as a building stone quite extensively, but in recent years this outlet has been completely eclipsed by the growth in the aggregate industry. In addition, there is a small industry which exploits sandstone as a source of silica, usually for use as refractories.

The main uses of sandstone extracted in Great Britain in 1973 are shown quantitatively in Table 2, where they are compared with the total output of hard rocks used for similar purposes.

Table 2. Uses of sandstone and other hard rock in the construction industry in Great Britain – 1973

Thousand tonnes

Use	*Sandstone*	*Total (a)*	*Sandstone as % of total*
Building stone (incl monumental)	98	714	13.7
Broken or crushed stone:			
for Coated roadstone	888	20,308	4.3
Uncoated roadstone	4,448	54,245	8.2
Railway ballast	416	4,353	9.6
Concrete aggregate	1,639	21,403	7.7
Other constructional purposes	6,255	26,129	23.9
Total	13,646	126,438	10.8
Grand total	13,744	127,152	10.8

(a) Total sandstone, limestone and igneous rock used for constructional purposes.

Source: IGS from data provided by the Business Statistics Office

Aggregates

Coarse aggregate used in highway construction is called *roadstone.* The structure of a typical flexible main road is shown in Fig. 1. The sub-base consists of unbound or lightly bound aggregate, which distributes the load onto the subsoil (the sub-grade) so as to raise the bearing capacity above a minimum level. The roadbase is the main load-bearing layer of the foundation; the basecourse forms the main element in the surfacing, which is overlain by a thin wearing course to provide the texture of the road surface. Specifications for materials used in road making are given in 'Specifications for Road and Bridge-Works' published by the Department of the Environment and in British Standards and some County highway authorities specifications.

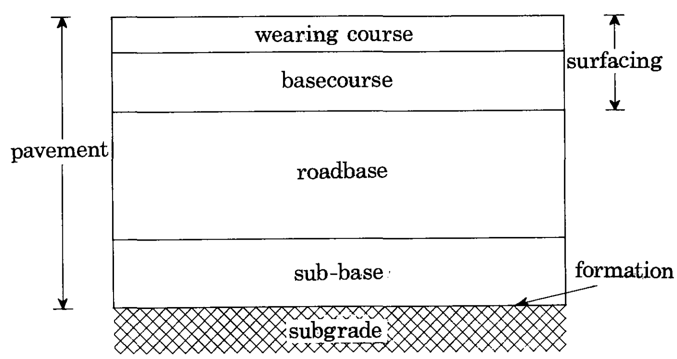

Fig 1 Cross-section of a typical highway

For most major highways, 'Type 1 Granular Sub-base Material' is specified, which allows for the use of crushed rock with a size range mainly between 39 and 0.60 mm. Material finer than 0.42 mm is required to be non-plastic, and aggregate to be used within 0.5 m of the road surface must be frost resistant, a requirement which excludes the more porous sandstones.

In 'Dense Bitumen Macadam,' which is commonly used as roadbase material in major highways, the coarse aggregate can include rock in the quartzite and gritstone groups. Although the required properties are not defined rigorously by the British Standards, strength and frost resistance are important. 'Wet Mix' and 'Dry Bound Macadams', both uncoated materials similar to, although somewhat finer than Type 1 Sub-base, are also used for the roadbase.

The basecourse is usually made from Rolled Asphalt or Dense Bitumen Macadam on major roads and open textured bitumen macadam on lightly used roads. The specifications for the aggregate are similar to those used for coated roadbase materials, except that for Dense Bitumen Macadam the size distribution of the coarse aggregate is specified as a function of the compacted thickness of the basecourse.

The wearing course provides a regular-shaped riding surface which will withstand the direct tractive forces and loads from traffic, protect the underlying layers from the elements and provide a durable skid-resistant surface. It can be made from a variety of bituminous materials, but for major highways rolled asphalt containing a maximum of 30 per cent coarse aggregate, with coated chippings rolled into the surface, is most frequently used. The chippings are specified rigorously in terms of resistance to impact and polishing as follows:

Surface aggregate requirements

	AAV	PSV
Difficult sites 1	10 max	62 min
Average sites 2	12 max	59 min

1. Difficult sites include roundabouts and their approaches, steep hills, sharp bends and approaches to traffic lights in unrestricted areas.
2. Average sites include motorways, trunk and class I roads, and other roads carrying over 2,000 vehicles per day.

Where heavy traffice is involved there is a further recommendation that for all surface dressings the minimum PSV should be 60 and the maximum AAV should be 10. This refers specifically to individual lanes on motorways and other high speed roads which carry over 1,000 commercial vehicles per lane per day.

Concrete is usually made from a mixture of cement and aggregate in the approximate ratio 1:5. Fine and coarse aggregates are used either separately or as a combined 'all-in' aggregate.

Concrete aggregate should be hard (the lower strength limit is generally specified), durable and clean, and should not contain any deleterious material which might adversely affect the strength of the concrete or its durability, or resistance to frost and corrosion. 'Deleterious material' includes clay, particularly as an adherent coating, flaky and elongated particles, mica, shale and other laminated materials, coal and other organic impurities, iron pyrites and soluble sulphates (BS 882: 1965). The shrinkage of the aggregate must not be excessive as it dries out in concrete, the aggregate must not be susceptible to frost damage and it must not be subject to attack by the alkaline cement environment.

Aggregates for use in particular types of concrete may be subject to additional requirements. For example, in structural concrete used in road-works, which is expected to reach a strength of 40 MN/m^2 (6,000 lb/in^2) after 28 days, the '10 per cent fines' value of the coarse aggregate should be at least 10 tons and the flakiness index should not exceed 35 (that is, not more than 35 per cent by weight of the pebbles may have a least thickness less than 60 per cent of the mean thickness).

In general, the relationship between the strength of the concrete and the properties of the aggregate used is complex. The strength of the bonding between the aggregate particles is clearly critical, as the crushing strength of concrete is usually less than half that of coarse aggregate, and it is generally necessary to increase the cement content, rather than use higher strength aggregate, to make high-strength concrete. The angularity and grading of the aggregate contributes to the strength in that well-graded (that is with a variety of pebble sizes) crushed rock tends to possess better bonding and interlocking characteristics than is obtained from rounded and uniformly sized pebbles.

Traditionally high-strength material such as basalt or granite has been preferred for railway ballast, although some high strength quartzite from Nuneaton is used. Material specification and test methods are currently being investigated by British Rail and it is expected that this work will show a requirement for aggregates with high resistance to impact and attrition sufficient to absorb the hammering effect of rail traffic without degradation of the ballast.

Large quantities of sandstone are used in the north of England as rough fill in the construction industry and in rough blocks for facing and protection from waves in reservoirs and harbour works. The specifications vary but are seldom very demanding, so that the relatively low strength local Carboniferous sandstones find a ready outlet. The crushing and screening of aggregates invariably involves the production of a fraction which is too fine grained for coarse aggregate or roadstone specification. This material is occasionally used as concreting or building sand but more often is sold as fill or goes to waste.

Building stone

Most of the sandstones now being worked have been used as building stone in the past. Within a single quarry separate beds may be utilised for different purposes. The harder material has often been used for setts and kerbstones, which according to BS 706: 1936 must have a minimum strength of 110 MN/m^2 (15,500, lb/in^2) while other beds may be worked for building stone, monumental stone, crazy paving etc. Inferior stone, which frequently forms an overburden, may be sold for fill.

In general, stone with relatively low compressive strengths can be used for building, a more important property being the resistance to shattering by the action of frost and crystallisation of soluble salts. Resistance to this type of damage depends largely on the size and extent of voids in the stone, usually expressed as the ratio of porosity to water absorption. Stone with low porosity or with large pores which allow absorbed water to drain out quickly tends to have good lasting properties, whereas a stone with a large number of fine pores will be susceptible to damage.

Ganister and silica stone

In the manufacture of silica refractories, crystalline quartz is slow to convert to tridymite, whilst amorphous silica, such as flint, converts too rapidly, resulting in poor dimensional stability. The ideal raw material is, therefore, one composed of small grains of quartz set in a matrix of amorphous silica such as is found in ganister. However changes in steel making have led to a substantial decline in the use of siliceous refractories. Processing techniques have been developed which allow high grade silica to be produced from impure sandstones and in the manufacture of refractories, mixtures of amorphous and crystalline silica which give controlled reactions can be used to replace ganister.

Specifications

There are many British Standards covering the various uses of sandstone, including the following:

B.S. 706:1936	'Sandstone kerbs, channels, quadrants and setts'
B.S. 812:1975	'Methods for sampling and testing of mineral aggregates, sands and fillers'
B.S. 1240:1956	'Natural stone lintels'
B.S. 1438:1971	'Media for biological percolating filters'
B.S. 3798:1964	'Coping units (of clayware, unreinforced cast concrete, unreinforced cast stone, natural stone and slate)'
B.S. 4374:1968	'Specifications for sills (of clayware, cast concrete, cast stone, slate and natural stone)'

British Standard Specifications for bituminous, asphalt and concrete mixes cover aggregates:

B.S. 882,1201: Part 2: 1973	'Aggregates from natural sources for concrete (including granolithic)'
B.S. 63:Part 2: 1971	'Single sized roadstone and chippings'
B.S. 594:1973	'Specification for rolled asphalt (hot process) for roads and other paved areas'
B.S. 4987:1973	'Specification for coated macadam for roads and other paved areas'

The British Standards Institution has also drafted a code of practice entitled 'Cladding of natural stone and precast concrete - non-load bearing'. Other widely used specifications are:

> Department of Environment Technical Memorandum No. T2/67, 'Polished stone value of aggregate for bituminous wearing courses and surface dressing'.
>
> Department of Environment: Specification for Road and Bridge Works, 1969 Edition.Relevant clauses are 2602, 2624 and those clauses in Series 800 and 900 specifying sub-base and roadbase, and flexible surfacings respectively.

