NOTTINGHAMSHIRE COUNTY COUNCIL - NOTTINGHAMSHIRE MINERALS LOCAL PLAN EXAMINATION 2020

Historic England Statement

1.0 Overview

1.1 Historic England (formerly English Heritage) has maintained concerns about a dolomite allocation at Holbeck in the draft MLP since 2012. Whilst any specific site allocation for dolomite extraction has now fallen away, the Publication Plan Policies Map, and associated inset Subject Area Plan B, highlights an area of safeguarding in respect of dolomite (Policy DM13), and the Publication Plan text includes a generic policy, Policy MP9, in respect of proposals for dolomite extraction.

1.2 Historic England submits that this approach is not sound since known sources of dolomite within the UK are limited and in respect of the draft Nottinghamshire Minerals Local Plan the main extraction location is found in the Holbeck area. This is acknowledged and expressed as such in the supporting text accompanying Policy MP9 in the Publication Plan. As such Policy MP9 in its current form would provide a *de facto* site allocation.

1.3 In addition, Policy MP9 sets out that extraction would be supported if need is demonstrated which ignores environmental and other social and economic factors which would have to be considered in the balance. Paragraph 4.84 sets out that a criteria based policy is being proposed but this consists of one criteria – 'where a need can be demonstrated'.

1.4 There is no evidence supporting the Publication Plan to demonstrate that the need for dolomite extraction has been considered, or if so, to what extent. The matter does not feature within the Local Aggregates Assessment which is fair, but we are not aware that any separate assessment in respect of industrial dolomite within the Plan area or alternative sources elsewhere, has been undertaken to inform the Plan. Historic England commissioned a report to consider such elements and this is attached as Appendix 1.

1.5 No specific heritage impact assessment of the impact on heritage assets in the Holbeck area has been undertaken in respect of the Plan and Policy DM9 which means that the strategic matter of dolomite extraction, which affects a processing site in Derbyshire, has not been fully dealt with at this stage but would be deferred to any planning application stage.

1.6 In conclusion, the Publication Plan cannot demonstrate a positive approach to the historic environment and is not consistent with the requirements of national policy or guidance set out in minerals guidance contained in the Planning Practice Guidance (PPG).

2.0 HE Current position in relation to the Matters, Issues and Questions Paper

2.1 With regard to the Inspector’s Matters, Issues and Questions Paper, Matter 3: Minerals Provision Policies - Issue ‘*Whether the minerals provision policies are positively prepared in terms of making adequate provision for minerals, whether they are consistent with national policy, justified and otherwise sound’* for Policy MP9: Industrial Dolomite Provision is the focus for HE.

2.2 HE is concerned that environmental factors, specifically historic environment related, have not been considered in respect of the proposed policy and as such the draft Plan, in HE’s view, is not sound.

3.0 HE Current position in relation to the Submission Nottinghamshire County Council Minerals Local Plan

3.1 The main site, within the Minerals Local Plan area, for industrial dolomite extraction would be at Holbeck and associated with the existing Whitwell site in Derbyshire. This is identified through the area shown on the Publication Plan Polices Map, including the inset Subject Area Plan B, on which a blue hatched area is shown as being safeguarded in respect of dolomite. This fallback position for identifying the possible intentions of the Plan is taken on the basis that, notwithstanding guidance contained in PPG Minerals Para 008 Reference ID 27-008-20140306, neither the Plan or its supporting information, designates specific sites, preferred areas, or areas of search.

3.2 There are heritage assets within the Holbeck locality including Cresswell Crags and it is not clear how these assets have been considered in the Plan process. Creswell Crags straddles the boundary between Nottinghamshire and Derbyshire and is designated as both a Scheduled Monument and a Site of Special Scientific Interest. The complex of caves and rock shelters preserve long sequences of in-situ deposits. First identified in the nineteenth century, the site has yielded Neanderthal and modern human material alongside faunal remains and palaeo-environmental data across successive periods of Ice Age occupation between 10000 and 50000 years ago. The discovery of the UK's only cave art assemblage in 2003 alongside the site's established archaeological importance at the northerly extreme of Ice Age human habitation set the basis for Creswell Crags placement on the UK Government’s Tentative List of potential UNESCO World Heritage Sites (WHSs) in 2012. Creswell Crags are an exceptional complex set of cultural assets. In very broad terms, key elements in their significance can be summarised as follows:

• They possess rare long sequences of well preserved in-situ archaeological deposits as well as the associated resource of material excavated in the 19th and 20th centuries.

• There is particular archaeological importance for the Middle Palaeolithic (around 44000 years ago) as a site of Neanderthal activity and in the Late Upper Palaeolithic as the type site for *Creswellian* dwelling and resource exploitation at around 14000 years ago, in both cases at the northern limits of human habitation.

• The artistic and archaeological significance in their containing Britain's only, and Europe's most northern, example of Palaeolithic Cave Art.

3.3 Any nomination of Creswell Crags for inscription on UNESCO's World Heritage List is likely to include a buffer zone as advised by UNESCO. The purpose of a buffer zones is to protect the Outstanding Universal Value of a WHS. UNESCO's *Operational Guidelines for the Implementation of the World Heritage Convention* (July 2015) go on to say that a Buffer Zone " *is an area surrounding the nominated property which has complementary legal and/or customary restrictions placed on its use and development to give an added layer of protection to the property. This should include the immediate setting of the nominated property, important views and other areas or attributes that are functionally important as a support to the property and its protection*." This would have implications for any extraction activities as well as traffic movements to the Whitwell plant, which would use the A616 through Cresswell Conservation Area. The Minerals Plan should take into account the potential for Creswell Crags to be inscribed on the World Heritage List, together with an associated buffer zone, and have full regard to NPPF paragraph 132 guidance that harm to significant heritage assets, and their settings, should be wholly exceptional.

