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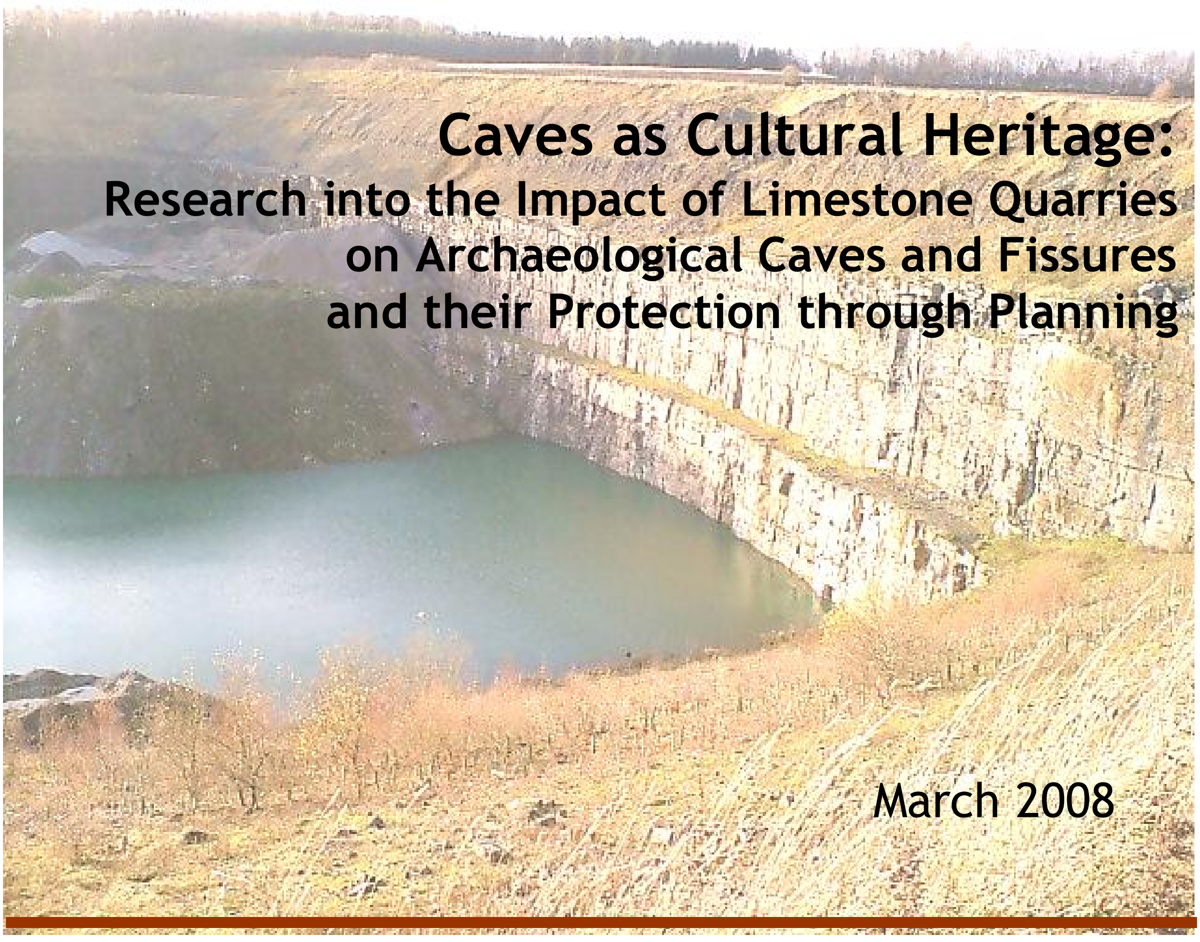

# Caves as Cultural Heritage:
## Research into the Impact of Limestone Quarries on Archaeological Caves and Fissures and their Protection through Planning

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# 1 INTRODUCTION

Archaeologists and environmental scientists the world over have long recognized the significant role that limestone caves and fissures play in the preservation of archaeological and palaeoenvironmental remains. But what of the conservation of these sites when they lie in the path of nationally important industries, such as limestone quarrying? Were it not for the quarrying of limestone for the aggregates industry, chemical purposes or building stone, many significant caves with archaeological deposits would never have been discovered. However, quarry operations can be as destructive as they are revealing (Ellis et al 2007; Last 2003: 10). This report presents the results of research into the known archaeology of limestone cavities discovered in the context of quarrying in the Carboniferous and Magnesian limestone of northern central England. In particular, it examines current archaeological strategies to assess and mitigate the loss of such sites and makes recommendations about assessing the archaeological resource in the context of quarry developments.

# 2 BACKGROUND

The English counties of Derbyshire, Nottinghamshire and South Yorkshire are known for their geologically distinct and economically important limestone resources. In the west, the Carboniferous limestone of Derbyshire outcrops at the southern tail of the Pennine Mountains, forming the characteristic uplands and dry valleys of the Peak District. In the east, the much thinner Permian 'Magnesian limestone' runs north in a narrow strip skirting the Pennine Mountains, from Nottingham in the south to the North Sea near Middlesbrough (Aitkenhead et al 2002). The region is well known for evocative karst features such as Lathkill Dale in the Peak District and the Don Gorge, but it is also internationally respected for its caves. If popular media sources can be considered a barometer of public perception, caves are important mainly as sites of tourism, recreation or nature conservation. However, caves also play a central role in our understanding of past cultures, which gives them special significance to archaeologists as well. In fact, two recent English Heritage funded studies on caves and cave sediments (Davies et al 2004; Holderness et al 2006) have highlighted the extent of caves and fissures in the region and their archaeological potential for providing clues about human history in the deep past.

Caves are mainly associated with classic karst landscapes, such as dry stone valleys or crags, where their entrances catch the eye; but as often as not, they may be found deep within the bedding structure of limestone. In such cases they may only be exposed through drastic forms of subsurface disturbance, principally through the operation of limestone quarries. Limestone has been quarried in the region on a small scale since at least Roman times. Yet, it was not until the development of new extraction technologies and the growth of the railway in the nineteenth century (Boden 1963: 53-56) that we can begin to speak of extraction on a scale which began to seriously augment our knowledge of the resource.

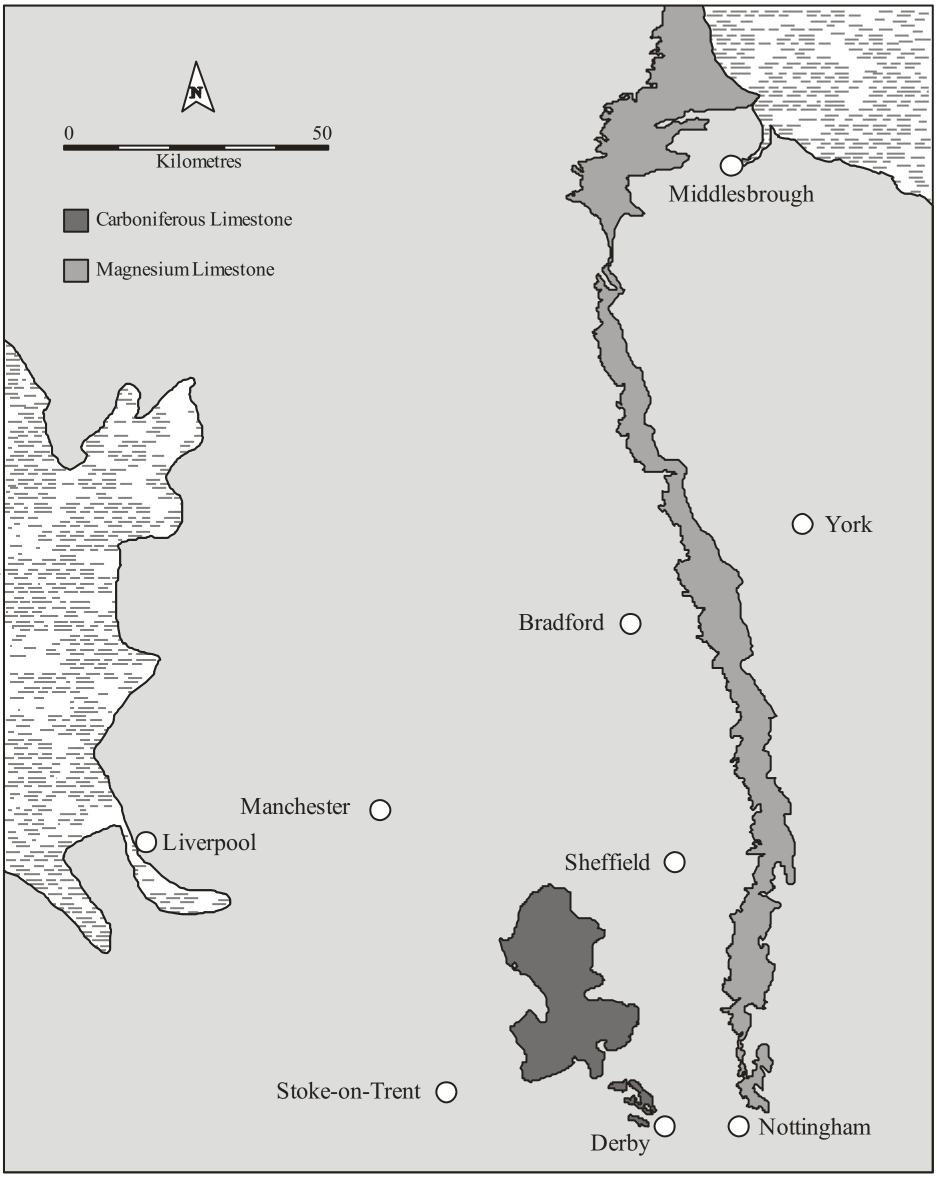



**Figure 1:** Map of northern and central England showing the extent of Carboniferous and Magnesian limestone regions discussed in the text.

While production figures for the early history of quarrying are difficult to assess, growth of well over 600% between WWII and the turn of the twenty-first century reflects the importance of limestone in the development of our modern economy. These figures reveal the strength of the industry, but they also hint at the massive amounts of stone removed from limestone bedrock and the opportunities this has meant for studying deeply buried geological formations. In particular, quarry faces constitute an important means of understanding the development of cave and fissure systems. However, quarrying can also have a negative impact on caves and cave archaeology. The principal of extracting rock for aggregate, industrial products or stone necessitates the removal of cavities, with obvious implications for cave archaeology (see Aldhouse-Green et al 1995; Currant and Jacobi 2001). With quarries continuing to erode limestone resources, what is the status of cave archaeology and what are the means by which we assess the significance of such resources in contexts where they may be under threat?

# 3 AIMS AND METHODOLOGY

This report describes the findings of research undertaken on the character and vulnerability of archaeological deposits in caves and fissures in the context of limestone quarrying, and considers methods available to assess these within the planning process. For the purposes of this study, caves may be defined as voids found in bedrock with a contiguous roof, while fissures may be distinguished as roofless fractures or cuts. Both may act as sediment traps and may at sometime have been open to the surface facilitating the accumulation of deep, if often discontinuous sequences. In this project we set out to review the current state of knowledge about cave archaeology, including cave deposits exposed through quarrying and other subsurface disturbances. Quarrying often exposes cavities containing sediments during working operations. However, archaeological or palaeoenvironmental remains are only recorded or analysed if subject to a specific planning condition. Such a condition will usually only exist if cavities containing sediments were identified as being present or likely to be present during initial site evaluation as part of the planning process. Therefore, we also set out review current techniques employed in assessing these resources through the planning process and have sought to produce guidelines on the value and reliability of such methods.

The specific objectives of the project have been:

- to assess the character and extent of unknown cave and fissure sediments buried within the southern Magnesian limestone in and the Carboniferous limestone of Derbyshire;
- to consider the value of these deposits as an archaeological resource, construed as cultural or palaeoenvironmental remains, which provide clearer understandings of past human-environment relations. .
- to assess the impact of modern quarrying upon caves and fissures within quarries and the effectiveness of protection afforded through PPG16.
- to assess the reliability of archaeological techniques used to identify the presence of caves and fissures containing sediments.

The study areas includes the whole of the Carboniferous limestone of Derbyshire and the Magnesian limestone from the Don Gorge, in the north to Mansfield in the south; thus, encompassing eastern parts of South Yorkshire and western parts of Nottingham. The two regions were selected to build on knowledge gained from a number of regional cave surveys that have been undertaken in recent years, and also to provide a comparison between the two main types of limestone within England, Furthermore, both the Carboniferous and Magnesian limestone have extensive and long standing limestone quarrying industries. Within these areas our research has focused on three key sub-regions which have historically witnessed high levels of quarrying activity. These include the surroundings of Buxton and Wirksworth in Derbyshire and the Don Gorge in South Yorkshire.