In addition, many local authorities (which are important consumers) have their own specifications for roadstones.

Production statistics

Since 1895, when official production statistics were first collected, nearly 385 million tonnes of sandstone have been extracted in the United Kingdom. Annual output remained below 5 million tonnes for most years before the early 1960's, but subsequently has increased sharply, reaching a peak of 16.8 million tonnes in 1973. Nearly 122 million tonnes have been produced since 1965, approximately 32 per cent of total recorded output, reflecting the increasing demand for sandstone for use as aggregate. Production since 1895 is shown in Table 3 and Fig 2. The old county distribution of production between 1967 and 1972 is shown in Table 4, Lancashire and Yorkshire together having supplied about 50 per cent of total United Kingdom sandstone production in most years. This corresponds with the outputs recorded in the new counties of Lancashire, Greater Manchester and North, West and South Yorkshire (see Table 5). Other major producing counties are Warwickshire and Devon. In many cases county outputs are grouped together in order to preserve confidentiality.

It is estimated that since 1955 sandstone has provided between 8 and 14 per cent of all crushed rock aggregates consumed in Great Britain. End-use statistics have been collected only since 1973 when the first detailed Annual Minerals Inquiry was conducted by the Business Statistics Office. Results for 1973 are shown in full detail in Table 6, and in summary in Table 2. In 1973, 38.8 per cent of the sandstone produced in Great Britain was for use as roadstone aggregate, 11.9 per cent as concrete aggregate, 3 per cent as railway ballast, and 45.5 per cent for other purposes believed to consist chiefly of material for fill and similar constructional use but also for filter media, drainage stone etc; less than 1 per cent of sandstone produced was for building or dimension stone.

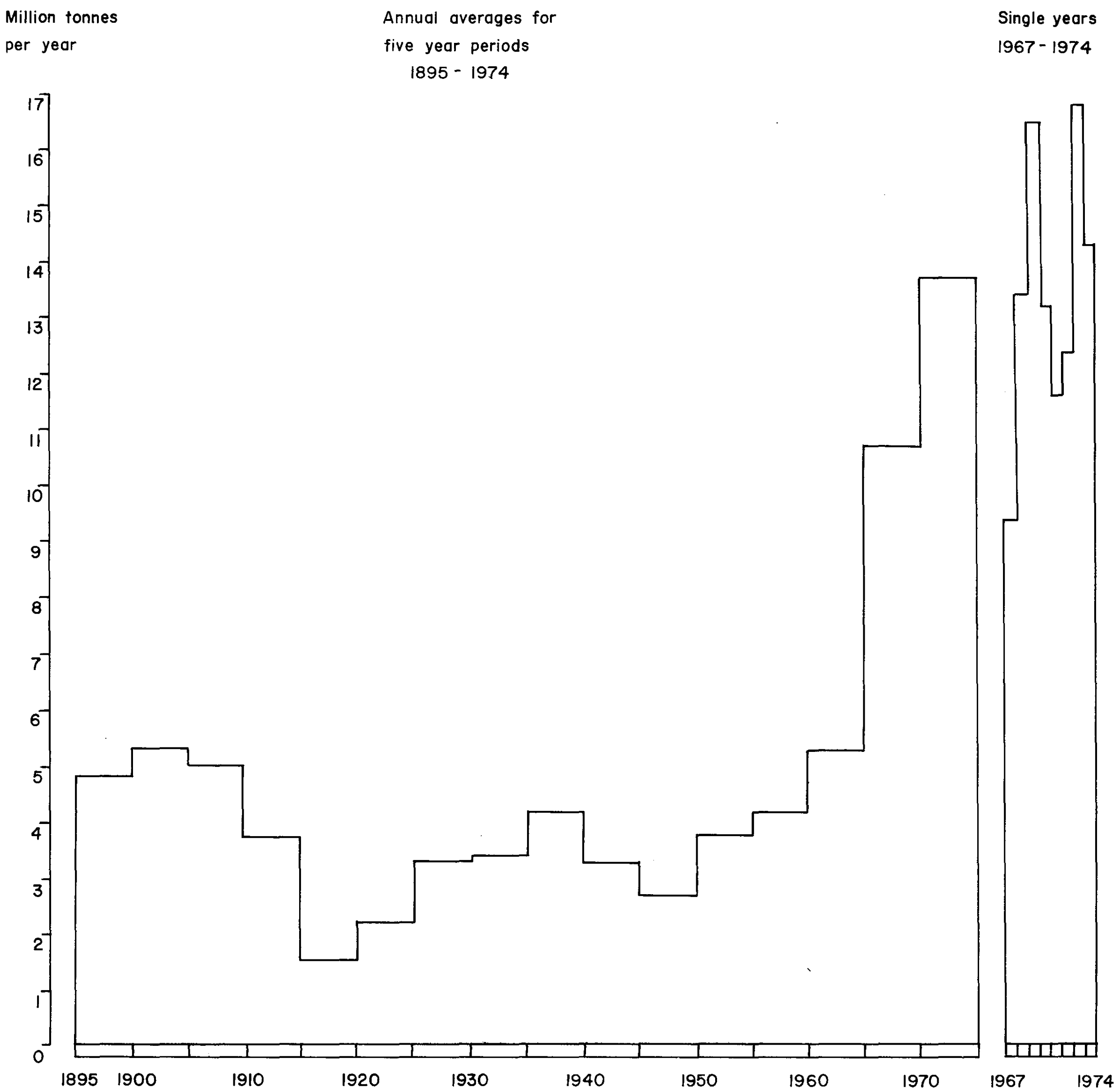

Fig 2 United Kingdom production of sandstone, 1895-1974

Table 3. United Kingdom production of sandstone 1895-1974 (a)

Million tonnes

	Total production			*Annual average*
5 year periods	*Great Britain*	*Northern Ireland*	*United Kingdom*	*United Kingdom*
1895-1899	24.1	0.0	24.1	4.8
1900-1904	26.2	0.1	26.3	5.3
1905-1909	24.8	0.1	24.9	5.0
1910-1914	18.4	0.0	18.4	3.7
1915-1919	7.2	0.1	7.3	1.5
1920-1924	10.8	0.3	11.1	2.2
1925-1929	15.5	0.8	16.3	3.3
1930-1934	15.9	1.0	16.9	3.4
1935-1939	20.0	1.1	21.1	4.2
1940-1944	14.9	1.4	16.3	3.3
1945-1949	11.9	1.6	13.5	2.7
1950-1954	16.4	2.8	19.2	3.8
1955-1959	17.8	3.3	21.1	4.2
1960-1964	21.6	4.7	26.3	5.3
1965-1969	46.1	7.5	53.6	10.7
1970-1974	55.7	12.6	68.3	13.7

(a) Data for the periods 1895-1902 and 1950-1966 have been adjusted to exclude small quantities of silica stone and ganister.

Table 4 United Kingdom : Production of sandstone by countries and old counties 1967-1972

Thousand tonnes

County and Country	*1967*	*1968*	*1969*	*1970*	*1971*	*1972*
Westmorland	-	-			-	-
Cumberland	144	110	1,292	940		27
Northumberland					497	472
Durham	16	47	198	1,205		
Yorkshire	885	927	1,218		2,024	1,679
Lancashire	1,911	4,928	6,416	4,021	2,053	3,096
Cheshire	395	1,468	1,273	585	333	271
Derbyshire	107	122	85	112	142	108
Nottinghamshire						
Warwickshire *(a)*	1,171	1,213			1,643	1,430
Northamptonshire, Norfolk	59	5	1,456	1,513		
Bedfordshire	-		-	-	-	-
Shropshire	125	31	100		161	220
Staffordshire	26			184		
Worcestershire	-	-	-			
Wiltshire	-	251				
Gloucestershire, Somerset *(b)*	261		224	200	170	194
Surrey, Sussex	246	214	144	175	239	167
Devon	872	979	862	880	987	705
Cornwall	-	-				
Total England	6,218	10,295	13,268	9,815	8,249	8,369
Wales	921	953	848	712	775	1,183
Scotland	846	358	411	559	332	372
Total Great Britain	7,985	11,606	14,527	11,086	9,356	9,924
Northern Ireland	1,464	1,752	1,950	2,149	2,230	2,466
United Kingdom	9,449	13,358	16,477	13,235	11,586	12,390

(a) Including production in Lincoln in 1970.

(b) Including production in Hampshire in 1967.