3.4 The Crags also form part of the Welbeck Registered Park and Garden (Grade II). Humphry Repton's inclusion of the sublime natural form of the Crags into the designed landscape of the Grade I listed Welbeck Abbey and the subsequent damming of the gorge to create a water-fowling lake provide additional layers of historic landscape significance. It is also partially within the Creswell Conservation Area.

3.5 Heritage impacts arising from the extraction of dolomite in this location are considered to be two-fold. Firstly, the dolomite resource area occupies the southern end of the magnesian limestone ridge through which the Creswell gorge passes. The existing quarry workings to the north severs the monument from the ridge leaving the proposed allocation area to the south as the sole opportunity to experience and understand the monument in something of its late Pleistocene landscape context. Neither Neanderthal nor Late Upper Palaeolithic populations were simply huddled in gorges and caves enclosed from their environment, they were also up on the ridges above working flint and hides and looking out across extensive steppe grassland (as demonstrated in recent and current excavations in Rutland and Leicestershire. The lives of hunter gather peoples were, we believe, intimately associated with the seasonal movements of large mammals and birds through the landscape in which they operated (as supported by the cave art at Creswell). The ability to experience this monument in its extant landscape context (as well as within the enclosed space of the gorge) is central to its significance.

3.6 Secondly, there are a number of significant unknown impacts which may give rise to further harm. Specifically, the *de facto* allocation area has unexplored potential for finds assemblages surviving both in topsoil and in-situ below hill wash or in fissures. Caves containing archaeological and palaeo-environmental remains potentially extend at depth beyond the Scheduled Monument boundary on this southern side of the gorge and would be vulnerable both to the proposed working and associated vibration. It is also proposed to process the mineral through the existing workings at Whitwell in order to utilise the existing infrastructure. The resulting haulage of mineral from the extraction site to the kilns via either the existing transport network, or new corridors through the landscape are likely to cause additional harm. It is anticipated that any future restoration of the quarry site is likely to be water based, which could also have unknown implications for the scheduled cave network and would not reinstate topographic form.

3.7 Historic England considers that the likely impact of dolomite extraction in the Holbeck area would constitute substantial harm to the significance of designated heritage assets of the highest importance contrary to the provisions and intentions of the NPPF and with the possibility of resulting in a situation where dolomite extraction is not deliverable at this location. Without any evidence within the Plan to demonstrate that heritage impact has specifically been considered through assessment work in order to designate sites or designate preferred areas, taking into account constraints such as the historic environment, the Plan is not sound in terms of its aspirations for dolomite extraction expressed in Policy MP9.

3.8 It is also noted that the justification text states that there is no national demand forecast or local apportionment for dolomite. It also states that the resource supplies an international market. However, there is no associated evidence base to support the 'international' importance of industrial dolomite provision in the UK. The company overseeing the extraction at the neighbouring Derbyshire site owns various dolomite related sites throughout the world but it is not clear what proportion of the extraction, or type (industrial grade or aggregate limestone) is used in the UK or abroad.

3.9 Due to ongoing concerns with the continued reference to industrial dolomite within the emerging Plan Historic England commissioned a report on the dolomite situation during 2018 and we are aware that potential alternative sources are available outside the Plan area. This is attached as Appendix 1. It is not clear how any such supplies have been considered in the context of the Publication Plan and its *de facto* site allocation situation. Such uncertainty clearly highlights that there is insufficient information available on which to determine impact, and further evidence base work and assessment is required to inform the Plan to ensure it is positively prepared, justified, effective and consistent with national policy.

4.0 Summary

4.1 Based on the current content of the Publication Plan and its supporting information Historic England maintains its concerns about soundness of the Plan in terms of the approach to dolomite extraction in the Holbeck area since there is a lack of evidence to demonstrate that the significance of heritage assets has been considered, and also what impact the allocation might have on that significance. Nor has it been clearly demonstrated that opportunities to avoid harm have been considered. As such, the Plan is not consistent with national policy in the NPPF, including the need to conserve heritage assets in a manner appropriate to their significance (NPPF Para.193).

4.2 No specific heritage impact assessment of the impact on heritage assets in the Holbeck area has been undertaken in respect of the Plan and Policy DM9 which means that the strategic matter of dolomite extraction, which affects a processing site in Derbyshire, has not been fully dealt with at this stage but would be deferred to any planning application stage.

4.3 In addition, there is no evidence supporting the Publication Plan to demonstrate that the need for dolomite extraction has been considered, or if so, to what extent such extraction is required.

4.4 In conclusion, the Publication Plan cannot demonstrate a positive approach to the historic environment, is not consistent with the requirements of national policy or guidance set out in minerals guidance contained in the Planning Practice Guidance (PPG) and does not clearly demonstrate that it is positively prepared, justified, or effective.

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Word Count: 2088

(Appendix 1 attached)

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Magnesian Limestone
and Dolomite Resources

An assessment of the distribution of the stone
and the potential impact of its extraction
on our cultural heritage and its setting

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SUMMARY

Although widely distributed throughout the united Kingdom, dolomite or, as it is often termed, magnesian limestone is used in a similar manner to pure calcitic limestone as aggregate. However, very high purity dolomite, that is stone with a very low silica, iron and alumina content, has a number of uses as an industrial mineral. These include the iron and steel industries and glass manufacture. The majority of the high-grade industrial dolomites occur in the Permian strata which outcrops from County Durham in the north-east of England down to Nottinghamshire in the East Midlands. Although some industrial grade stone occurs in Nottinghamshire, Derbyshire and South Yorkshire, the majority appears to be in the north-east of England, although none are as high-grade as many found elsewhere in the world. Due to the unprecedented closure of industry in the north-east of the country, as elsewhere, the demand for industrial dolomite has been drastically reduced. As a result the quarries and processing plants have now been closed or mothballed, only a lime plant at Whitwell in Derbyshire being operational. The principal use of dolomitic lime is still in the steel industry and about 250,000 tonnes per year are used for this purpose. It is used for refractory bricks and a wide range of monolithic and gunning materials. Bricks manufactured from high-grade dolomite are also used in lime and cement kilns. Glass-grade dolomite is produced from a quarry at Warmsworth.

