A NOTE ON THE SERIES

These maps of Great Britain are produced in two sheets, are on the Transverse Mercator Projection, and carry the new National Grid lines at ten kilometre intervals.

The series was initiated at the suggestion of the Advisory Maps Committee of the Ministry of Works and Planning (now the Ministry of Housing and Local Government) whose members included representatives of the British Association National Atlas Committee.

The planning maps already published or in preparation on this scale have been sponsored by the Ministry of Housing and Local Government and the Department of Health for Scotland and form a related series depicting the primary physical, economic, human and social facts concerning the country as a whole. They are listed within. For convenience of reference, maps prepared independently by the Ministry of Agriculture, the Geological Survey and by research organisations such as the Land Utilisation Survey are included in the list overleaf.

The series will be found valuable not only by those concerned with planning, but by all who wish to see in convenient form essential facts about Britain as a whole. They should be invaluable to schools, business men, and administrators, and constitute the nucleus of a National Atlas.

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No. 4
LIMESTONE

Published by the Director-General at the Ordnance Survey Office,
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1957
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Introduction

THIS map is one of a series showing the general relationship between the production and uses of mineral raw materials and the geological formations from which they are won. The geological information is derived from maps and memoirs of H.M. Geological Survey, and the location and output of the individual quarries chiefly from data supplied by the Ministries of Fuel and Power, Transport, Works and Agriculture. Grateful acknowledgment is also made of the assistance provided by the Limestone Federation, the Chalk Quarrying Association and the Cement Manufacturers' Federation. It should be noted that the quarries shown on the map are those for which returns of 1949 output were made to the Ministries concerned. It is known that certain other quarries were also in production.[1]

Limestone is a widely distributed rock-type, showing many variations in appearance, properties and usefulness. Chalk, because of its unique character and properties is commercially the basis of a separate group of industries with its own trade association. To geologists, however, chalk is a particular kind of limestone, and except where the context shows otherwise, this text uses the term "limestone" to include chalk. Only two counties in England (Cheshire and Cornwall)[2] and two in Wales (Cardigan and Montgomery) are absent from the list of producers; in Scotland its distribution is more limited. The areas shown on this map are sometimes more restricted than the corresponding formations shown on the Ten Mile map of "Solid" Geology. This is so for two reasons. Firstly, limestone outcrops are in some

[1]It is regretted that due to a clerical error one chalk quarry near Westerham, Kent, which should have been shown in the lowest size category, was omitted.

[2]Cornwall, although not listed as producing limestone does, in fact, produce shell sand for agriculture.

instances covered by superficial or "Drift" deposits, e.g., Boulder Clay, and sands and gravels of glacial origin; areas where the thickness of drift is such as certainly to render the working of the underlying limestones uneconomic under present conditions have been excluded from the map. Secondly, in certain formations limestones are interbedded with other rocks such as shales and sandstones; wherever sufficient information was available (e.g. for the Carboniferous Limestone Series of Scotland and northern England), and the scale of the map allowed, only the limestone beds have been shown.

Nevertheless, by no means all the areas shown on this map will be productive of economically-workable limestone. Limestones vary in their chemical and physical quality, in thickness and in structure. In certain formations it is impossible to show limestones separately from other rocks closely interbedded with them. Furthermore it is not always possible to say with certainty what thickness of drift will prevent economic working; this will depend on local circumstances. In addition to the availability of raw materials of the requisite quality and quantity, the working of quarries in a particular area will depend on a number of factors such as adequate road or rail access (both for the supply of fuel for the plant and for transport of the bulky products); the availability of labour and housing; the availability of water; sites for any necessary plant and for the disposal of waste.

I. Nature and Origins of Limestone

Nature

The essential constituent of Limestone is calcium carbonate ($CaCO_3$), usually in the form of crystalline calcite, which may form as much as 98 per cent. or 99 per cent. of the rock as it occurs in nature. Limestones may also contain magnesium carbonate ($MgCO_3$) and if this is present in sufficient quantities they are known as *dolomitic* or *magnesium limestones.* A true *dolomite* consists of the double carbonate of magnesium and calcium containing 45.65 per cent. by weight of $MgCO_3$). If such impurities as sand, clay, iron compounds or calcium sulphate are present in considerable quantities they may give the limestone certain specific properties and uses. When the proportion of sand is high, it may be difficult to decide whether the term "sandy limestone" or "calcareous sandstone" is more appropriate. (The term *Rag* is applied to certain sandy limestones.) Similarly, if a high proportion of clay is present the character of the rock may pass almost imperceptibly from an *argillaceous limestone* to a *calcareous clay* or *marl*. There is, in fact, no sharp division between rocks containing sufficient calcium carbonate to be classified as limestones, and rocks to which other names must be given. The colour of limestones varies from white through grey to blue-black according to their composition. Carbonaceous matter may cause a dark grey or blackish colour, and iron may give either a yellowish or a reddish tinge. In general, however, colour is not an indication of purity.

Origins

Limestones may be formed in several ways; by the accumulation on lake or sea-floors of calcareous shells and other calcareous skeletal structures of animals and plants; by accumulation of calcareous organisms in reefs by the precipitation and deposition of calcium or magnesium carbonate from water; or by the accumulation of fragments of pre-existing limestones which have suffered the disintegrating processes of weathering and denudation. However formed, these initially soft and incoherent deposits have been altered by chemical and physical processes. Percolating water containing dissolved carbonate of lime or other substances may, for example, deposit material to cement the fragments of the original rock, and pressure exerted by the accumulation of later sediments or by earth movements may itself cause hardening.

Limestones were normally deposited in horizontal layers but may have been subjected to earth-movements that have caused the beds to be tilted or folded at various angles. The present disposition of a particular limestone is an important factor in its economic exploitation.

II. Types of Limestone

Before considering the more important types of limestone it may be useful to point out that such terms as "Cretaceous" and "Carboniferous", which are mentioned on the map, are the names given to geological "Systems" the rocks of which follow each other in chronological order as shown in Table I. In themselves they are not necessarily indications of any specific type of limestone. Limestones of several different types may occur at different horizons within a single System.

The distribution and economic use of various types of limestone deposited at various horizons during the course of geological time is summarized in Table I below. This shows that although many geological formations contain a variety of limestones (for example, the very important Carboniferous Limestone Series), others may contain, or even consist of mainly one type (e.g. the Chalk). In some cases formations take their names from the predominant rocks present in them, which may or may not be limestone. Thus the Chalk, the Oolites and the Magnesian Limestone formations are so called because of the limestones which are characteristic of them; on the other hand limestones may be present in formations named after another type of rock, such as the Old Red Sandstone in Scotland. Sometimes, also, formations are named not after rocks contained in them but after a locality in which they are developed, such as the Portland and Purbeck Beds.