Source: UK Mineral Statistics, IGS

Table 5 Great Britain: Production of sandstone by new counties, 1973-1974

Thousand tonnes

New county	1973	1974 *(p)*
Cumbria, Durham Northumberland, Tyne and Wear,	489	379
North Yorkshire	1,959	2,456
West Yorkshire and South Yorkshire	2,157	
Derbyshire, Nottinghamshire, Northamptonshire	202	162
Cheshire, Merseyside	1,357	745
Greater Manchester	783	1,580
Lancashire	1,511	1,993
Cambridgeshire	-	451
Norfolk, Surrey West Sussex	327	
East Sussex	-	
Avon, Gloucestershire, Somerset	207	124
Cornwall		64
Devon	735	600
Salop, Staffordshire, Warwickshire, West Midlands	1,486	1,580
Total England:	11,214	10,134
Dyfed	503	199
Clwyd	337	-
Gwynedd		702
Mid and West Glamorgan Gwent	662	
Powys	174	
Total Wales:	1,676	901
Orkney	193	147
Caithness		98
Kincardine, Banff, Moray, Aberdeen, Fife, Dumfries, Ayr, Lanark; Roxburgh, Dunbarton, Stirling, Ross and Cromarty	313	345
Total Scotland:	506	590
Total Great Britain:	13,396	11,625
Northern Ireland:	3,066	2,676
United Kingdom:	16,462	14,301

(p) Provisional

Sources: Business Statistics Office
Ministry of Commerce (Northern Ireland)

Table 6 Production of sandstone in Great Britain by end-use and new counties 1973

Tonnes

County	*Building stone*	*Coated roadstone*	*Uncoated roadstone*	*Railway ballast*	*Concrete aggregate*	*Other purposes*	*Total*
Cumbria, Durham Northumberland, Tyne & Wear	10,414	-	469,305	-	83	9,581	489,383
Derbyshire, Northants, Notts	13,644	-	98,595	-	41,263	48,432	201,934
Norfolk, Surrey, West Sussex	3,303	-	138,196	-	-	185,176	326,675
Devon	6,164	108,208	257,024	-	115,393	248,229	735,018
Avon, Gloucs, Somerset, Cornwall	6,422	57,502	86,389	-	26,483	30,209	207,005
West Midlands, Warwicks, Staffs, Salop	1,258	43,444	389,676	356,235	39,704	655,988	1,486,305
Merseyside, Cheshire	5,167	50,800	86,682	-	-	1,214,905	1,357,554
Lancashire	1,540	-	1,001,792	-	190,530	317,130	1,510,992
Greater Manchester	-	-	435,050	-	50,750	297,149	782,949
North Yorkshire	75	163,787	373,308	864	216,894	1,204,249	1,959,177
West Yorkshire, South Yorkshire	33,485	-	267,346	51,531	281,749	1,522,429	2,156,540
TOTAL:	81,472	423,741	3,603,363	408,630	962,839	5,733,477	11,213,532
Wales							
Clwyd, Gwynedd	2,000	91,200	63,584	-	146,502	33,472	336,758
Dyfed	-	103,176	289,322	-	77,727	33,132	503,357
Mid-Glamorgan, West Glamorgan, Gwent	8,065	149,477	350,332	-	112,840	41,578	662,292
Powys	456	76,298	56,159	-	11,655	29,285	173,853
TOTAL:	10,521	420,151	759,397	-	348,724	137,467	1,676,260
Scotland							
Orkney, Caithness	506	37,188	65,958	6,980	17,219	65,666	193,517
Kincardine, Moray, Aberdeen, Fife, Dumfries, Lanark, Dunbarton, Stirling, Ross	8,112	6,699	19,751	-	36,011	242,169	312,742
TOTAL:	8,618	43,887	85,709	6,980	53,230	307,835	506,259
Great Britain Total:	98,212	887,599	4,448,469	415,610	1,639,111	6,255,018	13,744,019

Source: Business Statistics Office

Overseas trade

Sandstone is not separately identified in the Tariff and Overseas Trade Classification of the United Kingdom, and trade in sandstone (broken or crushed stone, or unworked and worked monumental and building stone) if any, is probably small. From 1970-1973 imports and exports of quartz and quartzite were recorded under three headings:

Quartz (other than natural sands), quartzite, including quartzite not further worked than roughly split, roughly squared or squared by sawing:

Quartz:	ground and powdered	code number 2506 0005
Quartz :	other	code number 2506 0165
Quartzite		code number 2506 0304

In 1974 only two headings applied:

Quartz:	ground and powdered; quartzite	code number 2506 0247
Quartz:	other	code number 2506 0368

Trade since 1970 is shown in Table 7.

Table 7 Imports and exports of quartz and quartzite 1970-1973

	1970	1971	1972	1973
Imports				
Quartzite	1,538	917	694	650
Ground and powdered quartz	4,736	5,300	3,746	4,915
Unground quartz	7,708	5,388	4,833	2,826
Total quartz and quartzite[1]	13,982	11,605	9,273	8,391
c.i.f. value	£309,927	£275,935	£210,698	£255,221
Exports				
Quartzite	26	25	46	7
Ground and powdered quartz	281	89	122	32
Unground quartz	2,264	366	91	189
Total quartz and quartzite	2,571	480	259	288
f.o.b. value	£76,884	£42,498	£14,202	£35,043

Source: HM Customs and Excise

[1] This refers essentially to high purity material for use in optics, glass making, fused silica etc; imported mainly from Belgium, Brazil, France, Portugal and Sweden.

Resources

Sandstones of a variety of geological ages occur extensively throughout the United Kingdom, particularly among rocks of pre-Mesozoic time and their area of outcrop is so extensive that it is not practicable to describe all existing resources.

Greywackes, which are present in abundance throughout the Lower Palaeozoic and Precambrian are of economic importance particularly in Wales, North Yorkshire, the Southern Uplands of Scotland and Northern Ireland.

Quartzites are of relatively limited occurrence. They are worked in the Precambrian of Anglesey and in the Lower Cambrian at Nuneaton and in the Wrekin area. Lower Ordovician quartzite is present in the Shelve area of Salop. In north-west Scotland, the basal Cambrian quartzite has an extensive outcrop and elsewhere in the Highlands there are metamorphic quartzites.

The most extensively worked sandstone resources are in the Carboniferous System; beds of thick, generally arkosic, sandstone are quarried on a large scale in the Millstone Grit and Lower Coal Measures within and adjacent to the Lancashire and Yorkshire coalfields. Further north, in the north Pennine area, the Northumberland and Durham coalfield and Scotland there are abundant sandstones in the Carboniferous although these are worked infrequently.

The Pennant series of the Upper Coal Measures of South Wales together with the Carboniferous and adjacent Devonian sandstones in north Devon are worked on a significant scale. These rocks have been subjected to a low grade metamorphism which has improved the crushing strength of the material beyond that usually possessed by Carboniferous sandstone.

Devonian sandstones also occur in Wales, the Welsh Borders, the Midland Valley of Scotland, north-east Scotland and Orkney. They are worked to an appreciable extent only in north Devon, north-east Scotland and Orkney.

Permian and Triassic sandstones, which outcrop over a wide area in the English Midlands and other parts of the country, are usually too weak to be of importance for aggregates, although they are still worked for building stone in some areas.

In the post-Triassic beds which make up most of south-east England, there are relatively few hard sandstones. Among those of economic significance, the Lower Greensand may be mentioned, together with the Hastings Beds which are worked in Sussex.

Resources of silica sand and ganister are difficult to define as changes in technology have altered raw material requirements. Originally the term ganister was applied to a refractory siliceous seatearth in the Sheffield area beneath the Ganister, Hard Mine or Halifax Hard Coal in the Lower Coal Measures. This bed, together with others in the Lower Coal Measures, extends along the strike northwards towards Bradford and southwards into Derbyshire. Elsewhere, silica stone, often called ganister, is of occasional importance, for example in the basal part of the Millstone Grit in South Wales, in the Cefn-y-fedw Sandstone on the western flank of the Flintshire Coalfield, in the Millstone Grit near Macclesfield and at several horizons in the Carboniferous of north east England and central Scotland.

The correlation between individual sandstone formations and engineering properties relevant to their use as roadstone or concrete aggregate is only possible in a generalised sense. Difficulties arise partly because the specifications for concrete coarse aggregate are neither petrologically precise nor infallible as a means of assessing the suitability of material. The main requirement is that the finished concrete should reach a certain strength and durability. The relationship between the mineralogical properties of coarse aggregate and the nature of the resulting concrete have not yet been investigated in detail sufficient for a reliable assessment to be made on geological grounds of material suitability. However, research on this subject is being carried out at the Building Research Establishment.

Similar considerations apply with roadstone, except for some surfacing materials where more rigid specifications, in terms of aggregate abrasion value and polished stone value, are used. However in this case relatively small changes in PSV and AAV lead to important differences in application, and although an estimate of these values can be made on geological grounds this is unlikely to be accurate enough to classify the material as suitable for a particular role. The PSV in particular is very sensitive to minor changes in the proportion of hard and soft minerals in a rock, so that significant changes can be encountered within an apparently homogeneous formation or even in a single quarry.

In a detailed study of the PSV and AAV properties of British arenaceous rocks, Hawkes and Hosking have shown that the degree of consolidation, which depends on age and tectonic history, tends to be more important than composition and grain size in controlling the mechanical and physical properties of a rock. They were able to demonstrate generally that sandstones which combine high PSV with adequate AAV include Precambrian unmetamorphosed arkose, subgreywacke and greywacke, together with similar pre-Permian rocks which have suffered low grade metamorphism.

