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*Department of the Environment,
Transport and the Regions*

Mineral Resource Information for Development Plans

Herefordshire and Worcestershire: Resources and Constraints



TECHNICAL REPORT WF/99/4
Mineral Resources Series

**Mineral Resource Information for
Development Plans: Phase One
Herefordshire & Worcestershire:
Resources and Constraints**

A J Bloodworth, D G Cameron,
D J Harrison, D E Highley, S Holloway
& G Warrington

Planning Consultant: J F Cowley
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This report accompanies the 1:100 000 scale map:
Herefordshire & Worcestershire Mineral Resources

Cover photograph

Kidderminster Formation sandstones being
worked at Shepley Quarry, adjacent to the
M42 near Bromsgrove, Worcestershire. Photo
courtesy of RMC Aggregates (UK) Ltd.

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CONTENTS

SUMMARY	1
INTRODUCTION	3
Minerals planning	4
Mineral resource classification	6
Mineral workings and planning permissions	7
Environmental designations	8
MINERAL RESOURCES	10
Overview	10
Sand and gravel	13
Limestone	17
Sandstone	18
Igneous rocks	18
Building stone	19
Clay and shale	19
Salt	20
Coal	21
Hydrocarbons	22
Secondary aggregates	22
MINERAL RESOURCES AND PLANNING CONSTRAINTS	24
SELECTED BIBLIOGRAPHY	26
a) British Geological Survey 1:50 000 geological map sheets	26
b) British Geological Survey sheet memoirs	26
c) British Geological Survey reports and other publications	27
ACKNOWLEDGEMENTS	30
APPENDICES	
APPENDIX 1 Mineral workings in Hereford & Worcester	31
APPENDIX 2 Contact addresses for further enquiries	33
APPENDIX 3 Methodology	34

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 Herefordshire Council and Worcestershire County Council. 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 as a digitally-generated summary map. The map is produced at 1:100000 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 evaluation and planning, and to establish baseline data for environmental impact studies and environmental guidelines. It also enables a 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 sand and gravel, hard rock, brick clay, silica sand, coal, hydrocarbons, and secondary aggregates.

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 the area covered by the Mineral Planning Authorities of Herefordshire Council and Worcestershire County Council (the former county area of Hereford & Worcester) and should be used in conjunction with the mineral resources map of the area which accompanies this report. The report and its associated map delineate and describe the mineral resources of current or potential economic interest in Herefordshire and Worcestershire and relate these 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, both in relation to the extraction of minerals and the protection of mineral resources from sterilisation, by providing 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 resources map is at 1:100000 which is a convenient scale for overall display and to show the information on a legible topographic base. The report and map represents the situation at 31st January 1999.

Mineral resources are valuable national assets and their extraction and use makes a major contribution to wealth creation, the infrastructure of our society and quality of life of individuals. However, minerals can only be worked where they occur and their 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. In the wider context of sustainable development, mineral resource data are required 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 mineral 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
- to 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 and unitary development plans, both in the context of identifying areas of future mineral working and the longer term objective of the protection of important mineral resources against sterilisation. 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 all 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 Herefordshire and Worcestershire 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 rendered non-viable by changing economic circumstances.

The map has 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 1:50000 scale and 1:63630 scale maps. These published maps are based on 1:10560 or 1:10000 scale surveys. In general, the more recent the survey the more detailed it is likely to be. Unfortunately, there are no modern maps available for some parts of southern and western Herefordshire, leaving some gaps in the resource data depicted on the map. However, a small amount of modern 1:10000 mapping has been carried out in these otherwise unmapped areas. These data have been used where available (chiefly around Hereford and Ross-on-Wye).

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 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 Mineral planning authorities.

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 sites where the permission is still valid. Sites which have been restored have not been separately identified. However, information is available on the planning and operational status of each planning permission on the database which underpins the map. 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. Thus the area containing extractable mineral reserves may not extend to the limit of the planning permission. 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:

- Areas of Outstanding Natural Beauty (AONB)
- 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, the best and most versatile agricultural land, 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 has 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 Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) as identified in accordance with EC Directives on wild birds and natural habitats, respectively.

MINERAL RESOURCES

OVERVIEW

The Herefordshire and Worcestershire area is an important source of a number of minerals. Three major rivers drain through the area (Severn, Avon and Wye) providing abundant sand and gravel resources. The presence of an ice margin over the west of the area during the last ice age has ensured abundant resources of glacial sands and gravels around Hereford. The Triassic Kidderminster and Wildmoor formations (part of the Sherwood Sandstone Group) are a source of sand and gravel (former) and silica sand and building sand (latter) in the eastern part of the area. The close proximity of West Midlands conurbation has led to continued demand for aggregate minerals.

Resources of rocks suitable for crushed-rock aggregates are not abundant in the area covered by this study. Working of moderate quality Silurian limestones is currently restricted to only three sites, two in Herefordshire and one in Worcestershire. Jurassic limestone is worked for building stone and aggregate in the extreme south-eastern part of Worcestershire. The Precambrian Malvern Complex was worked extensively in the past as a source of good-quality crushed rock aggregate. Quarrying has now ceased, although these rocks remain a resource. Although geographically extensive, the Devonian Old Red Sandstone rocks in Herefordshire are unsuitable as a source of aggregate because of their relatively poor physical properties, although they are an important local source of building stone.

The Triassic Mercia Mudstone Group is a locally-significant brick clay resource, supplying two major brick plants in the Stourport area. In the northern part of the Worcestershire basin, the Mercia Mudstone Group also hosts salt-bearing strata. The Worcestershire Saltfield was the centre of a salt industry which peaked in the 19th Century. Production ceased in the 1970s.

Although unlikely to attract any further commercial interest, coal was formerly worked in the Wyre Forest coalfield in north west Worcestershire and a small outlier of the Forest of Dean Coalfield which extends in the southern Herefordshire. The hydrocarbon prospectivity of the area is low. Wells drilled to test the oil and gas potential of sandstones in the Worcestershire Basin, and Lower Palaeozoic rocks in the Woolhope Inlier have failed to discover hydrocarbons.