The economic value of a particular limestone for any particular purpose is determined by its chemical composition, and its texture, porosity, toughness, and degree of fracture, factors which depend on its mode of formation and the natural processes to which it has been subjected.

The majority of limestones are made up of the calcareous skeletal remains of animals and plants. They range from fine grained varieties of *crystalline* limestone (composed of disintegrated shell fragments, and complete shells of microscopic creatures and similar material cemented together with calcite) to the coarse varieties which are formed of larger material, principally the recognizable remains of shells and other skeletal matter set in a calcareous cement. There are intermediate varieties between these two extremes. The hardness of these types of limestone depends both on the size of the particles and on the degree of cementation. Many fossiliferous limestones by reason of their pleasing appearance are esteemed as ornamental and building stones. *Chalk* is a relatively soft white variety of limestone confined to the Upper Cretaceous formation and not occurring in Wales or Scotland. It consists almost entirely of the skeletons of minute marine organisms and minute shell fragments and was deposited on the sea floor under special conditions which are not yet fully understood.

Another group of limestones are those formed by chemical or organic precipitation of calcium carbonate. Included here are *Oolites* which are composed principally of small, nearly spherical, grains resembling the hard roes of fish, formed by the deposition of calcium carbonate around such nuclei as shell fragments or sand grains; sometimes fragments of shells and other organisms are also present. They may be hard and compact or soft and friable. The softer varieties provide well-known limestone freestones which are free from obvious bedding and jointing planes and so can be readily cut in any direction. Other precipitated limestones, of restricted occurrence and limited economic importance, consist

TABLE I

LIMESTONES OF ECONOMIC IMPORTANCE

System	Scotland			England and Wales		
	Sub-divisions	Main Type	Present Uses	Sub-divisions	Main Type	Present Uses
Recent		Shell Sand, Shell Marl	Agriculture		Shell Sand	Agriculture
Oligocene				Bembridge Limestone	Freshwater Limestone	Roadstone
Cretaceous				Upper Cretaceous (Chalk)	Chalk	Cement, agriculture, lime, whiting and many other uses.
				Lower Cretaceous	Sandy limestone (Kentish Rag)	Roadstone, local building and walling stone.
Jurassic				Upper Oolite:		
				Purbeck Beds	Freshwater limestones (including "marble")	Building and ornamental stone.
				Portland Beds	Oolitic and shelly limestones	Building stone.
	Brora Arenaceous Series	Sandy limestones	Unimportant	Corallian	Oolitic and fossiliferous limestones	Local building stone, roadstone; flux (North Riding)
	Great Estuarine Series	Impure and shelly limestones	Worked in the past	Lower Oolite: Great Oolite	Oolitic, shelly, and sandy limestones	Building stone, cement.
				Inferior Oolite	Oolitic, shelly and fine-grained limestones	Building stone, cement, flux and constructional stone.
	Lias	Shelly, often sandy limestones	Worked in the past	Lias	Argillaceous and ferruginous limestones	Cement, lime, and local building stones.
Trias and Permian		Cornstones of Inch Kenneth (Trias)	Unimportant	Magnesian Limestone (Permian)	Dolomite, dolomitic limestone, and limestone	Basic refractory, flux, lime and building stone.

TABLE I—*contd.*

LIMESTONES OF ECONOMIC IMPORTANCE—*contd.*

System	Scotland			England and Wales		
	Sub-divisions	Main Type	Present Uses	Sub-divisions	Main Type	Present Uses
Carboniferous	Carboniferous Limestone	Various marine and freshwater limestones, cement stones. (Some limestones, e.g., the Burdiehouse—occurs in the Calciferous Sandstone at the base of the Carboniferous and is worked by underground mining.)	Lime, cement, flux, agriculture and roadstone	Culm Measures	Thin and impure limestones	Roadstone, lime and agriculture.
				Carboniferous Limestone Series	Various marine limestones including crystalline, fossiliferous and oolitic limestones, dolomites, calcareous mudstones and cementstones.	Roadstone, cement, flux, lime, agriculture, basic refractory.
Devonian	Old Red Sandstone	Cornstones and impure limestones	Cornstones have been extensively worked in the past	Old Red Sandstone	Cornstones	Agriculture and roadstones.
				Marine Devonian	Crystalline, fossiliferous and dolomitic limestones, "marble"	Roadstone, lime, cement, building and ornamental stone.
Silurian					Crystalline and fossiliferous limestones	Roadstone and lime.
Ordovician		Fossiliferous limestone	Roadstone and Agriculture		Crystalline fossiliferous and sandy limestones	Roadstone and lime.
Cambrian		Dolomites and limestones	Worked in the past, large reserves			
Dalradian		Crystalline metamorphic limestone	Agriculture, roadstone, lime			
Moinian		Crystalline metamorphic limestone	Unimportant			
Lewisian		Crystalline metamorphic limestone	Unimportant			

essentially of minute calcite crystals giving a compact, hard, uniform type of rock such as massive *calcite mudstones* and nodular *cornstones*. *Cementstones* are similar but have a considerable clay content.

Sometimes earth movements or volcanic activity may subject limestone to conditions of high temperature or great pressure causing re-crystallization so that the original structure of the limestone is lost. Any impurities present in the limestone may combine with the calcium carbonate, forming other minerals, and the resulting rock may appear quite unlike crystalline limestone. Limestone in which the original material has been re-crystallized to form a mass of interlocking crystals, giving great strength, is known geologically as *marble*. Commercially this term is applied more loosely to many types of limestone capable of taking a high polish.

Certain unconsolidated deposits of marine sands of Recent date contain a high proportion of shells (*Shell Sands*). In some instances calcareous mud (*Lake Marl*) has been laid down in freshwater lakes, and in addition to containing finely divided calcium carbonate, may also contain shells. (The term " shell marl " on the map includes both shelly and non-shelly types.) Both are sometimes useful sources of calcium carbonate for local agricultural use.

Lime

Lime (calcium oxide CaO) is not a form of limestone but is derived by burning limestone or chalk in kilns. As shown below a considerable amount of limestone and chalk is used in this way.