This implies that sandstone suitable for highway surfacing is to be expected mainly in the Lower Palaeozoic rocks of Northern Ireland, southern Scotland, Cumbria; western North Yorkshire and Wales and in the Carboniferous and Devonian of south-west England and parts of South Wales. Experience also suggests that these formations would be broadly suitable for concrete aggregate. However, other factors modify the potential of all deposits as practical sources of material. The shape of aggregate particles, although partly a function of the crushing process, also depends on the nature and tectonic history of the rock, and the tendency to produce flaky or elongated particles is often so marked in Lower Palaeozoic greywackes that they become unuseable for many purposes. Also some Scottish greywackes exhibit high shrinkage in concrete. The consistency of the deposit is similarly a critical factor since demanding specifications are difficult to meet economically in deposits which vary unpredictably or which contain too much waste material, as is the case where thin sandstone and shale beds alternate.

The practical resolution of the various technical and economic factors involved in sandstone exploitation is demonstrated in the following description of the present sandstone industry.

The Industry

Aggregates and building stone

At present the sandstone industry consists of about 200 working quarries in the British Isles, the precise figure being subject to frequent changes as new quarries open, old quarries close, go into temporary idleness or are reopened. (Fig 3).

The distribution of workings for building stone is influenced by aesthetic and traditional factors, but with most aggregate producers the quality of material and proximity of competition from limestone, igneous rocks or gravel workings are the controlling factors. Since the cost of transport tends to dominate the economics of the aggregate market there will be considerable incentive in any area of high demand to develop such local resources as may exist. These economic factors and the distribution of sandstone outcrops have resulted in a tendency for quarries to be concentrated into well defined groups which are described briefly.

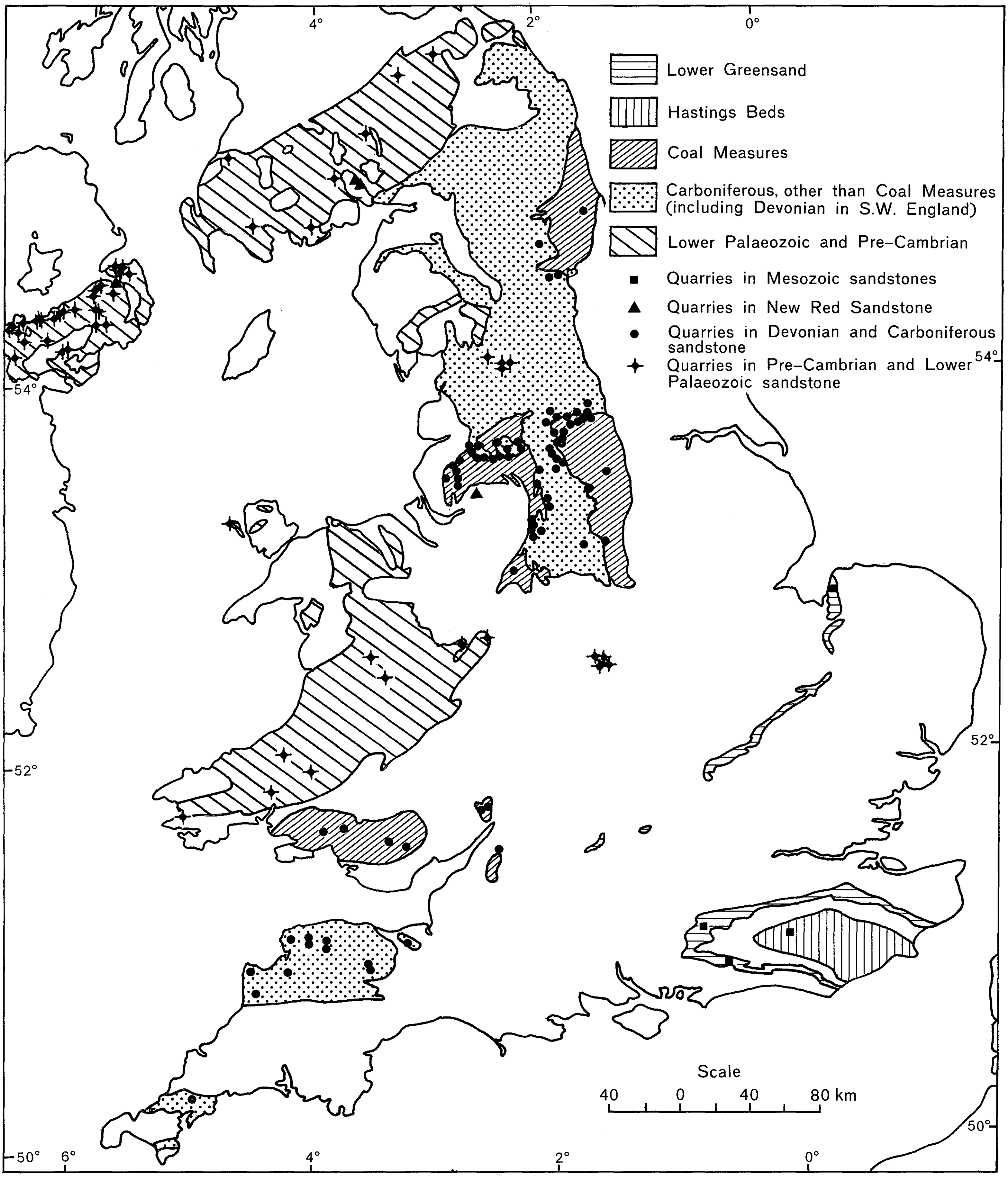

Fig 3 Location of important sandstone quarries with outline geology in relevant areas.

South-west England

Over much of Cornwall and south Devon the aggregate market is satisfied by other materials, but in north Cornwall, north Devon and adjacent parts of Somerset, where there are no alternatives, Carboniferous (Culm) and adjacent Devonian sandstones are worked in some twenty quarries, which accounted for about 5 per cent of UK production in 1973.

These sandstones tend to have good strength and polish resistance properties (Table 8) and are suitable for road surfacing, coarse aggregates for concrete and most other aggregate specifications.

Table 8 Properties of sandstone from selected quarries in south-west England

Quarry name		*Location*	*Geological Horizon*	*ACV*	*AIV*	*AAV*	*PSV*	*10% fine value (tons)*	*Strength MN/m²*
Venn	(1)	Nr Barnstaple, Devon	U Pilton Beds, Carboniferous	19	11	3.6	65	27	-
Tredinnick	(2)	Grampound, Cornwall	Grampound Grit, Devonian	-	15	7	66	-	-
Treworgans	(2)	Ladock, Cornwall	Grampound Grit, Devonian	-	10	6	64	-	-
Triscombe	(3)	Crowcombe, Somerset	Hangmans Grit, L Devonian	15	13	6	65	-	-
Bray Valley	(4)	Nr Barnstaple,	Carboniferous	12.6	5.0	-	61	-	290

Sources (1) ECC (Quarries) Ltd
(2) Hawkes and Hosking 1972
(3) Anglo-American Asphalt Co
(4) A Notts & Sons

The main centre of quarrying lies to the south of Exmoor. Most of the output is sold within a 60 km radius, although the quarries near Tiverton send some material as far as Hampshire. There are smaller sandstone quarries further to the west, particularly in the area around Bude, in Cornwall.

In the Quantock Hills, Triscombe quarry near Wellington in Somerset is currently producing roadstone which is distributed over a wide area to the east, extending as far as London.

In south-west England, Devonian and Carboniferous sandstone is characterised by considerable folding and by low-grade regional metamorphism which has improved the material's strength properties compared with unmetamorphosed sandstone of similar age. The individual sandstone beds are about one to two metres thick and are often interbedded with hard shale bands of varying thickness. Quarries tend to be located in zones where sandstone predominates over shale, shaly material being discarded with the fines fraction after crushing.

Almost all the quarries are in steeply inclined strata and beds dipping at up to 70° are frequently worked, as is intensely folded rock. The working faces are usually cut perpendicular to the strike, but in some cases, for example at Venn Quarry near Barnstaple and Holmingham Wood Quarry near Tiverton, the benches are cut parallel to the strike and are worked on the short face at the end of each bench leaving a steeply dipping bedding plane as a spectacular rear face to the quarry.

Sandstone for building in south-west England, traditionally used locally for buildings, stone walls and dimension stone, is still produced in some smaller quarries. However, the industry did not develop on a large scale and there are relatively few relics of previous quarrying activities.

North west England, Cumbria and north-west Derbyshire

In Lancashire, Cheshire, Greater Manchester, Merseyside and north-west Derbyshire there were approximately 35 working quarries in 1974 producing at least 26 per cent of the total UK output. This is the most important sandstone producing area in the country; most of the quarries, in Millstone Grit and Lower Coal Measure outcrops, are located in a relatively small strip which extends along the western slopes of the Pennines from Macclesfield through New Mills, Derbyshire, to Rochdale, then westwards along the southern limb of the Rossendale Anticline to near Chorley and finally southwards along the low hills separating the Wigan and Skelmersdale coalfields, almost to St Helens.

Almost all the quarries produce aggregates, but their strength is generally insufficient to make good road surfacing material and they tend to have a relatively high porosity, a property which gives rise to a high susceptibility to frost damage. They are not generally suitable for making normal strength concrete and consequently have limited application (Table 9).

The principal outlet is for fill in civil engineering works, as a deep sub-base in major roads below the level of frost susceptibility, as a drainage medium, and as a hardcore or foundation material under minor roads, paths or other surfaced areas where loading is light. The very high output in recent years has largely been the result of highway construction.

