SECTION 1:

IN THE BEGINNING: CLEADON'S GEOLOGICAL ORIGINS

By Brian Young

INTRODUCTION

Most of us have an interest, in some cases a real fascination, with the history of where we live. Perhaps we know our families have lived in the area for many years and we feel part of the place's history, or maybe we are relative newcomers keen to find out more about where we are. Uncovering local and family history is probably more popular today than ever. This is as true of Cleadon as anywhere else.

There are many ways of looking at history and, arguably, many types of history. All have much to tell us, not simply of how things were in the past, but of why things are the way they are now, and perhaps even to guide us into the future. Later sections of this village atlas explore what might at first seem a huge span of time, stretching back through prehistory and evolving into the 21st Century community we know today. However, there is a much longer history at play that takes us back vastly further, millions of years back to a period long before Cleadon, or indeed Britain, as we know it today existed. This is not science fiction, though at times it might seem so. It is a true story that, like its more recent counterparts, can be pieced together from reading the fragments of evidence that are all around us, and can speak to us if we take a little time to learn just a little of how to decipher them.

Historians, archaeologists and geologists all attempt to unravel past events. Historians and archaeologists reveal human history by researching written documents and interpreting objects and features uncovered during excavations. Geologists tell the longer history of the Earth by reading the evidence preserved in rocks, fossils, minerals and landscapes. The techniques used are surprisingly similar: all interpret the past by examining the evidence contained in what has been left behind.

As we explore Cleadon's rocks we will see, not only how they can reveal our distant history, but also the remarkably varied uses to which they have been put ever since humans arrived here. To do so we will look not just at our local rocks, but at some we see everyday around the village that have been brought from further, sometimes very much further, away. This is the geological story of Cleadon, and although we are looking at the village as part of the 'Magnesian Limestone Landscape', we will meet many more rocks along the way.

Our story begins not in the 12th Century, but hundreds of millions of years earlier when the small part of our planet that is now Cleadon lay far away in the southern hemisphere. Not so much a story, more of an adventure in time, let us piece this together from the evidence that is all around us. Before doing so though, we will look briefly at the huge timespans involved.

GEOLOGICAL TIME

The best evidence we have today indicates that planet Earth is about 4.6 billion years old. Expressed in figures – 4 600 000 000 – this looks especially impressive! As it is virtually impossible for us to comprehend the enormity of this, a helpful way to view such a huge time span is to imagine the whole history of the Earth as compressed into a single 24-hour day (Fig. 4). On this scale the rocks we see today in the Cleadon area formed at between 10.15 and 11.15 pm. Ice sheets began to cover the area at around one minute to midnight and the first human inhabitants arrived just about on midnight.

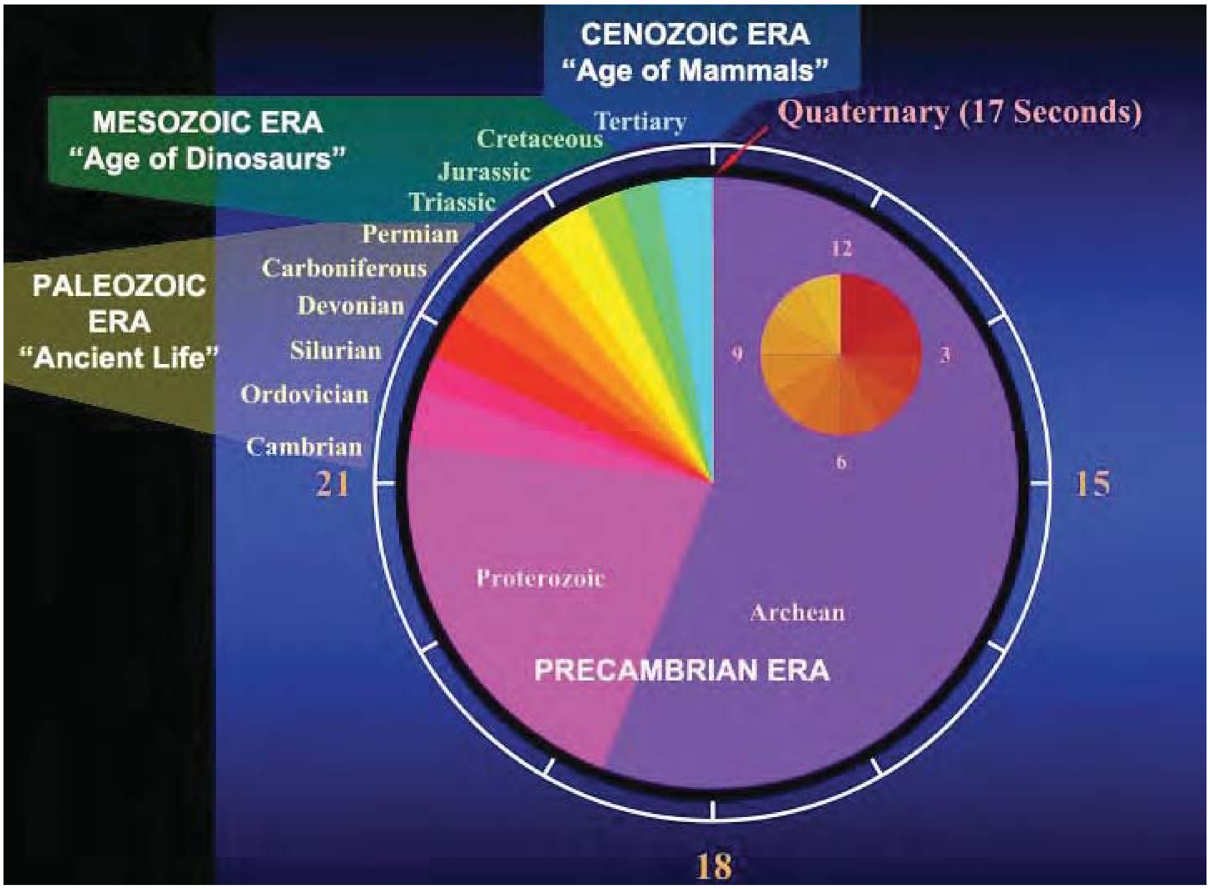


Figure 4: *Geological time expressed as a 24-hour clock.*

We are well used to thinking of human history divided into periods such as the Bronze and Iron Ages, Roman, Medieval and Tudor periods and so on. Geologists find it helpful to divide Earth history into the periods shown on Figure 4. By so doing, these give geologists and historians alike a convenient means for considering the relative timing of past events without having to worry too much about attaching precise numbers of years to them. To appreciate geological history it is usually much more useful to know the relative order of when things happened rather than to estimate the exact number of years involved.

The rocks present at the surface in the Cleadon area date from the Carboniferous, Permian and Quaternary periods. As we shall see, they have much to tell us of the varied past conditions and processes that created the landscape we know today. As we explore, we will encounter other rocks, buried deep beneath the surface, that take us back even further in time.

THE RESTLESS EARTH

To appreciate fully the history and evolution of our rocks and landscape over such enormous periods of time we need to consider the way the Earth itself has evolved, and continues to evolve today. This is not intended as a 'crash course' in Earth science, but rather a very short, and hopefully painless, introduction to some essentially simple ideas and concepts.

The Earth's outer layer, on which we live, is composed of large slabs or 'plates', that effectively 'float' on the mantle. These plates are in constant motion, moving up to around 15 centimetres a year, or about the speed at which our fingernails grow. As a result, many of our rocks were formed far from where we see them today, sometimes thousands of miles away. Their present position is the result of this relentless movement of the plates, a process known as 'plate tectonics'. This movement is not something that just happened in the past. The plates continue to move as fast as ever. The earth only appears to be fixed and static to us because the movement seems so slow in the context of human history but seen against the enormity of geological time it is rather rapid.

HOW WE READ ROCKS AND LANDSCAPE

Before we look at what our local rocks and landscape can tell us about Cleadon's earliest history it might be worth spending a little time examining some of the features of rocks that enable geologists to unravel the stories they have to tell.

To read the story preserved in rocks, geologists work from a rather simple but extremely important principle. Although rather dauntingly known in text books as the 'Law of Uniformitarianism', it is surprisingly easy to understand if you think of it as – *'the present is the key to the past'*. Put very simply this means that if we look at and understand the way Earth processes work today, and the materials and features they create, we can look at materials and features formed in the geological past and, by comparison with their modern counterparts, work out how these were formed all those years ago. Many of these vital clues can be *'read'* by looking at rocks in the field; others need investigation in a laboratory.

Geologists group rocks into three main types: igneous, sedimentary and metamorphic. Key characteristics of each of these give us many of the clues we need to interpret past conditions. We will meet examples of all three of these at Cleadon.

Igneous Rocks

Igneous rocks are formed by the cooling and crystallisation of molten rock or magma, which originates from deep within the Earth. When magma erupts at the surface, in volcanoes, it is known as lava: basalt is a common type of lava. Magma that does not reach the surface cools and crystallises at depth to form rocks, such as granite, which is only visible to us when the overlying rocks have been eroded away, perhaps many millions of years after it has cooled. Using a variety of laboratory techniques geologists can calculate to a high level of accuracy the age of these rocks, as well as the temperature and other conditions of their formation.

Sedimentary Rocks

Sedimentary rocks were formed, as their name suggests, from the accumulation of sediment composed either of fragments of older rocks or of organic materials such as plant or shell debris, usually underwater or more occasionally on land. As layers of sediment build up, the lower ones become progressively more compacted and eventually cement together to form rock. Sandstone is a rock formed of sand grains bound together by a natural ‘cement’. In contrast, limestone is formed from the accumulation of calcium carbonate, originally secreted by algae, shells or other, most commonly marine, creatures, and coal is a highly compacted fossilised accumulation of plant debris. Sedimentary rocks commonly contain fossils - recognisable remains of plants or animals living at the time of their formation. Studying fossils, and comparing them with their modern counterparts where they exist, we can interpret the conditions under which the rock containing them was formed, whether it was a lake, swamp, land area or sea. We might be able to determine the depth and even the temperature and salinity of water in which the sediment formed. Most fossils are of long extinct creatures, and the study of these allows us to decipher the history and evolution of life throughout geological time, and to give relative ages to the rocks containing them. Just occasionally animal tracks or footprints are preserved as trace fossils; long after the animal itself has died and decayed. As ancient sediments, sedimentary rocks commonly contain structures and textures that reflect the physical processes operating during their formation. For example we may be able to determine whether a sandstone accumulated under water or in a dry windy desert, and if so the direction the water was flowing or the wind blowing. Given the right lump of rock, and the means to read it, it is sometimes remarkable how much it can tell us.

Metamorphic Rocks

Metamorphic rocks are of igneous or sedimentary origin but have, at some stage in their history, been altered by the effects of heat or pressure, or both, within the Earth. Careful examination of their composition and textures can reveal their original nature and the often complex chemical and physical processes that have changed them into their present form.

Rocks, of whatever sort, are the foundations of landscape. The shape of our hills, valleys, coasts, etc. are all dependent upon the composition and texture of the rocks that lie beneath, and of the way in which they have responded to Earth processes over millions of years of geological history. Like the rocks themselves, the landscapes they create can, with a little care, reveal huge amounts about how it was formed and developed.

THE CLEADON LANDSCAPE

The essential physical features of the landscape: the hills, streams, valleys and flat areas we see around us, all reflect Cleadon's varied underlying geology (Plate 2). Over time, this has given rise to and supported a varied range of flora and fauna. However, like almost every part of Britain, the Cleadon area has been home to man for many centuries. During this time human activity, ranging from erecting primitive shelters to farming; industries such as mining and quarrying; road and railway building, and more recently the spread of housing, has fundamentally changed the appearance of the natural landscape. Man must, therefore, be seen as one of the most important agents in shaping landscape. The impact of man's activity and the changing nature of the natural environment are all discussed in the following sections of this report. However, what is apparent is that our perception of a present landscape is simply a snapshot in a continual process of change.

Plate 2: *View from Cleadon Hills looking south along the coast, across the Limestone Landscape Plateau, with Roker pier just visible in the distance.*

Although this section deals primarily with those natural processes that have formed the physical landscape, it is important to remember that man-made features comprise a vitally important ingredient in the complex mix that is the modern landscape. Just as the underlying rocks determine to a large extent the shape and character of hills and valleys, as well as the wildlife that populate them, it is those same rocks and the varied uses to which they have been put, that impart a distinctiveness to the area's buildings, fields and settlement patterns. Our examination of the Cleadon landscape will therefore look at both the natural features and the human and built environment. Both themes echo in the other sections of the report.

WHAT IS 'MAGNESIAN' LIMESTONE?

Perhaps a little confusingly, the terms 'magnesian limestone' or 'Magnesian Limestone', when used in north east England has two rather different meanings. As these terms are often encountered, and often misused, in descriptions of the rocks of the area, this is a good opportunity to clarify the distinction.

As we have seen, limestones are sedimentary rocks composed almost entirely of the mineral calcite, which, chemically, is calcium carbonate ($CaCO_3$). Nature rarely presents us with such minerals in a pure form and calcite, and thus limestones, usually contain variable amounts of other elements as impurities, often in the form of other minerals scattered through the rock. One such very common impurity in limestones is magnesium, which occurs combined with calcium as the mineral dolomite: the chemical calcium magnesium carbonate ($CaMg(CO_3)_2$). The proportions of dolomite relative to calcite within limestones can be very variable but as a good guideline where the rock contains up to 10% of the mineral dolomite it is often referred to as a **magnesian limestone**. Where dolomite forms between 10 and 50% of the rock it is known as **dolomitic limestone**. When more than 50% of the rock is made up of the mineral dolomite the rock itself is referred to as a **dolomite**. In this sense **magnesian limestone** is a term applied to limestones with this composition wherever they are found and of any geological age.

A large proportion of the varied group of limestones were formed during the Permian period, about 290 to 248 million years ago, and which today form a narrow belt of country between the mouth of the Tyne and Teesside (Fig.2) and extend southwards to Nottinghamshire, are of this composition. Geological science has recognised this by giving the full sequence of this group of rocks the formal name Magnesian Limestone, irrespective of the true composition of individual beds. Details of the different rock units that make up the Magnesian Limestone of north east England are discussed further below.

An important feature of the magnesian limestones of the Magnesian Limestone of north east England is the unusually magnesium-rich soils formed on its outcrops, which support a range of plants unique to this special Magnesian Limestone Grassland habitat.

THE MAKING OF CLEADON: A BRIEF GEOLOGICAL HISTORY OF THE AREA

Before we look more closely at our local rocks and landscape, and in order to gain a 'feel' for the stories they can tell, it is worth looking briefly at the main events that, over millions of years, have shaped the Cleadon we know today. In doing so it is important to recognise that geology does not recognise political or administrative boundaries. To explain and interpret Cleadon's rocks and landscape it is therefore necessary from time to time to look beyond our parish boundaries, sometimes even beyond our shores, in order to understand the rocks in their true context. It is also useful to attempt to look beneath the rocks we see today at the surface: older rocks, long buried far beneath us, can give important clues to an even earlier past.

As we have already seen, the rocks seen today at the surface in and around Cleadon date from the

Carboniferous, Permian and Quaternary periods of Earth history. Careful study of these rocks, both from the Cleadon area itself and further afield, has enabled geologists to interpret the abundant evidence they contain of the conditions and processes that were affecting the district during those times. As deposits dating from other geological periods are not present at the surface here, it is only possible to speculate, by comparison with the evidence contained in the rocks dating from these periods elsewhere in Britain, on the conditions and processes that were then affecting what was to become this small part of north east England.

Carboniferous Times

In order to glimpse the oldest rocks known from the Cleadon area we need to look a few kilometres to the east, to the coast at Marsden Lea, near Harton [NZ39663 65629]. Here, a deep borehole, drilled in search of oil by BP in 1960, reached a depth of 1769.06 metres. It ended in a thick group of rocks of Lower Carboniferous age, dating back approximately 350 million years (about 10.15pm using the 24-hour clock analogue). These are the equivalents of the sandstones, shales and limestones that form the Northern Pennines and western and central Northumberland. They reveal evidence that in Lower Carboniferous times, the area that eventually became northern England lay a little to the south of the equator. It was covered by a warm shallow tropical sea in which an abundance of marine life flourished. Beds of limestone containing abundant marine fossils formed in these seas. Huge rivers, draining a land area somewhere to the north east in the area now occupied by part of the North Sea, periodically washed in vast quantities of sand and mud that are preserved today as beds of sandstone and shale.

At the surface, the oldest rocks we see today in the Cleadon area date from Upper Carboniferous times, between about 315 and 305 million years ago (roughly 10.30pm using the 24-hour clock analogue). Movement of the continental plates had by this period brought our area further north to lie almost astride the equator. What was to become north east England was a vast forest-covered delta plain formed by great rivers draining from uplands to the north and north east in the area today occupied by parts of Scotland, the North Sea and Norway. Numerous plant and animal fossils collected from these rocks reveal much about the local Upper Carboniferous wildlife. The huge trees in these forests were unlike modern trees. They included primitive ancestors of the modern conifers as well as gigantic early relatives of the tiny club mosses found growing today on mountain tops. Alongside these was a wealth of tree ferns and giant relatives of the modest horsetails found growing in wet woodlands and gardens today (Fig 5). Animal life in these forests included freshwater shells, newt-like amphibians over a metre long and primitive dragon flies the size of large birds.

Thick accumulations of peaty plant debris on the forest floor were periodically buried beneath layers of sand or mud as the waters gradually subsided and the rivers flooded and shifted their courses. With time, as these layers became buried beneath more and more sediments, they became compacted and turned to rock. The muds became shales, the sands turned to sandstone, and the peat layers became coal seams. The term Coal Measures is used to describe the thick group of Carboniferous rocks formed at this time. The term 'Carboniferous' is derived from the abundance of coal seams found within rocks of this age across much of Europe and North America.

