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Mineral Resource Information for Development Plans

Durham and the Tees Valley: Resources and Constraints

TECHNICAL REPORT WF/00/6
Mineral Resources Series

Mineral Resource Information for Development Plans: Phase One County Durham and the Tees Valley: Resources and Constraints

D E Highley, D J D Lawrence, B Young, D J Harrison, D G Cameron, S Holloway, G K Lott and A J Bloodworth

Planning Consultant: J F Cowley
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This report accompanies the 1:100 000 scale map:
County Durham and the Tees Valley Mineral Resources

Cover Photograph
Workings in the Permian Basal Sands (lower, yellow), Marl Slate (dk. grey band) and Magnesian Limestone (top, grey) at Old Quarrington Quarry, Raisby Quarries Ltd, near Coxhoe.

This report is prepared for the Department of the Environment, Transport and the Regions. (Contract MP0624)

Bibliographic Reference
Highley, D E, Lawrence, D J D, Young, B, Harrison, D J, Cameron, D G, Holloway, S, Lott, G K and Bloodworth, A J. 2000. Mineral Resource Information for Development Plans: Phase One County Durham and the Tees Valley: Resources and Constraints (Co Durham, Darlington, Hartlepool, Middlesbrough, Redcar & Cleveland and Stockton-on-Tees): Resources and Constraints. *British Geological Survey Technical Report* WF/00/6
ISBN 0 85272 368 7

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The British Geological Survey is a component body of the Natural Environment Research Council.

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SUMMARY

This report is one of a series prepared by the British Geological Survey for various administrative areas in England and Wales for Phase One of the Department of the Environment, Transport and the Regions Research Project *Mineral Resource Information for Development Plans*.

The report and accompanying map relate to the area of the Mineral Planning Authorities of County Durham, Darlington, Hartlepool, Middlesbrough, Redcar & Cleveland and Stockton-on-Tees. The report and map delineate and describe the mineral resources of current, or potential, economic interest in the area and relate these to national planning designations which may represent constraints on the extraction of minerals. Three major elements of information are presented and described:

- the geological distribution and importance of mineral resources
- the extent of mineral planning permissions and the location of current mineral workings
- the extent of selected planning constraints (national statutory designations)

This wide range of information, much of which is scattered and not always available in a consistent and convenient form, is presented on a digitally-generated summary map. The map is produced at 1:100 000 scale, which is convenient for overall display and allows for a legible topographic base on which to depict the information. In addition, as the data are held digitally using a Geographical Information System (GIS), easy revision, updating and customisation are possible, including presentation of subsets of the data at larger scales.

Basic mineral resource information is essential to support mineral exploration and development activities, for resource management and land-use planning, and to establish baseline data for environmental impact studies and environmental guidelines. It also enables a more sustainable pattern and standard of development to be achieved by valuing mineral resources as national assets.

The purpose of the work is to assist all interested parties involved in the preparation and review of development plans, both in relation to the extraction of minerals and the protection of mineral resources from sterilisation, by providing a knowledge base on the nature and extent of mineral resources and the environmental constraints which may affect their extraction. However, it is anticipated that the map and report will also provide valuable data for a much wider audience, including the minerals industry, the Planning Inspectorate, the Environment Agency, the Countryside Agency, other agencies

and government bodies, environmental interests and the general public.

The mineral resource information has been produced by the collation and interpretation of data principally held by the British Geological Survey. The methodology for the collection and display of the data is described and a range of sources of information and further contacts is presented. The mineral resources covered are anhydrite, coal, crushed-rock aggregate (limestone and igneous rock), sand and gravel, clay and shale, fireclay, hydrocarbons, building stone (sandstone), potash, salt, secondary aggregates and vein and metalliferous minerals.

INTRODUCTION

> *'........ it will become increasingly important to have reliable information about the nature, quantity and location of mineral resources as workable reserves in environmentally acceptable areas become scarcer.'………*
>
> Sustainable Development: The UK Strategy.
> The UK Government's response to the Rio Earth Summit.

This report is one of a series that has been prepared by the British Geological Survey for various administrative areas in England and Wales as part of the Department of the Environment, Transport and the Regions research project *Mineral Resource Information for Development Plans*.

The report relates to County Durham and the Tees Valley area. It should be used in conjunction with the mineral resources map of the area which accompanies this report. In April 1996, four unitary authorities, Hartlepool, Middlesbrough, Redcar & Cleveland, and Stockton-on-Tees were created and the former county of Cleveland abolished. The unitary authority of Darlington was created in 1997. The Tees Valley area covers these five districts and all references to the area relate to County Durham and these five unitary authorities. Part of Redcar & Cleveland is, however, covered by the North York Moors National Park, which is a Minerals Planning Authority in its own right. The report and its associated map delineate and describe the mineral resources of current or potential economic interest in County Durham and the Tees Valley. These are related to national planning designations which may represent constraints on the extraction of minerals. The purpose of the work is to assist all interested parties involved in the preparation and review of development plans. This is in relation to the extraction of minerals and the safeguarding of mineral resources from sterilisation. The map provides a knowledge base, in a consistent format, on the nature and extent of mineral resources and the environmental constraints which may affect their extraction. An important objective is to provide baseline data for the long term. The results may also provide a starting point for discussions on specific planning proposals for mineral extraction or on proposals which may sterilise resources.

All the data are held in digital form which can be readily revised on a regular basis. This also provides scope for producing customised maps of selected information, including the display of part of an administrative area in greater detail or a grouping of administrative areas to provide a broader picture. The mineral resource map is at 1:100 000, which is a convenient scale for overall display and to show the information on a legible topographic base. The report and maps represents the situation at 1st January 2000.

Mineral resources are valuable national assets. Society enjoys important benefits from their extraction and, most importantly, use through their contribution to wealth creation, our infrastructure and quality of life of individuals. An adequate supply of minerals is, therefore, essential to the substantial development of our economy. However, mineral extraction is bound by geological location and the properties of the deposit. Extraction, particularly in the densely populated landmass of Britain, causes conflicts with other desirable aims of society, either by loss or change to valued landscapes, habitats or features of historical and archaeological interest, or due to amenity impact.

Basic mineral resource information is essential to support mineral exploration and development activities, and this may lead to an expanding resource base. Data on the properties of resources, as well as their distribution, allows specific resources to be matched with their most appropriate use. An understanding of whether these properties can be modified or enhanced by blending and/or mineral processing allows scope for producing value–added products, as well as facilitating the use of more unconventional deposits, including mineral wastes. All these factors will contribute to the more efficient use of primary resources. In the wider context of sustainable development, mineral resource information is of increasing importance for resource management and land-use planning. These data also contribute to the baseline information needed for environmental impact studies and environmental guidelines. Moreover, knowledge of the extent and quality of mineral resources, and their rate of extraction, can help value them as national assets. This ensures that the capital they represent is managed properly and rates of depletion monitored.

MINERALS PLANNING

It is the function of the planning system through the development plan and individual decisions to manage the supply of essential minerals at best balance between economic, social and environmental considerations. Achieving that balance requires adequate data on the relevant competing objectives, including the extent and details of mineral resources. As the development of workable resources in environmentally acceptable areas is becoming more difficult, it will become increasingly important in the policy development process to have comparative and reliable data on the distribution and quality of such resources.

The ‘development plan’ includes structure plans, which contain strategic planning policies, and local plans, containing detailed policies and proposals, or unitary development plans, which combine both functions. In addition, relevant authorities must produce local plans on minerals and/or waste. Development plans set out the main considerations on which planning applications are determined and form the essential framework of the planning system. The importance of the development plan system in planning decisions is emphasised by Section 54A of the Town and Country Planning Act 1990, which requires that planning applications and appeals be determined in accordance with the development plan, unless material considerations indicate otherwise. The planning system is, therefore, a plan-led system. Development plans are produced through an extensive process of consultation with prospective developers and the general public. Development plan preparation must take account of Government guidance. This is primarily set out in Planning Policy Guidance notes (PPGs), Mineral Planning Guidance notes (MPGs) and Regional Planning Guidance notes (RPGs). These provide advice on a range of general and specific issues.

The Planning and Compensation Act 1991 introduced a mandatory requirement that all Mineral Planning Authorities (MPAs) in England and Wales prepare either a local plan or a unitary development plan which set out the policies and proposals against which planning applications and appeals are determined. Mineral local plans are intended to provide a clear guide to mineral operators and the public where mineral extraction is likely in principle to be acceptable and where not. They cover a period of at least 10 years and are reviewed periodically to take account of new information and changing circumstances. MPAs are, therefore, required to undertake regular assessments of the existing resources in their areas and of the reserves for which planning permissions have been granted.

The key elements of a minerals local plan or of the mineral policies of a unitary development plan are:

- to balance through its policies the essential need for minerals against protection of the environment and local amenity
- to make an appropriate provision for the supply of minerals and provide an effective framework within which the minerals industry may make planning applications
- set policies for the control of mineral working and associated development
- to identify areas of possible future mineral working
- to prevent unnecessary sterilisation of resources by the use of safeguarding policies, including defining mineral consultation areas

It follows from the above that information on the extent, quality and, if possible, quantity of mineral resources is an essential prerequisite for the production of mineral local plans. This includes identifying areas of future mineral working and the longer term objective of the safeguarding of important mineral resources against unnecessary sterilisation**.** Policy decisions should be based on the best available information. Such data should be available to all parties to assist them in their contribution to the development plan process, both to protect mineral resources from sterilisation and to provide for sufficient resources to meet the needs of society. This work is intended to assist that process.

Three major elements of information are presented and described:

- the geological distribution and importance of mineral resources
- the extent of mineral planning permissions and the location of current mineral workings
- the extent of selected planning constraints (national statutory designations)

The maps bring together a wide range of information, much of which is scattered and not always available in a consistent and convenient form. The data are held digitally using a Geographical Information System (GIS), which allows for easy revision, updating and customisation, including presentation of subsets of the data at larger scales. It is anticipated that the maps and report will also provide valuable background data for a much wider audience, including the different sectors of the minerals industry, other agencies and authorities (e.g. The Planning Inspectorate Agency, the Environment Agency, the Countryside Agency and English Nature), environmental interests and the general public.

MINERAL RESOURCE CLASSIFICATION

Mineral resources are natural concentrations of minerals, or bodies of rock, that are or may become of potential economic interest as a basis for the extraction of a commodity. They will exhibit physical and/or chemical properties and be present in sufficient quantity to be of intrinsic economic interest. Mineral resources are thus economic as well as physical entities.

The identification and delineation of mineral resources is inevitably somewhat imprecise as it is limited not only by the quantity and quality of data currently available but also involves predicting what might, or might not, become economic to work in the future. The assessment of mineral resources is, therefore, a dynamic process which must take into account a range of factors. These include geological reinterpretation as additional data becomes available, as well as the continually evolving demand for minerals, or specific qualities of minerals, due to changing economic, technical and environmental factors. Consequently areas that are of potential economic interest as sources of minerals may change with time. Criteria used to define resources, for example in terms of mineral to waste ratios, also change with location and time. Thus a mineral deposit with a high proportion of waste may be viable if located in close proximity to a major market, but uneconomic if located further away. The criteria used to delineate mineral resources are outlined in the relevant commodity section of the report. These criteria vary depending on the quality of the information available.

The map of Durham and the Tees Valley mainly shows the extent of **inferred mineral resources**, that is those mineral resources that can be defined from available geological information. They have neither been evaluated by drilling or other sampling methods, nor had their technical properties characterised, on any systematic basis. Mineral resources defined on the map delineate areas within which potentially workable minerals may occur. These areas are not of uniform potential, nor do they take account of planning constraints which may limit their working. The economic potential of specific sites can only be proved by a detailed evaluation programme. Such an investigation is an essential precursor to submitting a planning application for mineral working. The individual merits of the site must then be judged against other land-use planning issues.

That part of a **mineral resource** which has been fully evaluated and is commercially viable to work is called a **reserve** or **mineral reserve**. The relationship between **measured, indicated** and **inferred resources** and evaluated commercial deposits (**reserves**) is described in more detail in Appendix 3. In the context of land-use planning, however, the term **mineral reserve** should strictly be further limited to those minerals for which a valid planning permission for extraction exists (i.e. **permitted reserves**). Without a valid planning consent no mineral working can take place and consequently the inherent economic value of the mineral resource cannot be released and resulting wealth created. The ultimate fate of a mineral reserve is to be either physically worked out or to be rendered non-viable by changing economic circumstances.

The maps have been produced by the collation and interpretation of data principally held by the British Geological Survey. The geological lines are taken, with some generalisations, from available BGS 1:25 000, 1:50 000 scale and 1:63 630 scale maps. These published maps are based on 1:10 560 or 1:10 000 scale surveys, which cover most of the county. In general, the more recent the survey the more detailed it is likely to be.

Where sand and gravel assessment studies have been undertaken by the British Geological Survey, sufficient information may be available to define mineral resources at the **indicated resource level**. The sand and gravel resources of the lower part of the Tees Valley fall into this category. The linework is based on the 1:25 000 scale mineral assessment maps, where these are available.

MINERAL WORKINGS AND PLANNING PERMISSIONS

The location and name of mineral workings that are currently active or temporarily inactive, together with the main mineral commodities produced, are shown on the map and in Appendix 1.

The extent of all known mineral planning permissions (other than coal) is also shown on the Mineral Resources Map. They include all permissions granted since 1st July 1948 and all Interim Development Order (IDO) permissions, whatever their subsequent status in relation to legislation relating to the Planning and Compensation Act 1991 and the Environment Act 1995. Planning permissions cover active mineral workings, former mineral workings and, occasionally, unworked deposits. They represent areas where a commercial decision to work minerals has been taken in the past and where the permitted mineral reserve may have been depleted to a greater or lesser extent. Within the overall site, there may be a number of individual planning permissions at various stages of development and restoration. All planning permissions data were obtained from the relevant mineral planning authorities.

For coal a somewhat different approach has been adopted. Areas of former opencast coal sites are shown based on information from the Coal Authority. For current coal licence areas, the extent is shown and a distinction is made between underground and opencast licences.

The present physical and legal status of individual permissions is not qualified on the map or in the report. The areas shown may, therefore, include inactive sites, where the permission has expired due to the terms of the permission, i.e. a time limit, and inactive (dormant) sites where the permission is still valid. Sites which have been restored have not been separately identified. A planning permission may extend beyond the mapped resource as it may make provision for operational land, including plant, overburden tips and landscaping, or it may extend to an easily identified or ownership boundary. Information on the precise status and extent of individual planning permissions should be sought from the appropriate Mineral Planning Authority (Appendix 2).

ENVIRONMENTAL DESIGNATIONS

The map shows the extent of selected, nationally-designated planning constraints as defined for the purposes of this study. These are defined on a common national basis and therefore represent a consistent degree of constraint across the country. No interpretation should be made from the map with regard to the relative importance of the constraints, either in relation to mineral development proposals or in relation to each other. Users should consult policy guidelines issued by the relevant Government department, statutory agency or local authority.

The constraints shown on the map are:

- North York Moors National Park (part)
- North Pennines Area of Outstanding Natural Beauty (AONB) (part)
- National Nature Reserves (NNR)
- Sites of Special Scientific Interest (SSSI)
- Scheduled Monuments

Mineral development may also be constrained by other factors not shown on the maps including local landscape designations, considerations relating to the protection of other resources, such as groundwater, and local amenity or environmental concerns such as noise, traffic and visual impact. These have been excluded because the constraint is not defined on a national basis or the information is not generally available. The extent or degree of relevance of such constraints can be ascertained from the relevant statutory agency or the appropriate Mineral Planning Authority (Appendix 2).

AONBs have been digitised from maps obtained from the Countryside Agency and English Nature provided digital data on SSSIs and NNRs. Information on the location of Scheduled Monuments has been obtained in digital form from English Heritage. The areas shown as NNRs and SSSIs may also be subject to international designations reflecting their wider ecological importance. They may include Ramsar sites (wetlands of international importance as listed in accordance with the Ramsar Convention), or proposed Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) as identified in accordance with EC Directives on wild birds and natural habitats, respectively. These areas can be separately identified if required.

MINERAL RESOURCES

OVERVIEW

A wide range of mineral resources occur in County Durham and the Tees Valley area. The coal resources hosted by Carboniferous rocks have a long history of working and continue to be a focus of opencast development in County Durham. A gas find in a borehole in the southern part of the area has ensured that the area remains of moderate interest for conventional hydrocarbons exploration. The Durham coalfield is not considered prospective for coalbed methane. Opencast coal workings in the Durham coalfield are also a source of fireclay. The fireclays from this area are an important raw material for the manufacture of buff and cream-coloured bricks in northern England. Coal Measures Group mudstones are utilised locally for the manufacture of red bricks.

