

LIMESTONES OF THE PEAK

A guide to the limestone and dolomite resources of the Peak District of Derbyshire and Staffordshire

Description of parts of 1:50 000 geological sheets 99, 111, 112, 124 and 125

D. J. Harrison and K. A. McL. Adlam

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Plate 1 Tunstead Quarry, near Buxton. This is the major producing unit in the Peak District and works very high purity Bee Low and Woo Dale limestones primarily for use in the chemical industry. Much of the production is moved by rail (photograph reproduced by courtesy of Aerofilms Limited)

The first twelve reports on the assessment of British sand and gravel resources appeared in the Report Series of the Institute of Geological Sciences as a subseries. Report No. 13 and subsequent reports appeared as Mineral Assessment Reports of the Institute. The Institute was renamed British Geological Survey at the beginning of 1984.

Details of published reports appear at the end of this Report.

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PREFACE

National resources of limestone may seem so large that stocktaking appears unnecessary, but in recent years the increasing demand for limestone and for land for all purposes has emphasised the need for regional assessments of limestone resources. The publication of information about the quantity and quality of limestone deposits over large areas is intended to provide a comprehensive factual background against which planning policy decisions can be made.

Following recommendations by central government that limestone resources should be investigated, a feasibility study was initiated in 1970 by the Survey, and the Industrial Minerals Assessment Unit began systematic surveys in 1972. The work was formulated and financed by the Department of the Environment and was undertaken with the co-operation of members of the British Quarrying and Slag Federation (now superseded by the British Aggregate Construction Materials Industries) as well as by independent members of the extractive industry.

This report describes the limestone and dolomite resources of some 540 km² in the Peak District in the centre of England, shown on the accompanying 1:50 000 resource map. The report is a summary of six earlier reports on the carbonate resources covering this area. The assessment was conducted by D. J. Harrison with the assistance of K. A. McL. Adlam who provided data systems support. H. Mathers undertook additional laboratory testing. Throughout this work, advice and guidance was given by representatives of the Peak Park Joint Planning Board, Derbyshire County Council, Staffordshire County Council and the Minerals Division of the Department of the Environment.

The assessment is based on geological surveys at the 1:10 560 scale by members of the BGS Land Survey staff.

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1 August 1984

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SUMMARY

The collation and synthesis of data from previous British Geological Survey (BGS) limestone assessment surveys together with information from the geological maps of the BGS forms the basis of the assessment of limestone and dolomite resources of the Peak District of Derbyshire and Staffordshire.

There is no single authoritative definition of the name 'The Peak District'. Its main origins and use are in connection with landscape appreciation and recreation. To most people it applies as much to the high gritstone moors of the Dark Peak between Sheffield and Manchester, as to the limestone plateau and dales of the White Peak. It has statutory meaning in the formal designation (1951) of the Peak District National Park. It is 'borrowed' for this study in that most of the limestone resource is attractive hill country and is within the spirit of the title 'Peak District' even though some of the Study Area lies outside the National Park. The Study Area is the area covered by the outcrop of the Carboniferous Limestone.

The Carboniferous Limestone of the northern, central and extreme south-western parts of the Peak District consists predominantly of pale grey, thickly bedded limestones with a known thickness of almost 2000 m, although only the uppermost 600 m of strata are exposed. These limestones were deposited in relatively shallow water on a marine shelf and are notable for their uniformity over wide areas. In the south of the Peak District, in the Manifold Valley — Dove Dale area, the limestones are mostly dark grey and contain some shales and sandstones. These beds, which are known to total around 1300 m in thickness, were deposited in relatively deep water and are of variable character.

The limestone sequence locally contains deposits of volcanic rock, chiefly lavas and tuffs, and in a few areas basaltic rock has been intruded within the sediments. Locally the limestones have been altered to dolomite and in some areas the limestones are mineralised and host deposits of a variety of minerals, many of which are currently extracted for use in industry. Fissures and solution-caverns in the limestone are often infilled with clays and sands but the limestone surface is typically free of drift cover and the few deposits of boulder clay or alluvium are not extensive.

Limestone quarrying in the area can be traced back as far as Roman times when small amounts of material were worked for building stone and lime. Extraction for these purposes continued through the years until by the early eighteenth century limestone quarrying was established as a major industry in Derbyshire. The improvement in transport brought about by the canal and railway systems gave a great impetus to the trade and the industrial expansion of the nineteenth century created an upsurge in demand for a variety of limestone products. In the early years of this century the industry grew steadily and, with the arrival of tarred materials for road construction, the demand for limestone aggregate increased dramatically. At the present time most of the limestone production in the Peak District is used by the construction industry but the exceptionally high purity of the Derbyshire limestones has resulted in extraction of large amounts of stone for use in the chemical and iron and steel industries and for other specialist industrial applications. Limestone is currently extracted from some

twenty eight quarries, most of which are situated near Buxton and Wirksworth in Derbyshire and near Waterhouses in Staffordshire. Several of the quarries have rail links but in most cases the limestone products are moved by road.

Striking a balance between the demand for limestone, the need to protect the landscape and the needs of the local community is the responsibility of the planning authorities. This work was commissioned by the Department of the Environment in order to assist land-use and mineral planners by providing information on the quality and quantity of the limestone deposits of the Peak District.

The limestones and dolomites have been classified on their carbonate content and the accompanying 1:50 000 scale resource map shows the distribution of the categories of limestones and dolomites recognised at outcrop. Peripheral smaller scale maps show the aggregate potential of the limestones and indicate the location of high chemical-grade limestones and dolomites. The geology and the aggregate and chemical properties, and resources of the rocks are described in the report.

The synthesis has shown that the limestones show little regional or stratigraphical variation in their aggregate properties, although the dolomites and dolomitised limestones and the shale-dominated parts of the succession may not be suitable for aggregate materials. The Woo Dale, Bee Low and Kevin limestones are consistently of very high purity and form one of the most important resources of high grade limestone in the country. High purity limestones are also found in the other formations, but generally they are of lower chemical grade and contain variable amounts of silica, alumina, iron and other impurities. The dolomites are iron-rich and are usually of low chemical grade, although some deposits of higher grade have been identified.

The limestone and dolomite resources are locally downgraded by the effects of mineralisation or by waste deposits of volcanic rocks, clays and shales which occur within the resource, but overburden is only rarely a constraint on mineral working in the Peak District.

This work is aimed as a general guide for non-geologists and a glossary of technical terms is included. A thematic bibliography covering Geology, Planning and the Environment, Resource Assessment and The Minerals Industry lists a comprehensive selection of publications relevant to each theme.

Bibliographical reference

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Limestones of the Peak: a guide to the limestone and dolomite resources of the Peak District of Derbyshire and Staffordshire

Description of parts of 1:50 000 geological sheets 99, 111, 112, 124 and 125

D. J. Harrison and K. A. McL. Adlam

INTRODUCTION

Limestone, which is required to meet many varied industrial needs, commonly gives rise to attractive rural areas of high scenic value. Limestone quarrying in the Peak District of Derbyshire and Staffordshire has a long history and quarries were once numerous and small. Modern quarries are fewer but are much larger so that their local impact may be much greater. Striking a balance between the need to satisfy the demands of society for limestone and its products and the desire to protect the countryside is the responsibility of the planning authorities.

In order to assist land-use and mineral planning by central and local government, the British Geological Survey (formerly the Institute of Geological Sciences) has been concerned since 1970 with the provision of detailed information on limestone resources. This work has been directed and financed by the Department of the Environment. The Carboniferous limestone and dolomite resources of Derbyshire and Staffordshire have been surveyed at the indicated level of resource appraisal (McKelvey, 1972). The results, which quantify the variations in the geological, mechanical and chemical characteristics of the rocks, have been published in the form of six 1:25 000 scale resource maps with accompanying descriptive reports in the Mineral Assessment Reports of the Survey (see bibliography for details).

The aim of this report, with its accompanying 1:50 000 scale resource map, is to collate and summarise the findings of the six previous reports and to provide an over-view to enable non-geologists (particularly planners, elected members, executives and people working in the industry) to appreciate the general variations in the limestones of the Peak District. Using the data from all six surveys, it has been possible to demonstrate regional trends, particularly in the geochemistry of the limestones. In addition to the previous survey data, new data have been collected from a small number of samples which were subjected to a wide range of laboratory aggregate tests, so that the physical and mechanical properties of the rocks could be more fully evaluated than had been attempted in the previous surveys. Also, for the first time, the isolated limestone outcrops at Ashover and Crich have been evaluated, although only at a reconnaissance level.

The rocks have been classified (Table 1) on their calcium carbonate (CaCO_3) content so that the relationship between limestone purity and possible end-use can be deduced. The resource map uses a modified version of this classification to show the surface distribution of the various grades of limestone and dolomite. Several smaller-scale maps which complement the main map show the distribution of the Dinantian formations, the aggregate potential and the location of high chemical grade limestone and dolomite. The report contains a brief summary of the geology (with references to published sources) and details of the limestone and dolomite resources. Some consideration is given to the distribution of resources at depth. The main factors affecting mineral working, such as the occurrence of igneous rocks, overburden, chert, interbedded clays, mineralisation and the water table, are also discussed. A glossary of technical terms and an extensive bibliography are appended.

History of quarrying

Limestone was quarried in Derbyshire in Roman times for building stone and lime, and intermittent local workings for these purposes continued through the centuries; total production, however, was small. The lime was used by farmers to 'sweeten' the soil and small timber-fired, and later coal-fired, kilns were established on most large farms. By the early eighteenth century the use of gunpowder for blasting and coal for firing had established quarrying and lime working in Derbyshire as a distinct industry. However, even with the improvement brought about by turnpike roads, the reliance on pack-horses and carts for transport constrained the growth of the industry.

By the late 1700s schemes were promoted to move limestone and lime by barge and in 1776 the Caldon Canal opened followed by the Cromford Canal in 1793 and the Peak Forest Canal in 1797. These gave a great impetus to trade in bulk materials and the early nineteenth century saw the beginning of the modern quarrying industry. A horse-drawn tramway was constructed to connect the limestone outcrop near Dove Holes with the Peak Forest Canal at Buxworth, and in 1822 the Cromford and Peak Forest canals were connected by an overland tramway, the Cromford and High Peak Railway. Horses were also used on this tramway but locomotives began to be introduced in the 1830s and the inclines were negotiated, with gradients as steep as 1 in 7, by steam winding engines. Many quarries were opened alongside the tramways; the canal system and the tramway feeders determined the location of quarries up to about 1860.

During this period, the great industrial expansion of the nineteenth century had begun and factories and gas-works were built, the chemical and glass industries were expanding rapidly and agriculture was prosperous. All these industries required limestone and the demand for Derbyshire limestone to feed the industries of Lancashire, south Yorkshire and the Midlands increased dramatically.

The application of steam power to locomotion made possible the development of the railways. This gave further impetus to the development of the limestone quarrying industry. In the 1860s the main line railways arrived in the area (Figure 1) primarily to facilitate the

Table 1 Classification of limestones by purity

Category	Percentages	
	CaCO_3	Equivalent CaO
1 Very high purity	>98.5	>55.2
2 High purity	>97.0 - <98.5	>54.3 - <55.2
3 Medium purity	>93.5 - <97.0	>52.4 - <54.3
4 Low purity	>85.0 - <93.5	>47.6 - <52.4
5 Impure	<85.0	<47.6

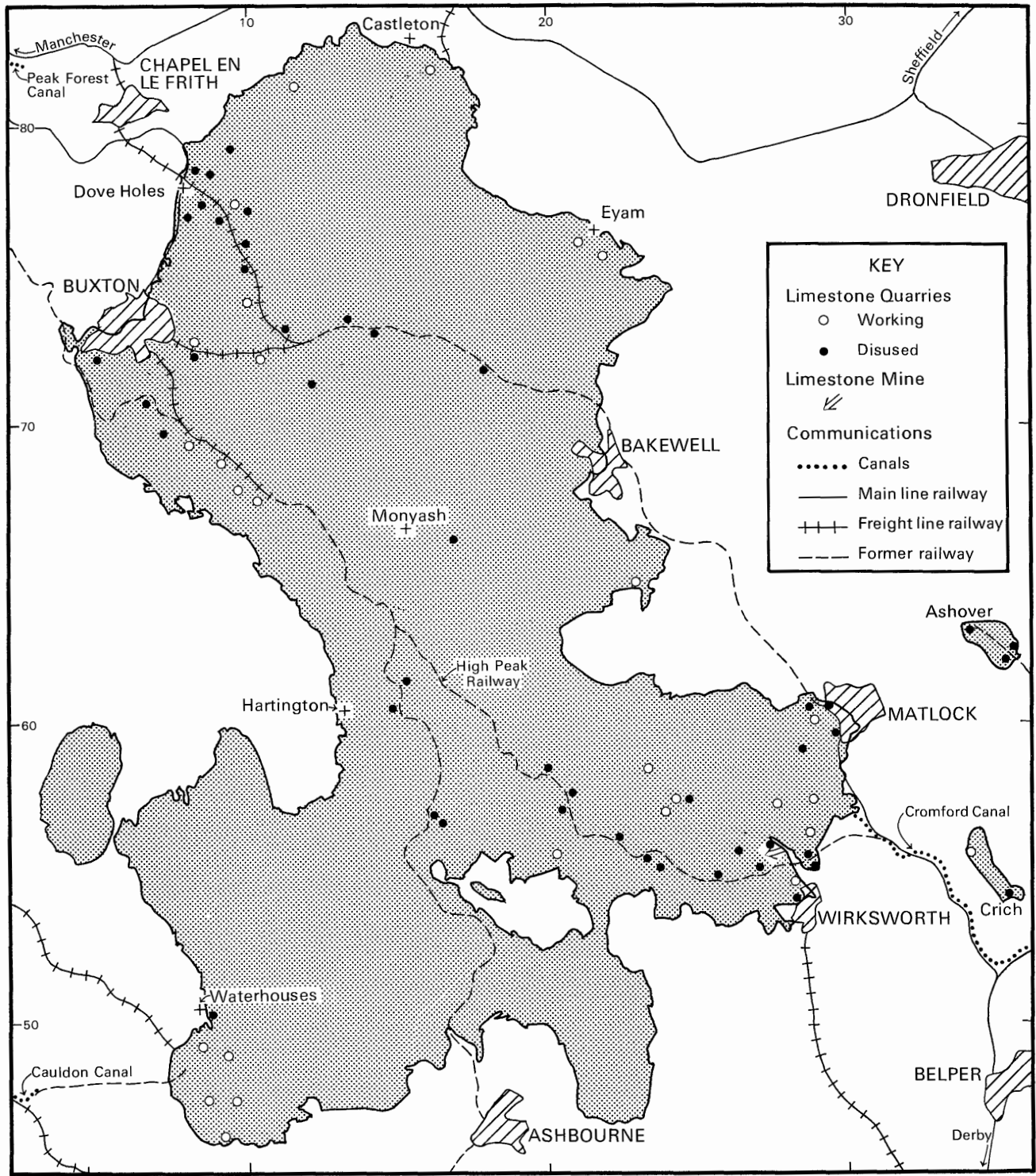


Figure 1 The distribution of quarries in relation to the location of canals and railways.

transportation of lime and limestone. Quarrying developed at a spectacular rate with most quarries having ready access to one of the main lines. A few quarries were not situated alongside railway lines and their increased transport costs could only be justified if their limestone products were of high unit value (e.g. ornamental marble, exceptionally pure glass-grade limestone). The canal – tramway system declined in importance and began to fall into disuse. It finally closed in 1926.

In the last quarter of the nineteenth century a fall in demand for agricultural lime, was replaced by an expansion in demand from other industries, such as the iron industry of Lancashire, Staffordshire and southwest

Yorkshire. This helped keep many of the quarries in business. However, there was much competition in the extractive industry at this time resulting in a large number of amalgamations. In the early years of this century the industry grew steadily with the continued search for new uses for limestone products. It was about this time that the use of tarred materials for road pavements began to expand. Derbyshire limestone proved to be of great value for this purpose. However, it was not until after the First World War that motor vehicles began to take over from horse-drawn traffic, and the age of the tar-bound road had truly arrived. Several new quarries opened to provide road-making materials, some of which were extracting limestone and others, basalt.

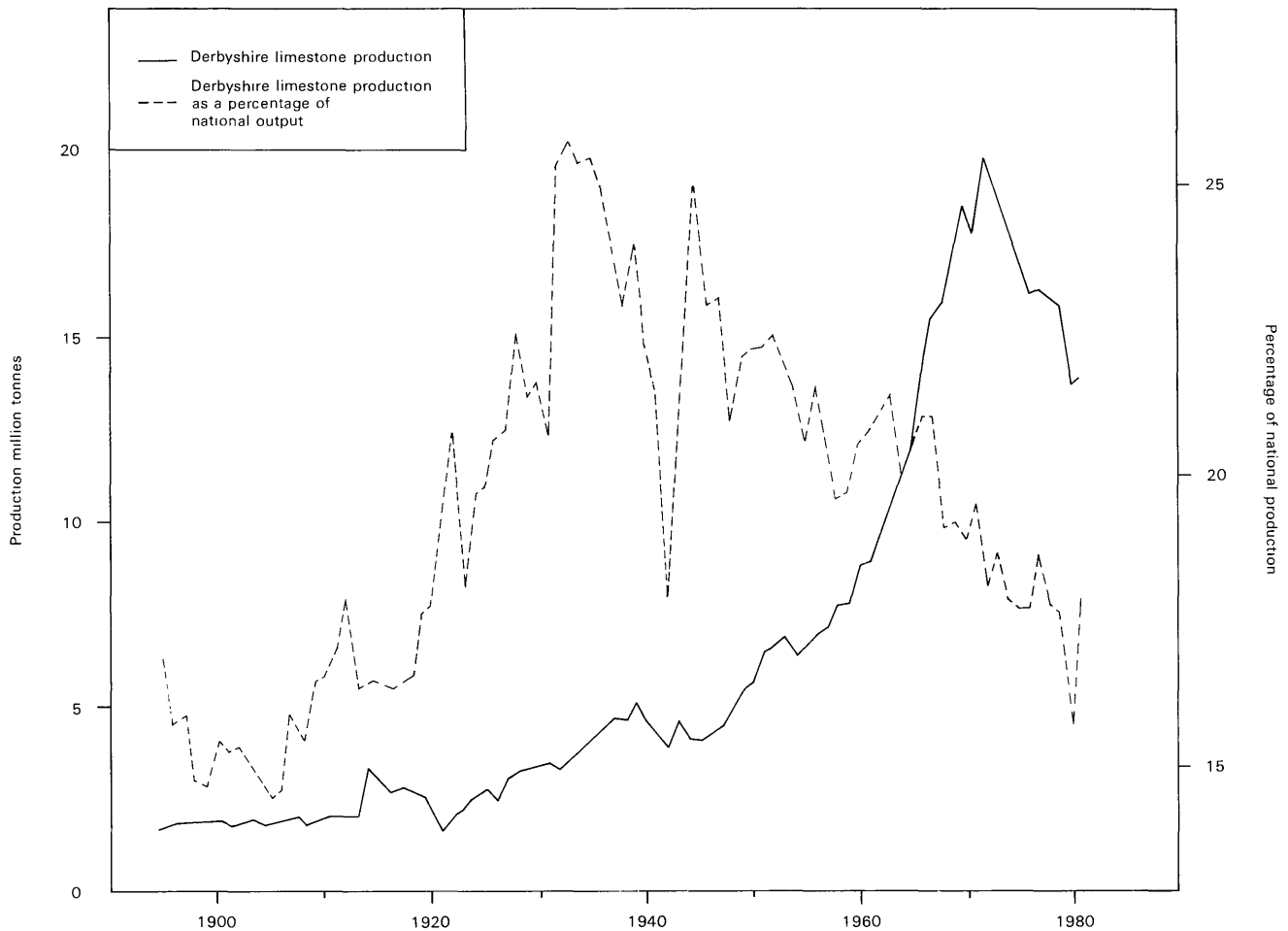


Figure 2 Annual production of limestone from Derbyshire in relation to national output.

Up to the time of the Second World War, limestone quarrying was relatively unsophisticated and largely dependent on manual labour but with the increased demands made by the war and the lack of manpower, the quarries began to mechanise (Plate 2). The process of mechanisation and rationalisation has continued rapidly and the number of men employed has fallen considerably. In 1939 approximately 5300 men worked in the quarries which represented about 15 per cent of the working males in the area. In 1982 about 1700 people were directly employed in limestone quarrying in Derbyshire and Staffordshire.

The other major change in the modern quarrying industry has been the shift from rail to road transportation of limestone products. Prior to the Second World War, the overwhelming volume of Derbyshire limestone products was carried away by rail, but this dropped to 50 per cent in the 1950s and then to about 20 per cent in 1960. Since then it has risen in the 1970s and probably now accounts for between a quarter and a third of total sales of what is now a much larger and more diverse market.

Limestone products

Limestone has a wide range of industrial uses although it is used principally as an aggregate and in the manufacture of cement. About 55 per cent of the total limestone production from the Peak District of Derbyshire and Staffordshire is used as roadstone, concrete aggregate or for other constructional purposes, but Derbyshire is nevertheless the main producing county for high purity industrial limestone in the United Kingdom (Figure 2).

Much of this high purity limestone is used in the manufacture of soda ash (sodium carbonate) at the ICI plant in Cheshire, or in the manufacture of glass, as a

metallurgical flux or in sugar-beet refining. There are many other specialised uses for limestone products ranging from lime used in wire drawing and in water treatment to ground limestone powders used in paints and rubbers. The markets for specialised limestone products are spread throughout the country but the major sales of limestone aggregates produced in the area are to the regions close to the Peak District.

Figure 3 shows the location of active quarries in relation to the main lines of communications and the distribution of administrative boundaries. The size of the quarries, in terms of relative output, is also shown. The major producing unit is Tunstead Quarry owned by ICI which has a nominal capacity of 5 million tonnes a year. Other quarries are smaller but several produce between 1-2 million tonnes of limestone annually. Cement works are situated at Hope and Cauldon, both of which work relatively impure limestones for admixture with local shales. A further small cement kiln is operated at Tunstead Quarry and this uses the wet process of cement manufacture utilising clay slurry (waste) from the washing plant. Hope cement works, Cauldon Low cement works, Middlepeak Quarry, Wirksworth and most of the quarries in the Buxton area, including Tunstead, have rail connections.

Limestone is also extracted at Middleton Mine, which is one of the very few limestone mines in the United Kingdom. It originated (in 1939) as an underground extension of a surface quarry and extracts very pure limestone by the pillar and stall method of working.

At present dolomite is worked on only a very small scale for aggregate at Ball Eye Quarry near Cromford, and basalt is quarried for roadstone at Waterswallows, near Buxton.