The market is sustained by a high demand in the Liverpool and Manchester areas. There are few conventional gravel pits in the region and crushed limestone from quarries in Derbyshire, to the north of Lancaster and near Clitheroe has for many years been the major source of good quality coarse aggregate. This is augmented by gravel from the Bunter Pebble Beds in Staffordshire, from glacial deposits in North Wales and from dredging operations in Liverpool Bay. Aggregates from these sources are relatively expensive as they must be hauled some 50-100 km to the main markets. Thus there has been an incentive to use local material where possible and over the last 15 years this has resulted in the reopening or expansion of many old quarries, which formerly produced building stone, in the Millstone Grit and Lower Coal Measures close to Manchester and Liverpool.

Building stone output in north-west England from Carboniferous sandstone is limited to a group of four producers near Bollington in Cheshire and to one remaining representative of a formerly extensive industry, which once worked the Haslingden Flags in Rossendale for paving materials. The Haslingden Flags, now extensively worked for aggregates, are unusual in that they are much stronger and more resistant to frost action than most other local sandstones. They have considerable shear strength in a direction perpendicular to the bedding.

Permo-Triassic sandstones in the industrial parts of north-west England are being worked for fill on a relatively small, but increasing, scale. The material has poor resistance to crushing and is unsuitable for any load bearing duties, but is easy to work and finds a ready outlet. Elsewhere, building stone is produced at one quarry in the St Bees Sandstone in west Cumbria and at two localities in the Penrith Sandstone, near Penrith. Sandstones from these formations are reported to have crushing strength of 34 and 48 MN/m^2 (4,900 and 7,000 psi) respectively.

Table 9 Properties of sandstone from some quarries in north-west England

Quarry name	*Location*	*Geological horizon*	*ACV*	*AIV*	*AAV*	*PSV*
Fletcher Bank	Ramsbottom	Fletcher Bank Grit Millstone Grit		48	21	69
Cox Green	Bolton	Ousel Nest Grit Lower Coal Measure		93	21	67
Little Quarry	Whittle-le-Woods	Revidge Grit Millstone Grit		>100	41	74

Source: Hawkes and Hosking 1972

The Silurian greywackes of the Lake District were worked recently at Holmscales, Cumbria, where an old quarry was reopened to supply material for motorway construction. This source contributed to the high outputs in 1969 and 1970 of the Northumberland, Cumberland and Westmorland group of counties.

Yorkshire and Humberside

Yorkshire sandstone quarries can be conveniently divided into two main groups with approximately equal outputs. In the upper Ribble Valley and Ingleton areas of North Yorkshire there are important roadstone producers which quarry material from Lower Palaeozoic or Precambrian rocks for distribution over a large area. Other workings tend to be concentrated in the Millstone Grit and Lower Coal Measures mainly in the Huddersfield, Bradford and Leeds areas. In addition, in recent years there has been some intermittent working in Bunter sandstone near Goole to provide fill for motorway construction.

In western North Yorkshire there are three major quarries near Helwith Bridge, Ribblesdale, which work Lower Palaeozoic greywacke, and one near Ingleton in Ingletonian greywacke. Typical properties of these materials are given in Table 10. Most of the rock is suitable for all types of roadstone and other aggregate uses. Aggregates from all these quarries are distributed over a wide area, reaching southward to approximately the Humber – Mersey line and northwards almost to Newcastle. Most of the material goes south into areas of high population density.

The Carboniferous sandstones of West Yorkshire are very similar in physical characteristics to sandstones of the same age in the North-West. However, because the market is smaller, and because gravel and crushed limestone are more readily available, less sandstone aggregate is usually produced than on the west side of the Pennines.

Exceptionally, as in 1973, official statistics for Yorkshire and Humberside have recorded very high outputs; however this is largely accounted for by a few quarries supplying fill for large construction projects such as reservoir dams and motorways which may not represent a significant long term change in the industry.

A feature of the Carboniferous sandstone industry in this area is the heavy emphasis on building stone production. The Natural Stone Directory lists 26 separate producers of building stone in Yorkshire (mainly in West Yorkshire), and the typical quarry in this area is essentially a building stone producer with ancillary crushing and screening facilities for aggregate production. The feed to the crushing plant usually consists of waste material from the dressing operation or rock which would make poor building stone but which must be removed to release better material.

Table 10 Properties of sandstone from quarries in western North Yorkshire

Quarry		*Location*	*Geological horizon*	*ACV*	*AIV*	*AAV*	*PSV*	*10% fines value (tons)*	*Strength MN/m^2*
Ingleton	(1)	Ingleton	Ingletonian	11	11	6.3	62	35	260
Helwith Bridge	(1)	Helwith Bridge	L. Palaeozoic	16	16	12.5	58	26	
Dry Rigg	(2)	Helwith Bridge	L. Palaeozoic	9	8	9.8	65	42	290
Arcow	(3)	Helwith Bridge	L. Palaeozoic	12	7	12	62	34	290

Sources: (1) Amey Roadstone Corporation Ltd
(2) Redland Roadstone Ltd
(3) Tarmac Roadstone Holdings Ltd

Formations currently worked for building stone include the Gaisby Rock and Elland Flags on the north side of Bradford, the Elland Flags and to a lesser extent the Rough Rock in the Halifax area, the Rough Rock in the Crosland Hill area to the south-west of Huddersfield, the Elland Flags and Grenoside Rock to the south-east of Huddersfield and the Huddersfield White Rock to the west of Holmfirth.

The Elland Flags are probably the most important of the West Yorkshire building stones, and the ease with which they can be split in a direction parallel to bedding planes renders tham particularly suitable for paving slabs. In many respects they are similar to the Haslingden Flags of Lancashire, although at a different geological horizon. Strength values for Elland Flags quoted in the 1972 Natural Stone Directory for various quarries vary from 70-100 MN/m^2. Corresponding values for Rough Rock and Gaisby Rock are between 43 and 76 MN/m^2.

Yorkshire Carboniferous sandstone, mainly in the form of facing stone but also as paving stone, monumental stone, roofing material, walling stone, crazy paving etc., known in the trade as 'York Stone', is widely used in the north of England and to a lesser extent over most of the country. Formerly the industry was much more extensive, but it has shown signs of modest expansion in recent years.

The Midlands

The most important group of sandstone quarries in the Midlands lies to the north west of Nuneaton in a narrow, steeply-dipping belt of Cambrian rocks which forms the north eastern edge of the Coventry Coalfield. The Hartshill Quartzite, the lowest member, is 275 m thick and is one of the few sources of high strength rock in central England. It is worked from several large quarries within an outcrop 3 km long by 0.4 km wide. As shown in Table 11, the material is strong enough for all types of aggregate use, although its relatively low PSV restricts its application as road surfacing material. The total output is about 1.5 million tonnes a year of which some 30-50 per cent goes for railway ballast. Small amounts are used for special purposes such as filter media or tennis court surfaces, and the remainder is used for roadstone or concrete aggregate.

Because the Nuneaton quarries occupy one of the nearest sources of hard rock to south-east England, the distribution pattern of products tends to be heavily weighted towards the south. The lower priced products, such as concrete aggregate and sub-base material, tend to be sold with 50 km of the quarries, while chippings for surfacing and other special purposes may be sold throughout southern England.

Other quartzites in the Midlands include the Lower Cambrian Lickey Quartzite, recently worked only at Rubery near Birmingham. This stone was similar to that from Nuneaton but the workings were relatively small and the material was used locally only for fill. The Wrekin quartzite, also Cambrian, is exploited at Ercall, near Wellington, mainly for local use as road sub-base and concrete aggregate.

Precambrian outcrops at Haughmond Hill and Bayston Hill to the north-east and south of Shrewsbury respectively, have both provided good sites for large quarries. At Bayston Hill a tuffaceous greywacke is worked for high quality roadstone (Table 11) which is distributed over a wide area extending northwards to Lancashire and southwards over most of the Midlands and south-east England. At Haughmond Hill a large quarry, recently in production, is now idle.

In north Staffordshire there is a small industry providing Carboniferous sandstones for local use as fill and aggregate. In the Matlock and Chesterfield area Carboniferous sandstone is worked only for building stone, the demand for coarse aggregate in this part of Derbyshire being satisfied by crushed limestone and gravel.

Table 11 Properties of sandstone from quarries in the Midlands

Quarry		*Location*	*Geological horizon*	*ACV*	*AIV*	*AAV*	*PSV*	*10% fine value (tons)*	*Crushing strength MN/m²*
(Several)	(1)	Nuneaton	Hartshill Quartzite L. Cambrian	16	21	3	55-58		
Haughmond	(2)	Shrewsbury	Precambrian	15	10	5.1	63-61	30	280
Bayston Hill	(2)	Shrewsbury	Precambrian	17	14	6.3	65-68	26	220

Sources: (1) Quarry operations in the Nuneaton area
(2) Tarmac Roadstone Holdings Ltd

South Wales, Gloucestershire and Avon

The Pennant Measures which form the central part of the South Wales coalfield, typically include thick, massive, sandstones (or subgreywackes) which when unweathered are bluish grey, but rapidly become rusty-brown on exposure.

In the Pennant of South Wales there are four large or medium size quarries; Trehir Quarry, near Cardiff, Craig-Yr-Hesg, near Pontypridd, Cwmrhydyceiw, near Swansea and Gilfach, near Neath, which produce aggregates with some of the highest PSV measurements found in the UK (Table 12).