III. The Distribution of Limestones

In Scotland*

Compared with England, limestone is of limited occurrence. In the Highlands the prevailing schists and gneisses are only occasionally interrupted by beds of limestone, although such outcrops often provide a startling local contrast in the prevailing vegetation, forming a green oasis of lime-loving plants amid the prevailing browns of acid-loving heather and nardus grass. Limestones are almost absent from the Southern Uplands where Ordovician and Silurian shales, mudstones and grits prevail. The Carboniferous Limestone Series occurs in parts of the Central Lowlands but is less consistently limestone than its English counterpart.

The Scottish limestones range in age from the Lewisian, deposited some 1,200 million years ago, to the Shell Sands and Marls of Recent accumulation.

Lewisian. A few thin beds of crystalline limestone occur within the prevailing metamorphic schists and gneisses, more particularly in Wester Ross and Tiree, but are not exploited.

Moinian and Dalradian. Rare in the Moinian Series, limestones occur more frequently in the Dalradian, and the map shows a number of narrow but fairly persistent outcrops, which can be traced discontinuously from Kincardineshire to Argyllshire, following the well-marked north-east to south-west trends of the Caledonian folds. These crystalline limestones outcrop chiefly in Shetland, Banffshire, Perthshire, around the southern end of the Great Glen and in Islay.

These limestones are mostly relatively thin and are often impure and sometimes highly altered. They are often in remote areas but where accessible they are worked chiefly for agricultural purposes and roadstone. They have considerable importance to agriculture both in these areas of acid, lime-deficient soils and in the arable lowlands to the east and south. About two thirds of all active limestone quarries in Scotland in 1949 were in the Dalradian and about one third of the total output was obtained from them.

* Memoirs of the Geological Survey, Special Reports on the Mineral Resources of Great Britain, Vol. XXV " The Limestones of Scotland", by T. Robertson (et al) H.M.S.O., 1949.

Cambrian and Ordovician. The Durness Limestone which reaches over 1,700 feet in total thickness occurs in the far north-west, near Cape Wrath, and in the wild Assynt district of Sutherland. It contains potential reserves of high grade dolomite but its remote situation has so far prevented exploitation. A comparable formation is found in the Isle of Skye around Broadford.

Ordovician limestone occurs near Girvan in South Ayrshire, and is worked for roadstone and agricultural purposes.

Old Red Sandstone. (Devonian). This predominantly sandstone formation was laid down largely under desert conditions and consequently contains only occasional thin limestones (chiefly cornstones), mainly found in the Upper Old Red Sandstone of Ayrshire.

Carboniferous Limestone Series. Within the Central Lowlands the chief limestones occur in the Carboniferous Limestone formation towards the base of the Carboniferous System. On the map only the Carboniferous Limestone Series is shown, but some limestones also occur in the older Calciferous Sandstone Series, e.g. the Burdiehouse, which is worked only by mining at the present time. Over half the total Scottish limestone output in 1949 was produced from Carboniferous quarries and mines, which comprised about half of the total active workings. It is burnt for lime and is used in cement making, the iron and steel industry and for agricultural purposes.

Jurassic. The Jurassic System is very poorly represented in Scotland but some Liassic limestones occur in the Isle of Skye, and elsewhere along the west coast. Thin limestone beds are found in the Great Estuarine Series in Skye, Raasay, Eigg and in the Brora Arenaceous Series on the east coast of Sutherland.

Recent. Shell Sands occur in many sheltered inlets in the Western Isles, Orkney, Shetland and in places on the west and north coasts.

Shell Marl is found only in old lake hollows within the lowlands of Caithness.

In England and Wales

Although ranging from the Ordovician (laid down from 400 to 500 million years ago) to the Shell Sands of Recent age, three Systems (the Carboniferous, the Jurassic and the Cretaceous) are of overwhelming importance, not solely in the economic sense but because of their part in the structure and the physical features of England and Wales. Their extensive outcrops have allowed the characteristic scenic qualities of limestone to show themselves on a large scale (see Section V) and are important for water supply. (Section VI.)

Ordovician. These limestones are of limited extent, and occur chiefly in the Lake District and parts of Wales.

Silurian. Limestones of the Wenlock and Ludlow Series are rather more widespread. They outcrop mainly in the Welsh Borders, and are worked for agricultural lime and roadstone on Wenlock Edge, near Old Radnor, and between Malvern and Bewdley.

Devonian. Some massive limestones up to 200 feet in thickness occur in the Middle and Upper Devonian in South Devon, especially around Newton Abbot and Torquay, and near Plymouth. These are worked for roadstone, concrete aggregate, railway ballast, agriculture, cement manufacture and to a small extent for ornamental stone. (Devon " Marble ".) The cornstones of the Old Red Sandstone of South Wales and the Welsh Borderland were worked in the past for lime burning and road metal.

Carboniferous. The Carboniferous Limestone Series includes shale and sandstone as well as limestone, particularly in Northern England. The map shows those areas in which limestone predominates and for this reason the outcrop shown on the present map is more restricted than the outcrop of the formation as a whole shown on the 1/625,000 Geological Map. Nevertheless limestones of this age are of wide occurrence and account for no less than 45 per cent. of the total production of limestone of all types and contain some of the most important reserves in the country. Carboniferous Limestone outcrops north, east and south of the Lake District and is the dominating formation in the northern Pennines where it largely contributes to the scenery of some of the Yorkshire Dales. Although absent from the Central Pennines it reappears in Derbyshire in the Peak District, between Matlock and Buxton, where some of it is of high purity and where there is an important concentration of quarries. Carboniferous Limestone also outcrops in North Wales on the western side of the coalfield, in the Vale of Clwyd and in Anglesey. In Gloucestershire and Somerset the Carboniferous Limestone forms much of the higher ground, as in the Mendips. Across the Severn the plateau of eastern Monmouthshire and adjacent Gloucestershire is partly composed of Carboniferous Limestone, through which the Wye has cut its impressive gorge north of Chepstow. Farther west the limestone forms a narrow rim to the South Wales coalfield and gives rise to fine coastal features in the Gower Peninsula and in South Pembrokeshire. Carboniferous Limestone in its varying qualities is suitable for a very wide range of uses, including roadstone, lime for many purposes, cement production, agriculture, metallurgical flux and for numerous chemical purposes. In limited areas chiefly in South Wales and Shropshire it contains reserves of high grade dolomite rock with over 40 per cent. of magnesium carbonate.

In Devon and Cornwall a fairly wide area is underlain by Carboniferous rocks known as the Culm Measures. These are predominantly sandy shales and grits, but occasional bands of thin limestone and calcareous nodules occur, particularly in the Holcombe Rogus area where they are worked at a number of quarries.