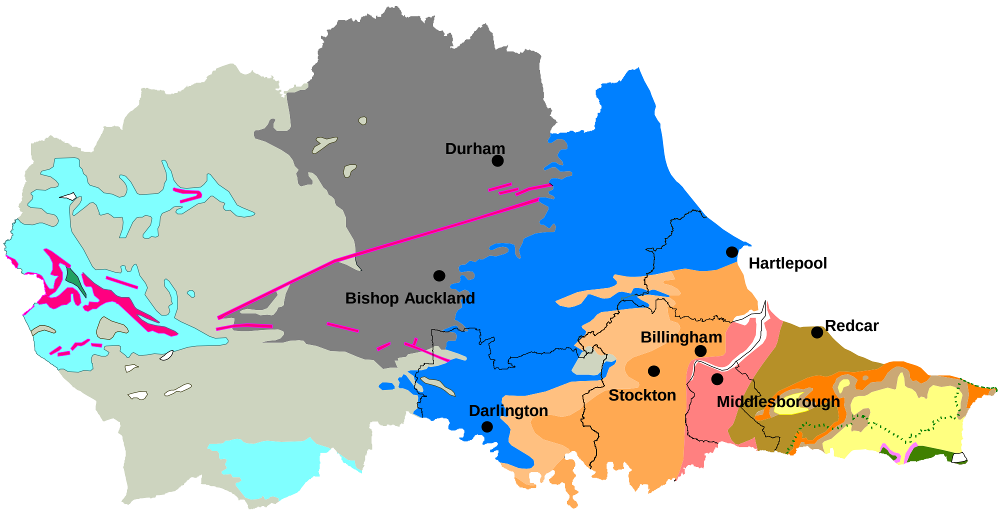

Figure 1. Simplified geological map of County Durham and the Tees Valley. Based on 1:625 000 Geological Survey Ten Mile Map North Sheet (Solid).

The Magnesian Limestone of County Durham constitutes a nationally important resource of industrial-grade dolomite, used in the manufacture of seawater magnesia and as a flux in steelmaking. The Magnesian Limestone is also an important source of aggregate for use in less demanding applications. Resources of high-quality crushed-rock aggregates occur in the Carboniferous limestones and in the Whin Sill dolerite, both of which crop out in the western part of the area. Carboniferous limestones are also worked at one location for the manufacture of cement.

Period	Epoch	Unit	*Mineral resources*	*Uses and Products*
		Quaternary omitted for clarity	river and glacial gravels, clays	sand and gravel, brick making
Jurassic	*Upper*	Oxford Clay	mudstone	
		Cornbrash	mudstone, limestone	
	Middle	Ravenscar Group	mudstone, sandstone	
	Lower	Upper Lias	mudstone	
		Middle Lias	mudstone, ironstone	iron ore
		Lower Lias	mudstone, limestone	
Triassic		Mercia Mudstone Group	mudstone	brick and tile making
		Sherwood Sandstone Group	sandstone, conglomerate	
Permian		Permian Mudstones	mudstones, evaporites	anhydrite, salt potash
		Magnesian Limestone and Basal Sands	dolomite limestone, sands	aggregates, industrial dolomite, construction sand
Carboniferous		Coal Measures	coal, fireclay, mudstone, sandstone, ironstone	coal, brick and tile making, iron ore, building stone
		Millstone Grit (Stainmore Group)	Sandstone, mudstones	aggregates, building stone, silica sand
		Carboniferous Limestone (Alston Group)	limestone, mudstone, sandstone	aggregates, cement, silica rock
		All divisions of the Carboniferous	mineral veins	fluorspar, lead, zinc, barytes, silver
Ordovician		Skiddaw Slate, Borrowdale Volcanic Group	Slate. tuffs	
		Intrusive igneous rocks Carboniferous and Tertiary Whin Sill, Cleveland Dyke	dolerite, basalt	high specification roadstone, aggregates

Figure 1 (continued). Key for sketch map. Commodities and resources which are no longer worked are shown in blue text.

Glacial activity in the Quaternary has created extensive glacial and fluvio-glacial sand and gravel resources across the area, particularly in parts of the valleys of the Tees and Wear. The Permian Basal Sands, which immediately underlie the Magnesian Limestone, are also an important source of fine aggregate. Carboniferous sandstones are worked in a number of locations in County Durham as building stones.

Evaporites hosted within sub-surface Permian rocks in the eastern part of the area constitute mineral resources of historic and current importance. The Billingham Anhydrite was extensively mined in the past as a source of sulphur for the manufacture of the fertiliser ammonium sulphate and sulphuric acid. The Boulby Halite formed the basis of the Teesside chemical industry and is still worked today by brine pumping. The Boulby Potash is Britain's only source of the fertiliser raw material potash and is worked at the large mine at Boulby in Redcar and Cleveland.

The Northern Pennine Orefield occurs in the western part of County Durham and was formerly a major source of vein minerals. Lead and iron were the main minerals produced, with some by-product silver, with peak activity being achieved in the mid to late 19th century. Zinc was locally of importance towards the beginning of the 20th century. Fluorspar and baryte were worked extensively in this area during the 20th century. However, fluorspar mining ceased in 1999 and remaining production is now confined to one small baryte operation.

A simplified geological sketch map of County Durham and the Tees Valley area is shown in Figure 1.

LIMESTONE AND DOLOMITE

Durham is one of the major centres of limestone and, particularly, dolomite production in Britain. In 1998 some 6.5 million tonnes of limestone and dolomite were quarried in the county, of which some 80 per cent is estimated to have been derived from the Permian Magnesian Limestone. Most is consumed in the construction industry as aggregate or fill, with the fines being used as a source of agricultural lime. Cement is produced from the Carboniferous Great Limestone in Weardale. Some Permian dolomites are of sufficiently high quality to be used in the manufacture of seawater magnesia, and as a flux in steelmaking. Some deposits may also be suitable for glass manufacture or for making dolomite refractories, although none is currently consumed for this purpose.

Limestones of Carboniferous age are the major source of limestone raw materials in England and Wales. In Durham, individual limestone beds are generally thin. The Great Limestone is the only one worked at several sites in Weardale, Teesdale and near Barnard Castle. Overall, therefore, Carboniferous limestone resources are not as extensive as elsewhere. The most extensive and important limestone resource is the Permian Magnesian Limestone. There are currently eight quarries working Permian limestone, but the outcrop is also marked by many disused quarries.

Permian limestone and dolomite

The Permian Magnesian Limestone is the main source of dolomite in Britain and is a resource of national and regional importance. Despite its name, it consists of dolomites and dolomitic limestones, with subordinate limestones. It extends in a narrow, easterly dipping belt, up to 300 m in thickness, almost continuously from Newcastle to Nottingham. A major part of the outcrop occurs in the area. The terminology applied to these rocks is as follows:

- *Limestones* are sedimentary carbonate rocks consisting almost entirely of the mineral calcite [$CaCO_3$], although the term is also often used informally to describe any sedimentary carbonate rock.
- *Dolomites* are sedimentary carbonate rocks consisting almost entirely (>90 per cent) of the mineral dolomite [$Ca,Mg(CO_3)_2$].
- Limestones containing between 10 and 50 per cent dolomite are called *dolomitic limestones*.

The Magnesian Limestone is highly variable, both regionally and locally, in its physical, mechanical and chemical properties and thus in its suitability for particular applications. It is inferior to Carboniferous limestones as a source of aggregate because of its more variable character and generally lower strength and higher porosity.

It also varies in thickness and lithology and contains both dolomites and limestones. Some are strong enough to make good quality aggregates, but others are porous, weak and friable. It is widely quarried for a range of construction applications, mostly as a granular sub-base and for fill. Less commonly, it is used for coated roadstone and concrete aggregate. Fines are sold for agricultural purposes (to neutralise soil acidity and to correct magnesium deficiencies). Impurities such as silica, iron oxides and alumina are a prime consideration in the selection of dolomite for industrial applications. Dolomites with sufficiently low levels of impurites to be used in applications, such as the manufacture of seawater magnesia and as a flux in steelmaking, are comparatively scarce in Britain. Durham is one of the few sources of high quality dolomite for industrial applications in England (Rendel, Palmer and Tritton, 1988).

The Magnesian Limestone has been traditionally divided into three formations. Table 1 shows how this nomenclature relates to the modern lithostratigraphic terminology.

'Traditional' nomenclature	Revised nomenclature
Upper Magnesian Limestone	Seaham Formation (0–18 m) Roker Dolomite Formation (0–50 m) Concretionary Limestone Formation (0–60 m)
Middle Magnesian Limestone	Ford Formation (0–160 m)
Lower Magnesian Limestone	Raisby Formation (0–70 m)

Table 1. Simplified stratigraphy of the Permian Magnesian Limestone in County Durham

The limestones were deposited at the margin of a shallow sea with the development of lagoonal, shelf, reef and basinal environments, each with a characteristic lithology. Fluctuations in sea level and variable rates of regional subsidence during deposition resulted in great variations in both lithology and thickness. After deposition the limestones were affected by circulating magnesium-rich waters causing dolomitisation. The processes of dolomitisation and subsequent dedolomitisation are often incomplete and have resulted in great variability in composition. Thus rocks defined as 'dolomite' may consist of variable mixtures of dolomite, dolomitic limestone and limestone. This fact, together with the variable presence of impurities such as silica, iron oxides and alumina, has an important bearing on the suitability of dolomite for specific applications.

The Lower Magnesian Limestone (Raisby Formation) consists mostly of buff-coloured, well bedded dolomites which in the lower and middle parts of the unit grade locally (such as around Coxhoe) into hard limestones. The limestones are relatively strong, durable and frost-resistant (Table 2) and are suitable for concreting aggregates and for coated roadbase materials. The dolomitic parts of the formation are generally weaker and more porous, but are usually sufficiently frost-resistant for use as road sub-base and fill. Lower Magnesian Limestone aggregates may also locally be suitable for use as filter aggregate, building stone and armourstone.

Most quarrying of the Magnesian Limestone in Durham is from the Raisby Formation. The overlying dolomites and dolomitic limestones of the Ford Formation (Middle Magnesian Limestone) are mostly relatively soft and porous and are not suitable for aggregate use, apart from granular sub-base or fill applications. Over much of Durham, exposure of this formation is very limited and large areas are concealed beneath relatively thick overburden.

The Upper Magnesian Limestone consists of a number of dolomitic rock units with associated marls and evaporites. In eastern County Durham, the Concretionary Limestone and Roker Dolomite formations occur. The former contains hard crystalline limestones together with softer coarse granular limestones and bedded dolomites, whereas the latter mostly consists of soft, oolitic dolomites. These rock types are generally only suitable for low-grade aggregates, such as granular sub-base roadstone and fill. The uppermost limestone unit, the Seaham Formation, consists of thin bedded dolomitic limestones which are extensively broken up (brecciated) due to the dissolution of the evaporites in the underlying Ford Formation. The Upper Magnesian Limestone is quarried at one site near Hartlepool for less demanding aggregate uses and agricultural lime. The extent of the Lower, Middle and Upper Magnesian limestones are shown on the map, although they may be locally covered by substantial thicknesses of superficial deposits.

Rock Type	Locality	PSV	AAV	AIV	ACV	TFV kN	Rel. Den.	Water absorption (%)
Permian – Concretionary Limestone	South Shields	-	-	53	38	50	2.84	3.4
Permian – Raisby Formation	Houghton-le-Spring	-	11.4	31	24	120	2.84	4.9
Permian – Raisby Formation	Aycliffe	-	-	25	30	170	-	4.3
Carboniferous – Great Limestone	Weardale	46	12	20	22	180	2.66	0.9
Carboniferous – Great Limestone	Bowes	43	8.9	17	21	170	2.71	0.4
Carboniferous – Great Limestone	Bowes	47	13	19	22	160	2.75	0.7
Whin Sill – Dolerite	Middleton-in-Teesdale	57	3.1	10	11	375	2.95	0.8
Whin Sill – Dolerite	Middleton-in-Teesdale	59	4.9	8	10	390	2.95	0.4

Table 2. Typical aggregate properties of some limestones and igneous rocks in County Durham and South Tyneside

Definitions:

Ten Per Cent Fines Value: Resistance of an aggregate to crushing as measured by the force in kN applied in the ten per cent fines value test. The larger the value, the more resistant the rock is to crushing.

Aggregates Abrasion Value (AAV): Resistance of an aggregate to abrasion as measured by the aggregates abrasion test. The smaller the value the more resistant the rock is to abrasion. Abrasion resistance is particularly important for road surfacing materials.

Aggregate Crushing Value (ACV): Resistance of an aggregate to crushing when subjected to a crushing force as measured by the aggregate crushing test. The smaller the value, the more resistant the rock is to crushing.

Aggregate Impact Value (AIV): Resistance of an aggregate to repeated impact as measured by the aggregate impact test. The smaller the value, the more resistant the rock is to impact.

Polished Stone Value (PSV): Resistance of an aggregate to polishing as measured in the accelerated polishing test. A measurement of skid resistance on road surfaces. The larger the value the more resistant the rock is to polishing.

Properties

Most of the Permian dolomites, dolomitic limestones and limestones are of low chemical quality (Table 3), although in certain areas parts of the sequence contain rocks of higher and more consistent chemical grade. The Raisby Formation is notable for its relatively high purity and consistent quality. Although CaO and MgO values vary over small lateral and vertical distances, even within the scale of quarries, the levels of impurities (silica, iron oxides and alumina) are relatively low. Other parts of the sequence are generally of lower purity and are more variable in chemical quality.

	Concretionary Lst (South Shields)	Concretionary Lst (South Shields)	Ford Formation (Quarrington)	Raisby Fm (Thrislington)	Raisby Fm (Thrislington)
			wt %		
CaO	50.94	30.85	31.02	32.37	33.99
MgO	4.51	19.95	20.67	20.03	18.64
SiO_2	0.00	1.40	0.54	0.48	0.00
Fe_2O_3	0.16	0.46	0.43	0.55	0.53
Al_2O_3	0.00	0.19	0.23	0.21	0.00

Table 3. Chemical analyses of the Permian Magnesian Limestone of County Durham and South Tyneside (from: Harrison, 1990)

The Raisby Formation at the Thrislington quarry is a nationally important source of dolomite for industrial applications. Calcined dolomite (dolime) from Thrislington quarry has, for many years, being used as a primary feedstock for Britain's sole seawater magnesia plant which is located at Hartlepool. Here, calcined dolomite is hydrated and used to precipitate magnesium hydroxide from seawater (containing 0.2 % MgO), the dolomite also contributing additional magnesia units. Magnesium hydroxide is subsequently calcined to produce a range of magnesia products for the refractory, environmental and specialty chemicals markets. Not all of the impurities present in the original raw material can be eliminated in the process and the quality of the magnesia product is thus highly dependent on the quality of the dolomite feedstock. Chemical specifications for calcined dolomite are rigorous, particularly for silica and iron oxide, which should not exceed 0.55 and 1.2 per cent respectively. Additionally, alumina should be less than 0.3 per cent. Calcined dolomite is also produced at Thrislington for use as a flux in basic oxygen steelmaking. This is a larger tonnage application than for seawater and is supplied to all four major steel plants in Britain This application also demands dolomite with relatively low levels of impurities.

Carboniferous limestones

The Carboniferous limestones (Table 4) of Weardale, Teesdale and the Stainmore Trough (south of Barnard Castle) occur predominantly within a mixed, cyclical sequence of limestone, mudstone and sandstone beds (the so-called 'Yoredale facies'). Although limestone beds are numerous, they are usually less than 10 m in thickness and, therefore, too thin to support a modern quarrying operation. Consequently the latter have been excluded from the mineral resources map. The limestones are also often dark grey and argillaceous (muddy).