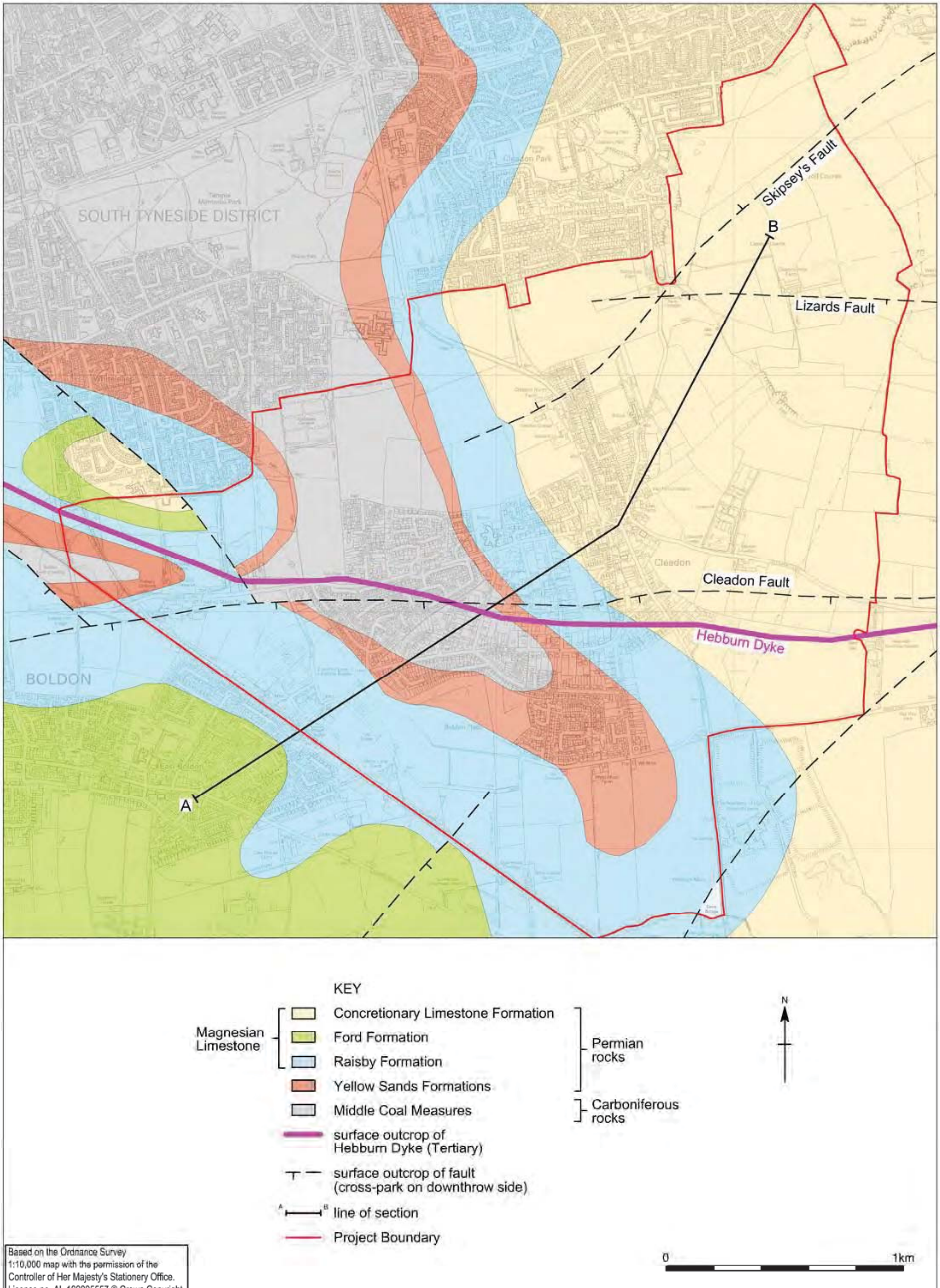
Figure 5: *Interpretation of Coal Measures swamp (image courtesy of British Geological Survey).*

These are the rocks of the Great North Coalfield that were for centuries so important in shaping the economic and social history of North East England. As can be seen on the geological map and section (Figs.6 and 7). Coal Measures rocks crop out at the surface over much of the western parts of Cleadon village and lie buried beneath the Magnesian Limestone in the remainder of the area.

Permian Times

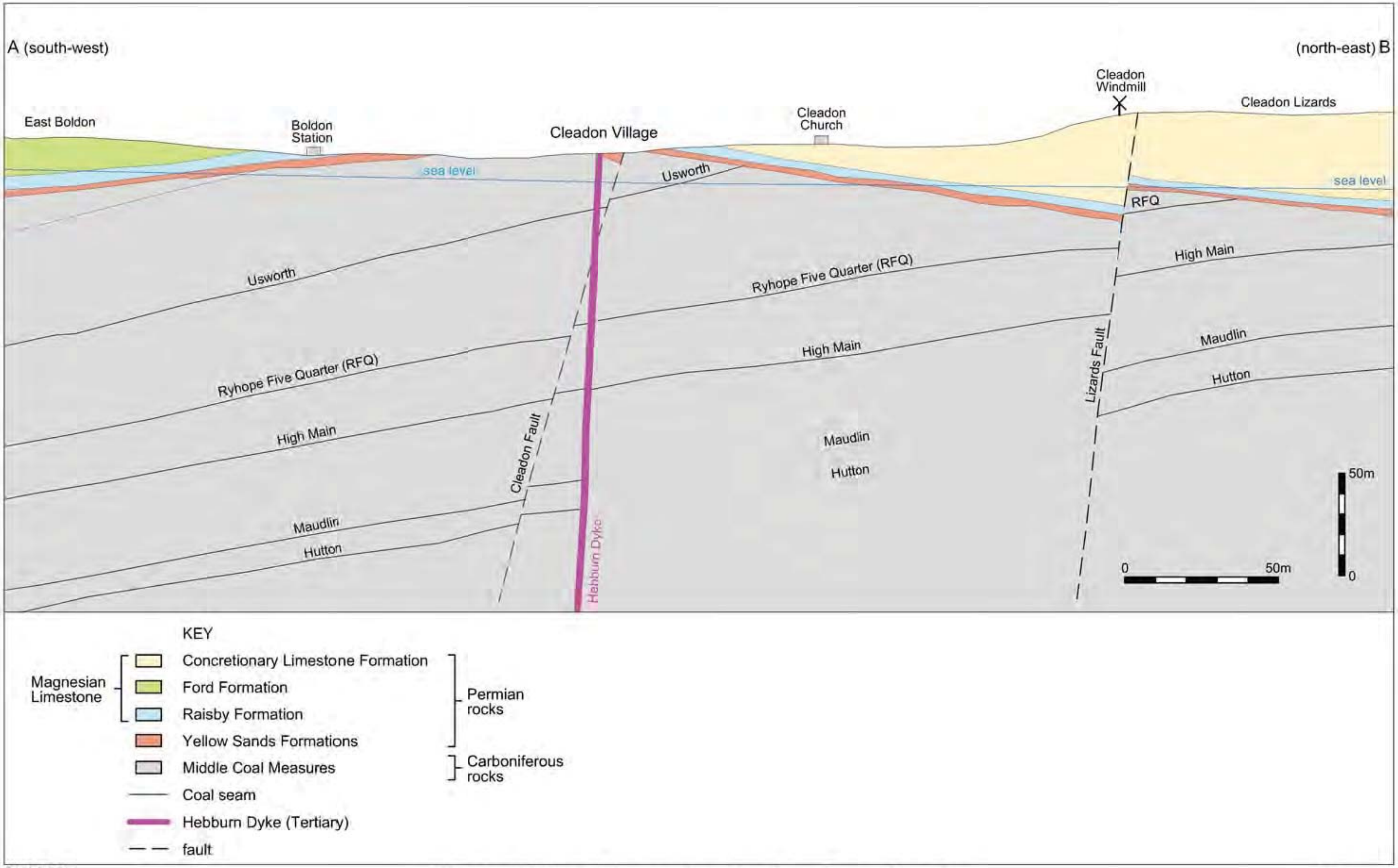
Towards the end of Carboniferous times, powerful Earth movements that were creating mountains further to the south in what is now continental Europe, uplifted the land surface in the area that became northern England, destroying the tropical swamps. The Carboniferous rocks were folded and tilted as they were raised up, creating mountains and hills and setting the scene for the next episode of Earth history, the Permian Period. Although the folds created in our rocks were comparatively gentle compared to those in areas further south, the rocks of north east England were bent into low arch-like folds, called anticlines, and trough-like folds known as synclines. Fractures along which the rocks were displaced relative to each other, are called faults. Overall the rocks of our region were given a gentle easterly tilt with successive layers dipping gradually eastwards towards, and eventually beneath, the North Sea.

These Earth movements were accompanied, about 295 million years ago (roughly 10.35pm using the 24-hour clock analogue), by the intrusion, from deep within the Earth, of large volumes of molten rock, or magma. This did not reach the surface, but spread out between the layers of the recently formed sandstones, shales and limestones. Here it cooled and crystallised, forming thick sheets of the hard black rock called dolerite, collectively known throughout northern England as the Great Whin Sill. It is the



Cleadon Village Atlas: solid geology (after BGS mapping)

Figure 6



Cleadon Village Atlas: section of solid geology along line A-B on Solid Geology map

Figure 7

Whin Sill that forms many of northern England's most striking landscapes, including the Farne Islands, the crags at Bamburgh and Dunstanburgh castles, the crags of the Hadrian's Wall country and the waterfalls of High Force and Cauldron Snout. Although it lies buried deep beneath Cleadon, the Whin Sill (Plate 3) appeared in three separate layers in the Harton Borehole, and can be found as a building material in Cleadon's houses and walls.

Plate 3: *The Whin Sill outcropping at Dunstanburgh, on which stands the 14th Century castle, creating a dramatic and atmospheric landscape.*

By late Permian period, about 250 million years ago, (about 10.40pm using the 24-hour clock analogue), further northerly movement of the continental plates had brought the area we know today as South Tyneside to about 30 degrees north of the equator. The area had then become an arid desert, covered by broken rock eroded from the newly created landmass and marked by long lines of wind-blown sand dunes. These dune sands are preserved today as the Permian Yellow Sands, which lie beneath the Magnesian Limestone. Although their surface outcrop in and around Cleadon is clearly seen on the geological map (Fig. 6), there are no exposures of these rocks within the parish today. However, they may be seen a few miles inland at Claxheugh Rock in Sunderland and on the coast at Frenchman's Bay. They were also reached in several boreholes in the Cleadon area and we shall hear more of them when looking at the uses of our local rocks.

Subsidence of the land surface during Permian times allowed the waters of an extensive sea, known to geologists as the Zechstein Sea, that occupied much of the area of the present North Sea, Holland, Germany, Denmark and Poland, to flood the sandy desert country of what is today north east England. Flooding appears to have been comparatively rapid, as many of the original sand dunes were buried without being eroded by the advancing water of this warm tropical sea.

Plate 4: *Palaeoniscus sp., a fossilised fish typical of the Marl Slate, from Downhill Quarry, West Boldon.*

The sediments that accumulated on the floor of the Zechstein Sea were to form the rocks that lie at the heart of north east England's limestone landscapes – the Magnesian Limestone. Familiar and commonplace though they are to anyone living in and around Cleadon, these rocks are internationally famous for the evidence they provide of this period of Earth history. At their base lies the Marl Slate, a thin bed of grey bituminous limestone that rests directly upon the Yellow Sands, famous for superbly well-preserved fossilised fish (Plate 4), and more rarely the remains of early reptiles. Above this lies the complex succession of pale yellow and cream limestones, collectively known as the Magnesian Limestone. Because of their great local importance, we shall look at these rocks in rather more detail later. For the present, however, and in order to appreciate something of the area's geological history it is important to recall that the warm salty Zechstein Sea in which they formed, dried up almost completely on several occasions.

Tertiary Times

From the close of the Permian period, about 245 million years ago, the record of Earth history, as evidenced from the rocks of South Tyneside, falls silent for many millions of years. Based on evidence gathered from the rocks elsewhere in Britain and Europe we know that during this time further Earth movements caused additional twisting, tilting and faulting of the Coal Measures rocks and the Permian rocks, though the precise timing of these movements is uncertain.

By about 55 million years ago (roughly 11.45pm using the 24-hour clock analogue), during the Tertiary Era, movement of the continental plates had brought our area much closer to its present latitude. Major fractures were beginning to open in the continental plates beneath what are today Northern Ireland, the Hebrides and Iceland. Accompanied by extensive volcanic activity, these movements were to have a major impact on the subsequent geography of the northern hemisphere. As the fractures extended, the plates split progressively further apart creating the opening that we now know as the Atlantic Ocean; a process that is continuing today as the Atlantic widens and moves Europe and North America further apart. Huge volumes of basaltic lavas erupted at this time, examples of which can be seen in the Giants Causeway in Northern Ireland (Plate 5) and in the Hebrides on Skye, Mull and at Fingal's Cave on Staffa. These enormous movements were accompanied by very widespread cracking of the rocks for some distance from the main fracture points. A series of roughly west-north-west to east-south-east fractures developed across northern England at this time and were rapidly filled by molten basaltic magma from the main volcanic centres, forming narrow vertical bodies of basalt, known as dykes. One such dyke, known as the Hebburn or Monkton Dyke, run under Cleadon and was observed during coal workings in the area, though it does not reach the surface at Cleadon.

Plate 5: *The Giant's Causeway in Northern Ireland, caused by volcanic eruptions during the Tertiary Period.*

Quaternary Times

The geological record falls silent once again as no rocks survive in our area to record events between the intrusion of the Hebburn Dyke, approximately 55 million years ago, and the Quaternary Period that began about 2.5 million years ago (11.58pm using the 24-hour clock analogue). By now, continued movement of the continental plates had brought our area to its present latitude. There was a major episode of global cooling during the Quaternary period and the onset of repeated glacial conditions across much of northern Europe, including Great Britain. These intensely cold glacial episodes alternated with much warmer periods, known as interglacials, during which the ice cover melted, only to be succeeded by a return to glacial conditions.

A variety of erosion features and sediments deposited during Quaternary times record a complex history of events as ice sheets moved across the area from the west, north and east. The distribution of sediments formed at this time is shown in figure 8. Evidence of the origins of the various ice streams is to be seen in the scatter of exotic, or erratic, boulders of distinctive rock types across the landscape. Other sediments and landforms are evidence of the effects of water melting from or ponded behind ice sheets. Of particular interest in Cleadon is the huge lake, named glacial Lake Wear by geologists, that covered an area between Durham and the River Tyne in late glacial times (Fig. 10). It is believed that this lake formed as a result of water from melting ice-sheets being ponded behind thick ice along the line of the present coastline. The details of its history are complex, but it is thought that its water level may have been as much as 130m above present sea level at some stage and that it eventually drained rapidly southwards, cutting the channel seen today south of Sunderland at Tunstall Hope. Bench-like features at between 43m and 45m above present sea level on the boulder clay covered flanks of Fulwell and Cleadon hills may reflect lower water levels in this lake.

Since the last ice melted as recently as about 11,000 years ago (midnight using the 24-hour clock analogue), erosion and depositional processes have shaped, and continue to shape, the landscape of our area. It is worth reflecting here, especially in the light of some of the current, gloomier predictions of climate change, that we are today living in a rather low grade interglacial episode: Britain's climate is known to have been much warmer in some previous interglacials. Glacial conditions will almost certainly return, though certainly not within the span of a human lifetime. The causes of the comparatively rapid alternations of cold and warm periods during the last 2 million years are not fully understood. Again, it is important to appreciate that whatever might have caused these changes in the past, human influence could not have been a factor throughout the vast majority of this period.

It is during this last 11,000 years, a mere blinking of the eye on a geological timescale, that our area was gradually re-colonised by vegetation as the ecosystems we know today developed. Subsequent centuries of human occupation, and exploitation of the area's natural resources, have further modified the landscape, which, through continuing human activity, continues to evolve.

GEOLOGICAL MAPS: AN INTRODUCTION

We are all more or less familiar with maps of different sorts. We see a weather map on television every day and when visiting a shopping centre, especially one new to us, we generally seek out the street map to get our bearings and guide us to our chosen shops. Even in these days of 'Sat. Nav.' road maps remain essential tools for finding routes and destinations, especially when the 'Sat. Nav.' proves misleading! This village atlas contains maps of several different sorts, some of which, like the geological maps, might appear unfamiliar and initially a bit daunting. However, they can tell us a great deal about our landscape.

Geological maps show the nature, extent and geological age of different named geological ***formations***, usually by the use of contrasting bright colours. Such ***formations*** might be made up almost entirely of one rock type, though they commonly comprise a number of different rock types related to one another by their age, mode of formation etc. The geological map is therefore not simply a location map telling us '*there be limestone, sandstone, etc.'* In order to compile such maps, all surface geological features are examined and recorded, but so too is information gathered from aerial photography, boreholes, mine workings, geophysical surveys and lots of other sources. The resulting map is an ***interpretation***, by the geologist or geologists who compiled it, of the configuration of the geological features of that area.