Because the Carboniferous Limestone forms attract-

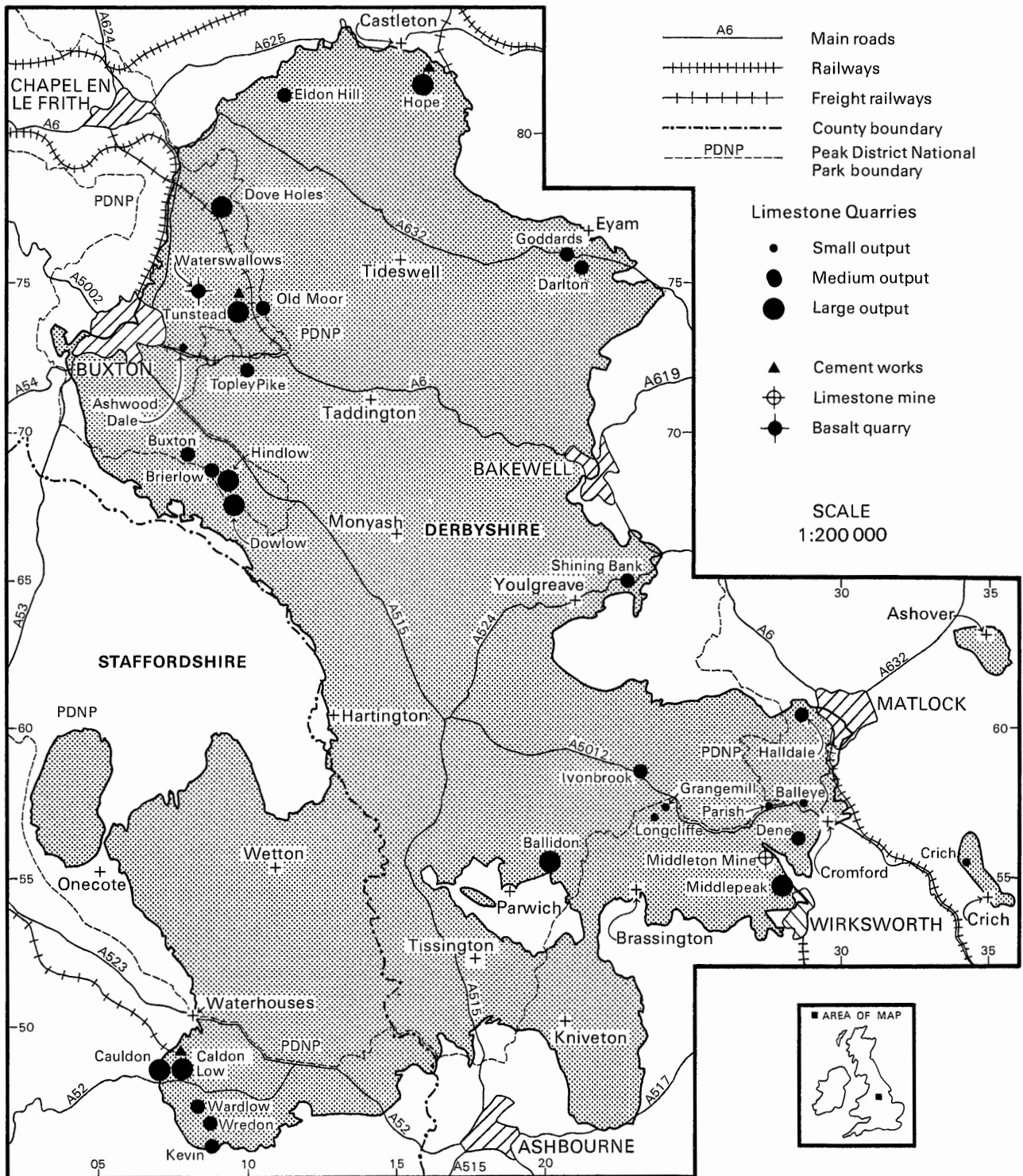


Figure 3 Location of working quarries in the early 1980's.

tive scenery a relatively large proportion of its outcrop is included within the Peak District National Park, the boundary of which was drawn to exclude the main concentrations of quarries near Buxton and Wirksworth in Derbyshire, and Waterhouses in Staffordshire.

National Parks, Areas of Outstanding Natural Beauty and other areas given protection for environmental conservation (e.g. Sites of Special Scientific Interest, National Nature Reserves, etc.) often owe their designation, in part, to the underlying geology. Many of these areas contain economically workable deposits potentially useful for aggregates. DoE Circular 4/76 states in respect of National Parks new applications to work aggregate minerals 'should be subject to the most

rigorous examination'. Such an approval is also relevant to the consideration of new applications in environmentally protected areas in all counties. These principles can be extended to the wider range of end-uses for which these minerals are suitable and to other minerals. However, if a mineral is scarce or a quantity of mineral suitable to meet a particularly demanding standard or specification is required, there may be a stronger case for working it in a protected area if alternative sources are not available elsewhere.

GEOLOGY OF THE CARBONIFEROUS LIMESTONE

The aim of the following geological account is to outline the regional variations in the general characteristics of

the Dinantian (Lower Carboniferous) rocks of the Peak District. More specific geological data are given in the six detailed limestone assessment reports which cover the region and these are based mainly on published information in the Chapel en le Frith, Chesterfield and Matlock, and Derby Geological Survey memoirs together with the geological investigations detailed in the forthcoming Buxton and Ashbourne memoirs. A selection of papers covering the lithology, stratigraphy, structure, mineralisation and hydrogeology of the Dinantian rocks is given in the bibliography.

Geological setting

The Dinantian rocks of the Peak District are a marine sequence composed mainly of limestones, but also containing some shales and sandstone units. These rest unconformably on pre-Carboniferous rocks which are not exposed in the area but have been proved in three deep boreholes at Caldron Low, Woo Dale and Eyam. During the early Dinantian, carbonates were probably deposited throughout the region but these beds are at present only exposed in the Dovedale – Ecton – Caldron Low area in the southwest of the region. During later Dinantian times shallow, well-oxygenated seas were established in northern and central parts of the region (the Derbyshire shelf) and also, on a smaller scale, in the extreme southwest (the Staffordshire shelf) while an area of deeper water covered the intervening 'off-shelf' area (Aitkenhead and Chisholm, 1982). On the shelves, pale-coloured limestones were deposited which are distinctive for their lithological uniformity over wide areas, but in the off-shelf province a much more varied sequence was laid down. During the closing stages of the Dinantian a series of localised volcanic eruptions occurred in both the shelf and off-shelf provinces and lavas and tuffs were interbedded with the limestones. Carbonate deposition diminished at the end of the Dinantian and gave way to muds and sands during the Namurian.

There were slight earth-movements during deposition but the main phase of deformation took place at the end of the Carboniferous period. The effect of the earth movements on the shelf limestones was relatively minor but the rocks of the intervening area were arched up into a series of north- or northwesterly-trending folds.

A long erosional interval followed the earth movements. Alteration of the limestones to dolomite occurred locally probably during Permian times, and episodic mineralisation took place from the Carboniferous through to Jurassic times, when fissures in the limestones were in places infilled with calcite, baryte and fluorite locally containing lead, zinc and copper ores.

Renewed uplift during the Tertiary led to the removal of the post-Dinantian cover rocks and the deposition on the limestone surface of sands and clays of fluvial and lacustrine origin. These are now only preserved in steep-sided solution-pockets in the limestone and are collectively termed Pocket Deposits.

Spreads of surface drift, dating from the Quaternary Ice Age and later, are the most recent deposits in the region. On the limestone outcrops the main deposits are head, a reddish brown, cherty silt that attains a few metres thickness locally in hollows, and boulder clay. Alluvial deposits follow the main watercourses.

Stratigraphical nomenclature

In past years the geological literature of the region has produced a lithostratigraphy containing a large number of local rock names. With the completion of the British Geological Survey's primary six-inch mapping of the region, it has been possible to produce a formalised stratigraphical scheme for the whole region (Aitkenhead and Chisholm, 1982). This has defined a single set of formational names for extensive rock units of similar character and age (Figure 4).

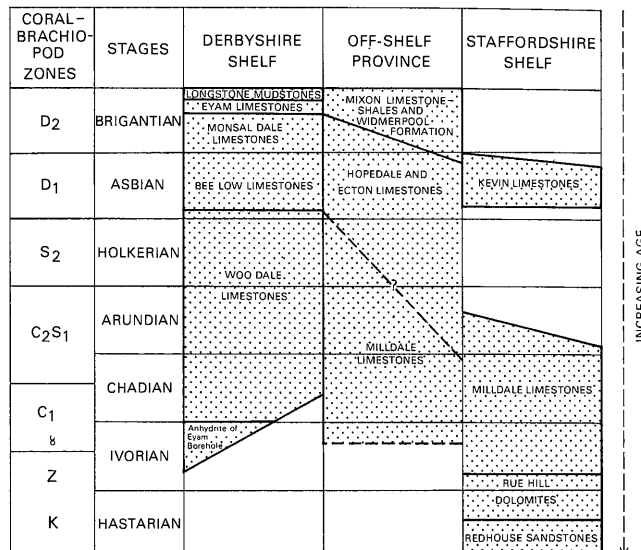


Figure 4 Nomenclature and age relations of the Dinantian formations of the Peak District.

Formations of the Derbyshire shelf

Woo Dale Limestones These rocks occur in several relatively small and isolated outcrops (Figure 5) although they underlie the whole of the Derbyshire shelf area. The base of the formation has been encountered only in the Woo Dale [0985 7248] and Eyam boreholes [2096 7603] and laterally the formation passes into the Milldale Limestones of the off-shelf province. The proved thickness of the formation is 402 m at Woo Dale and a maximum of 1324 m in the Eyam Borehole.

Normally the formation consists of limestones with minor dolomitisation, but a dolomitic facies is developed in the outcrops in Woo Dale (Woo Dale Dolomites). The dolomitic facies is present at depth in all boreholes that have penetrated the lower parts of the Woo Dale Limestones; the Woo Dale (Cope, 1973), Eyam (Dunham, 1973) and Ryder Point No. 3 boreholes (Chisholm and Butcher, 1981). The facies is therefore believed to persist throughout the shelf area, though at varying stratigraphical levels.

The top part of the sequence is generally characterised by thin-bedded, pale to dark grey, porcellanous micritic limestones. These pass down into a thicker-bedded sequence of pale grey, bioclastic limestones. At Peak Forest, however, the limestones (the Peak Forest Limestones) are pale grey, coarsely crinoidal biosparites throughout.

The Woo Dale Limestones are quarried at two sites in Wye Dale, east of Buxton.

Bee Low Limestones This formation forms about 50 per cent of the limestone outcrop and is of considerable economic importance as it provides most of the limestone quarried in the Derbyshire shelf area. It is estimated to be about 185 m thick near Buxton, a maximum of about 213 m near Hartington, and only about 70 m at Wirksworth.

The formation is characterised by the lateral and vertical homogeneity of its limestones which are mainly thick-bedded, pale grey biosparites and biopelsparites. Beds of reddish brown and greyish green volcanic clay up to 0.5 m thick ('wayboards': Walkden, 1972) are present at certain horizons (Plate 3) throughout the sequence, particularly in the middle and upper parts of the formation. Locally, especially in the northern half of the shelf area, basaltic lavas and tuffs are interbedded with the limestones (Walters and Ineson, 1981). At the northern, western and southern margins of the shelf, an apron-reef



Plate 2 Quarrying in Dove Holes Dale c.1947 (photograph reproduced by courtesy of Aerofilms Limited).



Plate 3 Pale grey, thick bedded Bee Low Limestones with clay wayboards. Hillhead Quarry, Buxton.

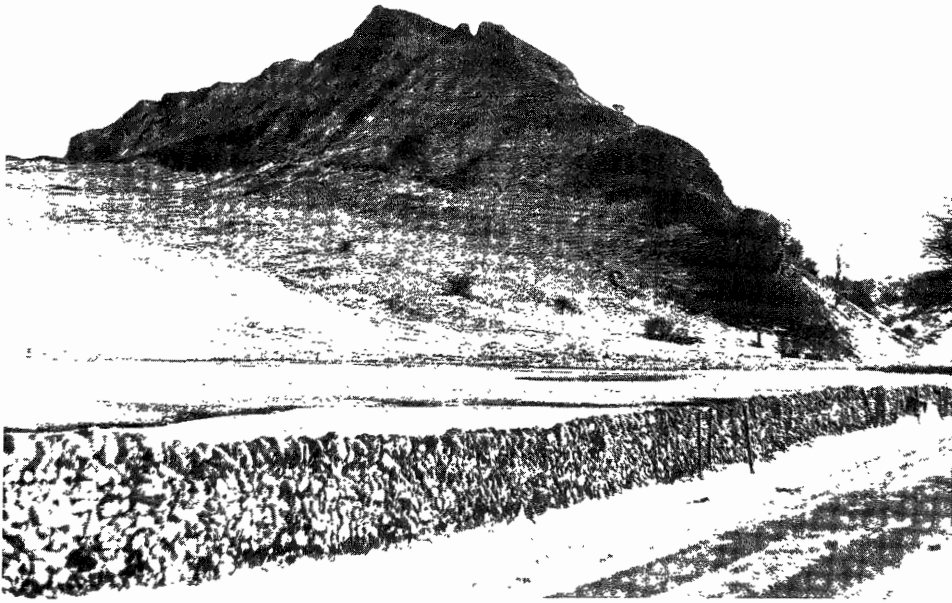


Plate 4 Apron-reef facies limestones forming steep-sided hills. Parkhouse Hill, Longnor.



Plate 5 Dolomitised Bee Low Limestones at Harboro' Rocks, Brassington. These rocks are the most consistent deposit of high grade dolomite proved by the survey.



Plate 6 Miller's Dale Limestones with Dove Holes Tuff. Holderness Quarry, Dove Holes.



Plate 7 Eyam Limestones: interbedded dark limestone and mudstone. Little Longstone.



Plate 8 Knoll-reef limestones in the Milldale Limestones of the off-shelf province. Thorpe Cloud, Dovedale.

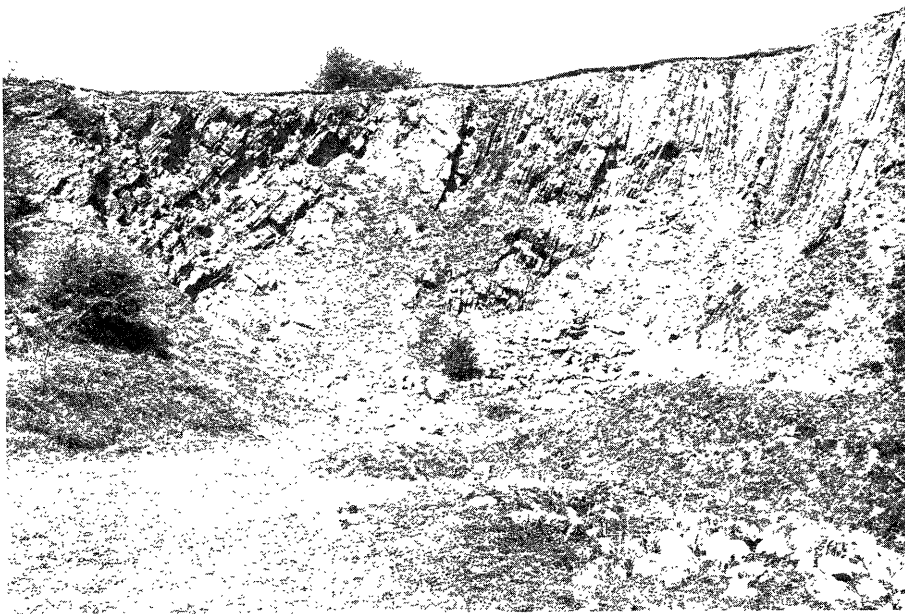


Plate 9 The Milldale Limestones at Brownend Quarry, Waterhouses: steeply dipping, thin-bedded limestones with shale intercalations.

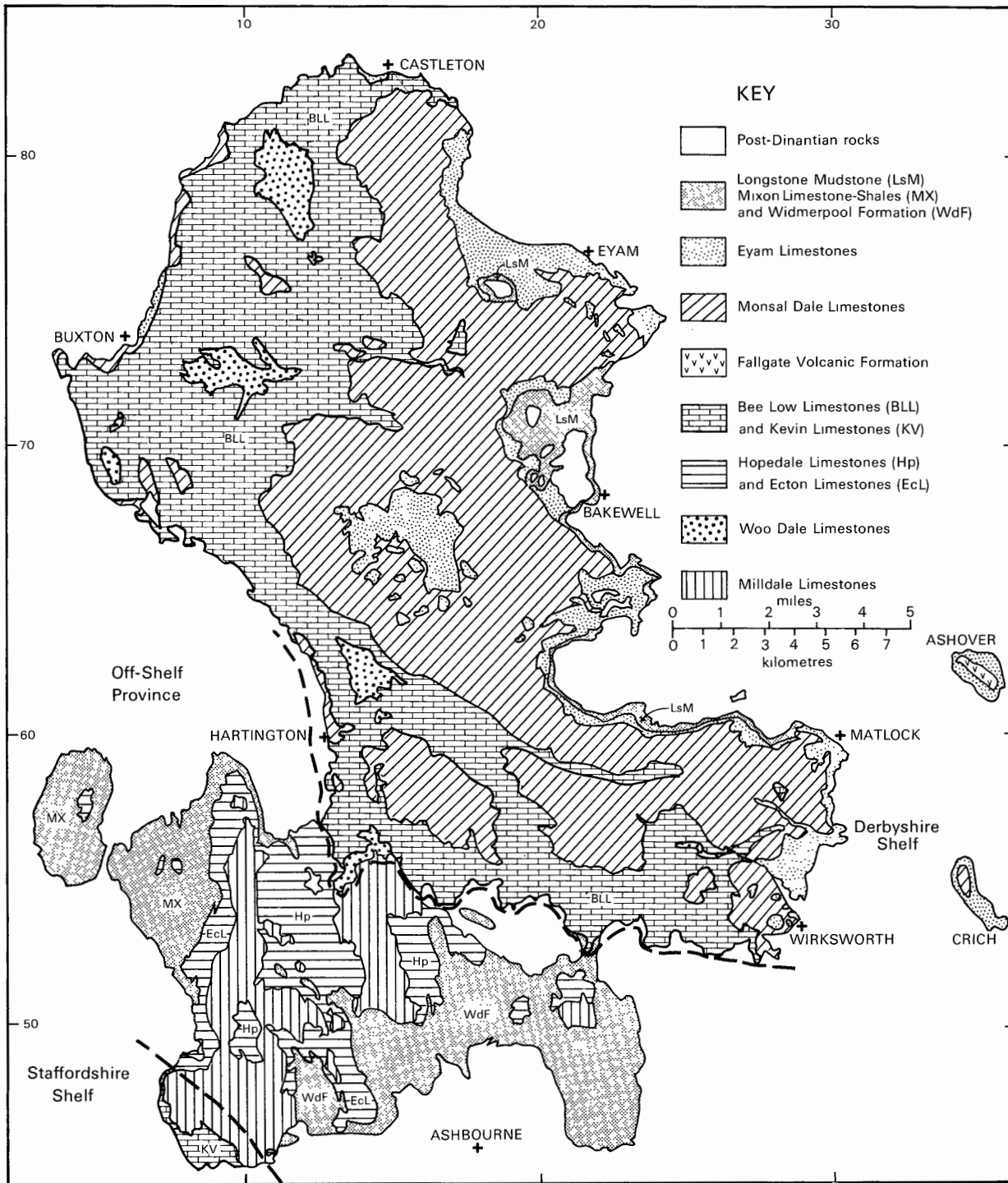


Figure 5 Simplified map of the Dinantian formations of the Peak District of Derbyshire and Staffordshire.

facies of poorly bedded, fossiliferous micritic limestones is developed (Plate 4).

Monsal Dale Limestones These limestones crop out extensively in the eastern half of the shelf area where they are quarried mainly for aggregate materials and for the manufacture of cement. Over much of the area, they are about 180 to 200 m thick, increasing to more than 375 m beneath Longstone Edge [205 731] and decreasing to about 16 m near Wirksworth. Locally, the formation is absent due to intra-Carboniferous erosion at the edges of the shelf province.

The formation is characterised by its lithological variability. Over much of the outcrop the limestones are pale to mid-grey, thin- to thick-bedded biosparites and biomicrites, with sporadic cherts and a few chert-rich

beds. However, dark thin-bedded cherty limestones with shaly partings form the lowest third of the sequence in the Miller's Dale area and nearly the entire sequence around Ashford.

A distinctive feature of the formation is the presence of volcanic horizons of basaltic lava and tuff. They make up a large proportion of the succession in the Matlock — Bakewell area and a particularly thick sequence of volcanic rocks (the Fallgate Volcanic Formation) has been proved near Ashover (Ramsbottom and others, 1962).

Eyam Limestones These rocks principally crop out along the eastern margin of the shelf area where they are quarried for aggregate materials. Small areas of Eyam Limestones also occur around Monyash and near Buxton.

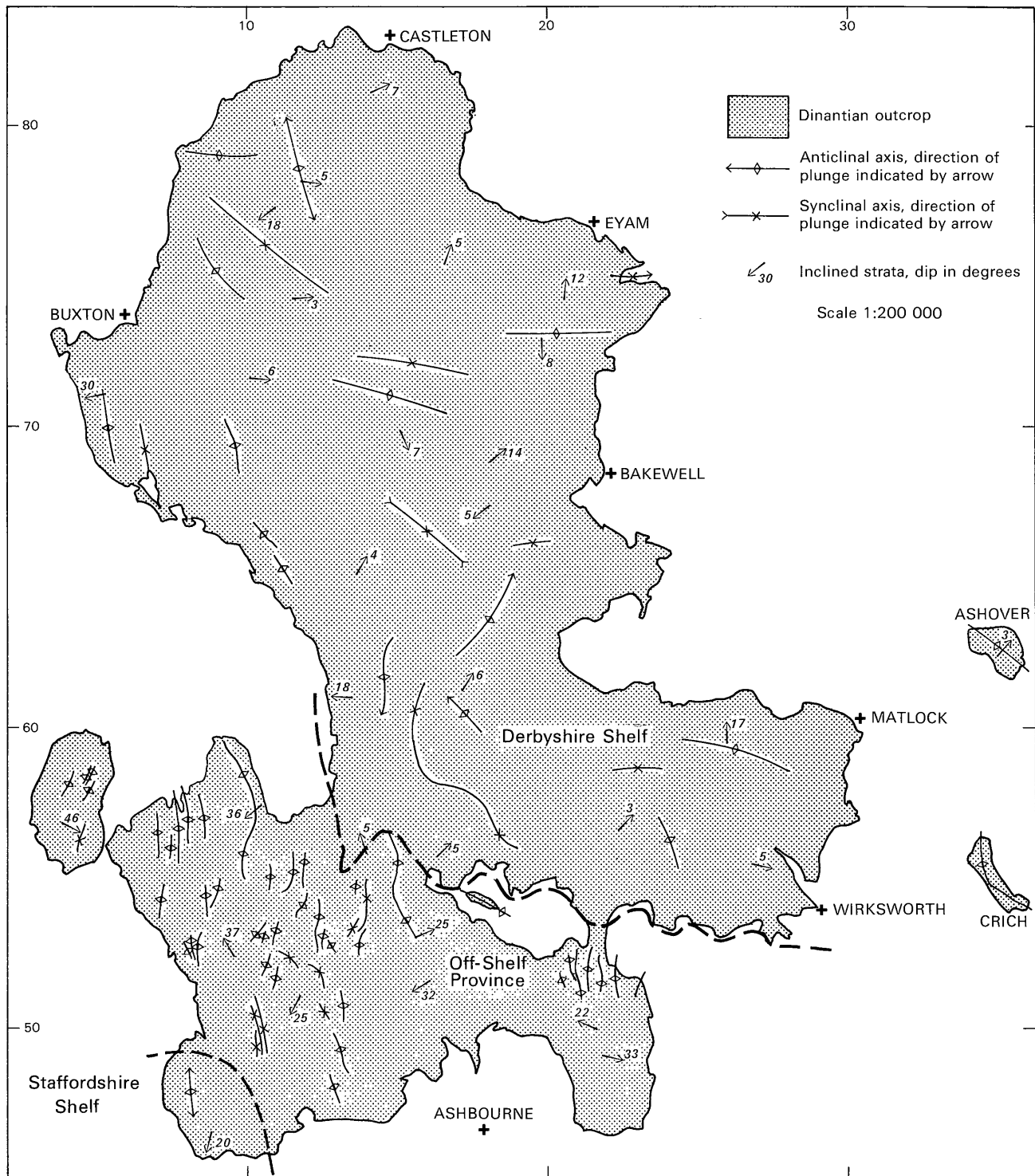


Figure 6 Fold structures in the Carboniferous Limestone of the Peak District of Derbyshire and Staffordshire.

Across much of the ground, the succession can be divided into a bedded facies of mid- to dark grey, thinly bedded, sometimes cherty, bioclastic limestones (Plate 7), and a reef-facies of massive, pale grey, fossiliferous, micritic limestones. In places, the reefs comprise the whole thickness, but generally they occur at or near the base of the succession in the central and southern parts of the area, and in the upper part farther north.

The thickness of the formation is largely dependent on the presence or absence of the reef facies. Around Eyam the reef facies is about 30 m thick resulting in a total thickness of about 54 m. The bedded facies is normally between 10 and 25 m thick.

Longstone Mudstones This formation consists predominantly of mudstones with a few thin, dark grey, muddy

limestones. The formation is about 40 m thick around Little Longstone, 14 m at Matlock and a maximum of 9 m is noted at Crich.

Dolerite sills

The lavas, tuffs and clay wayboards already mentioned are the products of volcanic activity that continued intermittently during late Dinantian times. At a later date there were local intrusions of basaltic magma into the limestone sequence and these solidified as dolerite sills.

Formations of the Staffordshire shelf

This account describes the rocks which are exposed at the surface and those liable to be encountered at normal quarrying depths but not the Redhouse Sandstones and

Rue Hill Dolomites which have only been encountered at depth in the Caldron Low Borehole.

Milldale Limestones These rocks are worked extensively around Caldron Low for the production of aggregates and cement. The formation is about 470 m thick but only the uppermost 180 m are exposed.

The beds are typically well-bedded, mid-grey, finely bioclastic limestones with some darker thin-bedded bands. Chert occurs in some of the darker beds and shaly partings occur sporadically throughout the sequence, particularly in the upper part. The limestones become more argillaceous as they pass north-eastwards into the off-shelf province.