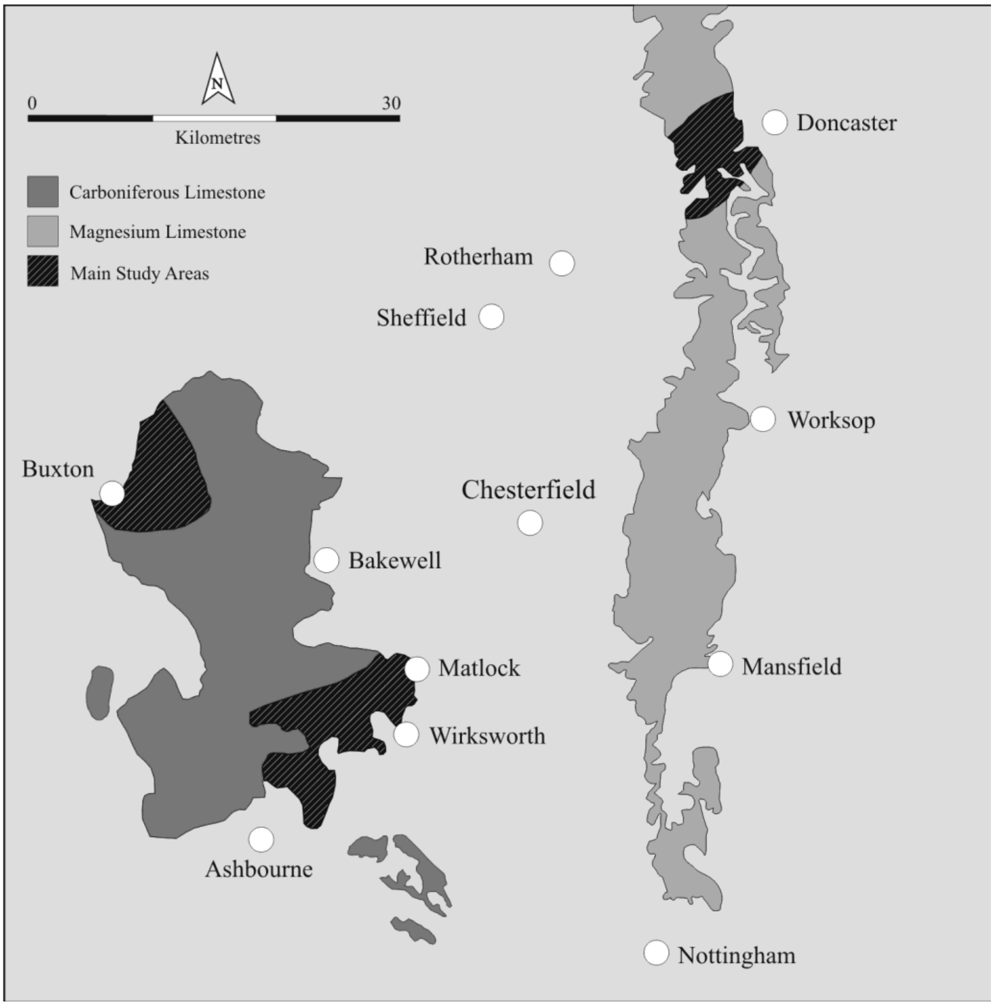



**Figure 2:** Detail map of the two limestone regions assessed by the project and main study areas.

Our findings are based primarily on archival sources, through consultations with various expert bodies such as planning departments and heritage managers and through published materials. These have included but were not limited to:

- the Cave Audit Study database;
- the Creswell Limestone Heritage Area database;
- local SMRs/HERs, for the extent of the known source and evaluation and mitigation methodologies currently employed;
- planning departments, for the history of planning applications, the nature of supporting geological data regarding applications, and potential future developments in quarrying in the areas;
- Peak District National Park Authority, for sources on archaeological and planning data;
- the British Geological Survey, for information of the geological background and detailed geological mapping data of quarry areas;
- local museums, for the extent of the known source;
- cavers active in the two study areas;

- other interested local parties including archaeologists

Our results are organized in two major parts. In the first we draw from museum and archive based sources which we use to characterize the cave archaeology of the region and to compare this with what we know about archaeological deposits discovered through quarrying. In the second part we use archaeology 'grey' literature to assess current methods for establishing the potential of cave resources. Finally we draw from a variety of sources to outline a number of methods which should serve to augment current assessment strategies.

# 4 THE ARCHAEOLOGY OF CAVES

Archaeology is the study of human history and its interaction with the wider environment using both artefactual and organic remains recovered from buried and surface deposits. Due to their enhanced preservation of archaeological deposits, caves can afford one of the best opportunities to study early periods of human society and culture. With their own often more stable micro-climates, localised parent sources of sedimentation and protection from erosion processes, caves can often provide a window on past human-environmental interactions not found at more exposed archaeological sites (Last 2003: 2). This is particularly the case for the study of earlier prehistoric archaeology, notably the glacial and interglacial epochs of the Palaeolithic, where evidence of human interaction with animal and plant life is sometimes entirely restricted to caves (Barton and Collcutt 1986). While the relationship between Palaeolithic archaeology and caves is well established, the archaeology of British caves demonstrates that limestone cavities have been significant places for people in the past across a very broad range of periods, depending on local environmental characteristics and the amount of space and light they provided. A pattern which seems to hold throughout the world suggests that caves were initially used as temporary shelters and caches, reflecting more mobile forms of social and economic organisation. Later periods evidence a wider blueprint of use, including what we might more confidently attribute to 'ritual' purposes, such as burial, in step with changes toward more sedentary societies (Tolan-Smith 2004: 427).

In comparison to their continental counterparts (baring the recent cave art finds at Creswell Crags (Bahn et al 2003)), it has been said that the archaeological caves of Britain are relatively 'impoverished' (Chamberlain 2004: 160). However, on a national scale, the limestone caves and fissures of northern central England are nonetheless impressive, both in the temporal sequences they preserve and the range of site types they represent. In fact, without caves, we would know very little about early prehistoric archaeology in the Midlands and the north due to the devastating impact of ice sheets in the late Pleistocene. Indeed, the evidence of stone tools and animal bone became an important focus of the work of nineteenth century scholars, such as William Buckland (1823) and William Boyd Dawkins (1874) among others, who helped to popularise the field internationally. Through their own work as well as that of researchers in the two following centuries, the limestone cavities of Derbyshire, Nottinghamshire and South Yorkshire have proved to be a significant resource for answering foundational questions about past human-environment interaction.

A high proportion of caves and fissures located in the study area contain human and animal remains from several periods, although in many cases there may be long hiatuses between depositions and erosional events. In the brief overview of cave archaeology provided below we give examples of the nature of archaeological finds discovered from caves and fissures as an indicator of the character of the archaeological record from different periods.

## 4.1 Palaeolithic

The earliest evidence of human occupation in the study areas has been attributed to Middle Palaeolithic; although a few scattered Lower Palaeolithic artefacts are known from the gravels of the Trent and Dove rivers. On the Carboniferous limestone, Middle Palaeolithic stone tool technologies are restricted to two sites, at Ravenscliffe Cave and Harborough Cave, Brassington (Bramwell 1977; McNabb 2000; Myers 2000b), although the veracity of the latter is debated (Wragg-Sykes per comm.). Faunal assemblages from these sites, although as yet unstudied, may add to our understanding of the local environmental conditions in which early human populations interacted. In the Northeast of Derbyshire, caves within the Magnesian limestone provide a more rounded picture of Middle Palaeolithic occupation. Excavations at Ash Tree Cave and most notably the complex of caves at Cresswell Crags, in particular Pin Hole Cave, have produced lithic and faunal assemblages which attest to a variety of occupation activities (Jacobi et al 1998; Myers 2000b).

A much broader range of artefacts and related evidence from the research area is associated with the Upper Palaeolithic. Sites containing a range of lithic forms including flint knives, scrapers, cores, burins as well as animal bones from reindeer and giant red deer, have been characterized as temporary 'campsites' and caches, most likely associated with large game hunting, although other practices cannot be excluded. Although a small number of human burials are known from this period elsewhere in Britain, no human bones have as yet been discovered. In the Carboniferous limestone sites are found at Dowel Cave, Elder Bush Cave, Fox Hole Cave, Thor's Fissure, One Ash Cave and Ossom's cave in the Manifold Valley (Bramwell 1977; Myers 2000b). However, it is the Magnesian limestone which provides the most important and prolific evidence from this period (Myers 2000b). Certainly the most well known is the internationally renowned site of Creswell Crags, where well over a century of excavations have revealed large assemblages of human and related environmental and faunal evidence, including mobiliary art. Most recently investigations at Church Hole Cave have uncovered Britain's earliest cave art, firmly dated to the 13th millennium BP (Bahn et al 2003; Petit 2003). Outside of the finds at Cresswell, Upper Palaeolithic period materials are known from the Don Gorge, Edlington Wood Rock Shelter, Pleasley Vale Cave, Steetly Quarry Cave and Whaley 2 Rockshelter (Bramwell 1977; Davies et al 2004; Jenkinson 1984; Howes n.d.; Mellars 1973; Myers 2000b).

## 4.2 Mesolithic

Caves represent only a minor component of archaeological finds during the Holocene and understandably, much more attention has been focused on open air sites. Nevertheless, sites from the Mesolithic onwards have produced significant assemblages which continue to shape our understanding of the human use and perception of the post-Pleistocene landscape. The early Mesolithic period begins at the end of last glaciation and appears to share the tool technologies and nomadic subsistence pattern of the late Upper Palaeolithic. Later Mesolithic sites are identified by the development of characteristic microlith industries, such as the trapezoidal tool technology, which have been found at a number of sites in the research area. Mesolithic cave sites from the Carboniferous limestone include Dowel Cave, Darfur Ridge Cave, Foxhole Cave, Sevenways Cave in the Manifold Valley, Wetton Mill Minor and a fissure site at Sheldon. On the Magnesian limestone Mesolithic flints are known from the Creswell sites of Mother Grudy's Parlour and

Pin Hole Cave, while to the north finds have been reported from Ash Tree Cave and Whaley 2 Rockshelter (Bramwell 1977; Myers 2000a).

## 4.3 Later Prehistory

Finds from the later Neolithic and Bronze Age suggest striking differences in the use of caves. From sites which stress an emphasis on hunting and temporary occupation in earlier periods, by the later Neolithic evidence points to very different range of activities, notably the use of caves for burial. Unfortunately, cave deposits are often difficult to interpret due the poor recording of early excavations and the heavily disturbed character of cave stratigraphy (e.g. Chamberlain 1999). Nevertheless, the sheer number of human inhumations and the occasional occurrence of limestone cists or 'walls' preventing ingress into caves and fissures demonstrate their importance as burial features. A recent review of the evidence from the Peak District carried out by Gilks (1989) and more recently by Chamberlain and Williams (1999) indicates a total of 26 caves containing burial evidence dating to the Neolithic or Early Bronze Age (Barnatt and Edmonds 2002: 116). Similar forms of burial are evident in the Magnesian limestone with late Neolithic and Early Bronze Age sites being excavated at Scabba Wood Rock Shelter, (Chadwick 1992; Buckland et al 1999), Ash Tree Cave, Sepulchral Cave, Langwith Basset and Whaley Rock Shelter (Chamberlain and Williams 1999; Davies et al 2004). While there is less evidence of the use of caves for burial during the Iron Age, a number of sites from the study area demonstrate the continuing significance of caves from this period. For example, radiocarbon dates from recently excavated skeletal material at Carsington Pasture Cave in the Carboniferous limestone indicate two discrete phases of burial, one during the Neolithic and a second from the Late Iron Age (Chamberlain 1999, 2001).

Due to the often disturbed character of cave deposits, it is difficult to attribute other discrete forms of activity from this period. However, following the pattern seen at late prehistoric cemeteries more generally, some of this material was probably associated with or at least acknowledged earlier inhumations (Barnatt and Edmonds 2002: 126). If this assessment is correct, then we are probably looking at forms of ritual activity as well. Nevertheless typological examinations of archaeological deposits reflect important developments in stone tool technology, metalwork, the domestication of animals, as well as limited evidence on the emergence and transformation of ceramic industries (Bramwell 1977).

## 4.4 Romano-British

In England and Wales, proto-historic and Roman use of caves has been recently brought to light in a gazetteer by Branigan and Dearne (1992). The widespread use of caves from this period is indicated by the fact that some 36% of sites listed in the gazetteer by Chamberlain and Williams (1999) produced Romano-British artefacts (Last 2003: 8). What is more, artefacts and features from this period display a very wide range of types indicating that caves were used for an expanding range of activities. While Romano-British material from caves has been less well studied that that for prehistoric periods, finds from the study reflect a widening pattern of use. For example, Roman material from Pool's Cavern near Buxton indicates an ambiguous occupation. Finds including metal work, ceramics, glass and skeletal material and have been interpreted (Bramwell et al 1983) as a rural shrine, while evidence of Iron and lead working suggest domestic and metalworking activity (Branigan and Dearne 1992: 43). Finds are less well know from Magnesian limestone, although material suggested to be a possible votive deposit has been recorded from Scabba Wood Rock Shelter near Sprotsbrough (Buckland et al 1999).

## 4.5 Historical

Very little is known of the medieval and post-medieval use of caves from the study area, although a number of sites do contain artefacts, most notably pottery sherds. Perhaps the most dramatic find has been a Saxon hoard from Saint Bertram's Cave in Staffordshire, a site which also produced material from earlier periods (Chamberlain and Williams 1999). More recent evidence comes from the rock shelters of the Magnesian limestone. Recent excavations at Roche Abbey Gorge have documented the foundations of a seventeenth or eighteenth century 'tool shed' erected in a rock shelter, possibly erected by quarry men working the rock face. It has also been suggested that tanks were garaged under the shelter during World War II, although this is not evident archaeologically (Dolby 2001). A recent archaeological survey of the Magnesian limestone recorded further improvised historical uses for rock shelters. At Roche Abbey Gorge, one limestone overhang was used as a protected site for a drinking trough for horses (**Figure 3**), while at a further site in Lindrich Vale, rock shelters formed a structural backing for a number of outbuildings (Davies et al 2004).