Permian. The Magnesian Limestone, dipping gently eastwards, has an outcrop some five miles in width extending in a continuous sweep from Nottingham to South Shields and giving rise to a distinct escarpment overlooking the Carboniferous rocks to the west. As the name implies, magnesium carbonate is usually an important constituent, although the amount varies from less than 5 per cent. to 45 per cent., and the rock types include dolomite rock, dolomite limestones, and limestone. This formation is the principal source of high grade dolomite rock for refractory and chemical use, even though such deposits form only a small part of the outcrop. High grade dolomite is of special importance in steel making, in the manufacture of magnesia from sea water and for certain uses in chemical industry. Over 70 per cent. of the total output of Magnesian Limestone in 1949 came from a relatively small number of quarries producing mainly for these purposes. Stone of lower magnesian content is quarried for aggregate, flux, agriculture, building stone and is burnt for lime.

Jurassic. The map shows limestones of the three major divisions of the Jurassic: the oldest is the *Lias* (or Lower Jurassic); next comes the *Lower Oolite* (Middle Jurassic); the youngest is the *Upper Oolite* (Upper Jurassic). The Lower Oolite includes the Inferior and the Great Oolite limestones, while the Upper Oolite includes the Corallian, the Portland and the Purbeck. The outcrops of Jurassic limestones extend inland from the Dorset coast across the east Midlands where they reach their greatest width, and continue northwards in a narrowing belt to the Humber. They outcrop again near the southern edge of the North York Moors. Limestones of the Jurassic System are best known as building stones, and they are the most widely used stones for the purpose. However, about two thirds of the Jurassic output is nowadays used for cement making, and it is also used as aggregate, as flux in the iron and steel industry, and for agriculture.

The *Lias* is predominantly clay or shale but towards its base occurs the Blue Lias, an argillaceous limestone interbedded with shale, which is worked for cement making in Glamorgan, Warwickshire and Nottinghamshire. Hydraulic lime made by burning the limestone is now less important than before the development of Portland cement. Beneath the Blue Lias a white limestone up to 25 feet thick, and known as the White Lias, occurs in Devon, Somerset, Warwickshire and Leicestershire. In the Upper Lias of Somerset occurs the Ham Hill building stone. North of the Humber the Lias contains virtually no limestone.

Among the many important building stones of the *Lower Oolite* are the Doulting and Dundry Stones of Somerset, the Painswick and Leckhampton Stone of Gloucestershire, the Ketton and Clipsham stones of Rutland and the Ancaster Stone of Lincolnshire (all in the Inferior Oolite). In the Bath area the Great Oolite yields the important Bath Stone, varieties of which are Box Ground, Corsham Down and Coombe Down Stone. The Taynton and Minchinhampton Stones of Gloucestershire, and the Bladon Stone of Oxfordshire also come from the Great Oolite. Oolite limestone has been used in many well-known buildings, including the Houses of Parliament and adds to the beauty of much Cotswold architecture. Certain thin sandy limestones are still worked for use as " Slates ", such as the Collyweston Slate (Inferior Oolite) of Northamptonshire and the Stonesfield Slate (Great Oolite) of Oxfordshire and Gloucestershire. Cement is made from the Lincolnshire Limestone of the Inferior Oolite in Rutland and Lincolnshire and from the Great Oolite in Oxfordshire.

Limestones of the *Upper Oolite* are less widely distributed and apart from the Corallian exposures around Pickering in Yorkshire they do not occur to any appreciable extent north of Aylesbury. In Dorset, however, are the well-known building freestones of Portland and Purbeck.

The Corallian limestones are mainly sandy limestones and calcareous grits, but oolitic and coral limestones also occur, particularly in the Howardian Hills of east Yorkshire (where they are quarried for flux, roadstone, agriculture and building stone), and also near Oxford (Headington Stone), in North Wiltshire (Calne Stone), and in Dorset (Marnhall and Todber Stones). An isolated mass of oolitic and coralline rock also occurs at Upware, ten miles north-east of Cambridge.

Portland Stone has been extensively used for many of the important buildings of London (including St. Paul's Cathedral), and much has been exported.

Purbeck Stone has long been worked in the Isle of Purbeck from small shallow mines and has been used for building and ornamental purposes such as garden furniture. Purbeck " Marble ", red or greenish grey limestone crowded with shells, has been much used for interior decoration, especially in churches.

Cretaceous. The Kentish Rag is a sandy limestone developed locally in the Lower Greensand formation of the Weald. It is worked in the Maidstone district, chiefly for roadstone and for such constructional work as dock and river walls, because it is the only local source of hard massive stone in an area composed essentially of relatively soft strata. In the past it was locally important for building. Chalk, however, is by far the most important Cretaceous limestone, and is unique in being relatively soft and white. This formation gives rise to some highly distinctive landscapes : the rolling plateau of Salisbury Plain, the Marlborough Downs, the Chiltern Hills, and the North and South Downs. Further north the Chalk of East Anglia and the Lincolnshire and Yorkshire Wolds is largely masked with boulder clay and other glacial deposits,* and

* The Chalk area shown on the map includes not only the outcrop but also Chalk that is covered by up to about thirty feet of Tertiary and Glacial deposits.

very small outliers of Chalk occur around Seaton (East Devon), well to the west of the main outcrop.

At present the dominant use of the Chalk is for cement manufacture and it provides three quarters of the total limestone of all types used for this purpose. In the past its widest use, and one still of great importance, was its application to agricultural land as a corrective to soil acidity, either in the form of ground chalk or as lime. Many of the smaller chalk quarries (now much less numerous than formerly) still exist primarily for this purpose. Chalk is worked also for the preparation of whiting, for lime burning and for use as flux in the iron and steel industry. Although it is essentially a soft formation, certain hard beds provide useful building stone, for example the Beer stone of East Devon, and the flints occurring abundantly at certain horizons have long been employed as a facing material and are also used in the pottery industry.

Oligocene. The Bembridge Limestone, a freshwater limestone of minor importance, occurs in the Isle of Wight.

Recent. As in Scotland, unconsolidated shell sands are confined to several relatively sheltered bays and coves, chiefly on the north coast of Cornwall between Land's End and Bude, and in Mount's Bay. They have a long history of use in liming the local acid soils.

IV. Production and Uses of Limestone

The production of Limestone

Despite their wide distribution, especially in England and Wales, the map shows that two of the ten geological Systems containing limestone have quite outstanding importance. Table II (based on statistics of the Ministry of Fuel and Power) shows that the Carboniferous Limestone alone accounted in 1949 for nearly half the national output (45.6 per cent.) while the Cretaceous (almost all chalk) accounted for a further 34.8 per cent.