Kevin Limestones These rocks crop out in a small area in the Weaver Hills. The limestones resemble the Bee Low Limestones lithologically and are quarried for aggregate materials. Thin clay wayboards lie along some of the bedding planes. At the southern end of the Weaver Hills the shelf limestones pass eastwards into apron-reef facies limestones. Northwards, the Kevin Limestones pass into the laterally equivalent Hopedale Limestones of the off-shelf province.

Formations of the off-shelf province

The deposits of the off-shelf province are highly variable in thickness and lithological character, and each formation consists of a number of separate lithofacies. At the present time this area does not support any active quarrying operations.

Milldale Limestones These rocks crop out in the axial zones of the Dovedale and Ecton anticlines where they are estimated to be between 220 and 510 m thick. Limestones of knoll-reef facies form laterally extensive bodies at least 180 m thick in Dovedale (Plate 8) and the Manifold Valley. The knoll-reefs consist of unbedded, sparsely fossiliferous, pale to mid-grey micrite. They pass laterally and vertically into inter-reef deposits of very variable character. The inter-reef facies consists mainly of well-bedded, mid- to dark grey biosparites and biomicrites, including some cherty limestones with shaly intercalations (Plate 9). Towards the southwest of the province the reef masses become smaller and more widely scattered.

Hopedale Limestones The Hopedale Limestones and the laterally equivalent Ecton Limestones crop out extensively around the Dove and Manifold valleys and near Bradbourne. The former are about 60 m thick at Hopedale and around 300 m north of Thorpe. The beds are highly variable lithologically but are mainly thin- to thick-bedded, mid to dark grey and fine- to coarse-grained. Conglomeratic beds are common and chert occurs in some outcrops. Large knoll-reefs, similar to those found in the Milldale Limestones, are present along the northern margin of the outcrop, and smaller ones occur elsewhere.

Ecton Limestones These rocks are similar lithologically to the Hopedale Limestones but they contain a high proportion of graded beds. Some beds are argillaceous and cherty. The formation is 150 to 250 m thick.

Mixon Limestone - Shales These rocks crop out in the west and contain substantial proportions of mudstone. The limestones are thinly bedded and show graded bedding features. Sandy limestones and sandstones predominate locally in the upper part of the formation where they comprise the Onecote Sandstone Member. The formation is about 190 m thick around Mixon and Butterton but thins to the northeast.

Widmerpool Formation These rocks crop out in the south and east of the off-shelf province and are laterally

equivalent to the Mixon Limestone - Shales. The formation is predominantly argillaceous and contains thin limestone and sandstone beds interbedded with mudstones, but a sequence of dark cherty limestones with subordinate mudstones is developed locally towards its base. Around Tissington, the formation contains a sequence of lavas and tuffs.

Structure

The shelf limestones are characterised by gentle folding and generally low dips. The traces of the main fold axes are shown in Figure 6. In the off-shelf province the limestones are much more intensely folded. The axes of some of the main structures coincide with the lines of the main knoll-reefs. Dips commonly exceed 30°.

Faults occur in both shelf and off-shelf strata and are shown on the resource map.

Dolomitisation

The limestones at outcrop have been locally altered to dolomite (Figure 7). The most extensive dolomitisation is in the southeast of the Derbyshire shelf area around Matlock, Brassington and Monyash (Parsons, 1922). In detail the margins of the alteration are irregular and may be sharp or gradational. The zone of alteration is of variable thickness and unaltered limestone has been proved beneath the dolomite in several places. Recorded thicknesses of dolomite range to over 200 m.

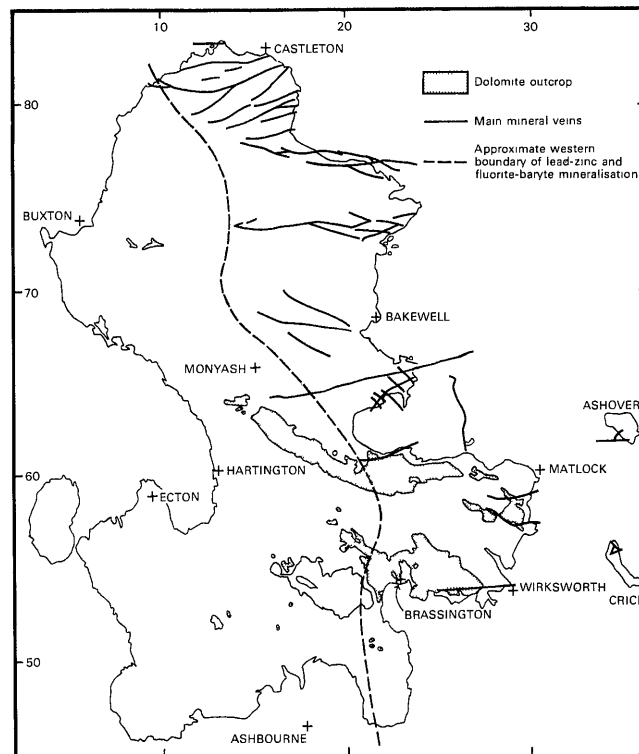


Figure 7 Distribution of dolomite and the main mineral veins in the Carboniferous Limestone of the Peak District.

The limestones of the off-shelf province commonly contain disseminated dolomite and locally, small areas of limestone have been completely altered to dolomite. The Woo Dale Limestones of the Derbyshire shelf also contain small amounts of disseminated dolomite and the outcrops around Woo Dale contain 30 m of interbedded dolomite and dolomitic limestone.

Mineralisation

The carbonate rocks of the eastern half of the Derbyshire shelf have been affected by mineralisation that gave rise to a suite of veins and replacement bodies

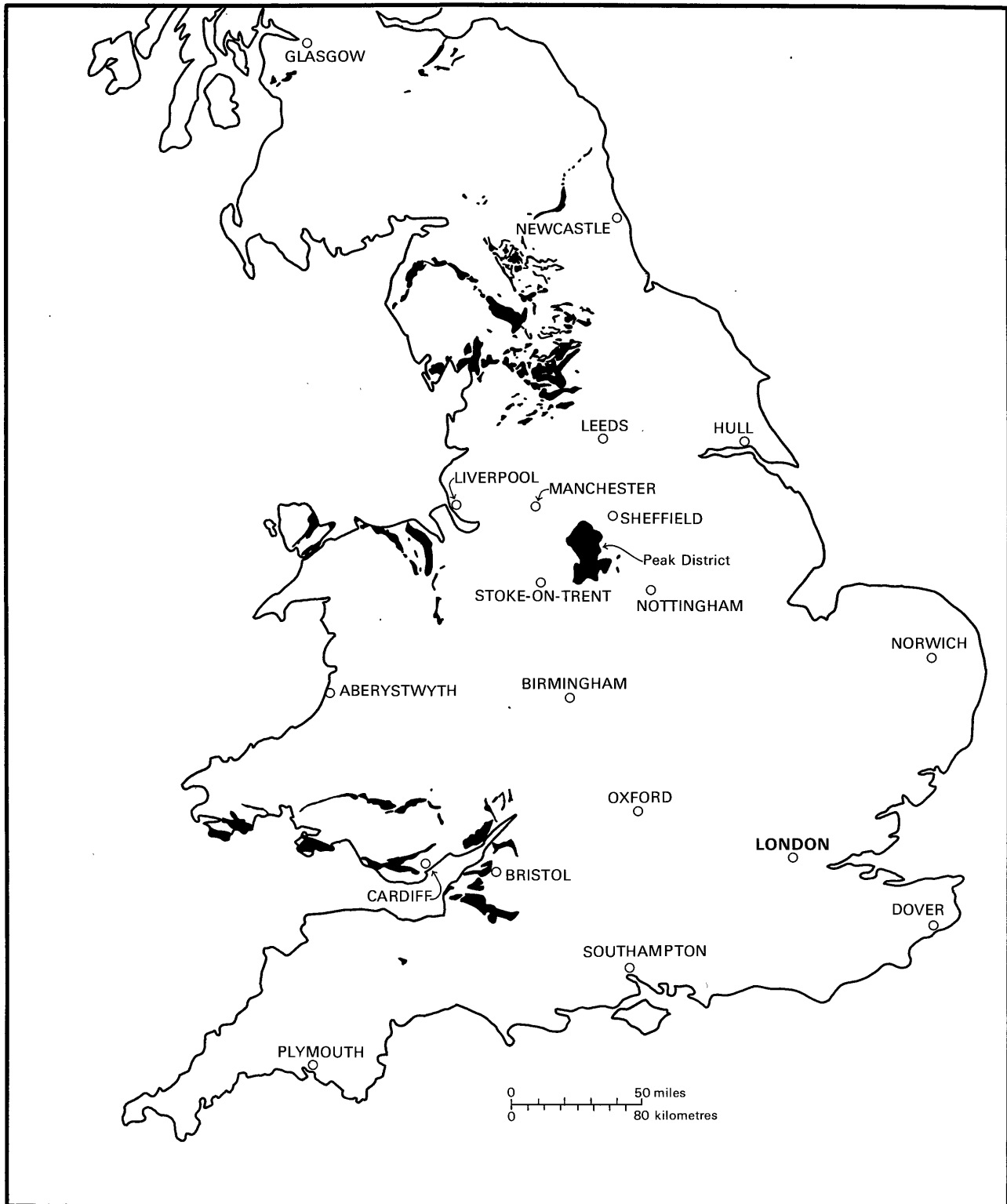


Figure 8 Distribution of limestone resources in the Carboniferous of Great Britain.

in which the lead and zinc sulphide ores, galena and sphalerite, lie in a matrix of gangue minerals, calcite, baryte and fluorite. The metallic ores form generally less than 10 per cent of the mineral content of the veins but are higher locally. Calcite is ubiquitous, but baryte and fluorite occur in variable amounts although it has been shown that the bulk of the fluorite occurs in the east of the limestone outcrop (Mueller, 1954; Firman and Bagshaw, 1974; Mostaghel, 1983). Most of the large veins occupy near-vertical fault or joint fissures, up to 20 m wide. Minor veins range up to about 4 m wide. A few ore bodies are sub-horizontal and were formed by the

replacement of limestone adjacent to veins and bedding planes. The ore minerals have been exploited for many centuries and more recently the demand for the gangue minerals, particularly fluorite and baryte, has led to the re-opening of veins and the re-working of old waste tips.

The limestones of the western part of the Derbyshire shelf and of the Staffordshire shelf and off-shelf province lie outside the main ore-field and most are not significantly mineralised except for the small area of copper mineralisation around Ecton, Butterton and Mixon.

Table 2 Summary of the aggregate properties of the limestones and dolomites

Formation	Facies/Lithology	AIV			AAV	Relative Density	Water Absorption
		Range	Mean	SD*	Range	Range	Range
Eyam Limestones							
	Coarse-grained, bioclastic limestones	18-33	22	2	11.0-18.0	2.68-2.70	0.1-0.7
	Dark, fine-grained, cherty limestones	18-33	22	2	4.5-6.5	2.68-2.70	0.1-0.7
	Knoll-reef facies	23-30	24	2	10.1-12.0	2.68-2.70	0.1-0.7
Monsal Dale Limestones							
	Variable lithology - mainly fine- to coarse-grained biomicrites (pale facies)	18-29	22	3	8.2-14.3	2.68-2.71	0.1-0.8
	Dark facies; dark, fine-grained limestones	18-24	21	2	4.3-8.0	2.68-2.71	0.1-0.8
	Dolomite	21-31	26	3	9.3-18.5	2.75-2.82	0.5-4.5
Bee Low Limestones							
	Pale grey, biosparites	16-32	23	4	10.0-16.8	2.62-2.70	0.5-2.0
	Apron-reef facies	22-29	25	2	7.9-8.8	2.62-2.70	0.5-0.2
	Dolomite	21-39	28	4	11.1-34.2	2.70-2.80	1.0-4.5
Woo Dale Limestones							
	Fine-grained and porcellanous limestones	17-27	22	2	7.1-8.8	2.69-2.71	0.1-1.0
	Peak Forest Limestones-coarsely crinoidal biosparites	26-30	28	1	14.8†	2.69-2.71	0.1-1.0
	Woo Dale Dolomites	25-34	29	4	17.0†	2.70-2.78	0.9-5.0
Mixon Limestone-Shales							
	Interbedded shales, limestones, sandstones	16-31	25	2	-	-	-
Widmerpool Formation							
	Interbedded shales, limestones, sandstones	22-27	25	2	-	-	-
Hopedale Limestones							
	Dark grey, bioclastic limestones	18-28	22	3	4.2-13.0	2.70†	0.3†
	Knoll-reef facies	20-27	23	3	8.6-10.2	-	-
Ecton Limestones							
	Dark grey, bioclastic limestones	17-29	23	3	7.1-8.8	-	-
Milldale Limestones							
	Dark grey, argillaceous bioclastic limestones	16-26	21	3	5.2-9.6	2.72†	0.4†
	Knoll-reef facies	20-27	23	3	7.8-8.9	-	-

* Standard Deviation

† Single Test Value

LIMESTONE AND DOLOMITE RESOURCES

The Dinantian (Lower Carboniferous) is the major source of limestone in the United Kingdom. Extensive outcrops occur in South Wales and the adjacent parts of southwest England, North Wales, Derbyshire, the north of England, the Peak District (Figure 8) and Northern Ireland. The outcrop in Derbyshire and Staffordshire is conveniently close to several urban centres and this factor, together with the desirable chemical and aggregate properties of the stone, has led to the development of an extensive industry.

The following text describes the regional and stratigraphical variations in the physical, mechanical and chemical properties of the Carboniferous Limestone of the Peak District, and is largely a summary of the more detailed resource assessment surveys covering this area (e.g. Cox and Harrison, 1979; Bridge and Kneebone, 1983).

Aggregate properties

The factors governing the suitability of a material for use as aggregate are its physical and mechanical properties. The former are a measure of the intrinsic physical characteristics of the material (e.g. density, porosity) while the latter are a measure of the physical response of the material to external stimuli, e.g. compressive, impact or shear stresses. Several standard index tests (B.S. 812, 1975) have been devised to measure these properties and are used to evaluate the likely in-service performance of the aggregate.

The aggregate impact value (AIV) test (see Glossary for definition) was widely used in the previous surveys to assess the aggregate strength of the limestones, and the results are detailed in the six assessment reports. In order to provide further information on the aggregate potential of the rocks, for this report a small number of samples were subjected to a wide range of the standard index tests. The physical property data, the aggregate abrasion value (AAV) results and the AIV data abstracted from the previous surveys are given in Table 2.

Aggregate strength A minimum aggregate strength limit is generally specified in most construction contracts and in most cases the material would be expected to have an AIV and ACV of less than 30. The limestones of the Peak District typically produce aggregates with AIVs and ACVs in the range 20-25 and there are only minor regional and stratigraphical variations (see Table 2) in aggregate strength. The Bee Low Limestones, particularly in the Matlock - Wirksworth area, have a relatively wide range of strength and AIVs range up to and above 30. Nevertheless, the mean AIV given by the Bee Low Limestones, is only slightly higher than that of the other formations. The coarsely crinoidal facies of the Woo Dale Limestones and the dolomites and dolomitised limestones are relatively weak, but the dark facies of the Monsal Dale Limestones produce aggregates which are slightly stronger than other Carboniferous Limestone aggregates.

Aggregate durability The durability of an aggregate is evaluated with regard to its resistance to abrasion (AAV) and resistance to polishing (PSV). A minimum PSV of 45 is required for road surfacing aggregates but the PSVs given by limestone aggregates from the Peak District only exceptionally exceed 45. Most fall in the range 41-45. This contrasts with sandstones, greywackes and some igneous rocks which usually give PSVs of 60-75 and these materials are therefore, widely used in the production of skid-resistant road surfacings. Most of the limestones, however, have a moderate or good resistance to abrasion (low AAVs) and the lowest AAVs were given by dark, fine-grained limestones.

Physical properties Test values for relative density (specific gravity) are usually unspecified but values of at least 2.65 are desirable. The relative density values given by the limestone aggregates were very consistent (at around 2.70) but the dolomites and dolomitised limestones gave values varying between 2.70 and 2.82. Of more practical importance in the assessment of the quality of limestone aggregates is the degree of water absorption, which is useful in assessing resistance to damage from frost and the effects of crystallisation of soluble salts. In addition, the degree of water absorption also indicates the extent to which the aggregate may absorb bitumen in coated aggregates (increased absorption increases cost) or cement in concrete aggregates. Classifications of absorption values are imprecise but a low absorption value (the smaller the value the better) might reasonably be considered as less than 1 per cent. In general, limestone aggregates produced from all formations gave water absorption values of less than 1 per cent, although those produced from the Bee Low Limestones ranged up to 2 per cent. Dolomite aggregates were noticeably more absorbent (porous) and gave a wide range of water absorption values.

Aggregate resources

There is little regional and stratigraphical variation in the aggregate properties of the limestones. All formations, with the exception of the mudstone-dominated Longstone Mudstones, Mixon Limestone-Shales and Widmerpool Formation, produce limestone aggregates suitable for roadstone (except for wearing course materials), concrete aggregate and also for other general construction purposes such as railway ballast, hard core, rock fill, armourstone, pathway or roofing chippings, French drains, etc. There is some evidence to suggest that the Bee Low Limestones, particularly in the Matlock - Wirksworth area, are capable of a wider range of aggregate end-uses with some beds producing relatively weak and porous aggregate. However, even the poorest quality Carboniferous Limestone aggregate is harder and less porous than, for instance, most Jurassic limestone or Chalk aggregates.

One of the major factors affecting the quality of the aggregate resource is the degree of dolomitisation of the limestones, which makes them generally weaker and more porous. Large tracts of ground between Matlock, Monyash and Brassington have been dolomitised and the rocks in this area can be expected to produce aggregates of variable, and generally low quality. Mineralisation of the limestones will also downgrade the quality of the rock as aggregate, but the effects are localised and restricted generally to the width of the vein.

Roadstone and concrete aggregates are required to be clean and free from shale and mudstone impurities. Most of the limestones are free of clay impurities, but the occurrence of clay wayboards, particularly in the Bee Low Limestones, and interbedded mudstones in the formations of the off-shelf province can cause production problems for quarry operators. Similarly, the occurrence of clays in fissures and cavities in the limestones can also cause problems of excessive waste, and hence

downgrade the value of the resource.

Concrete aggregates must also be free from iron pyrite which contaminates the limestones immediately adjacent to igneous rocks and clay wayboards. Concrete aggregates should also not be susceptible to attack by an alkaline cement environment. This requirement can affect limestones carrying amorphous silica and it is therefore possible that chert-rich limestones, in parts of the Monsal Dale Limestones, Eyam Limestones and formations of the off-shelf province, may cause problems in the production of high quality concrete aggregates. However, the alkali-aggregate reactivity of the limestone aggregates has not been evaluated during the survey and no definitive judgements can be made in this text.

Many of the lavas and dolerite sills are of sufficient thickness and extent to support a modern quarrying operation and the aggregate potential of these rocks should not be overlooked. Roadstone is quarried from a dolerite sill at Waterswallows near Buxton and, in the past, other quarries have worked basaltic rocks, particularly at Calton Hill and near Tideswell. Only limited aggregate testing has been carried out on the igneous rocks, but the more competent rocks have been shown to have a high aggregate strength, with AIVs in the range 10-19. However, the tops and bottoms of many lavas have been altered to clays so the thinner lavas may be unsuitable as aggregate material.

Chemical Properties

The following summary of the rock chemistry of the limestones and dolomites is based on data obtained during the previous surveys: over 1600 chemical analyses and around 11 000 determinations of carbonate content have been used. For convenience, the limestones have been divided into those of the Derbyshire shelf, the Staffordshire shelf and the off-shelf province. The chemical properties of the formations, occurring in each area are described below.

The summary statistics quoted in Tables 3 to 18 indicate the composition of the formations but make no allowances for the inclusion of mineralised stone or for limestone; contaminated with clay from wayboard or fissure-fill material.

Limestones of the Derbyshire shelf The **Woo Dale Limestones** are very high purity deposits (impurities rarely total more than 1 per cent of the rock) and calcium oxide values are generally greater than 55 per cent (Table 3), except when the limestones are significantly dolomitised. Silica has a low mean value relative to that of the other formations, confirming the absence of widespread silicification within these beds, although boreholes (Cox and Harrison, 1979; Chisholm and Butcher, 1981) penetrating the lower parts of the sequence in the Via Gellia Valley (near Matlock) show lithologies with higher silica contents. In addition, these beds which are low in the Woo Dale Limestones contain some pyritic mudstone, resulting in iron, sulphur and alumina values which are much higher than the very low values typical of higher beds in the formation. MgO values are variable depending on the degree of dolomitisation which is mostly at a minor level. Dolomitised Woo Dale Limestones are only likely to be encountered in the uppermost 60 m (200 ft) of strata in the outcrops around Buxton.

The succeeding beds of the **Bee Low Limestones** are also consistently of very high purity (Table 4) and show a marked uniformity of chemistry throughout the Derbyshire shelf area. The formation typically contains limestones with high CaCO₃ values (over 80 per cent of samples contained greater than 54.5 per cent CaO) and only small proportions of magnesia, silica, alumina, SO₃ and iron. Sodium, potassium, phosphorus, fluorine, strontium, manganese, copper, lead, zinc and arsenic are virtually absent.

Table 3 Chemistry of the Woo Dale Limestones

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	3.40	0.10	0.88	0.6
CaO	56.50	32.00	54.66	3.3
MgO	21.00	0.10	0.96	2.8
SiO ₂	2.30	0.00	0.26	0.4
Al ₂ O ₃	0.60	0.00	0.08	0.1
Na ₂ O	0.00	0.00	0.00	0.0
K ₂ O	0.20	0.00	0.02	0.0
SO ₃	0.60	0.00	0.14	0.1
P ₂ O ₅	0.10	0.00	0.00	0.0
Loss at 1050°C	47.50	42.60	43.89	0.6
F	0.10	0.00	0.01	0.0
SrO	0.30	0.00	0.02	0.1
	ppm	ppm	ppm	ppm
MnO	2500	10	253	373
Cu	35	0	4	5
Pb	40	0	5	7
Zn	1000	0	26	89
Fe ₂ O ₃	12000	0	833	1633

Note The chemical data were obtained from 127 analyses, except for those for SrO which were obtained from 119 analyses.

Table 4 Chemistry of the Bee Low Limestones (excluding dolomitised Bee Low Limestones)

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	30.20	0.00	1.30	2.3
CaO	57.10	37.10	55.09	1.5
MgO	2.71	0.00	0.37	0.4
SiO ₂	13.10	0.00	0.64	1.2
Al ₂ O ₃	2.30	0.00	0.11	0.2
Na ₂ O	0.30	0.00	0.00	0.0
K ₂ O	1.00	0.00	0.02	0.1
SO ₃	5.80	0.00	0.18	0.4
P ₂ O ₅	1.90	0.00	0.02	0.1
Loss at 1050°C	47.10	26.40	43.44	1.1
F	3.50	0.00	0.01	0.2
SrO	0.10	0.00	0.02	0.0
	ppm	ppm	ppm	ppm
MnO	2060	20	186	191
Cu	50	0	4	4
Pb	310	0	10	27
Zn	380	0	21	36
Fe ₂ O ₃	35200	0	721	1851

Note The chemical data were obtained from 546 analyses, except for those for SrO which were obtained from 459 analyses.

Table 5 Chemistry of the Chee Tor Rock

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	7.40	0.00	0.90	0.8
CaO	56.30	52.10	55.12	0.7
MgO	1.30	0.20	0.33	0.1
SiO ₂	3.70	0.00	0.51	0.5
Al ₂ O ₃	2.30	0.00	0.13	0.2
Na ₂ O	0.00	0.00	0.00	0.0
K ₂ O	0.40	0.00	0.03	0.1
SO ₃	0.80	0.00	0.12	0.2
P ₂ O ₅	0.00	0.00	0.00	0.0
Loss at 1050°C	44.00	41.50	43.56	0.4
F	0.10	0.00	0.00	0.0
SrO	0.10	0.00	0.02	0.0
	ppm	ppm	ppm	ppm
MnO	700	30	140	95
Cu	15	0	3	3
Pb	30	0	2	5
Zn	40	0	8	7
Fe ₂ O ₃	4400	90	428	605

Note The chemical data were obtained from 100 analyses.

Table 6 Chemistry of the Miller's Dale Limestones.