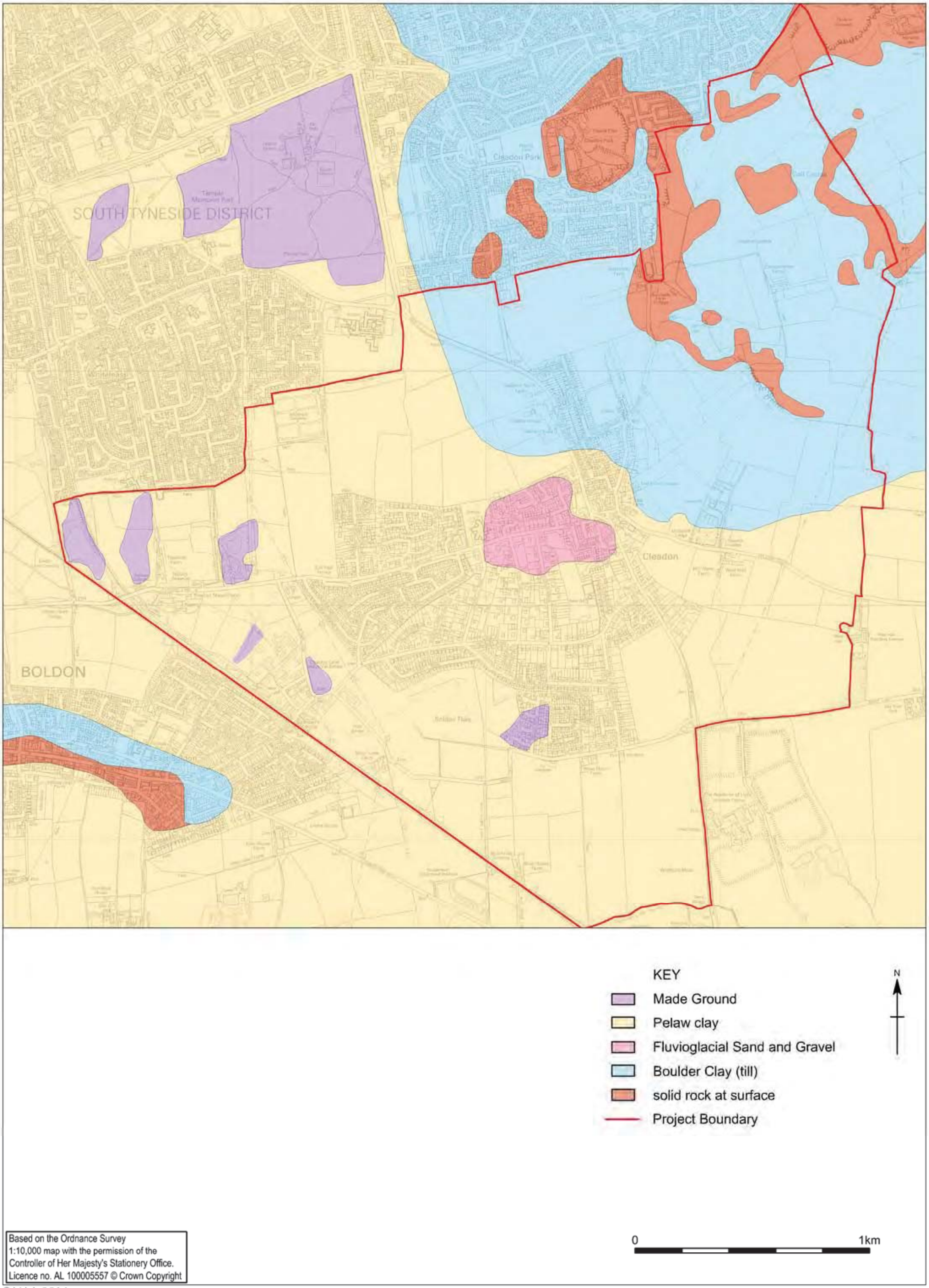
As well as telling us what we might find at the surface, the map can be used to deduce information about soil type, engineering properties of the ground, potential for mineral deposits and possible groundwater conditions, often far below the surface. Geological maps are used by geologists, both professional and amateur; civil engineers; mineral extraction, oil and water companies; planners; land surveyors and indeed anyone who needs information on what lies on or beneath the ground surface and can be used to depict and interpret a great variety of geological features. In an area like Cleadon two distinct sets of geological information are generally produced as separate editions of the same map. These were traditionally known as ***Solid*** and ***Drift*** editions.

The ***Solid*** edition (Fig.6), now more precisely known as the ***Bedrock*** edition, depicts those rock formations as they would appear if all surface or superficial materials were removed. This is particularly important in areas such as northern Britain, including Cleadon, where substantial quantities of superficial materials, mainly of comparatively recent glacial or post-glacial origin, conceal the underlying bedrock.

The ***Drift*** edition (Fig. 8), now known as the ***Superficial Deposits*** edition, depicts the distribution and configuration of unconsolidated superficial materials that in our area typically comprise geologically recent materials of glacial or post-glacial origin, but also include man-made deposits such as landfill sites, worked and made ground.

Like all maps, geological maps may be produced at all sorts of scales, depending on the level of detail available or the purpose for which it is intended. In areas where superficial deposits are widespread it is common for two separate editions of the geological map to be published at the 1:50 000 scale. In such places it is important to refer to both editions when attempting to understand an area's geology.

Geological maps of the UK are produced by the British Geological Survey (BGS). This state-funded national survey, part of the Natural Environment Research Council, is the world's oldest geological survey and was founded in 1835. Geological field mapping is carried out at the scale of 1:10,000 (1:10,560 scale prior to metrication) and maps at this scale are published, though available only directly from BGS but cannot be reproduced here because of copyright issues. The most widely available publication scale for BGS geological maps in the UK is 1:50,000. These maps are derived from the larger scale field mapping, though with some generalisation and simplification of the 1:10,000 scale information.



Cleadon Village Atlas: drift geology (after BGS mapping) *Figure 8*

For the Cleadon area the most readily available geological map of this sort is BGS 1:50, 000 scale Sheet 21 (Sunderland), on which the bedrock (solid) and superficial (drift) geology are shown side by side as two separate maps. For much more detailed geological information BGS 1:10,560 scale Sheet NZ36SE (available from BGS) depicts both the bedrock and superficial geology together on one single map. This sheet also includes the sites of significant wells and boreholes, with abbreviated logs of the rocks encountered in them. The positions of former quarries, clay and sand pits are also shown, again with brief notes on what was formerly visible in these. A selection of relevant geological features recorded in underground coal workings, deep beneath the area, are also shown.

The original Geological Survey mapping of the Cleadon area was undertaken by H.H. Howell between 1868 and 1871. The area was resurveyed between 1954 and 1972 by D.B. Smith and published at the 1:10,560 scale in 1975. The 1:50,000 scale Sheet 21 (Sunderland) was published in 1978.

A CLOSER LOOK AT CLEADON'S ROCKS AND LANDSCAPE

Having taken a brief look at over 300 million years of Earth history it is now time to look rather more closely at the rocks beneath our feet. We will explore where they occur, where we might see them, how we can read some of the stories they have to tell, and how they influence our landscape. A little later we will examine how man has used, and continues to use, those rocks available locally, and has brought others into the area from elsewhere. All of these elements are important in our understanding of the Limestone Landscape.

The configuration of the different rocks that underlie the Cleadon area is shown on the simplified geological maps prepared from information contained on geological maps published by the British Geological Survey (Figs 6 and 8). As we shall see, not all of the rocks known to lie beneath Cleadon can be seen at surface in the parish. Where this is the case we will need to look at what is known about these rocks, both from adjoining areas and from excavations, mine workings and boreholes beneath Cleadon. As these are important to interpreting and understanding Cleadon's story, and as some of them shape parts of the nearby landscape, we will look at these briefly and suggest a few places where we might venture outside the strict confines of the parish to look for clues.

Our Oldest, and Hidden, Rocks

No review of an area's geology is complete without taking a brief look at those rocks that, although not exposed at the surface, are known to be present at depth. The oldest rocks at the surface in and around Cleadon belong to the Coal Measures, of Carboniferous age. However, a deep borehole drilled in 1960 in search of oil and gas at Harton penetrated over 1300 metres of Carboniferous sandstones, shales and limestones equivalent to those seen at outcrop in the Northern Pennines and western and central Northumberland. As outlined above, these rocks record evidence of their origins during Carboniferous times as soft sediments on the floor of a warm, shallow equatorial sea into which huge rivers drained. The Whin Sill, the major igneous intrusion of dolerite seen today on the Northumberland coast, the

Roman Wall country and the Northern Pennines, appeared as three separate layers within these rocks. The borehole ended in Lower Carboniferous rocks at a final depth of 1769.06m below the surface, without discovering economic concentrations of oil or gas.

As in most exploration boreholes of its type, the Harton Borehole did not recover cores of the rocks through which it passed because coring is a hugely expensive process. Instead, drill cuttings – the small fragments of rock ground away by the drill bit and returned to the surface – provided geologists with evidence of the rocks passed through as the borehole went deeper. Samples of the drill cuttings from the Harton borehole are preserved in the collections of the British Geological Survey at its headquarters at Keyworth, Nottingham.

We have no direct evidence of what lies beneath these rocks, but from our understanding of the wider geological structure of northern England it is likely that these are ancient mudstones, equivalent to those that form Skiddaw and adjacent mountains in the Lake District. These are rocks formed around 410 million years ago (roughly 9.20pm using the 24-hour clock analogue) in a deep ocean somewhere south of the equator.

Carboniferous Rocks: The Coal Measures

The term Coal Measures is the name used in British geology for the thick succession of coal-bearing rocks formed in the latter part of the Carboniferous Period between about 315 and 305 million years ago (roughly 10.30pm using the 24-hour clock analogue).

For convenience, geologists subdivide the Coal Measures into three divisions, named in upward succession the Lower, Middle and Upper Coal Measures. The means of making these subdivisions, based on identifying beds containing distinctive key fossils, need not concern us here: readers wishing to know more about this can find full descriptions in the appropriate references listed at the end of the Atlas. For the current discussion it is sufficient to know that Lower and Middle Coal Measures rocks underlie the whole of the area, with Upper Coal Measures rocks occupying only a tiny area in the extreme west of the area near East Boldon. Over much of the Cleadon area Coal Measures rocks are concealed beneath the overlying Magnesian Limestone though, as shown on the geological map (Fig. 6) they crop out beneath the western part of the village in the centre of a shallow basin-like fold structure, known as the Boldon Syncline.

Although the outcrop of Coal Measures rocks in the area is clearly depicted on the accompanying geological map, these rocks are nowhere exposed at the surface within the parish, but are covered by a superficial mantle of glacial deposits. However, we know a considerable amount about them, both from surface exposures in the adjoining areas, and more especially from underground coal workings that extend beneath the whole of the Cleadon area.

Coal Measures rocks were reached at a depth of 114m in the well at Cleadon Waterworks and at a depth of 81.7m in the Fulwell Pumping Station well, which lies immediately south of the parish boundary. A feature of the Coal Measures rocks reached in both of these wells was their red colour. Although the Coal Measures rocks of north east England are typically grey in colour, a zone of locally quite intense red colouration is commonly encountered within a few metres of the overlying Permian rocks. This reflects intense tropical weathering of the newly emerged land surface prior to the deposition of the overlying Permian rocks.

For anyone interested in examining rocks typical of the Coal Measures of north east England, the fine cliff sections along the coast between St Mary's Island and Seaton Sluice are highly recommended: they are amongst the finest sections of such coal-bearing rocks available anywhere in Europe.

The Coal Measures rocks of the Cleadon area form part of the Northumberland and Durham, or Great North, Coalfield. Their surface outcrop, over the western and northern parts of the coalfield, constitutes the area known as the 'exposed 'coalfield. Traced eastwards, these Coal Measures rocks dip beneath the overlying Permian rocks, including the Yellow Sands and Magnesian Limestone. This area of concealed Coal Measures rocks comprises the 'concealed' portion of the coalfield. Although many seams are known within the Northumberland and Durham coalfield the main production of coal has been obtained from between 20 and 30 main seams, mostly within the upper parts of the Lower Coal Measures and lower portion of the Middle Coal Measures. The 1:50,000 scale geological maps of the British Geological Survey indicate the surface outcrops of the seams present in South Tyneside.

In common with other parts of Britain, the Coal Measures rocks beneath Cleadon typically consist of a more or less regularly repeated succession of shales, siltstones, sandstones, thin beds of clay ironstone and coal seams. All were deposited as sediments in an extensive delta swamp environment in equatorial latitudes. The regular upward succession of shale-sandstone-coal reflects the changing environmental conditions in the muddy delta swamps as huge rivers built up sand banks that eventually became colonised by dense tropical forests. Thick accumulations of peaty plant debris on the forest floor were periodically buried beneath layers of sand or mud as the land gradually subsided and the rivers flooded and shifted their courses. This pattern of swamp development, the building of sand banks followed by forest colonisation and subsequent flooding, was repeated many times. As the layers of mud, sand and plant debris became buried beneath more and more sediment they became compacted and turned to rock. The muds became shales, the sands turned to sandstone, and the peat layers became coal seams. Segregation of iron compounds within the muds locally produced concentrations of ironstone.

Despite their former economic importance, coal beds, or seams, actually comprise a comparatively small proportion of the overall thickness of the Coal Measures. Individual seams vary in thickness from a millimetre or so to seams in excess of a metre thick; although thicknesses of a metre or less are most common in north east England. Seams may vary considerably in thickness and quality when traced laterally across coalfields: a thick workable seam in one area may pass into a thin and unworkable seam elsewhere. In addition, many seams separate, or 'split', into two or more leaves. Most coal seams tend to look much like one another, though some internal characteristics and differences in their overlying (roof) and underlying (floor) rocks may help to distinguish them one from another. Details of these characteristics in the Northumberland and Durham Coalfield can be found in some of the more specialised references listed in the bibliography.

From the earliest days of coal working, seams have acquired individual names. It was common, especially in the earliest days of the industry, for each colliery to devise its own set of names for the seams present within its workings. With time, names gradually became more standardised and by 1957 the National Coal Board had adopted a series of names for seams in the Durham portion of the coalfield, of which the Cleadon area of South Tyneside forms part. These are the names employed on the most recent geological maps.

Coal was worked beneath Cleadon from collieries at Whitburn and Boldon. Plans of these workings enable geologists to work out the detailed structure of the rocks deep beneath the surface in the Cleadon and surrounding areas.

Permian Rocks

Permian rocks were deposited during the Permian Period of Earth history between about 290 and 250 million years ago (from about 10.30pm to 10.40pm using the 24-hour clock analogue). The name 'Permian' is derived from the city of Perm in the Ural Mountains of Russia, where some of the earliest studies on rocks of this age were undertaken.

Permian rocks are present over wide areas of Great Britain and reflect two main, and widely different, environments of deposition. Most widespread of Britain's Permian rocks are the so-called 'red beds' that consist mainly of red or reddish brown sandstones formed under desert conditions. These are the Permian rocks today found in the Hebrides, south west Scotland, the Isle of Arran and across eastern Devon, the Welsh Borders, wide areas of the English Midlands, Lancashire, north and west Cumbria and the Vale of Eden. Britain's Permian rocks also include smaller areas of rocks deposited under marine conditions and it is these that interest us in the Cleadon area. British marine Permian rocks are restricted to the outcrop that extends northwards from Nottinghamshire to South Tyneside, though tiny outlying areas of similar rocks occur immediately north of the Tyne at Tynemouth and Cullercoats and in west Cumbria at Whitehaven. As we shall see, Cleadon's rocks include important parts of the British marine Permian succession, though important non-marine Permian rocks, lying beneath these, are also present.

North east England, including South Tyneside, contains some of the finest exposures of marine Permian rocks in Great Britain, and indeed the world. From the earliest days of geological science these unique rocks have attracted, and continue to attract, research interest. It is neither necessary nor appropriate to examine the more technical aspects of these fascinating rocks here, but it is nevertheless useful to see them in their true context as part of the regional geology of north east England. As some of the formal modern names applied to these rocks may be unfamiliar, the nomenclature and classification currently used by geologists for the different groups of Permian rocks present in north east England are outlined in Table 1. This includes earlier, and now obsolete, names for different parts of the succession that may still be encountered in many published descriptions of the geology.

Some of this nomenclature is comparatively recent and post-dates the most up to date published BGS maps. Rather confusingly, this older terminology is employed on the currently available BGS maps, though the newer names are adopted in the detailed descriptions of the local geology given by D.B.Smith (1994) in the BGS Sheet Memoir for the Sunderland area. The following notes are intended to help explain the meaning of these newer names and their relationship with those that are more familiar in the older literature

Zechstein Group - The term formally adopted internationally today by geologists for all of those limestones and associated rocks, deposited in the former Zechstein Sea, including those limestones long known in north east England as the 'Magnesian Limestone'. Although this latter term is now strictly obsolete in formal geological nomenclature, it is so well embedded in the literature of local geology, ecology and landscape that we will use it here in its original sense and as a synonym for *Zechstein Group*.

***Rotliegende Group* -** Similarly, the *Rotliegende Group* is the formal group name for those Permian rocks beneath the Zechstein Group, including the sands, formerly known in north east England as the Basal Permian Sands, or perhaps more familiarly as the 'Yellow Sands'. We will use the latter term here.

***Raisby Formation* -** Although depicted on the currently available BGS maps as the Lower Magnesian Limestone, revisions to formal geological nomenclature since these were published have introduced the term *Raisby Formation* that is today the formal name for this group of rocks.

Ford Formation - The Middle Magnesian Limestone, as shown on the currently available BGS maps and as described in older texts, is today formally known as the *Ford Formation*.

***Hartlepool Anhydrite and Roker Formations* -** The obsolete term 'Upper Magnesian Limestone', although employed on the currently available BGS maps includes groups of rocks today formally classified as the *Hartlepool Anhydrite Formation* and the *Roker Formation*.

Table 1: *Classification of the Permian rocks of South Tyneside*

ZECHSTEIN GROUP formerly known as the MAGNESIAN LIMESTONE	Roker Formation, includes the 'Concretionary Limestone', (*formerly part of the Upper Magnesian Limestone*)
	Hartlepool Anhydrite Formation (removed by dissolution in onshore area) (*formerly part of the Upper Magnesian Limestone*)
	Ford Formation, including reef limestones (*formerly known as the Middle Magnesian Limestone*) [Present only in the extreme west of Cleadon Parish and to the south of Cleadon]
	Raisby Formation (*formerly known as the Lower Magnesian Limestone*)
	Marl Slate Formation
ROTLIEGENDE GROUP	Yellow Sands Formation
unconformity	
COAL MEASURES	

Substantial parts of this succession of Permian rocks, although present beneath Cleadon, are not exposed at the surface and lie concealed beneath much more recent superficial deposits. Although we cannot see these rocks today they can be seen at various places nearby. We will therefore look briefly at these rocks, commenting on where they can be seen.

Our Permian rocks rest upon an eroded surface of the Coal Measures created by the erosion of these rocks following their uplift by huge earth movements about 300 million years ago. Although this erosion surface, or unconformity, is not exposed today in the Cleadon area it may be seen further south in the Sunderland area and in places in County Durham.

Yellow Sands Formation (Rotliegende Group)

Although these rocks are not exposed at the surface in the Cleadon area, their outcrop can be reliably depicted on geological maps from subsurface information gathered from numerous boreholes drilled in search of water and coal. The Yellow Sands crop out rather extensively beneath the southern and central parts of the parish, though their outcrop is everywhere concealed beneath superficial deposits. The nearest good surface exposures of the Yellow Sands are at Claxheugh Rock, Sunderland and in the base of the cliffs at the head of Frenchman's Bay, though the later section here is usually difficult to access safely.

In these exposures the rocks consist of sand grains, a very high proportion of which are almost spherical in form, typically with frosted surfaces. Such sand grains are commonly known as 'millet seed' grains. This feature, together with the large scale cross-bedding seen in many places, is characteristic of sands deposited by wind in a desert environment. From the variations in thickness of these sands, as revealed by numerous boreholes drilled through them across the region, it is clear that they were formed as elongated rows of desert sand dunes with a distinct WSW-ENE orientation. The reason for their common name – the Yellow Sands – is obvious from their bright colour in most sections through them. However, when proved in boreholes, particularly offshore, they are commonly blue-grey in colour due to a small content of the iron sulphide mineral pyrite, which is generally oxidised to a yellow or brown colour near the surface.