**Figure 3:** Rock shelter at Stone in Roche Abby Gorge, used to protect a drinking trough for horses (Photograph by Glyn Davies).

While archaeological information remains vague as to the use of caves from this period, historical records suggest that caves were employed for different purposes. For example it is well known that the hollowed sandstone passages under the city of Nottingham were used for the tanning industry as well as serving as homes for the cities poor, a pattern which still holds in parts of southern Europe (Tolan-Smith 2004). Still other records point to the favoured use of caves by hermits as permanent or semi-permanent dwellings, with a well documented example from Cheshire a short distance to the west of the study area (Sinclair and Mathews 1999). Future archaeological and historical research may help to provide better clarity on this matter.

# 5 LIMESTONE QUARRIES AND CAVE ARCHAEOLOGY

The above overview suggests that our present understandings of past cave use and the survival of the archaeological record are developing clear cut patterns. But what is the relationship between our current state of knowledge and evidence which has been furnished from caves and fissures found in the context of quarrying? Throughout the history of palaeoenvirnomental research quarries have consistently furnished some of the most significant if at times controversial evidence. For instance, quarrying in the Vale of Pickering and the coasts of Devon and Wales revealed some of the earliest faunal evidence upon which William Buckland developed his theories on Diluvian geology (Buckland 1823). Likewise blasting of limestone at Westbury Quarry in the Mendips produced evidence, which has sparked long-lasting debates about the earliest human occupation in Britain (Andrews et al 1999; Cook 1999). To place this in a more international context, quarrying has played an important role in revealing some of the earliest phases of Palaeolithic settlement in continental Europe (Svoboda 2001). Considering the clear potential that quarries possess for revealing deeply buried cavities, one of the main objectives of this research has been to identify the character of archaeological resources from the study area discovered in this context.

To asses the possible significance of the resource we conducted research at a number of local and nationally important research collections including local museums, the British Caving Association and the University of Sheffield. Archival research and consultation focused on locating both primary and secondary sources on the discovery (and sometimes subsequent excavation) of archaeological and related environmental evidence exposed in the Carboniferous and Magnesian limestone. Archival sources produced a range of different documentary sources including historical and contemporary journal articles, monographs and primary sources such as hand written surveys and excavation notes. In addition, museum databases furnished evidence on a number of unpublished collections.

## 5.1 Results

Twenty-one former quarries and related bedrock cutting operations known to have produced archaeology were located in the study areas. These principally clustered in the areas of Buxton and Wirksworth in the Carboniferous limestone. More scattered evidence was revealed in the Magnesian limestone. While in a number of cases it was difficult to attribute an absolute date of discovery, the unearthing of archaeological resources spans a broad timeframe beginning in the later half of the seventeenth century and continuing up to the present. The earliest recorded evidence comes from 1663 at Balleye Lead Mine near Wirksworth (Buckland 1823), while the most recent was discovered in association with a rock shelter at Roche Abbey Gorge in the southern Magnesian limestone (Dolby 2001). However, as we will discuss in greater detail below, most finds date to limestone quarrying operations in the late nineteenth and early twentieth centuries.

The fact that deeply buried cavities containing archaeology have been exposed through other intrusive activities is also considered of importance here, and historical records clearly show that railway cutting and the laying of water pipes, along with lead mining could result in the discovery of caves or fissures. For example, water works developments along the Don Gorge in 1878 exposed fissures containing a range of Pleistocene fauna (*Doncaster Chronicle* 1878; see also Howes n.d.), while railway cutting at Pleasley Vale in 1863 exposed the Yew Tree Cave (Ransom 1867) near Mansfield, the most southern archaeological deposit exposed within the Magnesian limestone.

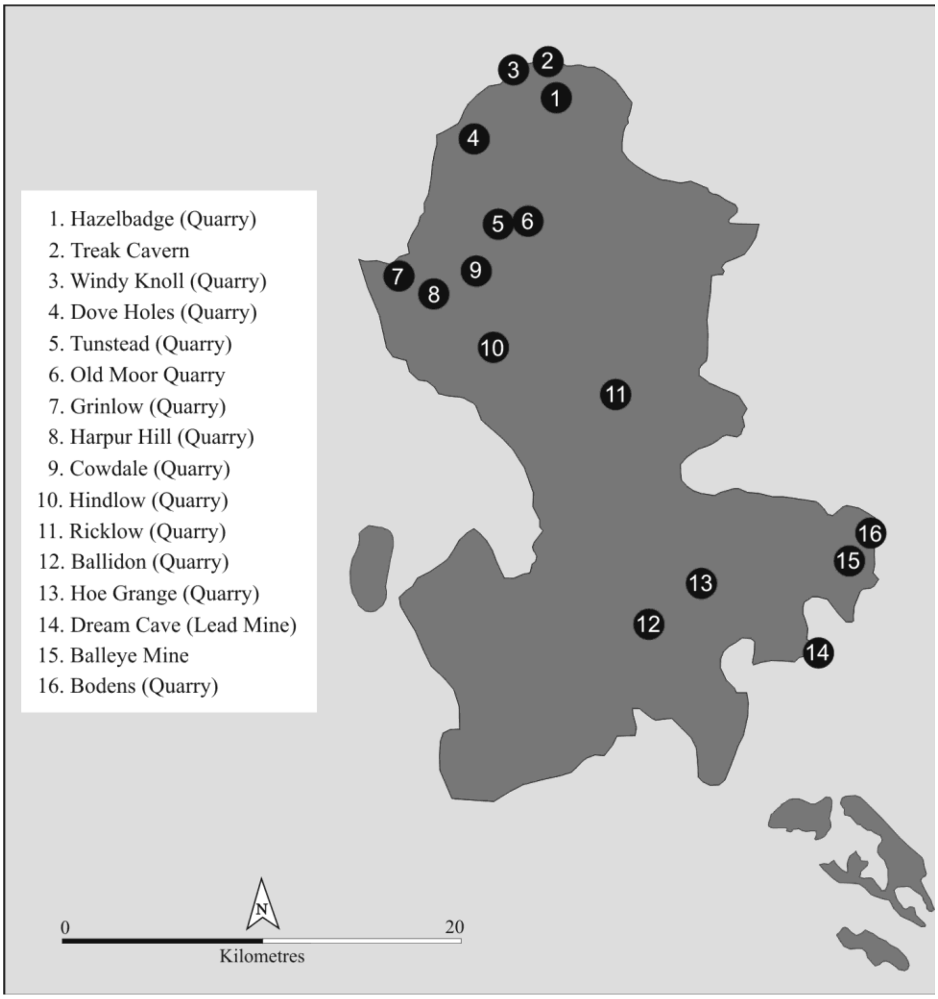



**Figure 4:** Carboniferous limestone regions showing quarries and lead mines associated with archaeological caves.

Both the Carboniferous (**Figure 4**) and Magnesian limestone (**Figure 5**) regions produced evidence from quarries of significant value for understanding past human-environmental interaction. According to our research 16 archaeological sites have been revealed in the Carboniferous limestone while 6 sites have been found in the Magnesian limestone (See **Table 1.**). A number of factors may help to explain this numeric discrepancy. The most obvious is the fact that the Carboniferous limestone is approximately double the size of the latter. Moreover, considering the former contains the particularly pure form of Bee Low limestone, (with characteristically over 98.5 % Calcium Carbonate) the Peak District and surrounding areas have a more extensive history of quarrying (Aitkenhead et al 2002; Boden 1963), which we reasonably assume results in a higher number of archaeological discoveries.

Finally, it should be noted that in the majority of cases, little information was gleaned on the physical proportions of caves or contextual information on archaeology or Pleistocene fauna. While a small number of sources provide rough plans or (e.g. Dawkins 1903; Armstrong 1926) much of the historical record is inconclusive.

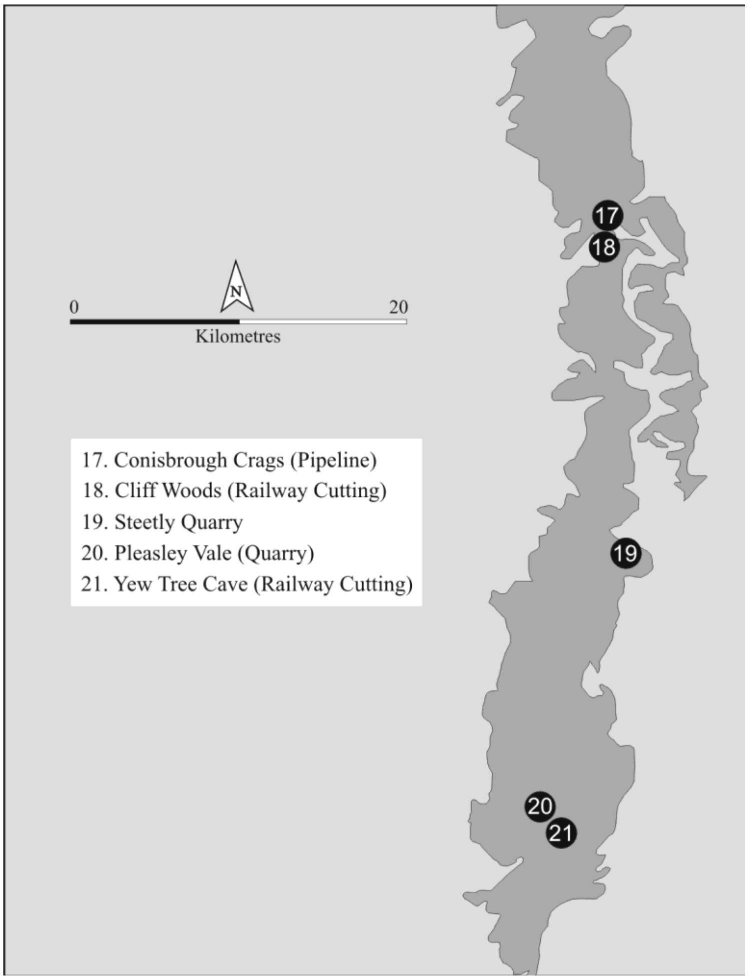



**Figure 5:** Magnesian limestone region showing quarries and cuttings associated with archaeological caves.

**Table 1:** Quarries producing evidence of deeply buried archaeology

| | *Carboniferous limestone: 15 Quarries* | *Magnesian limestone: 5 Quarries* |
|---|---|---|
| *Period* | *Number of archaeological sites* | *Number of archaeological sites* |
| Palaeolithic or Mesolithic | 7 | 5 |
| Later Prehistory, Roman | 7 | 0 |
| Historic | 0 | 1 |
| Undefined flint | 2 | 0 |
| *Total sites* | *16* | *6* |

## 5.2 Upper Palaeolithic

Twelve quarries spread between the two study areas (or 60% of the total), produced materials commonly associated with the Upper Palaeolithic (See **Figures 1** and **2**). Of these, eleven are limited to faunal assemblages, which according to mammalian biostratigraphy span much of this period (Currant and Jacobi 2001).

The majority of finds are mega fauna and other large boned animals including woolly mammoth (*Mammuthus primigenius*), woolly rhinoceros (*Coelodonta antiquitatis*), horse (possibly *Equus ferus*), bison (*Bison priscus*), spotted hyena (*Crocuta crocuta*) lynx (*Lynx lynx*) and reindeer (*Rangifer tarandus*), indicator species characteristic of steppe-like conditions. Tellingly, microfauna such as vole, rabbit and lemming, tend to be absent from early cave and fissure discoveries until recording standards became more systematic in the later part of the 20th century (e.g. Jenkinson 1984; Riley n.d.). Only one quarry site, a rock shelter from Roche Gorge in the Magnesian limestone, contained evidence of Upper Palaeolithic stone tool industries (Dolby 2001).

## 5.3 Later Prehistory and Romano-British

Seven quarry sites (or 35% of the total), produced stone tool assemblages most easily assigned to the Neolithic. Unlike the Palaeolithic sites discussed above, all were limited to the Carboniferous limestone (Figure 1) and include diagnostic flint axes, a granite axe, as well as less chronologically secure finds such as whetstones, scrapers, a chisel and flakes which may belong to other periods. One site, at Treak Cavern near Castleton, also produced skeletal remains of three individuals, along with animal bones of dog, pig, sheep and roe deer (Armstrong 1926), a not unexpected pattern for Neolithic cave burials. At Tunstead quarry near Buxton, in addition to Neolithic materials, quarrying produced a metal spear head and socket axe of unknown composition as well as a Roman coin: an aureus of Trajan.

## 5.4 Undated flints

In addition to the quarries mentioned above, museum database research also produced evidence of two further lithic finds found at Ballidon and Grindlow quarries in the Carboniferous limestone. Unfortunately due to the vagueness of the record we were unable to assign even tentative dates.

## 5.5 Historic

Only one quarry is related to the historic period. In addition to Palaeolithic evidence, the rock shelter and associated quarry at Roche Gorge, produced evidence that the excavator interpreted as the post-medieval foundations of a quarryman's shed (Dolby 2001).