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	8.90	0.40	1.89	1.8
CaO	56.00	51.60	54.63	0.9
MgO	0.50	0.20	0.33	0.1
SiO ₂	7.00	0.20	1.23	1.2
Al ₂ O ₃	0.30	0.00	0.14	0.1
Na ₂ O	0.00	0.00	0.00	0.0
K ₂ O	0.10	0.00	0.03	0.0
SO ₃	0.30	0.00	0.09	0.1
P ₂ O ₅	0.10	0.00	0.00	0.0
Loss at 1050°C	44.60	40.50	43.23	0.7
F	0.10	0.00	0.01	0.0
SrO	0.10	0.00	0.03	0.0
	ppm	ppm	ppm	ppm
MnO	1600	90	302	302
Cu	15	0	5	3
Pb	50	0	7	15
Zn	100	0	22	20
Fe ₂ O ₃	4200	100	894	1019

Note The chemical data were obtained from 29 analyses.

Silica is present in variable amounts depending on the concentration of authigenic quartz crystals but the SiO₂ content is rarely as high as 1 per cent. The beds immediately above and, more particularly, beneath clay wayboards and igneous horizons are commonly enriched in quartz euhedra and pyrite but the alteration is usually localised and rarely totals more than 5 per cent of the rock.

Although the chemistry of the Bee Low Limestones is relatively uniform throughout its thickness, it has been shown (Harrison, 1981; Gatliff, 1982) that the upper part of the sequence (the Miller's Dale Limestones) in the Buxton — Tideswell area is less pure chemically than the underlying Chee Tor Rock, being slightly poorer in CaO and richer in silica (Table 5 and 6).

The chemistry of the apron-reef limestones is shown separately in Table 7 and is very similar to that of the equivalent Bee Low Limestones, although high phosphorus values have been recorded from some apron-reef limestones. Figure 15 shows the regional distribution of phosphorus in the Carboniferous Limestone and clearly indicates that the highest concentrations generally occur around the margins of the Derbyshire shelf and in the off-shelf province.

Table 7 Chemistry of the apron-reef limestones

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	7.50	0.20	1.36	1.5
CaO	56.00	52.60	55.17	0.8
MgO	1.40	0.30	0.43	0.2
SiO ₂	2.10	0.00	0.48	0.5
Al ₂ O ₃	0.30	0.00	0.08	0.1
Na ₂ O	0.10	0.00	0.01	0.0
K ₂ O	0.10	0.00	0.00	0.0
SO ₃	2.30	0.00	0.17	0.5
P ₂ O ₅	0.30	0.00	0.09	0.1
Loss at 1050°C	44.20	40.60	43.46	0.9
F	1.20	0.00	0.06	0.2
SrO	0.10	0.00	0.02	0.0
	ppm	ppm	ppm	ppm
MnO	550	140	283	111
Cu	50	0	5	9
Pb	80	0	8	19
Zn	300	0	31	58
Fe ₂ O ₃	13500	70	1113	2755

Note The chemical data were obtained from 27 analyses.

The Bee Low Limestones are extensively dolomitised in the Matlock — Monyash — Brassington area and although a detailed evaluation of their chemistry has not been undertaken, the chemistry of the dolomite belt as a whole has been reviewed by Bridge and Gozzard, 1981. MgO values are variable but most of the dolomites contain between 18.0 and 20.5 per cent MgO. The dolomitised Bee Low Limestones (Table 8) contain only small amounts of silica, alumina and alkalis and their high purity reflects the composition of the parent rocks. However, iron and manganese have also been introduced during dolomitisation resulting in dolomites containing significant amounts of these elements.

The **Monsal Dale Limestones** are more variable chemically and somewhat less pure overall than the underlying formations, reflecting the influx of cherty and argillaceous lithologies. Nevertheless, in some areas substantial

Table 8 Chemistry of the dolomitised Bee Low Limestones (Matlock — Monyash — Brassington dolomite belt)

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	-	-	-	-
CaO	42.10	29.30	32.62	2.9
MgO	21.10	10.50	18.74	2.6
SiO ₂	1.04	0.00	0.19	0.2
Al ₂ O ₃	0.20	0.0	0.03	0.1
Na ₂ O	0.05	0.00	0.03	0.0
K ₂ O	0.05	0.00	0.02	0.0
SO ₃	1.00	0.00	0.06	0.2
P ₂ O ₅	0.22	0.01	0.60	0.1
Loss at 1050°C	48.21	45.12	47.32	0.8
F	0.85	0.00	0.04	0.2
SrO	0.10	0.00	0.00	0.0
	ppm	ppm	ppm	ppm
MnO	2800	620	1250	510
Cu	15	0	5	5
Pb	10100	0	490	2100
Zn	3800	20	260	780
Fe ₂ O ₃	7900	1100	3435	1711

Note The chemical data were obtained from 29 analyses.

Table 9 Chemistry of the Monsal Dale Limestones (pale facies)

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	64.10	0.10	4.00	6.5
CaO	57.30	30.80	53.60	3.1
MgO	19.50	0.00	0.46	1.2
SiO ₂	46.00	0.00	2.71	5.3
Al ₂ O ₃	5.50	0.00	0.19	0.4
Na ₂ O	0.20	0.00	0.01	0.0
K ₂ O	1.00	0.00	0.03	0.1
SO ₃	2.30	0.00	0.30	0.3
P ₂ O ₅	1.10	0.00	0.03	0.1
Loss at 1050°C	47.00	21.90	42.39	2.7
F	1.90	0.00	0.04	0.2
SrO	0.30	0.00	0.03	0.1
	ppm	ppm	ppm	ppm
MnO	1600	30	220	220
Cu	120	0	8	11
Pb	2000	0	22	108
Zn	1500	0	42	105
Fe ₂ O ₃	33900	0	1428	2906

Note The chemical data were obtained from 521 analyses, except for those for SrO which were obtained from 505 analyses.

Table 10 Chemistry of the Monsal Dale Limestones (dark facies)

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	54.30	0.20	7.67	10.6
CaO	56.20	21.90	51.57	5.3
MgO	7.10	0.00	0.73	0.8
SiO ₂	52.80	0.10	5.36	9.0
Al ₂ O ₃	2.50	0.00	0.32	0.4
Na ₂ O	1.20	0.00	0.02	0.1
K ₂ O	0.30	0.00	0.04	0.1
SO ₃	1.40	0.00	0.41	0.3
P ₂ O ₅	0.50	0.00	0.05	0.1
Loss at 1050°C	44.10	18.80	41.24	4.3
F	0.20	0.00	0.07	0.1
SrO	0.20	0.00	0.03	0.1
	ppm	ppm	ppm	ppm
MnO	470	35	138	92
Cu	65	0	14	13
Pb	100	0	7	16
Zn	170	0	33	31
Fe ₂ O ₃	14200	200	1553	2207

Note The chemical data were obtained from 93 analyses.

Table 11 Chemistry of the dolomitised Monsal Dale Limestones (Matlock — Monyash — Brassington dolomite belt)

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	-	-	-	-
CaO	34.10	27.00	31.47	1.7
MgO	21.34	15.60	19.72	1.5
SiO ₂	19.70	0.19	2.75	4.2
Al ₂ O ₃	1.01	0.00	0.10	0.2
Na ₂ O	0.06	0.01	0.05	0.0
K ₂ O	0.11	0.01	0.03	0.0
SO ₃	0.05	0.00	0.02	0.0
P ₂ O ₅	0.17	0.00	0.04	0.0
Loss at 1050°C	47.75	37.03	46.00	2.4
F	1.30	0.00	0.16	0.3
SrO	0.10	0.00	0.01	0.0
	ppm	ppm	ppm	ppm
MnO	1270	490	860	200
Cu	60	5	15	15
Pb	180	0	35	55
Zn	580	20	250	180
Fe ₂ O ₃	8200	1200	3515	1579

Note The chemical data were obtained from 33 analyses.

parts of the sequence contain pale grey, chert-free limestones which are of very high purity (>98.5 per cent CaCO₃) or high purity (97.0–98.5 per cent CaCO₃), although even in the chert-free areas the pale facies limestones contain higher levels of silica than either the Bee Low or Woo Dale limestones (Table 9). The dark facies (Table 10) of the Monsal Dale Limestones are of low purity or are impure, and are distinguished by high silica, alumina, magnesia and potash values due to the presence of chert and clay minerals. Pyrite is also widely distributed throughout the Monsal Dale Limestones, particularly in the dark facies and in the beds adjacent to the volcanic rocks, resulting in relatively high levels of iron and sulphur. The dolomitised Monsal Dale Limestones are less pure chemically than the dolomitised Bee Low Limestones and give higher values for silica, alumina and alkalis (Table 11).

The dark, sometimes cherty, facies of the **Eyam Limestones** consists mainly of impure-grade limestones (Table 12), but some areas of higher purity mineral occur where there is less chert. Chemical analyses are characterised by high silica, alumina and potash values. However, the knoll-reef facies of the Eyam Limestones contains only small amounts of impurities and these rocks are of medium to high purity, with chemical analyses (Table 13) showing high values of CaO and small values of silica, alumina, iron and other elements and oxides.

Table 12 Chemistry of the Eyam Limestones (dark, thin-bedded facies)

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	58.90	0.20	12.31	13.9
CaO	56.00	25.70	49.88	7.1
MgO	1.00	0.20	0.47	0.2
SiO ₂	56.00	0.10	10.35	14.4
Al ₂ O ₃	3.00	0.00	0.32	0.6
Na ₂ O	0.10	0.00	0.01	0.0
K ₂ O	0.50	0.00	0.06	0.1
SO ₃	0.60	0.00	0.21	0.2
P ₂ O ₅	0.40	0.00	0.08	0.1
Loss at 1050°C	44.00	18.40	39.10	6.0
F	0.20	0.00	0.04	0.1
SrO	0.20	0.00	0.07	0.1
	ppm	ppm	ppm	ppm
MnO	2500	90	359	422
Cu	75	0	8	14
Pb	480	0	48	105
Zn	680	0	99	137
Fe ₂ O ₃	11600	140	1615	2170

Note The chemical data were obtained from 36 analyses.

Limestones of the Staffordshire shelf The **Milldale Limestones**, which are extensively quarried at Caldron Low, are of medium to high purity (>93.5 to <98.5 per cent CaCO₃) and contain substantial, though variable, amounts of silica, alumina and iron. The silica occurs chiefly as disseminated authigenic quartz crystals and as a replacement of fossil debris, but some sections also contain chert. The alumina is contained within clay minerals and the high values of iron are the result of the hematite staining which is a striking feature of these limestones.

The overlying **Kevin Limestones** (Table 14), which are quarried at Kevin Quarry and adjacent sites, are very

high purity deposits (>98.5 per cent CaCO₃) similar in composition to the Bee Low Limestones. The formation is notable for its chemical uniformity but small variations have been recorded, especially in beds adjacent to clay wayboards.

Table 13 Chemistry of the Eyam Limestones (knoll-reef facies)

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	15.50	0.80	3.87	4.4
CaO	55.40	51.50	54.37	1.2
MgO	0.50	0.10	0.32	0.1
SiO ₂	7.40	0.20	1.58	2.0
Al ₂ O ₃	0.50	0.00	0.15	0.2
Na ₂ O	0.00	0.00	0.00	0.0
K ₂ O	0.10	0.00	0.05	0.0
SO ₃	1.80	0.00	0.26	0.5
P ₂ O ₅	0.20	0.00	0.07	0.1
Loss at 1050°C	43.90	36.50	42.25	2.1
F	3.90	0.00	0.44	1.1
SrO	0.10	0.00	0.02	0.1
	ppm	ppm	ppm	ppm
MnO	550	160	282	115
Cu	40	0	8	11
Pb	270	0	39	82
Zn	190	10	53	56
Fe ₂ O ₃	6200	140	1623	1744

Note The chemical data were obtained from 12 analyses.

Table 14 Chemistry of the Kevin Limestones

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	1.30	0.10	0.63	0.3
CaO	55.80	55.20	55.47	0.2
MgO	0.40	0.20	0.26	0.1
SiO ₂	0.30	0.00	0.11	0.1
Al ₂ O ₃	0.20	0.10	0.11	0.0
Na ₂ O	0.00	0.00	0.00	0.0
K ₂ O	0.10	0.00	0.01	0.0
SO ₃	0.00	0.00	0.00	0.0
P ₂ O ₅	0.00	0.00	0.00	0.0
Loss at 1050°C	44.00	43.50	43.82	0.1
F	0.00	0.00	0.00	0.0
SrO	-	-	-	-
	ppm	ppm	ppm	ppm
MnO	350	130	222	53
Cu	15	0	4	3
Pb	30	0	18	8
Zn	30	10	18	6
Fe ₂ O ₃	600	100	277	111

Note The chemical data were obtained from 26 analyses.

Limestones of the off-shelf province The limestones of this area are highly variable and are predominantly of low chemical purity, although the knoll-reef limestones which occur in the Milldale and Hopedale limestones are mainly of high, or very high, purity (Table 15). Most of the knoll-reef limestones contain only small amounts of

silica and other impurities, although locally the secondary red iron oxide staining, which affects the limestones in this area, results in high values for iron. The facies is also characterised by relatively high P₂O₅ values similar to the apron-reef facies of the shelf areas.

Table 15 Chemistry of the Milldale and Hopedale knoll-reef facies limestones

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	21.40	0.20	3.35	5.7
CaO	56.00	45.80	53.74	2.5
MgO	2.80	0.30	0.80	0.7
SiO ₂	17.00	0.00	2.25	4.4
Al ₂ O ₃	0.90	0.10	0.21	0.2
Na ₂ O	0.00	0.00	0.00	0.0
K ₂ O	0.20	0.00	0.07	0.1
SO ₃	0.50	0.00	0.17	0.1
P ₂ O ₅	0.30	0.00	0.09	0.1
Loss at 1050°C	44.10	34.70	42.76	2.4
F	0.10	0.00	0.00	0.0
SrO	0.10	0.00	0.03	0.0
	ppm	ppm	ppm	ppm
MnO	730	130	284	164
Cu	10	0	2	3
Pb	130	0	8	25
Zn	70	0	14	13
Fe ₂ O ₃	6900	100	1238	1626

Note The chemical data were obtained from 26 analyses, except for those for SrO which were obtained from 7 analyses.

Table 16 Chemistry of the Milldale Limestones (excluding knoll-reef facies)

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	42.10	0.50	10.44	8.4
CaO	55.30	32.10	49.98	4.3
MgO	2.60	0.40	0.77	0.4
SiO ₂	27.00	0.30	7.55	6.7
Al ₂ O ₃	3.50	0.10	0.85	0.7
Na ₂ O	0.10	0.00	0.01	0.0
K ₂ O	0.70	0.00	0.21	0.2
SO ₃	3.10	0.00	0.29	0.4
P ₂ O ₅	0.50	0.00	0.03	0.1
Loss at 1050°C	43.80	30.50	39.84	3.4
F	0.50	0.00	0.04	0.1
SrO	0.20	0.10	0.11	0.0
	ppm	ppm	ppm	ppm
MnO	3950	90	601	678
Cu	120	0	5	14
Pb	90	0	12	19
Zn	1000	0	56	121
Fe ₂ O ₃	28500	100	5506	5508

Note The chemical data were obtained from 89 analyses, except for those for SrO which were obtained from 7 analyses.

In contrast, the Milldale Limestones are impure or are of low purity (Table 16) although a number of localities have been identified (Bridge and Kneebone, 1983) where they are of higher purity. The Milldale Limestones are siliceous and on analysis, they typically show high values of silica, alumina, potash and iron. The presence of some disseminated dolomite is reflected in the relatively high MgO values.

Table 17 Chemistry of the Hopedale Limestones (excluding knoll-reef facies limestones) and the Ecton Limestones

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	54.80	0.60	6.92	7.1
CaO	55.70	30.40	48.83	5.9
MgO	19.40	0.20	3.39	4.5
SiO ₂	33.00	0.10	4.71	4.9
Al ₂ O ₃	5.40	0.00	0.60	0.8
Na ₂ O	0.20	0.00	0.01	0.0
K ₂ O	1.10	0.00	0.14	0.2
SO ₃	1.50	0.00	0.27	0.3
P ₂ O ₅	0.40	0.00	0.06	0.1
Loss at 1050°C	46.90	26.50	41.61	3.0
F	0.80	0.00	0.04	0.1
SrO	0.10	0.00	0.01	0.0
	ppm	ppm	ppm	ppm
MnO	30000	130	1415	2947
Cu	100	0	6	10
Pb	600	0	19	63
Zn	1750	0	83	244
Fe ₂ O ₃	21600	200	6169	4597

Note The chemical data were obtained from 110 analyses, except for those for SrO which were obtained from 12 analyses.

Table 18 Chemistry of the Mixon Limestone-Shales and the Widmerpool Formation

	Max value	Min value	Mean	Standard deviation
	wt %	wt %	wt %	wt %
Insoluble residue	48.50	2.40	11.83	11.1
CaO	54.90	31.60	48.68	5.7
MgO	1.50	0.40	0.87	0.3
SiO ₂	35.00	1.20	9.57	8.7
Al ₂ O ₃	3.20	0.20	1.07	0.8
Na ₂ O	0.10	0.00	0.00	0.0
K ₂ O	0.60	0.00	0.20	0.2
SO ₃	2.70	0.00	0.52	0.6
P ₂ O ₅	0.30	0.00	0.13	0.1
Loss at 1050°C	43.40	21.30	38.60	5.1
F	0.10	0.00	0.6	0.1
SrO	-	-	-	-
	ppm	ppm	ppm	ppm
MnO	1700	210	654	331
Cu	15	0	6	3
Pb	40	0	11	10
Zn	190	0	53	50
Fe ₂ O ₃	23000	900	6783	4386

Note The chemical data were obtained from 23 analyses.

The Hopedale and Ecton limestones both contain thick sequences of impure or low purity limestones (Table 17) but in some areas considerable thicknesses of medium and high purity resources have also been identified (Bridge and Kneebone, 1983). The patchy dolomitisation of these limestones results in variable but fairly high MgO values and, although they are less siliceous than the Milldale Limestones, silica is nevertheless the major impurity. Hematite and pyrite are common contaminants and the presence of clay is shown by the variable, but usually high, values of alumina and potash.

The mudstone dominated Mixon Limestone-Shales and Widmerpool Formation are classified as impure-grade mineral (<85 per cent CaCO₃) and although the limestone-dominated parts of the sequence may be of higher purity, the overall carbonate content does not exceed 93.5 per cent CaCO₃. Analyses of these limestones show high values of silica, alumina, sulphur, iron and potash (Table 18) and low CaO values (usually less than 50 per cent).

Regional chemistry of the Carboniferous limestones The stratigraphical variation in chemistry has been described above but it is also desirable to investigate any regional variations or trends in the chemistry of the Carboniferous limestones of the Peak District. Figures 9 to 18 show the regional distribution of most elements and oxides in the limestones. Square symbols are used to show the relative amounts of a particular oxide or element at each location. The presence of symbols of different size at a site (i. e. 'squares within squares') indicates the degree of measured variation, for example, down a borehole, for the particular element or oxide. For SO₃, SrO and Cu there are insufficient data to compute a true representation of their regional distributions and these are therefore, not included. No data were available on the chemistry of the limestones at Ashover and Crich.

The regional distribution of both **silica** (SiO₂) and **alumina** (Al₂O₃) show the close relationship between the geology and the resource potential of the limestones. The limestones of the off-shelf province, except the knoll-reef limestones, consistently contain high levels of both oxides, and in the shelf areas the beds classified as very high purity limestone, mainly the Woo Dale, Kevin and Bee Low limestones, invariably contain only small amounts of silica and alumina. Higher values are typical of the limestones (mainly the Monsal Dale and Eyam Limestones) in the eastern part of the Derbyshire shelf area and in the Caldron Low area (Milldale Limestones) of the Staffordshire shelf.

When considering the regional distribution of **iron** (Fe) in the limestones (Figure 11) the most striking feature is the high levels recorded in the limestones of both the off-shelf province and the Staffordshire shelf. They are commonly reddened by iron oxides, particularly along joints, cracks and fissures. This is presumably the result of iron-rich fluids, possibly derived from a former cover of Triassic sandstones, percolating through the limestones. Elsewhere, high iron values correlate with the occurrence of dolomite or with limestones containing small amounts or pyrite.

Relatively high concentrations of **magnesia** (MgO and **manganese oxide** (MnO) occur in the limestones of the off-shelf province but the highest values of both oxides are associated with the dolomitised limestones (Figures 12 and 13). The undolomitised limestones of the shelf areas typically contain very small amounts of both oxides. Both the limestones and dolomites usually contain very small amounts of **alkalis** (Na₂O and K₂O), although the more clay-rich lithologies (particularly in the off-shelf province) tend to give higher values (Figure 14). Similarly, most of the limestones and dolomites contain very little or no phosphorus (P₂O₅). However, the regional distribution of **phosphorus** (Figure 15) shows that the limestones around the margins of the Derbyshire shelf usually contain small but significant

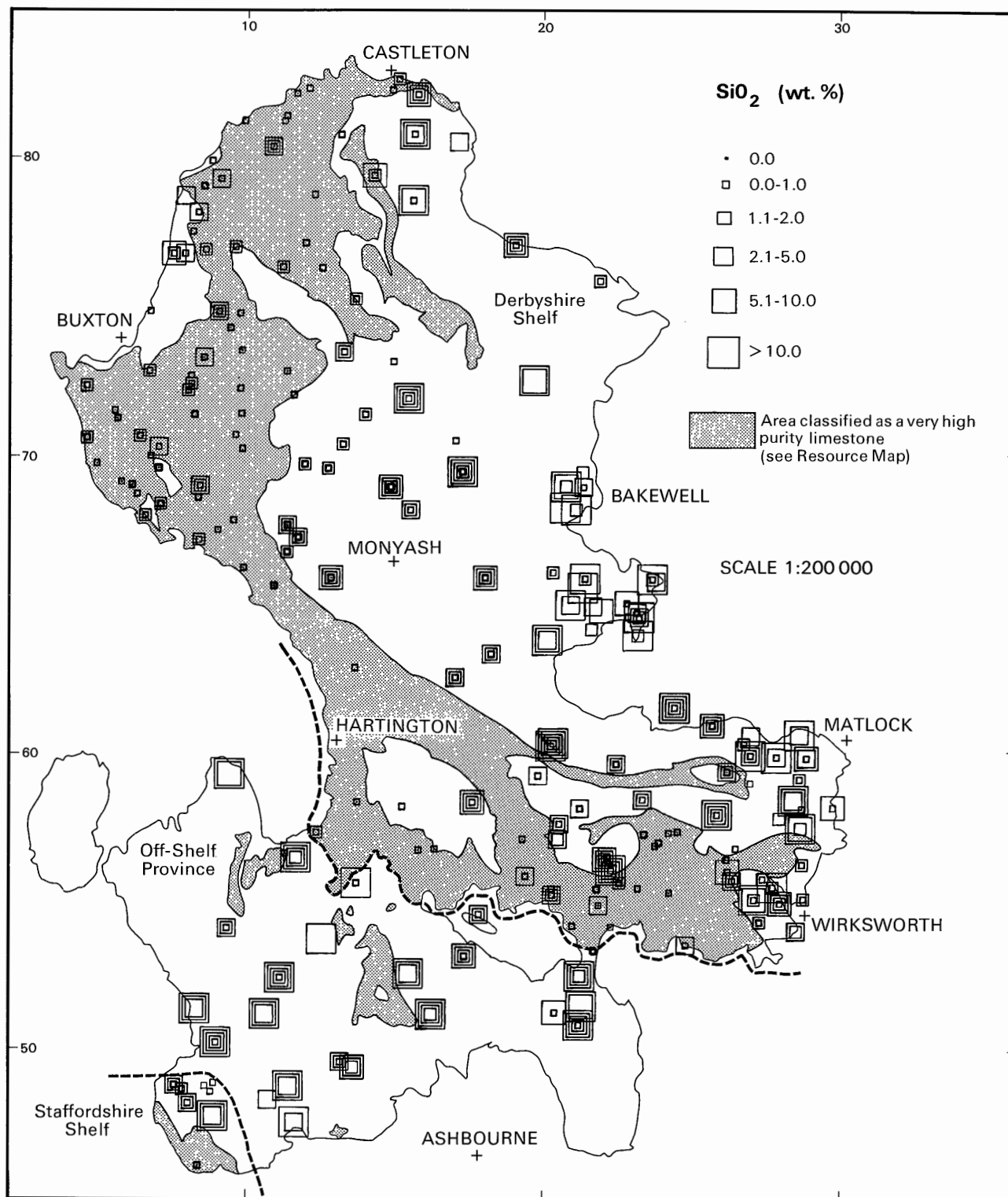


Figure 9 Distribution of silica (SiO_2) in the Carboniferous Limestone of the Peak District.

amounts. These anomalously high P_2O_5 values may be related (Harrison, 1980) to the presence of fluorapatite, possibly occurring as fish teeth, scales or bones.