The Yellow Sands are characteristically very porous rocks that, beneath the surface in the onshore area, are normally saturated with water. It was this abundance of groundwater that led to difficulties in sinking colliery shafts through them, but which also made them valuable sources of ground water. The Yellow Sands were proved to be 42.4m thick in the well drilled at Fulwell Pumping Station, but only a little under 15m could be attributed to these sands in the well at Cleadon Pumping Station. We shall hear more of their water, and also gas bearing, properties later.

Marl Slate Formation (Zechstein Group)

Over much of north east England the basal few metres of Zechstein Group limestones, immediately above the Yellow sands Formation, consists of a very distinctive rock long known locally as the Marl Slate. The name is extremely misleading as the rock is not a slate but a fissile (i.e. easily split into thin slabs) bituminous limestone.

The Marl Slate varies considerably in thickness across the area and is known to be absent in many places. It is too thin to be depicted separately on geological maps and it is not exposed at the surface in the Cleadon area, though its presence is recorded in at least two boreholes. At Cleadon Waterworks it was found to be only 0.3m thick, though this increased to 1.2m at Fulwell Waterworks.

One of a number of distinctive features of the Marl Slate is the local abundance within it of beautifully preserved fossilised fish, accompanied in places by rare plant and early reptilian fossils. Many magnificent examples of fossil fish have been collected from exposures of the Marl Slate across much of its outcrop in north east England and fine specimens may be seen in collections such as those at Sunderland Museum, the Great North Museum (formerly the Hancock Museum), Newcastle upon Tyne and the Natural History Museum, London. The nearest prolific Marl Slate fossil locality to Cleadon was the former limestone and sand quarry at Downhill, West Boldon. The exposures here have for many years lain buried beneath a land fill site, though during the 1960s numerous very fine fossilised fish were recovered (Plate 4), many of which are today preserved in the Sunderland Museum collections. The Marl Slate is also present above the Yellow Sands at Frenchman's Bay, though due to the instability of the cliffs here it is not always exposed and is difficult to access safely except during very low tides.

Another characteristic of the Marl Slate is its significant content of bituminous material and high concentrations of base metals, most notably lead, zinc and copper. Traced across the North Sea into East Germany and Poland the Marl Slate can still be recognised, though here its metal content, especially that of copper, has increased to such an extent that the rock is known as the 'Kupferschiefer' (Copper Shale) and was formerly mined as a copper ore. In north east England the copper content is very much lower, but lead and zinc are sometimes visible as traces of the lead ore mineral galena (PbS) and zinc ore sphalerite (Zn,FeS), though never in workable amounts.

The nature of the Marl Slate, its well-preserved fossil content, and its unusual metal-rich geochemistry have long attracted research interest into its conditions of formation. It is now thought likely that it was deposited in water depths of between 200 and 300 metres in a basinal environment, the rising waters of which rapidly drowned the dune topography of the underlying Yellow Sands.

Plate 6: *View south-west from the Cleadon Hills, looking across to Penshaw Monument and the Magnesian Limestone escarpment.*

Raisby Formation (Zechstein Group)

Originally known as the Lower Magnesian Limestone, these rocks occupy a wide outcrop in the Cleadon area though everywhere concealed by glacial and later deposits. Examples of these rocks can be found a short distance away along the coast at Trow Point or the lower parts of Downhill at West Boldon. It is these rocks that form much of the prominent escarpment that marks the inland edge of the Magnesian Limestone outcrop, and is such a conspicuous feature of the landscape to the south west of Cleadon, seen from such vantage points as Cleadon Hills (Plate 6). Good exposures of these rocks, which typically consist of well-bedded yellowish or cream coloured magnesian limestones and dolomites, can be seen on the Magnesian Limestone escarpment around Penshaw Hill, in the sides of Houghton Cut at Houghton-le-Spring, and in their type development at Raisby Hill quarries near Coxhoe in County Durham. The prominent bedding seen in these places clearly records the layers in which the limy muds that hardened to form these rocks accumulated on the floor of the Zechstein Sea.

Rocks of the Raisby Formation would have been penetrated in the boreholes drilled for water at both Cleadon and Fulwell pumping stations, though they are not separately identified on the abbreviated logs shown on the British Geological survey 1:10,560 scale map of the area (NZ 36 SE).

Ford Formation (Zechstein Group)

Formerly known as the Middle Magnesian Limestone, parts of this group of rocks crop out beneath the extreme western parts of Cleadon, though like the rocks of the underlying Raisby Formation, these too are here completely hidden from view by a covering of more recent superficial deposits. Ford Formation rocks, also largely concealed beneath glacial materials, crop out extensively around East Boldon, immediately south of Cleadon, but are not present beneath the greater part of the township. Here, rocks of the Raisby Formation are overlain directly by rocks of the Roker Formation, described below.

Although Ford Formation rocks play only a very minor direct role in the geology of Cleadon, they are an important part of the Magnesian Limestone story and figure rather prominently in the adjoining areas. They can be seen at the surface notably around East and West Boldon, where their outcrops form rather conspicuous features in the landscapes seen from the higher parts of Cleadon Hills. Perhaps most conspicuous from such vantage points is the nearby rounded outline of Downhill at West Boldon. This, together with other prominent land marks, such as Tunstall and Humbledon hills in Sunderland, is composed mainly of rather massive limestones that originally formed part of a long submarine reef that lay roughly parallel to the shoreline of the Zechstein Sea. This would have resembled some of the world's modern barrier reefs, including the Great Barrier Reef off the eastern coast of Australia. Standing on Cleadon Hills today, looking towards Downhill, it is possible to imagine the position of the shoreline of the Zechstein Sea that lay a few miles further to the west, in the area now occupied by the foothills of the Pennines.

Unlike modern reefs of this sort, our Permian reef in north east England was composed not of huge numbers of corals but predominantly of mat-forming colonies of animals known as bryozoans. Amongst these lived huge numbers of shells including molluscs, gastropods and brachiopods, crinoids, algae and a few rare corals. Fossils of these can be seen today at Downhill and at other sites along the course of this long-extinct reef. Beautifully preserved fossils of the abundant reef fauna have been collected from many sites, especially famous being those from Humbledon and Tunstall hills, road cuttings at Hylton Castle and the now long abandoned and partially filled Ford Quarry at Sunderland. Large, and internationally important, collections of these fossils are held locally by Sunderland Museum and the Great North Museum (Hancock), Newcastle as well as by the Natural History Museum, London.

In addition to the distinctive reef limestones, other limestones formed at the same time on either side of the reef. Limestones formed on the seaward site of the reef occupy a wide outcrop around, and to the south, of East Boldon where a very few small exposures may be seen, for example at Turner's Hill on Boldon Golf Course.

Hartlepool Anhydrite Formation (Zechstein Group)

Although no rocks belonging to this formation are to be found onshore in this part of north east England, the Hartlepool Anhydrite has had a major influence on rocks we do see today in and around Cleadon. How can this be and what does it mean in terms of understanding our local rocks?

Before exploring this conundrum further we need to cast our minds back to the brief glimpses we had earlier of the area's geological history. In particular we should recall the description of the Zechstein Sea, a warm sea within tropical latitudes that on occasions was prone to drying up completely, or almost completely. One of these episodes occurred after the formation of the limestones of the Ford Formation.

When sea water dries up the mineral salts dissolved in it are precipitated out as the concentrating water can no longer hold them in solution. As the water evaporates, layers of these minerals build up forming rocks and minerals known as ***evaporites***. During evaporation these evaporite minerals are precipitated in a particular order depending on their solubility. One of the first salts to be precipitated is calcium sulphate $CaSO_4$ that forms as either the mineral anhydrite ($CaSO_4$) or gypsum ($CaSO_4.2H_2O$).

The Hartlepool Anhydrite is a formation composed predominantly of a fine grained aggregate of the mineral anhydrite. It takes its name from Hartlepool, further south on the Durham coast, where it used to be mined for making cement and sulphuric acid. Numerous boreholes offshore from South Tyneside show it to be up to several tens of metres thick, lying above rocks of the Ford Formation. Onshore in the South Shields and Cleadon area it is absent. This brings us back to our conundrum, which can now be explained.

In a near surface environment, exposed to rain and groundwater, anhydrite readily alters to gypsum that, with further exposure to rainwater, dissolves completely. Although the Hartlepool Anhydrite was originally deposited above the Ford Formation in our area, it has since been completely removed as rain and groundwater penetrated these rocks, dissolving all trace of the original anhydrite and gypsum. The precise timing of this dissolution process is not certain, but it must have occurred soon after the succession of Permian rocks was raised above sea level and exposed to downward percolating rain and groundwater.

As a result of this dissolution we see no trace of the Hartlepool Anhydrite onshore in the South Tyneside and Cleadon area, save for a 15 cm thick layer of grey and brown clay exposed in the cliffs near the car park at Trow Point that is the meagre insoluble residue from the total dissolution of the anhydrite. A striking feature of this exposure is the chaotic jumbled nature of the rocks above the former position of the anhydrite. These limestones have collapsed into the void space created by the dissolving anhydrite and gypsum, resulting in the formation of so-called ***collapse breccias***. These rocks, with their distinctive broken appearance are found widely across the area at this level. They are yet another feature of great scientific interest and are some of the world's best developed and most studied rocks of their type. We shall meet them again a little later in our exploration of Cleadon's rocks.

Before leaving the Hartlepool Anhydrite and evaporite rocks it is worth commenting very briefly on the more advanced processes of sea water evaporation. Having expelled all traces of calcium sulphate from the evaporating water, continued evaporation will begin to precipitate more soluble salts. First of these will be sodium chloride (NaCl) that forms the mineral halite, the major component of 'rock salt'. With further drying up, potassium salts eventually precipitate forming such minerals as sylvite (KCl), carnallite ($KMgCl_3.6H_2O$) and polyhalite ($K_2Ca_2Mg(SO_4)_4.2H_2O$). Later episodes of drying up of the Zechstein sea produced beds of these evaporite minerals in what is now the offshore parts of the North Sea, southern County Durham and North Yorkshire. Although not part of Cleadon's immediate landscape, views from Cleadon Hills on a clear day extend far to the south where the conspicuous chemical plants on Teesside owe their origins partly to the exploitation of these very Permian evaporate rocks and where huge potash deposits are being mined from beneath the distant Boulby Cliff.

Roker Formation (Zechstein Group)

Until recently the topmost division of the Magnesian Limestone in north east England was known as the Upper Magnesian Limestone. Although this is the name used on current BGS maps of the Cleadon area, the name has now been superseded: the former Upper Magnesian Limestone of the South Tyneside area is now named the Roker Formation, which includes two divisions previously known as the Concretionary Limestone and the Hartlepool and Roker Dolomite. The relationships of these subdivisions is rather complex and need not concern us here. The rocks formerly classified as Upper Magnesian Limestone in Cleadon all appear to belong to the Concretionary Limestone.

As noted above, over much of the Cleadon area, these limestones rest directly upon those of the Raisby Formation: the intervening Hartlepool Anhydrite is absent as a result of being completely dissolved since its formation. Rocks of the Concretionary Limestone form the higher land around Cleadon (Plate 7). These are the rocks of Cleadon Hills and, as we shall see later, the rocks used to build some of the oldest houses in the village.

Plate 7: *General view of Cleadon Hills, showing small exposures of Concretionary Limestone in old quarries.*

The Concretionary Limestone comprises a variety of limestones and dolomitic limestones and includes some of the most remarkable and unusual rocks within the marine Permian rocks of Europe. The eminent geologist, W.A. Tarr, described these rocks as containing "… *the most remarkable patterns in sedimentary rocks anywhere in the world* …" proof indeed of the special character of some of Cleadon's rocks.

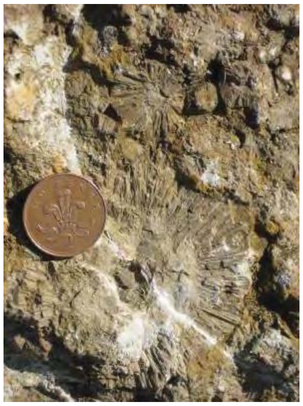
Like much of the Magnesian Limestone of north east England, some parts of the Concretionary Limestone, at least at a first glance, appear to consist of bedded pale cream or yellowish limestone. However, in most places closer examination reveals that the original horizontal bedding is partially or completely obliterated by a bizarre range of concretionary structures. Perhaps best known of these is the odd looking rock, widely known in the district as 'cannon ball limestone' because of the presence of characteristic almost perfectly spherical hard concretionary structures (Plate 8). When weathered in natural rock faces, or in walls, these rocks commonly look like piles of almost perfectly round balls that range in size from concretions a few millimetres across to 'cannon balls' over 0.3m across (Plate 8). In their un-weathered state these rocks usually show the rounded balls or concretions surrounded by rather softer and friable yellowish coloured matrix. In places the ball-like concretions pass into groups of strange elongated rod-like or finger-like concretions, these are sometimes arranged in fan-shaped or concentric aggregates that defy description. In un-weathered sections, these too exhibit a yellowish friable matrix (Plate 14).

Such rocks are especially well known in the area between South Shields and Sunderland, including Cleadon. Some of the most spectacular examples of these rocks, to be seen in museum collections throughout the world, were recovered from the now long abandoned Fulwell Quarries, a short distance to the south of Cleadon. Magnificent examples of these structures are preserved in the collections of Sunderland Museum. Good examples may, however be seen *in situ* at Marsden Old Quarry, on the coast near Whitburn, in places on Cleadon Hills and in Cleadon Park Quarry. Blocks can also be seen in the numerous walls throughout the older parts of Cleadon Village (Plate 8).

Plate 8: *Typical 'cannon ball' limestone in a block in the garden wall of East Farm.*

In addition to these concretion types, and perhaps the most typical and widespread of the Concretionary Limestone varieties in our area, is that consisting of radiating groups, or spherules, up to a few centimetres across, composed of calcite crystals, typically forming 'daisy-like' aggregates when seen in section. Spectacular examples of these, ranging from tiny spherules a few millimetres across, developed along individual beds of limestone, to complex aggregates in which all trace of original bedding has been destroyed, are exposed in abundance in Cleadon Park Quarry, in places on Cleadon Hills and in the weathered faces of Marsden Old Quarry (Plates 9 to 11). Some especially fine fresh examples of this strange rock type were exposed a few years ago in the land adjoining Marsden Old Quarry, which was stripped of topsoil in an attempt to rejuvenate Magnesian Limestone grassland habitats. At Marsden, weathered-out rounded hollows, marking the position of large concretions, are locally conspicuous. Although it has been suggested that these are man-made features, possibly cup and ring marks, they are undoubtedly of natural origin.

In many places the recrystallization of the Concretionary Limestone has created a rock with a rather sponge-like appearance, composed of hard irregular cellular structures surrounding small open voids (Plates 12 and 13). Remnants of the original horizontal lamination, or bedding, are often clearly preserved in these rocks, good examples of which are characteristic of much of the limestone exposed in the old quarry pits on Cleadon Hills. Similar rocks are common in the limestone blocks seen in many of the older buildings in the village, including the windmill, All Saints Church, and the field boundary walls on Cleadon Hills.



Plates 9 to 11: *Stellate concretions in Concretionary Limestone at Cleadon Hills (left) and Cleadon Park Quarry.*


Plates 12 and 13: *Sponge-like Concretionary Limestone exposure in old quarry on Cleadon Hills, and utilised in the boundary wall of Cleadon Waterworks.*

Despite having attracted the interest of geologists since at least the early 19th Century, the processes involved in the formation of these strange rocks are still not fully understood. The British Geological Survey study of the Sunderland area includes an excellent review of the evolution of ideas on these rocks, together with numerous references to the detailed technical literature on the subject.

However they were formed, it is clear that since their original deposition as limestones with a high magnesium content, segregation of the minerals calcite and dolomite has taken place; a process known to geologists as de-dolomitisation. In the resulting concretionary limestones, the cannon balls, rods, or daisy-like aggregates consist of almost pure hard calcite surrounded by a matrix of rather softer, and locally friable, powdery dolomite (Plate 14).

Plate 14: *'Cannon ball' concretions, with yellow powdery dolomitic matrix, found in the garden wall of East Farm.*

A feature of many parts of the Concretionary Limestone is the abundance of disseminated hydrocarbons within the rock. Although not visible in the limestone, which is almost invariably very pale cream coloured, this hydrocarbon content is apparent from the strong oily smell given off when the rock is hammered. Most of the limestones exposed on Cleadon Hills, and in and around Marsden Old Quarry, exhibit this feature very clearly.

Plate 15: *Cleadon Park Quarry, bedding in Concretionary Limestone Formation showing local evidence of very slight disruption due to collapse resulting from the dissolution of underlying evaporite beds.*

As noted above, the dissolution of the underlying Hartlepool Anhydrite from onshore parts of north east England resulted in the widespread collapse of the overlying formations, creating the remarkably broken appearance typical of many of the limestones seen in the coastal cliffs of South Tyneside, Sunderland and County Durham. These rocks, known from their mode of formation as 'collapse breccias', are an important feature of the geology of this area. The effects of this collapse brecciation are much less obvious in Cleadon than in the surrounding area, though evidence of such collapse, in the form of rather undulating and broken beds of limestone, may be seen locally in parts of Cleadon Park (Plate 15) and at Marsden Old quarry.

Plate 16: *Efflorescent crusts of white epsomite on limestone at Marsden Old Quarry.*

An interesting feature of the rocks exposed in Marsden Old Quarry is the presence of a white fluffy crystalline crust (Plate 16), or efflorescences, on some sheltered rock faces. Analysis has shown these to be composed of the mineral epsomite ($MgSO_4.7H_2O$) (natural Epsom salts), which forms here and elsewhere on exposures of the Magnesian Limestone as a result of continued reaction of the dolomite with traces of calcium sulphate contained within the rock. As epsomite is readily soluble in water, these crusts are best developed after prolonged periods of dry weather in summer. They are very much less conspicuous in winter or during damp weather.

The limestones of the Concretionary Limestone have been much used for local building and for lime burning, over many centuries. The finest exposures of these rocks visible today in the Cleadon area are in old quarries opened for these purposes. We shall examine the uses to which these rocks have been put a little later.

Folds and Faults

Most of the rocks we have so far examined were formed as more or less horizontal layers of sediment beneath water. The single exception to this is dolerite of the Hebburn Dyke, which forms a vertical wall of rock that cuts through these earlier formed sedimentary rocks. Over millions of years of geological time since their formation, these sedimentary rocks have been disturbed and disrupted by a variety of Earth movements. Such activity has resulted in the tilting of layers of the region's rocks, giving them a general easterly inclination towards the coast. Because of this, successively younger layers of rock are encountered at the surface as we approach the coast, as the underlying older layers dip beneath them. This overall easterly dip is, however, interrupted locally by small folds. Cleadon village lies on the eastern limb of one such fold, known as the Boldon Syncline, a shallow 'u-shaped' fold, the axis of which is aligned roughly north-north-west to south-south-east through East and West Boldon, to the west of the township. Immediately to the north east of the Boldon Syncline, a corresponding arch-like upfold, known as the Harton Dome or Marsden Anticline, affects the Coal Measures rocks beneath the Harton and Marsden areas.