## 5.6 Discussion

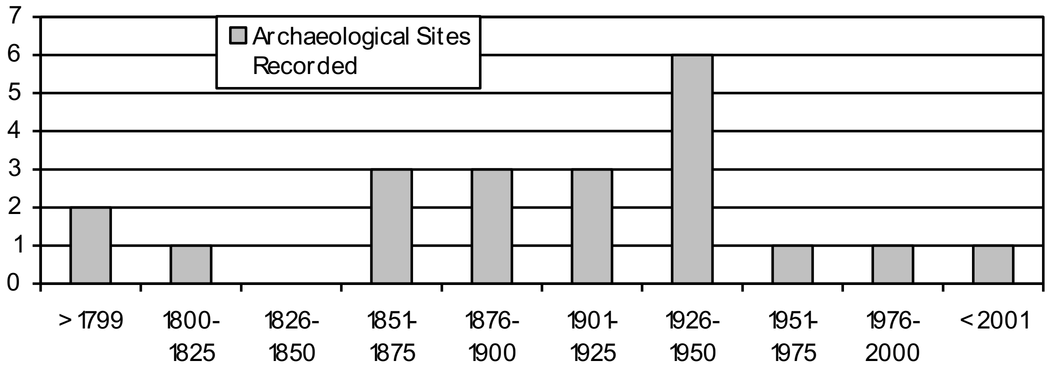
The results of our research align well with the pattern of cave archaeology seen from other parts of the country. Simply said, quarrying operations over a period of several centuries in the Carboniferous and Magnesian limestone study areas have produced a number of nationally important finds fairly typical of the resource in Britain more broadly. Ranging from Pleistocene fauna and lithic industries to Neolithic burials and a Roman coin hoard, archaeological evidence produced from limestone quarries provides an addition picture of human-environmental interaction across a considerable time span of human history.

While the character of the resource is broadly expected, a number of points deserve discussion. One noticeable pattern from the archival record is that Pleistocene evidence, which forms over half of the resource, is largely limited to faunal evidence. It is possible that certain bone assemblages are unrelated to prehistoric activity, however, it is equally likely that we are simply missing a good deal of the evidence. We should keep in mind that the potentially destructive capacity of quarrying combined with relatively poor archaeological recording strategies employed during the early history of the discipline (when the majority of sites were found) may not be favourable for detecting the more ephemeral nature of human signatures, such as micro-debitage or cut marks on bone. What is more, as much of Palaeolithic archaeology attempts to contextualize human activity in a fluctuating environment, and to understand adaptation strategies, it is crucial to understand how past environments changed over time. Coming to grips with different hunting strategies, for example, requires not only an understanding of stone tool technologies, but also knowledge about the kinds of species available. Therefore, it is crucial to assess all bone assemblages in order to inform the development of models about past human behaviour.

In addition to the archaeological evidence, other patterns have emerged relating to the history of the quarrying industry itself. Most obviously the history of development of quarrying has had a direct impact on our knowledge of deeply buried cavities. That such extensive 'ossiferous caverns' or 'bone caves' were not discovered in the eighteenth and early part of the nineteenth century, when scholarly interest in archaeology and geology emerged, is not surprising considering that most of the cavities were deeply buried. Of interest is the clear relationship between the discovery of buried cavities and the advent of industrial scale quarrying in the late nineteenth and early twentieth centuries. In fact, while commercial quarrying can be traced back to the development of turnpikes and canals in the late eighteenth century, large scale enterprises did not truly get off the ground until the development of the railways (Boden 1963) and blasting technology (Gunn and Bailey 1993) in the late nineteenth century. While these advancements in technology facilitated the establishment of workings such as Dove Holes Quarry near Buxton, capable of mining massive quantities of limestone, they also facilitated the discovery of buried caves and fissures in unprecedented numbers (Dawkins 1903)(**Table 2**).

However, our research also complicates the simplistic correlation that greater numbers of larger quarries will in all likelihood expose more cave archaeology. A less optimistic trend is evident in the history of discovery after the introduction of high explosive technology in the 1950's. If black powder technology, introduced in the late nineteenth century, improved the amount of rock liberated from the quarry face, then the intensive shock waves of high explosives have increased this capability by many times. While this has spelled considerable advantages for increasing the size of the blast pile and the shape and size of limestone fragmentation, it would also seem to have lessened the possibility of finding caves. The fact that fewer archaeology-bearing cavities have been reported from quarries over the later part of the twentieth century to the present day (14% of the total number of sites) than the first part (43%) may well correlate to this shift in technology, meaning that some cavities, particularly smaller ones, will simply be erased from the bedrock geology.

**Table 2:** Number of cave related sites discovered at limestone quarries from the study area.




In general, our findings are in agreement with others who have shown how quarrying has led to an increase in our knowledge of cave archaeology and related earth heritage issues (e.g. Ellis et al 2007; Last 2003; Prosser 2003). While limestone quarrying and the conservation of archaeological and earth heritage may not appear compatible, considering the destructive capacity of quarrying, it is clear that it has also been instrumental in exposing archaeological and associated information that would otherwise not have been known. However, our findings also show that quarrying is not unreservedly positive for archaeological knowledge. The introduction of high explosive technology has clearly made quarrying more efficient; but, it has also made the survival of cavities less likely, an issue that we will return to below.

# 6 ASSESSING METHODS OF ARCHAEOLOGICAL PROSPECTION

Demand for crushed limestone aggregate and industrial grade limestone in the UK continues to drive the expansion of quarries. To appreciate the scale of current production, it is useful to draw some comparative statistics: in 1955 the UK produced 11 million tons of crushed limestone aggregate alone, rising to 106 million tons in 1986 and falling to a figure of 70 million by 2004 (Taylor et al 2005: 20). In Derbyshire alone, production rose from 3,166,802 tons of limestone in 1954 (Boden 1963: fig I) to 20,247,000 tons by 2004, although this is below historic maximum production levels seen in the 1970's (Taylor et al 2005: 69).

For much of this history, the recording of archaeological finds has been largely due to the benevolence of quarry owners and the persistence of scientists and other interest groups, a system which mirrored the conservation of archaeology across the country more generally. With the introduction of *Planning Policy Guidance 16* (PPG 16) (Department of Environment 1990), at the end of the last century, planning authorities were provided with a new systematic and staged approach for managing finite archaeological resources, including those potentially threatened by quarrying. Since 1990, planning applications to establish or extend quarries have been encouraged to undertake desk-based assessments including historical research and non-intrusive methods such as geophysical survey. Where archaeological potential is found this is followed up by archaeological field evaluations using intrusive methods such as trial trenching. As advocated by PPG 16, archaeological prospecting methods have been successfully employed to assess and if need be mitigate the loss of heritage sites, allowing decisions to be made about how the resource is managed. From a general heritage management point of view the implementation of archaeological assessment has ‘provided a generally effective framework for mitigating the impacts of mineral extraction on archaeological remains’ (English Heritage 2007: 8), but how have current prospecting methods affected our knowledge of the specific case of archaeological caves and fissures?

In this section of the report, we outline the results of research into current techniques used in assessing deeply buried cavities in limestone geology falling within the boundaries of quarry developments. The findings from the first part of this report indicate that while recent discoveries offered salient information to archaeological questions, they have been relatively few and far between. Does this mean that we are finding fewer cavities because the best examples have already been documented, or are current methods simply not addressing the problem of deeply buried archaeology? To help answer these questions we surveyed archaeological ‘grey literature’ in the form of desk top assessments, geophysical reports and archaeological excavations held at SMRs or HERs in Derbyshire, Nottinghamshire and South Yorkshire as well as through consulting with other expert individuals and organisations. As we will discuss below, the emerging picture suggests that current strategies have significant room for improvement.

## 6.1 Desk-based assessments

Desk top assessments concentrate on known historical and archaeological features gleaned through documentation. They may draw from a variety of sources including previous archaeological work in the form of finds data bases and reports as well as historical information such as maps, articles or monographs. The method is rarely exclusive, and often serves to inform more intensive site surveys or excavations. The fact that desktop assessments work exclusively with documentary evidence means they can only be as good as the documentation they are based on. For periods which we have little in the way of previous work, particularly more remote periods, desk top methods may not be reliable in determining the accuracy of the resource, as they depend on baseline information which is incomplete at best (Bates and Wenban-Smith 2005). In our assessment, it is therefore not surprising that such literature surveys are almost entirely focused on surface features and other known archaeology, not the potential for buried caves and fissures, although a few studies stand out which have integrated geological information at the desk-based stage (see Collcut 1999; Davies 2005; Oliver 2008). In some cases even published sources can be overlooked, leading to a blind spot with regard to assessing caves and fissures. For example a recent assessment carried out at the Hope limestone and shale quarries carried out exemplary research on known surface features and finds, such as Roman archaeology (Chadwick 2002), but appears to have overlooked the well-documented Neolithic burial site at Treak Cliff cavern (Armstrong 1926), a cave which also appears on Ordnance Survey maps.

If desk based assessments seem to be limiting, one aspect of this method may yet prove to be more positive. In a single case, air photo analysis prior to the development of motorway services in the Magnesian limestone revealed ‘fuzzy marks’ suggesting ‘natural cracks and fissures’ (Newman et al 1996). As is so often the case, however, nothing beyond a vague description of the presumed cavities was attempted, a situation which largely mirrors our findings with regard to other methods,

## 6.2 Site Evaluations

Following desk-based assessment, should the potential for archaeological remains be considered present, an archaeological field evaluation is normally undertaken.

The methods employed take a variety of forms and will typically be guided by previous desk-based research. In the main, site evaluations may employ survey methods, including geophysical survey, and frequently depend on trial trenching to assess subsurface finds.

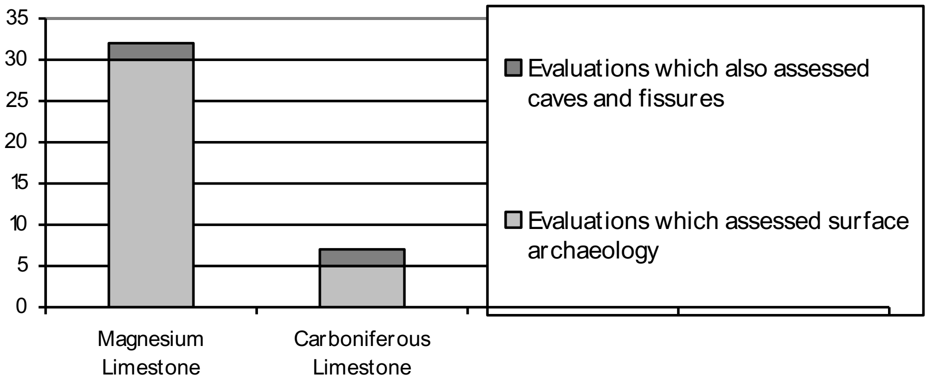
In many cases, an element of surface survey forms the basis to assess further archaeological potential. This may take the form of topographical survey (e.g. Badcock 2004: Motterhead 2004) field walking (e.g. ARCUS 1994) or more casual forms of site visit. While this method may be valuable for establishing the presence of visible features not documented by sources, such as OS maps, or landscape characterizations, because they are strictly concerned with features visible on the surface, they tend to shed little if any light on the situation below ground.

More commonly, in addition to the methods described above, geophysical survey forms a baseline from which to assess buried features. In addition to locating archaeology, geophysical surveys conducted in the Carboniferous and Magnesian limestone have historically yielded regular evidence of subsurface geology. In fact, in a significant number of cases, they rightly identify geological interruptions, duly interpreting them as 'anomalies'. In a majority of cases (6 out of 10 instances where geophysical survey was carried out), archaeologists suggested more detailed causes for the irregularities. Circular and sub-circular features were attributed to being 'hollow pits', 'natural depressions', 'water seepage' or 'solution holes' (e.g. Collcut 1999; GeoQuest 1994a 1994b; Holbrey 1992; Nicholas 1998). In other instances, formations which had a clear linear arrangement were deemed to be 'erosion gullies', 'ice fracture', 'jointing' or indeed 'fissures' (GeoQuest n.d.; Geoquest 1994b; Holbrey 1992; Mineral Planning Group 1993; Pine 2002; WYAS 2001). In all of these cases, features have been identified as voids full of sediment of unknown date, yet have not been investigated to determine their archaeological value.

One way of taking this would be to applaud the recognition of geological signatures, thereby extinguishing the possibility that subsurface features are human-made and terminating the need for further investigation. However, in the majority of cases it is also telling of another phenomenon. The vagueness of much terminology and the fact many determinations remain speculative, suggests that archaeologists feel that such assessments are beyond the interests of archaeology and heritage planning guidelines, therefore excusing a need for investigation. Such statements draw a clear – if very simplified – line between the responsibilities of archaeology and those of geology.

Once the possibility for archaeology is determined through a desktop assessment, geophysical survey or both, it is common to employ trial trenching to expose buried artefacts and features. As in the pattern noted above, trenching and other forms of excavation routinely uncovered geological 'anomalies', sometimes confirming tentative geophysical assessments, while other times revealing formations not previously noted. Following established practice, excavations typically proceeded until deposits could be firmly attributed a cultural or natural origin, however, in all instances where a limestone cavity was encountered, i.e. a sediment filled fissure, investigations ceased, implying there was little of interest in deeply buried sediments. For example, trial trenching on land to be included within Skelebrook Quarry suggested 'depressions' in the bedrock were 'natural', but did not determine their depth nor assess the nature of the infill (Nicholas et al 1998; WYAS 1996). At Hazel Lane Quarry a similar strategy was used to test features believed to be cultural, however, investigation stopped once a decision was made that they were natural soil-filled depressions in solid bedrock (Geoquest 1994b). Similarly at Harry Croft Quarry 'cracks and fissures' were found in the limestone, yet again, because they contained ‘a remnant subsoil layer’ (SYAU 1996), the decision was made to halt further investigations. To put this simply, the evidence suggest that field evaluations are presently not considering that sediments found in voids may be of much later date and may contain archaeological resources.