Fluorine (F), lead (Pb) and zinc (Zn) have been principally introduced into the limestones and dolomites during the mineralisation which mainly affected the beds in the east of the Derbyshire shelf area. Although mineralised limestone samples were specifically excluded from analysis, the background levels of these elements in the rocks (Figures 16 to 18) reflect the regional distribution of the minerals within the Derbyshire Ore-field. All three elements are at their

highest levels in the limestones around Wirksworth, Matlock and Bakewell and, although data are limited, it appears likely that this zone extends northwards to the Castleton area. In the west and south, the limestones contain only small amounts of these elements, although some of the limestones of the off-shelf province contain relatively high levels of zinc.

High purity limestone and dolomite resources

The purity (in terms of carbonate content) of the limestones and dolomites at outcrop is shown on the accompanying resource map and detailed information on the

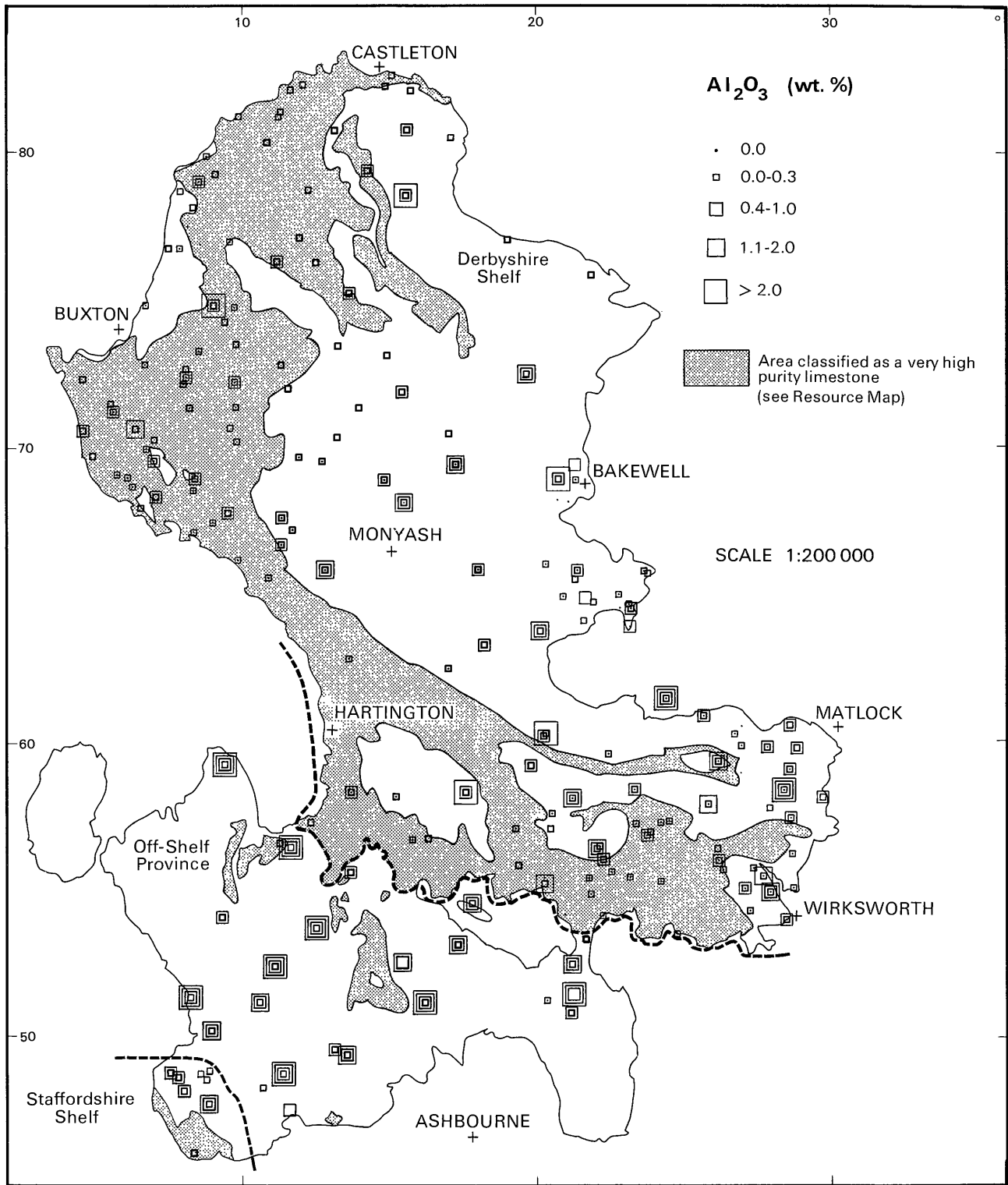


Figure 10 Distribution of alumina (Al₂O₃) in the Carboniferous Limestone of the Peak District.

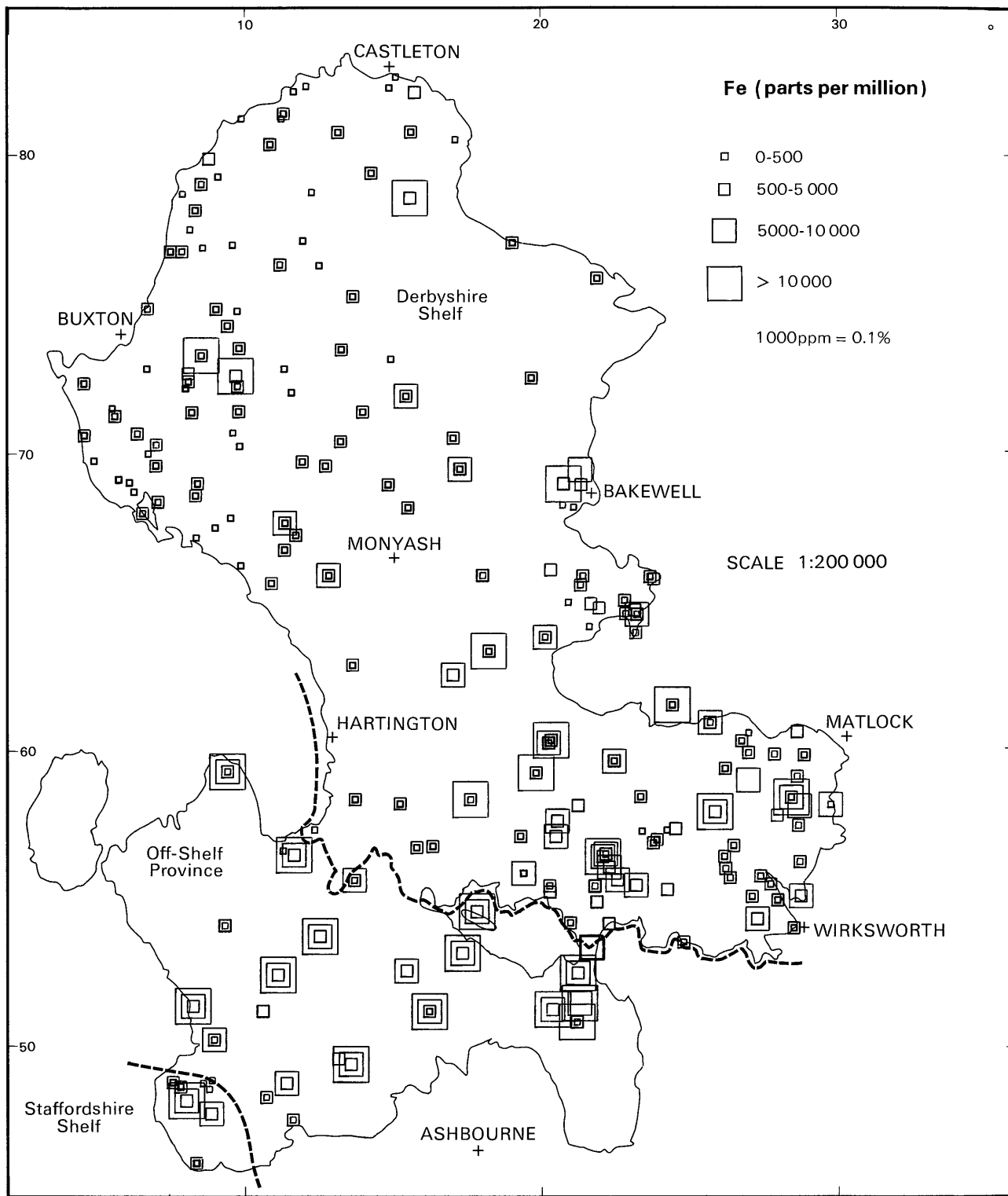


Figure 11 Distribution of iron (Fe) in the Carboniferous Limestone of the Peak District.

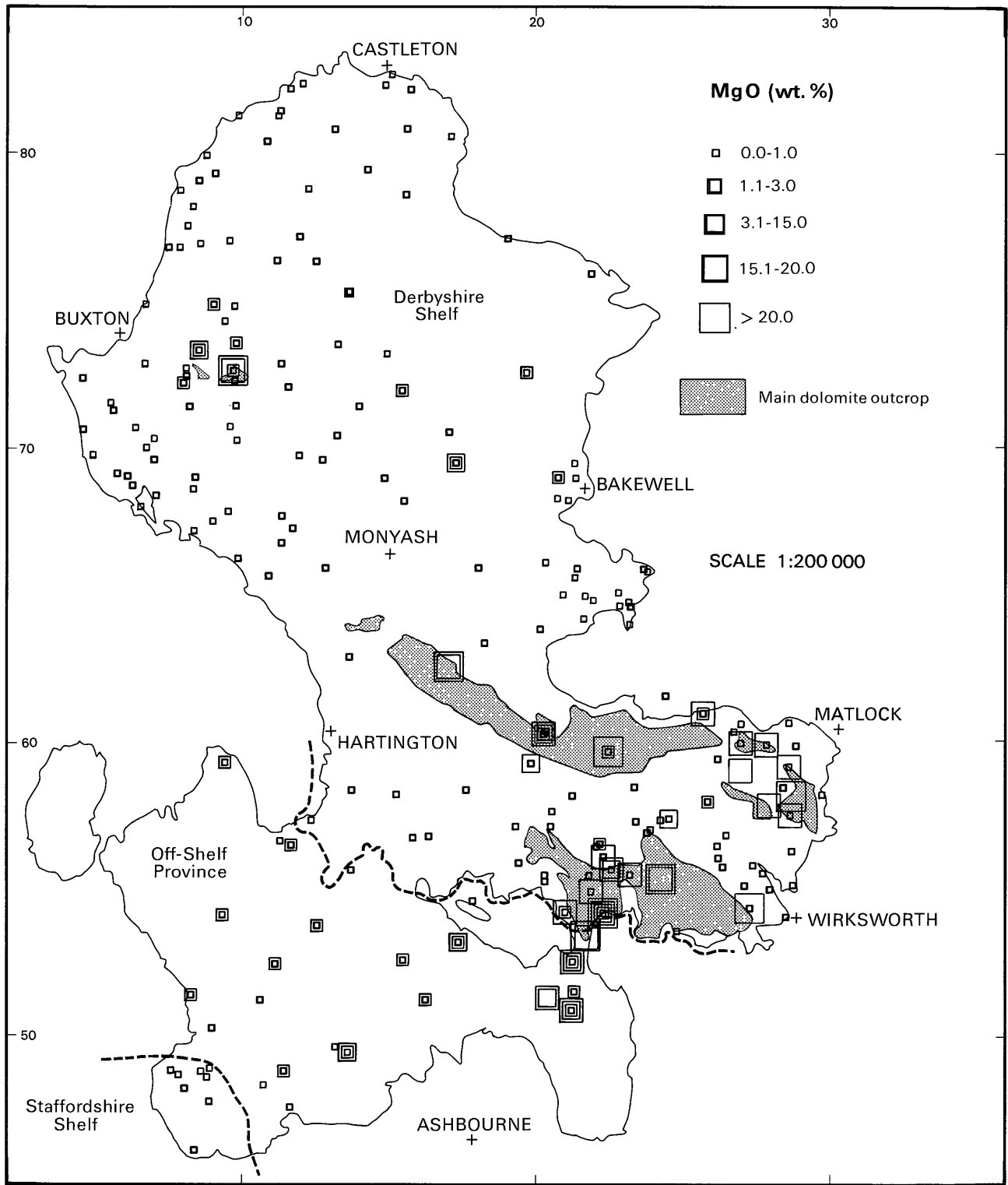


Figure 12 Distribution of magnesia (MgO) in the Carboniferous Limestone of the Peak District.

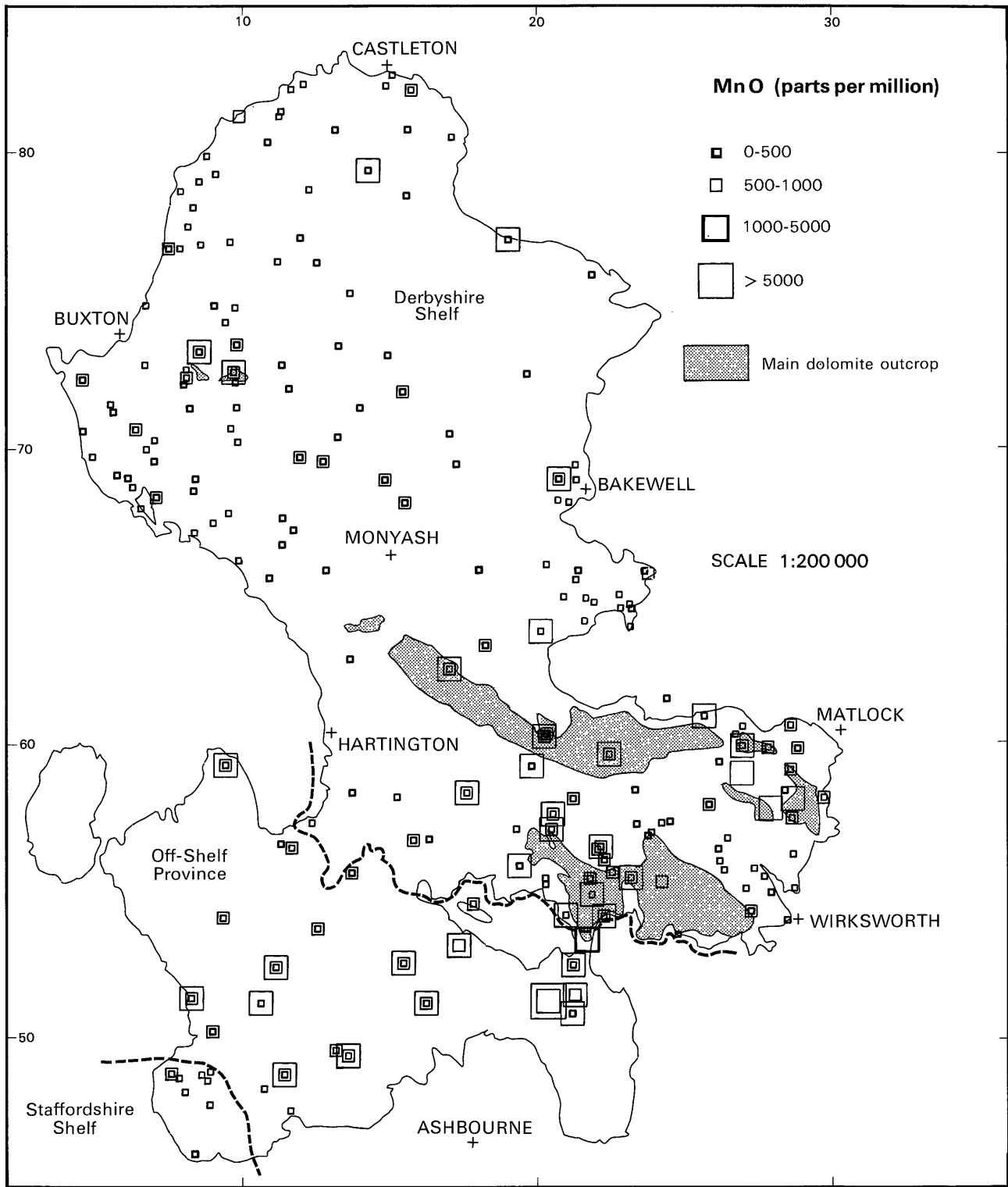


Figure 13 Distribution of manganese oxide (MnO) in the Carboniferous Limestone of the Peak District.

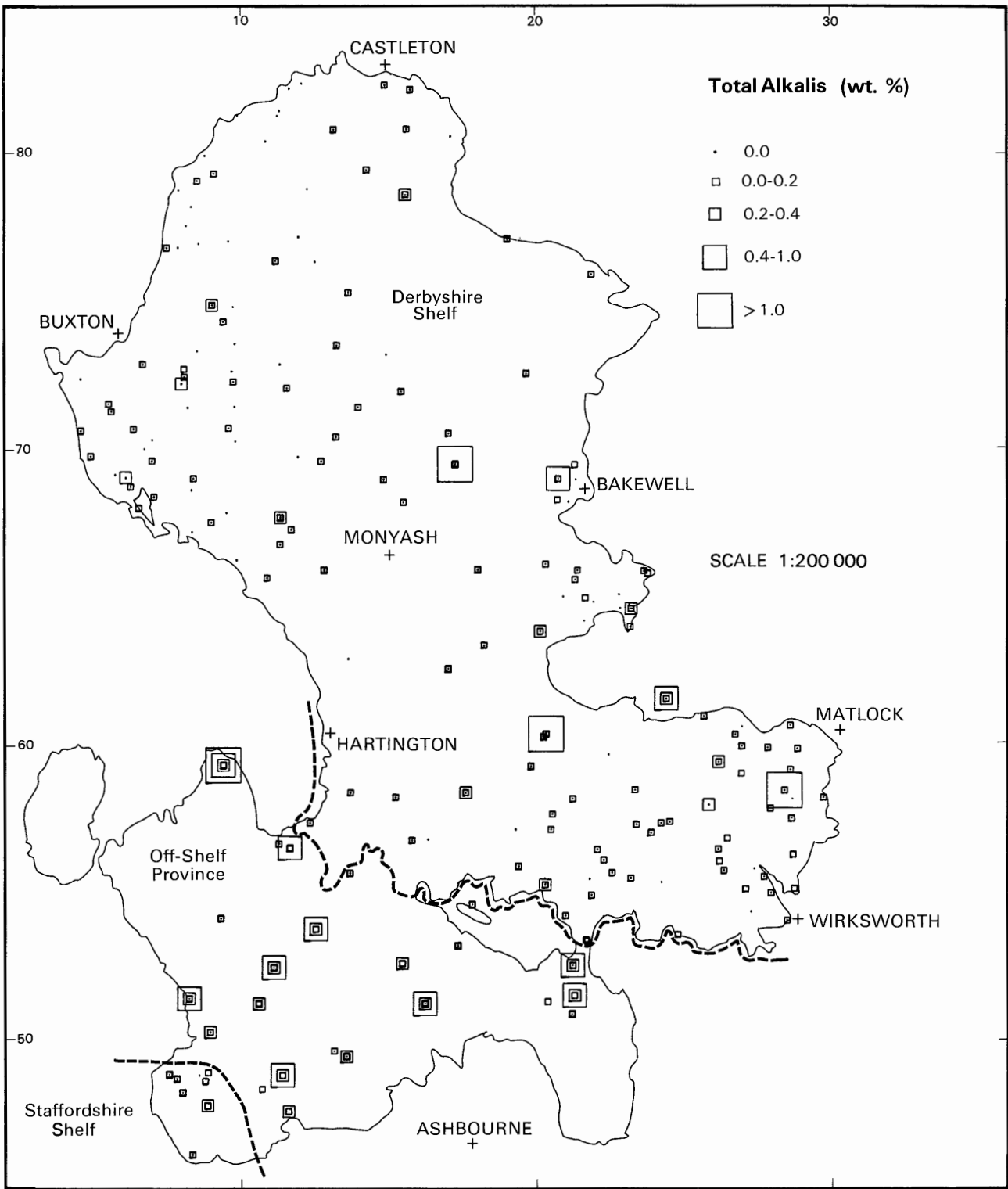


Figure 14 Distribution of total alkalis ($K_2O + Na_2O$) in the Carboniferous Limestone of the Peak District.

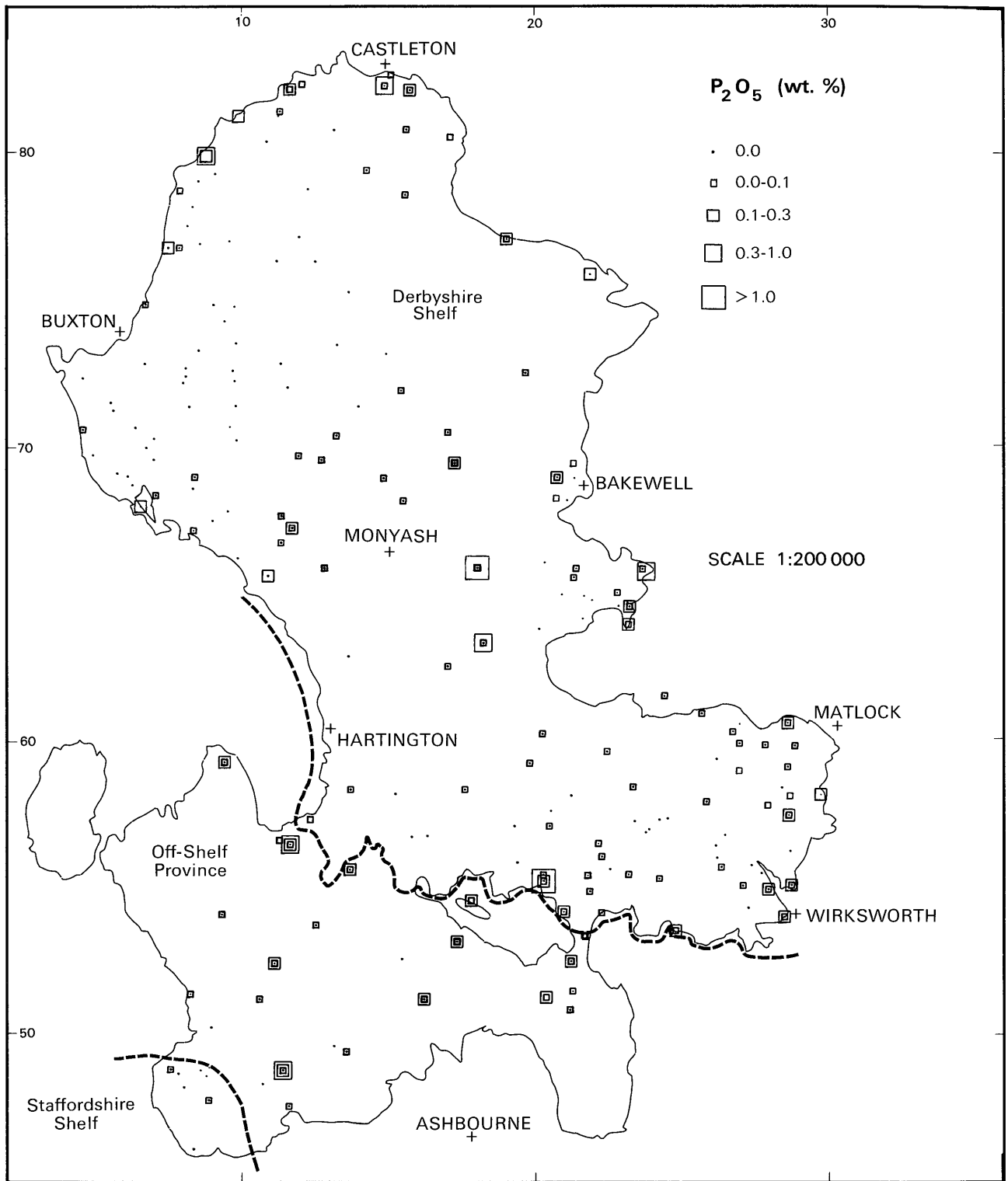


Figure 15 Distribution of phosphorus pentoxide (P_2O_5) in the Carboniferous Limestone of the Peak District.