Most of the aggregate is used in South Wales, although Gilfach and Craig-Yr-Hesg quarries supply southern England with material for road surfacing, and some material is exported by boat from Gilfach. There are a few small quarries in the eastern part of the coalfield which produce flagstone and crazy paving. Trehir and Cwmrhydyceiw quarries have produced large quantities of blockstone for harbour works but there is little production of building stone in South Wales.

Pennant sandstone is also worked in Barnhill and Bixhead quarries near Coleford in the Forest of Dean, exclusively for building stone. The strength, quoted as 46 and 56 MN/m^2 for two separate horizons, is far below that found in the South Wales quarries. Also in the Forest of Dean, Perseverence quarry near Ruspidge, in the Drybrook Sandstone, (the local equivalent of the Millstone Grit) is one of the few sandstone quarries in which the entire, but relatively small, output is crushed for building sand.

At Cromhall, near Charfield, the Drybrook Sandstone (known locally as Cromhall Sandstone) is quarried for use as roadstone. This rock, which has a high strength and resistance to polishing, is used mainly for road surfacing in Gloucestershire, Avon and Wiltshire, although London and the South Coast are also served. The processing plant is unusual in that it incorporates a washing stage to remove soft shale, being similar in this respect to those at the Nuneaton quarries. The sand fraction from the washing plant is sold as asphalting sand (Fig. 4).

Table 12 Properties of sandstone from quarries in South Wales and Bristol areas

Quarry		*Location*	*Geological horizon*	*ACV*	*AIV*	*AAV*	*PSV*	*10% fines value (tons)*	*Crushing strength MN/m^2*
Creig-Yr-Hesg	(1)	Mid Glamorgan	Pennant Grit	19	17	8	69	26	-
Cwmrhydyceiw	(1)	West Glamorgan	Pennant Grit	20	19	12	72	-	-
Gilfach	(2)	West Glamorgan	Pennant Grit	19	18	8.2	72	20.0	160
Pencaemawr	(3)	Mid Glamorgan	Pennant Grit	-	-	-	-	-	140
Barnhill	(4)	Forest of Dean	Pennant Grit	-	-	-	-	-	39
Cromhall Quartzite	(5)	Charfield, Avon	Drybrook Sandstone	19	17	9	68	-	-

Source: (1) Amey Roadstone Corporation Ltd.
(2) Wotton Roadstone Ltd
(3) Natural Stone Directory
(4) Forest of Dean Stone Firms Ltd
(5) Cromhall Quartzite Ltd

Central and North Wales

Over much of Wales Lower Palaeozoic greywackes form the only source of road surfacing material. The principal quarries are at Forge, near Carmarthen; Dinas and Alltgoch, near Lampeter; and Cerrigwynion, near Rhayader. Precambrian gritstone and conglomerates are worked at Gore quarry in Powys and the Precambrian Holyhead Quartzite is worked at South Stack Quarry, Holyhead. The Lower Palaeozoic quarries can make good quality roadstone but the presence of interbedded shaly material in highly folded strata together with a tendency to produce flaky particles can cause difficulties in controlling the quality of the product.

Table 13 Properties of sandstone from quarries in Central Wales

Quarry		*Location*	*Geological horizon*	*ACV*	*AIV*	*AAV*	*PSV*	*10% fines value (tons)*	*Crushing strength MN/m^2*
Gore	(1)	Walton, Presteign	L. Palaeozoic	16	13	6.7	62-65		
Forge	(2)	Carmarthen	L. Palaeozoic	18	18	7	62	26	285

Sources: (1) Tilling Construction Services Ltd
(2) Amey Roadstone Corporation Ltd.

The quartzite worked at Holyhead is now little used as a refractory, and aggregate from this source has mainly been sold for construction work in Anglesey.

Most of the quarries in Central and North Wales are in rural areas, remote from the main aggregate markets, and therefore satisfy only local demand. However before its recent closure Craig Lelo Quarry sent significant quantities of roadstone into north east Wales and adjacent parts of north-west England; Gore Quarry sends material to the West Midlands.

North-east England

Aggregates in north-east England are obtained mainly from limestone or igneous rocks, and sandstone is exploited primarily as building stone.

The largest quarry in the region is located in Carboniferous sandstone near Gateshead where aggregate is produced as a by-product from inferior rock overlying a bed of high quality building stone. The aggregate, which has an ACV of 28-32, is sold within a 30 km radius of the quarry, mainly in the Newcastle and Gateshead area. Like aggregate from other Carboniferous sandstones in northern England, it is relatively weak and susceptible to frost damage.

Carboniferous sandstones are also exploited for building stone in quarries at Stainton and Staindrop near Barnard Castle, at Blaxters quarry near Elsdon, Quickburn near Tow Law, and intermittently at Doddington, near Berwick.

In the area around Hexham in the valley of the North Tyne and north-east of Carlisle the Forestry Commission owns large areas of woodland which are serviced by rough tracks built on crushed sandstone. Sandstone for this purpose is normally taken from small temporary quarries by the Forestry Commission.

South-east England and East Anglia

In this region gravel is the main source of coarse aggregate and almost all other material needed, mainly for road construction, is imported from other regions. Sandstone occurs only in the Upper and Lower Greensand and Hastings Beds. It is usually porous with low crushing strength, and is used on a limited scale for ornamental and building purposes. The only large sandstone quarry is at Bognor Common, Fittleworth, Sussex, where the Lower Greensand is worked mainly as fill or aggregate for road sub-base, with minor amounts for building and walling.

Other small scale workings in the Lower Greensand are at Snettisham near King's Lynn, Norfolk, where the Carstone is exploited, and at Churt, Surrey, where the Bargate Stone is worked. In both these quarries overburden and inferior stone are sold for fill or hardcore and better quality material for building or walling stone. There is a small building stone industry using the Hastings Beds of the Wealden Series at West Hoathly, Sussex.

Scotland

Most of the demand for aggregates in Scotland is met by igneous rock and gravel. However in the Southern Uplands there are several quarries in greywackes of good strength and polish-resisting characteristics which supply roadstone over a wide area. These rocks are sometimes described as whinstone which may account for the relatively low output of sandstone recorded in official statistics in this part of the country.

The larger producers include Morrinton Quarry near Dumfries, Coatsgate Quarry near Moffat and Barbae Quarry near Girvan, which together supply a wide area between Penrith and Glasgow. There are smaller greywacke quarries operated by local highway authorities at Fountainhall, Peebles; Tongland near Kirkudbright and Kirkcowan near Wigtown.

Building stone is produced from Permian sandstone at two quarries at Locharbriggs near Dumfries. Other building stone quarries are located on a Permian sandstone outcrop near Lossiemouth. In Caithness there are two quarries working the Caithness Flags of the Middle Old Red Sandstone which formerly supported a larger industry supplying paving stone. Orkney consists almost entirely of Middle Old Red Sandstone which is exploited in several quarries and satisfies most of the local demand for building stone and certain types of aggregate and roadstone.

In the past sandstone was used extensively for building in the industrial parts of Scotland. New Red Sandstone from the Isle of Arran was used in Clydeside and there were several large quarries in the Carboniferous and Old Red Sandstone of the Midland Valley.

A small industry in Edinburgh specialises in the production of cutting wheels for use in the manufacture of cut glass. Medium grained sandstones from old local quarries or imported York Stone are preferred for this purpose.

Northern Ireland

Half of the aggregate output in Northern Ireland is derived from the Antrim Basalts, the remainder being mainly sandstone, limestone and gravel. Sandstone quarries in Northern Ireland are mostly located in Lower Palaeozoic greywackes which crop out in County Down and the southern part of County Armagh. The deposits consist of alternating beds of greywacke and hard shale which commonly dip steeply. In most working quarries the proportion of shale is small and is discarded in the production of good quality aggregate. There is a tendency for crushed greywacke to be excessively flaky unless crushing is carefully controlled; otherwise the material has good strength and polish-resisting properties.

There were 32 quarries producing greywackes in 1974, with a total output of 2.6 million tonnes. Thus the Northern Ireland industry is of considerable local and national importance as it accounted for 19 per cent of total UK sandstone production in 1974.

Other workings in Northern Ireland include a quarry in the Triassic at Scrabo Hill, County Down which is worked for ornamental stone.

Refractories and other uses

At present the number of mines and quarries producing ganister and silica stone is small, reflecting both the decline in the use of siliceous refractories and changes in the structure of the industry. Traditionally the refractories industry involved a large number of independent producers, but as a result of mergers during the last 15 years, it is now dominated by a few large companies.

At Harthope quarry in Durham the British Steel Corporation extract a Carboniferous quartzite which is processed at Consett Steel Works for use in coke ovens, glass furnaces, electric arc furnaces etc. Some of this is sold outside the Corporation.

The Basal Grit of the Millstone Grit is worked in South Wales, north of the coalfield; the material is processed elsewhere. Silica stone is now extracted from the Holyhead Quartzite at Holyhead for the manufacture of silica refractories only on a small scale. Very little ganister is now worked in the Sheffield area.

In the non-refractory fields, Millstone Grit at Oakamoor, Staffordshire, is crushed and beneficiated for use as glass sand. At Biddulph, also in Staffordshire, a pure silica sand is produced from local sandstone for use in the manufacture of sodium silicate.