Although, as we have already seen, Coal Measures rocks do not crop out at the surface within the township, we know a great deal about them and their structure from underground coal workings deep beneath the surface. The Earth movements that created the Boldon Syncline and Harton Dome must have occurred at some time between the formation of the Coal Measures and Permian rocks, as the latter rest on an eroded surface of these folded older rocks, known as an unconformity (see Fig 7).

In addition to tilting and gentle folding, Earth movements have created fractures within the region's rocks adjacent to which the rock layers have been displaced. These structures, known as faults, disrupt the continuity of surface outcrops and show up clearly on geological maps and sections (Fig. 6 and 7). Most prominent of these in our area is the roughly east to west trending fracture named the Cleadon Fault, the surface course of which passes directly through Cleadon village. As can be seen on the geological section (Fig. 7), the plane of this fault dips southwards with the rocks on the southern side displaced downwards relative to those on the northern side. Where encountered in coal workings in the Maudlin Seam deep beneath the village, the amount of this displacement has been recorded as between 12 and 21m beneath Tilesheds Lane and East Boldon, increasing to as much as 37m beneath Cleadon Lane, to the east of the village. In this area the Hebburn Dyke appears to have been intruded into the fault, clearly indicating that the fault formed well before the dyke.

Two other prominent faults are known running beneath Cleadon Hills and Cleadon Lizards (Fig. 6). These are the Lizards Fault and the Skipsey's Fault. The first of these, which trends almost due E-W, dips southwards with a southerly displacement of about 47m, measured underground in the Maudlin Seam The roughly north-east to south-west trending Lizards Fault dips to the north-west, with a displacement in that direction of up to 23m, also in the Maudlin Seam.

A prominent north-east to south-west trending fault, which delights in the name of the 'Muck Dyke Fault', one of the most prominent faults in this part of the Great North Coalfield, crosses the south-east corner of the parish, displacing the rocks up to 26m to the north-west. It was named by the early coal miners because of the alteration of the coals found close to it.

Although these named faults must displace the surface positions of the various rock units beneath the township, as shown on the geological map (Fig. 6), the almost universal mantle of superficial deposits conceals their effects and no direct evidence of them can be seen at the surface. A number of other, mainly much smaller, faults encountered in underground coal workings are recorded on BGS 1:10,560 scale Sheet NZ36SE, though these generally have little impact on the pattern of surface outcrops.

Igneous Rocks

All of the rocks we have looked at so far originated as sediments in a variety of surface environments over geological time: they are sedimentary rocks. In contrast, igneous rocks are formed by the cooling and crystallisation of molten rock or magma. This may be erupted onto the earth's surface as lava, or intruded into the pre-existing surrounding rocks. These latter types of igneous rock are known as ***intrusive igneous rocks***. The rocks upon which Cleadon stands include a single example of such an intrusive igneous rock. Although it lies deep beneath the surface, and we cannot see it today, it has an important place in the area's geological history. How then do we know about it, and what can it tell us?

To unravel this we need to cast our thoughts back once more into geological time, though this time nowhere near as far back as the Permian rocks we have just explored. To understand this rock, we must look back only some 55 million years to the Tertiary, or Palaeogene, era of earth history. Huge though this time interval might seem it is just 23.45pm using the 24-hour clock analogue – not long at all in geological terms.

At this time splitting of the continental plates in the area that is now occupied by Northern Ireland and the Hebrides marked the earliest beginnings of what eventually became the Atlantic Ocean. Enormous out-pourings of basaltic lavas were accompanied by the intrusion of magma of similar composition into long cracks in the existing rocks. Some of these cracks extended far beyond the volcanic centres. The injection of magma, at temperatures of around 1100ºC, into such vertical cracks, created narrow wall-like bodies of intrusive rock, known to geologists as ***dykes***. One such group of dykes, often referred to as the Mull Swarm, extends from the Isle of Mull and across northern England, including Cleadon in South Tyneside.

The Coal Measures rocks beneath Cleadon are cut by a west-north-west to east-south-east trending dyke known as the Hebburn Dyke; further to the west this is known as the Monkton or Harton Dyke. Its mapped course beneath Cleadon village (Fig. 6) is based upon its recorded position in underground coal workings in the Maudlin Seam. As we have already seen, the dyke appears to have been intruded locally into the pre-existing Cleadon Fault, to the east of the township. However, over almost its entire known outcrop through South Tyneside its surface position is concealed beneath a mantle of superficial deposits. The only surface exposure recorded near Cleadon was at the former quarry at Brockley Whins, near East Boldon, though the precise location of this exposure is not now identifiable. An exposure of the dyke, cutting the Magnesian Limestone, in coastal cliffs near Whitburn has also been reported, though with no descriptive details. Elsewhere, records reveal that the dyke varied from 4m to 15m in width and consisted of a black fine-grained tholeiite (a variety of basalt) in which occur small spherical vesicles, or gas cavities.

Metamorphic Rocks

Reports of the Hebborn Dyke as seen in the underground coal workings record that the Coal Measures rocks up to several metres on either side of it were altered, or baked, by the heat of the intrusion. These provide Cleadon's only *in situ* examples of metamorphic rocks though, like the dyke itself, they are not visible at the surface.

Quaternary Deposits

The Quaternary Period comprised the last 2.5 million years of Earth history (the few seconds running up to midnight using the 24-hour clock analogue) during which time Great Britain experienced a succession of 'ice ages'. During this time cold ***glacial*** episodes with thick accumulations of ice cover, alternated with much milder ***inter-glacial*** episodes during which the ice disappeared to be replaced by temperate conditions, on occasions warmer than the present British climate. Over this comparatively short episode of geological time, a variety of earth processes has shaped, and continues to shape, the landscape as we see it today.

The British landscape owes much to the effects both of erosion and deposition resulting from successive episodes of Quaternary glaciation. During Quaternary times, a major episode of global cooling resulted in ice sheets, up to 1km thick, developing across Britain on several occasions, at their maximum extent reaching as far south as the Thames valley and possibly even approaching the Scilly Isles. By their very nature, successive glacial episodes tend to destroy the features and deposits created by previous glacial activity. However, careful study over many years has allowed a rather detailed picture to be built up of the alternation of the cold glacial episodes with milder interglacial episodes when ice retreated and the climate warmed. Classic effects of glacial activity in Great Britain include erosional features such as the 'U-shaped' valleys, corries and hanging valleys of mountainous areas, as well as mounds and ridges of glacial debris in upland areas, and extensive thick spreads of glacial materials including stony clays (boulder clay or 'till') and sands and gravels over many parts of lowland Britain. These sediments include debris transported and dumped by the ice sheets themselves, or from the streams of glacial meltwater associated with those ice sheets.

The term Holocene Epoch is generally applied to the time since the melting of the last ice, about 11000 years ago.

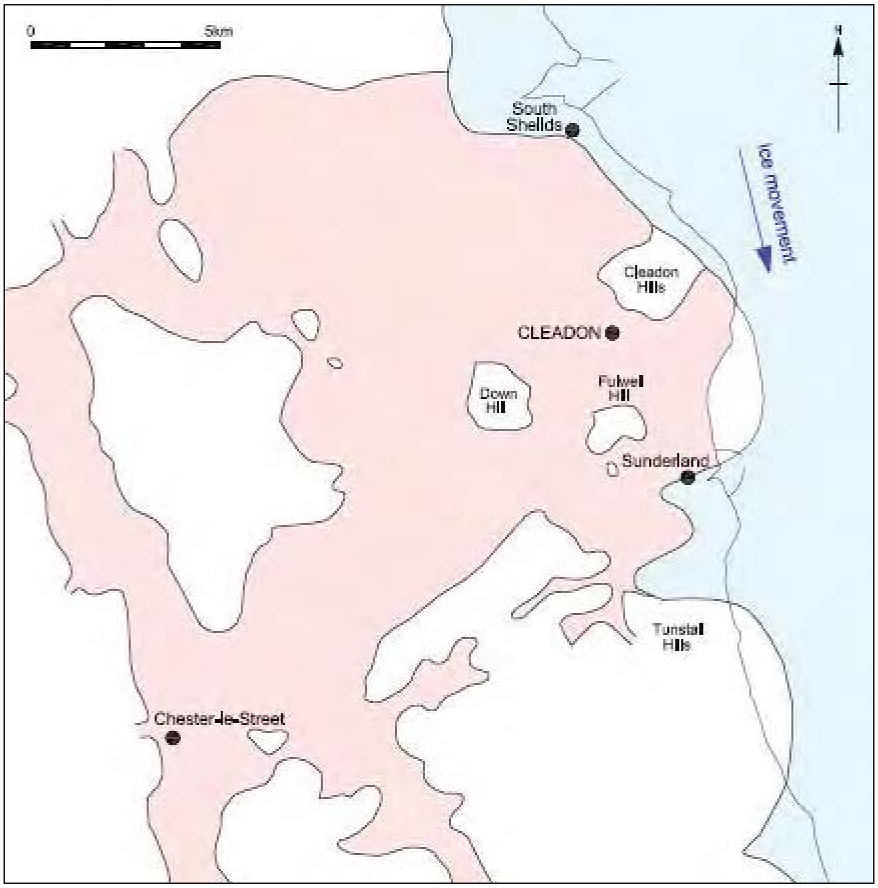


Figure 10: Glacial Lake Wear. The approximate extent of the lake (pink) dammed by the ice (blue) flowing from the Cheviots along what is today the North Sea coast (after Smith 1994).

Quaternary deposits in north east England are believed to date from the most recent glacial episode, known as the Late Devensian, and later times, between about 20 000 years ago and the present day. No older Quaternary deposits have been identified with certainty from the district. The first ice cover in our area during Late Devensian times appears to have been by thick ice sheets that streamed east and south-eastwards through the Tyne Gap and down the east coast, depositing the Durham Lower Boulder Clay. Elsewhere in the region, and perhaps locally in the South Tyneside district, tongues of ice from the north later pushed into parts of the Tyne and Wear valleys depositing the Durham Upper Boulder Clay. Ponding of water between these two major ice sheets created an extensive lake, known by geologists as Glacial Lake Wear (Fig. 10), that covered much of what is today South Tyneside, including Cleadon. Within this lake were deposited a group of silts, sands and laminated clays known today as the Tyne-Wear Complex. As the ice sheets waned, re-working of previously deposited clays under 'freeze-thaw' conditions produced the Pelaw and Prismatic clays, with small spreads of glacial sands and gravels being deposited locally by streams of meltwater pouring out from the waning ice sheets. Post-glacial fluctuation of sea levels resulted in the accumulation of marine alluvium, in places in the lower Tyne valley, to at least 25m below present sea level and a submerged forest peat bed, only slightly above modern sea level, near Whitburn.

Although fine sections through these deposits can be seen in the coastal cliffs of South Tyneside, there are no permanent exposures of these materials in and around Cleadon today, though they are exposed from time to time in temporary trenches. However, in a well-populated area such as that around Cleadon, and especially where mineral extraction has formerly been so important, a great deal is known about the detailed nature and succession of these 'drift' deposits. Such information has, over many years, been obtained from sinking shafts or trial boreholes for coal, water and other minerals, as well as from countless excavations and site investigation for the construction of buildings, roads, docks and other services. From these records a detailed picture of the events and processes that shaped the district throughout the Quaternary period has been built up.

Deposits of geological materials formed during this period include a range of clays, sands and gravels and are commonly referred to in geological literature by the collective term 'drift' deposits, to distinguish them from the older, harder 'solid' rocks upon which they rest. Over recent years a very detailed and complex succession of these deposits has been established, though we do not need to concern ourselves here with the details of this. Instead, in our description of the Cleadon area we will adopt the much simplified succession of superficial, or 'drift' deposits listed in Table 2, the distribution of which is shown on Figure 8.

Table 2: *Succession of Quaternary deposits present in South Tyneside*

Made Ground

Alluvium
Pelaw Clay
Fluvioglacial sand and gravel
Tyne-Wear Complex
Durham Lower Boulder Clay
Basal sand and gravel
----------Rock head Surface (unconformity) --------
BEDROCK

Rock Head Surface

Evidence from numerous borehole records across the region reveals that the Quaternary deposits rest upon a pre-glacial land surface, known as the rock head surface, that, although resembling the present day topography, was one of rather more pronounced relief. The records of numerous boreholes through these deposits reveal that this pre-glacial surface was graded to a lower sea level than that of today.

Pre-glacial topographical features, such as stream and river valleys, are commonly completely concealed beneath glacial deposits of the types described here. Borehole records have revealed the presence of a major roughly north-north-west to south-south-east trending pre-glacial valley, now completely concealed beneath glacial deposits, that formerly drained to the sea near Whitburn. Borehole records also indicate that this valley ran beneath the village and was joined by a smaller tributary valley, the centre-line of which lies a few metres north of Tilesheds Lane. No sign of these features can be detected on the modern ground surface.

A number of bench-like erosion surfaces are known to be present beneath the 'drift' deposits of the area immediately east of Cleadon. The best developed of these is the smooth rock head surface, up to 0.8km wide that extends southwards from South Shields to Whitburn. Its elevation, at about 30m above sea level, has invited comparison with the well-known raised beach, at a similar level, further south at Easington in County Durham.

Except in nearby coastal cliff sections, the rock head surface at the junction between the 'solid' bedrock and the overlying Quaternary deposits is rarely seen. It would have been well exposed in some former quarry faces, though all of these in the Cleadon area are today either overgrown or degraded. However, ice-smoothed surfaces, known as ***roches moutonées*** were recorded from Trow Point Quarry in the 19th Century, and a few examples of ice-scratched (striated) surfaces may be seen exposed immediately beneath the boulder clay on the coast near Man Haven between Frenchman's Bay and Velvet Beds. Similar ice-smoothed surfaces must exist beneath the superficial cover over large parts of Cleadon, particularly where Concretionary Limestone forms the bedrock. Trenches or other excavations may reveal these features from time to time.

Basal Sand and Gravel

Thin pockets of sand and gravel have been described from hollows in the rock head surface beneath later 'drift' deposits locally in cliff exposures and in boreholes in the areas adjoining Cleadon, though little is known of the presence or nature of these materials beneath Cleadon: they do not crop out at the surface.

Durham Lower Boulder Clay

This is the deposit depicted simply as Boulder Clay on currently available BGS maps. It is typically a tough grey or brown, sandy clay, or 'till' and includes scattered pebbles, cobbles and boulders of a variety of rock types that were picked up by the ice and dragged here from source areas far beyond Cleadon. Known as ***glacial erratics*** these exotic rock types give us clear evidence of the source of the ice and its direction of travel. In the Cleadon area the suite of erratics found in the local boulder clay include fragments of Coal Measures sandstone and ironstone, grey limestone and dolerite ('whinstone') derived from the Pennines or south Northumberland, and cobbles of grey greywacke sandstones derived from the Scottish borders, together with rarer fragments of volcanic rocks from the Cheviots, and grey-green slates from the Lake District. Some of the included boulders, especially those dug from excavations, exhibit conspicuous scratches, or striations, resulting from the grinding of boulders against one another as they were transported by the ice.

Plate 17: The boulder clay covered fields surrounding Cleadon Hills Farm include shallow ponds and evidence of well-defined 'rig and furrow' cultivation.

The fields to the east of Cleadon Hills lie on a plateau of limestone on which lies a patchy veneer of boulder clay, in most places only a couple of metres or less thick. Shallow ponds at Cleadon Hills Farm owe their presence to the impervious nature of the clay. The clay characteristically supports heavy brown soils in which cobbles and pebbles are common. The fields to the south west, south and south east of Cleadon Hills provide fine examples of this material. During the winter months, when bare of crops, the stiff, heavy nature of the soil is obvious. Typical examples of all of the erratic rock types mentioned above can be seen in abundance in any of the fields. In places, clearance stones, gathered from these fields and dumped in the field margins, include larger examples of these erratic boulders (Plate 18). As we shall see below, a variety of erratic boulders are conspicuous in walls and buildings around the village.

Tyne-Wear Complex

This term is applied to a variable, and locally rather complex, succession of laminated silty clays, silts, sands and some gravels. Most of these deposits are believed to have been laid down in the former Glacial Lake Wear. Deposits of the Tyne-Wear Complex are known to be extensively present over much of our area though, because they are generally concealed beneath the widespread cover of Pelaw Clay that mantles most of South Tyneside, little is known about their precise distribution of composition here. Laminated clays of the Tyne-Wear Complex were formerly worked for brick and tile making, from beneath the Pelaw Clay at the old brickworks at Tilesheds. They may also have been dug for brick making in several old and degraded clay pits, the sites of which are recorded on BGS 1:10,560 sheet NZ36SE. Sediments of the Tyne-Wear Complex are notorious to foundation engineers because of their plasticity when wet, causing extremely poor ground conditions.

Plate 18: Clearance stones in arable field on south side of Cleadon Hills including Glacial erratic boulders of Whin Sill dolerite (hammer shaft is 35cm long).

Fluvioglacial Sand and Gravel

Small patches of sand and gravel, believed to have been deposited by glacial meltwaters, are present locally in a few locations in South Tyneside, including Cleadon. A conspicuous outcrop of this material, depicted on the geological map (Fig. 8), underlies part of the centre of Cleadon village. Its extent has been reliably mapped from the presence of old gravel pits excavated on both sides of Boldon Lane. Little evidence of these can be seen today, though the modern street known as Sandgrove recalls the former workings. A note on the BGS 1;10,560 map records that '*Red-brown gravelly sand'* more than 4.6m thick was seen here at the time of the field survey between 1954 and 1972. The overgrown excavations in the woodland of Cleadon Park (Plate 19) mark other now almost completely degraded sand and gravel workings. Although flint and chalk pebbles, indicating their derivation from glacial material transported from the floor of the North Sea, have been recorded from these gravels, none were seen here during the present investigation.