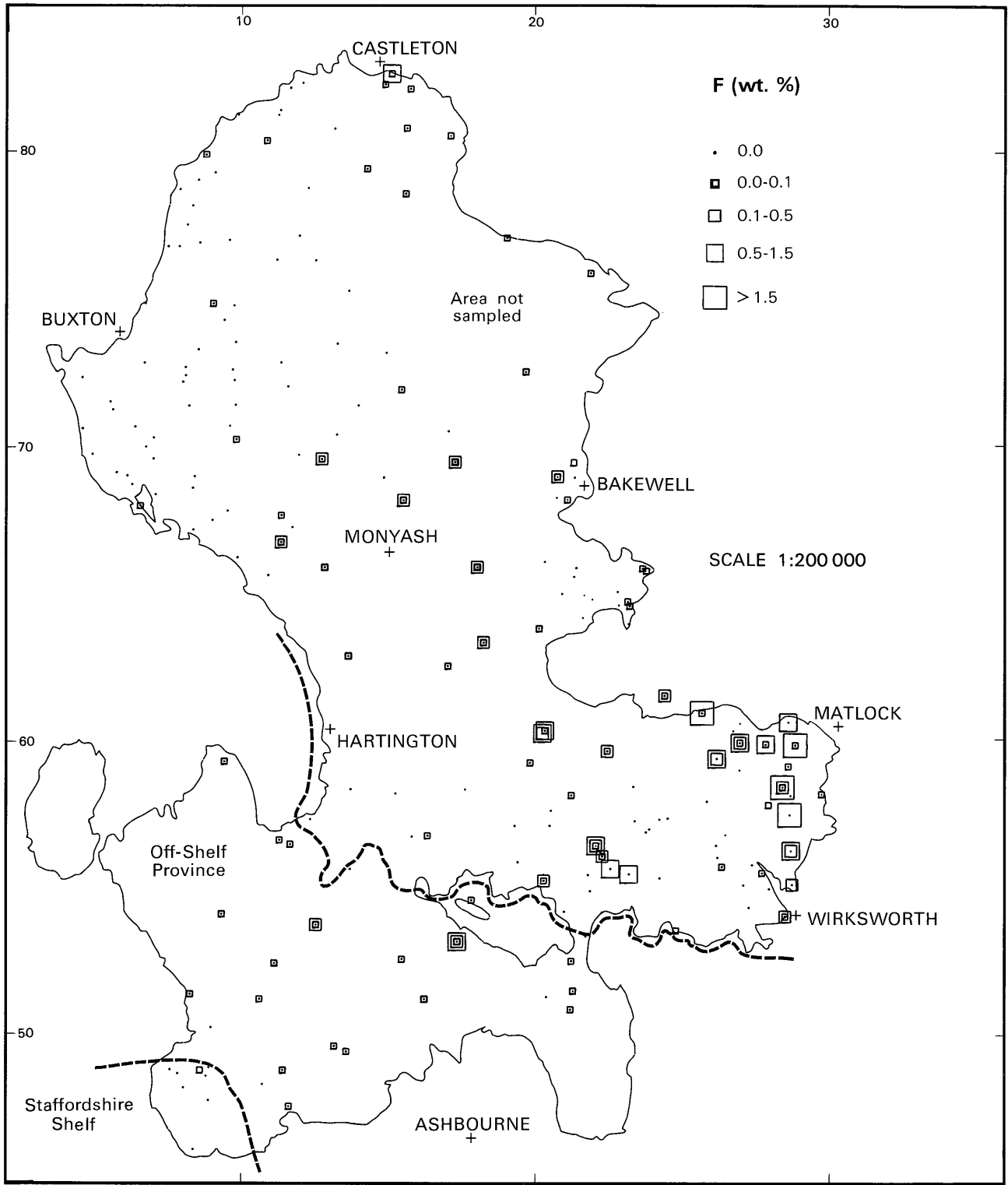


Figure 16 Distribution of fluorine (F) in the Carboniferous Limestone of the Peak District (excluding mineral veins and bodies).

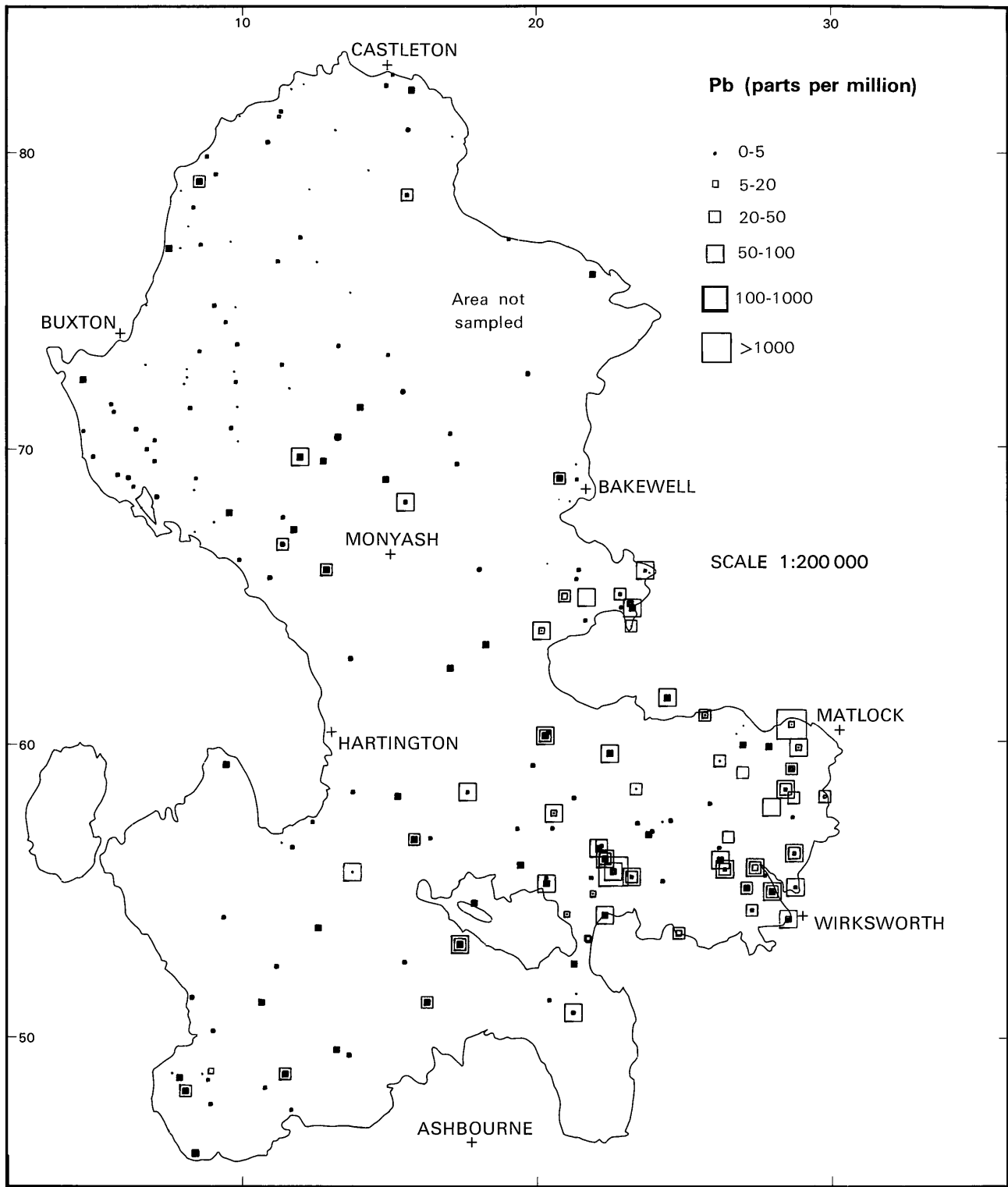


Figure 17 Distribution of lead (Pb) in the Carboniferous Limestone of the Peak District (excluding mineral veins and bodies).

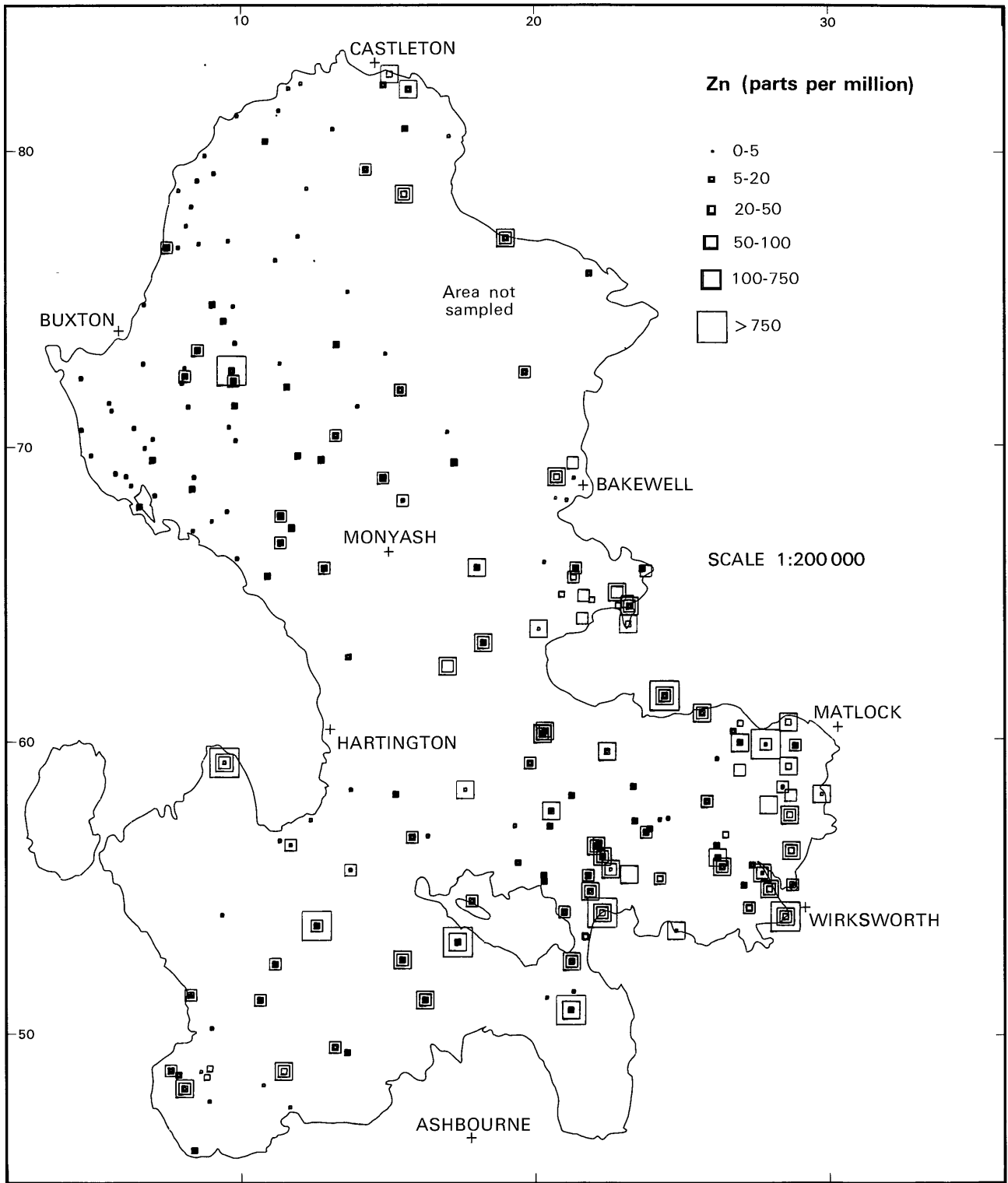


Figure 18 Distribution of zinc (Zn) in the Carboniferous Limestone of the Peak District (excluding mineral veins and bodies).

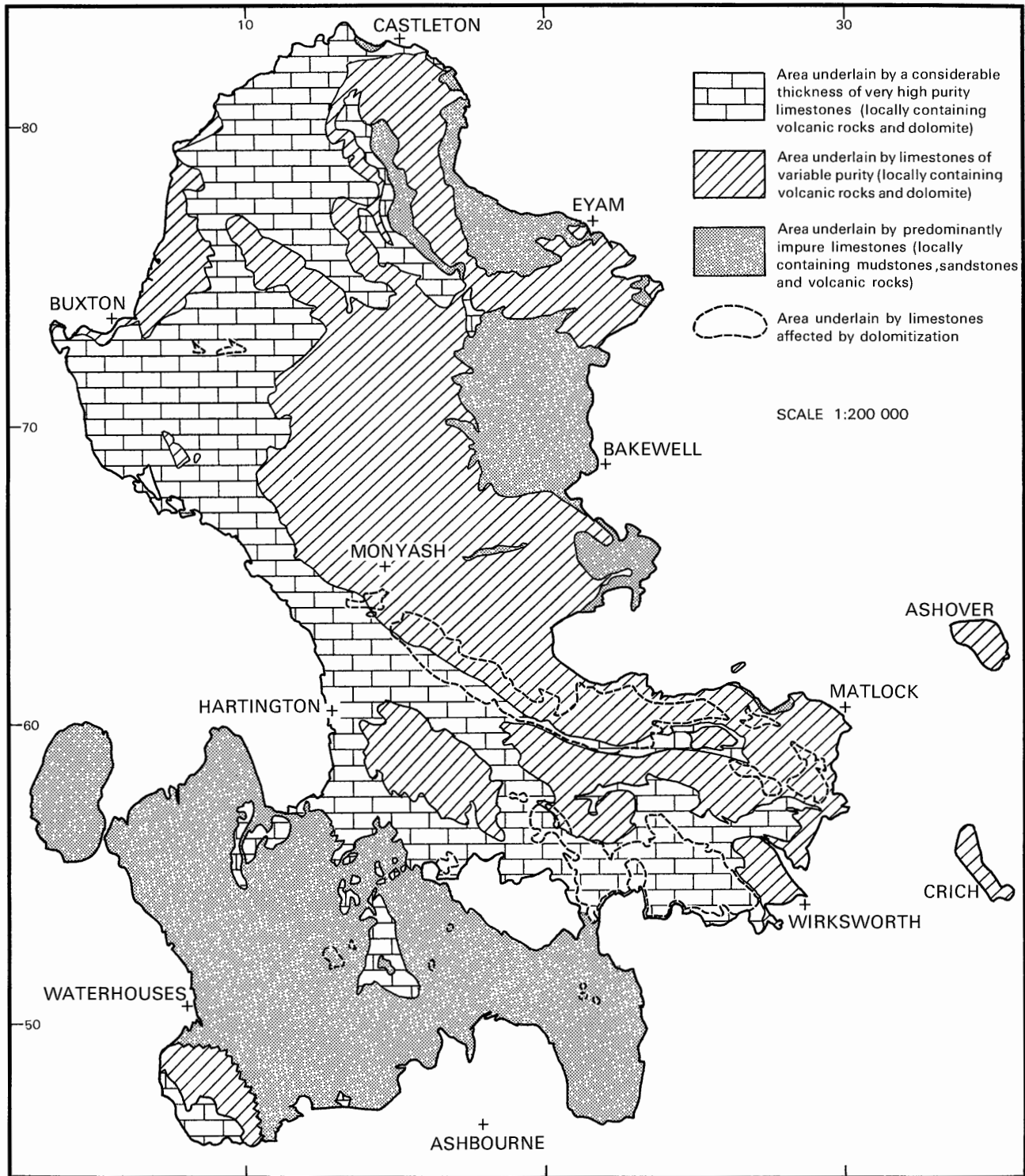


Figure 19 Summary of limestone purity at surface.

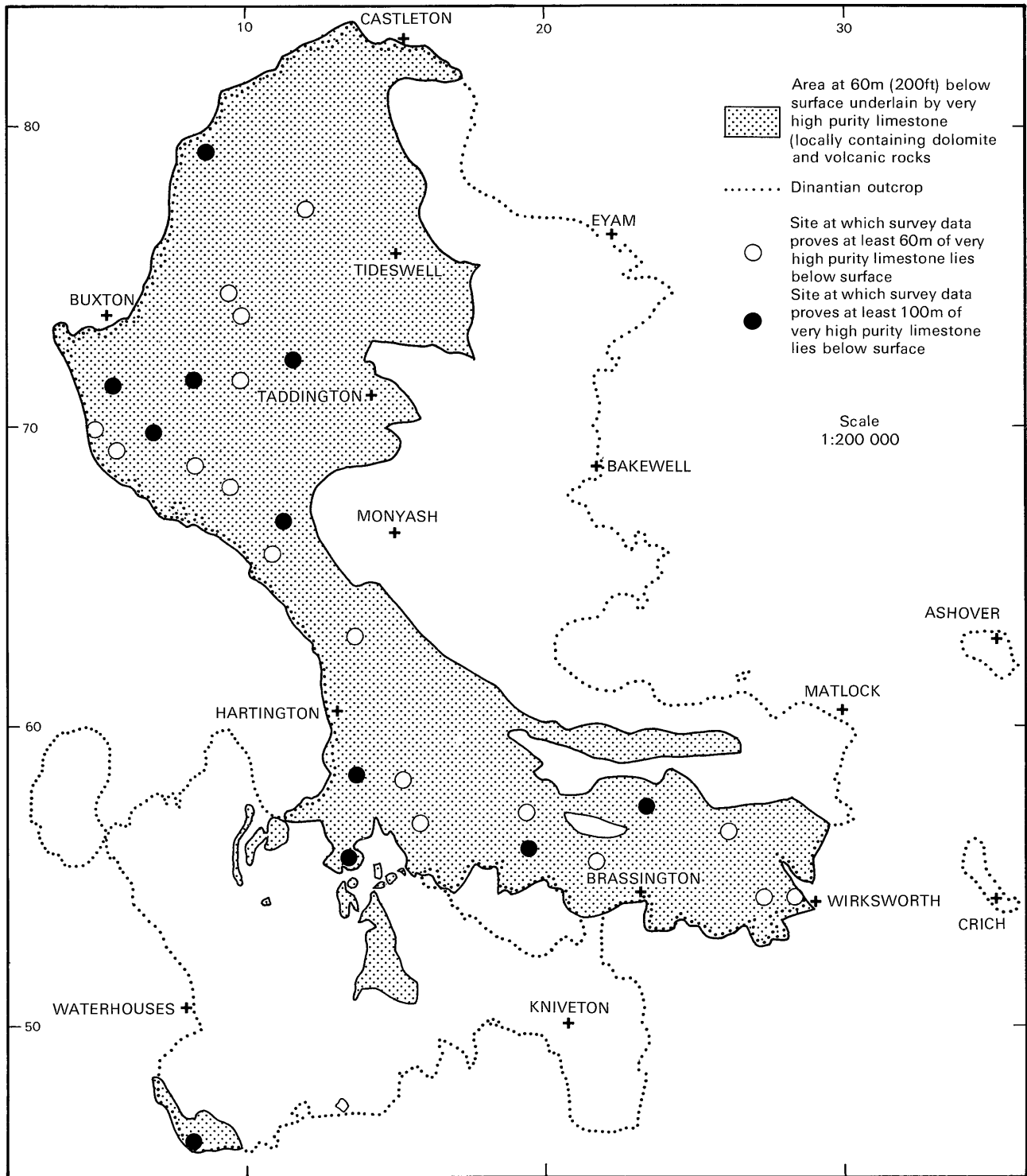


Figure 20 Sub-surface distribution of very high purity limestone.

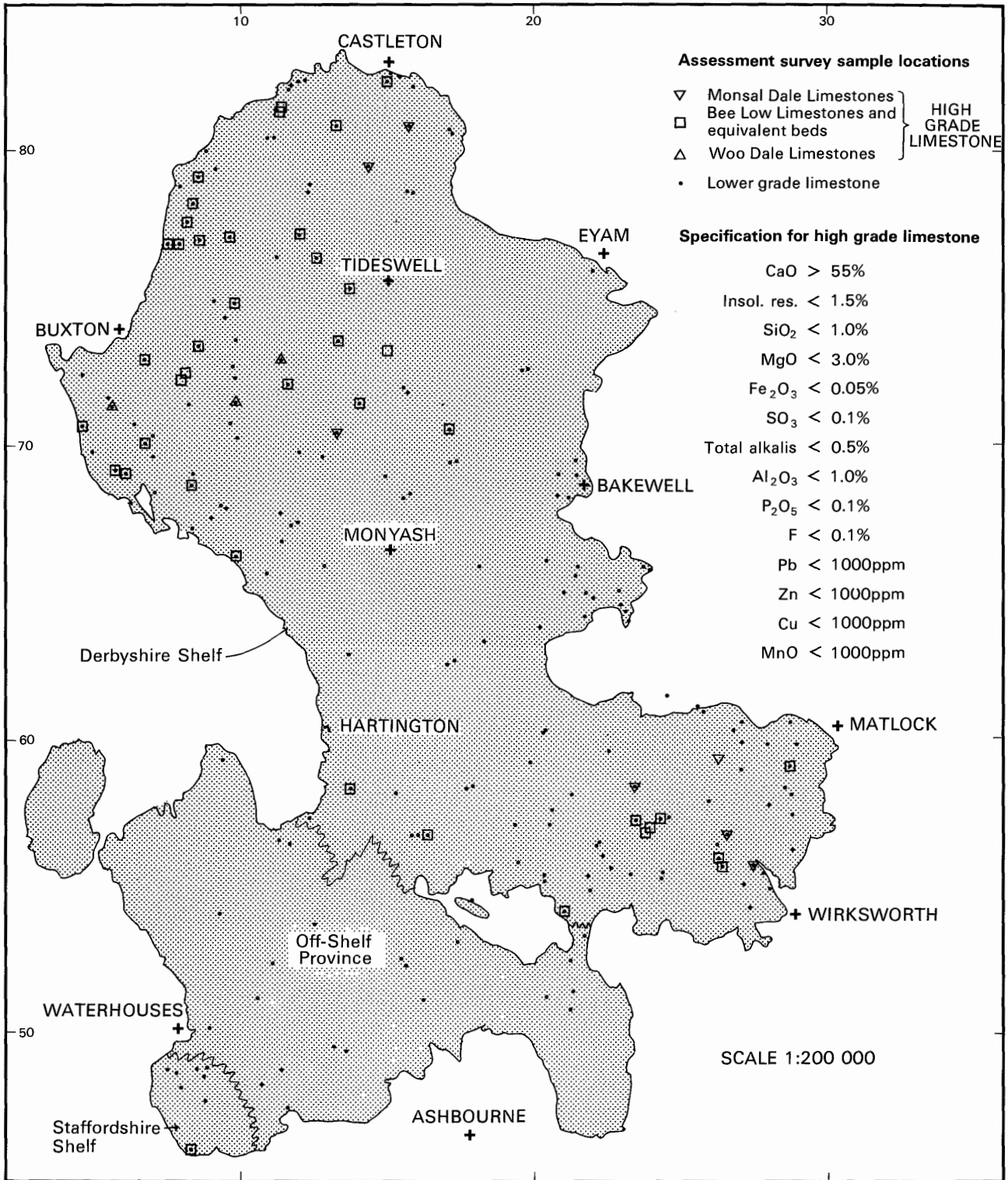


Figure 21 Distribution of high grade limestone in survey samples.

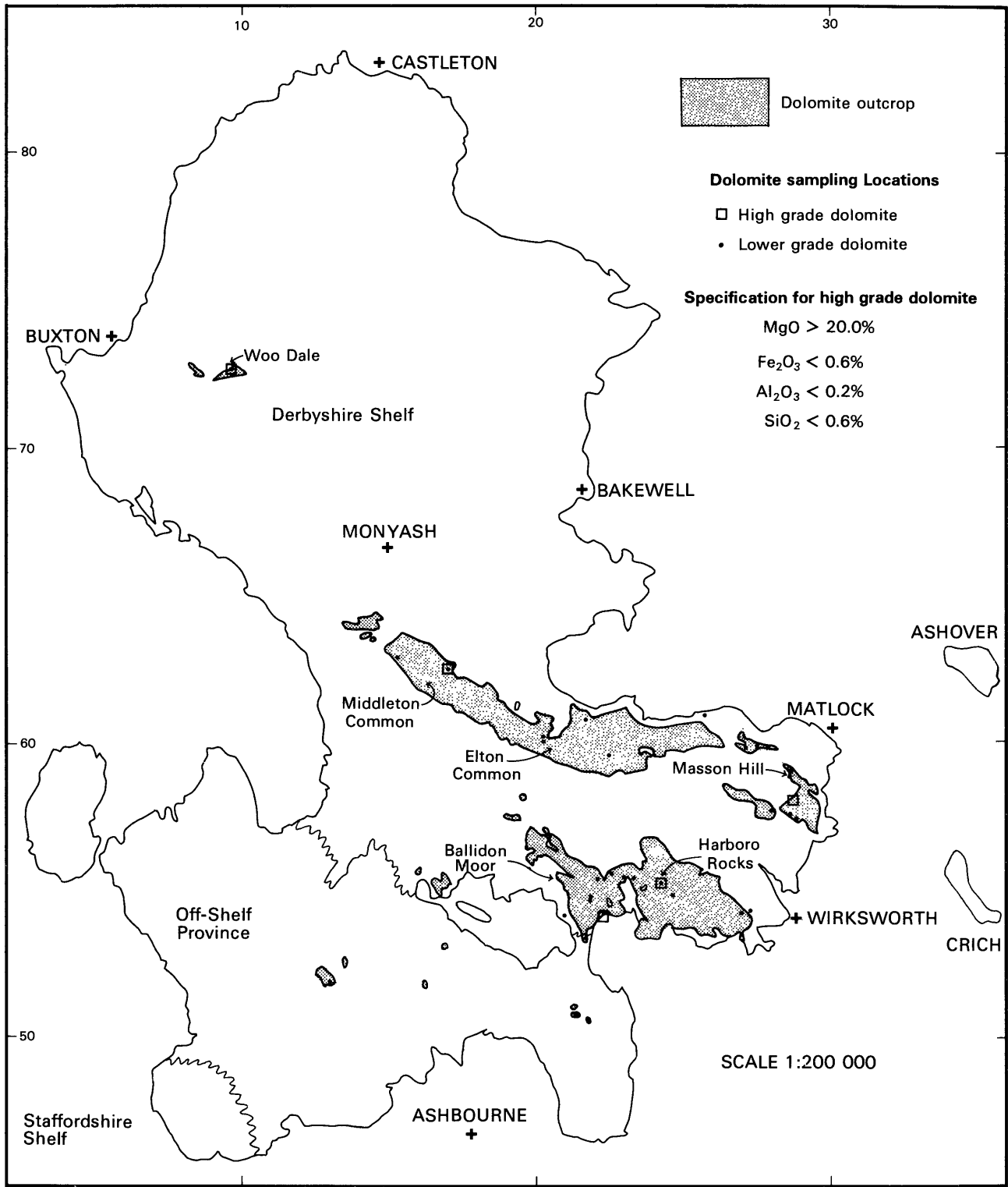


Figure 22 Distribution of high grade dolomite in survey samples.