Output data for 1949 are used on the map because that is the most recent year for which details are available of separate uses of all the different types of limestone.

TABLE II

PRODUCTION OF LIMESTONE FROM THE VARIOUS GEOLOGICAL SYSTEMS, 1949

(SYSTEMS ARRANGED IN ORDER OF AGE)

System	*Proportion*(%)
Recent	—
Cretaceous	34.8
Jurassic	9.3
Permian	7.1
Carboniferous	45.6
Devonian and Old Red Sandstone	1.8
Silurian	0.6
Ordovician	0.1
Cambrian	—
Pre-Cambrian (Dalradian, Moinian, Lewisian)	0.7

Since 1922 the total output of limestone, including Chalk, has increased over threefold and the upward trend is shown by the graph on page 11.

With minor fluctuations annual production climbed fairly steadily from 12 to 31 million tons from 1922 to 1943, although a marked recession had occurred in the slump years 1931-34. After a considerable contraction towards the end of the war output rose rapidly and the 1955 production of over 45 million tons is the highest recorded. (See Table III.)

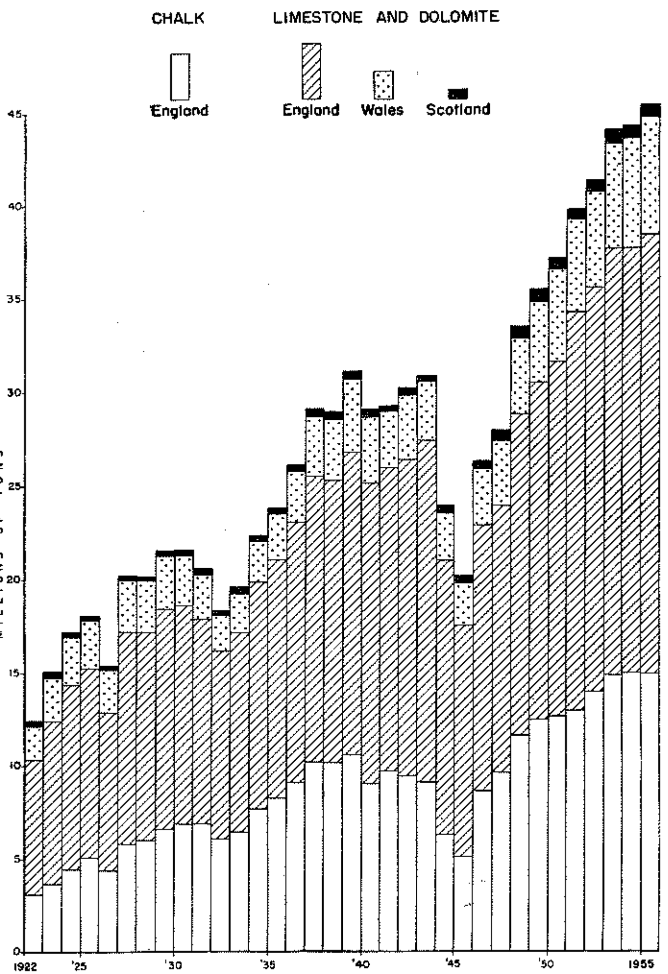
In 1922 limestone and dolomite accounted for 75 per cent of the total output. In 1955 this proportion had dropped to 67 per cent. because of the relative increase in the production of chalk. This reflects very largely the increased demand for chalk in the production of cement. In 1955 the output of chalk was five times that of 1922.

Table III shows the subordinate role of Scotland as a limestone producer; her output in 1955 was only 1.6 per cent of the total output of limestone and chalk in Great Britain.

In 1953 the following thirteen counties each had a production of limestone or chalk exceeding one million tons and together accounted for nearly 32 million tons

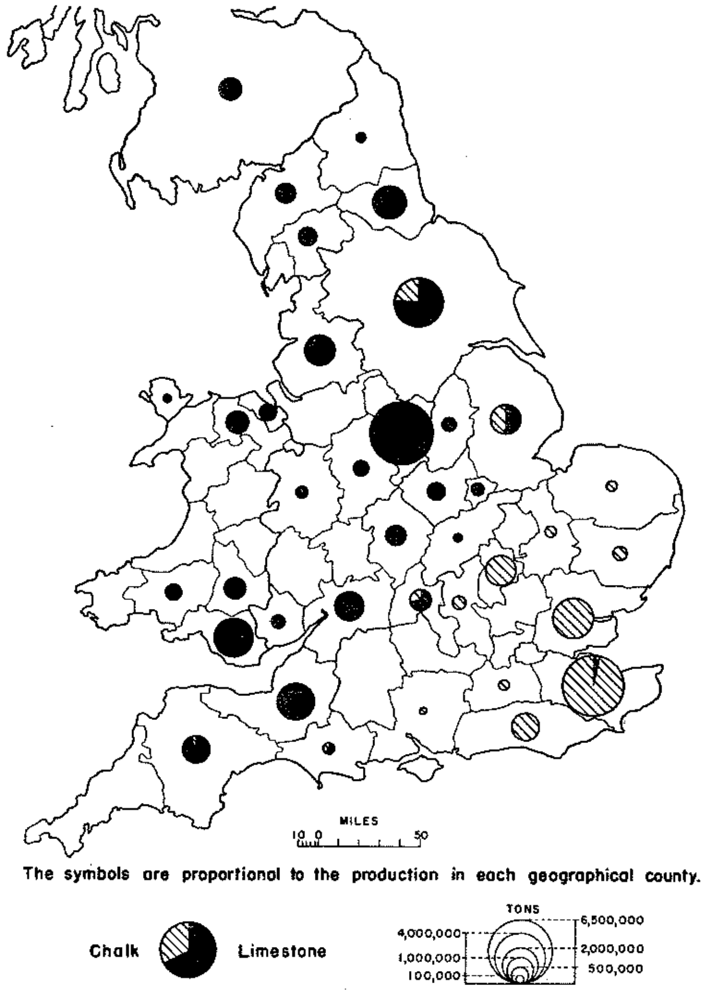
PRODUCTION OF LIMESTONE AND CHALK

1922-1955



OUTPUT OF LIMESTONE AND CHALK

1953



The symbols are proportional to the production in each geographical county.

Counties whose total output is less than 100,000 tons are not represented. Scotland's output is represented by one circle.

or three-quarters of the national output:—

(in thousands of tons).