'Traditional' nomenclature	Revised nomenclature		Thickness (m)
Namurian (Millstone Grit)		Great Limestone	12–23 m
Dinantian (Lower Carboniferous)	Alston Group	Upper (Yoredale facies) Lower (Melmerby Scar, Robinson limestones)	300 m

Table 4. Carboniferous Limestone succession in County Durham

Thicker pale grey, more massive limestones (the Melmerby Scar and Robinson limestones) occur beneath the Yoredale sequence but are only exposed in small areas of Teesdale. Here, the Melmerby Scar Limestone has locally been thermally metamorphosed to a coarse marble as a result of the intrusion of the Whin Sill. The Melmerby Limestone and Robinson Limestone are capable of producing strong, durable aggregate materials; they are also of relatively high chemical purity. Similar rocks are quarried for aggregates, lime production and other industrial purposes in adjacent areas of the north Pennines.

	wt %					
CaO	49.6	52.3	50.2	51.3	48.8	50.6
MgO	1.1	1.4	1.5	1.5	1.5	1.5
SiO_2	5.5	2.4	4.6	3.6	7.1	5.1
Fe_2O_3	0.8	0.4	0.5	0.4	0.7	0.4
Al_2O_3	1.1	0.3	0.7	0.4	1.5	1.0

Table 5. Range of chemical analyses of the Great Limestone of Weardale (from: Harrison, 1990)

The Great Limestone at the base of the Millstone Grit (of lowest Namurian age) outcrops widely in the valleys of Weardale and Teesdale. It is by far the thickest (12–23 m) and most uniform of the Yoredale-type limestones. It is generally a mid-grey, well-bedded, bioclastic limestone with mudstone partings. Locally, the top 5–7 m (the Tumbler Beds) is distinguished by the presence of thin mudstone partings. The Great Limestone is quarried at five sites in Durham; for cement manufacture at Eastgate (see below) and for aggregates in Weardale, Teesdale and near Bowes. The Great Limestone is of moderate purity, averaging 5–6 per cent of non-carbonate minerals (Table 5), but the average quality of the formation is downgraded by the impure Tumbler Beds and also locally, by clay contamination from joints and cavity fills. In Weardale, mineral veins locally affect the limestones and fluorspar mineralisation can cause problems for cement manufacture. The Great Limestone generally produces good quality aggregate materials (Table 2) suitable for most constructional purposes other than wearing-course aggregates.

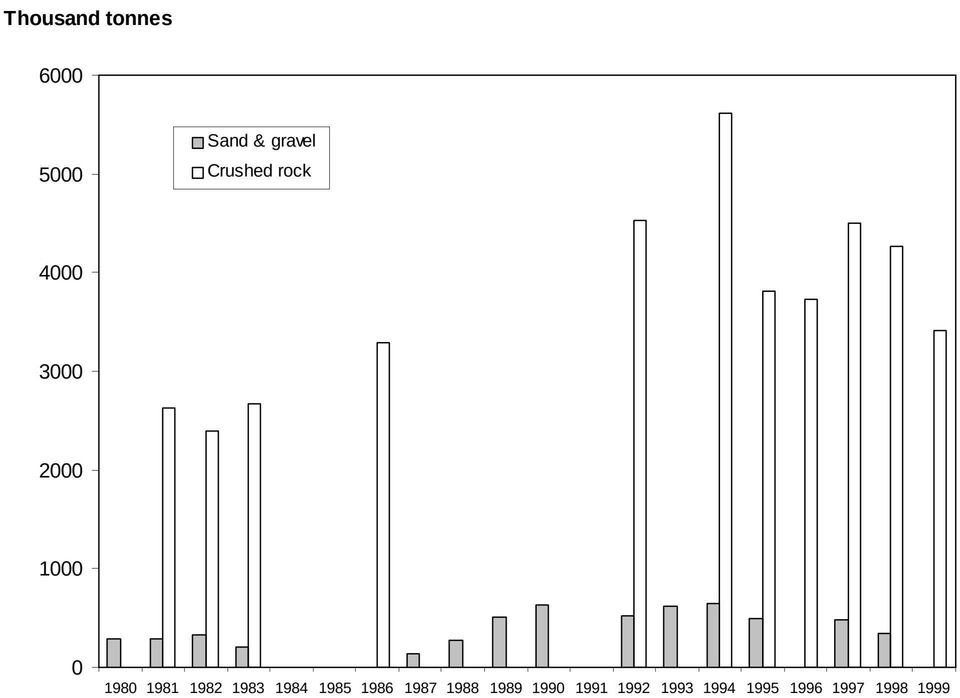

Figure 2. Production of sand & gravel and crushed rock aggregate in Co. Durham 1980–1999. Missing data withheld to protect commercial confidentiality.
Source: *Annual Minerals Raised Inquiry. Office for National Statistics*

IGNEOUS ROCK

The Whin Sill is an important resource of crushed rock aggregate in northern England. In County Durham, the finest exposures of the Whin Sill are in Teesdale, where there are continuous outcrops on the south side of the valley above Middleton-in-Teesdale. There are numerous disused quarries in the intrusion, but currently only one working quarry at Force Garth in Upper Teesdale. This produces concreting aggregate and good-quality roadstone (Table 2). The Whin Sill is a hard, fine- to medium-grained quartz dolerite, which is dark in colour. It is relatively consistent in its petrology and aggregate properties, although along the margins of the intrusions, the dolerite has been locally extensively altered to a softer, clay-like form, known as ‘white whin’.

The Whin Sill is a late Carboniferous sheet intrusion averaging around 30 m in thickness. It reaches a maximum thickness of up to 80 m in Upper Teesdale and is present at a number of stratigraphical horizons. At some localities, the intrusion consists of two layers, which may be separated by hundreds of metres of strata. The uppermost leaf is locally referred to as the ‘Little Whin Sill’ and is well exposed near Eastgate, Weardale, where it is some 12 m thick. The outcrop of the Whin Sill is shown on the map. Associated with the Sill are a number of dykes of similar composition which trend roughly east-north-east. The Hett dyke can be traced for some 32 km across the Durham coalfield.

The northwest-southeast Cleveland dolerite dyke (of Tertiary age) occurs in the Tees Valley. Although these were formerly worked for roadstone, they are too narrow to support a modern quarrying operation and have not been shown on the map.

SAND AND GRAVEL

Although conveniently grouped together, sand and gravel are separate commodities, the term 'gravel' currently being used for material which is coarser than 5 mm and the term 'sand' to material that is finer, but coarser than 75 μm. The principal uses of sand are as fine aggregate in concrete, in mortar and in asphalt, and the main use of gravel is as coarse aggregate in concrete. Substantial quantities of sand and gravel are also used for constructional fill. County Durham and the Tees Valley area produced some 602 000 tonnes of sand and gravel in 1998 (Figures 2 and 3).

The sand and gravel resources of the region may be divided into two broad categories;

- superficial, or ‘drift,’ deposits of Quaternary age, which are economically the most important,
- bedrock, or ‘solid,’ sand deposits within the Basal Permian Sands.

The variability of sand and gravel deposits together with their possible concealment within or beneath till (boulder clay), means that, compared with other bulk minerals, it is more difficult to infer the location and likely extent of potentially workable resources from geological maps. The properties which influence the economic potential of a sand and gravel deposit include:

- sand to gravel ratio
- proportion of fines and oversize material
- presence of deleterious rock types (such as coal or mudstone)
- thickness of deposit and overburden ratio

- position of the water table
- possible presence of unwanted interbedded material
- the ease with which material can be processed to produce a saleable product (clay fines are more difficult to remove than silt)
- location relative to demand

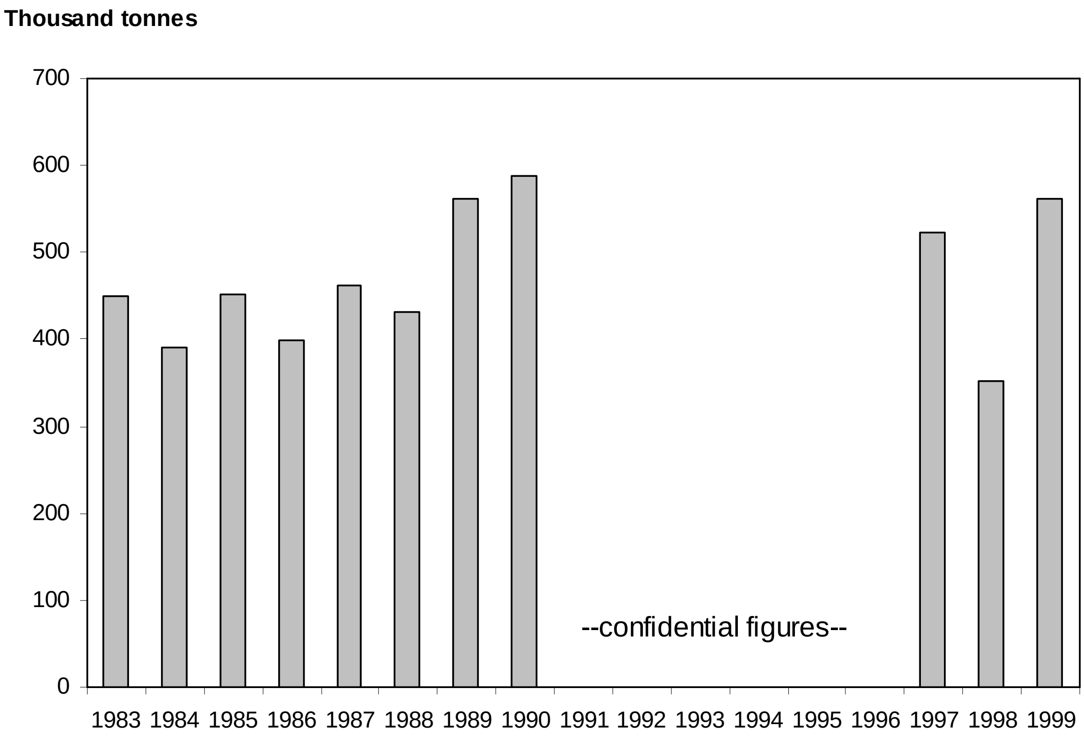

Figure 3. Production of sand & gravel in Cleveland, 1983 – 1999
Figures include marine dredged material. Missing data withheld to protect commercial confidentiality.
Source: *Annual Minerals Raised Inquiry. Office for National Statistics.*

Two methods have been used to show the distribution of sand and gravel resources on the map. Where BGS sand and gravel assessment has been undertaken, the resources defined by these surveys have been utilised. The boundaries of the survey areas are clearly shown on the map. Within these areas, the category 'concealed sand and gravel' is shown. This is defined by overburden to mineral ratios. Outside mineral assessment areas, the extent of sand and gravel resources have been inferred from available BGS geological maps, supplemented by the work of other investigations where available (Engineering Geology Ltd, 1989). Only sand and gravel present at outcrop is shown, although resources concealed by till may be extensive in some areas. As stated in the section on Mineral Resource Classification, the distribution of sand and gravel resources shown on the map is at the 'inferred resource' level, except in the mineral assessment areas where the data has be upgraded to 'indicated' resources. The physical criteria used by

BGS and Engineering Geology Ltd to define indicated sand and gravel resources are set out in Table 6.

	BGS Mineral assessment reports	Engineering Geology Ltd. Report
Deposit thickness	>1 m	>1 m
Overburden: sand & gravel ratio	3:1	3:1
Sieve size for which the proportion of fines passing should not exceed 40%	0.0625 mm	0.075 mm
Proximity of deposit to surface	25 m	25 m

Table 6. Physical criteria used by BGS and Engineering Geology Ltd to define indicated sand and gravel resources

Superficial deposits

Superficial deposits comprise all those sediments laid down during the last two million years. For the purpose of this report these materials have been divided into three groups:

- River sand and gravel
- Glacial sand and gravel
- Blown sand and beach deposits.

River sand and gravel

River sand and gravel includes post-glacial river terrace deposits, alluvial deposits and fluvioglacial deposits. The fluvioglacial deposits are included in this category as they tend to occur beneath river terraces, as well as underlying flood plain deposits (alluvium) and may be difficult to distinguish or, on older maps, undifferentiated. Sand and gravel quarrying operations based in river valleys will generally work both alluvial and underlying fluvioglacial deposits where present.

Alluvial sand and gravel is usually found in thin beds compared to the fluvioglacial deposits. Rivers gravels are generally well- to fairly well-graded with a moderate fines content. Alluvial gravels on the Wear are composed mainly of hard limestone of Carboniferous age.

The post-glacial river terrace deposits and alluvial deposits are developed along the major river valleys. Narrow belts of flood plain gravel are common in valleys in the west of County Durham. They are widespread and well developed in the Tees valley as high up as High Force, and are also relatively common in some of the larger tributaries such as the Greta. They occur along the Wear in the central lowlands of the county, but are present to only a limited extent in some of the deeply incised river channels which dissect the east Durham coastal platform. West of Darlington, alluvium is found along the River Tees where it consists of sand and silt with some pebbles. River sand and gravel in the Tees Valley to the west of Darlington has an average thickness of 4.6 m (Smith, 1979), 2.3 m to the east and south of Darlington (Gozzard & Price, 1982) and 2.5 m to the south of Stockton-on-Tees (Crofts, 1981).

Area	**Fines % (<0.063 mm)**	**Sand % (0.063-4 mm**	**Gravel % (>4 mm)**
West of Darlington	9	41	50
Sedgefield	10	39	51
North and west of Billingham	3	48	49 (one bh only)
East and southeast of Darlington	16	39	45

Table 7. Mean grading data for alluvium and river terrace deposits in those parts of Durham and the Tees Valley covered by BGS mineral resource surveys

Fluvioglacial sands and gravels are derived from glacial deposits and have been partially, but imperfectly, sorted by streams issuing from the melting glaciers which transported debris down the main valleys. These valley deposits are usually more regular both in depth and composition than the glacial material from which they are derived and tend to contain a higher proportion of gravel, much of the finer material having been washed out. They are generally well rounded and contain few flaky particles of mudstone. Fluvioglacial terraces are widespread in Tees valley and are also common in valleys now abandoned by the main river. Deposits on the Wear near Bishop Auckland are more constricted in their extent and are shallower.

Area	**Fines % (<0.063 mm)**	**Sand % (0.063-4 mm**	**Gravel % (>4 mm)**
West of Darlington	16	40	44

Table 8. Mean grading data for fluvioglacial deposits in the area west of Darlington.
(Source: *BGS data*)

Glacial sand and gravel

These deposits form the largest group of sands and gravels found in County Durham and the Tees Valley, although they tend to be more poorly graded, with a higher fines content and are generally more variable than the river sand and gravel.

They are ice-contact sediments laid down by streams flowing on the top, within and beneath ice sheets. Their relationship to the other elements of the drift sequence is complex, both vertically through the succession and laterally across the district. They are commonly associated with till (boulder clay) and commonly occur as lenses either within or beneath the till. The essential feature of these deposits, critical in terms of their economic value, is their variation in both thickness and composition. Glacial gravel beds may be up to 30 m thick but can disappear within a distance of a few metres. Similarly the composition of the deposits is highly variable (Table 9), although they are characteristically sandy. They are mainly derived from local rocks with the addition of some erratics and are characteristically 'dirty', often being polluted by small coal fragments as well as containing varying amounts of clay and silt. The nature of any one deposit depends very much on local conditions at the time of deposition.

Detailed sand and gravel surveys carried out in the south of the district by BGS in the 1970s and 1980s (Crofts, 1981; Gozzard & Price, 1982; James, 1982; Samuel, 1979; Smith, 1979) reveal considerable thickness of glacial sand and gravel. Average thicknesses of 8.3 m were recorded around Billingham, 6.8 m in the Sedgefield area and 8 m to the south and east of Darlington. Other resources in County Durham are in the vicinity of Chester-le-Street and Durham and to the north and west of Darlington. However, the deposits in the central lowlands of the county may contain a significant proportion of fines and considerable portions of deleterious material, particularly coal. The intimate association of the sands and gravels with glacial clays and silts within the complex drift sequence of central Durham makes it difficult to estimate resources. Deposits are relatively small in the upland areas. On the higher ground in the western half of County Durham thin outcrops are mapped along valley sides and follow the contours around hillsides, although with a reasonable spread in the valley of the River Tees east of Barnard Castle. County Durham deposits are composed of Carboniferous limestones, mudstones and sandstones with Magnesian Limestones in the south-east. Deposits on the Tees include igneous material derived from the Lake District. Pebble shape, which is important economically, tends to vary from deposit to deposit. Some gravels may be water worn and well rounded, but more usually the glacial material contains a high proportion of flaky mudstone particles which reduces its economic value.