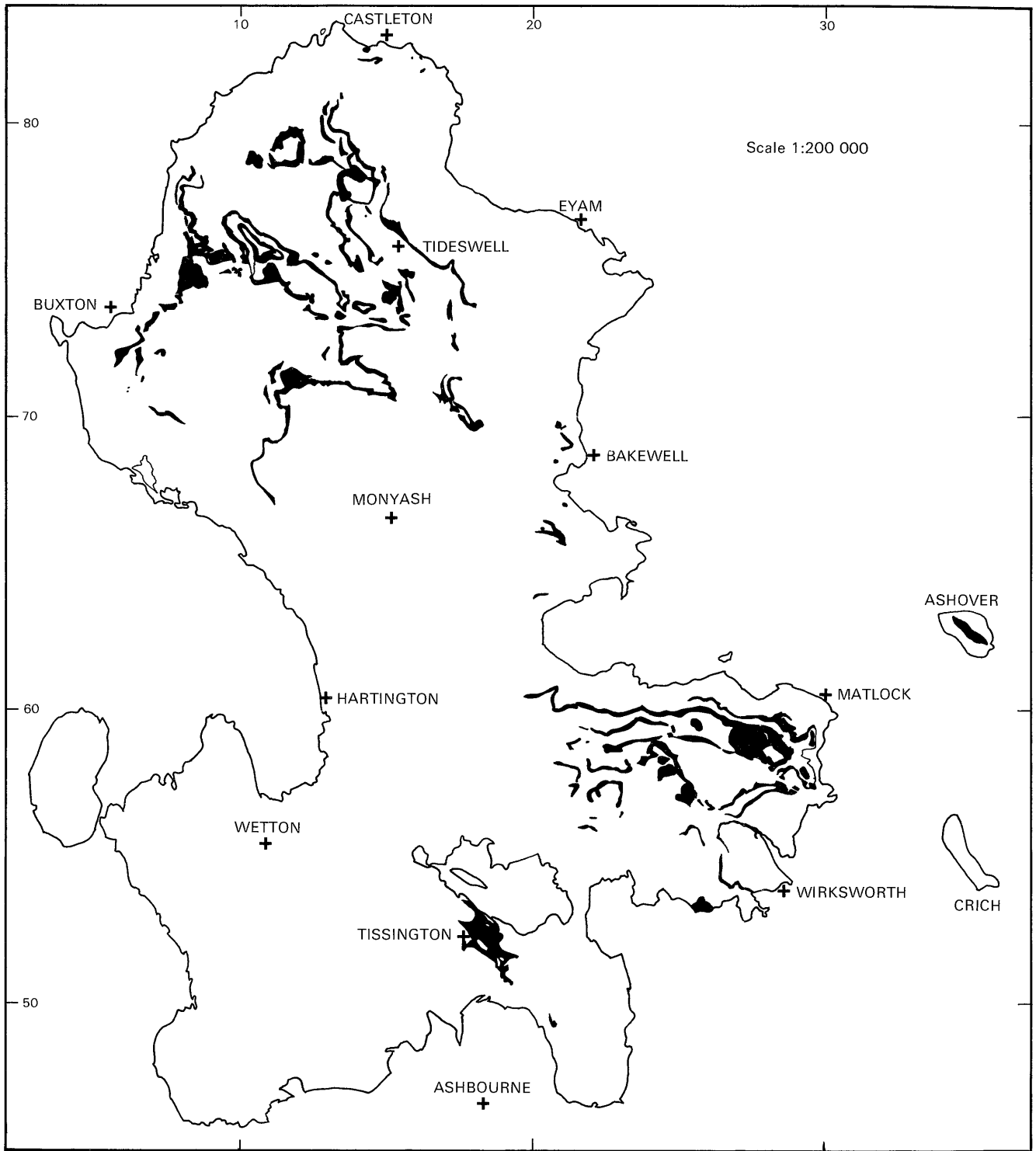


Figure 23 Distribution of volcanic rocks.

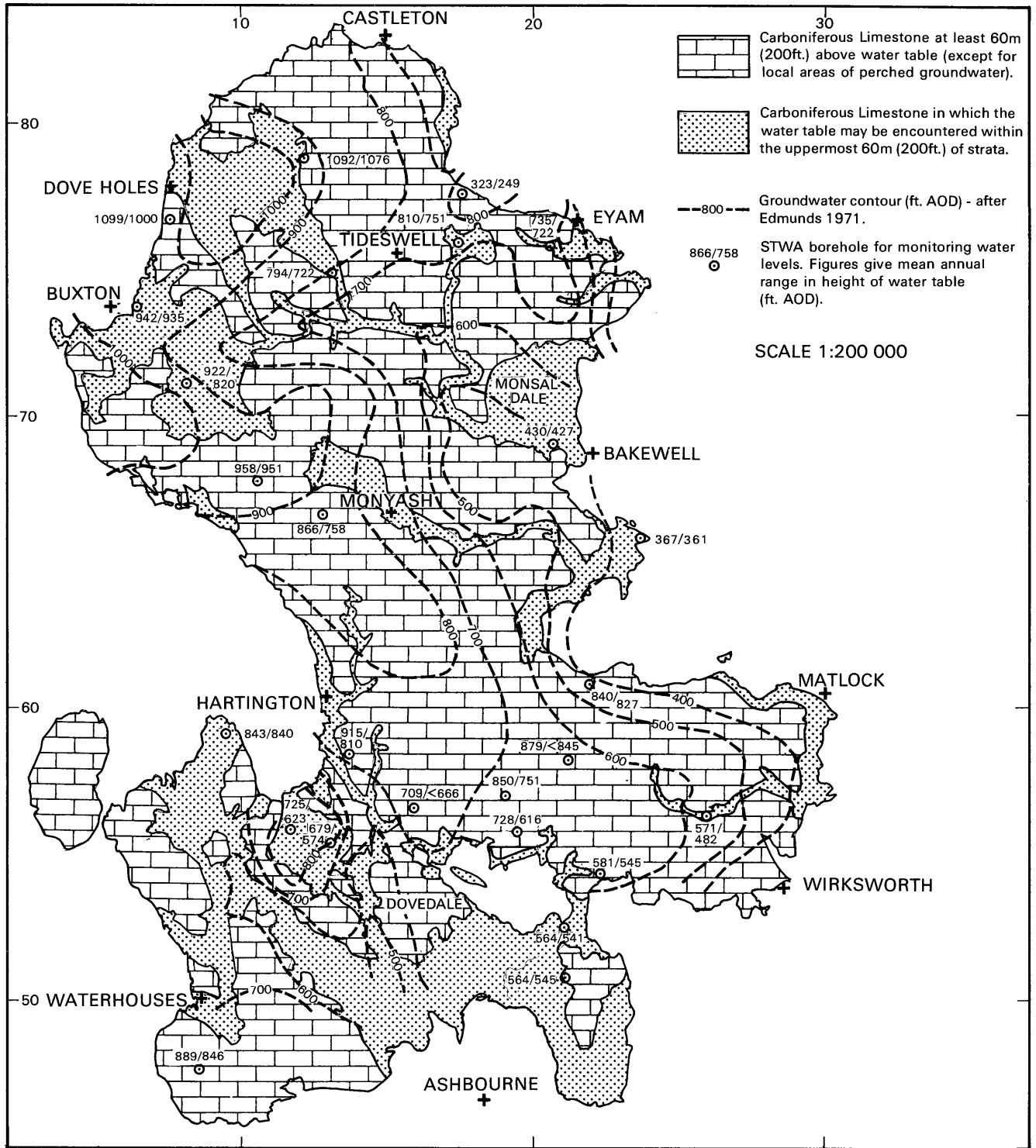


Figure 24 Groundwater levels in the Carboniferous Limestone of the Peak District.

various grades of limestone at surface and at depth is given in the six previous reports. Although the purity of the limestones is variable, large areas of the Peak District are underlain by considerable thicknesses of very high grade limestone (and some dolomite) and it is the location of these resources which is considered here.

Figure 19 summarises the limestone and dolomite resources at the surface and shows that large areas of the outcrop are classified as very high purity limestone, although this also includes some dolomite and igneous rocks (see below). The vertical extent of the very high purity limestone resource, which is mainly represented by the Woo Dale and Bee Low limestones, is considerable and the distribution of very high purity limestone at 60 m (200 ft) below the surface is shown in Figure 20.

High carbonate content is, however, only one of several chemical specifications required for high grade industrial limestones and dolomites. A typical, although not a uniformly acceptable, specification for high grade limestone is given in Figure 21 and the location of survey samples which fit this specification, and of those which do not, are shown diagrammatically. Most of the high grade limestones in Figure 21 occur in the northwest around Buxton, with others in the south between Hartington and Wirksworth. They are predominantly from the Bee Low Limestones (and their equivalents) although high grade limestones have also been proved in the Woo Dale Limestones and to a lesser extent in the Monsal Dale Limestones. No samples from the off-shelf province, not even the knoll-reef limestones, met the suggested specification for high grade limestone.

Figure 22 similarly shows the location of survey samples which fit a typical, although not a uniformly acceptable, specification for high grade dolomite. In fact, most of the samples analysed did not fulfil these requirements as they are iron-rich and, in addition, the dolomitised Monsal Dale Limestones usually contain excessively high proportions of silica. The most consistent deposits of high grade dolomite proved by the surveys are found in the outcrops around Harboro' Rocks, northeast of Brassington. These dolomites average 20.2 per cent MgO, 0.06 per cent SiO₂ and 0.32 per cent Fe.

Other geological factors affecting resource potential

In addition to the intrinsic physical, mechanical or chemical characters of the limestones, other factors may affect the quality of the resource. There may be the other rocks which occur as waste within the resource, such as clay wayboards, igneous rocks, overburden etc., or there may be alteration of the limestones by mineralisation etc. Other factors include the structure and hydrogeological characters of the resource. Although many of these factors have been mentioned previously they are separately discussed in the context of resources below.

Waste deposits within the limestones **Igneous rocks** (basalts, dolerites, tuffs and agglomerates) occur throughout the limestones (although they are most important in the Monsal Dale Limestones) and occupy large areas of outcrop (Figure 23). Although they usually vary between a few metres and a few tens of metres in thickness, particularly thick volcanic sequences (lavas and tuffs) are present at Masson Hill near Matlock, in the area between Bakewell and Youghreave, and also in the Ashover inlier. The igneous rocks are, therefore, a major control on limestone quarrying, although basaltic rocks are themselves quarried for road aggregate at Waterswallows near Buxton.

The limestone beds adjacent to the igneous bodies are also usually contaminated by silica and pyrite in zones which may, in the more extreme examples, be up to 10 m thick, although usually the alteration is restricted to within one or two metres of the volcanic unit. Similar alteration is often encountered in the beds beneath **clay**

wayboards. These are themselves a source of waste material and are removed during quarrying in order to prevent contamination. The clays are very sticky and tend to coat any stone with which they come into contact and they are, therefore, difficult to efficiently remove during crushing and screening. Although high pressure water-jets have been used to remove the clays it is more usual in near-horizontal strata to mechanically remove the clay beds by scraping. However, this is not possible in dipping strata with the result that blasting and extraction of limestones interbedded with these thin clays can produce up to 30 per cent of waste material from a quarry. The wayboard clays are not discarded as waste at Tunstead Quarry near Buxton, but are utilised in the manufacture of cement. Clay wayboards occur mainly in the Bee Low and Kevin limestones and are most common in the middle and upper part of the succession, where they are spaced at intervals ranging from several metres to several tens of metres.

Shales and mudstones occur in parts of the limestone succession, particularly in the off-shelf province, but it is only in the Longstone Mudstones of the Derbyshire shelf area and in the Mixon Limestone-Shales and Widmerpool Formation of the off-shelf province, that they constitute a major part of the sequence. Although the high proportions of shale prohibits the use of these rocks as aggregate or chemical grade material it is possible that they may be suitable resources for the manufacture of cement.

Clay deposits are also found in joints and irregular fissures and caverns in the limestones. The dimensions of these **fissure-fillings** are extremely variable but their presence in quarries may create considerable volumes of waste causing prospecting, blasting and production problems for quarry operators. Such fissure-fillings have been recorded at various localities throughout the limestone outcrop but their occurrence is irregular and cannot be predicted at the resource level of appraisal.

In the south of the Derbyshire shelf area and in the Staffordshire shelf area there are isolated deposits of clays, sands and gravels preserved in steep-sided solution pockets in the limestone and dolomite surface. These are collectively termed **Pocket Deposits** and many are of considerable size and have been worked in the past for refractory materials. Their position is marked on the resource map although some of the worked out pits have now been partially or completely backfilled.

The limestones of the shelf areas are largely free of **drift** which is restricted to small isolated thin patches of boulder clay on the plateau tops and thin spreads of alluvium in the valley bottoms. Locally the boulder clay may be fairly thick (e.g. 9 m at Shining Bank Quarry near Youghreave). There are larger spreads of boulder clay in the off-shelf province but these mainly obscure the shale-dominated Mixon Limestone-Shales and Widmerpool Formation.

Alteration of the limestones The dolomitisation and mineralisation which affects the limestones has been discussed earlier but it is necessary to note here their importance when considering resources. The occurrence of dolomite can be seen either as a contaminant or a resource depending on the desired end-use of the stone. The dolomites of the Matlock — Monyash — Brassington belt are mostly poor quality aggregate materials, but at some sites they may be sufficiently pure to be used in agriculture, as a flux, or in the manufacture of refractories. Although the limestones are mineralised by lead and zinc minerals with accompanying calcite, baryte and fluorite, the mineralisation is mostly confined to the veins or replacement bodies and hence of only local effect to limestone quarrying. The wall rocks are in general little altered although the limestones flanking Dirlow Rake, south of Castleton are widely silicified, as are those flanking the Great Rake near Matlock. However, an evaluation of the geochemistry (see above) of

the limestones in the mineralised areas shows that the limestone wall rocks contain relatively high concentrations of trace elements, although it would be expected that the concentration of trace elements would decrease away from the mineralised bodies (see Ineson, 1969).

Structure The shelf limestones are characterised by low angles of dip although south of Buxton the beds locally steepen to 35° near the western margins of the outcrop. The limestones of the off-shelf province are much more intensely folded and thus may require careful planning of extraction to ensure safety and the most economical recovery of mineral. The limestones in both provinces are faulted and even the minor faults may cause quarrying problems. The limestones are usually fractured by well-developed joint sets although these are usually fairly widely-spaced. Local details of the fracture spacing in the various limestones are given in the six earlier assessment reports.

Water table Groundwater flow in the Carboniferous Limestone is predominantly controlled by topography and the lithology and geological structure of the rocks. The water is stored and transmitted by the joints and fissures in the limestones and the storage capacity has been significantly altered by the underground excavations for ore minerals. Although most of the Carboniferous Limestone plateau is elevated well above the levels of the river valleys there are areas where the water table is close to the surface and a study of the local hydrogeological conditions in the Carboniferous Limestone is likely to be of some importance in the siting and development of quarries.

Figure 24 shows water table contours (from Edmunds, 1971) for the limestone region and unpublished water table data made available by the Severn Trent Water Authority. These data were obtained by monitoring the water levels in 26 boreholes at monthly intervals for at least the past 5 years and show that in some areas the annual variation in the height of the water table may be over 30 m (100 ft). Figure 24 also shows the areas in which it is calculated that the water table may be encountered within the uppermost 60 m of strata. However, this interpretation does not take into account the presence of the volcanic horizons which locally give rise to perched water tables.

GLOSSARY OF TECHNICAL TERMS

Agglomerate A rather chaotic assemblage of unsorted predominantly angular volcanic fragments. The deposit is localised near to its centre of eruption.

Aggregate Materials, used for mixing with a matrix to form concrete, macadam, mortar, or plaster; or used alone as in railway ballast or graded fill.

Aggregate Abrasion Value (AAV) A measure of the surface wear of an aggregate following abrasion (BS. 812). A lower numerical value indicates a more resistant rock.

Aggregate Impact Value (AIV) A measure of the resistance of an aggregate to granulation under impact stresses (BS. 812). A lower numerical value indicates a more resistant rock.

Aggregate Crushing Value (ACV) A measure of the resistance of an aggregate to crushing under a gradually applied load (BS. 812). A lower numerical value indicates a more resistant rock.

Alluvial deposit Detrital deposits of modern rivers.

Amorphous Non-crystalline.

Anticline An arch fold, the core of which contains the stratigraphically older rocks.

Argillaceous rocks Detrital sedimentary rocks that contain clay or silt grade material.

Authigenic Refers to those constituents that came into existence after the formation of the host rock.

Baryte A white, orange, or colourless crystalline mineral: BaSO₄. It is used in paint, drilling mud, and as a filler for paper and textiles, and is the principal ore of barium.

Basalt A general term for dark-coloured extrusive igneous rocks.

Bioclast A fossil fragment.

Biomicroite A limestone consisting of a variable proportion of skeletal debris and carbonate (micrite) mud.

Biosparite A limestone consisting of a variable proportion of skeletal debris and clear calcite (spar).

Boulder clay Glacial deposits consisting of subangular boulders of various sizes embedded in stiff clay.

Chert A hard, extremely dense, microcrystalline sedimentary rock, consisting of interlocking crystals of quartz.

Conglomerate A rock consisting of rounded or sub-rounded fragments which range in size from 2 mm upwards.

Crinoidal limestone A limestone consisting almost entirely of the fossil skeletal parts of crinoids.

Dinantian Lower Carboniferous

Dip The angle that a bedding plane makes with the horizontal.

Dolerite Fine-grained, dark-coloured, intrusive igneous rocks.

Dolomite A carbonate sedimentary rock of which more than 50 % by weight consists of calcium magnesium carbonate: CaMg (CO₃)₂.

Drift A general term applied to all rock material (clay, silt, gravel, boulders) transported by a glacier and deposited directly from the ice or by running water emanating from a glacier.

Euhedral A term applied to grains displaying fully developed crystal form.

Facies The sum of all the primary lithological and palaeontological characteristics exhibited by a sedimentary rock and from which its origin and environment of formation may be inferred.

Fluorite A transparent to translucent mineral: CaF₂. It is found in many different colours (often purple and blue). It is the principal ore of fluorine, and is used as a flux, in the preparation of glass and enamel, and in the manufacture of aerosol propellants.

Fluvial Produced by the action of a stream or river.

Formation The primary local rock stratigraphical unit which possesses distinctive lithological features or homogeneity.

Greywacke A hard, dark grey, clayey impure sandstone.

Hematite A common iron mineral: Fe₂O₃.

Horizon An interface indicative of a particular position in a stratigraphic sequence.

Lacustrine Produced by, or formed in a lake or lakes.

Limestone A sedimentary rock consisting chiefly of calcium carbonate.

Lithology The general characteristics (composition, texture) of a rock.

Member Part of a formation

Micrite Crystalline matrix component of limestones consisting of carbonate mud whose crystals have diameters of less than 4 micrometres.

Mineralisation The process by which a mineral or minerals are introduced into a rock.

Mudstone A blocky or massive, fine-grained sedimentary rock in which the proportions of clay and silt are approximately equal.

Ore The material from which minerals of economic value can be extracted. Also the minerals thus extracted.

Overburden Unconsolidated material resting on solid rock.

Pelsparite A limestone consisting predominantly of pellets or peloids (micrite grains) in a spar matrix.

Perched groundwater Groundwater separated from an underlying main body of ground water by an unsaturated zone.

Plunge The inclination of a fold axis measured in the vertical plane.

Polished Stone Value (PSV) A measure of the resistance of an aggregate to polishing (B.S. 812). A higher value signifies greater resistance to polishing (i. e. greater skid resistance).

Pyrite A common, bronze-yellow, iron mineral: FeS₂. Pyrite is an important ore of sulphur, less so of iron.

Reef A mound-like structure built by sedentary calcareous organisms and consisting partly of their remains.

Refractory A material not damaged by heating to high temperatures. Such materials are made into bricks and used for lining furnaces, etc.

Resource A natural concentration of materials from which now or in the future economic situation, extraction of a commodity may be possible.

Sandstone The consolidated equivalent of sand, intermediate in texture between conglomerate and shale.

Shale A fine-grained, laminated, sedimentary rock, formed by the consolidation of clay, silt, or mud.

Silica The chemically resistant dioxide of silicon: SiO₂.

Silt A rock fragment smaller than a very fine sand grain and larger than coarse clay.

Sparite Transparent crystalline matrix component of limestones consisting of calcite having diameters that exceed 10 micrometres.

Stratigraphy The study of stratified (layered or bedded) rocks especially their sequence in time, the character of the rocks and the correlation of beds in different localities.

Syncline A trough fold, the core of which contains stratigraphically younger rocks.

Tuff A consolidated pyroclastic rock, predominantly consisting of fine-grained volcanic fragments.

Unconformable Describes strata which do not succeed the underlying rocks in immediate order of age.

Vein A mineral filling of a fault or other fracture in a rock.

Wayboard An old mining term used commonly in Derbyshire to describe a discrete and deleterious thin rock bed, usually of clay.

