A Geological Conservation Strategy for Hertfordshire

Hertfordshire RIGS Group
2003

Great Britain is the cradle of the science of geology. It was here that many of the periods of geological time were first defined and named. Countless eminent geologists, professional and amateur, have sharpened their eyes and scientific minds on Britain's earth science sites. Yet these sites, which display the visible evidence of the Earth's formation and transformation through rocks, fossils and landforms, have been disappearing at an accelerating rate in the face of the many pressures imposed by our modern way of life.

Extract from the foreword by David Attenborough to Earth Science Conservation in Britain – A Strategy (Nature Conservancy Council, 1990)

Cover photograph

A typical scene on the Chalk scarp. Deadman's Hill, Sandon (photo by Brian Sawford).

A GEOLOGICAL CONSERVATION STRATEGY

FOR HERTFORDSHIRE

2003

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PREFACE

The only record of the history of our planet lies in its landscapes and in the rocks beneath our feet. Here and only here can we trace the cycles of change and renewal that have shaped the Earth in the past and that will continue to do so in the future. This record is unique and much of it is surprisingly fragile. It must be conserved so that future generations can enjoy it and seek a greater understanding of it for the benefit of the planet and humanity.

(Malvern International Task Force for Earth Heritage Conservation, 1993)

Geology, the study of all matters pertaining to our Earth, of rocks, minerals, crystals and fossils, is high on the list of the natural sciences which capture the imagination of children and adults alike, as evidenced by the number and high quality of media programmes and exhibitions devoted to the subject.

Today there is also a growing awareness that preserved in the rocks is a record of past changes in the Earth's climate. During the Earth's recent history, its climate has oscillated between periods of global warming and global refrigeration. At a time when we seem to be entering a renewed period of global warming, the geological record provides us with lessons and insights from the past and a guide to the future.

Under the microscope, in the analytical laboratory and in the field, rocks reveal the history of their formation and of past environments. In many deposits, such as the Chalk in Hertfordshire, fossils provide evidence of what life was like millions of years ago and help explain how plants and animals have evolved to create the present range of the Earth's ecosystems. Geomorphological features too, such as the swallow holes at Water End, mysterious hollows into which streams disappear, provide interest and an educational resource. The timescale of geological processes is awesome and has an unusual educational value in putting history and our own lifespan into a broader perspective.

The connection between landscape and the rocks that underlie it has long been recognised. The 'character' of landscape depends to a great extent upon its rock foundations, using the term 'rock' to include all the hard and soft deposits, which lie beneath the soil cover. The rock types not only contribute to the land forms - the hills and valleys, the plateaux and flood plains - but also to the soils, which, in turn influence the biodiversity and agriculture of the region. Rainwater percolating into certain formations, particularly the Chalk in this county, emerges from them as springs to form our streams and rivers. Hydrogeological studies also indicate the availability of groundwater resources and how pollution by agricultural and industrial wastes can be minimised. In addition, geology indicates the size and distribution of industrial mineral resources. In Hertfordshire these include sands and gravels for aggregates, clay for brick making and pottery and the Chalk, which now supplies agricultural lime, cement and whiting, and in the past supplied building stones and flint.

These factors have all been critical in determining where and why people have settled in this county. The historical pattern of farms, villages, towns and cities, footpaths, roads and railways has been strongly influenced by our local geology. Engineering geology indicates the suitability of land for the construction of large buildings, airports, roads etc. and where life-threatening hazards such as landslips may occur.

This volume outlines the importance of geological features within the county of Hertfordshire, and explains a strategy developed by the Hertfordshire RIGS Group for their conservation and enhancement. The principal reason for the strategy is the need to ensure that the county maintains a local natural resource of value in geological research and in education at school and undergraduate levels.

Except where the context indicates otherwise, words which, when they appear in the text for the first time, are shown in bold type are *either* defined in the Glossary (e.g. hardground) or refer to a stratigraphic rock unit (e.g. Gault Clay).

Geological site conservation is concerned with protecting and sustaining that resource, ensuring that future generations can continue to learn about the geological history of the Earth and their immediate environment through education and research, and that the public can continue to enjoy the beauty of the landscape.

1. INTRODUCTION

1.1 Geological Site Conservation in Britain

The foundations for nature conservation in Britain were laid down in 1949 with the creation of the Nature Conservancy and the passing of the National Parks and Access to the Countryside Act 1949. In particular, the 1949 Act introduced protection for sites notified by the relevant nature conservation agencies as being Sites of Special Scientific Interest (SSSIs) by reason of their flora, fauna or geological or physiographical (landscape) features. The relevant nature conservation agency in England is now English Nature.