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1 GEOLOGY AND DISTRIBUTION

1.1 **Classification, Mineralogy**

Although at first glance it would appear to be easy to define what constitutes a limestone, it is in fact rather difficult. In general terms a limestone could perhaps be considered to be a sedimentary rock that is composed of over 50% carbonate minerals. However since these minerals include the carbonates of calcium, magnesium and iron, this would classify a sedimentary iron ore deposit composed of the iron carbonates siderite and ankerite as a limestone, which would clearly be unsatisfactory. Some definitions suggest that limestone could be used as a general term for that class of rocks which contain at least 80% of the carbonates of calcium or magnesium. However there are plenty of accepted limestones, which being formed close to rivers or other sources of arenaceous material, contain less than 80% calcium carbonate. In fact using the term limestone should always consider the mode of formation of the rock as well as its chemistry and mineralogy. True limestones are formed from sediments which originally consisted of fragments of the calcium carbonate shells or other hard parts of marine or fresh water organisms. In addition there can be fine-grained carbonate present, created either biochemically by micro-organisms or by evaporation. Impurities in the form of sand grains, clay minerals and other terrestrial material is not uncommon and may form quite a high proportion of the sediment. Due to the nature of the calcite crystal lattice, some calcium carbonate can be replaced by magnesium, ferrous iron, manganese and strontium carbonates. Of these magnesium is the most important since it can be present in calcareous shells in quite high concentrations. Calcite with less than four mole percent $MgCO_3$ is termed low-magnesian calcite, whereas calcite containing 4–30 mole percent is known as high-magnesian calcite. The same terminology is used for the limestones, resulting in low-magnesium limestone and high-magnesium limestone. However, since the fossil constituents of a limestone cover a range of organisms, the percentage of fragments from high-magnesium bearing calcite, found in organisms such as calcareous algae and soft corals, is normally not all that great and the maximum level of magnesium carbonate in unaltered high-magnesium limestone is probably of the order of 10 mole percent.

If a limestone contains more than about 10 mole percent $MgCO_3$ it is probable that the magnesium has entered into the stone after lithification and diagenesis. In fact there appears to be a jump from limestone containing calcite with about 10 mole percent magnesium carbonate to limestone consisting largely of the mineral dolomite with a theoretical stoichiometric value of 50 mole percent, although in reality the figure is slightly above or below this. This change from a rock containing calcite which includes some magnesium carbonate to one which is composed of the recognisable mineral dolomite, which has the composition $CaMg(CO_3)_2$, is probably the result of seepage refluxion by magnesium-rich brines. The source of such fluids will vary depending upon the post-depositional history of the strata of equivalent age, or younger, which occur in the immediate vicinity of limestone which has undergone dolomitization. Once this process has occurred the resulting rock is termed a dolomite or, if the limestone is not completely converted, a dolomitic limestone. In England the term 'magnesian limestone' has been used to describe dolomitic limestone and dolomite. However this term is based on the suite of dolomite-rich rocks of Permian age, which stretches from County Durham to Nottinghamshire, and which was termed the Magnesian Limestone by Adam Sedgwick in 1829. The term has been discontinued and replaced by a more precise stratigraphical terminology, although it still occurs on older geological maps and in popular and scientific literature on the geology of northern England.

In recent years the term dolostone has been introduced to avoid confusion between the rock and the mineral dolomite. The usage of the term dolostone is controversial because the name dolomite was first applied to the rock during the late 18th century and thus has technical precedence. The use of the term dolostone is not recommended by the Glossary of Geology published by the American Geological Institute. It is, however, still used in some geological publications. In fact the context in which the term 'dolomite' is being used should make it clear whether or not the rock or the mineral is being referenced.

1.2 **Distribution of the magnesian limestone and dolomites in the UK**

Dolomite and magnesian limestone occur, to a greater of lesser extent, throughout the UK. They are, however concentrated in the North of England, especially east of the Pennines.

1.2.1 Scotland

The Durness Limestone which extends in a narrow band from Durness down to the Isle of Skye is largely dolomitic. It is worked at Ullapool for agricultural and aggregate purposes. On Skye the stone has been metamorphosed and is worked for marble. In the Midland Valley of Scotland some thin argillaceous bands of dolomite are present near to the base of the Carboniferous strata, although they have little significance.

1.2.2 England

Although the Devonian limestones which outcrop in the south-west of England are largely pure calcium carbonate-rich rocks, sporadic dolomitization has occurred, resulting in patches of dolomite. These are normally small, although a small quantity of dolomitic stone has been produced for agricultural use.

Gloucestershire, in particular around the Forest of Dean and north of Chipping Sodbury, has relatively major deposits of dolomite. In Shropshire south of Oswestry dolomitized Carboniferous limestone has been quarried.

Although Carboniferous limestone outcrops over a considerable area of the Peak District in Derbyshire, dolomite occurs mainly in the south of the area. West of Wirksworth there is an area of a little over 12 km^2 of exposed dolomite and dolomitized limestone, with magnesium oxide levels of up to 21%, only a little under the theoretical maximum for pure dolomite of 21.8%. In fact magnesium metal was produced in the 1960s using rock from a quarry near Hopton. A further area of at least 12 km^2 of dolomitized limestone is present between Matlock and Monyash; MgO values again of more than 21% having been recorded for this area. Small areas of Carboniferous limestone and dolomite outcrop on the north-eastern side of the Leicestershire coalfield, two of which, Breedon Cloud and Breedon Hill have been quarried.