Derbyshire:	6,446	Durham:	1,623
Kent:	6,170	Lancashire:	1,414
Yorkshire:	3,798	Lincolnshire:	1,377
Essex:	2,803	Bedfordshire:	1,312
Glamorgan:	2,423	Gloucestershire:	1,220
Somerset:	2,112	Sussex:	1,096
		Devon:	1,047

The remarkable concentration of workings in the Carboniferous Limestone made Derbyshire for a long period the chief producing county; however in recent years its production has been rivalled by Kent, reflecting the increasing importance of chalk for cement making. The Carboniferous Limestone is worked on a considerable scale in almost all of the other localities where it occurs, particularly in and around the Mendips (hence the large Somerset production), in South Wales (the Glamorgan output also includes a large amount of Liassic limestone for cement making), in Lancashire and in South Gloucestershire. The very large Yorkshire production derives not only from the Carboniferous Limestone of the Dales, but also from the Magnesian Limestone belt, the Jurassic limestone area around Pickering and the Chalk of the Wolds. The large production from Durham is mainly from the Magnesian Limestone, whilst that from Essex, Bedfordshire and Sussex illustrates the importance of chalk for cement. Devonian limestones are worked on a considerable scale and largely account for the production in Devon.

The Uses of Limestone

On the map the chief uses of the stone supplied by each quarry or group of quarries have been indicated by distinctive letters. Uses which absorb less than 10 per cent. of the total output of a quarry are not generally shown except in certain cases, such as building stone or flux, where the importance of the product merits its inclusion even though the tonnage supplied is relatively

TABLE III

PRODUCTION OF LIMESTONE AND CHALK 1922-1955

(in thousands of tons)

(Source—Ministry of Fuel and Power)

Year	Limestone and Dolomite				Chalk	Total
	England†	Wales	Scotland	Total	England	
1922	7,320	1,826	273	9,419	3,024	12,443
1923	8,716	2,387	329	11,432	3,593	15,025
1924	9,916	2,557	320	12,813	4,403	17,216
1925	10,101	2,638	241	13,060	5,035	18,095
1926	8,537	2,259	222	11,018	4,315	15,333
1927	11,356	2,788	268	14,412	5,765	20,177
1928	11,127	2,755	226	14,108	5,996	20,104
1929	11,800	2,095	283	14,988*	6,529	21,517
1930	11,860	2,656	312	14,828*	6,712	21,530
1931	11,000	2,425	292	13,717*	6,870	20,587
1932	10,059	1,933	324	12,316*	6,036	18,332
1933	10,744	2,026	312	13,082*	6,484	19,566
1934	12,196	2,176	322	14,694*	7,682	22,376
1935	12,791	2,435	334	15,560*	8,255	23,815
1936	13,991	2,702	370	17,063*	9,091	26,154
1937	15,322	3,209	432	18,963*	10,218	29,181
1938	15,146	3,230	481	18,857*	10,164	29,021
1939	16,278	3,986	459	20,723*	10,519	31,242
1940	16,168	3,572	426	20,166	9,021	29,187
1941	16,358	2,972	360	19,690	9,646	29,336
1942	16,942	3,514	374	20,830	9,421	30,251
1943	18,334	3,198	326	21,858	9,090	30,949
1944	14,726	2,593	380	17,699	6,363	24,062
1945	12,424	2,322	336	15,082	5,098	20,180
1946	14,269	3,058	435	17,762	8,594	25,356
1947	14,329	3,522	517	18,368	9,582	27,950
1948	17,263	4,124	601	21,988	11,559	33,547
1949	18,071	4,393	673	23,137	12,416	35,553
1950	19,058	4,970	641	24,669	12,592	37,261
1951	21,458	4,918	672	27,048	12,914	39,962
1952	21,798	5,133	686	27,617	13,878	41,495
1953	22,914	5,661	778	29,353	14,885	44,238
1954	22,997	5,788	677	29,462	15,025	44,487
1955	23,750	6,291	761	30,802	14,952	45,750

*Includes 14,000-29,000 tons of calc-spar (a massive crystalline form of calcium carbonate) produced mainly in Derbyshire.

†Production in the Isle of Man from 1922 to 1948 inclusive is included in the total of limestone and dolomite for England; thereafter it is excluded from the Table.

small. The order of the symbols indicates the relative importance of the uses to which the stone is put. The small maps (on page 15) show the distribution in 1939 of quarries supplying certain of these uses.

Table IV shows how the total production of limestone and chalk is shared between the chief uses. In columns (1), (2) and (3) the amount converted into lime has been shown separately under the heading "burnt for lime"; in column (4) it has been credited to the various industries or uses served.

Column (4) shows that over one third of the national output of all limestone goes to the cement industry, and nearly a quarter for roadstone and concrete aggregate. With the small amount (3 per cent.) used directly in building (as stone and as builders' lime) some 60 per cent. of the country's limestone output thus serves building and constructional needs in the broad sense.

From column (3) it is seen that over 12 per cent. of all limestone and chalk is converted to lime at the quarries. The quicklime which results from the burning process is equivalent to about half the weight of the raw material, and can be converted to hydrated or slaked lime by the controlled addition of water. As hydrated lime it is as effective for most purposes as quicklime, with the added advantage of being more stable and thus more easily stored and transported. (Hydraulic limes produced from limestones containing up to 25 per cent. alumina and silica have a composition and properties similar to those of cement.) In addition a proportion of the limestone sent to some users is burnt for lime at their works, as for example in the iron and steel and chemical industries. (On the map quarries producing lime are distinguished as such, and this is in fact the chief function of many quarries.)

Columns (1) and (2) illustrate the different uses of limestone and chalk. Nearly 80 per cent. of the chalk output, but only 12 per cent. of limestone, goes to cement. One third of limestone (because of its hardness and other physical properties) is used for roadstone and aggregate.

Table V, below, shows the main uses of lime produced at quarries in 1949; in the building industry a high proportion of the lime used is derived from chalk.

TABLE IV

THE PRINCIPAL USES OF LIMESTONE (including DOLOMITE) AND CHALK IN GREAT BRITAIN IN 1949*

(derived from statistics of the Ministries of Transport, Fuel and Power, and Works)

Uses	Index letters used on map	Limestone and Dolomite (1)	Chalk (2)	All Limestone, Dolomite and Chalk (3)	(4)
		%	%	%	%
Cement ...	(c)	12.4	79.1	35.0	35.0
Roadstone, Ballast and Aggregate	(r)	33.2	0.5	22.1	22.1
Agriculture ...	(a)	7.6	10.6	8.6	12.8†
Iron and Steel (Flux) ...	(f)	12.0	1.2	8.3	11.3†
Chemical and other Industries	(o)	12.4	3.7	9.5	12.0†
Refractory and Chemical Dolomite	(m)	5.7	—	3.8	3.8
Building ...	(s)	0.6	—	0.4	3.0†
Burnt for Lime at quarry ...	(b)	16.1	4.9	12.3	not separately shown

*1949 is the most recent year for which details are available of the separate uses of all the different types of limestone.