Area	**Fines % (<0.063 mm)**	**Sand % (0.063-4 mm**	**Gravel % (>4 mm)**
West of Darlington	8 (locally 20)	43	49
Sedgefield	15	73	12
North and west of Billingham	16	73	11
East and south east of Darlington	Highly variable	Highly variable	Highly variable

Table 9. Mean grading data for glacial sand and gravel in those parts of Durham and the Tees Valley covered by BGS mineral resource surveys. (Source: *BGS data*)

Blown sand and beach deposits

Beach sands are found along the length of the Durham coast and are often backed by sand dunes. The sand dunes are rarely worked because of planning control. The area of beach worked usually lies between low water mark to within about 20 m of the dunes. The material is generally clean and of uniform grading, but contains salt which limits its commercial use. The material removed for use as a concreting and building sand is brought in by the tide and removed at regular intervals.

Blown or dune sands are of variable thickness. The deposit consists of uncemented sand composed of fine- to medium-grained subangular to rounded, commonly polished, quartz grains. Shell fragments and organic remains may be present.

Bedrock deposits

The Permian Basal Sands crop out intermittently along the base of the Magnesian Limestone escarpment and dip to the east beneath the limestone. They consist mainly of weakly cemented, yellow, fine to medium-grained, well-sorted sands of wind blown origin. They comprise a resource of fine aggregate and are mainly worked as a source of building sand, with some also being used as asphalting sand. Resources at outcrop are limited and the sands are now worked mainly in association with the overlying Magnesian Limestone both at the escarpment edge, as at Crime Rigg quarry, and where they have been exposed in the floors of quarries, for example at Thrislington and Raisby quarries which are substantial producers.

The sands occur in west-south-west to east-north-east trending ridges, which crop out along the base of the Magnesian Limestone escarpment and which continue beneath the limestone for some distance. These ridges are between one to two kilometres wide with sand thicknesses of up to 35 m and are separated by belts where the sands are thin or absent. Sand resources are thus contained entirely within the ridges.

COAL

The exposed Durham Coalfield occupies a broad outcrop over 32 km in width extending eastward from Consett towards the coast. East of a line through Ferryhill and Boldon and extending to the offshore area, coal-bearing strata dips beneath the overlying Permian rocks to form the concealed coalfield. The coals of Durham cover a range of rank from coking coals in the west to high-volatile bituminous coals in the east.

The Durham and Northumberland coalfield was perhaps the first British coalfield to be developed commercially. The earliest mention of coal-mining by the monks of Durham is in 1188, but workings only seem to have become important during the 14th century, when a considerable revenue began to be derived and continued throughout the monastic period until the 16th century. In 1820 a new era opened when Hetton Colliery was sunk through the Magnesian Limestone to the Hutton seam. Prior to that it was generally thought that no valuable coal existed beneath Permian strata. The next major breakthrough was in the development of coastal collieries at the beginning of the 20th century when techniques of drilling through the loosely-cemented Permian Basal Sands by means of freezing water-bearing strata were introduced. In its peak years of production almost the entire output of coal was obtained from underground mines. During the final years of deep mining coal extraction became concentrated in a handful of amalgamated coastal collieries in which workings extended up to 5 km offshore.

Exhaustion of reserves and economic factors has led progressively to the closure of all the mines and large-scale deep mining came to an end in 1993 with the closure of Vane Tempest Colliery. With the closure of the small Park Drift mine, near Willington, in 1999, all underground mining has ceased and production is now by opencast mining. Future commercial interest in the coalfield is likely to be confined to sites suitable for opencast extraction.

The coalfield has been extensively worked by opencast mining since the Second World War. Recent opencast coal production is shown in Figure 4 and has been on a declining trend in recent years. Only two sites were in production in March 2000.

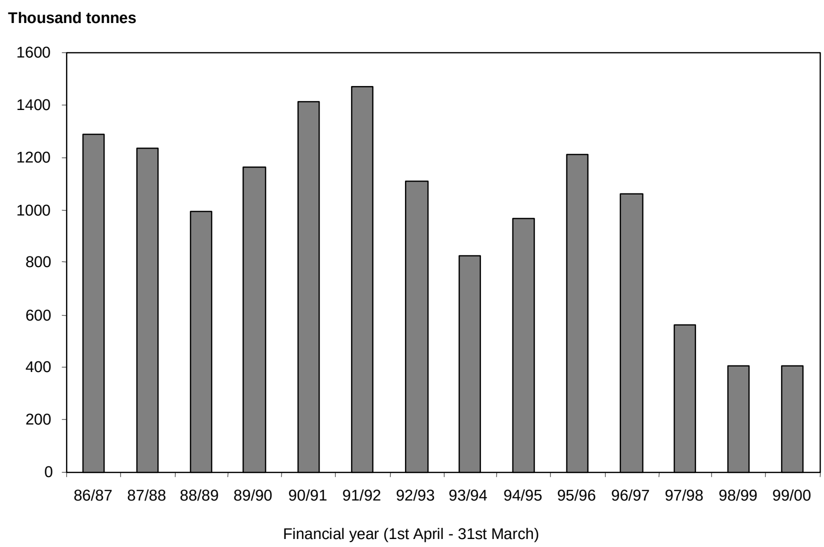

Figure 4. Opencast coal output in Durham by financial year
Source: *Opencast Coal Mining Statistics and the Coal Authority*.

Opencast activity is confined to the exposed Lower and Middle Coal Measures, the main concentration of coals of economic interest being between the Bottom Marshall Green seam and the High Main seam (Figure 5). The crop of the Bottom Marshall Green seam has been used to define the lower boundary of the principal opencast coal resource zone on the map. The upper limit of the principal resource zone is taken as the High Main, or the base of the overlying Permian strata that oversteps Coal Measures in east Durham. In the latter case, thick overburden precludes opencast coal extraction, except from the floors of large dolomite quarries. Strata comprising the more widely-spaced coals above the High Main seam have been classified as a subsidiary resource area. Opencast coal from Durham typically contains 0.04–0.08 % Cl and 1.8–2.8 % S (Minchener and Barnes, 1999).

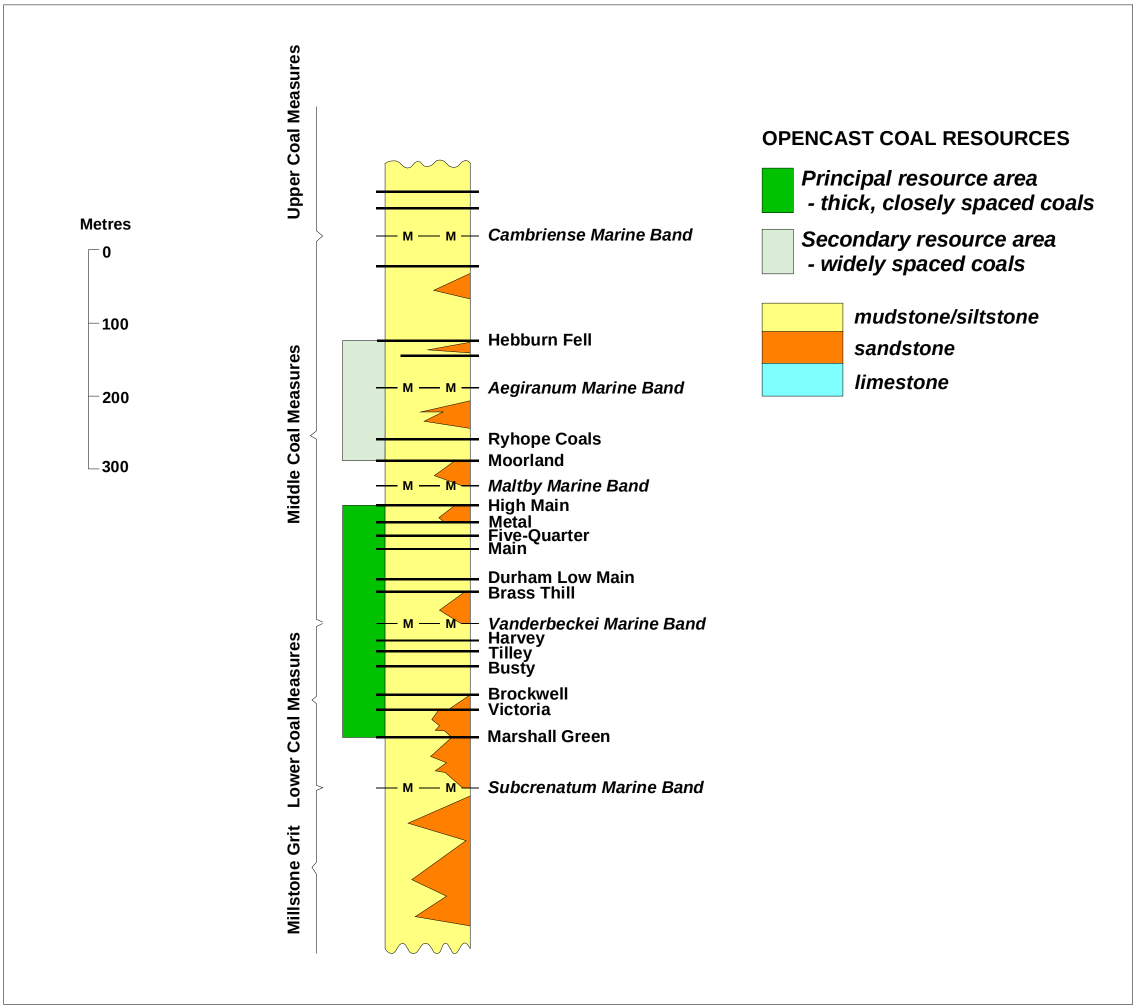

Figure 5. Generalised vertical section showing the Coal Measures succession in the Durham Coalfield

The characteristics of Durham coals have been described by Jones (1945). Although there is an impoverishment in certain of the lower seams towards the eastern part of the county, this trend is compensated by upper seams, so that in the sequence as a whole there is little variation in the thickness of seams developed. The recognition of this by Hickling (1949) was significant in prolonging the active life of deep mining in the coalfield by encouraging the extension of the mines beneath the sea.

Most of the coal seams in Durham are concentrated in the upper part of the Carboniferous succession, the Coal Measures. However, thinner seams are developed in the Namurian and Visean rocks lower in the succession. A number of the Namurian seams have been worked on a commercial scale including the Winston Coal between Darlington and Barnard Castle. Other coals in strata beneath the Coal Measures have been worked sporadically where locally thickened. These were used for household consumption, lime burning or smelting.

Areas of opencast coal extraction

The Coal Authority is a non-departmental public body which was established by the Coal Industry Act 1994. On 31st October 1994 it assumed responsibility for all the interests previously vested in British Coal in respect of unworked coal and coal mines and for the liabilities associated with past coal mining and unworked coal. The main functions of the Authority are to manage the coal resources under its control, encourage economically viable operations to work these resources, grant licences for coal exploration and extraction, provide effective management of subsidence damage claims, and provide information on past, present and proposed future coal mining activities.

For active sites, the extent of the current licence area for coal extraction issued by the Coal Authority is shown. All licences in Durham are opencast licences. Areas of extracted opencast coal are shown on the map, although these data may not be completely up-to-date. The Coal Authority's mining reports database contains information on past opencast coal mining activity, which is an aggregate of information derived from a number of sources. The areas shown on the map mainly reflect the limits of coal extraction. However, the recent entries into the mining reports database principally reflect site boundaries. More detailed information on specific sites may be obtained from the Coal Authority and the relevant mineral planning authority.

The extensive nature of these former opencast coal sites does not imply that the coal resource has been exhausted. The economics of coal extraction have changed with time, allowing coals with higher overburden ratios to be extracted. Some sites, or parts of sites, have been worked on more than one occasion and may be worked for deeper coal in the future. However, modern sites worked within the last 25 years are likely to have exhausted the economically recoverable coal resources. Extensive areas of the coalfield have been worked by deep mining but these are not shown on the map. This information may be obtained from the Coal Authority.

CLAY AND SHALE

Clay and shale are used mainly in the manufacture of structural clay products, such as facing and engineering bricks, pavers, clay tiles and vitrified clay pipes. Across the UK, brick manufacture is the largest tonnage use. Clays may also be used as a source of constructional fill and for lining and sealing landfill sites. The suitability of a clay for the manufacture of structural clay products depends principally on its behaviour during shaping, drying and, most importantly, firing. This behaviour will dictate the final properties of the fired product, including its strength, porosity (water absorption), durability and aesthetic qualities.

Small brickworks mainly producing 'common' bricks from locally won raw materials were formerly a common feature in many industrial areas of Britain and were particularly associated with coal mining. However, in the last two or three decades there has been a major rationalisation of the brick industry which is now based on a small number of plants operated by a limited number of companies. With the demise of the 'common' brick, the main products are now high-quality facing bricks, engineering bricks and related products such as clay pavers. Modern brickmaking technology requires a high capital investment and is increasingly dependent, therefore, on raw materials with predictable and consistent firing characteristics in order to achieve high yields of saleable products. Blending different clays to achieve improved durability and to provide a range of fired colours and aesthetic qualities is an increasingly common feature of the brick industry. Continuity of supply of consistent raw materials is of paramount importance.

Bricks are produced at two locations in County Durham. Both plants are in the Bishop Auckland area and are based primarily on Coal Measures mudstone won from on-site captive pits. These plants also consume varying tonnages of fireclay produced from a number of opencast coal sites in Durham. The plant at Todhills produces a range of red and buff facing bricks using the soft-mud process. Buff bricks are based on a blend of fireclays, the red bricks are made primarily from the mudstone. The Eldon plant produces a range of red and buff facing bricks using the extrusion process. Again, fireclay blends are used to make the buff product. This plant also produces Class ‘B’ engineering bricks from Coal Measures mudstone. Northumberland fireclays are said to be too refractory for use in these plants. A plant at Birtley, Gateshead, just outside the area, also uses the soft-mud process and produces facing bricks.

This unit uses a glacial lake clay of Quaternary age which is dug from a pit adjacent to the manufacturing site but which is in County Durham. This glacial clay is blended with a clay imported from outside the area.

Although Coal Measures mudstones are widespread in the Durham Coalfield, the occurrence of those which meet the requirements of the brick industry is far more limited. Brick clays must have consistent forming and firing properties which minimise production problems. In Coal Measures mudstones, illite/disordered kaolinite-rich materials with carbon contents of less than 1.5 per cent are preferred, along with less than 0.2 per cent sulphur. Clays of this type within the Coal Measures tend to be restricted vertically and will comprise only a small part of the sedimentary sequence.

FIRECLAY

Fireclays are non-marine sedimentary mudstones and occur as seatearths, the fossils soils on which coal-forming vegetation once grew, which underlie almost all coal seams. Resources are, therefore, mainly confined to coal-bearing strata. They consist of comparatively thin (usually <1.0 m), unbedded mudstones with rootlets. The term 'fireclay' is used to describe seatearths which are of economic interest and they are generally named after the overlying coal.

Originally fireclays were valued as refractory raw materials, because of their relatively high alumina and low alkali contents. Demand for fireclay for refractory use has, however, declined markedly since the late 1950s. This is mainly due to changing technology in the iron and steel industry where more severe operating conditions now demand much higher quality refractories. Only very small quantities of fireclay are now used for refractory applications. However, some fireclays may have relatively low iron contents compared with other brickmaking clays and they are now valued for the production of buff-coloured facing bricks and pavers. They are often blended with red-firing brick clays to give a range of fired colours.

Fireclays exhibit a wide range of mineralogical compositions and properties, both in terms of their vitrification characteristics and fired colour, the latter being largely a function of iron content. They consist essentially of the clay minerals kaolinite and hydrous mica, together with fine-grained quartz in varying proportions. Typically these three minerals make up some 90 per cent of the rock. Seatearths include all grades of sediment from mudstone (seatclay) to sandstone (ganister). Ganisters, or high silica sandstones, are comparatively rare, although they were formerly locally worked for refractory applications. Clay-rich seatearths, (seatclays), are much more common. Seatearths may exhibit rapid vertical and lateral variations in composition and thus properties All are contaminated to a greater or lesser extent by impurities which render part, or the whole, of a seam unusable. Siderite, present as both clay ironstone nodules of variable size and sphaerosiderite less than 1 mm in diameter, and carbonaceous matter, present as coaly matter and fossil debris, are common constituents. They may represent serious impurities in commercial fireclays and restrict their use. Pyrite, which is often associated with carbonaceous material, may also be present as an impurity. In addition to carbon and sulphur, which should normally be less than 1.5 per cent and 0.1 per cent respectively, fired colour is the main criterion on which the suitability of a fireclay is judged for facing brick manufacture. Iron oxide contents should normally be less than 2.5–3.0 per cent Fe_2O_3 and on firing the fireclay should give a uniform buff/cream colour. However, depending on how the iron occurs, higher iron contents may be tolerated. The majority of seatearths are unsuitable for use, and fireclay production is localised both geographically and geologically.