The production of silica sand from sandstone forms the basis of an important industry in Scotland. The well known Cretaceous sandstone at Loch Aline is the source of a high purity sand used mainly in the glass industry; other silica sand producers include Devilla Forest near Alloa where Carboniferous sandstone is quarried and processed on a large scale to give a high purity sand which is mainly used for glass making in Scotland. At Levenseat near Whitburn, Carboniferous sandstone from a nearby quarry is subjected to a large scale comprehensive processing operation and sold for use in foundries and for special concrete work. At Dullatur near Cumbernauld, Carboniferous sandstone is crushed to a sand which contains sufficient clay to make a naturally bonded moulding sand. Other smaller workings in Carboniferous sandstones occur at Gartverrie, Glenboig near Coatbridge and at Monkredding near Kilwinning. In these cases the product is ground and sold for foundry work or for special plastering or concreting sand.

There are large workings in a quartz conglomerate in the Calciferous Sandstone Series at Douglasmuir near Milngavie some 10 km north-west of Glasgow, and nearby at Muirhouse, Strathblane. At both these quarries the quartz pebbles are extracted from the crushed conglomerate for sale as a high quality coarse aggregate, mainly for use in concrete. After further treatment the finer product is sold for foundry sand and for use in special concrete work, market gardens, and other outlets, where it commands a premium price.

In a number of places, unconsolidated or loosely cemented silica sands are worked for a variety of specialist uses. These together with the specialist sands produced from crushed sandstone, will be described in detail in a dossier entitled *Silica*.

Technology

Quarrying

There are two fundamentally different concepts in sandstone extraction, depending on the end use of the product. In the production of aggregate the emphasis is on achieving maximum rock breakage for minimum expense, while in building stone production breakage must be very localised, sufficient only to release blocks from the quarry face without damaging them.

After overburden such as top soil, glacial drift and weathered rock, has been stripped with a mechanical scraper and a face has been started, working for aggregates continues by drilling a line of vertical holes parallel to and the same depth as the face from the top of the bench. The holes, spaced at calculated distances from the face and from each other are charged with nitroglycerine based or ammonium nitrate explosives. A short delay in detonation between successive holes results in an attenuated shock wave which minimises the vibrational effects of blasting on the surrounding area.

After blasting, the broken rock is usually picked up by a front-end loader and transported in large rubber-tyred trucks to a crushing and screening plant. Quarrying practice now tends to avoid high single face workings on grounds of safety and it is becoming more usual to work faces in a series of benches some 10-20 m high. In recent years there has been a tendency to use angled rather than vertical holes, as there is less danger from rocks falling from a bench face inclined at 60-80^{o}. This also tends to obviate the danger of the formation of overhanging faces and creates some improvement in blasting efficiency.

High explosives produce rock breakage by exploiting tensional failure. When an explosive-filled borehole detonates, the force initially is greater than the compressive strength of the rock which results in an intense shattering around each hole. Beyond this zone, the shock waves pass through the rock leaving it undisturbed until they reach a rock interface, such as the face of a quarry where they are reflected. If at this point the force exceeds the tensional strength of the rock, then the rock will break away along the interface.

In some quarries, the use of explosives has been discontinued and mining is carried out by 'ripping' with a large earth moving machine carrying a rear mounted single tooth which loosens the rock sufficiently for it to be picked up with an excavator. The advantages of this method are largely environmental in that there is no ground vibration or danger from flying fragments. Ripping is frequently used in the working of weaker rock types such as Bunter Sandstone, or flaggy Carboniferous sandstones, but it may occasionally be used for working strong rocks, where these are well jointed.

In building stone quarries, particularly in Carboniferous sandstones, it is usual for certain layers within the sequence to be sought for specific uses. This involves the production of a considerable amount of waste which, unless some is sold as aggregate, forms a spoil heap. Extraction of the crude blocks is often done by hand, using wedges to open out joints, bedding planes or drill holes. Otherwise a gunpowder type of explosive may be used to lift the rock, but not a high explosive of the type used in aggregate working. Quarries producing large blocks invariably have a tripod crane which is used to raise the block and swing it away from the face for loading.

Processing

Processing of quarried sandstone for aggregates usually involves crushing and screening in either fixed or mobile plants, most of which consist only of a

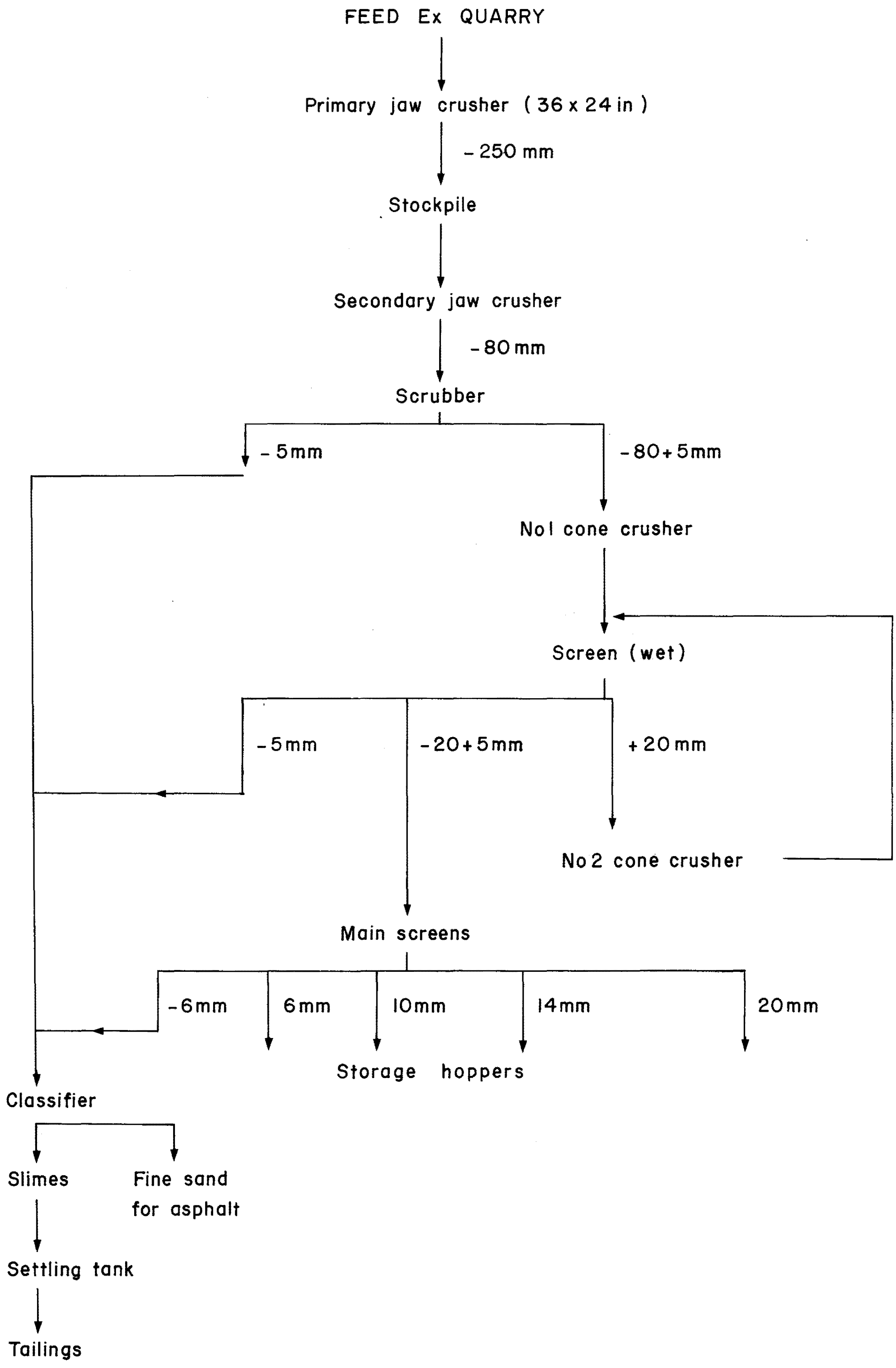

Fig 4 Quartzite Quarry, Avon; processing flowsheet

jaw or gyratory crusher and a battery of coarse screens. However if there are shale partings in the stone (for example at Nuneaton and Cromhall), it is also necessary to wash the product. The Cromhall flowsheet, one of the most comprehensive found in the sandstone industry, is shown (Fig 4).

In Devon, where the sandstones are often contaminated by hard shale, a system of fines rejection is sometimes employed to minimise the shale content of the product. The run of mine rock is first passed over a 45 mm grizzly from which the fines are rejected. The oversize then goes to a jaw crusher, the product is screened at 20 mm and again the fines are rejected. The oversize from this operation passes to a hammer mill and the product is finally screened into the required size fractions for sale.

In the building stone industry, primary cutting of freestone is often carried out by means of a frame saw. This machine frequently consists of six or eight diamond tipped saw blades each about 4-5 m long which are arranged in parallel about 0.3 m apart in a rectangular frame attached to a reciprocating drive. A rough block of stone is run under the frame on a rail mounted truck and cut under a water spray. The resulting slabs are then cut into smaller blocks by means of diamond impregnated circular saws. Flagstones can often be split by hand to avoid primary sawing. Final surface finishing, where necessary, may be carried out by hand. Not all quarries have cutting facilities and it is not unusual for individually selected crude blocks to be transported over a hundred miles to a dressing plant. Such dressing plants tend to build up stocks of various types of stone, mainly to be able to offer a choice of colours in their product.