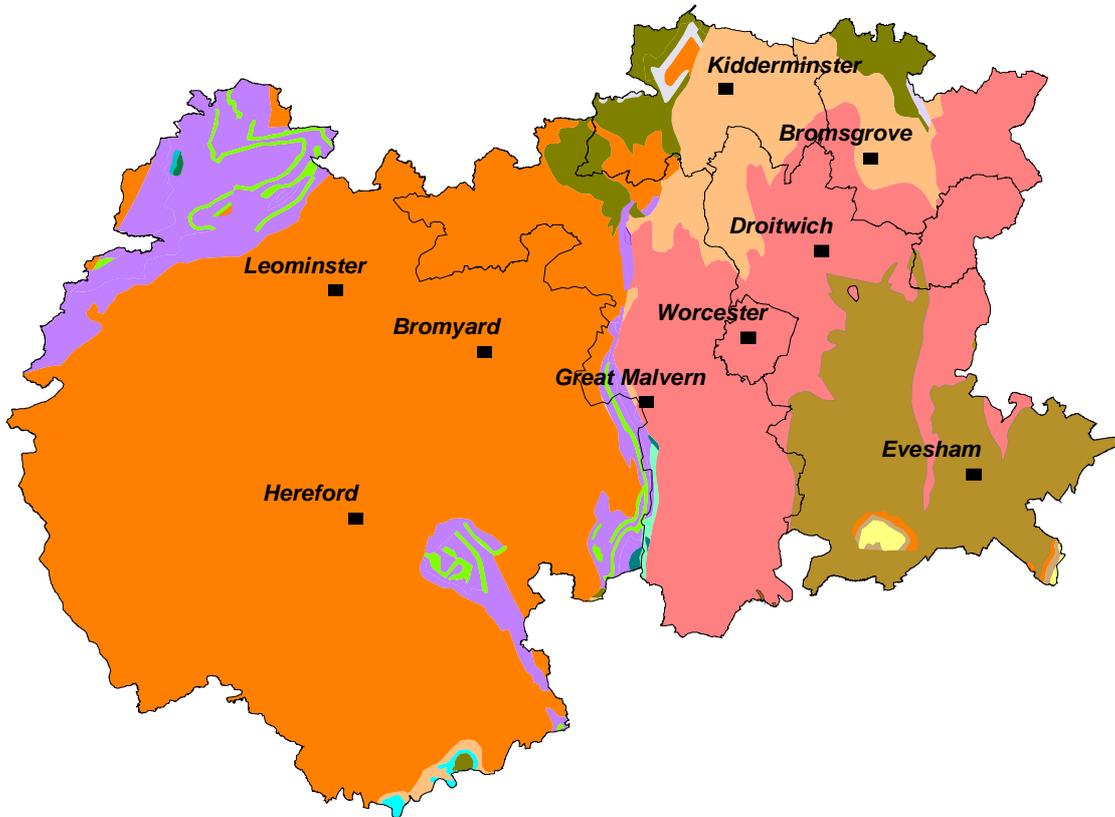


Figure 1 Simplified geological map of Hereford & Worcester. Key relating mineral commodities to geology is shown on the next page.

Herefordshire and Worcestershire Mineral Resources and Constraints

Quaternary omitted for clarity			river and glacial gravels	sand and gravel
Jurassic Middle		Inferior Oolite	oolitic limestone	aggregates building stone
		Upper Lias	clay, limestone	
Lower		Middle Lias	ironstone, limestone	iron ore, building stone
		Lower Lias	limestone, clay	
Triassic		Sherwood Sandstone Formation	sandstone, conglomerate	silica sand, sand, gravel, moulding sand
Permian		Mercia Mudstone Group	mudstone	bricks
Carboniferous		Upper Coal Measures	shale, limestone, coal	coal, bricks and tiles
		Lower, Productive Coal Measures	coal, ironstone, sandstone	coal, building stone
Devonian		Old Red Sandstone	sandstones, limestones	building stone
Silurian		Aymestry Limestone Wenlock Limestone	shale, limestone, mudstone, sandstone	aggregates, lime, blast furnace flux
Ordovician		Barnt Green Volcanics Lickey Quartzite	quartzite	building stone, aggregate
Cambrian		Tremadoc, Merioneth	shales, tuffs, quartzites	
Pre-Cambrian		Malvernian	gneiss, schists, acid igneous intrusions	aggregates

Figure 1 (continued) Key relating mineral commodities to geology

SAND AND GRAVEL

Herefordshire and Worcestershire produced 1175000 tonnes of sand and gravel in 1997, of which some 84 per cent was sand. Production of sand and gravel in Herefordshire and Worcestershire is shown in Figure 2. There are 17 sites producing sand and gravel or sand in the area covered by this study. The sand and gravel resources of the area are divided into two main categories: (i) superficial (drift) deposits, subdivided into both glacial, and river sands and gravels, together with (ii) bedrock (solid) deposits represented by sandstones of the Triassic Sherwood Sandstone Group.