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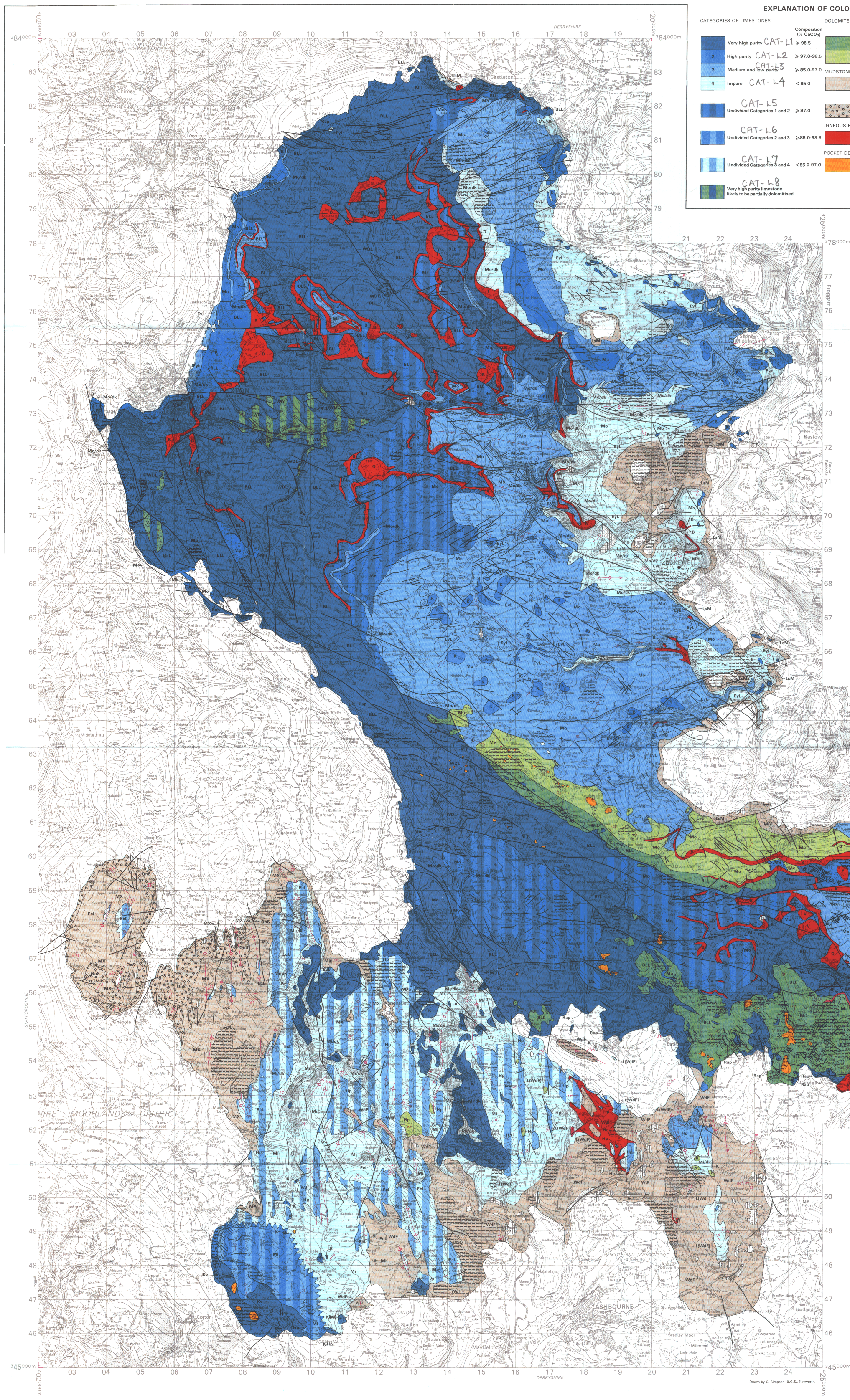
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THE LIMESTONE AND DOLOMITE RESOURCES OF THE PEAK DISTRICT OF DERBYSHIRE AND STAFFORDSHIRE
Mineral Assessment Report No 144

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EXPLANATION OF COLOURS

CATEGORIES OF LIMESTONES	Composition (% CaCO ₃)	DOLOMITES	Composition (% CaCO ₃)
1 Very high purity CAT-1.1	> 98.5	DOL-1	High purity (> 97.0% carbonate)
2 High purity CAT-1.2	> 97.0-98.5	DOL-2	Low purity (> 85.0-97.0% carbonate)
3 Medium and low purity CAT-1.3	> 85.0-97.0	MUDSTONES	MUD-1
4 Impure CAT-1.4	< 85.0	MUDSTONES	MUD-2
5 Undivided Categories 1 and 2	> 97.0	MUDSTONES	MUD-3
6 Undivided Categories 2 and 3	> 85.0-98.5	MUDSTONES	MUD-4
7 Undivided Categories 3 and 4	< 85.0-97.0	MUDSTONES	MUD-5
8 Very high purity limestone likely to be partially dolomitised		MUDSTONES	MUD-6

IGNEOUS ROCKS
 UGR-1 Undivided (basalt, dolerite, tuff)
 POC-1 Pocket deposits (sands and clays)

EXPLANATION OF GEOLOGICAL SYMBOLS

Derbyshire Shelf Province

LAM	Longstone Limestones
FK	Knoil-reef Limestones
Mk	Monal Dale Limestones
Mk/dk	Monal Dale Limestones (dark facies)
BL	Bea Low Limestones
Rap	Apron-reef Limestones
WDL	Woo Dale Limestones

Staffordshire Shelf Province

OSB	Onecote Sandstones
MX	Main Limestone Shales
WVF	Widmerpool Formation
L(WVF)	Limestone in Widmerpool Formation
ECL	Eaton Limestones
Hp	Hopetate Limestones
K	Knoil-reef Limestones
Kv	Kevin Limestones
Ml	Milbide Limestones
Ml/dk	Milbide Limestones (dark facies)

IGNEOUS ROCKS

B	Basalt lava
T	Tuff
H	Hyaloclastite (fragmented lava)
V	Agglomerate
D	Dolerite

OUTLINE OF DINANTIAN GEOLOGY AND SUMMARY OF RESOURCES

Derbyshire Shelf Province (Buxton - Castleton - Bakewell - Wirksworth area)
 Longstone Limestones: Mainly mudstones with minor argillaceous limestones.
 Eym Limestones: Thin-bedded, dark grey cherty limestones and knoll-reefs of massive and well-bedded, pale grey limestones.
 Monal Dale Limestones: Lithologically variable limestones. Mainly pale to medium grey, thin to thick bedded with argillaceous chert, a dark facies which is principally developed in the Miller's Dale - Ashfield area.
 Bea Low Limestones: Pale grey, thick bedded limestones, laterally and vertically homogeneous throughout the limestone.
 Woo Dale Limestones: Predominantly dark to pale grey, thin bedded, porous limestones in the upper part, passing downwards into medium to pale grey, thick bedded limestones.
 Staffordshire Shelf Province (Caldon Low - Weaver Hills area)
 Kevin Limestones: Equivalent and lithologically similar to the Bea Low Limestones.
 Milbide Limestones: Mid-grey, well-bedded limestones with some darker beds.
Off-Shelf Province (Dove Dale and Manifold Valley area)
 Widmerpool Formation: Mainly mudstones with variable sequences of turbidite sands.
 Mixon Limestone-Shales: Mainly mudstones with limestone turbidites.
 Eaton Limestones: Fine-grained to coarsely crystalline limestones with graded beds of turbidite facies.
 Hopetate Limestones: Highly variable lithologically but mainly consist of mid-grey, thin to thick bedded, fine to coarse grained limestones.
 Milbide Limestones: Limestones of off-shelf facies are also widely developed around Manifold in the Manifold Valley.

EXPLANATION OF GEOLOGICAL SYMBOLS

Derbyshire Shelf Province

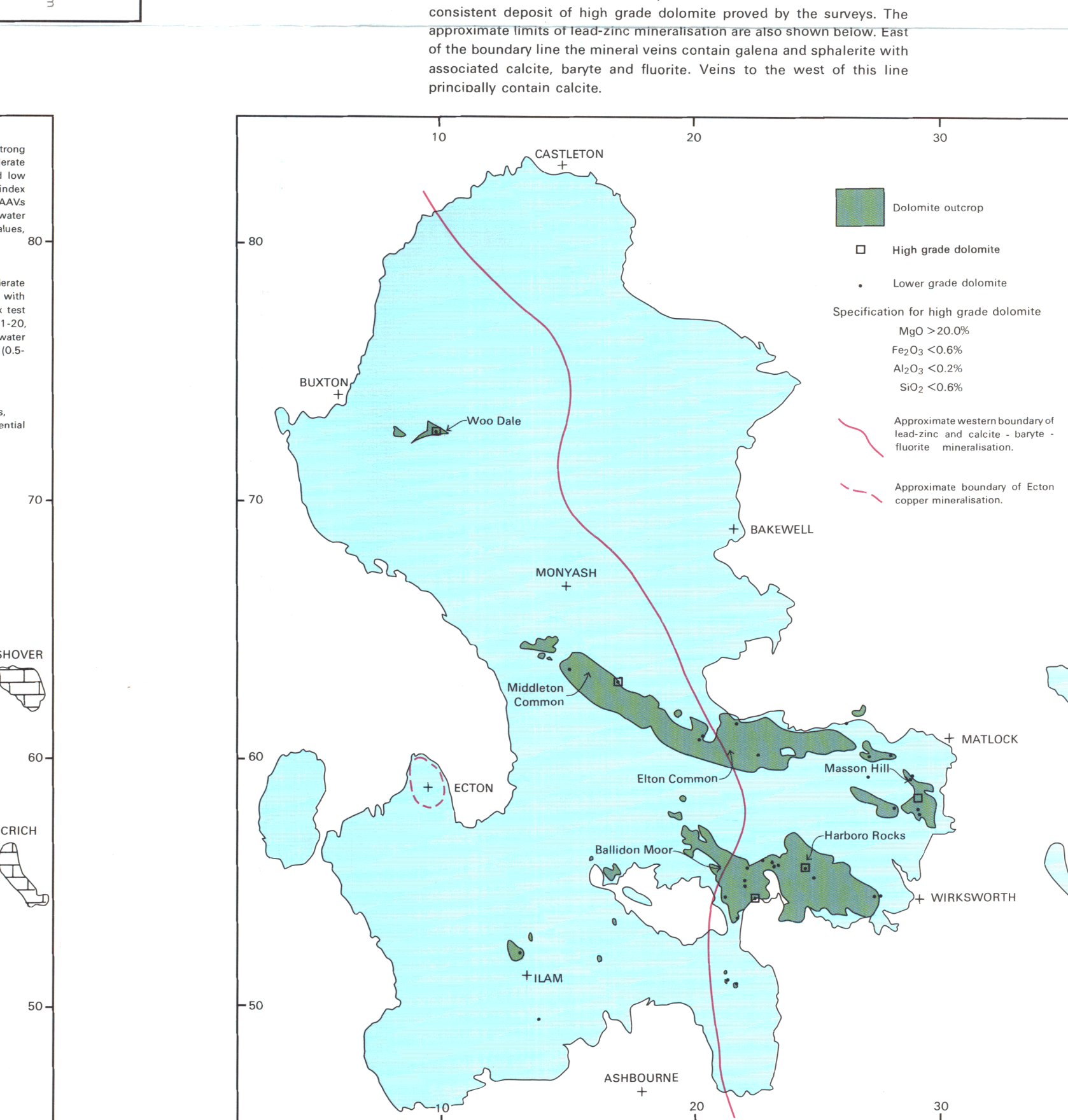
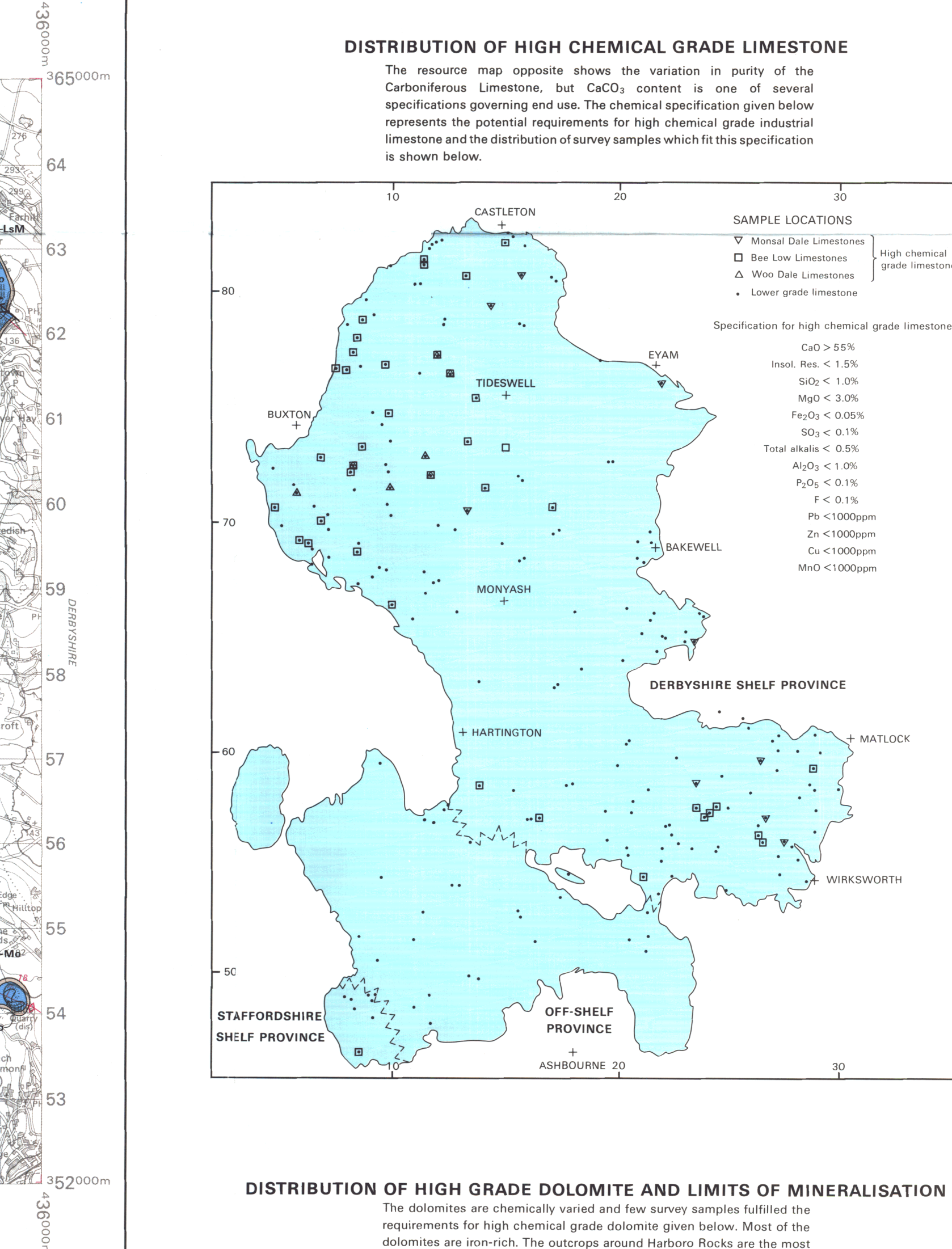
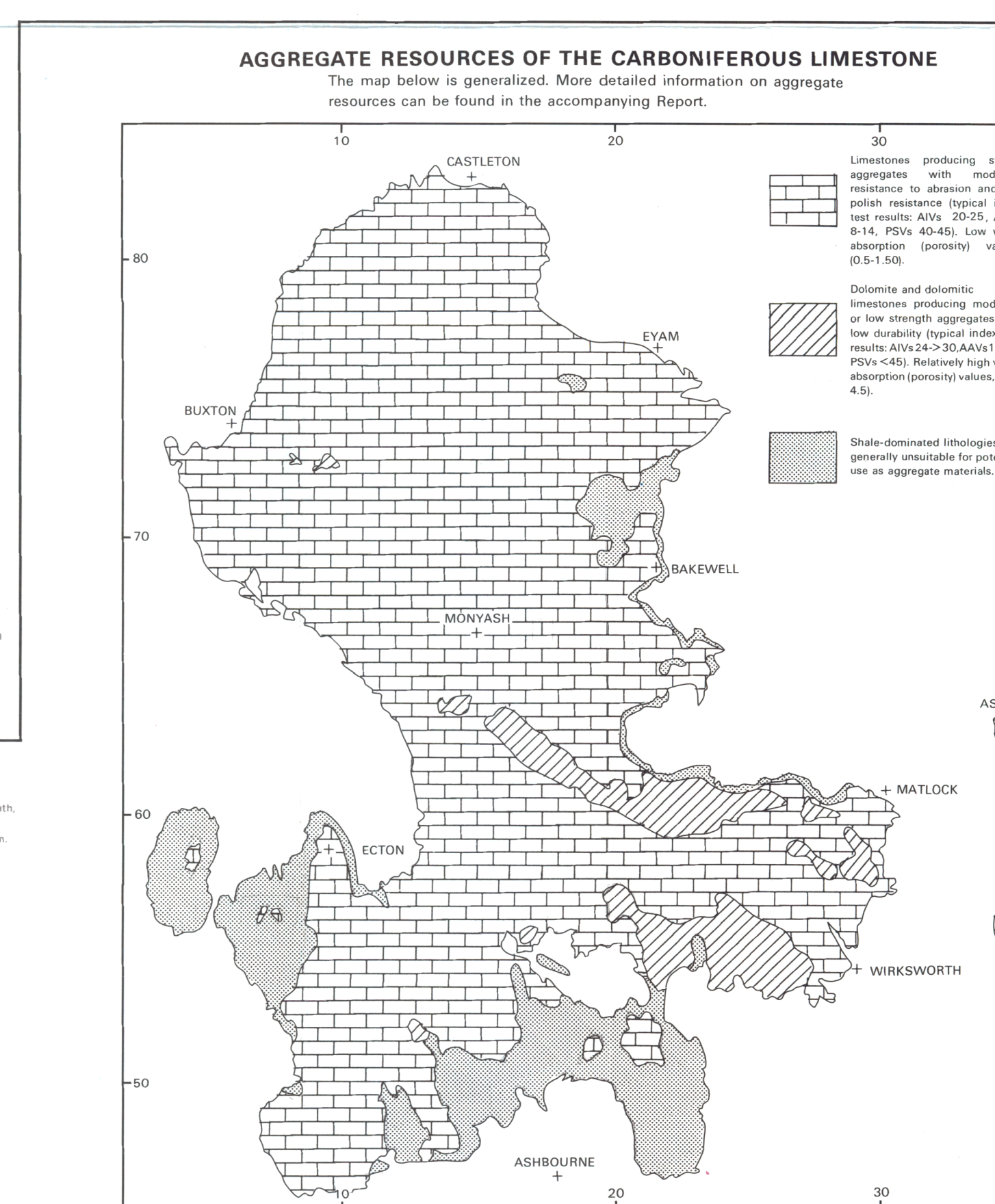
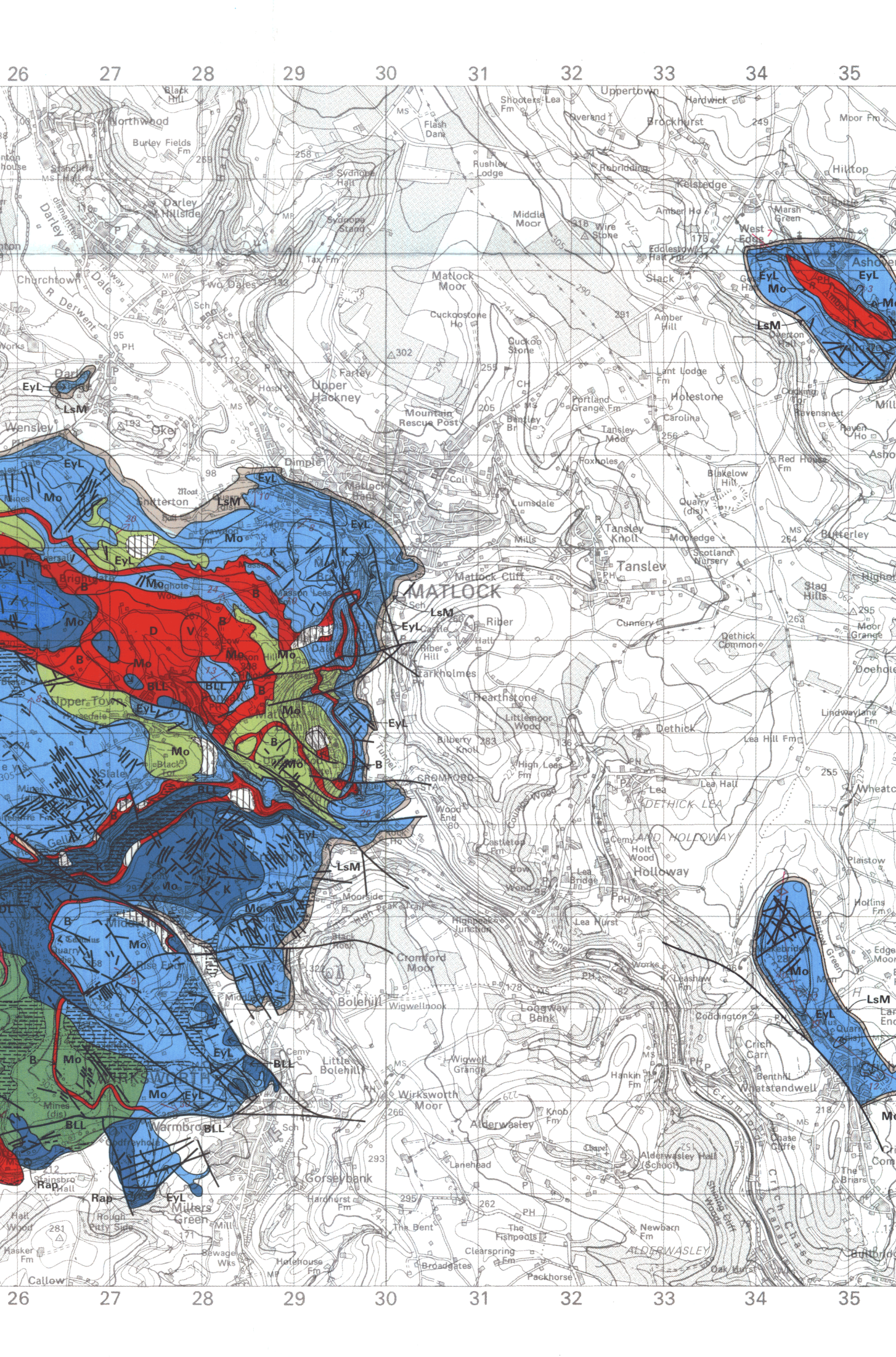
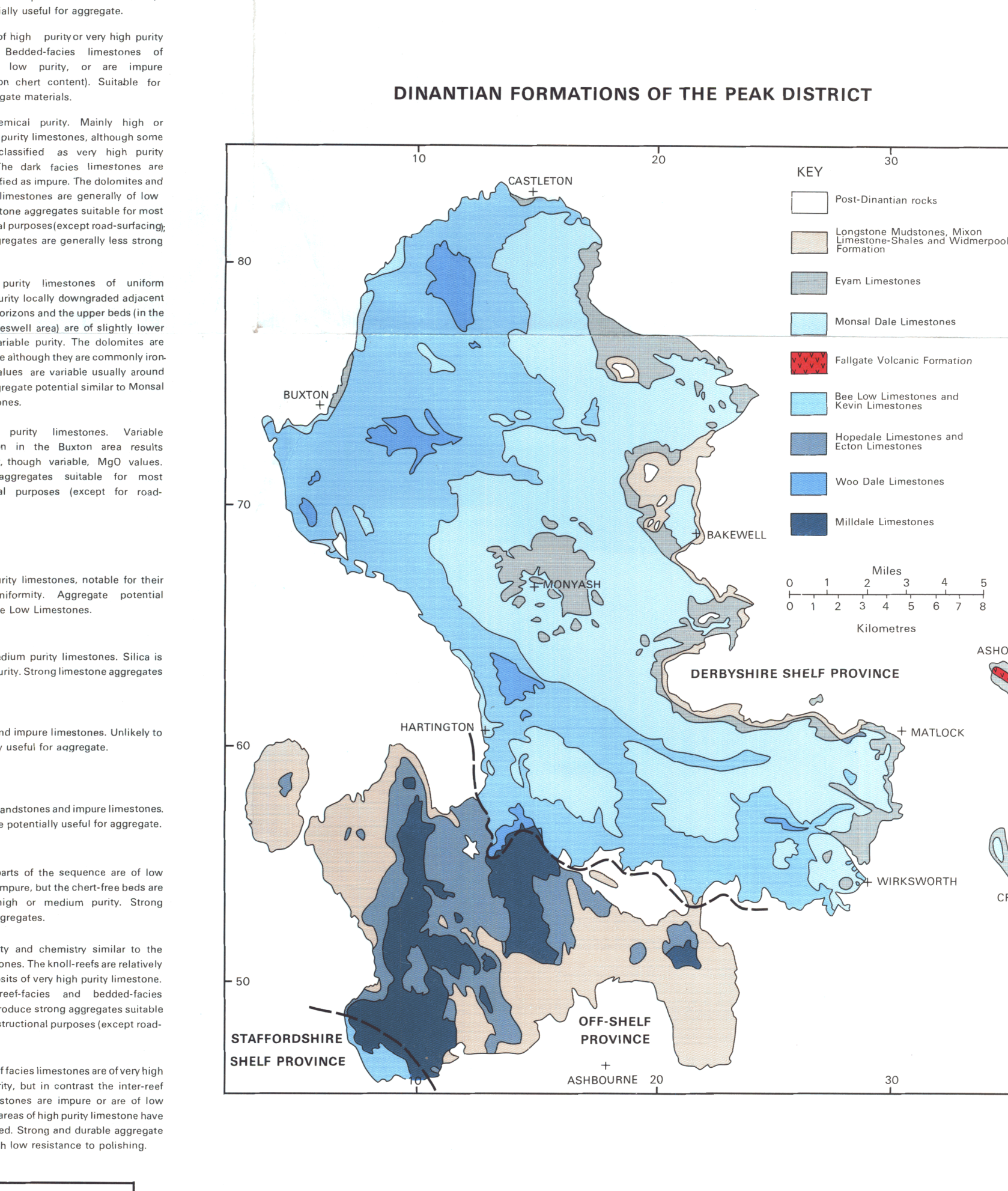
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1000 Limestone and Dolomite Resources Sheet by D.J. Hanson. Published 1985.
 British Geological Survey, 61, Gordon Square, London WC1H 9GU.
 Scale 1:50,000. Contour values are given to the nearest metre. The vertical interval is, however, 50 feet.
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