**Table 3:** Number of archaeological assessments carried out on quarry extensions (or similar developments).




| |
|---|
| *Evaluations which assessed surface archaeology* |
| Adams (1993); ARCUS (1994); Aitcheson (2000, 2001); *Archaeology in South Yorkshire* (1995); Beelow Quarry (n.d.), Badcock (2004), Cumberpatch (n.d.) Gardner (2005), GeoQuest (1994a, 1994b, 2004, n.d.): Holbrey (1992); Lines (2001a, 2001b, 2001c); Lines et al (2003); Mills Whipp Partnership (1999); Motterhead (2004); Newman et al (1996); Nicholas et al (1998); Pine (2002); *Reclamation of Nearcliff Quarry* (2004); Sidebottom (1999); Taylor (2002a; 2002b); Taylor and Hammon (2006); Trent and Peak Archaeological Trust (1993a, 1993b, 2001); Webb and Burgess ( 2001); Webb et al (2005); WYAS (1996a, 1996b, 1997, 2001) |
| *Evaluations which also assessed buried cavities* |
| Collcut (1999); Davies (2005); Oliver (2008); Willies (2000) |

## 6.3 Discussion

If the grey literature serves as an index of awareness about the potential for deeply buried cavities, then it would seem that archaeologists are largely in the dark about the possibility of cave archaeology. Our results indicate that outside of small number of assessments, heritage assessments of limestone pay very little attention to geological processes beneath the overburden and their implications for archaeology (**Table 3**). The few contributions which fall outside of this appraisal were conducted in places well known for their cave archaeology (Collcut 1999; Davies 2005; Oliver 2008; Willies 2000). Perhaps the most commendable example was conducted by Collcut at Whitwell Quarry adjacent the internationally famous site of Creswell Crags (Collcut 1999). In view of the clear potential for caves and fissures at this site, a range of methods were employed to test for cavities, and this will form the subject of additional discussion below. However, in the vast majority of cases, archaeologists appear to be uninformed about the potentials of the resource which in some cases lies literally beneath their feet.

Given that cave archaeology enjoys a relatively high profile within the discipline – we need look no further to media hype devoted to sites such as Lascaux, Altamira and more recently Creswell Crags, the 'Sistine Chapel' of the ice age, as reported by the *Guardian* (Ward 2004) - why are our methods failing to address this hidden potential? One way of answering this is the simple fact that common beliefs about caves dictate that they have conspicuous entrances, usually located on perpendicular rock faces or steeply sloping ground, the gorge of Creswell Crags being a superb case in point. In classic karst landscapes such as the Dordogne in France, or the Mammoth Cave region in Kentucky, caves are an intrinsic part of the social and cultural landscape. Indeed, it is only in such places that caves can enter national mythologies, as 'objects of superstitious dread' (Carrington 1866: 203), 'sacred spaces' (Bradley 2000) or symbols of reverent nationalism (Alego 2004). Quite simply, to register as objects of affection, aversion or otherwise, they must be 'on display' to the senses. In other words the failure can be attributed to a simple case of 'out of sight, out of mind'. A further candidate for responsibility lies firmly within the discipline itself: archaeological training. Principally concerned with shallow and surface deposits, archaeological training and assessment methods are in the main not suited for addressing the potential of cultural remains below stratigraphy we might rightly assume to be 'sterile'. In fact, while not surprising considering the specialisation of the subject, most fieldwork text books and manuals neglect cave archaeology altogether (e.g. Barker 1993; Roskams 2001), never mind the complexities of assessing deeply buried cavities.

The simple facts of limestone solution betray common expectations. Because cave and fissure systems are promoted through the movement of groundwater along horizontal bedding planes and vertical joints, they 'often do not have a surface expression' (Gibson et al 2004: 35), and are therefore not necessarily restricted to 'typical' karst environments, such as the edges of dry valleys. This means that they may develop under deposits of overburden in areas without significant topography, such as the Magnesian limestone, and typically at depths below most archaeological investigations. One of the most famous cave finds was discovered, by accident, in such circumstances. In 1969 the much celebrated Westbury Cave was exposed in the limestone of the Mendip Hills during quarrying operations. Despite its size, there was little indication of the buried void at ground level. As Stanton (1999: 13) explains 'Prior to the blasting…there was no surface indication of the huge infilled and collapsed cavern beneath', a detail which greatly compromised the quality and quantity of the faunal assemblages which were eventually excavated from the cave system. The first clues of its whereabouts were noted only when the maxilla of an extinct species of rhinoceros turned up in the stone crushing plant (Stringer et al 1999: 4). In the context of this discussion, we need to keep in mind that over geological time, caves often have a fluctuating record of exposure to the surface, and that some cavities, particularly very deep ones, may never have been open to the surface.

Although finds of scientific interest have provoked changes in planning in the past, since the Westbury finds over three decades ago, no new guidelines have been adopted, even in cave-riddled landscapes such as the Mendips (Somerset Historic Environment Record 2007). As reflected in the vast majority of assessments we have studied for the Carboniferous and Magnesian limestone of central northern England, strategies used to assess the likelihood of limestone cavities and their archaeological significance have strayed little from this plotline. Rather, as we have illustrated, archaeological training tends to eschew geological processes any deeper than the bottom of cuts and deposits with clear surface relationships. While some archaeologists may be familiar with geological processes and features, we would argue that little is done to understand the implications of such formations for archaeology.

These findings need to be addressed as quarry developments in the Carboniferous and Magnesian limestone continue to exploit existing bedrock. According the Derby and Derbyshire Minerals Local Plan (Derbyshire County Council 2000), while extraction of crushed rock aggregates will not require access to any new reserves in the immediate future, it will nevertheless continue to focus on production in existing permissions within the areas of Buxton and, Wirkswork, with smaller developments proposed for the Magnesian limestone. A similar situation is found within the Doncaster Local Development Framework (2007) covering the Magnesian limestone of South Yorkshire. Here minerals policy indicates that limestone production will focus on existing permissions, although provisions are in place to rethink this strategy in the future. Thus, while new areas of limestone production are not proposed, the expansion of existing quarries remains a threat to potentially buried caves and fissures.

# 7 ASSESSING METHODS FOR THE DETECTION OF CAVITIES

Our analysis of the present situation suggests that the archaeological profession is largely unaware of the resource and methods to assess its potential. As means of addressing this lacuna in archaeological practice, the remainder of this report highlights a range of approaches to gage the potential of archaeology bearing caves and fissures. The methods discussed below are largely complied from established areas of research, principally the geological sciences, but also from archaeology. In many cases they constitute investigative means familiar to archaeologists and simply require that they be adapted to a new form of archaeological potential. In other cases, we have borrowed methods presently employed by consulting geologists and others to assess the quality and quantity of limestone reserves prior to extraction. The recommendations advocated here, do not necessarily represent a significant burden to the developer, as archaeological assessments may well inform quarries where not to dig, as heavily fissured rock may be of less economic interest.

## 7.1 Desk-based methods

### *7.1.1 Historical research*

Desk-based research is seldom exclusively effective as a tool for establishing the presence of deeply buried cavities and fissures. Nevertheless, scrutiny of modern and historic maps and survey of SMR or HER finds data can be useful for establishing baseline information. Even limited archival work on tithe maps, and historic editions of Ordnance Survey maps, can bring useful evidence to light. For example a post 1875 tithe map of Hope parish, straddling the Carboniferous limestone of the Peak District, clearly shows the pot hole cavity where Dawkins (1875) made important discoveries of Pleistocene fauna in the late nineteenth century. This information may then be employed to inform further desk-based work and field assessments. Such an approach was effectively employed by Collcut (1999) during the initial assessment of Whitwell Quarry adjacent the archaeological cave complex at Creswell Crags.

### *7.1.2 BGS memoirs and geological maps*

Because caves and fissures form under particular geological circumstances, assessing the character of limestone beds can help to focus investigations on areas with high potential for cave formation, particularly where dolomite (dolomitic limestone) rests on softer variations of limestone (Aitkenhead et al 1985), or where water breaks through perching layers. Information on particular limestone beds can be obtained at the desk-based phase by drawing on published geological information in the form of British Geological Survey (BGS) memoirs, and associated reports available for most regions of the UK. More pointed evidence is available in the form of BGS 1:10560 scale maps (6 inches to 1 mile), which act as parallel visual illustrations for regions covered by the memoir series. In particular, maps provide high resolution information about the location of natural faulting and therefore provide an indicator about where fissures might be expected. Indeed, combined with an examination of quarry faces (discussed below), faulting information on BGS maps forms an important cornerstone of geological assessments in advance of quarry extensions (e.g. C.L. Associates 2005). Supplementary geological information to BGS resources may also be found by consulting the Association for UK RIGS (regionally important geological site) and Natural England's Sites of Special Scientific Interest (SSSI) data base.

### *7.1.3 Professional reports*

Quarry extensions require detailed geological and hydrogeological exploration prior to drawing up formal plans. Consulting geologists and hydrogeologists are called upon to asses the quality and quantity of underlying limestone as well as to assess environmental impacts on hydrology regimes and regional ecology. As such, quarry applications to local planning departments contain a variety of specialist reports and plans which may be illuminating to the archaeologist. In particular geological overviews may provide the locations of swallet holes or other known cavity systems which influence the water table (e.g. Leake 1994). Where descriptive information is less forthcoming, subsurface topographical maps derived from borehole data may be more revealing. In recent geological assessments, topographical maps characterizing the depth of overburden at different locations in the site may be used to provide quarry operators with information about the most accessible stone. However, such plans may also be used to highlight fissured ground and palaeochannels, which cut the surface of limestone bedrock. Such an instance was revealed in our research on quarrying applications within the Magnesian limestone. In this case a palaeochannel up to 20 meters deep had eroded the underlying bedrock providing a context where cavity formation might be expected. Where archaeologists are working on behalf of the quarrying industry, company or consultant geologists may also be available for further assistance.

### *7.1.4 Borehole data*

Based on the documentary sources analysed, one of the most effective means of assessing buried caves and fissures is through using Borehole data itself. Derived from deep geological testing to determine the quality of limestone reserves, boreholes are typically dug using a hydraulic drill. As the drill proceeds through different layers of stratigraphy, rock chips and sediment are blown to the surface where mineral content from different stratigraphic layers may then be measured. When cavities are encountered, rock fragments frequently fail to reach the surface as they become trapped in the void. As reflected in the quarry applications and supporting geological assessments we surveyed from local planning offices, this phenomenon is commonly registered stratigraphically on borehole data sheets using terminology such as 'crack no returns' (Williams 1980), or 'no returns at interface' (AIG 2000). Where cavities form a major feature of underlying geology they may be mapped in profile and appended to data sheets (e.g. Tarmac 1975). As Barker (1993: 69) notes, boreholes have been used by archaeologists, particularly in urban sites, to understand the nature and depth of cultural stratigraphy. By adapting this approach to borehole data from limestone bedrock, they can also be of value for locating air-filled or sediment choked voids.

The BGS holds data on more than 10,000 boreholes drilled throughout the UK and these are commonly consulted by minerals companies to form the basis of quarry extensions. In addition, minerals companies regularly commission new boreholes as a means of assessing local conditions, and derived data may appear as supplementary evidence in planning applications, making them relatively easy for archaeological contractors to review. Our research found this a generally effective way of establishing the location of cavities.

While a potentially revealing method, borehole data is not without its shortcomings. In some cases data sheets may simply outline the general mineral content of limestone beds ignoring cavities, while in other cases limestone is ignored all together if minerals other than limestone form the basis of exploration. For example, the majority of existing borehole data held by the BGS on the Magnesian limestone is focused on underlying coal deposits rather than the relatively thin near surface limestone beds.

## 7.2 Field Evaluation

### *7.2.1 Assessing the quarry face*

Perhaps the most expedient form of field assessment is surveying the quarry face. Existing quarry faces have historically formed an important means for understanding the geological history of different regions (Ellis et al 2007). Like archaeological stratigraphy, quarry faces can be a revealing window into the history of cavity formation. In particular, observation, detailed mapping and analysis represent one of the principal means employed by hydrogeologists to consider the impact of quarrying on groundwater flow (e.g. C.L. Associates 2005). Even an expedient site visit can quickly bring to light open or truncated voids, commonly recognized through brecciated surfaces, or fissures choked with sediment, which may be a positive indicator for cavity filled geology and the potential for archaeological finds. This method has been recently used, with great effect, to assess the potential of caves and fissures exposed in a disused quarry near Doncaster (**Plate 2**) (Davies 2005).

**Figure 6:** Disused quarry, Don Gorges, near Conisbrough, South Yorkshire, containing a large cave, with eroding fine grained sediments and occasional larger stone (photograph by Glyn Davies).

### *7.2.1 Geophysical methods*

Geophysical surveys are commonly employed in archaeology and typically involve the use of magnetometry and electrical resistivity. While these techniques are used to assess near surface archaeology, such as buried ditches or metal objects, they routinely pick up 'anomalies' where the underlying geology dips down. They may therefore provide a useful prospecting tool for establishing the whereabouts of indicative features which may be associated with buried caves or fissures. Limestone has a very low magnetic susceptibility and thus hollows infilled by sediment with a higher susceptibility will be associated with higher magnetic readings (Gibson et al 2004). As we have previously discussed, archaeological assessments surveyed in this research revealed that magnetometers, the most commonly employed technology, frequently register the location of natural hollows, cracks or pits produced through natural faulting or limestone solution. Combined with a basic knowledge about the potential implications of such features, magnetometry can provide a useful means of locating sub-surface irregularities in the bedrock, offering baseline field information for further subsurface testing.