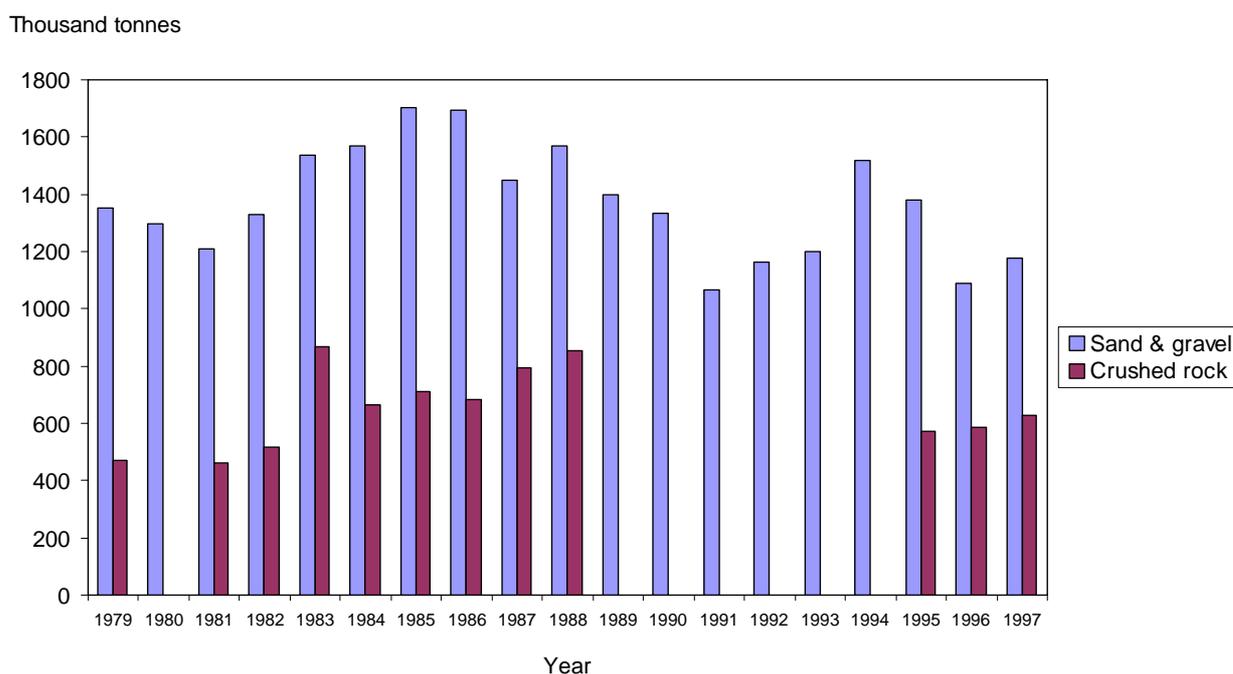


Figure 2 Output of sand and gravel and crushed-rock aggregate from Herefordshire and Worcestershire, 1979-1997.

Source: Office for National Statistics, Annual Minerals Raised Inquiry.

The variability of sand and gravel deposits means that, in comparison with other bulk minerals, it is more difficult to infer the location and the likely extent of potentially workable resources from geological maps. The criteria that 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

- location relative to demand

Information on the sand and gravel resources in Herefordshire and Worcestershire was gathered in reconnaissance (desk) studies carried out in several areas by the BGS in the 1970s and 80s. The results of these desk studies are available as BGS Open File or Internal Reports. BGS sheet memoirs represent a valuable additional source of information on the distribution of sand and gravel in Herefordshire and Worcestershire.

Superficial deposits

Superficial deposits (or drift deposits) of sand and gravel of Quaternary age are subdivided into river and glacial deposits. This division reflects differences in their mode of occurrence and to some extent in their quality (particle-size distribution and lithology).

River sand and gravel deposits include spreads which occur beneath alluvium forming the floors of the major river valleys and river terrace deposits flanking the valley sides. In Herefordshire and Worcestershire they are mainly associated with the rivers Severn, Teme, Avon, Wye, Frome and Lugg. The unconsolidated deposits consist of a mixture of sand and gravel, in varying proportions, from which coarse and fine aggregates are produced by a process of washing and size separation, usually involving screening and hydrocyclone separation. In several of the river valleys in the county, terrace-like spreads of sand and gravel occur at higher levels than the river terrace deposits and have been mapped previously as glacial sand and gravel. It seems likely, however, that many of these were deposited by river action and thus they are included here with the river sand and gravel deposits. There are 9 sand and gravel pits in Herefordshire and Worcestershire working river terrace deposits, mainly concentrated in the valleys of the Severn and Avon.

River sand and gravel deposits have been naturally processed by running water. This is an efficient mechanism for separating the different size fractions of the sediment being transported. As a result, beds of sand and gravel are likely to be relatively consistent in terms of particle size and usually contain a lower proportion of fines (silt and clay) than glacial deposits. Their particle-size distribution is therefore closer to user specifications. Nevertheless, beds of silt and clay may occur within these deposits.

The deposits only rarely exceed 10m thickness, with 3 to 6 m being typical for the river terraces of the Severn and Avon, but thinner elsewhere. River terrace deposits comprise the major resource of sand and gravel in the area. Although there are six terraces in the Severn valley, only the lower ones, particularly the second and third terraces, are important as sand and gravel resources. Individual terrace deposits are likely to be relatively consistent in thickness and

composition locally, but different depositional conditions caused by such factors as changing valley shape and stream confluences can cause considerable variation.

The flood plains of the major valleys are underlain by a layer of clay or silt which averages 3 to 5 m thickness. Much of this rests on sand and gravel deposits which may be workable in places.

The composition of river sand and gravel deposits vary across the area. In the Severn and Avon valleys, the terrace sands are composed of quartz grains, whereas the gravels are composed of quartzite pebbles derived from the Sherwood Sandstone Group, together with pebbles of Malverns complex, Silurian limestone and sandstone, flint and coal. Farther east, the gravels incorporate Jurassic limestone pebbles. In the west they contain a significant load of limestone and sandstone fragments derived from the Devonian Old Red Sandstone, as well as greywacke and sandstone clasts derived from the Silurian. Quartzite and sandstone pebbles are generally harder and more durable than those composed of limestone.

Not all the spreads of river gravels shown on the accompanying map are likely to be of commercial value, some being too limited in extent, thickness or quality.