In the North of England the Carboniferous limestones tend to be free of dolomite, although in the Craven Fault complex some small patches of magnesium-rich stone occur at the surface and have also been found at depth in boreholes. These deposits are probably related to mineralization along the numerous faults. At one location, Threshfield quarry near to Grassington, dolomite for agricultural use was produced, although aggregate was the main output when the quarry was operational.

In the north-east of England some thin argillaceous beds of dolomite occur in the Ballagan Formation near the base of the Carboniferous System, although these are not likely to have any commercial significance. This is in complete contrast to the overlying Permian strata in the north-east which contains the most important source of dolomite and magnesian limestone in the UK. Stretching about 230 kilometres from Newcastle in the north down to Nottingham, the dolomites and limestones outcrop in a near continuous but narrow easterly dipping band. The rocks were originally deposited as shallow coastal limestones, the adjacent land, a tropical sandy and gravelly desert, being to the west of the present outcrop of the strata. In Nottinghamshire the Permian coastline was close to the present outcrop of the strata. As a result the carbonate sediments can contain large quantities of quartz sand washed and blown in from the landmass. However, as the outcrop is followed north, the distance from the neighbouring land increases, at least in the early stages of sedimentation. As a result the nature of the sedimentary facies changes along the outcrop, from close inshore in the south, through an off-shore shallow reef complex in south Yorkshire, to a uniform shallow sea environment in the north. However a series of rhythmic climate changes, resulting in changes in sea level, throughout the Permian caused variations in the sediment type. These changes which are referred to as the English Zechstein Cycles, five cycles having been identified, not only caused the sea depth to vary and the location of the coastline to change, but also resulted in more and more hypersaline marine conditions occurring. As a result considerable quantities of evaporites, such as anhydrite, potash, halite and gypsum, were deposited to the east of the present outcrop of the dolomites. It is these evaporites which are mined at the Boulby mine near Whitby and will shortly be extracted from the new Woodsmith mine in the same area.

Although it is possible that some primary dolomite was formed with the evaporites, it is believed that the majority of the magnesian limestone was created by underground fluids, originating in the evaporites, reacting with the calcium carbonate reef and associated lagoonal and other deposits which had been formed in the shallow sea parallel to the coastline to the west. Known as reflux dolomitization, the process is believed to occur due to spatial variations in the salinity of the hypersaline sea which result in variations in fluid density. The resulting brines then pass downwards and laterally through the limestone, reaction with the calcium carbonate to form the mineral dolomite.

1.2.3 Wales

Dolomite deposits occur in the Carboniferous limestone of South Wales, especially at the eastern end of the South Wales coalfield. Another occurrence, west of Caldicot, extends northwards into England and the Forest of Dean. South Pembrokeshire and Gower also have important deposits.

In North Wales, small areas of dolomitization are present in eastern Anglesey and near Llandudno.

1.2.4 Northern Ireland

Dolomitic limestone occurs at several localities in Northern Ireland. Extensive secondary dolomitization of the Carboniferous Knockmore Limestone Member near Belcoo in County Fermanagh, which is associated with faulting, has been quarried in the past, although the quarry appears to be currently idle. Analyses of the dolomite showed it to be high grade, having a magnesian carbonate content of 39.5%. A 5 metre thick bed of dolomite has been found in Ballysudden quarry, 3 km SSW of Cookstown, in the Carboniferous Derryloran Grit Formation.

Magnesium-rich limestones are clearly common in the UK and distributed widely. However, due to their modes of formation, reflux dolomitization of complex limestone deposits or mineralization associated with tectonic activity, or possibly even primary, chemical and physical variation within any given deposit can be expected. Although this can, to a certain extent be tolerated in the aggregate industry, the main user of the material, it can be extremely significant in an industrial context, where uniformity and high quality is commonly required.

2 PROPERTIES

2.1 **Physical properties**

Due to the nature of the majority of bedded dolomite deposits, the physical properties of the stone can be complex. This is due to two main reasons. Firstly the deposit is probably the result of dolomitization of an existing limestone deposit, frequently one formed close to a shoreline. Such limestones may well have been formed in environments similar to those which exist today in the Bahamas or the Arabian Gulf. As a result the stone can be formed from a mixture of barrier or patch reefs, lagoonal sediments, sabkha-type deposits and somewhat deeper water offshore sediments. The resulting limestones can therefore range from dense largely unbedded but massive reef structures, to well bedded permeable oöidal rock and very fine-grained calcareous mudstone. Furthermore the mineralogy can range from low-magnesium calcite, to high-magnesian calcite and aragonite. All these materials can occur in close proximity to each other. The extent and type of dolomitization is affected by the mineralogy, structure and permeability of the original limestone. For example both high-magnesium calcite and aragonite are probably dolomitized faster than low-magnesium calcite, suggesting that certain fossil fragments could be transformed to dolomite quicker than the surrounding calcite fragments. Temperature, concentration and the longevity of the presence of the magnesium-rich solutions will also affect the degree of dolomitization. As a result of the numerous factors affecting the dolomitization process, dolomites can range from rocks where the original fabric of the limestone is well-preserved, to others where nothing is visible except a mass of dolomite crystals, all intermediate phases being possible. The textures created by the dolomite crystals can also vary widely, ranging from dolomite with planar faces, which can range from euhedral planar-e type to subhedral planar-s crystals, to material with irregular intercrystalline boundaries, known as nonplanar dolomite. Cavities can contain crystals of coarse-grained saddle dolomite, which is characterized by curved crystal faces and sweeping extinction. All these variants will affect the physical properties of the rock, and therefore its suitability for different uses.