Electrical resistivity is thought to be generally less successful in limestone (Chamberlain et al 2000); however, this method has been shown to be particularly effective in locating clay or water filled cavities (Stierman 2004). Research conducted in eastern Ireland by Gibson et al (2004), showed how using a multi-core cable and 25 electrodes it was possible to map a collapsed cave feature approximately 70 meters wide and 25-30 meters deep under a 10 meters of Quaternary glacial sediments (see also Monteiro Santos and Andrade Afonso 2005). While such a survey programme is more complex than the traditional 2 electrode technique used to survey large areas, the method may be useful for gaining high resolution information about keyhole study areas which are suspected of sealing buried cavities.

Perhaps the most effective for subsurface detection and for delineating the shape of cavities, is through ground penetrating radar (GPR). A recent study of this technique (Chamberlain et al 2000) carried out on karstic formations in Devon has recorded a reflection anomaly, interpreted as a large subterranean void, in a region known for extensive cave systems. The most important choice when carrying out a survey is the selection of radar frequency as lower frequencies (10-300MHz) allow depth penetration to several tens of meters, but will not detect smaller anomalies. While GPR is less useful as a form of prospection, due to its high cost and relative bulkiness, it is considered accurate to between 20 and 30 meters below ground surface, and may therefore provide detailed metric information about buried features in areas with high potential.

#### *7.2.1 Subsurface testing*

Once assessments are made about the character of underground conditions, methods such as test pitting or auguring may be used to provide detailed information about the contents and relationships of cavities determined through non-intrusive methods. Test pitting and trial trenching is already a commonly employed technique for determining the nature of features visible at the surface or for shedding light on cultural or natural features revealed through geophysical surveys. For this method to be effective, however, investigations must proceed beneath the head of the bedrock into hollows and other voids to assess the nature of sedimentation and whether there is evidence of associated cavity systems.

### 7.3 Discussion

Following the basic tenets of PPG 16, a phased approach should be adopted beginning with desk-based assessment and proceeding to field evaluation where a strong potential for archaeology and related remains exists. Such a strategy should begin with magnetometry or quarry face assessments (where in existence) to determine the subsurface character of the land to be developed. Where geological potential exists, this might be followed up by test pitting to assess whether hollows are actually closed pits, or deeper solution holes, supplemented by auguring to explore deeper sediments and the possibility of open voids. Where caves systems are suspected, the use of ground penetrating radar or resistivity methods is suggested. In extreme circumstances, where evidence is particularly promising and where conditions permit, full excavation techniques can be considered (for an outline protocol, see for example Griffiths and Ramsey 2005).

## 8 CONCLUSION

The caves and fissures of the north central England provide a valuable resource for the conservation of archaeological and paleontological materials. Without their heightened capabilities of preservation, we would know considerable less about the archaeology and palaeoenvironmental conditions of the region, particularly early prehistory. As we have discussed at length in this report, while many caves are open to the surface, many more are exposed only in limestone quarries and other forms of industrial scale bedrock modification. Quarries have clearly been crucial in helping to tell the story of human-environment relations in Britain. This is attested by the large number of archaeological cave remains exposed through quarrying operations in the region, going back to at least the upper Palaeolithic and possibly earlier. However, as quarrying is essentially a destructive process, the industry is potentially as threatening as it is productive to the goals of archaeological research and conservation. And as extractive techniques become more efficient, we have also found that there is a correlation with fewer and fewer archaeological finds coming from modern workings.

Furthermore this report has outlined the current state of archaeological assessment in contexts of limestone quarry development. According to our archival surveys of grey literature, the vast majority of professional archaeologists are unaware, or have little knowledge about the vulnerability of potential of caves systems in relation to bedrock disturbances. As we have shown, failure to expect the possibility of caves has had serious consequences on archaeological and environmental resources, as perhaps best exemplified by the destruction of large parts of the famous site of Westbury cave. The present situation is not without way forward to mitigate the loss of such information. Education is obviously a priority, as knowledge of the potential for the existence of caves is half the battle. Once archaeological assessments build into their investigative strategies the possibility of the existence of caves and fissures, the appropriate desk-based methods, followed by field work, as outlined here, may help to significantly reduce the loss of this nationally important resource.

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## APPENDIX 1: LIST OF LIMESTONE QUARRIES IN DERBYSHIRE, NOTTINGHAMSHIRE AND SOUTH YORKSHIRE ACTIVE AS OF 2004/2005

| Quarry | Operator | Products | Reference |
|---|---|---|---|
| Ashwood Dale Quarry, Buxton, Derbyshire | Omya UK Ltd<br>Ashwood Dale<br>Buxton<br>Derbyshire<br>01298 213840 | Carboniferous limestone: crushed stone; coated stone, concrete products | www.quarryed.co.uk 2004 |
| Ballidon Quarry, Ballidon, Derbyshire<br>SK 200 555 | Tarmac Central Ltd<br>Ballidon Quarry<br>PO Box 6<br>Ashbourne<br>Derbyshire<br>DE6 1GU<br>01335 390301 | Carboniferous limestone: crushed stone | Cammeron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Breedon Hill Quarry, Breedon-on-the-hill, Leicestershire/Derbyshire | Ennstone Johnston Ltd<br>Breedon on the Hill<br>Derby, Derbyshire<br>DE73 8AP<br>01332 862254 | Carboniferous limestone: crushed stone; dimension/lump stone | www.quarryed.co.uk 2004 |
| Brierlow Quarry (Hindlow Quarry), Buxton, Derbyshire | Lhoist UK Ltd<br>Hindlow<br>Buxton<br>Derbyshire<br>SK17 0EL<br>01298 768600 | Carboniferous limestone: crushed stone, industrial limestone, lime | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Bolsover Moor Quarry (Whaley)<br>SK 500 716 | Tarmac Central Ltd<br>Bolsover Moor Quarry<br>Whaley Road<br>Bolsover<br>Chesterfield<br>Derbyshire<br>S44 6XE<br>01246 823141 | Magnesian limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Bone Mill Quarry (Ryder Point, Golconda)<br>SK 256 547 | Longcliffe Quarries Ltd<br>Ryder Point Quarries<br>Ryder Point<br>Hopton<br>Derbyshire | Carboniferous limestone: crushed stone; dimension/lump stone | Cameron et al (2005)<br>www.quarryed.co.uk 2004 |

| Quarry | Operator | Products | Reference |
|---|---|---|---|
| Brassington Moor Quarry (Longcliffe, Griffeton Wood)<br>SK 237570 | Longcliffe Quarries Ltd<br>Brassington Moor Quarry<br>Brassington<br>Matlock<br>Derbyshire<br>DE4 4BZ<br>01629 540284 | Carboniferous limestone: crushed stone | Cameron et al (2005) |
| Cadeby Quarry<br>SK 521 002<br>01709 867474 | Lafarge Aggregates<br>Cadeby Quarry<br>Garden Lane<br>Cadeby<br>nr Doncaster<br>South Yorkshire<br>DN5 7SN | Magnesian limestone: crushed stone | Cameron et al (2005) |
| Cloud Hill Quarry, Derbyshire | Ennstone Johnston Ltd<br>Breedon on the Hill<br>Derby, Derbyshire<br>DE73 8AP<br>01332 862254 | Carboniferous limestone: crushed stone; dimension/lump stone | www.quarryed.co.uk 2004 |
| Crich Quarry<br>SK 343 555<br>01773 852542 | Barden Aggregates - Midlands<br>Crich Quarry<br>Matlock<br>Derbyshire<br>DE4 5DP | Carboniferous limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Darlton Quarry<br>SK213 756 | Tarmac Central Ltd<br>Darlton Quarry<br>The Dale<br>Stoney Middleton<br>Derbyshire<br>S32 4TR<br>01433631227 | Carboniferous limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Dene Quarry<br>SK 288 563 | Tarmac Central Ltd<br>Dene Quarry<br>Cromford<br>Matlock<br>Derbyshire<br>DE4 3QS<br>01629 822104 | Carboniferous limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Dove Holes Quarry | Cemex North East<br>Dale Road Dove Holes<br>Buxton<br>Derbyshire<br>SK17 8BH<br>T: 01298 77531 | Carboniferous limestone: crushed stone, industrial limestone, concrete products | Cameron et al (2005) |

| Quarry | Operator | Products | Reference |
|---|---|---|---|
| Dowlow Quarry | Lafarge Aggregates Ltd<br>Sterndale Moor<br>Dowlow<br>Buxton<br>Derbyshire<br>SK17 9QF<br>UK | Carboniferous limestone: crushed stone, industrial limestone, lime | Cameron et al (2005) |
| Goddards Quarry<br>SK 221 754 | Goddards Quarry<br>Cemex North East<br>Middleton Dale<br>Stoney Middleton<br>Hope Valley<br>Derbyshire<br>S32 4TR<br>0115 922 0660 | Carboniferous limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Grange Mill Quarry<br>SK 241 573 | Ben Bennet Jr Ltd<br>Grange Mill Quarry<br>Wirksworth<br>Derbyshire<br>DE4 4HD<br>01629 540334 | Carboniferous limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Harrycroft Quarry<br>SK 534 818 | Harrycroft Quarry<br>LaFarge Aggregates<br>GrangeFarm Road<br>Lindrick Dale<br>Warsop<br>Nottinghamshire<br>S80 3EH<br>01909 472623 | Magnesian limestone: crushed stone | Cameron et al (2005) |
| High Rake Quarry (Bow Rake, Longstone Edge)<br>SK 208 733 | Glebe Mines Ltd<br>High Rake Quarry<br>Cavendish Mill<br>Stoney Middleton<br>Hope Valley<br>Derbyshire<br>S32 4TH<br>01433 630966 | Carboniferous limestone: crushed stone | Cameron et al (2005) |
| Holme Hall Quarry (Glen Quarry, Stainton)<br>SK 548 952 | Tarmac Limited - Midlands<br>Holme Hall Quarry<br>Stainton<br>Maltby<br>Rotherham<br>S66 7RH<br>01709 814491 | Magnesian limestone: crushed stone | Cameron et al (2005) |
| Hope Quarry<br>SK 233 584 | Lafarge Cement UK<br>Hope Works, Hope<br>Hope Valley<br>Derbyshire<br>S33 6RP<br>01433 622200 | Carboniferous limestone: crushed stone, cement | www.quarryed.co.uk 2004 |

| Quarry | Operator | Products | Reference |
|---|---|---|---|
| Ivonbrook Quarry | Bardon Aggregates Midlands<br>Grangemill<br>Wirksworth<br>Derbyshire<br>DE4 4HY<br>01629 650275 | Carboniferous limestone: crushed stone | www.quarryed.co.uk 2004 |
| Middleton Mine (Hopton Quarry)<br>SK 278 555<br><br>(closed 2006?) | Omya UK Ltd<br>Middleton Mine<br>Middleton<br>Wirksworth<br>Derbyshire<br>DE4 4LR<br>01629822171<br>01629 822222 | Carboniferous limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Milltown Quarry<br><br>(closed – www.mindat.org) | Bardon Aggregates – Midlands<br>Milltown Ashover<br>Chesterfield<br>Derbyshire<br>S45 0EY<br>01246 590212 | Carboniferous limestone: crushed stone | www.quarryed.co.uk 2004 |
| Moss Rake Quarry<br>SK 152 803 | Netherwater Environmental Ltd<br>Moss Rake Quarry<br>Moss Rake,<br>Hope Valley<br>Derbyshire<br>S33 9HB<br>01433623663 | Carboniferous limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Nether Langwith Quarry (Boons Hill, Cuckney)<br>SK 541 696 | Lafarge Aggregates<br>Nether Langwith Quarry<br>Boons Hill Farm<br>Shirebrook<br>Nottinghamshire<br>NG20 9JQ<br>0870 336 8436 | Magnesian limestone: crushed stone | Cameron et al (2005) |
| Once-a-week Quarry | Mandale Stone Co Ltd<br>Old Station Yard<br>Rowsley<br>Matlock<br>Derbyshire<br>DE4 2EJ<br>01629 735507 | Carboniferous limestone: building stone | www.quarryed.co.uk 2004 |

| Quarry | Operator | Products | Reference |
|---|---|---|---|
| Slinter Top Quarry<br>SK 283 570 | Slinter Mining Co Ltd<br>Slinter Top Quarry<br>Chestnut House<br>Cromford<br>Matlock<br>Derbyshire<br>DE4 3QU<br>01629 822498 | Carboniferous Limestone: crushed stone | www.quarryed.co.uk 2004<br><br>Cameron et al (2005) |
| Shining Bank Quarry<br>SK 228 650<br>01629 636366 | Cemex UK Ltd<br>Shining Bank Quarry<br>Alport<br>Bakewell<br>Derbyshire<br>DE4 1LE | Carboniferous Limestone: crushed stone | Cameron et al (2005)<br><br>www.quarryed.co.uk 2004 |
| Topley Pike Quarry, Buxton | Bardon Aggregates - North England<br>Nr Buxton<br>Derbyshire<br>SK17 9RE<br>01298 22351 | Carboniferous Limestone: crushed stone, cement | www.quarryed.co.uk 2004 |
| Tunstead Quarry (Old Moor)<br>SK109 739 | Tarmac Ltd North Western<br>Tunstead Quarry<br>Wormhill<br>Buxton<br>Derbyshire<br>SK17 8TG<br>01298 768 555 | Carboniferous Limestone: Industrial limestone, lime | Cameron et al (2005)<br><br>www.quarryed.co.uk (2004) |
| Warmsworth Quarry<br>SE 537 005 | WBB Minerals<br>Warmsworth Quarry<br>Warmsworth<br>Doncaster<br>DN4 9RG<br>01302 853354 | Magnesian Limestone: crushed stone | Cameron et al (2005) |
| Whitwell Quarry<br>SK 530 753 | Lafarge Aggregates<br>Whitwell Quarry<br>Whitwell Works<br>Southfield Lane<br>Whitwell<br>Worksop<br>Nottinghamshire<br>S80 3LJ<br>01909 720751 | Magnesian Limestone: crushed stone | Cameron et al (2005) |

| Quarry | Operator | Products | Reference |
|---|---|---|---|
| Yellow Stone Quarry<br>SK 537 522 | Yellow Stone Quarry<br>Primrose Hill<br>Quarry Lane<br>Linby<br>Nottinghamshire<br>0115 9680272 | Magnesian Limestone: crushed stone | Cameron et al (2005) |