The close association of fireclay and coal means that opencast coal sites provide one of the few viable sources of fireclay from which they are derived as a by-product. Fireclay resources are thus essentially coincident with shallow coal resources. However, only a small proportion of opencast coal sites normally produce fireclay. This may be due to the variable quality of the fireclays, or may be the result of operational or planning restrictions. However, the size and speed of opencast mining invariably creates a mismatch between potential supply and immediate market demand. Unless marketable fireclays can be stockpiled, either on or off site, they are usually backfilled with overburden and irrecoverably lost.

The Durham Coalfield has historically been an important source of fireclay. Up to the Second World War, before the advent of opencast coal mining, all fireclay was extracted by underground mining. The last two fireclay mines near Bishop Auckland closed in 1975. Fireclay production is now dependent on the level of opencast coal activity, which in recent years has been declining (Figure 4) with a resulting decrease in the supply of fireclay. Several fireclays within the Lower Coal Measures are of economic interest for brick manufacture, most notably those associated with the Tilley and Busty seams, but also the Victoria and Brockwell. Fireclay is transported to brick factories locally and in Lancashire, Yorkshire and the Midlands for the manufacture of buff bricks.

BUILDING STONE

Sandstones are the principal building stone resource in County Durham and the Tees Valley area. Sandstones are accumulations of sand-size particles composed predominantly of quartz, with variable amounts of feldspar and rock-fragments, set in a fine-grained matrix of cementing material. Sandstones are precisely defined as sedimentary rocks composed of mineral grains that lie in the size range 0.063–2 mm and are described as fine, medium or coarse grained within these limits.

The suitability of a sandstone for building stone depends not only on strength and durability, but also on aesthetic qualities and textural consistency, as well as the size of block that can be produced. A continuing supply of building stone for new building work and for restoration is important to maintain local vernacular architecture. Building stone quarries are often small and based on resources of only local significance. For this reason, the extent of the resource is not shown on the map.

Good building sandstones demonstrate two principal characteristics. Firstly a durable mineralogical framework of detrital grains, most commonly sand-sized quartz and feldspar. Secondly resistant natural intergranular mineral cements including silica, various carbonates and clay minerals, which rigidly bind the grain framework together.

In the selection of sandstone for building purposes, several other parameters are often measured and considered. These include properties such as colour, porosity and bed thickness. For example, sandstones with low porosity values are generally able to withstand the effects of constant wetting and drying and/or freezing caused by water penetration during the weathering cycle.

In Durham, as elsewhere in Britain, Carboniferous sandstones are highly valued as a source of building stone. This is because of their hardness and general durability (Table 10). The Carboniferous rocks in the area which have yielded building sandstones principally comprise the Stainmore Group (Namurian age), which includes the Millstone Grit, and the Coal Measures (Westphalian age).

The quarrying of Carboniferous sandstone in the Durham area for building purposes dates back to at least the 12th century. This is evident from the substantial ashlar sandstone blocks of the Norman castle and cathedral in Durham city. Both secular and non-secular buildings were principally constructed of local Carboniferous sandstone from medieval times onwards.

The modern building sandstone industry is, however, largely a product of Britain's industrial revolution. Peak production was from the 19th to the early part of the 20th century. Throughout most of this period, a large number of quarries were actively supplying sandstone for public buildings, industrial constructions (such as railway bridges and docks) and housing in cities and towns county-wide.

The most important production of sandstones came from quarries in the Stainmore Group at Dunhouse, Shipley Bank and Stainton. These quarries remain in operation. Sandstone was also obtained from quarries at East Westerton and Pensher in the Coal Measures succession (Hunt 1860).

Today there are nine building sandstone quarries in operation in County Durham. Production is currently concentrated on sandstones of uniform colour (buff, pale yellow and grey) and fine to medium grain-size. Coarser granular and pebbly sandstones or gritstones which were once popular are now generally less commonly worked. Durham sandstones are widely used in the north east. They are also exported further afield, particularly to cities and towns elsewhere in England and in Scotland. A considerable amount of Durham sandstone is used for buildings in Edinburgh.

Quarry/ Commercial rock name	Nearest town	Colour	Grain-size	Crushing strength MN/m^2	Density kg/m^3	Porosity %	Age / formation
Baxton Law	Hunstanworth	Buff	fine				Carboniferous, Stainmore Group
Castleside	Consett	Buff	fine				Carboniferous, Coal Measures
Catcastle	Barnard Castle	Creamy buff	medium to coarse	53	2400-2600	11.5	Carboniferous, Stainmore Group
Dead Friars	Stanhope						Carboniferous, Stainmore Group
Dunhouse	Bishop Auckland	Creamy buff	fine	55.49	2400-2600	18.1	Carboniferous, Stainmore Group
Harthope Head	Weardale						Carboniferous, Stainmore Group
Quickburn	Satley						Carboniferous, Coal Measures
Shipley Banks	Barnard Castle	Buff	fine	43.5			Carboniferous, Stainmore Group
Stainton	Barnard Castle	buff, brown speckles	fine	48	2220	17	Carboniferous, Stainmore Group
Windy Hill	Barnard Castle	Pale brown					Carboniferous, Stainmore Group

Table 10. Building sandstone quarries in County Durham

SILICA SAND / ROCK

Deeply weathered sandstones within the Millstone Grit were formerly extensively worked to the north west of Wolsingham for use as naturally bonded foundry sands. There are two basic types of foundry sand; naturally bonded, which contains sufficient clay to give the mould strength without the addition of a bonding agent, and clay-free or washed foundry sand, which requires the addition of a bonding agent, either clay (usually bentonite) or a chemical/resin.

Naturally bonded sands were formerly of great importance to the early development of the foundry castings industry, but their properties are difficult to control and they are little used today. However, small amounts are still produced at Weatherhill, north of Stanhope but the sand is mainly used to optimise the chemistry of the feed for the manufacture of cement at Eastgate. The sandstone bed worked is the highest in the Millstone Grit and its outcrop is shown on the Mineral Resources map. The rock is poorly cemented and friable and contains kaolinite.

The term ‘silica rock’ (or silica stone) is a commercial term used to describe a well-cemented, even-grained rock consisting essentially of quartz from which silica bricks and other silica refractories are manufactured. Both ganister (highly siliceous seatearths) and quartzitic sandstone have been extensively worked from rocks of Carboniferous age in Durham for use in the manufacture of silica refractories. However, rapid changes in refractory technology in the iron and steel industry, and particularly the replacement of the open-hearth furnace by basic oxygen steelmaking and electric arc furnaces, has resulted in a rapid decline in the demand for silica refractories since the late-1950s. The manufacture of silica refractories has now ceased in Britain. The requirements for silica rock for refractory manufacture were a high silica content, (> 97 per cent SiO_2), together with low alumina and alkalis, and a hard rock with a high bulk density and low porosity. The latter properties also make some silica rock resources potentially suitable for aggregate use and for building stone. They include quartzitic sandstone in which the detrital quartz grains are cemented by secondary silica to form a hard compact rock.

In the northern Pennines some of the quartzitic sandstone beds within the Millstone Grit are sufficiently pure to have been used in the manufacture of silica bricks, and Durham was formerly an important source of supply. The only deposit to have been of economic interest in more recent times was worked at Harthope quarry in Weardale. The deposit consists of a quartzitic sandstone bed some 6 m thick which occurs beneath the Upper Felltop Limestone. The deposit is now worked for building stone. A typical chemical analysis of this material is shown in Table 11.

wt %	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	TiO_2
	97.5	0.9	0.5	0.03	0.15	0.1

Table 11. Chemical analysis of selected quartzitic sandstone from Harthope Quarry, Weardale. Source: *Highley, 1977*

CEMENT

Portland cement clinker is manufactured by heating an intimately homogenised and controlled mixture of calcareous and clayey raw materials to partial fusion (typically at 1400°–1500°C). Small amounts of iron oxide and sand (silica) may be added to optimise the mix. These raw materials supply the lime, silica, alumina and iron oxide necessary for the formation of the calcium silicates and smaller quantities of calcium aluminates that constitute cement clinker. The clinker is cooled and then finely ground, typically with 5 per cent gypsum/anhydrite, to form the final cement. Gypsum/anhydrite is introduced to control the initial rate of reaction with water and to allow concrete to be placed and compacted before hardening commences. Limestone provides lime for the production of cement clinker and typically accounts for 80–90 per cent of the raw mix. Clay or shale accounts for some 10–15 per cent and provides most of the silica, alumina and iron oxide. Cement-making is highly capital intensive and cement plants are normally located in close proximity to the main limestone raw material.

Cement manufacture is based on the Carboniferous, Great Limestone at Eastgate in Weardale. The mudstones overlying the Great Limestone, and which are removed as overburden, are used as the principal source of silica, alumina and iron oxide. Locally won silica sand is brought into the plant, together with some iron oxide, to optimise the chemistry of the raw feed. Two types of cement are produced at the Eastgate works, Ordinary Portland Cement (OPC) and sulphate resistant cement. The latter requires a higher iron and silica content than OPC. The clinker capacity of the plant is 678 000 tonnes a year, and some 1.6 tonnes of dry raw materials are required to produce a tonne of cement clinker. Finished cement is dispatched by road.

HYDROCARBONS

Conventional hydrocarbons

Fifteen exploration wells have been drilled in the area. Thirteen of these (the Redcar and Kirkleatham groups of boreholes) are on an anticline near Redcar.

The Redcar G1–G10 boreholes were drilled by the Anglo-American Oil Company in 1939. Their purpose was to define and test a surface anticline recognised in the Lower Lias. The boreholes did not encounter any oil or gas shows. Three boreholes at Kirkleatham were drilled by D'Arcy Exploration Co. Ltd. between 1945 and 1963. The purpose of these wells was to test the concept that gas or oil generated from Carboniferous coals and mudstones would be found in commercial quantities in the Permian Magnesian Limestone and Permian Basal Sands. Gas shows were encountered in the Magnesian Limestone in Kirkleatham 1. This produced some

2 070 m^3 of gas per day from the interval 860–904 m. This was, however, considered non-commercial. Only minor shows of oil and gas were otherwise encountered in the three boreholes.

Gas has also been encountered in boreholes in the Magnesian Limestone in North Yorkshire. However, the Magnesian Limestone is generally considered to be unsatisfactory as a reservoir because its permeability is largely controlled by fractures. This makes it difficult to estimate the size of resources and renders it prone to premature water breakthrough.

The Brafferton well (near Newton Aycliffe) drilled by Enterprise Oil in 1989 and the Scaling well (between Guisborough and Whitby) drilled by Shell in 1987–88 were both plugged and abandoned without testing. No significant gas or oil shows were recorded in either well.

The gas found in the Kirkleatham 1 well indicates that there has been gas generation and/or migration in the area Current exploration activity indicates that the area is still considered prospective, and it is likely that small numbers of exploration wells will continue to be drilled. Candeca Resources currently hold two petroleum licences in the area: (PEDL 002 and PEDL 029).

Coalbed methane

Methane is one of the main by-products of the natural process of coalification, which is the low-grade metamorphism of peat through lignite to coal and anthracite. Some of this methane migrates from the source rock as it is formed and some remains within the coal bed. The recovery of coalbed methane involves entering the coal by boreholes, then fracturing and depressurising the coal bed to facilitate desorption and degassing of the methane.

The average methane content of seams in the Durham/ Northumberland coalfield is 1.3 $m^{3/}$t (Creedy, 1991). Most commercially-extracted coalbed methane comes from seams with more than 7 m^3/t of coal. These low gas contents, together with intensive past underground working for coal, make the Durham coalfield unattractive for coalbed methane exploitation.

The outlier coalfields in the west of County Durham are not considered prospective for coalbed methane. A similar situation prevails in the coal-bearing strata lower in the Carboniferous succession. Coal seams in the Millstone Grit and Limestone Coal groups are considered to be too thin and/or shallow to form prospects for coalbed methane.

EVAPORITE MINERALS

Evaporite minerals, including gypsum and anhydrite, halite (rock salt), and, more rarely, potash and magnesium salts, are precipitated during the evaporation of seawater. The arid conditions that existed during Permian times in north-east England resulted in several cycles of evaporite deposition. The most extensive led to the deposition of the Billingham Anhydrite Formation and the overlying Boulby Halite Formation, which includes the Boulby Potash Member. These deposits are of considerable economic importance. The Billingham Anhydrite was extensively mined on Teesside between 1927 and 1971 as a source of sulphur for the manufacture of the fertiliser ammonium sulphate and sulphuric acid. The Boulby Halite formed the basis of the Teesside chemical industry and is still worked today by brine pumping. The Boulby Potash is Britain's only source of the fertiliser raw material potash. It is mined at Boulby Mine, which is located in that part of Redcar and Cleveland, falling within the North York Moors National Park.

Salt

Halite (sodium chloride, NaCl) or 'rock salt' of Permian age underlies extensive parts of Teesside and the major chemical industry in the area was originally based on these large deposits. The resource comprises the Boulby Halite Formation and is up to 90 m thick in north-east coastal areas but thins gradually westward before dying out abruptly due to dissolution near the outcrop. Salt-bearing strata do not crop out at surface because of dissolution by groundwater. Most of the area to the north-east and east of Middlesbrough is underlain by salt and the deposits extend offshore. The sub-surface extent of the Boulby Halite, and its conjectured western limit, is shown on the mineral resources map. The Boulby Halite is present in the Boulby potash mine from which large tonnages of rock salt are produced as a co-product. The Boulby Halite lies below the potash bed and achieves a total thickness of about 40 m. About 8–10 m below the potash bed is a bed of relatively pure and strong halite through which the mine's principal roadways are driven. Rock salt is produced from the arterial roadways which are mined to maintain access to the current potash mining areas and to explore and develop new areas for potash production. Salt production was 483 000 tonnes in 1999 and is sold for de-icing roads. The Boulby Mine is one of only two mines producing rock salt in Great Britain.

Salt was discovered in Permian strata on Teesside in 1859–62 and commercial brine pumping began between 1876 and 1882, with the first recorded salt production in 1888. The salt was originally worked by allowing water from the overlying Sherwood Sandstone aquifer to flow down the well and into the salt bed. The resulting brine was extracted through a central pipe. Dissolution tended to occur principally in the upper part of the bed, because of the lower density of freshwater compared with brine, giving rise to uncontrolled lateral cavity extension and some subsidence around Haverton Hill and south of Saltholme. Brine was also pumped south of the Tees near Grangetown.

Current brine extraction by ICI is in an area to the north of Saltholme Farm (NZ 503 233) at depths of over 300 m. Extraction is by controlled brine pumping which removes by dissolution about 25 per cent of the exploitable resource. Single voids, or cavities, are created in the salt bed and the size and the shape of these cavities is designed to maintain the stability of the overlying strata and so avoid surface subsidence. Each cavity is developed through a single borehole containing two moveable concentric tubes. Water is raised from local boreholes in the sandstone aquifer and pumped into the cavities through the outer of these tubes and brine is continuously displaced through the centre tube. Once the cavity has enlarged sufficiently, usually after about two years, this process produces saturated brine. The position of the water injection tube and the depth of an air blanket, which is used to prevent upward development, control the area of salt dissolution. By changing the position of these during development, the final size and shape of the cavity can be controlled. During the development the size and shape of the cavity is monitored by sonar techniques. The brine wells are laid out on a regular grid with new wells being drilled to replace completed solution cavities, some of which are used for storage purposes. Controlled brine pumping has taken place on Saltholme and Cowpen Marshes, to the west of Seal Sands. Extraction started in the south and has gradually moved northward.

The Boulby Halite is 30–40 m thick in the brinefield, although locally it may be thicker in flow structures and thinner or absent against dislocations. The salt bed dips gently to the east. Brine is used by ICI as a feedstock for the manufacture of chlorine by electrolysis: caustic soda (NaOH) is produced as an important by-product. Chlorine is the feedstock for the production of a wide range of products. Salt-in-brine production is some 300 000 tonnes a year. Brine extraction for the production of white salt was formerly carried out in the area south-east of Marsh House Farm (NZ 501 264) and north of Greatham Creek, but production ceased in 1969.