Glacial sand and gravel deposits include those laid down by variety of glacial and glaciofluvial processes associated with icesheets, glaciers and, particularly, their meltwaters. They are also unconsolidated deposits, but are more variable than river sands and gravels. They are less predictable in geographical extent and have a wider range of particle-sizes. They may incorporate a considerable proportion of fines (<0.063 mm), which may restrict their commercial potential. They may be extensive locally and show considerable lateral variations in thickness and grading. In general, deposits are likely to be less than 10 m thick, but may exceed 20 m thickness where they infill hollows and channels scoured into underlying deposits. Compositionally, they are mostly derived from the erosion of the underlying rocks, but erratics derived from rock units outside the county are a feature of such deposits. These are mostly derived from the west and include Silurian sandstones, siltstones and greywackes, as well as less common volcanic rocks. There are four sites in Herefordshire and Worcestershire producing glacial sand and gravel.

In several parts of the area, but particularly in the west around Hereford and Leominster, glacial sand and gravel occurs in association with spreads of till (boulder clay) and other glacial deposits. These deposits are typically very variable in extent, thickness and lithology but such accumulations may represent valuable sand and gravel resources. The morainic deposits typical of

the Wye valley west of Hereford contain one of the largest potential sources of sand and gravel in the area and up to 20 m of sand and gravel are exposed in the working pits at Stretton Sugwas. Further north, patches of gravel with lenses of sand lie within, or extend beneath, the till plain and have been worked in the past for local use.

Bedrock deposits

Bedrock resources are confined to weakly-cemented rocks of the Triassic Sherwood Sandstone Group in the northern part of Worcestershire. Four sites are currently working this material for sand. Building sand is quarried from the Kidderminster Formation at Shepley, near Bromsgrove. The basal beds of the Kidderminster Formation are mainly conglomerate, whilst overlying beds consist of massive, weakly-cemented, yellow- and red-brown sandstones. Sand grains are coarse to fine grade. The basal conglomerate is composed of pebbles and cobbles in a weakly-cemented matrix of coarse sand. Approximately 65 per cent of the pebbles are quartzite, with 25 per cent vein quartz. The quarry at Shepley is in the upper part of the formation where conglomerates are largely absent. At least 41 m of cross-bedded, medium to coarse sandstone have been proved by borehole at this site.

The overlying Wildmoor Sandstone Formation (formerly the Upper Mottled Sandstone) is also worked in the Bromsgrove area, principally as a source of building sand, but also for naturally-bonded moulding sand. It consists of uniform, very weakly cemented, fine-grained micaceous, red sandstone which is easily crushed to produce a sand. A finer-grained horizon is worked to produce foundry sand and coarser sand is extracted and washed to produce building sand.

This sandstone was an important source of naturally-bonded foundry sand and was worked in different parts of the West Midlands region. Production is now confined to the Bromsgrove area. There are two basic types of silica sand used for mould and coremaking in the foundry industry. Naturally-bonded sand contains sufficient clay to give the mould strength without the addition of a bonding agent, and clay-free foundry sand (washed or synthetic foundry sand) 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. However, the properties of naturally-bonded sand cannot be controlled as easily as synthetic foundry sand and this, together with the wider use of chemical binders, has contributed to the decline in their use.

LIMESTONE

Limestones are currently the only source of crushed rock aggregate in Herefordshire and Worcestershire. 629000 tonnes of limestone were produced in 1997, almost all of which (628000 tonnes) was used for aggregate purposes, the remainder being used for building stone. Data for the last 20 years are given in Figure 2. Several limestones of Silurian age crop out in narrow, strongly folded and faulted zones west of the Malverns, southwest of Stourport, in the Woolhope inlier between Hereford and Ledbury, and also in the west of the county at Kington. These limestones are relatively thin and shaly and belong to three formations known as the Woolhope, Wenlock and Aymestry limestones. Production of Silurian limestone is confined to three quarries (all in the Aymestry Limestone) in the area covered by this study.

The **Aymestry Limestone** is a sequence of dark grey, thinly bedded, nodular limestones, interbedded with siltstones and mudstone. It is between 15 m and 40 m in thickness and is generally lower purity than the Wenlock Limestone, locally grading to calcareous mudstone. It is currently used to produce coated roadstone and constructional fill.

The **Woolhope Limestone** consists mostly of alternating grey nodular limestones and darker grey calcareous mudstones. Over much of its outcrop it is around 15 m thick, although thickness may vary between 0 m and 75 m. Although generally only suitable for production of constructional fill, this formation can locally comprise relatively clean, massive limestones which are suitable for relatively good quality aggregate materials. The **Wenlock Limestone** usually forms a bold ridge at outcrop. It has been extensively quarried in the past, although working has ceased in this area. Similar limestones on Wenlock Edge in Shropshire are quarried for aggregates and agricultural lime. The formation consists predominantly of flaggy or well-bedded mid-grey limestones, with thin siltstone or mudstone interbeds. The Wenlock Limestone is between 50 m and 100 m thick in this area. Purity is low due to presence of non-calcareous silt and mud.

A small area of Carboniferous Limestone occurs on the county boundary south of Ross on Wye. This forms part of a much larger outcrop in the adjacent Forest of Dean. These outcrops contain dolomite (Lower Dolomite) and both high purity limestone (Crease Limestone) and lower purity limestone (Whitehead Limestone). All of these formations are suitable for crushed rock aggregate materials.

Limestone from the Jurassic Inferior Oolite Group is worked for building stone and aggregate at Broadway, in the extreme south of Worcestershire. Limestone from this quarry is widely used as a

dimension stone (freestone) and building stone in the Cotswolds area.

SANDSTONE

Sandstones of Ordovician, Silurian and Carboniferous age have been widely used as building stone within the area. These rocks (which include gritstones and quartzites) may represent resources which are suitable for applications which require high resistance to abrasion.