Pelaw Clay

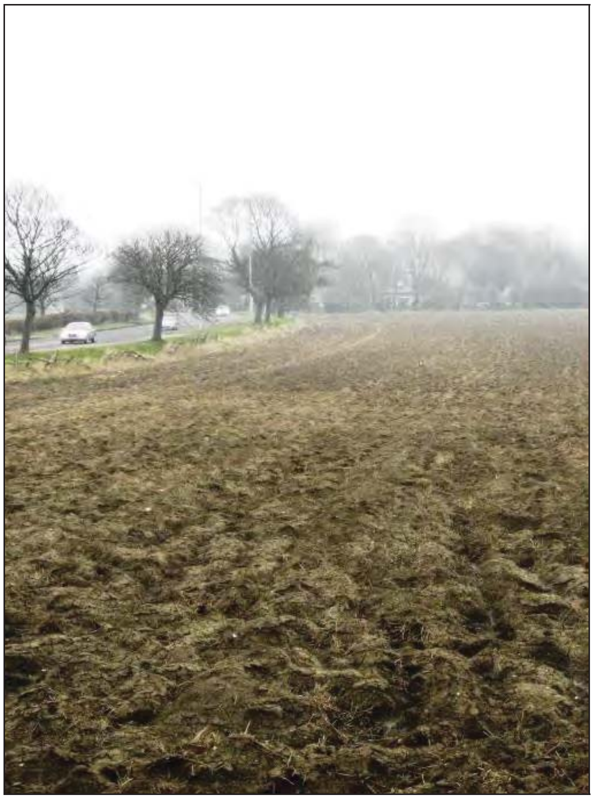
This deposit, previously referred to as the 'Upper Wear Clay' takes its name from the disused Pelaw Brick Pits a few kilometres to the west of Cleadon. It typically consists of brown to purple silty clay with scattered stones. It has been interpreted as a product of re-working of previously deposited glacial sediments, possibly during periglacial conditions. Generally between 1 and 2m thick, though locally over 4m thick, it conceals other 'drift' and 'solid' formations and underlies much of Cleadon Village and the surrounding countryside, including Boldon Flats. Like the boulder clay described above, the Pelaw Clay typically gives rise to heavy soils that readily become waterlogged during winter conditions (Plate 20). Cleadon Pond (Plate 21) lies on the outcrop of the Pelaw Clay and almost certainly owes its permanence as a pond to the impervious nature of this clay. Early historic mapping shows numerous small ponds distributed across the Pelaw Clay outcrops of the Cleadon area..

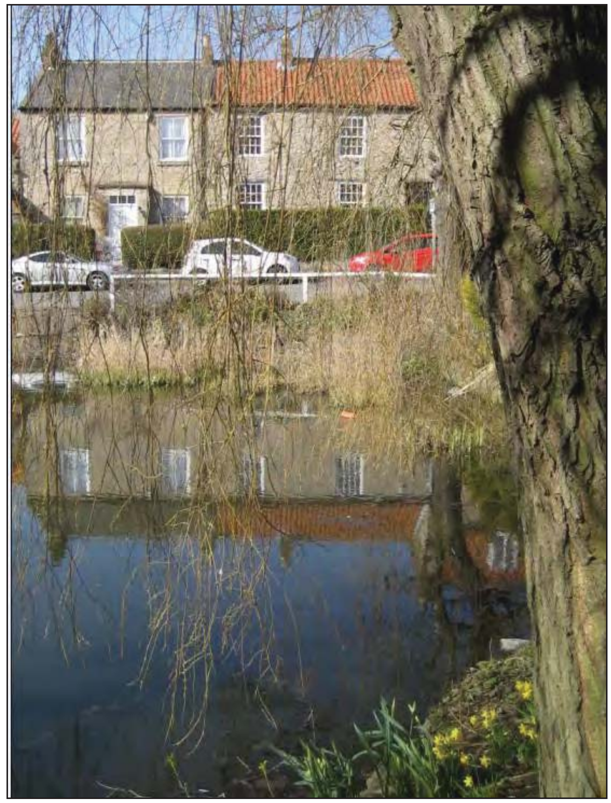
Plate 19: *Former gravel pits in Cleadon Park.*

There are no permanent exposures of this clay within the parish, though it is commonly exposed in temporary excavations in and around the village and small sections of it may be seen on parts of the nearby coast. A number of pits were excavated in this clay throughout the parish for brick and tile production; the name 'Tileshed's Lane' plainly referencing this activity. Sections through the clay are no longer exposed at its type locality, in the former Pelaw Brick pits. A number of former pits are depicted on BGS 1:10,560 sheet NZ36SE and a note on this map at Moor Lane records a little over 2m of '…*brown plastic clay, some stones*…', relating to one such pit at the southern part of the works. Another note on the same map records '…*laminated clay*…' in the old clay pits north of Tilesheds Lane, part of the Tyne-Wear Complex.

Alluvium

This name is given to deposits of clay, silt, sand and gravel deposited from, and currently being deposited by, present day streams and rivers. Whereas no accumulations of such materials are mapped in Cleadon a note on BGS Sheet NZ36SE makes reference to alluvium covering an unspecified area of land at Boldon Flats. The alluvium here is likely to be very thin, probably less than a metre thick, and is restricted to the lowest and flattest-lying ground.





Plates 20 and 21: *Heavy clay soil typical of the Pelaw Clay in this field adjacent to A1018 road, south of Cleadon, and Cleadon Pond.*

Plate 22: *Heap of grey Coal Measures shale in Marsden Old Quarry.*

Made Ground

Made ground is a term applied to artificial deposits created by human activities rather than natural geological processes. Although not a natural deposit, brief comments on it are given here for completeness of description. It includes all manner of industrial and domestic waste materials and spoil from quarrying and mining. Also included are road and railway embankments and areas where substantial quantities of natural geological materials may have been re-deposited by landscaping activities.

Within Cleadon several areas of made ground have been mapped and are shown on Figure 8. Apart from a rather extensive area of made ground, known to include substantial amounts of domestic waste, beneath what is today Temple Memorial Park, areas of made ground within the township are generally small and confined to the fills of former clay pits. The nature of this fill is not known, but almost certainly includes some domestic and farm waste together with soil and sub-soil used in filling and landscaping the old pits. A small mound of un-vegetated colliery spoil, consisting mainly of grey shale, remains today at Marsden Old Quarry Local Nature Reserve, though the source of this material is not known (Plate 22).

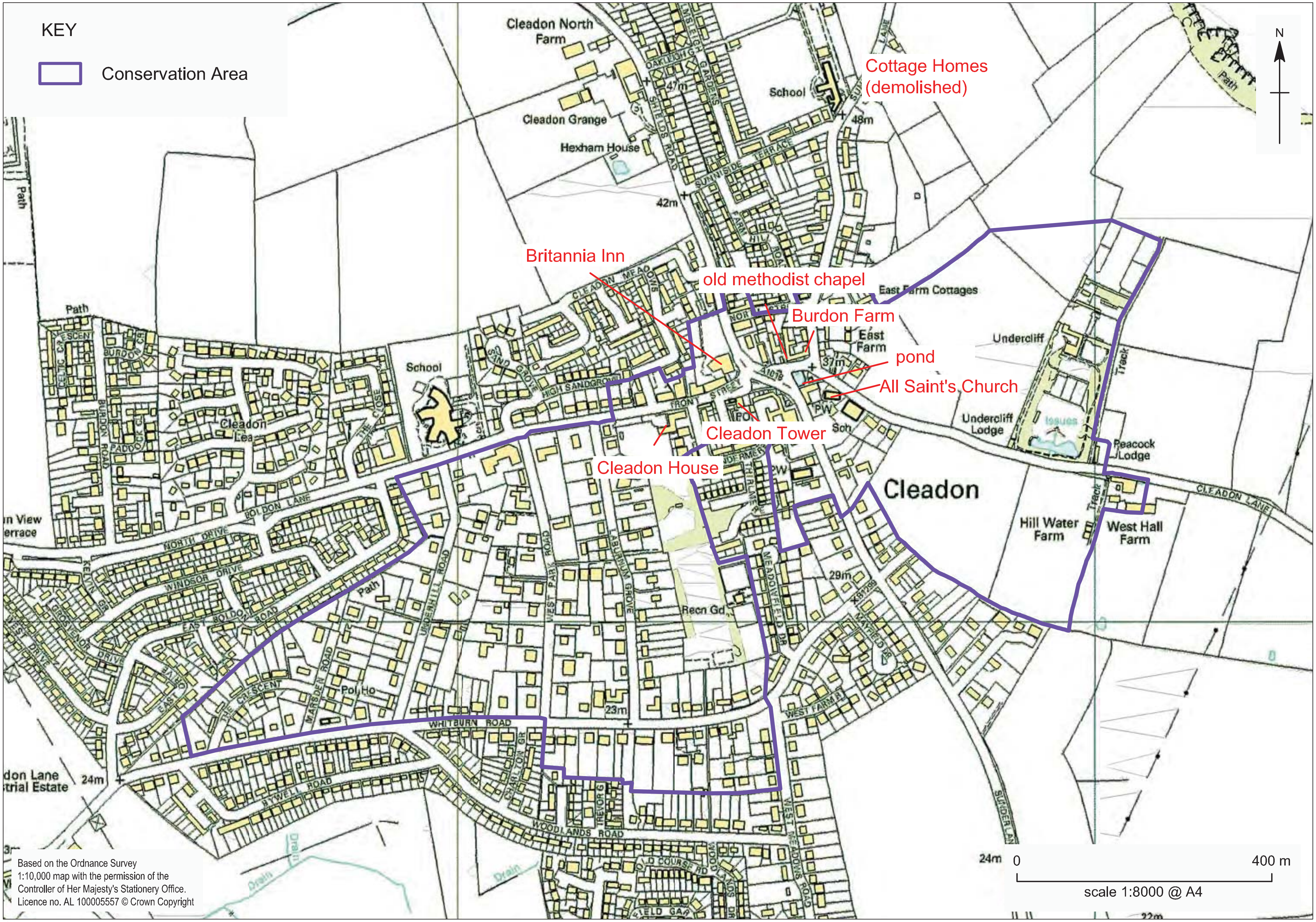
HOW OUR LOCAL ROCKS AND MINERALS HAVE BEEN USED

Everything that is, and ever has been, used by humans, since the dawn of civilisation, has either been dug from the Earth or grown upon it. From the means of creating even the simplest weatherproof shelter, to the fuels we need, the water we drink and the food we eat, everything ultimately depends upon the rocks and soils beneath our feet. The earliest human settlers would have found the materials, and food, they needed close to hand. With time, as life became more sophisticated, and as local materials became insufficient, they needed to look further and further afield for these necessities. Leaving aside the production of food and crops, which are discussed elsewhere, we will look here at those rocks and minerals that Cleadon has had to offer.

Coal

North East England, and in particular the area around the rivers Tyne and Wear, is probably best known as being part of the Great North Coalfield. Surface exposures of individual coal seams, which actually form a very small, but extremely valuable, proportion of the total thickness of Coal Measures rocks, must have been exploited by the earliest human settlers, though we know little or nothing about where and how it was then worked. However, by the 12th and 13th centuries there are records of coal mining along the banks of the Tyne and adjoining areas, and by the 16th Century a well organised and profitable trade in coal had developed between Tyneside and London and south east England. This was an industry that lay at the very heart of life in this part of the country. Who is not familiar with the term 'coals from Newcastle', or has never heard the song 'the Keel Row'?

As we have seen, Cleadon lies within the Coalfield. Rocks of the Coal Measures crop out at the surface to the north and west of Cleadon, and indeed beneath the central part of the village as shown on the geological map and section (Fig. 6 and 7), but here they are hidden from view by later layers of superficial clays and gravels. This is the area known as the 'exposed coalfield'. However, across much of



Cleadon Village Atlas: detail map of the village centre

Figure 11

the township these same Coal Measures rocks are buried beneath the various subdivisions of the Magnesian Limestone and are in an area known as the 'concealed coalfield'.

It was the 'exposed' coalfield that first attracted attention and that was the source of the vast tonnages of coal mined here until the second decade of the 19th Century. The year 1820 was hugely significant in the industrial history of north east England. At Hetton Colliery, a few miles to the south of Sunderland a new shaft ended years of speculation and conflicting technical opinion by finally proving that the area's Coal Measures rocks do indeed extended eastwards beneath the Magnesian Limestone. This was to mark a period of considerable expansion of the east Durham Coalfield, as the known coal seams were followed underground towards the coast, and beyond, and new collieries were sunk at places like South Shields, Whitburn and Monkwearmouth. Offshore mining eventually extended almost 7.5km out to sea before the closure of the majority of the pits in the 1980s.

Although no coal mines were sunk in Cleadon itself the whole parish is undermined and several seams were worked from the nearby collieries at Westoe, Whitburn and Boldon. At least 10 named seams of the local Coal Measures succession are known to be present beneath Cleadon, with workings recorded in at least 5 of these (Fig. 7). In upward succession these are the Harvey, Hutton, Brass Thill, Maudlin and Main seams. Most extensive are those workings in the Hutton and Maudlin seams. Beneath Cleadon the seams varied in thickness from 1.0 to >2.0m, the latter from 1.5 to 1.75m.

The precise extent of workings in these seams can be found on abandonment plans of the relevant collieries, held by the Coal Authority. Certain key geological features recorded in these plans were used in compiling the detailed geological maps of the area. These indicate that the Maudlin seam lies at a depth of around 200m below sea level at the north east of the township, near Marsden Old Quarry; at about 370m below sea level beneath the centre of the village; and at almost 400m below sea level near Fulwell, at the southern boundary of the parish.

Limestone

In addition to its role in shaping the natural landscape, man's varied uses of limestone has had a considerable impact on the human, agricultural and economic landscape of the village and surrounding countryside.

Limestones of the Concretionary Limestone in and around Cleadon offer a reasonably durable stone suitable for building, particularly for the construction of cottages, barns and boundary walls. It seems certain that these limestones were used in building the very earliest stone structures in Cleadon. The variable, and commonly rather open, concretionary textures make the rock generally unsuitable for dressing into shaped block and, with a few exceptions, most of the local limestone used for building in and around the village is in the form of undressed rubble. The local limestones can rarely be obtained in blocks large enough for making sills, lintels etc. and for these purposes other stones from outside the area have been brought in.

Plate 23: *Old stone pits, now almost completely grass-covered, on Cleadon Hills. Penshaw Monument is a conspicuous landmark on the Magnesian Limestone escarpment in the far distance.*

The most obvious sources of suitable stone in the Whitburn parish is the higher ground on the summit and south west facing slopes of the Cleadon Hills. These areas are today scarred by numerous small pits from which limestone has plainly been extracted (Plate 23). Stone that closely matches the limestone exposed at these sites is seen widely in some of the older buildings and boundary walls within the village. The age of these old pits is difficult or impossible to establish with certainty, though if they were the sources of stone used in buildings of known age, these buildings offer evidence of a minimum age of the workings. Some pits could well be very much older, having supplied stone to long-vanished buildings.

Larger-scale workings can be found at Cleadon Park (Plate 24) and Marsden Old quarries. Lime kilns are recorded only at Marsden Old Quarry, but it is likely that limestone was burnt to produce quicklime at both sites. In addition both also probably yielded stone for building, as hard core for local road making and other purposes.

Quicklime was an important product employed originally for use in lime mortars and also in the making of slaked lime, widely used in the past as a soil improver. Today powdered limestone dust is widely used, large quantities of which are produced in modern limestone quarries. No limestone has been worked within Whitburn parish for many years.

Plate 24: *Cleadon Park Quarry. This large, long-disused limestone quarry is today an important and pleasant public park.*

Sand and Gravel

The single isolated outcrop of glacial sand and gravel, which underlies the central part of Cleadon, was worked from at least two small pits (BGS 1:10,560 NZ36SE). The northernmost of these, on the north side of Boldon Lane, is today concealed beneath the housing development of Sandgrove. More than 4.6m of red-brown gravelly sand were recorded here at the time of the geological survey between 1954 and 1972. The overgrown excavations in the woodland of Cleadon Park (Plate 19) marks another, now almost completely degraded, sand and gravel working where, at the time of the geological survey, more than 4.6m of gravel was recorded.

Clay

The sites of several former clay pits on the outcrop of the Pelaw Clay are shown on the BGS 1:10,560 map NZ36SE. These would have been worked for brick and tile making, in many, if not all cases, penetrating into the underlying laminated clays of the Tyne-Wear Complex. Except for the abandoned pits north of Tilesheds Lane, and those near Boldon Station, these workings were on a comparatively small scale.

Several old walls within the village include substantial amounts of brick, obviously made by the firing of clay with small scattered stones. These almost certainly are examples of bricks made from clays obtained from one or other of these former clay pits.

Glacial Erratics

The presence of boulders of far-travelled rock types – 'glacial erratics' – in the local boulder clay has already been mentioned. Whereas it is extremely unlikely that these were ever specifically worked as a source of building stone, whenever they were encountered in excavations they are likely to have been accepted as suitable materials to be incorporated into buildings where the uniformity of stone type was unimportant. Several older cottages and walls within the village contain examples of erratic boulders of Whin Sill dolerite, the dark grey or black colour of which contrasts conspicuously with the more widespread use of pale cream coloured local limestone (Plate 24).

Plate 24: *Although originally built predominantly of local Magnesian Limestone, this wall in North Street has been raised using a variety of rock types including material derived from glacial erratic blocks including Whin sill dolerite (dark grey to black) and Coal Measures sandstones (shades of brown).*

Flint

Small pebbles of flint are recorded from the glacial gravels found in the former extraction sites within the township; though none was seen during the present study. This flint would have been derived from outcrops of flint-bearing Chalk to the east, in the area now occupied by the North Sea. Although small the pebbles would have been conspicuous and may have been noticed by early man and perhaps employed in making stone tools. There is, however, no way of determining whether any such tools were produced from locally sourced flint, or from flint carried from the much more abundant sources of this material in East Yorkshire.

When considering flint it is important to realise that glacially transported 'erratic' flint of this sort is rather scarce. It should not be confused with the very abundant flint found as pebbles on the nearby beaches. Whereas this includes very small amounts of such 'erratic' flint, the overwhelming amount of flint present on our beaches arrived here only in the past few centuries, as ships' ballast carried from southern England to the Tyne during the peak years of the coal trade and would not have been available to our earliest ancestors. Except for those within the glacial gravels described above, the rare fragments of flint, seen occasionally in local soils, are likely to have been derived from beach gravels used in construction in and around the village

Water

Although commonly overlooked, water is one of the most valuable and widely used mineral products. Our earliest inhabitants would have met their rather modest demands for water from surface streams or springs, but as local demand increased dramatically with increasing population and industrial development, these soon proved inadequate. By the late 19th Century abundant quantities of high quality groundwater was identified beneath this part of north east England. Its source lay in the Permian rocks deep beneath our feet.