The salt resources on Teesside are not comparable in size and thickness to those within the Cheshire Basin. Nevertheless, they support the only brine operations in Britain outside Cheshire, and provide an essential raw material for the local chemical industry.

Potash

Potash is a generic term for a variety of potassium-bearing minerals and refined products. Potassium (K) is one of the three primary nutrients, with nitrogen and phosphorus, that are essential for plant growth. About 95 per cent of potash production is consumed in the manufacture of fertilisers and the balance is consumed in the chemical and pharmaceutical industries. The soluble mineral sylvine (potassium chloride - KCl) is by far the most important source of potash worldwide and has accounted for all the potash produced in Britain to date. As a fertiliser nutrient, potash has no substitute and cannot be recycled.

In the last 25 years Britain has emerged as a significant world producer of potash with the development of the Boulby Mine near Loftus. Potash resources were first discovered at depth within Upper Permian strata in North Yorkshire during exploration for oil in 1939. Further exploration was undertaken in 1948 and later in the 1950s, 60s and 70s. Shaft sinking for the Boulby Mine began in 1968 and was completed for production in 1976, although some production was possible from a single shaft by 1973. Output has steadily increased and was a record 1 030 000 tonnes of refined KCl in 1996. Production declined to 824 000 tonnes in 1999 as a result of a water inflow but returned to normal levels by the last quarter of the year. Some 55 per cent of the output is exported through Tees Dock and the mine supplies about 55 per cent of the UK potash market. The Boulby Mine is Britain's only potash mining operation. Two other proposals to extract potash in North Yorkshire, one of which involved solution mining, were permitted in the late 1960s, but were never implemented.

The Boulby mineshaft and associated facilities, although situated within Redcar and Cleveland Borough, fall within the North York Moors National Park, which is the Mineral Planning Authority. Much of the southern mining area is located beneath the National Park and falls outside the current map area. However, the northern mining area extends into Redcar and Cleveland outwith the Park. The eastern and northern mining district extends out beneath the sea.

Mining is confined to a single bed, the Boulby Potash Member, which occurs at the top of the Boulby Halite Formation. The bed dips at a shallow angle from north-west to south-east and occurs at depths of over 1300 m in southern onshore areas and 800 m offshore in the north. The sub-surface extent of the Boulby Potash and its conjectured western limit is defined on the Mineral Resources map. Mining operations extend some 7 km from the shaft bottom and cover an area of about 40 km^2. The Boulby Potash averages 7.5 m in thickness, ranging from 0 to over 30 m. The bed consists of sylvinite, a mixture of sylvine and halite, with minor clay minerals and anhydrite, and traces of other minerals. The ore is of high grade by international standards with a mean KCl content of 34 per cent (21 % K_2O). However, grade varies both vertically and laterally and mined grades are typically 38–41 per cent KCl (24–26 per cent K_2O). The potash bed has a sharp basal content with the underlying rock salt and a less distinct and undulating upper contact with the overlying Carnallitic Marl. This is a weak rock and at least two metres of potash are left in the roof for safety reasons. Mining is remotely operated by continuous miners in a specialised form of room and pillar mining.

A stratigraphically higher, but less extensive evaporite succession in north-east England, the Sneaton Halite Formation, also includes the Sneaton Potash Member. These deposits are not currently of economic interest and do not extend as far northwest as the Redcar and Cleveland boundary.

In the extreme east of the area and extending offshore, extensive resources of a lower grade potash mineral, carnallite ($KCl.MgCl_2.6H_2O$), occur as a replacement of the lower part of the Boulby Potash and significant quantities of polyhalite ($K_2SO_4.MgSO_4.2CaSO_4.2H_2O$) are present in the lower evaporites. The potential for mining these minerals is being investigated.

Gypsum / anhydrite

Gypsum ($CaSO_4.2H_2O$) and anhydrite ($CaSO_4$) are the naturally-occurring forms of calcium sulphate which normally occur as beds or nodular masses up to a few metres thick. The gypsum here is secondary, formed by the hydration of anhydrite at or near surface, but passes into anhydrite generally at depths of more than about 100 m. Anhydrite is, therefore, very much more extensive than gypsum and Britain's anhydrite resources are extremely large. Several gypsum/anhydrite beds occur in strata of late Permian (Zechstein) age in north-east England. Gypsum is highly soluble and dissolves rapidly at or near surface and may give rise to subsidence problems. Its presence near surface may be unpredictable. Gypsum has not been produced on any significant scale in the area. Anhydrite, however, was formerly extensively mined on Teesside and between 1923 and 1955 virtually all the production of anhydrite in Britain was derived from the area. Britain is deficient in sulphur resources and anhydrite, which in its pure form contains 23.5 per cent sulphur, is the only naturally-occurring form of the element to have been worked on any scale. However, anhydrite is no longer of economic importance as a source of sulphur. Gypsum is used principally in the manufacture of plaster and plasterboard. A mixture of gypsum/anhydrite is also used as a retarder in the production of cement.

Permian rocks crop out in a relatively narrow belt from the Durham coast southward into Yorkshire. The strata dip gently eastward with the succession gradually thickening in this direction. Anhydrite is present at depth throughout most of the area and occurs at several horizons. In ascending order these are; the Hartlepool Anhydrite, the Permian Middle Marls, the Billingham Anhydrite and the Sherburn Anhydrite. The Hartlepool Anhydrite, which is up to 150 m thick, occurs near the surface in the Hartlepool area. Thinner deposits occurring as gypsum at outcrop are also present to the south and south-west. The Billingham Anhydrite and the Sherburn Anhydrite are much thinner but more uniform in thickness and extent. The anhydrite in the Middle Permian Marls is not as extensive but is over 20 m thick over significant areas. The Billingham Anhydrite has been of considerable economic importance in the past and together with the Hartlepool Anhydrite, its conjectured western limit is shown on the Mineral Resources Map.

The most prospective horizon for gypsum is the 4–7 m thick Billingham Anhydrite Formation. However, the bed has been affected by both gypsification and dissolution near outcrop over a 2–3 km wide belt. As a result the presence of gypsum cannot be predicted with certainty at any one location. In addition, the gypsum has a high soluble halite content which is a disadvantage. Exploration for gypsum has been carried between Great and Little Stainton and north-eastward to the west of Sedgefield, but there has been no production.

The Hartlepool Anhydrite was mined on four separate levels at the Warren Cement Works Mine (NZ 516 345) in Hartlepool between 1923 and 1930 for use by ICI at Billingham in the manufacture of the fertiliser ammonium sulphate. The anhydrite was of poor quality, being contaminated with dolomite, and production ceased when the Billingham Mine came on stream. The Billingham anhydrite mine was sunk to a depth of 260 m in 1926 to extract the Billingham Anhydrite Formation, mining being at an average depth of about 220 m. Initially, anhydrite was used in the production of ammonium sulphate, but subsequent technical and economic studies showed that it could also be used in the production of sulphuric acid. Cement was produced as a valuable by-product. However, demand for ammonium sulphate declined rapidly in the late 1960s. In addition, due to the availability, both current and foreseen, of cheap and plentiful supplies of sulphur, the economics of producing sulphuric acid from anhydrite became increasingly unattractive. The production of sulphuric acid from anhydrite ceased on Teesside in 1971, and elsewhere in Britain in 1975. Of cumulative UK output of anhydrite estimated at some 52 million tonnes, some 31 million tonnes was derived from the Billingham mine until its closure in 1971. It is difficult to foresee anhydrite being used as a source of sulphur in the foreseeable future. Since the closure of the mine consideration has been given to its use for the storage of a number of materials but none has come to fruition, and the mine is now flooded.

VEIN MINERALS

The veins and associated deposits of the Northern Pennine Orefield (a large part of which lies within County Durham) have a long history of production of metal ores. The most important of these were lead (galena - PbS) and iron, with some by-product silver. Zinc ores (mainly sphalerite - ZnS) have been mined locally. Total production of lead concentrates for the whole orefield has been estimated at some 3 million tonnes and peak metal mining activity was achieved in the mid to late 19th century. Mining for metal ores as the principal product ended in the late 1930s. However, small but valuable quantities of lead and some zinc concentrates have been produced as by-products of fluorspar mining. Like other associated gangue minerals, fluorspar was discarded as a waste product during lead mining, for which these veins were mainly first worked. Its emergence as a valuable industrial mineral during the closing years of last century led to the reworking of several mines specifically for fluorspar, together with its recovery from numerous mine dumps. County Durham played a major role in the development of the British fluorspar industry. Large tonnages, estimated at some 2 million tonnes, have been raised, mainly from mines in Weardale. However, fluorspar mining in Durham ceased in 1999 and is unlikely to resume under current market conditions. Small-scale production of baryte from one site continues in Lunedale, near Middleton-in-Teesdale.

Mineral exploration during the last thirty years by both the private (Mineral Exploration Industry Grants Act 1972 [MEIGA]-sponsored) and public (DTI-sponsored Mineral Reconnaissance Programme) has been low key and focused on looking for extensions to the known vein and replacement style base-metal-baryte and fluorite mineralisation (Figure 6). This work has assessed the likelihood of finding base-metal deposits similar to those worked economically in Ireland. No major discoveries of economic significance have been made, but some potential still exists for new mineral deposits to be found and worked in the North Pennines.

The most numerous mineral deposits of the Northern Pennine Orefield in County Durham comprise vein fillings within faults which cut the Carboniferous rocks and Whin Sill. In addition, intense mineralisation of limestone, and locally dolerite, wall-rocks adjacent to several major veins has produced a number of important replacement deposits, commonly referred to locally as flats . These vein and flat deposits are most numerous within the Pennine uplands and dales, though more widely spaced veins within the Durham Coalfield comprise an outer expression of the orefield.

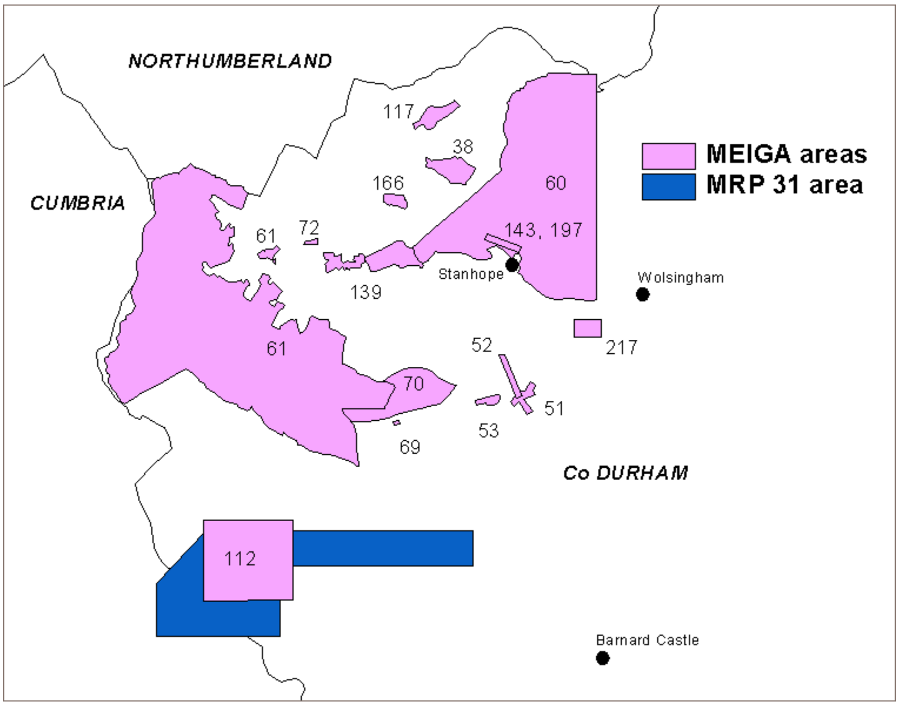

Figure 6. Location of MEIGA and MRP exploration areas in County Durham

A notable characteristic of the Northern Pennine Orefield is the very well-marked zonal distribution of constituent minerals within the deposits (see Mineral Resources map). Although the details are complex the essential feature is the presence of abundant fluorite within the deposits in the centre of the orefield with barium minerals predominating in the outer, marginal, zones. Within the Northern Pennines the distinction between these zones is sharp: fluorite and barium minerals are almost mutually exclusive in their distribution and very rarely occur together.

Wall-rock lithology exerts a vital influence on vein width and productivity throughout the orefield. Veins are typically wider and well mineralised between hard or competent wall-rocks such as most limestones, many sandstones and the Whin Sill. Where mudstone or soft sandstone forms the walls veins are generally barren or only weakly mineralised. The alternation of hard and soft wall-rocks throughout the field has resulted in vein oreshoots being characteristically much more restricted in vertical height than in strike length.

Fluorspar

Fluorspar is the commercial term for the mineral fluorite (CaF_2), the only major source of the element fluorine. Fluorite is principally valued for its chemical properties and most fluorspar ore is produced for the manufacture of acid-grade fluorspar. The latter contains > 97 per cent CaF_2 and most is used in the manufacture of hydrofluoric acid, the starting point for the production of a wide range of fluorine-bearing chemicals. Fluorspar production began in

Britain at the turn of the century following the introduction of the Basic Open Hearth steelmaking process in which fluorspar was used as a flux. However, the replacement of the Open Hearth Furnace by Basic Oxygen Steelmaking, in which fluorspar is only used sparingly because of its effects on refractory linings, has significantly reduced demand in the steel industry.

Fluorspar mining in the Northern Pennines has had a chequered history over the last 20 years. Increasing demand for fluorspar, both from the chemical and steel industries during the late 1960s and early 1970s, stimulated exploration activity and led to an increase in mining and processing capacity. Swiss Aluminium Mining's (SAMUK) 80 000 tonne/year Broadwood plant at Frosterley and British Steel's 80 000 tonne/year Blackdene plant, near St John's Chapel were commissioned in 1978 and 1979, respectively. However, declining demand for fluorspar, both in the home and export market, stimulated a much-needed rationalisation of the industry. In 1982/83 the fluorspar interests of both SAMUK and the British Steel Corporation came under the single ownership of Minworth plc. The former operated under the name of Weardale Minerals Ltd and the latter Weardale Mining and Processing Ltd. However, the high cost of underground mining and ore development proved to be unsustainable in the face of low cost imports and Minworth plc went into receivership in 1991. The interests of Weardale Minerals Ltd and Weardale Mining and Processing were offered for sale and Sherburn Stone Co Ltd acquired the assets of Weardale Minerals Ltd in 1991. The company operated the Frazer's Hush and Groverake mines in Rookhope, for a number of years, although these operations closed during 1999. These were commonly referred to by their combined name of Frazer's Grove.

Whereas most veins within the centre of the field contain significant quantities of fluorite, workable concentrations appear to be confined to certain types of vein structure. With a few minor exceptions the major fluorspar deposits were found within the so-called quarter-point veins. These comprise a relatively small number of veins, or vein systems, which typically exhibit a roughly E-W trend. Whereas vein widths of over 6 m were common, often composed mostly of fluorite, lead values were characteristically low and thus considerable lengths of these veins were comparatively little worked by the lead miners. Experience has shown that these veins typically are widest and most productive where their strike direction most nearly approaches E-W. The major fluorite-bearing veins are shown on the map.

Grades of crude ore mined have generally varied between about 40 and 75 per cent, though in recent years lower grade ore has been worked from Frazer s Grove mine.

More than a century of mining and exploration have resulted in the extraction of virtually all known fluorspar-rich spoil in dumps and backfill in old workings. Underground mining has removed the most accessible deeper reserves. Future fluorspar production depends upon identifying and accessing downward extensions of major orebodies and perhaps on locating new orebodies in poorly exposed ground on lateral extremities of major vein structures.

Barium minerals

Barium minerals are major components of veins in the outer zones of the Northern Pennine Orefield. Most abundant is baryte ($BaSO_4$) though the orefield is renowned for the abundance of barium carbonate minerals, the most common of which is witherite. Baryte and witherite have both been important mineral products of County Durham; baryte production continues today at only one small site.

Baryte and witherite, like fluorspar, were regarded as waste products of lead mining until they too became valuable commodities towards the end of last century. Several old lead mines, particularly in Teesdale were reopened for baryte production and substantial tonnages were raised. Only one operation remains in production in the county today. Closehouse Mine, near Middleton-in-Teesdale, works baryte by openpit methods from a wide vein and associated replacement deposits within the Lunedale Fault System. The fault is here occupied by a wide dolerite dyke belonging to the Whin Sill suite. Baryte occurs as fracture fillings and replacements in the dolerite and associated rocks. Much of the richest baryte-bearing ground has now been extracted at Closehouse. Investigation of the deposit beneath the previously worked levels are understood to have been disappointing. There is some scope for exploration for further reserves to the west and east of the existing workings.