†The proportions shown in column (4) include Lime which has been accredited to the uses concerned in terms of quarried stone or chalk.

TABLE V

PRINCIPAL USES OF LIME (PRODUCED AT QUARRIES) IN GREAT BRITAIN IN 1949

(derived from statistics of the Ministries of Transport and of Works)

Uses	From Limestone %	From Chalk %	From Limestone and Chalk %
Agriculture	37·1	19·8	37·7
Iron and Steel	27·3	—	23·7
Chemical and other Industries	21·8	11·2	20·4
Building	13·8	69·0	21·2

Cement

Portland cement is made by heating a natural or artificial mixture of calcium carbonate and clay in the proportion of approximately 3 : 1. The requisite proportions occur naturally in parts of the Lower Chalk and in the alternating shales and limestones of the Lower Lias and parts of the Lincolnshire Limestone, although a purer limestone sometimes has to be added to the local materials. Usually, however, the clay and the limestone are worked separately. The limestone must be free of certain impurities and magnesian limestones are not suitable.

Cement works usually adjoin the quarries and the map on page 15 shows how the industry is largely concentrated in certain districts. The works in the important Lower Thames and Medway area use Chalk together with either London Clay, Gault Clay, or alluvial clay. This area owes much to the use that can be made of water transport and the nearness of the Greater London market. The cement works at the foot of the Chiltern escarpment use the Lower Chalk as their raw material and are sited near gaps in the Chalk scarp which are followed by railways and roads connecting London and the Midlands. Small groups of cement works occur on the Glamorgan coast, where the Lower Lias is worked, and along the Humber estuary where the Chalk and alluvial clay provide the raw materials.

In Scotland there is no natural occurrence of the raw materials comparable in scale and convenience, for example, to that of Thames side. At the present time cement is manufactured from blast furnace slag and Carboniferous Limestone quarried in East Lothian and Midlothian.

Roadstone and Aggregates. The second most important group of uses of limestones of all types (in terms of tonnage utilized) includes road making materials, concrete aggregate and railway ballast. The suitability of a limestone for these purposes is mainly dependent on physical properties: massive compact crystalline limestones or dolomitic limestones with a relatively high crushing strength being particularly suitable. Limestone has a high adhesive value towards tar and bitumen, an advantage in the production of coated macadam for road surfacing. Most of the harder limestone formations provide material for road making purposes, the Carboniferous being the most important.

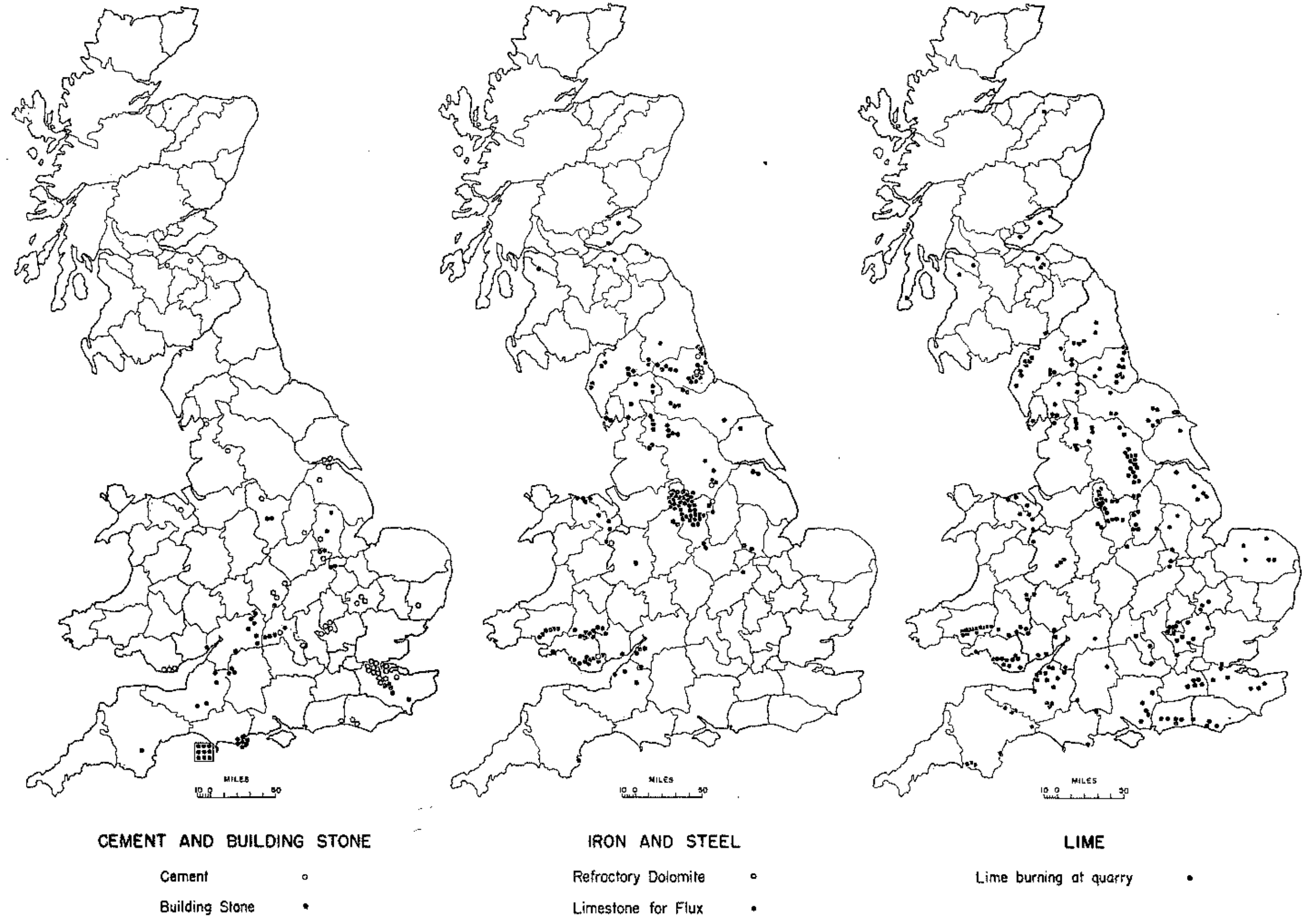
Agriculture. Large quantities of limestone and chalk are used in agriculture and horticulture, either ground or as quick and hydrated lime. They are applied directly to the soil for several purposes, chiefly as a soil dressing to correct soil acidity. Limestone and lime are also used in the manufacture of cattle cake, poultry grit, insecticides, fungicides and weed killers. Quarries working limestone for agricultural purposes are generally widely distributed in order to serve local needs.