2.2 **Chemical properties**

Just as the complexity of the formation of dolomite and magnesian limestone deposits can cause large physical variations in the rock, it can also result in considerable variation in the chemistry of the strata. This can be the result of variation in the original limestone, for example the inclusion of variable quantities of quartz sand grains from a neighbouring land mass, or variation in the degree and type of dolomitization. Being caused by the influx of magnesium-rich brines the original limestone can range from being completely converted to dolomite to only partially converted. The mineral dolomite itself can also vary in composition. Although having a theoretical composition of $CaMg(CO_3)_2$, it is not uncommon for some of the magnesium to be substituted by iron and/or manganese, to eventually form the mineral ankerite with the composition $Ca(Mg, Fe^{2+}, Mn)(CO_3)_2$. The amount of iron and manganese can be variable and the change from the mineral dolomite to the mineral ankerite is considered to occur when the ratio of $Fe^{2+} / (Mg + Fe^{2+}) \geq 0.2$. The term ferroan dolomite is used for minerals with a composition between dolomite and ankerite.

3 SPECIFICATIONS AND USES IN THE UK

The most common use for magnesian limestone and dolomite is as aggregate. However they tend to be highly variable as well as having a higher porosity and being much softer than typical Carboniferous limestone, which tends to outcrop relatively close to all the UK dolomite deposits. As a result they are generally quarried for low-grade aggregate applications such as sub-base roadstone and fill. However, although there is the slight potential for an alkali-carbonate reaction resulting in the aggregate swelling, durability tests up to 13 years for concretes containing magnesian limestone aggregates have confirmed a good all-round performance as long as good practice is followed. As with many industrial minerals, the use of the typical material for aggregate can make the extraction of limited areas or thicknesses of underlying high-grade material, suitable for industrial use, cost effective. This is due to the fact that if the rock overburden overlying the mineral-grade material can be sold, the cost of overburden removal, which would otherwise make the mineral-grade rock uneconomic, is removed.

In addition to aggregate, the fact that as-dug dolomite can be relatively easily crushed to a fine powder allows it to be used directly for agriculture. Dolomite is similar to limestone in neutralising soil acidity and can also be used as an important source of magnesium for plant nutrition. Traditionally dolomite lime was used for this purpose, the rock being calcined in local kilns. Some calcined dolomite is still used for this purpose in addition to that which is merely fine-ground stone.

Dolomitic lime is made from dolomite or magnesian limestone by calcining it in a rotary kiln fired with natural gas, coal, petroleum coke and a range of waste derived fuels, such as old tyres and solvents. The calcining temperature used is about 1000º C. Horizontal rotary kilns are used to ensure complete decomposition of the dolomite.

$$CaMg(CO_3)_2 + \text{heat} \rightarrow CaO + MgO + 2CO_2 \nearrow$$

Although the original rock is composed of the mineral dolomite, the result of calcining is a mixture of two separate compounds, calcium oxide and magnesium oxide. Dolomitic lime is also known as calcined dolomite, dolime, lightly calcined dolomite and burnt dolomite. The dense form of dolomitic lime used as a basis for a range of refractory products, which are important for making steel, is known as sintered or dead burnt dolomite. It is again produced by burning dolomite rock at temperatures of around 1000ºC but with a longer residency time in the burning zone of the kiln, which causes the material to become more dense. The small crystals of magnesium oxide grow larger and the pores in the structure disappear. The bulk density may increase from about 1,600 kg/m^3 to more than 3,100 kg/m^3.

In the case of dolomite and magnesian limestone, the highest grade rock has been worked in the UK for a number of purposes. Although steadily decreasing in demand, dolomitic lime was used in the iron and steel industry as a binder for pellets/sinter in iron making and in steelmaking as a slag component in the production of alloys such as ferro-chrome, ferro-manganese. It was also used in the manufacture of the refractory brick linings for the furnaces as well as a wide range of monolithic and gunning materials. It has also been used in the manufacture of glass, especially flat glass, as well as a source of lime and magnesia in the glass fibre industry. High-grade dolomite from quarries in the north-east of England was once extensively used for the manufacture of seawater magnesia, mainly used for the production of refractory magnesia at a plant in Hartlepool. However this ceased in 2002 although the production of chemical grade magnesium oxide powders and magnesium hydroxide suspensions continued until 2005 when the plant finally closed. Although the steel and glass manufacturing processes use calcined dolomite, high quality dolomite can be used as-dug as a filler if finely ground. This material has been used in plastics, paints, rubbers, adhesives and sealants. Where high brightness white fillers are required, for example for use in paper, dolomite in the UK is rarely white enough for use and finely-ground chalk ‘whiting’ is preferred. Other uses include addition to drilling muds as a pH modifier, adjusting the acidity of sewage sludge and as neutralising agent in water treatment.

The primary difference between the dolomite used for aggregate and that suitable for industrial use is the chemistry of the material, in particular the quantity of secondary minerals. Silica, normally in the form of quartz sand or silt grains, frequently cannot be accepted when the content of SiO_2 is greater than 0.55% and for some applications this figure can be as low as 0.30%. A low iron content is frequently required due to the colouring effect even small traces of iron can have on the product, for example flat glass, for which they are used. A maximum Fe_2O_3 content of 0.55% is common and can be frequently less. It is the iron content of the dolomite rock which produces the typical yellowish colour of the stone. A white dolomite or magnesian limestone therefore tends to be of higher purity, in the context of iron, than the darker coloured rock. In addition to these two major elements, specific processes requiring a dolomite feed-stock may have limits on trace elements such as sulphur and phosphorus, for example $S < 0.1\%$ or $P < 0.02\%$. Typical grades of industrial dolomite from the UK, in particular the north-east of England and the Nottinghamshire - South Yorkshire - Derbyshire area are given in the following table.