Substantial quantities of witherite, and some baryte, were extracted from veins in the Durham Coalfield until the late 1950s. Whereas good grounds exist for supposing that similar orebodies may exist within these and other veins in the coalfield, the abandonment of the coalfield and subsequent flooding of old workings, renders future exploration or mining extremely unlikely.

IRONSTONE

Although no longer of economic significance, sedimentary ironstones up to 3.5 m in thickness occur at several horizons in rocks of Lower Jurassic age in the Tees Valley area and formed the basis of an important extractive industry. The most important ironstone was the Main Seam which was discovered at Eston in 1850 and which formed the basis of the Teesside iron smelting industry. Mining extended rapidly and annual output reached a maximum of 6.9 million tonnes in 1883 (Goldring, 1974). From 1875 to 1900 the Cleveland industry supplied half of all the iron ore produced in Britain. Originally the ironstone was won from quarries and small drifts along the outcrop but shafts were sunk to extract the ironstone under increasing cover down dip. Total iron ore production from the field between 1854 and 1964, when the North Skelton mine closed, was some 372 million tonnes. The Main Seam had an average Fe content of about 30 per cent with 12.7 per cent SiO_2, 5.1 per cent CaO and 0.5 per cent P (Goldring, 1974). The high cost of mining, the low-grade of the ore and competition from high grade, foreign iron ores progressively reduced the viability of the operations. The locations of many of the mines are shown on the map.

Nodular clay ironstones and 'blackband' ironstones within the Coal Measures were formerly worked both on their own and as a by-product of coal mining.

Iron ores, both 'limonites' and siderite ($FeCO_3$) occur with many of the vein deposits in the Northern Pennine Orefield and were extensively worked, both underground and openpit, particularly during the 19th century. None of these deposits are now of economic significance.

SECONDARY AGGREGATES

The term ‘secondary aggregates’ is used to describe a range of materials which may be used as alternatives to primary natural aggregates (subject to considerations of quality and contamination), but which arise as wastes from a variety of activities. These may be considered under three main headings:

- Naturally-occurring materials arising as by-products of mineral extraction and processing operations, such as colliery spoil, overburden and quarry/processing waste
- Materials arising from industrial manufacturing processes, such as slags and ash, which may be of variable composition
- Recycled construction and demolition wastes which may be either in a natural or manufactured state and include asphalt planings, road sub-base, concrete rubble and masonry. These materials are excluded from this study as their arisings are highly variable in location, type and duration.

Utilising the aggregate potential of such materials has the advantage of both reducing the demand for primary aggregates and thus land for extraction, and the problems of disposing of waste. In general, however, secondary aggregates are only suitable for less demanding aggregate applications, and their production and use may not always be environmentally or economically desirable.

The area is a major source of slag derived from the Teesside iron and steel industry. There are no coal-fired power stations in the area and colliery spoil is no longer produced.

Blastfurnace and steel slags

Blastfurnace and steel slags are co-products of iron and steelmaking respectively and both have for many years been widely used as secondary aggregates. Blastfurnace slag in particular is one of the few sources of secondary aggregates which can be used as a direct alternative to the more demanding applications of natural aggregates, notably as a road surfacing aggregate. The different types of slag vary in their physical, mechanical and chemical properties and thus their suitability for particular applications.

Blastfurnace slag is a non-metallic product consisting essentially of the silicates and alumino-silicates of lime and other bases. It is a co-product of the manufacture of iron and results from the fusion of limestone/dolomite with ash from coke and the silica and alumina-bearing residues remaining after the reduction and separation of the iron from iron ore. Slag formation performs an important function in the ironmaking process through the removal of sulphur which cannot be tolerated in the molten iron. The slag rises to the surface in the blastfurnace and is tapped periodically. Depending on the method of cooling the slag, three types of material are produced; air-cooled slag, pelletised slag and granulated slag.

Air-cooled slag, which is crushed and screened, exhibits a crystalline structure and produces a rock-like material which is mainly used as roadstone, but also for concrete aggregate, railway ballast and as a biological filter medium. Pelletised slag is partially in decline but is used as a lightweight aggregate. Granulated slag is produced by cooling the molten slag rapidly to give a vitrified sand-like material with a very consistent chemical composition which is finely ground for use in blended cements. Some 1 Mt/y of blastfurnace slag is produced at the Teesside steelworks and finds a ready market, mainly in blended cement. All the production is utilised.

The conversion of iron into steel involves lowering and controlling the content of impurities, such as carbon, silicon, manganese, phosphorus and sulphur, in the hot metal iron by removing them either as gases or incorporating them into the slag by the formation of complex oxides. This refining process is achieved by the reaction of the iron with lime (CaO) or dolime (CaO.MgO) as a flux. The composition of steel slags is complex and very variable. There are two types of steel slag - basic oxygen steel (BOS) slag and electric arc furnace (EAF) slag - depending on the steelmaking method used. Steel slags have a high free lime content which makes them unstable and causes expansion on contact with water. Weathering of the slag hydrates the lime and reduces the risk, but this can be a time consuming process. BOS slag is produced at Teesside steelworks. and some may be used, after weathering, as sub-base material. It is also used in agriculture as a soil conditioner.

MINERAL RESOURCES AND PLANNING CONSTRAINTS

Mineral extraction can cause irrevocable, but not necessarily harmful, change to a locality over a relatively short timescale. In order to ensure that such changes are sustainable, and do not harm the environment, the most valuable landscapes and habitats (National Parks, AONB, SSSIs etc.) are given a greater degree of protection from mineral working. The need for mineral workings in such areas has to be justified by a most rigorous examination of the merits of the proposal. This examination considers the wider public interest in the development of the resource and the social and economic issues as well as the need to protect the environment.

Mineral extraction in areas designated as Special Protection Areas (SPA) or Special Areas of Conservation (SAC) may be acceptable if there are no alternatives and if there are imperative reasons of overriding public interest which support the development. For certain priority SACs, development can only be considered to be acceptable if there are overriding reasons of public health or safety or due to beneficial environmental consequences. Whilst the requirement to assess the acceptability of mineral working in such designated areas is therefore stringent, there is no total prohibition on working minerals in such areas.

The resolution of conflicts between mineral resource development and other considerations is undertaken through the development plan framework and the development control system with a balanced appraisal of the issues raised. The Mineral Resource Map of County Durham and the Tees Valley provides a synthesis of available information which can be revised and updated as additional data becomes available. Additional environmental designations may be incorporated as required. It is hoped that the map and the associated report will assist local and national government, the minerals industry and other interested parties in the consideration and production of policies in development plans.

The landscape character of County Durham and the Tees Valley reflects the nature and structure of the underlying rocks, the erosive forces to which they have been subjected and the soil and vegetation that they support. This character is constantly changing due to economic and social pressures in the short-term and to geomorphological processes in the long-term. The area contains a number of landscapes from the highly urbanised and industrialised Lower Tees Valley and former coalfield areas from the coast of County Durham. These pass through the farming areas of the Pennine foothills, to the upland areas of moorland which form the western edge of County Durham and in the south, the North York Moors. These are some of the most attractive landscapes in Northern England and, to a large extent, this landscape diversity results from the diversity of the underlying geology.

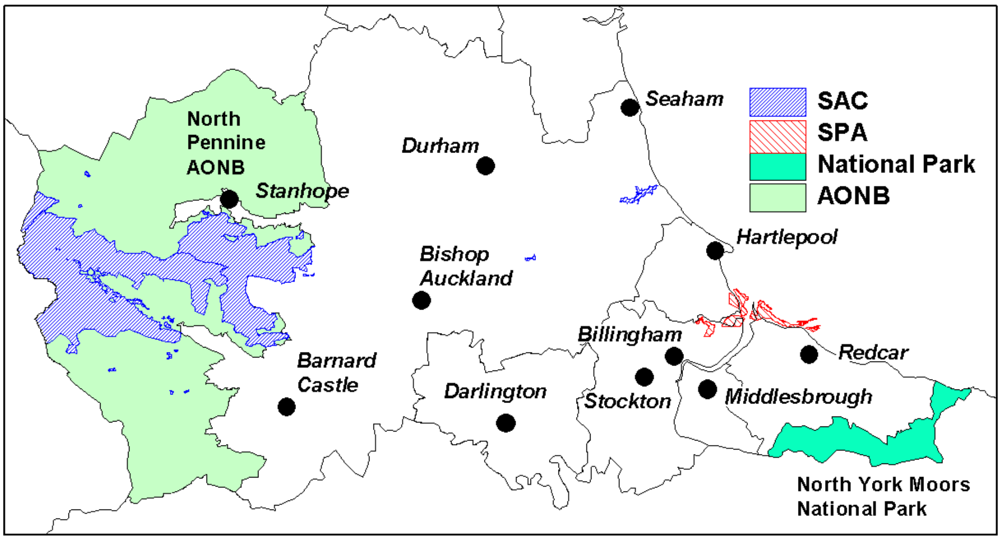

Figure 7. SPA, SACs, AONB and National Park in Durham and the Tees Valley. For other active nature conservation designations, see Resource map.

The North Pennine AONB in the west of the area covers 25 per cent of County Durham and contains much of the higher relief land in the area, although parts of the Upper Wear and Tees Valleys are excluded. Extensive areas of SSSI are also coincidental with the AONB. Within this area, the principal mineral resources are Carboniferous limestones and the Whin Sill. The area was also formerly the centre of the Northern Pennine Orefield. Silica rock was also formerly worked and there is still a small production of silica sand and building stone within the AONB.

South of the Tees, the land rises to the North York Moors, part of which in the east is now part of the North York Moors National Park. Extensive SSSIs also occur coincident with the National Park. The area was formerly of considerable economic importance for the extraction of iron ore. The surface operations of the Boulby Potash Mine lie just within the National Park, but workings extend under Redcar and Cleveland and offshore.

Elsewhere, SSSIs extend along the coast and cover extensive areas in the estuary of the Tees. There are also numerous Scheduled Monuments which cover important sites ranging from the Roman occupation to more recent industrial heritage. The other major mineral resources of the area, including opencast coal, Magnesian Limestone and sand and gravel, occur mainly outside major designations, although urban development has sterilised some of the resources.

Local landscape and conservation designations made by local authorities are not shown on the accompanying map however these will be found on the relevant local plans. These include Green Belts and Areas of High Landscape Value, which lie outside the nationally designated areas. Green Belt policy is to keep land open and prevent urban sprawl. Mineral extraction need not be incompatible with Green Belt status provided high environmental and restoration standards are maintained

Other local and site specific factors may affect mineral operations, these include the designation of high-grade agricultural land which may become a constraint if land cannot be restored to at least the same grade after extraction. These factors represent technical constraints rather than fundamental policy constraints and can only be considered on a site by site basis. They are excluded from the map.

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For further information on national planning policy, users should consult the following:

- Planning Policy Guidance
- Mineral Planning Guidance Notes
- Regional Planning Guidance Notes

published by the HMSO for the Department of the Environment, Transport and the Regions.

Information from the following documents and maps was used.

a) British Geological Survey 1:50 000 and 1:63 360 # geological map sheets

Sheet	Name	Edition	Published
19	Hexham	S	1975
20	Newcastle upon Tyne, Gateshead	SwD	1989
20	Newcastle upon Tyne, Gateshead	S&D	1992
21	Sunderland	S, D	1978
25	Alston	SwD	1973
26	Wolsingham	SwD	1977
26	Wolsingham	S&D	1977
27	Durham	SwD	1965# (1992 F)
31	Brough-under-Stainmore	SwD	1974
31	Brough-under-Stainmore	S&D	1974
32	Barnard Castle	SwD	1969#
32	Barnard Castle	S&D	1969#
33	Stockton	S&D	1987
34	Guisborough	S&D	1998 P
40	Kirkby Stephen	S&D	1997 P
41	Richmond	S&D	1997 P
42	Northallerton	S&D	1994

S Solid edition
D Drift edition
S&D Solid and Drift combined
SwD as above with uncoloured drift linework

P – Provisional edition
F – 1:50000 scale

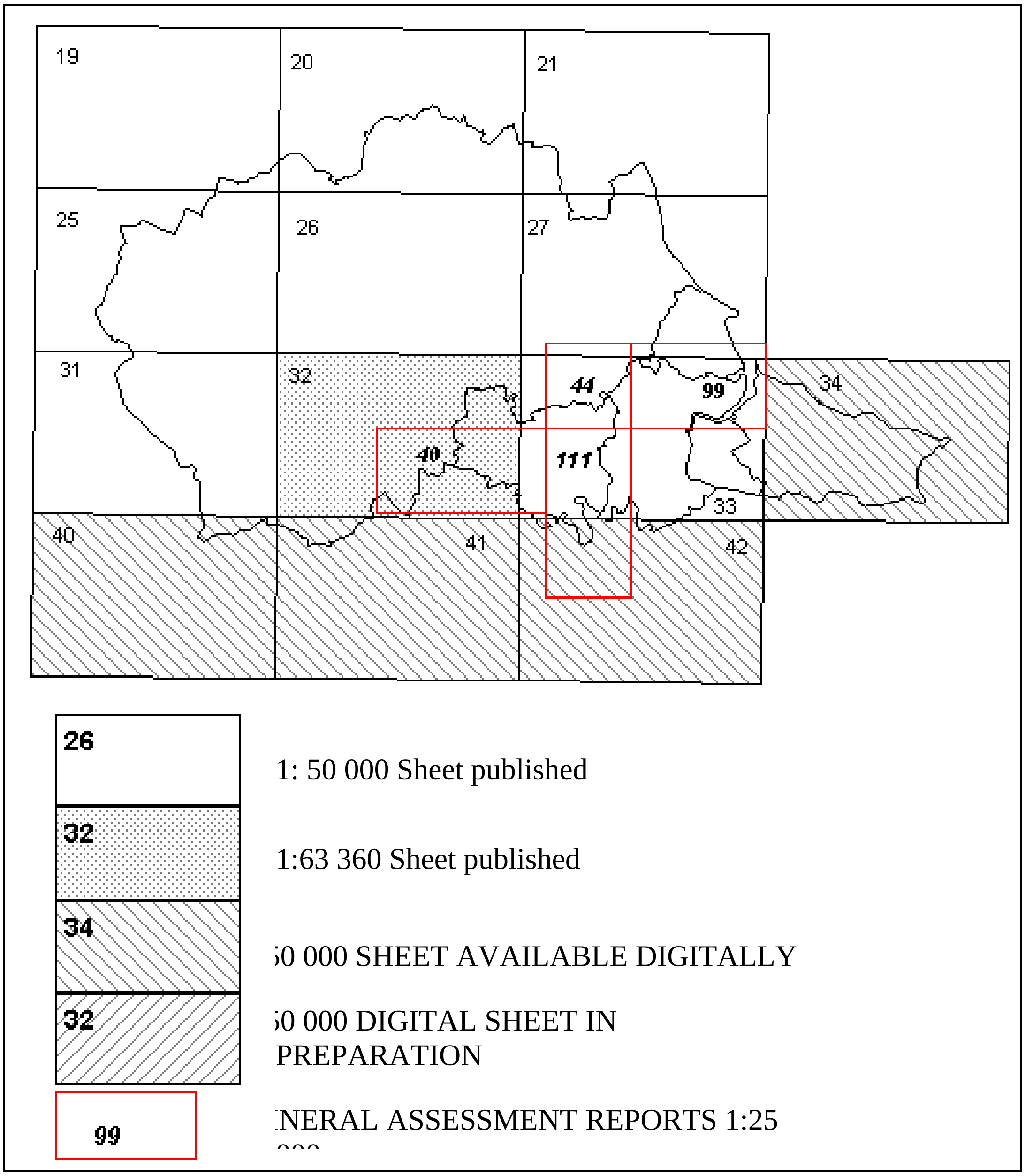

Figure 8. Availability of British Geological Survey 1:25 000, 1:50 000 and 1:63 360 scale geological map coverage in 1999

b) British Geological Survey Sheet Memoirs

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d) Mineral Exploration and Investment Grants Act 1972 Reports available at BGS Keyworth

Ref No AE	Project Name	Target Elements			Company
38	Weardale	Pb	Zn	F	Acmin Explorations (UK) Ltd
51	Sharnberry	Pb	Zn	F	SAMUK Ltd
52	Little Eggleshope	Pb	Zn	F	SAMUK Ltd
53	California	Pb	Zn	F	SAMUK Ltd
60	Stanhopeburn	F			William Baird Ltd
61	Durham Fluorspar	F	Pb	Zn	EXSUD Ltd
69	Hudeshope	Pb	Zn	F	SAMUK Ltd
70	Harnisha Hill	Pb	Zn	F	SAMUK Ltd
72	Old Middlehope	Pb	Zn	F	SAMUK Ltd
112	Closehouse	F			SAMUK Ltd
117	Ramshaw	F			EXSUD Ltd
139	Slitt and Heights Veins	F	Ba	Pb	EXSUD Ltd
143	Red Vein	F	Pb	Zn	SAMUK Ltd
166	Rookhope Test Bores	F	Pb	Zn	SAMUK Ltd
197	Red Vein Eastern Extension	F	Pb	Zn	SAMUK Ltd
217	Sunnyside Exploration	F	Pb		SAMUK Ltd

ACKNOWLEDGEMENTS

This trial study has greatly benefited from the co-operation of many organisations and individuals who provided information and advice, and their assistance is gratefully acknowledged. Particular thanks are due to Dr Brian Marker at the Department of the Environment, Transport and the Regions, Durham County Council, the Tees Valley Joint Strategy Unit, North York Moors National Park, English Heritage, English Nature, the Coal Authority and Cleveland Potash Limited.