The Ordovician Lickey Quartzite occurs in a small inlier near to Bromsgrove. Silurian sandstones are found in association with limestones in the north western part of Herefordshire. The Folly Sandstone Formation was formerly worked for aggregate (along with the overlying Nash Scar Limestone) at Nash Scar Quarry near Kington. A high PSV (Polished Stone Value) of 67.5 has been reported for the Folly Sandstone Formation (Thompson *et al.*, 1993), along with an AAV (Aggregate Abrasion Value) of 4.4. However, the outcrop area of this sandstone is very small and resources are likely to be limited. This quarry is currently mothballed. A thick sandstone occurs within the Carboniferous Highley Formation of the Wyre Forest Coalfield. Information on the aggregate properties of this Coal Measure sandstone is extremely limited and its extent is, therefore, depicted on an inset, rather than the main map

IGNEOUS ROCKS

The Malverns Complex of Precambrian age forms the Malvern Hills which straddle the Worcestershire/ Herefordshire border. The Complex comprises mainly intrusive igneous rocks (molten material solidified beneath the earth's surface). These include diorites and tonalites, with minor granites and ultrabasic rocks. Many of the rocks are extensively sheared and are cut by microdiorite dykes and granite pegmatites. The intrusive Malvernian rocks are a potential source of good quality aggregate materials suitable for road surfacing, as well as for use in the lower layers of road pavements. In the past they were widely quarried for roadstone and building stone. Quarrying ceased in the 1980s. Aggregate property data for quartz diorite formerly produced from Tank quarry is given in Table 1.

Specific gravity	2.72
Water absorption	0.6%
Aggregate Crushing Value (ACV)	16.7
Aggregate Impact Value (AIV)	14.8
Aggregate Abrasion Value (AAV)	4.4
Polished Stone Value (PSV)	57

Table 1 Aggregate properties of quartz diorite from the former operation at Tank Quarry at the northern end of the Malvern Hills (Barclay *et al.*, 1997).

Definitions:

Aggregate Abrasion Value (AAV):

Resistance of an aggregate to abrasion as measured in the aggregate 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.

The Warren House Formation (also of Precambrian age) has a small outcrop in the Malvern Hills and is composed of a mixed series of extrusive rocks comprising basaltic lavas and rhyolites, with some lavas of intermediate composition (keratophyres) and pyroclastic rocks. The volcanic rocks are also intruded by dolerite dykes. These rocks have not been extensively quarried in the past and are likely to be inferior in quality to those of the Malverns Complex.

BUILDING STONE

Building stone has been produced from a number of horizons within the Silurian and Devonian rocks in Herefordshire. Working of building stone was widespread in the past. Present quarrying activities are restricted to four small sites in the south western part of the county, all working sandstone horizons within the Devonian Old Red sandstone. A continuing supply of building stone for new building and for restoration is necessary to maintain local vernacular architecture.

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 brick, including its aesthetic qualities.

Small brickworks mainly producing 'common' bricks from locally won raw materials were formerly a common feature in many industrial areas of Britain. 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 in the north east of the area from sites at Waresley and Hartlebury near Stourport. Both brick factories operate separate pits in the Triassic Mercia Mudstone Group for the production of facing bricks. Although it is an important raw material for the brick manufacturing sites in the Stourport area, the suitability of the Mercia Mudstone Group for brickmaking throughout much of its outcrop is largely unknown. For this reason, it has not been shown on the main map, but is defined on an inset map.

Clay from the Mercia Mudstone Group is utilised for a variety of reasons. It is a raw material with consistent forming and firing properties and has a relatively low firing temperature (1050°C). In this area, it is used for production of facing bricks for the high-volume housing market, where pricing is an important factor. The relatively pale fired body colour produced by this clay is suited to taking a variety of sanded and textured finishes in extruded wire-cut bricks, allowing the production of a significant proportion of the wide range of colours and textures demanded by the house building sector. The clay can be used to manufacture both extruded wire-cut and soft mud bricks. Other clays from outside the area may be blended-in in small quantities to improve the physical and aesthetic characteristics of some bricks.

SALT

Droitwich has been famous for its brine springs for many centuries and these may have provided the reason for siting the town, probably in pre-Roman times. The town became a salt manufacturing centre with a peak output of 122 000 tonnes in 1872-73. Stoke Prior subsequently supplanted Droitwich as the focus of salt production. Rock salt was discovered at Stoke Prior in 1828 and

was mined for a time until the workings flooded. The industry was re-established on natural brine pumping and continued until 1972 when the operations were closed by ICI because of subsidence problems. Output during the latter years of operation were some 150 000 tonnes a year .

Rock salt, or halite (sodium chloride, NaCl), underlies an area of at least 50 km² to the north-east of Worcester. The rock salt occurs within the Droitwich Halite member of the Eldersfield Mudstone of the Triassic Mercia Mudstone Group; it occurs in the northern part of the Worcester Basin. Salt-bearing strata does not crop out because of solution, but has a concealed crop, or 'wet-rock head', masked by collapsed strata and younger beds. The wet-rock head zone associated with the Droitwich Halite is thought to be about 1 km to 3 km wide and to extend from the Stoke Prior area south-westwards for at least 10 km, to around Martin Hussingtree. Salt-bearing strata extend south-eastwards from this zone and appear to be confined to a downfaulted block up to 10 km wide. The southern limit of the salt deposits is not known.

The inferred extent of the salt-bearing strata is defined by boreholes. The main record is the Saleway borehole, some 4 km south-east of Droitwich (Poole and Williams, 1981). Here the Droitwich Halite is 158.57 m thick and its top is at a depth of 248.41 m. The lower 73 m of the member consists largely of mudstone, with rock salt in beds up to 2 m thick. The upper part (85 m) of the member contains a higher proportion of salt (c.55 per cent) which forms beds up to 11 m thick, but mostly less than 4 m. For this reason it is difficult to see the deposit being of economic interest in the foreseeable future unless the salt beds thicken appreciably to the south-east.