	Durham area			Doncaster area
	Raisby Formation		Ford Formation	Cadeby Formation
CaO (%)	32.37	33.99	31.02	30.23
MgO (%)	20.03	18.64	20.67	21.10
SiO_2 (%)	0.48	0.00	0.54	1.11
Fe_2O_3 (%)	0.55	0.53	0.43	0.29
$A1_2O_3$ (%)	0.21	0.00	0.23	0.23
Na_2O (%)	0.00	0.00	0.00	0.00
K_2O (%)	0.00	0.00	0.00	0.00
TiO_2 (%)	0.01	0.01	0.02	0.02
P_2O_5 (%)	0.00	0.01	0.03	0.01
MnO (%)	0.05	0.05	0.05	0.07
L.O.I. (%)*	46.50	46.57	46.73	46.72
F (ppm)	1054	635	452	388
S (ppm)	906	551	3608	729
Ba (ppm)	604	78	62	36
Cu (ppm)	1	1	1	1
Zn (ppm)	27	109	38	40
Pb (ppm)	20	14	18	19

* L.O.I. = Loss on ignition, mainly the loss of carbon dioxide from the carbonate.

An even higher grade dolomite, with a thickness in excess of 30 metres, has been proved at Hawthorn quarry near Seaham in County Durham. An analysis by the BGS indicated the following chemistry, silica, iron and alumina all being low for British dolomites.

	Hawthorn quarry
CaO (%)	31.70
MgO (%)	20.60
SiO_2 (%)	0.50
Fe_2O_3 (%)	0.11
Al_2O_3 (%)	0.12

There are three industrial dolomite operations established in the UK, those at Thrislington in County Durham, Whitwell in Derbyshire and Dolomite Quarry at Warmsworth. The Thrislington Lime Works is operated by both Steetley Dolomite Limited and Tarmac Aggregates Limited. The latter extract aggregate from the quarry as well as supplying industrial-grade dolomite to Steetley Dolomite Limited. Since October 2014 Steetley has been fully owned by the Lhoist Group, reported to be a global leader in lime, dolime and minerals. Steetley Dolomite has always specialised in dolomitic products for the steel and refractory industry. However, the lime kiln process at Thrislington is currently mothballed. Furthermore it cannot be put back into operation until the operators have demonstrated compliance with the Best Available Techniques (BAT) conclusions under Directive 2010/75/EU of the European Parliament and of the Council on Industrial Emissions for the Production of Cement, Lime and Magnesium Oxide. Although such an application does not yet appear to have been made, a planning application, number DM/17/04033/MIN, was submitted to Durham County Council in December 2017 by the owners of the quarry, Tarmac Trading Limited ('Tarmac'), under the Environment Act 1995: Periodic Review of Mining Sites regulations. The application is for the determination of new planning conditions for working and restoration relating to the existing Planning Permission No. IDO/5/1. The documentation appears to indicate that, although of industrial grade, the stone will be used for aggregate. The current status of the application is still 'Pending Consideration' by the Council.

A similar joint operating arrangement is in place at Whitwell, where Tarmac produce aggregate and supply the raw materials to Whitwell Lime Works, again operated by Lhoist. The dolomite kilns, which are the only ones currently operating in the UK, are apparently capable of producing materials for the iron and steel making process, about 250,000 tonnes per year are used for this purpose. However as far as can be ascertained, 90% of the product from the Whitwell Lime Works is exported to other countries worldwide, with an approximate revenue of £21M.

The Dolomite Quarry at Warmsworth, operated by the Belgian-based company Sibelco, produces glass grade dolomite which is generally used in flat glass production to improve general resistance to natural or chemical attack or weathering. Aggregates are also produced at this site since the low-iron dolomite does not occur throughout the geological sequence and lower-grade stone has to be removed to gain access to the industrial mineral grade material.

Although it is considered that the highest grade dolomites in the UK, in the context of industrial use, are found in the north-east of England, current production from Whitwell and Warmsworth are exploiting the southern outcrop of the Permian strata in north-west Nottinghamshire, eastern Derbyshire and South Yorkshire. This has also occurred in the past, one example being the pale-coloured stone from the quarries at Steetley, west of Worksop, which was used for the production of basic refractories. Analyses of this stone from the British Geological Survey are shown in the following table.

	Steetley area	
	Lab . No. 560	Lab . No. 561
CaO (%)	30.25	30.58
MgO (%)	20.83	20.22
SiO_2 (%)	0.09	0.30
Fe_2O_3 (%)	0.01	0.01
FeO	0.39	0.34
Al_2O_3 (%)	0.76	1.84
MnO (%)	0.05	0.02
L.O.I. (%)*	46.43	44.05

* L.O.I. = Loss on ignition, mainly the loss of carbon dioxide from the carbonate.

The light-coloured dolomite found at Cadeby quarry, now used only for the extraction of building stone, was once a source of glass-grade dolomite. Resources of this stone still exist and the fact that it is no longer utilised has been attributed to the fact that it is considered unsuitable for use in a rotary kiln, although whether or not modified kiln systems similar to those used in the cement industry have been considered, is unknown. Boreholes, not only in the area of the outcrop, but also further to the east, have indicated the presence of beds of dolomite of similar thickness to those in the quarries and also pale in colour, which indicates a low iron content and therefore of potential interest for industrial processes such as glass, metallurgical and refractory applications.