Plate 25: *The tower of the Cleadon Pumping Station, a conspicuous local landmark visible for miles on the skyline. Today, most of the fine red brick buildings of this former water pumping station are converted for residential use.*

Of particular importance was the Yellow Sands Formation, described earlier. Although they were to prove of enormous importance as a major aquifer (water-bearing formation) beneath much of the Magnesian Limestone country, they initially proved troublesome. When colliery shafts were first sunk through the Magnesian Limestone to reach the coal seams in the concealed Coal Measures, the Yellow Sands were found to present an almost impenetrable barrier to progress. At depth these very porous sands contain vast quantities of water and being mainly un-cemented sands they effectively turned to quicksand. Only by using timber shuttering, and later the use of ground freezing techniques, could new colliery shafts be completed. Lives and huge amounts of money were lost as a result of these heavily watered strata.

However, it was their enormous water-bearing capacity that was to establish the Yellow Sands as one of the region's most productive aquifers, with numerous extraction boreholes drilled into them across the Magnesian Limestone outcrop from South Tyneside southwards into County Durham. At Cleadon pumping station (Plate 25), and at Fulwell immediately south of the parish, deep wells tapped the Yellow Sands, though the former well is no longer in production.

Offshore, beneath parts of the North Sea, the Yellow Sands Formation is important as a reservoir for another vital mineral product. In places, the pore spaces in these sands are filled not with water but with natural gas. Very substantial amounts of North Sea gas are produced from reservoirs in the same Yellow Sands that we see onshore in north east England.

GEOLOGY AND THE BUILT ENVIRONMENT

It is common, when thinking about landscape, to focus solely on what we normally perceive as natural features – hills, valleys, coasts, lakes, rivers, woods, fields, hedges and so on, though these latter two features are, of course, far from truly natural. In a country like ours the others have also almost invariably been hugely influenced by human activities too. There is no truly 'natural' landscape surviving in north east England, but landscape is much more than this. Landscape may be seen as what gives any area or region is distinctive identity. If presented with a series of pictures of different parts of Britain, it is usually not difficult to work out where the picture has been taken, even if we do not recognise any particular place or feature within the picture. In making these judgements we are reading the landscape, actually at rather a sophisticated level. A picture of the Lake District, for example, can be recognised not just by the presence of mountains or lakes. Undeniably those mountains and lakes have a particular shape and character that distinguish them from other mountains, but so too do the farms, villages and stone walls. The same is true of virtually any part of this country. The distinctiveness of any landscape is an amalgam of its natural features and its buildings and other man-made features.

Plate 26: *All Saints Church. The walls of the original church are built mainly of local limestone, though sandstones are employed as quoins and for door and window casings, with imported Welsh slate used on the roof.*

We have explored a little of how geology has shaped Cleadon's natural landscape and, to some extent, considered how it has been modified by centuries of human occupation and exploitation. It is now time to turn our sights to some aspects of Cleadon's landscape that most of us probably take for granted - the buildings, roads and streets and even the houses we live in.

Even in a comparatively small village like Cleadon it is impossible to examine in detail every building or every street, and we will not attempt to do so. We will, however, explore some of the remarkable variety of different geological materials that go to make Cleadon the place we know today. The term 'geological materials' is used deliberately, as our sights will not be confined to searching out different rock types. This geological look at Cleadon's 'built environment' will not be confined to the village's buildings, but will also look at its boundary walls, pavements, roads and any other uses made of materials 'dug from the ground'.

Buildings – The Walls

Perhaps the most obvious use of stone in any village or town is in its buildings. Creating shelter for himself, his family and animals was one of early man's first occupations. In a place like Cleadon the nearby availability of stone would have provided a ready supply of durable building material initially perhaps gathered as loose blocks from the surface but later specifically extracted from natural rock exposures, creating the first quarries.

Plate 27: *Cleadon Windmill. The walls are of local limestone with Coal Measures sandstone used for door and window lintels.*

We don't know when locally sourced limestone was first used for building in and around Cleadon, though locally sourced limestone is the major stone visible today in the villages oldest buildings. Its use is not, however, confined to these oldest structures and it has clearly been employed at various times as a convenient local building material, for example in All Saints Church (Plate 26), the Britannia Inn (Plate 49), Sunniside Farm (Plate 31) and various field and boundary walls (Plates 32,51,52) (Fig.11).

The most conspicuous, and probably earliest, use of limestone in building is in the houses on Front Street to the north of the Cleadon pond, which were once part of Burdon Farm, and Cleadon Windmill (Plate 27). Although the precise source of the stone used in these buildings is not known, the character of the material, its internal textures and features, is comparable to the limestones of the Concretionary Limestone exposed today in the faces of the abandoned quarries and stone pits on Cleadon Hills and is would seem very unlikely that the stone employed in the windmill would not have come from the immediately adjoining stone pits. In common with much architecture of its type and age, the mill is built of rubble blocks, either unshaped or with minimal dressing, bound together originally with lime mortar, another product of local limestone pits.

Plates 28 to 30: *(left to right) squared blocks of local limestone in the west wall of All Saints Church. The quoins and commemorative stone (lower right) are of Coal Measures sandstone (note the loss of detail, through weathering, in the commemorative stone); squared blocks of local limestone blocks used in buttresses of the south wall of the nave; and East Farm, the walls of which, including the quoins, are predominantly of local limestone.*

The irregular shape of these blocks reflects both the nature of the stone and, to some extent, the budgets then available. The limestones of the Concretionary Limestone include beds of hard and durable stone suitable for buildings of this sort. Their concretionary structure, commonly including a variety of rather open cellular textures, makes them unsuited to fine shaping and dressing. Moreover, shaping and dressing blocks in this way adds greatly to the cost of the stone. In common with many other areas unshaped or very crudely shaped blocks were generally used for comparatively low cost vernacular architecture and squared blocks of limestone are not seen in the majority of the village's older buildings. Squared blocks are used in the construction of All Saints Church (Plate 26), though here too the majority of the walls here comprise roughly shaped or largely undressed blocks. Carefully squared blocks of local Concretionary Limestone can be seen in the buttresses of the nave (Plate 29) and in the quoins of a few buildings, notably East Farm, opposite Cleadon pond (Plate 30), although the use of limestone in this specialist way is relatively rare. A good example of the use of more or less uniformly squared limestone blocks in construction is the farmhouse at Sunniside Farm, on Cleadon Hills (Plate 31). Similarly, carefully shaped limestone blocks can also be found used in the coping stones of the wall surrounding

Cleadon Waterworks (Plate 32). Much more roughly fashioned coping stones can be found capping the field walls on Cleadon Hills.

Plates 31 to 32: *Sunniside Farm - a rare example of construction using squared blocks of local limestone and the same material used nearby in the coping stones of the Waterworks boundary wall*

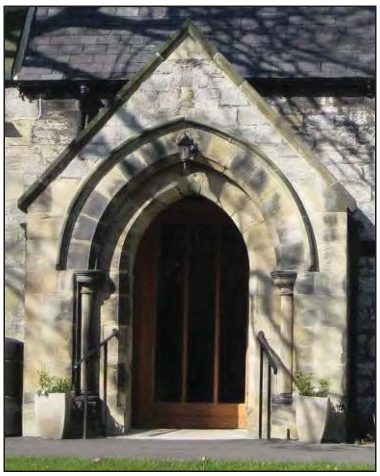
Examples of buildings constructed solely of local limestone are rare and a number of other materials are locally conspicuous in several of the village's older buildings. In stark contrast to the pale cream-coloured local limestone are several black or very dark brown blocks, visible in the southern face of the old Methodist chapel on Front Street (Plate 33). Careful examination reveals that not only are these strikingly different in colour and texture, but their rather rounded outline contrasts with the much more angular limestone blocks. These are glacial erratic blocks of Whin Sill dolerite, derived from the local boulder clay; no doubt fortuitously discovered nearby during construction and adopted as an acceptable building material. A large erratic boulder of dolerite, from the Whin Sill, is incorporated into the foundations of the parade of shops on Boldon Road (Plate 34). Several houses in Front street, including East Farm, incorporate some red-brown bricks, either as scattered examples or forming significant areas of masonry within the otherwise limestone walls.

Although a few examples of dressed limestone quoins can be found in the village, in most limestone buildings sandstone has been the stone of choice for features such as quoins, lintels and other detailing. This is because it is a fine-grained and closer textured rock, better suited to carrying even rather simple carved detail than the more open-textured local limestone. Sandstone quoins are clearly seen in All Saints Church (Plate 35) and the Britannia Inn (Plate 36). Similarly, the local limestone can rarely be extracted in blocks sufficiently large to form lintels and door and window lintels and again sandstone is commonly used. Examples can be seen at Cleadon Mill (Plate 37), All Saint's Church, the Britannia Inn and in the houses along Front Street. A particularly large sandstone lintel, re-used and now covered in black paint, tops the rear doorway of the flower shop in Boldon Road.

Plates 33 and 34: *Front Street - The old Methodist chapel cottage incorporates a variety of building materials. The bulk of the walls are formed of local limestone rubble, though dark brown erratic boulders of Whin Sill dolerite are conspicuous, especially above the street name plate. Coal Measures sandstone blocks are used in the skews and cappings of the gable wall. Brick, almost certainly made from locally dug clay, marks the external course of the flue; and an erratic boulder of Whin Sill dolerite used as a cart stop in the foundation of a shop on Front Street.*

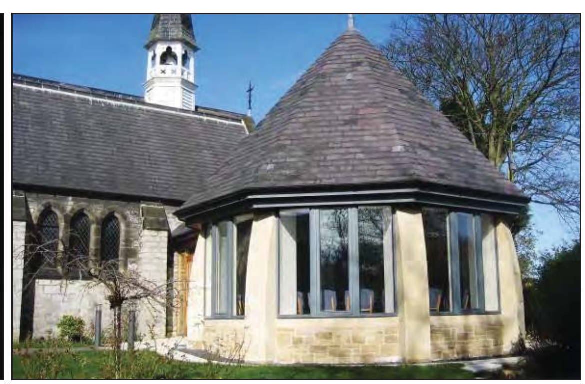
Plates 35 to 37: *(left to right) All Saints Church - the quoins are of sandstone, almost certainly from the Coal Measures. Cross-bedding, accentuated by weathering, is conspicuous in the block second from the ground. The Britannia Inn - sandstone, almost certainly from the Coal Measures, forms the quoins. Cleadon Windmill - the door lintel is a large slab of pale buff, cross-bedded sandstone, almost certainly from the Coal Measures*

The sandstones employed in All Saints Church exhibit a number of characteristics that deserve comment, especially in such a prominent and well-known village building. Sandstones are sedimentary rocks formed by the accumulation, under water, of sand grains that have subsequently been compressed and bound together by a natural 'cement' or matrix. When firmly cemented, and of fine or medium-grained texture, sandstones can be excellent building stones as they can be cut and carved to take fine detail. The sandstones seen in the church, and in other buildings in the village, are examples of such sandstones. The sandstone mouldings around the church's south door display good examples of a very common feature, known as cross-bedding (Plate 39). During their deposition as loose sand, the individual grains were commonly moved around as a result of interfering water currents, commonly giving rise to the inclined bedding, known as cross-bedding, which is particularly clearly seen when the stone has been cut to show a flat surface, as in these blocks. The detailed orientation of this bedding enables geologists to decipher much of the sandstone's history and mode of formation. Although these details need not concern us too much here, it is possible to see that some of these blocks are in their original orientation, whilst others have been inverted and are 'upside down' relative to the orientation in which they were originally formed.




Plates 38 and 39: *All Saints Church - Coal Measures sandstone used in the door mouldings, and detail of coarse-grained Coal Measures sandstone showing that this block is inverted.*

The ability of sandstones to be carved with comparatively fine detail is illustrated by the block seen in the south west corner of the church's outer wall. However, not all sandstones survive well in an external environment and this block well demonstrates how detail can be lost, and the inscription made illegible, in a comparatively short space of time (Plate 40).

Plates 40 and 41: *All Saints Church - eroded foundation stone (1869), and the recently built modern extension to the church, which is a fine example of modern sandstone ashlar*

Sandstones are also employed as quoins, lintels, window and door casings, and other architectural detailing in such prominent village brick buildings as All Saints Church Hall, Cleadon House (Plate 42) and the buildings of Cleadon Water Works (Plate 46).

The sources of sandstones employed in the village's buildings are largely unknown, although it is likely that they have been obtained from a variety of locations. Very similar sandstones have been widely exploited at a number of places across northern England, and it is very probable that most, if not all, of the sandstones seen in Cleadon's buildings were obtained from one or more of these sources.

Plate 42: *Cleadon House – built of locally produced red brick with Coal Measures sandstone used for window and door casings.*

By far the most common building material in the village is brick. Although modern bricks are available in a variety of styles, textures and colours, they are almost invariably the products of huge central plants and offer little or no regional or local character. There is little difference between the newer brick buildings in Cleadon and those in any other village or town anywhere in Great Britain. Without reference to the builders or architects involved in their construction, it is difficult or impossible to suggest the sources of brick in any single building and it is not realistic here to attempt to review the likely sources and uses of modern bricks within the village. However, prior to the centralisation of brick-making and the development of a comparatively restricted range of uniform styles, locally sourced bricks were almost as distinctive as locally worked stones. It is therefore worth looking briefly at the nature and likely sources of bricks used in some of Cleadon's older buildings.

When looking at Cleadon's geology we saw that very substantial parts of the township carry a mantle of clays of glacial origin, including the laminated clays of the Tyne-Wear Complex and the Pelaw Clay. Such clays are well-suited to brick and tile making and, in common with other areas with abundant sources of clay, locally fired bricks would have contributed to the character of local buildings. Such clays were worked locally on a significant scale until the mid 20th Century. The bricks visible in walls around Cleadon House (Plate 42 and 43), and as patches of brick masonry in the otherwise limestone-dominated walls of houses near Cleadon Pond, are likely to have been made from just such clays. Close examination of these bricks reveals the presence of small stone fragments that characterise this clay, still clearly visible in the fired brick (Plate 44). Until the 19th Century it was comparatively common for brick making to have something of the status of a cottage industry. Where suitable clay was available on or near a planned building, a pit might be opened to provide the raw material for bricks fired on site solely for that building. It is probable that some of the older bricks seen in Cleadon originated in this way.

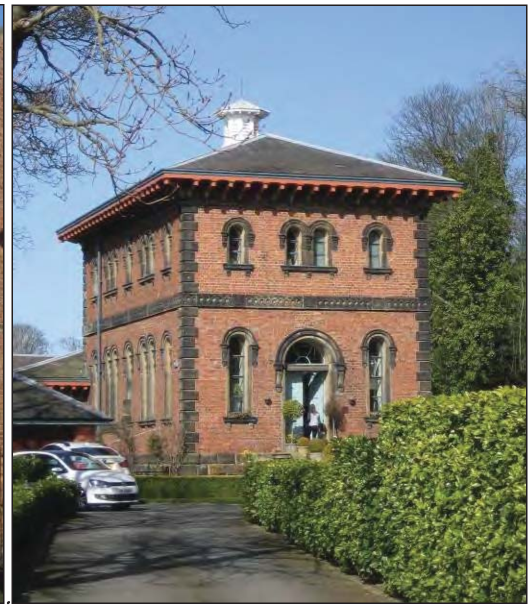
Plates 43 and 44: *The beautifully constructed brick wall at Cleadon House features a finely shaped brick coping, and detail of boundary wall, showing sandstone clasts in brick.*

One building, Grove House (Plate 45), demonstrates a type of brick otherwise unknown within the village. The conspicuous very pale cream coloured bricks of this house were made from fireclay, a type of clay found typically as the substrate to many coal seams in many of the region's collieries. Composed of aluminium-rich clay minerals these clays were very suitable for the making of heat-resistant, or refractory, fire bricks and were worked from small pits and mines, in some instances alongside coal in many collieries, some of which operated their own brickworks. As well as their more widespread use as refractory bricks in kiln and furnace linings, these distinctive pale-coloured bricks were also occasionally used for building. Although the precise source of these bricks is unknown they may safely be assumed to have originated somewhere within the north east coalfield.

Buildings – Roofs

Over time, and in different parts of the country, a variety of geological materials have been used for roofing. Like the materials used to build walls, these too contribute greatly to the landscape of the built environment and character of the village.

The earliest roofing material in the village was probably thatch, either traditional reed or straw or heather thatch collected from the moors. No thatched buildings survive today, but their former existence can be inferred from the pitch of some of the roofs. Thatch requires a very steep pitch to enable water to run off easily and reduce the risk of the thatch rotting. Two buildings in the village have such steep roofs, the florists on Front Street (Plate 47) and Briar Cottage and these were probably originally thatched. Locally sourced stone slabs soon superseded thatch across many parts of northern England, but material suitable for this purpose is not available within the Cleadon neighbourhood and instead clay pan-tiles would have been used. There are very few examples of original clay pan-tiles surviving in the buildings. A small number of original tiles might be preserved on Cleadon House, but roofing material in general is replaced relatively regularly. Most clay pan-tiles seen in the village today, like those on the houses of Front Street, are modern replacements, conspicuous by their bright and uniform orange-red colour (Plate 48). Like modern bricks, modern roof tiles are also the product of centralised mass-production units and thus lack distinctive local character of the older materials.

Plates 45 and 46: *Grove House, the front elevation of which is built of pale cream firebrick made from Coal Measures fireclay. Cleadon Waterworks, made of machine made brick with Sandstone detailing in the window and door casings, quoins and as the string course.*

Perhaps one of the most widespread and durable roofing stones in Cleadon, as elsewhere in the country, is slate. Slate is a metamorphic rock, originally deposited under water as mud that, over time, was compacted and compressed to form mudstone or shale. When subsequently subjected to heat and pressure during severe Earth movements, such rocks were altered to the rock we know today as slate. Significantly, the changes brought about by intense pressure during this metamorphism was the re-alignment of the individual clay minerals within the rock resulting in a fabric known as 'cleavage', whereby the rock splits readily into thin sheets parallel to the new alignment of the clay mineral crystals. Rocks in which the cleavage enables the rock to split into very thin sheets can be worked to make roofing slates. Slates occur in many parts of Britain such as Scotland, the Lake District and North Wales. Best known, and most widely used of these, are the slates quarried in North Wales, notably around Blaenau Ffestiniog.