Flux in Iron and Steel Manufacture

Suitable limestone is added to the mixture of iron ore and coke in blast furnaces to act as a flux. In the

QUARRIES PRODUCING FOR PARTICULAR USES

1949



process of smelting the limestone is converted to lime, which combines with impurities from the iron ore and coke ash to form slag. Molten steel is treated with quick-lime to reduce the content of impurities such as silica and alumina and to remove sulphur and phosphorus. Limestone and lime for use in iron and steel production must have a low content of silica, alumina, and sulphur.

Refractory and Chemical Dolomites

High grade dolomite-rock, containing over 40 per cent. magnesium carbonate and with the appropriate physical properties, is of great importance in the steel industry.

Dolomite-rock which has been burned at very high temperatures is used in maintaining basic open hearth steel furnaces and in the manufacture of bricks for their refractory lining.

When lightly calcined (burnt at lower temperatures) it is used with sea water for making magnesia which has many uses: for example, as a source of magnesium metal and for the manufacture of refractories. Dolomite-rock is also the raw material for a number of magnesium compounds including basic magnesium carbonate, one use of which is for the manufacture of fireproofing and heat-insulating material.

Building Stone

It has been shown in column (3) of Table IV that only a small proportion of the total limestone output is now used as building stone, and even in areas favoured with good natural stone, the tendency over the last fifty years or more, deplored by many, has been towards using bricks for domestic and ferro-concrete for large constructions. For building stone the physical properties are more important than the chemical composition; it should have high strength and durability (some stone suffers excessively in town atmospheres), should be easily worked, and the bedding planes must be suitably spaced. In the case of freestones the bedding and jointing are so spaced that large blocks (e.g., up to ten tons in weight) can be extracted and worked freely in all directions to provide masonry. The best known limestone freestones are the Portland and Bath Stones. These are sawn to provide masonry of all types including ashlar, while "rangework" is produced from the Bath Stone and is much used in house building. Building rubble (roughly shaped blocks) is produced in the Cotswolds for building houses, while some thinly bedded stone is still used for dry-walling, and as mentioned previously, thin fissile beds are used as "slates". Some of the "marbles" are still worked for ornamental stone, for example, the Devon "Marble", the Hopton Wood Stone and also the Purbeck "Marble" which has been used in the recent reconstruction of the war-destroyed Temple Church in London.

Other Building Purposes. Ground limestone is used in the preparation of mastic asphalt while quick-lime and hydrated lime are used in mortars, plasters, and for the production of sand lime bricks. Mortar is made by mixing slaked lime with sand and water; on exposure to air it "sets" and becomes hard. Hydraulic lime is produced from limestone which contains up to 25 per cent. alumina and silica. Chalk is sometimes added to brickearth in the manufacture of stock bricks.

Chemical and other industries

The industrial value of limestone and lime is due mainly to their being the most widespread source of alkali chemicals. They enter into so many chemical, manufacturing and industrial processes that only a few can be mentioned here. Prominent among them is their use as flux in the smelting and refining of non-ferrous metals, such as aluminium, lead and magnesium. Lime also enters, at one or more stages, into the manufacturing or processing of the following products:—

Paper, sugar, leather, textiles, paint, pigments, varnishes, whiting, putty, toothpaste, soap, greases, candles, glass, pottery, plastics, rubber and wire.

It is also used for various purposes in the provision of household water supplies, including purification and improvement of clarity and the amelioration of hardness. It is also widely used in sewage disposal.

V. Limestone Landscapes

When limestones have been tilted their relative hardness compared with neighbouring formations has caused them to form bold relief features. Surface streams and rivers are frequently lacking in limestone country. This is partly due to the presence of fissures which facilitate the percolation of water in both limestone and chalk. As both rocks are slightly soluble the long-continued dissolving action of water often results in the formation of caverns and underground water courses into which rivers and streams may disappear underground for long distances; the River Mole in Surrey is one such example. Subsidence of the roofs of such water courses may produce steep-sided gorges, as in the well-known Cheddar Gorge at the southern edge of the Mendip Hills. Solution of limestone by water may combine with the normal agents of erosion to produce impressive crags quite unlike the scenery developed on other types of rock. The softer character of the chalk gives a smoother, rounded landscape, but the absence of surface drainage remains a characteristic feature.

Normally the soils developed from limestone and chalk are rich in lime and this influences the character of the natural and semi-natural vegetation. In permanent pastures fescue grasses predominate giving the springiness associated with downland turf, and many lime-loving plants flourish such as vetches, travellers' joy and, more locally, juniper. Sometimes, however, soils over-lying limestone or chalk are entirely deficient in lime due to the dissolving or leaching action of percolating rain water, and in such cases the characteristic lime-loving vegetation is absent.

Limestone and chalk landscapes are generally of high scenic quality and interest. For example, the Carboniferous Limestone dominates much of the Peak District National Park in the southern Pennines. In a less spectacular way the Chalk lands of south-eastern England have considerable scenic qualities whose values are perhaps enhanced because of their nearness to London. Their open character is accentuated by the tendency for the largely compact villages to be placed unobtrusively below the skyline, within sheltered valleys and at the foot of escarpment slopes.

VI. Limestone and Water Supply

Owing to their permeability much, if not most, of the rainfall in limestone and Chalk districts finds its way underground. Thick beds of limestone may thus form important reservoirs of underground water, especially if there are impermeable formations such as clay or shale beneath the limestone. Although such water is invariably hard owing to dissolved calcium carbonate it is generally clear and of good taste, and rarely fails even in drought. Springs and spring lines usually occur at the junction of limestone or chalk with clay at the foot of escarpments or in deep valleys in otherwise dry uplands. They have had in the past an enormous influence upon the distribution of settlements in Britain, before the pumping and piping of water on a large scale became general. Where adequate surface water supplies are not available from rivers or lakes, the pumping of underground water from limestone or the Chalk may be an important supplement, or sometimes the sole source of water supply. This is especially the case in the relatively dry east and south-east parts of the country; London, for example, draws an important part of its supply from the underground reservoir of the Chalk.

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