Although considered rare and only worked at Whitwell, Thrislington and Warmsworth quarries in recent years, industrial grade dolomite is appears to be potentially more extensive than is being admitted by the industry. Further resources still remain at Cadeby and may well exist at Steetley. Many resources may well remain undiscovered. An example of this has been identified on the Studley Royal Estate, six miles north of Harrogate. The East Gate of the Estate, constructed from a light coloured dolomite, had been repaired with a different dolomite which was causing problems by becoming dark-coloured after a period of weathering. Investigations indicated that the original stone in the Gate had been obtained from a small Estate quarry. Analysis of the stone from this source gave the following result.

	Studley Royal Estate quarry
CaO (%)	31.34
MgO (%)	19.94
SiO_2 (%)	0.800
Fe_2O_3 (%)	0.293
Al_2O_3 (%)	0.452
BaO (%)	0.133
SO_3 (%)	0.109
K_2O (%)	0.073
Cl (%)	0.0688
Na_2O (%)	0.0394
P (%)	0.0247
MnO (%)	0.0195
SrO (%)	0.0125
TiO_2 (%)	0.0113

In UK terms this is a very pure dolomite, and although not as 'clean' as some of the stone from the north-east of England, it is certainly similar to that from the Nottinghamshire and South Yorkshire areas.

4 FACTORS AFFECTING COSTS AND MARKETS

4.1 **Extraction**

Since dolomitic limestone is used for both aggregates and as an industrial mineral, the quantities required are not only high but, in the case of the latter, are required on a continuous basis, it not being possible to stop and start a kiln-based calcining operation. Surface quarrying has therefore been the predominant method of extraction. This process brings with it a range of environmental implications which are discussed below. However, since minerals can only be worked where they occur, the most significant cost associated with extraction can be the transportation of the ex-quarry product to the market place or to the processing plant in the case of industrial dolomite. Limestone, whether pure calcium carbonate or dolomitic, is a heavy bulk material. Moreover, if lime is to be produced from the stone, transportation to the kiln is effectively carrying a large mass of carbon dioxide which will be lost to the atmosphere during the calcination process. It is normal practice therefore for the kilns, whether they be designed to produce cement or lime, to be located as close to the source of the carbonate as possible. This in turn will add to the environmental impact of the site.

The cost of overburden removal can often be high, overburden not only being the contaminated and broken surface material but also any stone which may not have the required chemistry or physical properties. This is the reason why industrial grade dolomite quarries also produce aggregate, the sale of the crushed product covering the cost of the overburden removal. Although common in the extraction of building stone, mining, or more correctly underground quarrying, is not used for the extraction of industrial dolomite. Calculations have indicated that, in many instances, underground mining is a viable alternative to surface quarrying. There is no requirement for overburden removal or for the extraction, transport and sale of often low-grade aggregate, nor are the environmental impacts as significant, with landscaping only required for a few buildings and the access portal. The potential problems of dust and noise are also avoided.

4.2 **Environmental factors**

Noise and dust suppression now considered essential in any surface quarry cost money, as does the building of landscape bunds and the planting of tree screens and other methods of minimising the visual aspect of a quarry. Mitigation of the potential impact of the extraction on neighbouring natural conservation areas, cultural heritage sites and archaeology can not only be expensive, especially if ground-water levels are likely to be affected, but can also result in the loss of resources. The requirement for backfilling, restoring and landscaping of the final void when the resource is exhausted also has to be considered when assessing the financial viability of a project. Since processing facilities such as kilns are normally located adjacent to the extraction area due to the high cost of moving the ex-quarry block or crushed stone in large quantities, the potentially high cost of landscaping such an industrial facility as well as meeting all modern emission standards adds a significant financial burden to the project. This results in the operator wanting to keep the plant in operation for as long as possible.

4.3 **Transport**

As indicated previously, industrial grade dolomite is a heavy product and required in large amounts on a continuous basis. This problem is resolved by building the processing facility adjacent to the raw material deposit. However when the byproduct of the operation is low-grade aggregate, produced from what is essentially the overburden, transport to the consumer market may be significantly higher that would normally be the case with a hard-rock aggregate plant, which tend to be as close to the market as possible. The bulk product from the processing plant will also have to be moved, possibly large distances to the industrial plants where it is required. Although transport by road is possible, assuming an acceptable network of main roads, transport by rail, river or canal is frequently a more cost-effective solution, especially as there is no deterioration of the product with time. Aggregate suppliers now use both bulk transport by special trains and by river barges for distribution purposes.

5 WORLD PRODUCTION

In Europe dolomite resources are located in Ireland, Germany, Belgium, Spain, France, Hungary, Italy, Austria and Greece. The stone from Italy can have a silica content of less than 0.05% and an iron content of less than 0.03% making it extremely pure. Dolomite from Andalucia in Spain is also very pure with silica and iron oxide content of 0.05% and 0.1% respectively and is used for colourless glass.

In Africa dolomite is worked or recorded in Algeria, Botswana, Burkina Faso, Burundi, Central African Republic, Egypt, Gabon, Ghana, Mali and Namibia. The dolomite mineral resources of Nigeria appear to be relatively extensive with deposits being located in the States of Abuja, Edo, Kogi, Nasarawa, Kwara, Yobe, and Oyo. Resources also occur in Rwanda, South Africa, Tanzania, Togo, Zaire and Zimbabwe.

China, India and Australia have concentrated dolomite extraction activities in the Asia Pacific region.

Iran and Brazil are two of the other countries having significant dolomite reserves.

Growth in the dolomite market is expected to occur with the North America and Europe regions being the leading consumer market. The Middle East and Africa (MEA) and Latin America regions are estimated to grow in future years with the development of industries in float glass production. The Asia Pacific dolomite market is expected to witness significant growth owing to the increasing road construction activities in the region. Growth in agricultural exports will aid in boosting the growth of the dolomite market in the Asia/Pacific Excluding Japan (APEJ) region in countries including China and India.