COAL

A small area of Worcestershire (to the north of Bromsgrove) lies at the southern end of the South Staffordshire Coalfield. However, the productive Coal Measures are absent, having been overstepped by about 400 m of barren Upper Coal Measures (Old *et al.*, 1991). Another comparatively small area of Worcestershire to the north and west of Kidderminster lies at the southern end of the Wyre Forest Coalfield. This coalfield was worked underground at Mamble and Bayton, to the west of Stourport, up until the 1940s (Whitehead & Pocock, 1947). Applications for opencast working in the Worcestershire portion of the Wyre Forest Coalfield were made in the 1980s, but these were refused by the Mineral Planning Authority. A small northern outlier of the Forest of Dean Coalfield lies in Herefordshire between Ross-on-Wye and the county boundary with Gloucestershire. This part of the coalfield comprises the basal Trenchard Group (Welch & Trotter, 1961). Coal was worked opencast on a small-scale at Howle Hill (4 km south of Ross) between 1972-1977.

These coalfields are unlikely to attract any further opencast interest and are not, therefore, shown on the main mineral resources map. Their extent can be seen on the inset map showing hydrocarbon potential.

HYDROCARBONS

Conventional oil and gas

Although three exploration wells have been drilled within the area, none discovered oil or gas.

Netherton 1 was drilled to test the Permo-Triassic sandstones of the Worcester Basin for oil and gas. This borehole, together with other wells drilled in the Worcester Basin outside the area, indicate that this basin is not prospective. This is due to the absence of hydrocarbon source rocks within the basin.

Collington 1 and Fownhope 1 were drilled to test the oil and gas potential of Lower Palaeozoic rocks which lies to the west of the Worcester Basin. These wells, drilled on two prominent anticlines, failed to discover hydrocarbons and therefore reduce the potential of these older rocks.

Coalbed methane

On the basis of current evidence, Herefordshire and Worcestershire is not prospective for coalbed methane. The exposed coalfields of Wyre Forest and South Staffordshire are considered to have low methane potential. No information is available on the methane potential of the concealed Coal Measures which lie between these two coalfields.

Despite its apparently poor prospectivity for coalbed methane, part of the South Staffordshire coalfield, a very small part of the exposed Wyre Forest Coalfield, and the intervening area where coal measures are likely to occur in the subsurface (EXL 208) are licenced to ANGI Ltd. (formerly Evergreen Resources. ANGI are primarily a coalbed methane company. An extremely small part of eastern Worcestershire (EXL 209) is also licenced to ANGI Ltd.

The Forest of Dean Coalfield has no significant coalbed methane potential.

SECONDARY AGGREGATES

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

- Naturally-occurring materials arising from mineral extraction and processing operations, such as colliery spoil, overburden and quarry/processing waste
- Materials arising from industrial processes, such as slags and ash, which may be of variable composition
- 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 material are excluded from this study as their arisings are highly variable in location, type and duration.

Utilising the aggregate potential of such materials may have 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. There are no coal-fired power stations, smelting activities or large spoil dumps from mining operations in Herefordshire and Worcestershire. The potential for producing secondary aggregates is, therefore, limited.

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 and SSSIs) 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 may only be acceptable in areas designated as SPAs or SACs if there are no alternatives and if there are imperative reasons of overriding public interest. 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.

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 Resources Map of Herefordshire and Worcestershire provides a synthesis of available information which can be revised and updated as additional data becomes available. Additional constraint information can be readily incorporated as required. It is hoped that the map and the associated report will assist local and national government, the minerals industry and other interests in the consideration and production of policies in development plans.

The landscape character of Herefordshire and Worcestershire 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 of Herefordshire and Worcestershire are predominantly rural (with the exception of the fringe to the urban area of the West Midlands conurbation) with contrasting landforms, notably the rise from the flat and broad valley of the Severn to the Malvern Hills. This contrast, which is related to the underlying geology and further enhanced by the vegetation cover, is reflected in various planning and conservation designations, including areas of AONB and SSSIs.

There is a close relationship between the extent of national planning designations and particular resource outcrops. All of the Malverns Complex, with the small exception of part of the town of Malvern, is

within the Malvern Hills AONB. This designated area also includes the majority of the central, north to south, outcrop of Silurian limestone resources. In addition, much of the remainder of the limestone outcrop in the Abberley Hills area is subject to a local policy safeguarding it from minerals extraction. Similarly, the outcrop of the Jurassic limestone is within the Cotswolds AONB and the Carboniferous Limestone, and part of the Silurian limestone at Woolhope, are within the Wye Valley AONB. Some of the sand and gravel resources are also within the AONBs.

The extent of SSSIs and NNRs reflect the diversity of geology and hence the diversity of habitats and species. Such designations are therefore concentrated in locations such as meadows, calcareous and acidic grasslands. These areas are also commonly underlain by valuable aggregate resources, such as in the Malverns, the Woolhope area and other parts of the Silurian limestone outcrop. Some SSSIs and NNRs have been designated due to the importance of geological outcrops.

Candidate SACs are treated as confirmed SACs for planning purposes and, in relation to development proposals, are subject to the same considerations as apply to SPAs.

Scheduled monuments are scattered throughout the area with major concentrations in the historic urban areas of Worcester and Hereford. Others are distributed along the river valleys and the ridges and uplands where they may overlie mineral resources.

In the north east, in the West Midlands urban fringe, land is designated as Green Belt. National policy on mineral working in Green Belt land is contained in PPG2.

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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 in the compilation of the map

a) British Geological Survey 1:50 000 geological map sheets

Sheet	Name	Edition	Published
167	Dudley	S+D	1975
182	Droitwich	S+D	1976
183	Redditch	S+D	1989
198	Hereford	S+D	1989
199	Worcester	S+D	1993
200	Stratford-upon-Avon	S+D	1974
216	Tewkesbury	S+D	1988
217	Moreton-in-Marsh	S+D	1981
233	Monmouth	S+D	1974
181	Ludlow (this sheet is in press)		
180, 197, 214, 215	No modern mapping available		
	S+D Solid and Drift combined		

b) British Geological Survey sheet memoirs

BARCLAY, W J, AMBROSE, K, CHADWICK, R A & PHAROAH, T C (1997). The geology of the country around Worcester. *Memoir of the British Geological Survey*, (England and Wales). Sheet 199.