Prices and other economic factors

In the aggregate industry, transport cost is the major variable affecting the price paid by the consumer. As a general guide a cost of 3p per tonne km, sometimes with a loading charge of approximately 20p per tonne, can be assumed for road transport in loads of at least 10 tonnes with an empty return journey. Costs increase significantly in congested urban areas and there is a saving when motorways or large trucks are used.

Ex-pit prices of aggregates depend mainly on the local supply situation and on the amount of treatment which the product has received. Thus an unscreened nominal 90 mm crusher-run product would be cheaper than a 90-45 mm screened product which in turn would be cheaper than finer screened chippings for road surface dressing.

In mid 1976, Hartshill Quartzite from the Nuneaton area, crushed, washed and screened to a 10 mm product for road surfacing was quoted at £3.67 per tonne, 90-45 mm material was £2.92 per tonne and crusher-run material was £1.47 per tonne. At the same time, in Lancashire, prices for crushed and screened Millstone Grit aggregate were £1.34 per tonne for 80 mm material, £1.42 per tonne for 40 mm material and £1.51 per tonne for 20 mm material. Carboniferous sandstone from south-west England was quoted at prices between £2.15 per tonne and £2.25 per tonne for material in size ranges between 40 and 10 mm.

In the building stone industry prices vary to some extent with the locality but are more dependent on the type of stonework. Prices quoted in imperial units by Natural Stone Quarries Ltd, for material from Springwell Quarry, Gateshead, are given below:

1. *Coursed Walling* – Random lengths, sawn beds and joints, three comparative heights.

Split face	2 in (50 mm) thick	£11.60 per square yard
	4 in (100 mm) "	£13.60 " " "
Rock finish	2 in (50 mm) "	£12.00 " " "
	4 in (100 mm) "	£14.60 " " "

2. *Random Walling* – Random heights and lengths, sawn beds and joints.

Split face	2 in (50 mm) thick	£9.00 per square yard
	4 in (100 mm) "	£11.60 " " "
Rock finish	2 in (50 mm) "	£10.00 " " "
	4 in (100 mm) "	£12.60 " " "

3. *Rubble Walling* (roughly cut)

   Approx 5 in-7 in on bed (3¼ square yards per ton) £19.80 per ton
   Approx 7 in-9 in on bed (2½ square yards per ton) £16.00 per ton

4. *Rockery Stone* £6.00 per ton

5. *Hearths, mantels etc.*

6 in x 1½ in mantels	£1.20 per liniar foot
12 in x 1½ in hearths	£2.00 per sq foot

Land use

Sandstone quarries are thought to consume about 20 ha of land a year in England and Wales. In England, there were over 2,200 ha of land with planning permission for surface working of sandstone at 1 April 1974. Of this total almost 1,200 ha were concentrated in the North-west and Yorkshire and Humberside Regions. It has been estimated that some 1,200 ha of land in Wales are covered by either working or disused sandstone quarries, of which a significant proportion, some 800 ha, is within the Carboniferous sandstones of the South Wales Coalfield.

The largest county area covered by sandstone permissions is in Lancashire, with 580 ha, followed by West Yorkshire with over 300 ha. For the most part these refer to quarries which originally supplied building stone to rapidly expanding towns during the 19th and early 20th centuries. After many years of dereliction or decline as building stone producers, the increased demand for aggregates in recent years has given some of these quarries a new role. In addition to the reopening or expansion of older quarries, a number of borrow pits have been operated recently on both sides of the Pennines to provide fill for major roads.

Elsewhere in England, extensive permissions (between 100 ha and 200 ha) have been recorded in a number of counties; Warwickshire, Salop, Devon and North Yorkshire. Quarries in these counties are in many instances working Lower Palaeozoic sandstones with high polished stone values. Because of the limited distribution of such resources, these quarries tend to supply large market areas, a number being rail-connected.

Sandstone quarries tend to be somewhat variable in terms of depth, and therefore in the amount of land consumed for a given extraction rate. However, in general, quarries are infrequent with total depths of less than 7 m or more than 30 m, that is, with yields of less than 200,000 or more than 800,000 tonnes per hectare, approximately.

Waste material produced during quarrying can become significant in the Carboniferous where sandstones worked for building stone occurs inter-bedded with inferior sandstones, shales, siltstones, mudstones etc. In part, the growth of demand for fill in road construction may allow some of this material to be used, particularly in the North-west and Yorkshire and Humberside Regions.

Sandstones play a significant role in the structure and scenery of a number of amenity areas, for instance the 'Dark Peak' of the Peak District National Park. The actual conflict between attractive landscape and sandstone workings is somewhat more restricted. In West Yorkshire, Lancashire and Greater Manchester the heavily exploited Carboniferous sandstones generally give rise to moorland scenery which in a number of areas has been designated as Green Belt. Some of the Lower Palaeozoic sandstones, providing higher quality material, also occur in amenity areas, for instance in the valleys of the Ribble and Greta north-west of Skipton, North Yorkshire, in the Yorkshire Dales National Park. Quarrying of sandstone also takes place in the Quantock Hills Area of Outstanding Natural Beauty in Somerset. In most areas, the major sandstone units of economic importance do not underlie high quality agricultural land.

Existing workings are subject to planning permission under the Town and Country Planning Acts, which provide for the imposition of restoration conditions. A recent survey, however, suggested that for England some 25 per cent of the total area permitted for surface working of sandstone was not covered by such conditions. In part, this relates to areas of Carboniferous sandstone where current aggregate workings are the successors to small-scale building stone quarries. The survey also showed that approximately a quarter of the total working area of sandstone quarries was covered by spoil heaps, tips and plant.

Most quarries are dry because of their location in upland areas together with the permeable nature of the sandstones. The method of after treatment depends, to some extent, on the type of working, the level and character of wastes and the location. Thus there may be some possibility of at least restoring the quarry floor by spreading waste together with any topsoil and overburden available. Quarry faces in Carboniferous and younger sandstones show some tendency to weather, and thus to resemble natural rock outcrop.

Some sites located close to urban areas may have a potential for solid waste disposal. Hydrological considerations are of importance in determining whether tipping can take place and what categories of material can be so disposed of.

In some circumstances, it has been economic to work sandstones by shallow mining. Disused flagstone mines, usually in the Haslingden and Elland flags, are found in the central Pennines, and there were also hearthstone mines in the Upper Greensand of Surrey and Sussex. Whilst there are no records of subsidence problems, the accurate location of cavities can cause difficulties in construction work.

Substitutes and future supplies

Other quarried materials (limestone, igneous rock and sand and gravel) are natural alternatives which compete with crushed sandstones, particularly for general purpose aggregate. The choice between them largely reflects availability in areas of high demand because of the major influence of transport costs on a low-price bulk commodity. The major exception to this is roadstone with the highest polished stone values, a requirement which only certain sandstones, among natural materials, fulfil.

Of the total production of crushed rock in Great Britain in 1973 (approximately 158 million tonnes) sandstones accounted for less than 9 per cent. However, they accounted for about 11 per cent of the 126 million tonne total of crushed rocks used for aggregates in the same year. When sand and gravel is included sandstone output comprised only about 5 per cent of the 256 million tonnes of natural aggregate production in 1973.

The major use of sandstone is as fill for road construction. Figures for 1973 demonstrated that out of a total output of about 26 million tonnes of crushed rock used 'for other purposes' (Table 6), which includes fill, sandstone accounted for almost 25 per cent; this end-use constituted almost half of the total sandstone output.

In recent years attention has been paid to the possibility of waste and alternative materials substituting for natural aggregates. A full review of the location, disposal and uses of these materials in Great Britain has been given in Gutt *et al* (1974). The major items with potential as aggregates included the following:

Waste	*Production million tonnes*	*Stockpile million tonnes*	*Comment on usage*
Colliery spoil	50	3,000	7-8 million tonnes per annum as construction fill, for lightweight aggregate.
China clay waste	22	280	Fine aggregate, construction fill.
Slate waste	1.2	300+	Expanded slate aggregate, construction fill.
Pulverised fuel ash (Pfa) Furnace bottom ash (Fba)	9.9	not known	Construction fill, lightweight aggregate.
Furnace clinker	2.3	-	Concrete block making.
Blast furnace slag	9	-	Roadstone, railway ballast.
Steel making slag	4	not known	Construction fill.

Blastfurnace slag has for many years been utilised as high quality roadstone, and to a limited extent substitutes for natural surfacing materials. Also calcined bauxite, a manufactured material, has been found to have an exceptionally high resistance to polishing under traffic as it possesses a polished stone value higher than any natural roadstone tested, it is however, comparatively very expensive.

The Report of the Advisory Committee on Aggregates (the Verney Committee), published in June 1976, has given advice and guidance on meeting the nation's future needs for aggregates. Regional local authority working parties on aggregates which have been established in Britain will be considering and reporting upon how best the future demands for all types of aggregates on their respective areas can be met.

As building stone, sandstone is mainly used for its ornamental and aesthetic appeal although once used as the cheapest available material for walls in some areas. As with other natural stone, competition from cheaper brick or concrete products caused a drastic reduction in consumption, but in recent years there has been a revival of interest in the use of sandstone for building stone particularly as cladding. Subject to changing architectural tastes this trend may continue. The tonnage of rock involved will remain small by the standard of aggregate production and no difficulty need be anticipated as to the shortage of future reserved.

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