Although clearly a relatively common rock, the production of dolomite, especially industrial dolomite is rarely provided in the global data on mineral supply and trading. Often it is lumped together with limestone and other materials as ‘crushed rock’. Where ‘dolomite’ is listed, the amount used for constructional use, that is aggregate and building stone, may be provided as is the total for the individual countries. The difference between the two is the sum of agricultural material and industrial material, both as-dug and calcined, the figures being suppressed 'to avoid disclosure'.

On a global scale the *World Mineral Production 2012 - 2016* published by the British Geological Survey contains no mention of dolomite. China is by far the world's greatest producer of both magnesite and primary magnesium metal and this may well reflect to a certain extent the potential dolomite resource available since the raw materials for magnesite and magnesium metal can be related to magnesium carbonate deposits. Russia and Turkey both produce significant quantities of magnesite and the USA is the world's second largest producer of magnesium metal, although this is a fraction of China's output. Although crushed rock output for the UK and Europe is detailed by the BGS, there is no breakdown of rock type used to produce this material. The more detailed *European Mineral Statistics 2010 - 2014*, also issued by the BGS, provides no further information. Individual countries do however detail their dolomite resources and grades. For example the Indian Bureau of Mines in the *Indian Minerals Yearbook* provide full details of reserves, resources, exploration, production and consumption of all grades of industrial dolomite, as well as exports and imports. Even the analysis of the dolomite used by the different Indian steel plants is provided.

6 NOTTINGHAMSHIRE DEPOSITS - DISCUSSION

The Permian magnesian limestone outcrop contains one of the most important assemblages of archaeological sites in the UK. To quote the report *A Conservation Audit of Archaeological Cave Resources in the Peak District and Yorkshire Dales National Parks – Protocol Report* prepared by ARCUS in January 2006 :

"The Magnesian Limestone, which is of Permian geological age, forms a narrow north-south oriented outcrop that runs from near Nottingham in the south to the North Sea coast near Tynemouth in the north. Most cave development is associated with west-east river valleys that bisect the linear outcrop (e.g. at Creswell Crags, the Don gorge, the

Nidd at Knaresborough and the Wear Valley). The Creswell Heritage Area has been intensively surveyed for archaeological caves (Davies *et al.*, 2004) but there is scope to extend the survey both northwards and southwards along the Magnesian Limestone outcrop. There are at least 10 known archaeological caves located north of the limits of the Creswell Heritage Area, but most of the Magnesian Limestone outcrop has not been systematically surveyed for caves and apart from the Creswell area the region has received negligible archaeological attention."

The report referred to by Davies *et al* is the *Creswell Crags Limestone Heritage Area Management Action Plan*, again prepared by ARCUS. The Heritage Area stretches from north of Tickhill down to Sutton in Ashfield, with Creswell at its centre. As described by ARCUS in the Action Plan :

"The Heritage Area contains the largest concentration of Scheduled archaeological sites for the Ice Age in Britain. These are concentrated in the vales and gorges. Surveys undertaken as part of the Management Action Plan show there is considerable potential for further discoveries.

The great ice sheets of the last Ice Age covered much of northern and western Britain. Here they stopped just north of present day Doncaster. South of the ice sheet, the grassy plateau of the magnesian limestone teemed with grazing animals including horse, bison, reindeer, mammoth and woolly rhinoceros. Many of these animals visited in the spring and summer to feed off the lush grass before heading south and east across 'Doggerland' (now under the North Sea) as winter approached.

Carved out in part by earlier ice sheets and melt water channels along fault lines in the limestone, the limestone vales and gorges provided sheltered havens for shrubs and trees and for carnivorous animals like the hyena that followed the animal herds and used the caves as dens.

Human hunters visited these same places, hunting the animals and leaving behind flint and bone tools. At Creswell Crags they left behind the most important collection of ice age artefacts and the earliest art found in Britain.

Today the limestone area contains the greatest concentration of ice age archaeological sites in the UK. Sediments found in the caves and along the rocky slopes of the gorges are important storehouses of scientific information for modern archaeologists and environmental scientists."

Although the archaeological significance of the area is important, in the context of mineral requirements there appears to be little, if any, reason at all for future extraction to be contemplated, since all the evidence indicates that there is no 'need' for any further stone to be quarried in this area.

As has been shown, most dolomite which is extracted is used as relatively low-grade aggregate. Certainly such material is important to our economy, although recycled materials are now being used in increasing amounts. The requirement for industrial-grade dolomite has also been reduced due to the loss of much of the country's iron and steel manufacturing capacity. In fact the bulk of the product from Whitwell lime plant appears to be exported. Hopefully our manufacturing industries will in due course recover and there will be a requirement once again for dolomite with a low silica and iron content. However, it is quite clear that not only is stone of this quality much more abundant in the north-east of England than in the East Midlands, there are also almost certainly deposits in less sensitive areas which have not yet been proved. The only argument which could be put forward for opening up a greenfield site south of Creswell would be to supply the lime works at Whitwell. Since a main railway line actually passes through the quarry by means of a tunnel, suitable high-grade stone could be easily brought from one of Tarmac's other quarries, either one which is operating or one which is currently mothballed. It may be that this imported stone may not be required in large quantities since, if of sufficient quality, it could be used as a 'sweetener' in order to make best use of the existing reserves of dolomite in Whitwell quarry but which is marginal in quality. Arguments, such as that which has been put forward for not using Cadeby high-grade stone, relating to the material not being suitable for the kiln, could potentially be solved in the same manner as in the cement industry by modifying the kiln process. Since the operators of both the quarry and the lime plant have a second quarry and operational plant, the latter being mothballed, in the north-east of England, it could be argued that, if high-grade stone cannot be brought in by rail, or even road, the whole manufacturing process could be moved to their second site.