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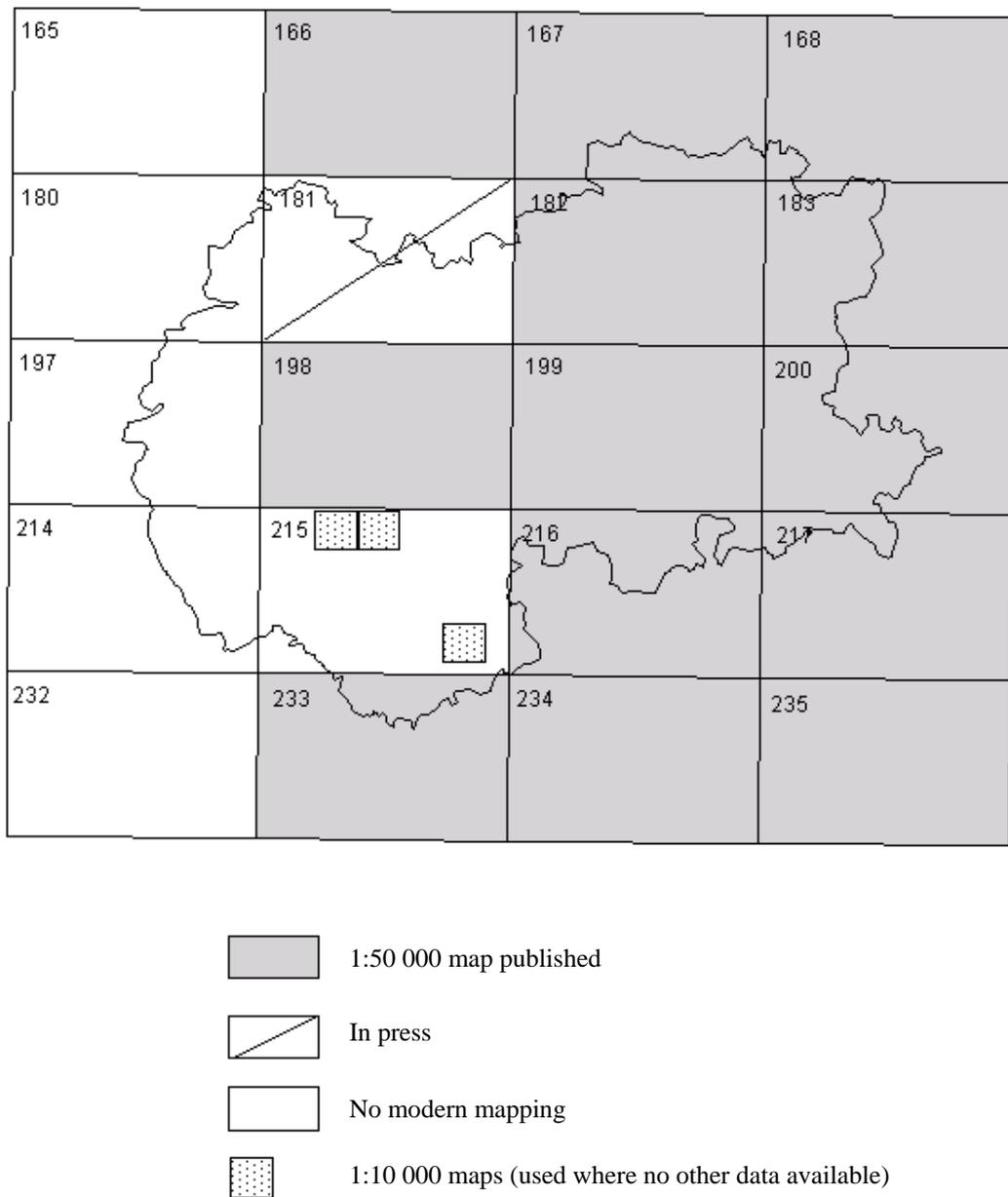


Figure 3 Availability of British Geological Survey 1:50 000 or 1:63 360 scale New Series geological map coverage of Hereford & Worcester

ACKNOWLEDGEMENTS

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APPENDIX 1 MINERAL WORKINGS IN HEREFORDSHIRE & WORCESTERSHIRE (1997)

Herefordshire

SITE_NAME	ALTERNATIVE NAME	LOCATION	EASTING	NORTHING	OPERATOR
Limestone					
Perton		Hereford	359500	239900	Huntsman's Quarries Ltd
Leinthall Earls		Aymestrey	344200	268200	Johnston Roadstone
Woodbury		Shelsley Beauchamp	374300	263700	Lafarge Redland Aggregates
Sand & Gravel					
Stretton Sugwas	Hereford Pit	Hereford	345200	242200	Hanson Aggregates - Central
Shobdon		Leominster	339500	260500	Hanson Aggregates - Central
Wellington	Marden Lane	Wellington	350798	248250	Lafarge Redland Aggregates
Lugg Bridge		Hereford	353688	242334	RMC Aggregates (Western) Ltd
Sandstone					
Coed Major		Craswell	325734	237226	Mr A Silver
Hunters Post		Welsh Newton	349347	217430	Radbourne's
High House		Llanveynde	330880	230800	zunknown

Worcestershire

Common Clay & Shale

Hartlebury		Stourport-on-Severn	385200	270900	Baggeridge Brick
Waresley	Baggeridge Brick	Stourport-on-Severn	385800	270000	Baggeridge Brick

Limestone

Broadway	Fish Hill	Broadway	411600	236800	Smith & Sons (Bletchington) Ltd
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Sand & Gravel