Plates 47 and 48: *Steep pitch of the florist's shop on Front Street would suggest that this building was once thatched, and the modern pantiled roofs contrasting with the Welsh slate of the building north of the pond, formerly part of Burdon farm.*

The rapid widespread adoption of Welsh Slate as a roofing material across Great Britain provides a good example of early marketing methods exploiting the availability of cheap bulk transport provided by the rapid growth of railways during the second half of the 19th Century. Within a relatively few years Welsh Slate was being used to roof buildings across the country, even competing successfully with more locally produced slates in parts of Scotland. The timing of the widespread use of Welsh Slate in an area can usually be closely correlated with the arrival of the local railway connection. Welsh Slate is relatively easily distinguished from other slates by its distinctive purplish blue-grey colour, especially when wet. Numerous buildings in Cleadon are roofed with this material, including the older houses around the pond, the Britannia Inn (Plate 49), All Saints Church Hall, All Saints Church (Plate 26), Grove House (Plate 45) and Cleadon Water Works (Plate 46).

Plates 49 and 50: *Welsh slate roof of the Britannia Inn, and Britannia Autoservices, roofed with sheets of corrugated asbestos cement.*

A rather more exotic roofing material, though one that might be easily overlooked, is that seen on the roof of Britannia Autoservices (Plate 50). This is made of sheets of asbestos cement, a material made by forming corrugated sheets from white asbestos bound together with cement. Asbestos is a commonly misunderstood substance. There is no single material called 'asbestos': it is a name applied to a variety of silicate minerals that in certain circumstances have developed a fibrous form capable of being spun into thread or matted together in felt-like masses. Some of these 'asbestiform' minerals are potentially hazardous if their fine dust is inhaled: others are virtually harmless. The most common sources of the asbestos used in making roofing sheets of this sort are in Canada and South Africa. The source of the asbestos used in this building is not known, though it almost certainly constitutes the most far-travelled building material to be seen in Cleadon.


Plates 51 and 52: *Field boundary wall on Cleadon Hills, and detail of the worked stone capping, a rare example of shaping the local limestone.*

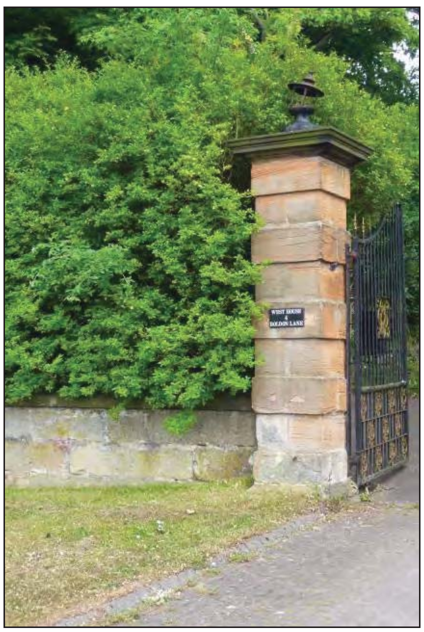
Boundary Walls

Many boundary walls can be viewed as extensions of a house or other building, though the selection of materials used in creating them has often been much less rigorous. In common with the older houses in the village, the most common constituent of the village's boundary walls is limestone rubble, derived from nearby outcrops of the Concretionary Limestone. Usually there is no shaping of the blocks used in walling, and the round-headed coping stones used in the walls surrounding Cleadon Waterworks are very unusual (Plate 32). To a lesser degree, the cap stones on the field boundary walls on Cleadon Hill, near Cleadon Windmill (Plate 51), that have been roughly trimmed into a triangular shape (Plate 52) are also a rare example of dressing of local limestone. Conspicuous in several of the boundary walls are roughly rounded boulders of dark brown or black dolerite erratics, derived from the local boulder clay. In addition to these, the old boundary walls in North Street include a number of boulders of sandstones (Plate 53), also derived from erratic boulders in the local boulder clay (Plates 53 and 54). Scattered bricks seen in some of these walls, notably those in North Street, might be derived from demolished buildings in the vicinity

Bricks, probably fired from locally extracted Pelaw Clay, have been used to build the fine boundary wall of Cleadon House (Plate 43). The beautifully varied textures and colours of this old brick contrasts markedly with the uniformity of colour and texture seen in the bricks used in nearby modern buildings.

Several substantial gate-posts around the village are built of large sandstone blocks, some incorporating especially large blocks. Those at Cleadon House (Plate 55) and the entrance to Cleadon Water Works (Plate 57) are particularly fine. The sources of these are unknown, though they almost certainly originate in northern England.

Plates 53 and 54: *Boundary wall in Cleadon Lane built of local limestone with conspicuous glacial erratic boulders of dark grey Whin Sill dolerite, and wall in North Street, built predominantly of local limestone, but with erratic blocks of dark brown Coal Measures sandstone and dark grey Whin Sill dolerite conspicuous below the letter box, as well as re-used brick.*



Plates 55 to 57: *(Left to right) Cleadon House, gates south of the pond and Cleadon Waterworks - three of Cleadon's fine gateposts, all built of imported sandstone, the source of which remains unknown but is likely to be from quarries in northern England. The colour and nature of the stone in each is slightly different.*

Roads and Pavements

Whereas the different materials used in buildings may attract attention, we rarely look down and consider what we might be walking or driving across. The materials used to make our roads and pavements are extremely important. They have to be durable and are usually made of geological materials selected for the particular properties they offer.

Most roads today are uninteresting and dull strips of black tarmac, although tarmac is actually a carefully designed mixture of broken rock bound together with tar. The most common stone used in the construction of our local roads is dolerite and is the same rock that appears as blocks in some of the village's older walls and buildings. However, the dolerite used in road construction has not been obtained from chance finds of glacial erratic boulders but is specifically quarried and crushed to make roadstone (Plate 58). The dolerite comes from the Whin Sill, the huge body of dolerite that underlies much of north east England, reaching the surface at Dunstanburgh and Bamburgh on the Northumberland coast, Hadrian's Wall country, and High Force in Teesdale. Large quarries in these areas today extract dolerite for road making, used across north east England and beyond. Dolerite is particularly well suited to road construction as it consists of an intricate intergrowth of two or three main minerals that exhibit differing amounts of resistance to wear. As a result, however much the rock is driven over by traffic it retains sufficient roughness to resist skidding, a vital property in making a good road.

Plates 58 to 60: *Crushed rock used in Cleadon's road surfaces – (left to right) Whin Sill dolerite chippings in the surface of Whitburn Road, Shap Granite chippings in Cleadon Hill Lane and distinctive red microgranite from Harden Quarry in north Northumberland, which gives a distinctive colour to Marsden Road.*

As well as being used as crushed stone for road surfacing, Whin Sill dolerite was once widely used to make setts, those rectangular blocks used to edge and pave some roads. These are commonly, though incorrectly, often described as 'cobbles'. Good examples of Whin Sill dolerite setts can be seen at the junction of North Street and Farm Hill Road (Plate 61). A handful of grey granite setts, of unknown origin, are also present here.

There are, however, a few roads made of other materials. Streets including Sunniside Lane, parts of Woodlands Road and West Meadows Road are obviously much lighter in colour and on a sunny day sparkle (Plate 59). These are surfaced with crushed pinkish grey granite from Shap Fell in Cumbria. The sparkle results from the bright broken surfaces of the flesh-pink feldspar crystals that make this rock so distinctive. Shap Granite was once a much used roadstone across parts of northern England, but the granite quarry stopped production some years ago and, unless it is re-opened, this use of this stone will disappear once the roads are resurfaced.

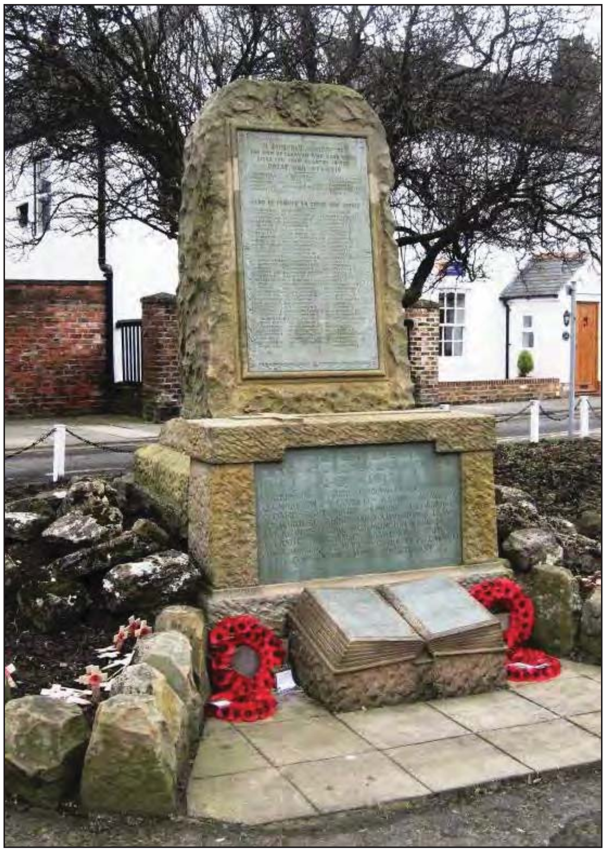
Another highly distinctive roadstone, which can be seen used in Marsden Road (Plate 60), is distinguished by an overall dull red colour. This is a fine-grained rock known as felsite or microgranite, quarried at Harden Quarry, near Alwinton in the Cheviots in north Northumberland. It can be seen in a number of Northumberland's roads, but one of its most distinguished uses lies far from here. It has for many years been used to surface the Mall in London, to give that imposing street its distinctive red colour.

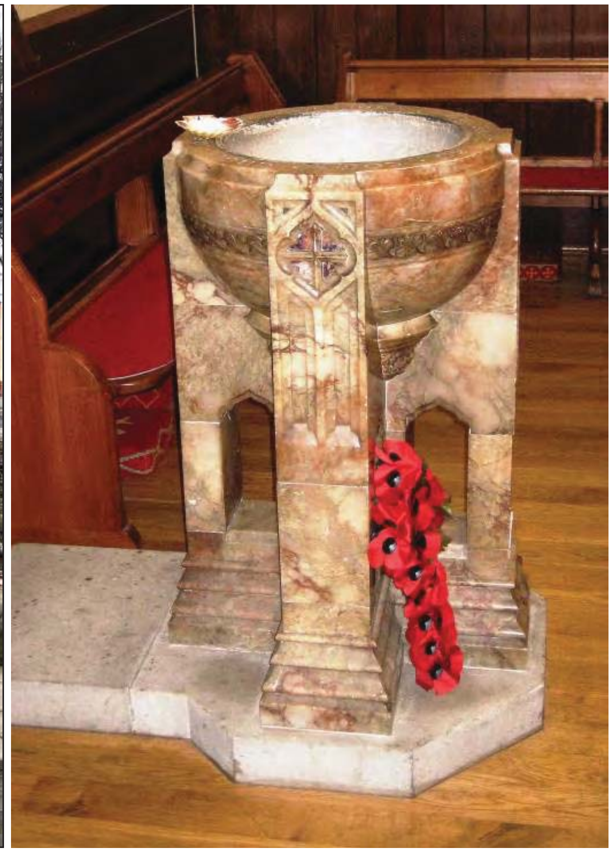
Before leaving the roads and crossing onto the pavement, we might care to recall that the tar that binds all of these roadstones together to form the hard-wearing and flexible road surface is yet another geological material. It is a by-product of the refining of crude oil.


Plates 61 and 62: *Whin Sill dolerite (dark grey) and granite (pale grey) setts in North Street, and the pavement in Front Street, which is built from sandstone slabs of unknown provenance.*

Whilst many of the village pavements are made of tarmac and call for little comment, the paving in Front Street and elsewhere is made of large sandstone slabs, almost certainly derived from West Yorkshire (Plate 62).

However rough and skid-resistant our roads and pavements are, in winter their safety often depends on another very common, though often overlooked mineral product. Rock salt or halite provides the means to thaw icy surfaces. It is one of the evaporate rocks we met earlier when discussing the drying up of the Permian Zechstein Sea. Most of the road salt used in northern England comes from one of two sources, Winsford in Cheshire or Boulby in North Yorkshire. It is usually quite easy to determine which salt is being used because Boulby salt, a by-product of mining Permian potash, is typically grey or white in colour while Cheshire salt is brown.





Plates 63 and 64: *The village war memorial is built of pale buff sandstone of unknown provenance set with inscribed tablets of green 'slate', a cleaved volcanic sediment from the Honister or Langdale areas of Lake District. The font of All Saints Church is carved from alabaster, a fine-grained crystalline form of gypsum.*

Ornamental Stones

As well as being employed for their practical uses in building, various stones have long been used primarily for their decorative value. Two good examples can be found in Cleadon. The village war memorial features four slabs of a distinctive grey-green coloured rock (Plate 63), the surfaces of which have been smoothed and, if looked at carefully, a faint rough banding can be seen, especially when wet. These are blocks of so-called 'Lake District Green Slate', a 400 million year-old rock from the central Lake District. Although not a true slate, this is a volcanic sediment made up of fragments of volcanic ash and other debris, deposited underwater, compacted and cleaved by intense pressure during Earth movements, and now able to be split into thin slabs. Such rocks are currently extracted from quarries in the Honister, Kirkstone and Langdale areas of the Lake District and used for ornamental stone and roofing slate. The precise source of the Cleadon memorial is not known.

All Saints Church features a fine alabaster font (Plate 64) donated by Domanique Warm who used to live in Cleadon Tower. Alabaster is the name given to fine grained gypsum that is capable of being polished. The source of the gypsum in this font is unknown but gypsum of this sort has been worked from parts of Cumbria, Staffordshire and the Midlands.

INFORMATION SOURCES AND FURTHER READING

In reviewing Cleadon's geological story it has been necessary to summarise and focus upon those most important parts of the wider story as they apply to the village itself. Much has been generalised and a great deal of detail has been omitted. For those inspired to explore in detail more of Cleadon's geological story and its place in the regional and national context, there are a number of published texts available.

Since the earliest days of geological science almost every aspect of the geology of north east England has attracted research interest, either from a purely academic or economic perspective. As a result there is a huge amount technical literature available contained in all manner of publications. It is therefore impossible to present anything approaching a complete list of all such sources of information, but a number of important summaries and regional syntheses have been produced that might act as a reference to guide further study. Listed below are some of the key publications of this sort. Some are long out of print but all can be accessed via public libraries or the internet. Most contain substantial lists of references to the detailed technical and scientific literature. However, it should be remembered that enormous though this volume of information might be, it is not, and never can be, complete. Research on the rocks of our region continues with new observations and ideas constantly emerging and, as our understanding of geological processes advances, new interpretations of long–known features are opened to re-interpretation.

Davies, B. J., Yorke, L., Bridgland, D.R. & Roberts, D.H. (2013). *The Quaternary of Northumberland, Durham and North Yorkshire: Field Guide.* Quaternary Research Association, London.
A modern series of specialised detailed technical field excursions to examine Quaternary geology across north east England that includes information and excursions relevant to the South Tyneside area. This is an important new publication, but not for novices in geology.

Durham Wildlife Trust (2007). *Magical Meadows and the Durham Magnesian Limestone*. Durham Wildlife Trust.
An exploration of the geology, ecology, social and economic development and conservation of the Magnesian Limestone of north east England. Colourfully illustrated and clearly written for non-specialists.

Henderson, M. & Lelliott, A.D. (1978). *Significant geological exposures in the Tyne to Tees area*. Durham County Conservation Trust.
A comprenehsive guide to the most important geological sites and exposures visible in 1978; although some sites have disappeared or been destroyed, the text remains an important reference and includes sites in South Tyneside.

Hollingworth, N.T.J. & Pettigrew, T. H. (1988) *Zechstein Reef Fossils and their Palaeoecology* Palaeontological Association Field Guides to Fossils No. 3. The Palaeontological Association, London.
A comprehensive and well-illustrated guide to the wealth of fossils found in the reef limestones of the Ford Formation, with descriptions of individual localities.

Johnson, G.A.L. (Compiler) (1970) 'Geology Of Durham County' in *Transactions of the Natural History Society of Northumberland, Durham and Newcastle upon Tyne.* Vol. 41, No. 1.
A detailed review of the geology of the former county of Durham, including the Cleadon area of South Tyneside.

Johnson, G.A.L. (editor) (1995) (2nd edition) 'Robson's Geology of North East England' in *Transactions of the Natural History Society of Northumbria,* Vol. 56, Part 5.
A detailed review of the geology of the whole of north-east England, including the Cleadon area of South Tyneside.

King, W. (1850) *Monograph of the Permian Fossils of England.* Monograph of the Palaeontographical Society, London.
A classic work of British palaeontology that describes and illustrates in detail the wealth of fossils found in the Permian rocks of North East England.

Lawrence, D.J.D., Vye, C.L. & Young, B. (2004) *Durham Geodiversity Audit*. Durham County Council.
A simplified, but comprehensive, description of the geology of County Durham. Written for non-specialists and highlighting the relative importance of the various elements in the county's geodiversity, this important text focuses on links between geodiversity, ecology, archaeology, economic history, etc. The topics covered overlap into South Tyneside.

Scrutton, C.T. (editor) (2004) (2nd edition). *Northumbria rocks and landscape. A field guide*. Yorkshire Geological Society.
A series of self-guided excursions that demonstrate key areas of North East England geology. Includes a simplified and easily understood general introduction to the region's geological evolution and an important excursion to South Tyneside.

Smith, D.B. (1994). Geology of the country around Sunderland. *Memoir of the British Geological Survey.* H.M.S.O.
A detailed and authoritative description of the geology covered by British Geological Survey 1:50 000 sheet 21 (Sunderland). Includes a wealth of detail on the geological features of the Cleadon area of South Tyneside.

Smith, D.B. (1995) *Marine Permian of England. Joint Nature Conservation Committee.* Chapman & Hall.

An authoritative description and interpretation of the Permian rocks of England with particular reference to those areas afforded special protection as Sites of Special Scientific Interest. Included are detailed accounts of several internationally important geological sites in South Tyneside.

Stone, P., Millward, D., Young, B., Merritt, J.W., Clarke, S.M., Mccormac, M. And Lawrence, D.J.D. (2010) *British Regional Geology: Northern England* (Fifth edition). (Keyworth, Nottingham: British Geological Survey).

An up to date general description of the geology of the whole of Northern England from Teeside and Morcambe Bay northwards to the Scottish Border with much relevant to the Cleadon area.

Young, B. (2006) *Marsden Old Quarry Local Nature Reserve, South Tyneside. A review of the geological features and their significance for geodiversity.* Report for South Tyneside Council.

A detailed description of the geological features in and around Marsden Old Quarry, with comments on their wider significance.