The authors would also like to thank their colleagues in BGS for their help, and in particular S E Wood and R J Parnaby, Cartographic Services, Dr E W Johnson and J Harrison, K A Linley, R White, T Colman of the Onshore Minerals and Energy Resources Programme.

APPENDIX 1: MINERAL WORKINGS (2000)

Name of Working	Operator	Commodity
Co Durham		
Closehouse	Closehouse Minerals	Baryte
Eldon Deep	RJB Mining (UK) Ltd	Coal, Opencast
Clarence Farm Extension	Ambion Brick Co Ltd	Common Clay & Shale
Eldon Brickworks	Ambion Brick Co Ltd	Common Clay & Shale
Birtley (Union Brickworks Claypit)	Ibstock Building Products Ltd	Common Clay & Shale
Force Garth (Middleton)	RMC Aggregates (Northern) Ltd	Igneous Rock
Heights	Aggregate Industries Northern Region	Limestone
Huland	Aggregate Industries Northern Region	Limestone
Eastgate	Blue Circle Industries PLC	Limestone, Shale; for cement
Old Quarrington	Hepplewhite Quarries	Limestone (Dolomite), Sand
Thrislington	Lafarge Redland Aggregates	Limestone (Dolomite), Sand
Raisby	Raisby Quarries Ltd	Limestone (Dolomite)
Crime Rigg	Sherburn Stone Co Ltd	Limestone (Dolomite), Sand
Witch Hill	Sherburn Stone Co Ltd	Limestone
Selset	Stonegraves Aggregates Ltd	Limestone
Aycliffe Quarry East	Stonegraves Aggregates Ltd	Limestone
Bishop Middleham and Extension	W & M Thompson (Quarries) Ltd	Limestone
Hett Hills (and Tribley)	Biffa Waste Services Ltd	Sand & Gravel
Thrislington	Lafarge Redland Aggregates	Sand & Gravel
Crime Rigg	Sherburn Stone Co Ltd	Sand & Gravel
Quickburn	Caird Environmental	Sandstone
Baxton Law	Dunhouse Quarry Co Ltd	Sandstone
Catcastle	Dunhouse Quarry Co Ltd	Sandstone
Dunhouse and Extension	Dunhouse Quarry Co Ltd	Sandstone
Stainton	Natural Stone Products	Sandstone
Harthope Head	R Scott	Sandstone
Shipley Banks	T H Cross	Sandstone
Dead Friars (Millstone Grit)	Tynecastle Stone (Haydens Northern)	Sandstone
Windy Hill	Windy Hill Quarry & Construction Co	Sandstone
Weatherhill	Hobson Brothers Ltd	Silica Sand
Hartlepool		
Hart	Sherburn Stone Co Ltd	Limestone (Dolomite), Common Clay & Shale
Hartlepool (North Gare Sands)	RMC Aggregates (Northern) Ltd	Sand & Gravel
North York Moors NP		
Boulby Potash Mine	Cleveland Potash Ltd	Potash, Salt
Redcar & Cleveland		
Grangetown Slag	East Coast Slag Products Ltd	Blast Furnace Slag
Stockton-on-Tees		
Saltholme Brinefield No 4	ICI Plc	Salt
Seal Sands Brinefield (No 6)	ICI Plc	Salt
Thorpe Thewles (Wynyard Road)	RMC Aggregates (Northern) Ltd	Sand & Gravel

APPENDIX 2: CONTACT ADDRESSES FOR FURTHER ENQUIRIES

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Dept of Environment & Development Services Hartlepool B C Planning & Building Control Division Brian Hanson House Hanson Square Hartlepool TS24 7BT Tel: 01429 266522 Fax; 01429 869625 Webpage: www.hartlepool.gov.uk	Economic Development & Transportation Dept. Middlesbrough B C PO Box 65 Vancouver House Gurney Street Middlesbrough TS1 1QP Tel: 01642 264061 Fax: 01642 248766 Webpage: www.middlesbrough.gov.uk
Dept of Economic Development & Planning Redcar and Cleveland B C Cargo Fleet Offices Middlesbrough Road PO Box South Bank 20 Middlesbrough TS6 6EL Tel: 01642 444000 Fax: 01642 444882 Webpage: www.redcar-cleveland.gov.uk	Technical Services Dept Stockton-on-Tees B C PO Box 34 Municipal Buildings Church Road Stockton-on-Tees TS18 1LE Tel: 01642 393092 Fax: 01642 391282 Webpage: www.stockton-bc.gov.uk
Planning Dept North York Moors National Park The Old Vicarage Bondgate Helmsley YO6 5BP Tel: 01439 770657 Fax: 01439 770691 Webpage: www.northyorkmoors-npa.gov.uk	Tees Valley Joint Strategy Unit PO Box 199 Melrose House Melrose Street Middlesbrough TS1 2XF Tel: 01642 264830 Fax: 01642 230870

Countryside Agency John Dower House Crescent Place Cheltenham Gloucestershire GL50 3RA Tel: 01242 521381 Fax: 01242 584270	English Nature Northminster House Northminster Peterborough PE1 1UA Tel: 01733 455000 Fax: 01733 455103
English Heritage Fortress House Savile Row London SW1X 1AB Tel: 0207 973 3000 Fax: 0207 973 3001	The Secretary Regional Aggregate Working Party Northumberland CC Planning & Environment Division County Hall Morpeth NE61 2EF Tel: 01670 533000 Fax: 01670 534069
The Environment Agency Regional Office Rivers House 21 Park Square South Leeds LS1 2QG Tel: 0113 244 0191 Fax: 0113 246 1889	The Coal Authority 200 Lichfield Lane Mansfield Nottinghamshire NG18 4RG Tel: 01623 427162 Fax: 01623 638338
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APPENDIX 3: METHODOLOGY

The British Geological Survey (BGS) was commissioned in 1993 by the Department of the Environment to prepare, on a trial basis, a set of concise statements mainly in map form, to show the broad distribution of mineral resources in selected counties and to relate these to selected, nationally-designated planning constraints. The trial study developed a methodology for the collection and display of data in a consistent and comparable format for four Mineral Planning Authority (MPA) areas - Bedfordshire, Derbyshire, Staffordshire and the Peak District National Park. The concept developed by the BGS for the trial study is now being extended to some twenty mineral planning authorities in England and Wales through a further phase of the project which started in 1996.

The main element of the trial study was the production of maps, with accompanying interpretative reports, for each MPA area. All mineral resource and planning constraint information has been collated digitally on a PC-based system to produce a cartographic database. Data has been captured as a series of files, structured on separate levels so that they can be viewed either independently or in various combinations, as required. Most of the information has been taken digitally from hard copy maps, mainly with scales between 1:50 000 and 1:10 000. Other material was obtained in a variety of digital formats which have had to be converted for use by the Intergraph Microstation System. The structure of the information will allow the data to be transferred in digital form to the BGS MINGOL (MINerals GIS On-Line) system. MINGOL is being developed to provide a decision-support system for the rapid solution of minerals-related problems to aid corporate and public mineral resource management. It applies a state-of-the art GIS to relate the nature and distribution of mineral resources to other information such as planning and environmental constraints, and mineral exploration, borehole and commodity statistics datasets.

Figure 1 Classification of resources and reserves

	IDENTIFIED RESOURCES			**UNDISCOVERED RESOURCES**
	Measured	***Indicated***	***Inferred***	
Economic	***Proved mineral reserve***	***Probable mineral reserve***	***Inferred mineral resource***	***UNDISCOVERED RESOURCES***
Sub-economic	***Measured mineral resource***	***Indicated mineral resource***		

increasing economic viability of extraction

increasing geological knowledge

Based on McKelvey, 1972

As the data are held digitally, map output can be on any scale but 1:100 000 has been found to be a convenient size to summarise the information for individual MPAs. This provides a legible topographic base which enables both the broad implications of the information, and sufficiently accurate detail, to be shown. The particular advantage of holding all the information in digital form is that it is comparatively easy to update and revise as additional information becomes available, and also provides scope for producing customised maps of selected information or areas on request.

CLASSIFICATION OF RESERVES AND RESOURCES

The diagram, Figure 1, is a representation of a conventional method for classifying mineral reserves and resources, based on a system introduced the US Bureau of Mines and the US Geological Survey and adapted by the British Geological Survey. In this conceptual diagram the vertical dimension of the diagram represents the economic viability of the resource and consists simply of two categories, **economic** and **sub-economic**, depending on whether or not the mineral deposit is commercially viable under prevailing economic circumstances. As demand, mineral prices and costs of extraction may change with time, so mineral resources may become reserves and vice versa.

The horizontal dimension represents degrees of geological knowledge about the resource, from mere speculation about its existence (right-hand side) to thorough assessment and sampling on a systematic basis (left-hand side).

In the present study the mineral resource information has been produced by the collation and interpretation of data principally held by the British Geological Survey. Since the mineral resource data presented are not comprehensive and the quality is variable, the boundaries shown are approximate. Most of the mineral resource information presented is, therefore, in the **inferred resource** category (Figure 1), that is to say, those resources that can be defined from available geological information and which may have some economic potential. They have neither been evaluated by drilling, or other sampling methods, nor had their technical properties characterised on any systematic basis. Inferred resources may be converted into indicated and measured resources with increasing degrees of investigation and assessment. However, where mineral resource studies (including drilling and testing) have been carried out, sufficient information is available to define the resource at the **indicated** level. Sand and gravel assessment studies have been carried out in parts of Durham and the Tees Valley area.

A mineral resource is not confirmed as economic until it is proved by a relatively expensive evaluation programme. This usually involves a detailed measurement of the material available for extraction together with an evaluation of the quality of the material, its market suitability, the revenues generated by its sale and, ultimately, the viability of the deposit. This activity is an essential precursor to submitting a planning application for mineral extraction. That part of a resource that is both ‘measured’ and ‘economic’, i.e. that has been fully evaluated and is commercially viable to work, is called a **reserve** or **mineral reserve**. It is customary to distinguish **proved** and **probable reserves**, which correspond to the economic parts of measured and indicated resources respectively (Figure 1).

It is invariably the case that there is a significant reduction in area or volume estimates as resources are further investigated to prove reserves. The reasons for this is that it is impossible to apply initially all the various constraints that working procedures and environmental issues may impose. This is particularly the case with extensive deposits like sand and gravel where physical constraints imposed by roads, railways and urban development may drastically reduce the potential area available for extraction, even before factors such as quality and mineral thickness are taken into consideration.

In the context of land-use planning the term **reserve** should strictly be further limited to those minerals for which a valid planning permission for extraction exists, i.e. **permitted reserves**. The extent of mineral planning permissions (other than coal) is shown on the Mineral Resources Maps. These cover both active mineral workings and inactive mineral workings. Some mineral planning permissions may have remained unworked, and others may have become uneconomic prior to being worked out. In many cases the areas involved are likely to have been worked to some extent in the past, and may now be restored. In addition, parts of the resource areas may have been fully evaluated by the minerals industry, but either have not been subject to a planning application or have been refused permission for extraction. These areas are not depicted on the map.

A **landbank** is a stock of planning permissions and is commonly quoted for aggregates. It is composed of the sum of all **permitted reserves** at active and inactive sites at a given point of time, and for a given area, with the following provisos:

- it includes the estimated quantity of reserves with valid planning permission at dormant or currently non-working sites;
- it includes all reserves with valid planning permission irrespective of the size of the reserves and production capacity of particular sites;
- it does not include estimated quantities of material allocated in development plans but not having the benefit of planning permission; and
- it does not include any estimate for the contribution that could be made by marine dredged, imported or secondary materials.

It is important to recognise, however, that some of the permitted reserves contained within landbanks have not been fully evaluated with the degree of precision normally associated with the strict use of the term reserves, indeed some may not have been evaluated at all.

Mineral workings and planning permissions

The locations and names of mineral workings in Durham and the Tees Valley area are shown on the maps. The information is derived from the British Geological Survey's Mines and Quarries Database, updated as appropriate from Mineral Planning Authority records. Letters (e.g. **Sg** = sand and gravel) are used to show the main mineral commodity produced.

The extent of the planning permissions shown on the Mineral Resources Map cover active mineral workings, former mineral workings and, occasionally, unworked deposits. The present physical and legal status of the planning permissions is not qualified on the map. The areas shown may, therefore, include inactive sites, where the permission has expired due to the terms of the permission, i.e. a time limit, and inactive (dormant) sites where the permission still exists. Sites which have been restored are not separately identified. Under the provisions of the 1995 Environment Act, after 1 November 1997, sites that are classified as dormant may no longer be worked until full modern planning conditions have been approved by the Mineral Planning Authority. A ‘dormant site’ is defined as a site where no mineral development has taken place to any substantial extent in the period 23 February 1982 and ending 6 June 1995. Information on the precise status and extent of individual planning permissions should be sought from the relevant mineral planning authority.

Most planning permissions appear on a mapped mineral resource area and thus the underlying resource colour identifies the mineral type. Planning permissions may fall outside resource areas for the following reasons:

- permissions shown partly off resource areas may extend to ownership, or other easily defined boundaries, or to include ground for ancillary facilities such as processing plants, roads and overburden tipping
- isolated workings occurring outside defined resource areas may reflect very local or specific situations, such as a borrow pit, not applicable to the full extent of the underlying rock type:

The latest data available for the total areas of planning permissions in Durham and the Tees Valley area, collected for the Department of Environment Minerals Survey of 1994, is shown in Tables 1 and 2. This information is updated at intervals.

Table 1 Areas of planning permissions for mineral workings in Durham (as at 1.4.94)

	Commodity	Total permitted area (ha)	No. of sites	%
Surface workings	Clay/shale	128	7	4.30
	Coal (opencast)	771	20	25.90
	Gypsum/anhydrite	15	1	0.50
	Igneous rock	50	1	1.68
	Limestone/dolomite	1066	25	35.81
	Sand and gravel (construction)	113	9	3.80
	Sandstone	582	13	19.55
	Vein minerals	36	8	1.21
	Other minerals	215	7	7.22
Total		**2977**	**92**	**100**
Underground workings	Coal (specific planning perm.)	156	1	0.04
	Vein minerals	369000	3	99.96
Total		**369156**	**4**	**100**

Source: *Department of the Environment, 1996. Survey of Land for Mineral Workings in England, 1994.*

Table 2 Areas of planning permissions for mineral workings in Cleveland (as at 1.4.94)

	Commodity	Total permitted area (ha)	No. of sites	%
Surface workings	Clay/shale	129	8	50.39
	Igneous rock	3	1	1.17
	Ironstone	23	5	8.98
	Limestone/dolomite	10	2	3.91
	Sand and gravel (construction)	88	4	34.38
	Sandstone	3	2	1.17
Total		**256**	**22**	**100**
Underground workings	Salt (including brine pumping)	1110	1	16.92
	Other minerals	5450	2	83.08
Total		**6560**	**3**	**100**

Source: *Department of the Environment, Survey of Land for Mineral Workings in England, 1994.*