Lower Moor Gravel Pit		Evesham	398000	245700	Avon Gravels Ltd	
Aston Mill		Tewkesbury	395500	235750	Gloucestershire Sand & Gravel Co Ltd	
Grimley / Ball Mill		Grimley	383220	261000	Nash Rocks Ltd	Minorco
Mill Farm	Pinches, Chadwich Mill Farm	Bromsgrove	396590	275550	Onyx UK	Onyx UK
Brant Farm		Stourport	379100	273600	R Constant & Co Ltd	
Lickhill		Stourport	379300	272700	R Constant & Co Ltd	
Ryall	Ryall House Farm	Upton-on-Severn	386750	240000	RMC Aggregates (Western) Ltd	RMC
Saxon's Lode Farm	Ryall	Upton-on-Severn	386650	239250	RMC Aggregates (Western) Ltd	RMC
Shepley		Bromsgrove	398300	273400	RMC Aggregates (Western) Ltd	RMC
Shepley North	Shepley	Bromsgrove	398450	273313	RMC Aggregates (Western) Ltd	RMC
Shepley South	Shepley	Bromsgrove	398260	273085	RMC Aggregates (Western) Ltd	RMC
Clifton		Great Malvern	384400	246000	Tarmac Quarry Products West Midlands	Tarmac
Retreat Farm	Grimley	Grimley	383205	259810	Tilcon - Western	Minorco

Herefordshire and Worcestershire Mineral Resources and Constraints

Silica Sand

Cinetic Sands		Bromsgrove	395100	275900	J Williams (Cinetic Sands) Ltd
Mill Farm	Pinches, Chadwich	Bromsgrove	396500	275500	Onyx UK
	Mill Farm				Onyx UK
Sandy Lane		Bromsgrove	395200	276300	Stanley N Evans Ltd

APPENDIX 2 CONTACT ADDRESSES FOR FURTHER ENQUIRIES

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<p>Redditch Borough Council Town Hall, Alcester Street, Redditch B98 8AH Tel:01527-64252 Fax:01527-65216</p>	<p>Wyre Forest District Council Civic Centre Stourport-on-Severn Worcestershire DY13 8UJ Telephone : 01562 820 505 Fax : 01299 879688</p>
<p>Malvern Hills District Council The Council House Avenue Road Malvern Worcestershire WR14 3AF Tel: 01684 892700</p>	<p>Worcester City Council The Guildhall High Street Worcester WR1 2EY Tel: 01905 723471</p>
<p>Wychavon District Council Civic Centre Station Road Persore Worcestershire WR10 1PT Tel: 01386 565000</p>	<p>Herefordshire Council Planning Services PO Box 43 Leominster HR6 8ZE Tel: 01432 260385 Fax: 01568 616559</p>
<p>Countryside Agency John Dower House Crescent Place Cheltenham Gloucestershire GL50 3RA Tel: 01242 521381 Fax: 01242 584270</p>	<p>English Nature Northminster House Northminster Peterborough PE1 1UA Tel: 01733 455000 Fax: 01733 455103</p>
<p>English Heritage Fortress House Savile Row London SW1X 1AB Tel: 0207 973 3000 Fax: 0207 973 3001</p>	<p>Environment Agency Regional Office Sapphire East 550 Streetsbrook Road Solihull West Midlands B91 1QT Tel: 0121 711 2324 Fax: 0121 711 5824</p>

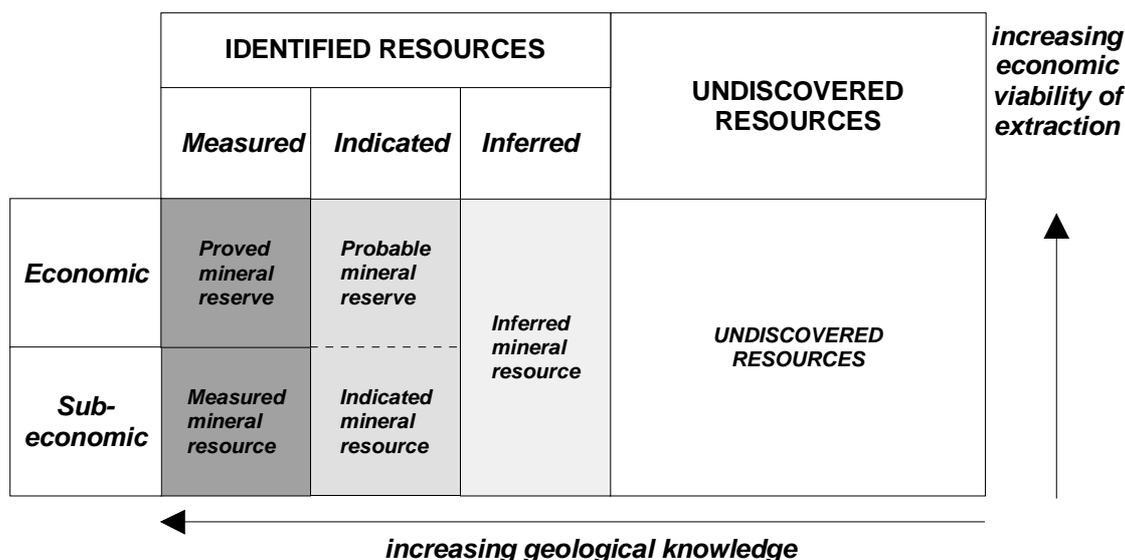
APPENDIX 3 METHODOLOGY

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 using Intergraph Microstation 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.

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.

Figure 1 Classification of resources



Based on McKelvey, 1972

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 it 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. No sand and gravel assessment studies have been carried out in parts of Hereford & Worcester.

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).

In the context of land-use planning, however, 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 Map. 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 Hereford & Worcester and the West Midlands are shown on the map. 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 Herefordshire District Council or Worcestershire County Council.

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 not applicable to the full extent of the underlying rock type:

The latest data available for the total areas of planning permissions in Herefordshire & Worcestershire, collected for the Department of Environment Minerals Survey of 1994, is shown in Table 1. This information is updated at intervals.

Table 1 Areas of planning permissions for mineral workings in Herefordshire & Worcestershire (as at 1.4.94)

	Commodity	Total permitted	No. of sites	%
Surface workings	Clay/shale	34	1	4.56
	Limestone/dolomite	78	7	10.46
	Sand and gravel (construction)	633	27	84.85
	Sandstone	1	3	0.13
	Total	746	38	100

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