# APPENDIX 2: HISTORICAL REFERENCES TO ARCHAEOLOGICAL AND PLEISTOCENE FINDS DISCOVERED IN THE CONTEXT OF QUARRYING, MINING & RAILWAY CUTTING

(Shaded entries refer to significant finds outside of the main study area)

| **Place** | **Find Date** | **Finds Discovered & Notes** | **References** |
|---|---|---|---|
| Ballidon Quarry, near Brassington | >1960 | Flint tool | Derby Museum, Record Number 1978-952/(19). |
| Balleye Mine, Worksworth (lead mine) | 1663 | Bones and Teeth of an "elephant" | Bateman, T. 1861. On the Extinct Animals of Derbyshire in their Relation to Man. *Reliquary*, 6: 225-229.<br>Buckland, W. 1823. *Reliquiane Diluvianae*, pg. 61.<br>Dawkins, W.B. 1874. *Cave Hunting*. Macmillan & co. pg. 285.<br>Heath, T. 1882. Pleistocene Deposits of Derbyshire and its Immediate Vicinity. *Derbyshire Archaeological Journal*, 4: 161-178. |
| Bodens Quarry Cave, Matlock | | "in a declivity about 20 feet above the river Derwent on the east side of the Heights of Abraham".<br>Finds included bones of rhinoceros, hyena, bear and bison | Law, R. 1880. On Bones of Pleistocene Animals Found in a Broken-up Cave in a Quarry Near Matlock, Derbyshire. *Transactions of the Manchester Geological Society* 15: 52-55. |
| Cliff Woods, near Conisbrough (railway cutting) | 1906 | Antler of cervus elephas and two bones of rhinoceros | Corbett, H.H. 1906. *The Naturalist* 31: 109.<br>Howes, C.A. n.d. When Mammoths and Woolly Rhinos Lived at Wormsworth: Ice Age Mammals in the Don Gorge. Unpublished Manuscript, Doncaster Museum. |
| Conisbrough, Limestone Crags (water works cutting) | 1878 | Radius, tibia, humorous of woolly rhinoceros, metacarpal of horse, tibia of mammoth | *Doncaster Chronicle*, July 9th, 1878.<br>Howes, C.A. n.d. When Mammoths and Woolly Rhinos Lived at Wormsworth: Ice Age Mammals in the Don Gorge. Unpublished Manuscript, Doncaster Museum. |
| Cowdale Quarry, Kingsterndale | >1932 | Neolithic axe<br>On loan to Buxton 1932-1982. | Buxton Museum, Record Number 575. |

| Place | Find Date | Finds Discovered & Notes | References |
|---|---|---|---|
| Crawley Rocks Cave, near Swansea (quarry) | 1792 | Bones of “elephant”, rhinoceros, ox, stag, hyena | Buckland, W. 1823. *Reliquiane Diluvianae*, pg. 80. |
| Dove Holes, Buxton (Victory or Victoria quarry) | 1901 | Bones of hyena, cat, mastodon, horse, deer | Dawkins, W.B. 1874. *Cave Hunting*. Macmillan & co. pg. 285.<br>Dawkins, W.B. 1903. On the Discovery of an Ossiferous Cavern of Pliocene Age at Doveholes, Buxton (Derbyshire) *Quarterly Journal of the Geological Society*, 59: 105 – 129.<br>Spencer, H.E.P. and Melville, R.V. 1974. Pleistocene Mammalian Fauna of Dove Holes, Derbyshire. *Bulletin of the Geological Survey of Great Britain* 48: 43-53. |
| Dream Cave, near Hopton, Worksworth (lead mine) | 1822 | Bones of rhinoceros, horse, ox and deer | Buckland, W. 1823. *Reliquiane Diluvianae*, pg. 62.<br>Heath, T. 1882. Pleistocene Deposits of Derbyshire and its Immediate Vicinity. *Derbyshire Archaeological Journal*, 4: 161-178. |
| Fairy Cave Quarry, Mendips | 1888<br>1952 | Pot sherds of Iron Age, medieval and other unidentified types found at the cave<br>Quarrying opened up further caves | Chipchase, N. 1977. ‘History of Discovery and Exploration’. In G. Price (ed.) *Fairy Cave Quarry, A Study of the Caves*, pp. 9-15. The Cerberus Spelaeological Society. |
| Grinlow Quarry, near Buxton | 1895/6 | Scraper<br>“Found whilst baring on Grinlow Quarry” | Buxton Museum, Record Number 3501.<br>Turner, W. 1899. Ancient Remains Near Buxton: The Archaeological Explorations of Mica Salt. C.F. Wardley: Buxton (Cat 2, no. 32). |
| Harpur Hill, near Buxton (presumed quarry) | 1870 | Granite axe | Turner, W. 1899. Ancient Remains Near Buxton: The Archaeological Explorations of Mica Salt. C.F. Wardley: Buxton (Cat 2, no. 12). |
| Hazelbadge quarry, Bradwell (lead mine) | >1660<br>1973 | Early reference to mammoth teeth taken as trophy but now lost.<br>Same site or nearby site discovered in 1973 during reworking of site. Found mammoth and other large species plus vole, rabbit, arctic lemming etc. | Riley, T. n.d. Hand Written Notes from 1973 & 1977 on Pleistocene Finds at Hazelbadge Quarry. Sheffield Museum.<br>*Sheffield Star*, April 10th, 1073. |

| Place | Find Date | Finds Discovered & Notes | References |
|---|---|---|---|
| Higher Kiln Quarry, Devon | 1939 | Bones of mammoth, elephant, hippo, lion, deer, bear | Peakland Archaeological Society, Field Notes, Buxton Museum, Accession no. 100047/83. |
| Hindlow Quarry, Hindlow | >1932 | Neolithic axes, scrapers, whetstones.<br>This collection was on loan to Buxton between 1932-1982, and may represent one or more discovery events. | Buxton Museum, Record Number 501, 527, 536, 537, 543, 545, 557, 564, 570, 572, 573, 577, 962, 966, 969, 971, 976, 981, 1115.<br>Moore, C.N. and Cummings, W.A. 1974. Petrological Identification of Stone Implements from Derbyshire and Leicestershire. *Proceedings of the Prehistoric Society* 40: 59-78. |
| Hoe Grange Quarry, near Longcliffe | >1905 | Bones of a lion, hyena, wolf, grizzly bear, bison, Irish elk, red deer, fallow deer (2 species), rhinoceros, straight tusked elephant (Elephus antiquis Falconer),<br>Found in a cave ; finds donated by Dr Bemrose | Bemrose, A and Newton, E.T. 1905. An Ossiferous Cavern of Pleistocene Age at Hoe-Grange Quarry, Longcliff near Brassington. *Quarterly Journal of the Geological Society of London* 61(1): 43-63.<br>Derby Museum, Record Number 1928-174/1, 1928-174/2, 1928-174/3, 1928-174/4, 1928-174/5, 1928-174/6, 1928-174/7, 1928-174/8, 1928-174/9, 1928-174/10, 1928-174/11. |
| Kirkdale Cave, Vale of Pickering (quarry) | 1822 | Bones of 200-300 hyena | Buckland, W. 1822. Account of an Assemblage of Fossil Teeth and Bones of Elephant, Rhinoceros, Hippopotamus, Bear, Tiger, and Hyena, and Sixteen other Animals, discovered in a Cave at Kirkdale, in the year 1821… *Philosophical Transactions* Part 1: 459-76.<br>Dawkins, W.B. (1874) *Cave Hunting*, pp. 14, 279-280. |
| Yew Tree Cave, Pleasley Vale, (railway cutting) | 1863 | Lynx, wolf, bison, reindeer and roe deer | Ransom, W.H. 1867. *On the Occurrence of Felis lynx as a British fossil. Report of the British Association for the Advancement of Science (Nottingham 1866)*. Vol. 66.<br>Heath, T. 1882. Pleistocene Deposits of Derbyshire and its Immediate Vicinity. *Derbyshire Archaeological Journal* 4: 161-178. |
| Pleasley Vale, near Mansfield (quarry) | 2001 | Upper Palaeolithic flints<br>From $17^{th}$/$18^{th}$ c quarrying? | Dolby, B. 2001. The Excavation of a Rock Shelter at Stone. *Transactions of the Hunter Archaeological Society* 21: 43-54. |
| Plymouth, “Three caves” (quarries) | 1817, 1820, 1822 | Bone and teeth of rhinoceros | Buckland, W. 1823. *Reliquiane Diluvianae*, pg. 67-68. |

| Place | Find Date | Finds Discovered & Notes | References |
|---|---|---|---|
| Ricklow, Quarry, near Monyash | 1902 | Neolithic axe | Buxton Museum, Record Number 476.<br><br>Moore, C.N. and Cummings, W.A. 1974. Petrological Identification of Stone Implements from Derbyshire and Leicestershire. *Proceedings of the Prehistoric Society* 40: 59-78. |
| Steetly Quarry, (Armstrong Quarry)<br><br>Worksop | 1926<br><br>1976 | Steetly Wood Cave: wolf, fox, bear, reindeer, bison<br><br>Steetly Quarry Cave: animal bones after last glaciation: lynx | Jenkinson, R.D.S. 1984. *Creswell Crags*. British Archaeological Reports, British Series 122. Oxford: B.A.R.<br><br>Jenkinson, R.D.S. and Gilbertson, D.D. 1984. *In the Shadow of Extinction*. Sheffield, JR Collis. |
| Treak Cavern, Castleton (Blue John or flour-spar mine) | 1926 | Human skeletal remains of three individuals, stone axe of probable Neolithic date and animals remains of dog, pig, sheep roe deer, rabbit, water vole. | Armstrong, L. 1926. A Spulchral Cave at Tray Cliff, Castleton, Derbyshire. *Journal of the Royal Anthropological Institute* 53: 123-131. |
| Tunstead Quarry, (Great Rocks Quarry), Wormhill | >1932, 1933 | Neolithic axes, chisel, Spear head, socket axe (>1932); coin: Aureus of Trajan (1933)<br><br>Spear head on loan to Buxton 1932-1982<br><br>Socket axe provenance not clear but suggested to be Great Rocks Quarry | Buxton Museum, Record Number 492, 530, 578, 987, 1066, 1545, 2882.<br><br>493 is apparently described in *I.C.I. Magazine*, March 1933. |
| Windy Knoll Quarry, Castleton | 1870 | Bones of bison, reindeer, wolf, fox and grizzly bear<br><br>Quarry worked out between 1874-76 | Catalogue of the Castleton Museum, c. 1876. Sheffield Museum, Rook Pennington Collection.<br><br>Dawkins, W.B. 1875. The Mammalia Found at Windy Knoll. *Quarterly Journal of the Geological Society of London* 31: 246-255.<br><br>Heath, T. 1882. Pleistocene Deposits of Derbyshire and its Immediate Vicinity. *Derbyshire Archaeological Journa*, 4: 161-178. |

# APPENDIX 3: METHODS USED TO ASSESS THE ARCHAEOLOGICAL POTENTIAL OF CAVES & FISSURES ON QUARRY EXTENSIONS IN CARBONIFEROUS AND MAGNESIAN LIMESTONE

| Site (Developer) | Ass. Date | Methods/Notes | Assess Caves & Fissures? | References |
|---|---|---|---|---|
| Adwick-le-street, Doncaster | 1995 | Surface/subsurface (air photos, geophysical survey) | No: "fuzzy marks" interpreted as natural cracks and fissure in bedrock | Newman, M. A., Badcock, A, Merrony, C. 1996. 'A Desktop Assessment and Geophysical Survey at Adwick-le-street, Doncaster'. In *Archaeology in South Yorkshire 1995-1996*. Sheffield: South Yorkshire Archaeology Service. |
| Ball Eye Quarry, Cromford (Deepwood Mining Company) | 2000 | Surface (desktop) | Yes: recommends further work to assess caves. | Willies, L. 2000. *Archaeological and Speleological Assessment of Ball Eye Quarry, Cromford, Derbyshire*. Unpublished Report. |
| Barnsdale Bar Quarry, Norton, Doncaster | 2003-05 | Surface (fieldwalking), Subsurface (geophysical, trial trenching) | No | Webb, A., Gidman, J. and Roberts, I. 2005. 'Barnsdale Bar Quarry, Norton, Doncaster'. In *Archaeology in South Yorkshire 2003-2005*. Sheffield: South Yorkshire Archaeology Service. |
| Barnsdale Bar Quarry, Norton, Doncaster | 2000 | Subsurface (Geophysical survey; Trial trenching) | No | Webb, A. and Burgess, A. 2001. *Barnsdale Bar Quarry Extension, Norton, Doncaster*. In *Archaeology in South Yorkshire 1999-2001*. Sheffield: South Yorkshire Archaeology Service. |
| Beelow Quarry, Buxton | ? | Surface/subsurface (Watching brief)<br>Located circular depressions, excavated in full. | No | Beelow Quarry, n.d. *Beelow Quarry: An Archaeological Watching Brief*. Unpublished Report. |
| Bolsover Moor Quarry | 1993 | Desktop & design for fieldwork | No | Trent and Peak Archaeological Trust 1993a. *Bolsover Moor Quarry Archaeological Assessment and Evaluation Design*. Unpublished Report. |
| Bolsover Moor Quarry | 1993 | Subsurface (test pits) | No | Trent and Peak Archaeological Trust 1993b. *A Report on the Archaeological Assessment of the Bolsover Moor Limestone Quarry Extension*. Unpublished Report, Trent and Peak Archaeological Trust. |

| Site (Developer) | Ass. Date | Methods/Notes | Assess Caves & Fissures? | References |
|---|---|---|---|---|
| Brassington Moor Quarry, Longcliffe<br><br>(Longcliffe Calcium Carbonates) | 2004 | Surface (Walk-over; desktop), Subsurface (Geophysical) | No | Geoquest 2004. *Geophysical Survey on Areas of Proposed Extension to the Pyro & Aldwark Quarries, Derbyshire*. Unpublished report, Geoquest Associates. |
| Campsal Quarry, Doncaster (Tilcon Ltd.) | 1993 | Surface (desktop), Subsurface (geophysical)<br><br>Archaeological Contractor unknown | No | The Minerals Planning Group 1993. *Planning Application and Environmental Statement in Support of the Proposed Development of a Magnesian Limestone Quarry, Land off Longland Lane, Campsal, Near Doncaster*. Planning application submitted to Doncaster Planning Department. |
| Campbell Quarry, Doncaster | 1992 | Surface (air photos) | No | Adams, M. 1993. 'Archaeological Investigations at Campbell Quarry, Doncaster'. In *Archaeology in South Yorkshire 1992-1993*. Sheffield: South Yorkshire Archaeology Service. |
| Don Gorge, Doncaster (electricity cable route) | 2003-05 | Surface (desktop) | No | Gardner, R.D. 2005. 'Electricity Cable Route, Don Gorge, Doncaster'. In *Archaeology in South Yorkshire 2003-2005*. Sheffield: South Yorkshire Archaeology Service. |
| Dove Holes Quarry, Buxton (RMC Aggregates) | 2004 | Surface (walk-over; topographical survey) | No | Motterhead, G. 2004. *Doveholes Quarry, Doveholes, Derbyshire*. Unpublished report, University of Manchester. |
| Harry Croft Quarry, Aston, Rotherham | 1992 | Subsurface (Geophysical survey; trial trenches)<br><br>Polished stone axe | No: anomalies attributed to ice fracture & water seepage in limestone | Holbrey, R.P. 1992. An archaeological evaluation at Harry Croft Quarry, Aston, Rotherham. In *Archaeology in South Yorkshire 1991-1992*. Sheffield: South Yorkshire Archaeological Service. |
| Hazel Lane Quarry, Hampole<br><br>(Catplant) | 2006 | Surface/Subsurface (Monitored soil stripping)<br><br>Late Neolithic bifacial flaked knife | No | Taylor, A. and Hammon, S 2006. *Hazel Lane Quarry, Hampole*. Unpublished report, Thames Valley Archaeological Services. |

| Site (Developer) | Ass. Date | Methods/Notes | Assess Caves & Fissures? | References |
|---|---|---|---|---|
| Hazel Lane Quarry, Hampole<br><br>(Catplant) | 2002 | Subsurface (excavation) | Yes: anomalies considered filled fissures, but no arch potential assumed | Pine, J. 2002. Hazel Lane Quarry, *Phase D, Hampole, South Yorkshire: An Archaeological Evaluation*. Unpublished Report by Thames Valley Archaeology Services. |
| Hazel Lane Quarry, Hampole<br><br>(Catplant) | 2002 | Surface (field walking) | No | Taylor, A. 2002a. *Hazel Lane Quarry, Hampole, South Yorkshire: An Archaeological Fieldwalking Survey*. Unpublished Report, Thames Valley Archaeology Services. |
| Hazel Lane Quarry, Hampole<br><br>(Catplant) | 2002 | | No | Taylor, A. 2002b. *Hazel Lane Quarry, Phase D, Hampole, South Yorkshire: An Archaeological Evaluation*. Unpublished Report, Thames Valley Archaeology Services. |
| Hazel Lane Quarry, Hampole<br><br>(Catplant) | 2001 | Surface (fieldwalking) | No | Lines, A 2001a. *Archaeological Evaluation by Fieldwalking, Area D, Hazel Lane Quarry, Hampole, South Yorkshire*. Unpublished report, ARCUS<br><br>Lines, A. et al 2003. 'Hazel Lane Quarry, Hampole, Doncaster'. In *Archaeology in South Yorkshire 2001-2003*. Sheffield: South Yorkshire Archaeology Service. |
| Hazel Lane Quarry, Hampole<br><br>(Catplant) | 2001 | Subsurface (soil stripping) | No | Lines, A. 2001b. *Archaeological Recording at Area C, Hazel Lane Quarry, Hampole, South Yorkshire*. Unpublished report, ARCUS<br><br>Lines, A. et al 2003. 'Hazel Lane Quarry, Hampole, Doncaster'. In *Archaeology in South Yorkshire 2001-2003*. Sheffield: South Yorkshire Archaeology Service. |
| Hazel Lane Quarry, Hampole<br><br>(Catplant) | 2001 | Subsurface (trial trenching) | No | Lines, A. 2001c. *Archaeological Recording at Hazel Lane Quarry, Hampole*. Unpublished report, ARCUS<br><br>Lines, A. et al 2003. 'Hazel Lane Quarry, Hampole, Doncaster'. In *Archaeology in South Yorkshire 2003-2005*. Sheffield: South Yorkshire Archaeology Service. |

| Site (Developer) | Ass. Date | Methods/Notes | Assess Caves & Fissures? | References |
|---|---|---|---|---|
| Hazel Lane Quarry, Hampole<br>(Catplant) | 2001 | Subsurface (Geophysical) | Yes: anomalies considered filled fissures, but no arch potential assumed | WYAS 2001. *Hazel Lane Quarry, Hampole, South Yorkshire: Geophysical Survey*. Unpublished Report, WYAS |
| Hazel Lane Quarry, Hampole<br>(Catplant) | 2000 | Surface/Subsurface (desktop assessment; trial trenching)<br><br>Leaf-shaped flake made from core reduction | No | Aitcheson, K. 2000. *An Archaeological Evaluation at Hazel Lane Quarry, Hampole, Doncaster*. Unpublished report, ARCUS<br><br>Aitcheson, K. 2001. Hazel Lane Quarry, Hampole, Doncaster. In *Archaeology in South Yorkshire 1999-2001*. Sheffield: South Yorkshire Archaeology Service. |
| Hazel Lane Quarry, Hampole<br>(Catplant) | 1999 | Desktop (Considered past geophysics and excavations) | No | Sidebottom, P. 1999. *Archaeological Desk-top Assessment on Land Adjacent to Hazel Lane Quarry, Hampole, South Yorkshire*. Unpublished report. |
| Hazel Lane Quarry, Hampole<br>(CSL Surveys) | 1997 | Subsurface (excavation) | No | WYAS 1997. *Hazel Lane Quarry, Hampole, South Yorkshire, Archaeological Excavation*. Unpublished Report, WYAS. |
| Hazel Lane Quarry, Hampole<br>(CSL Surveys) | 1994 | Subsurface (Geophysical Survey) | No | GeoQuest 1994a. *Geophysical Survey of Land North of Hazel Lane Quarry, Hampole, South Yorkshire*. Unpublished Report, Geoquest Associates. |
| Hazel Lane Quarry, Hampole<br>(CSL Surveys) | 1994 | Subsurface (Geophysical Survey) | No | GeoQuest 1994b. *Second Geophysical Survey North of Hazel Lane Quarry, Hampole, South Yorkshire*. Unpublished Report, Geoquest Associates. |
| Hazel Lane Quarry, Hampole | ? | Subsurface (Geophysical Survey) | No | GeoQuest (n.d.) *Geophysical Survey on the Site of a Proposed Extension to Hazel Lane Quarry, Hampole, South Yorkshire*. Unpublished Report. Unpublished Report, Geoquest Associates. |
| Hazel Lane Quarry,<br>Hampole, Doncaster | 1993-95 | Surface/ subsurface (Desktop, gradiometer survey, Test trenching) | No | *Archaeology in South Yorkshire* 1995. Survey and Excavation at Hazel Lane Quarry, Hampole, Doncaster. In *Archaeology in South Yorkshire 1994-1995*. Sheffield: South Yorkshire Archaeology Service. |

| Site (Developer) | Ass. Date | Methods/Notes | Assess Caves & Fissures? | References |
|---|---|---|---|---|
| Hazel Lane Quarry, Hampole | ? | Desktop | No | Cumberpatch, C. n.d. *A Desktop Evaluation of the Archaeological Potential of Land Affected by the Proposed Extension to the Hazel Lane Quarry, Hampole, Doncaster, South Yorkshire*. Unpublished Report. |
| Holm Hall Quarry<br>(Tarmac Quarry Products Ltd.) | 1994 | Desktop assessment; field walking<br>Surface scatters of flint | No | ARCUS 1994. *Desk-Top Study and Archaeological Investigation of the Proposed Northern Extension Area of Holm Hall Quarry*. Unpublished Report, ARUCS. |
| Hope Quarry, Bradwell<br>(CGM Consulting) | 2004 | Surface (Survey located above ground features and past excavation unites) | No | Badcock, A. 2004. *Archaeological Survey of Land at the Limestone Quarry near Dirtlow Rake, Derbyshire*. Unpublished Report, ARCUS. |
| Nearcliff Quarry, Conisbrough | 2005 | Surface (walkover) | Yes: Detailed visual survey of fissures in the quarry rock face | Davies, G. 2005. Archaeological Survey of Nearcliff Quarry, Doncaster. Unpublished Report, ARCUS. |
| Nearcliff Quarry, Conisbrough | 2004 | Surface (desktop, site visit)<br>Archaeological Contractor: Dr Philip Sidebottom | No | *The Reclamation of Nearcliff Quarry by Means of the Removal of Limestone to Provide Stable Quarry Faces, Nearcliffe Quarry, Sheffield Road, Conisbrough, Doncaster* 2004. Planning Application submitted to Doncaster Planning Department. |
| Nether Langwith Quarry, Derbyshire | 2001 | Subsurface (watching brief) | No | Trent and Peak Archaeological Trust 2001. *An Archaeological Watching Brief Undertaken During Overburden Stripping at Nether Langwith Quarry, Derbyshire*. Unpublished Report Available at Derbyshire SMR, Matlock. |
| Old Moor Quarry (Tunstead Quarry) | 2008 | Surface (desktop; walkover survey) | Yes | Oliver, J. 2008. *Desktop assessment and archaeological survey of Old Moor Quarry, Buxton*. Unpublished Report, ARCUS. |
| Skelbrook Quarry,<br>(Darrington Quarries Ltd.) | 1996 | Subsurface (excavation) | No | WYAS 1996. *Skelbrook Quarry, South Yorkshire: Archaeological Excavation*. Unpublished Report, WYAS. |

| Site (Developer) | Ass. Date | Methods/Notes | Assess Caves & Fissures? | References |
|---|---|---|---|---|
| Skelbrook Quarry, (Darrington Quarries Ltd.) | 1996 | Subsurface (geophysical survey) | No | WYAS 1996. *Skelbrook Quarry, South Yorkshire: Gradiometer Survey*. Unpublished Report, WYAS. |
| Skelebrook Quarry, Skelebrook. | 1996 | Subsurface (Geophysical survey; trial trenching) | No: Located depressions in bedrock, trial trenching suggested they were natural | Nicholas, J. Web, A. and Speed, G. 1998. 'A Survey and Evaluation at Skelebrook Quarry, Skelebroke'. In *Archaeology in South Yorkshire 1996-1998*. Sheffield: South Yorkshire Archaeology Service. |
| Tunstead Quarry, Derbyshire | 1999 | Desktop | No | Mills Whipp Partnership 1999. *Tunstead Quarry Derbyshire, Archaeological Baseline Report*. Unpublished Report, The Mills Whipp Partnership. |
| Whitwell Quarry, Derbyshire (Lafarge Aggregates) | 1999 | Surface/Subsurface/Geophysical (Field walking, Test pitting, trial trenching; various ground penetrating techniques) | Yes: Anomalies assumed to be cavities "choked with sediment" but no attempt to test for cultural features. | Collcutt, S.N. 1999. *Romp Application at Whitwell Quarry, Derbyshire: Cultural Heritage Statement*. Unpublished Report, Oxford Archaeological Associates. |