The Wildlife and Countryside Act 1981 and the Countryside and Rights of Way Act 2000 subsequently strengthened the protection given to SSSIs. The conservation agencies now have the power to impose permanent restrictions to prevent the owners or occupiers of an SSSI or third parties from carrying out any operations likely to damage the site. They also have power to require measures for conserving or restoring the special interest of a site in accordance with a management scheme.

A major initiative to identify and describe the most important geological sites in Britain began in 1977 with the launch of the Geological Conservation Review (GCR). The aim of the GCR was to provide a public record of the features of interest and importance at the localities already notified or being considered for notification as SSSIs. This review process was completed in 1990 and the results are being published in a series of 42 volumes. Volumes which are of relevance to Hertfordshire include *Quaternary of the Thames* (Bridgland, 1994) and *British Upper Cretaceous Stratigraphy* (Mortimore *et al*., 2001). When the process of notification is complete, the GCR is expected to list about 2300 Earth science SSSIs.

The network of SSSIs, however, forms only one part of the national strategy for Earth science conservation in Britain (Nature Conservancy Council, 1990). The other major part of that strategy lies in the conservation of a separate category of sites known as Regionally Important Geological and Geomorphological Sites (RIGS). RIGS sites are assessed and selected by regional and local RIGS groups throughout the United Kingdom (English Nature, 1991) on the basis of:

- The value of a site for educational purposes in life-long learning.
- The value of a site for study by both professional and amateur Earth scientists.
- The historical value of the site in terms of important advances in Earth science knowledge, events or human exploitation.
- The aesthetic value of a site in the landscape, particularly in relation to promoting public awareness and appreciation of Earth sciences.

Since 1990, over 2000 RIGS sites have been notified, 450 more sites are in the pipeline and a further 15,000 sites are being assessed (UKRIGS, 2001). The regional and local RIGS groups are supported by English Nature and are coordinated by the Association of UK RIGS Groups (UKRIGS) representing the whole of the UK.

Unlike SSSIs, RIGS do not enjoy statutory protection. However, many local authorities (including Hertfordshire County Council, see 1.2 below) provide protection for locally designated RIGS under their Structure and Local Plans.

Other relevant national and international initiatives in the field of geological and landscape conservation are referred to in Appendix I.

1.2 Geological Site Conservation in Hertfordshire

The Hertfordshire County Structure Plan is the document which sets the broad strategic direction for the planning of land use and development in the county. Produced and kept under review by Hertfordshire County Council, it looks 15 to 20 years ahead and seeks to provide a consistent framework for the preparation and review of more detailed development policies and proposals in the local plans prepared by each of the 10 district councils.

The current Structure Plan Review 1991-2011 (Hertfordshire County Council Environment Department, 1998a) recognises the importance of conserving Hertfordshire's heritage for future generations. To this end, it lists a number of categories of important environmental assets (which specifically includes RIGS) and stipulates that they shall

'*be given protection from development or other proposals which would cause loss, permanent damage or significant and irreversible change to those particular characteristics and features that define their special quality'*.

Also important are the Hertfordshire Minerals Local Plan 1991-2006 (Hertfordshire County Council Environment Department, 1998b) and the Hertfordshire Waste Local Plan 1995-2005 (Hertfordshire County Council Environment Department, 1999), which carry forward and develop in greater detail the minerals and waste policies of the County Structure Plan. The Minerals Local Plan states that:

'*Mineral Working sites sometimes contain important features of geological or geomorphological interest which are worthy of protection because of their research, educational, historic or aesthetic value. Some of these sites are sufficiently important to be nationally designated as Nature Reserves or Sites of Special Scientific Interest. Many others will be of regional importance in their own right and may need to be protected to prevent their destruction or obscuring of the important features, whenever possible. The County Council supports the RIGS project in Hertfordshire in its efforts to provide locally based advice and information for site owners, mineral operators and the local authorities, as well as practical management and interpretation work'*.

Minerals Policy 12 set out in the Minerals Local Plan provides that:

'Planning permission for mineral working may be refused where a proposal would adversely affect a regionally important geological or geomorphological site. Where such a site is likely to be affected by proposed mineral working the applicant should consider measures to protect and where practical enhance the important features within the site.'

Waste Policy 35 in the Waste Local Plan is in similar terms.

This Strategy Document was commissioned in 1996 by the Hertfordshire Countryside Forum in association with the Hertfordshire Environment Forum as part of a comprehensive approach to conserving the county's heritage. Following a consultation process, the Strategy was extensively revised and is now published as material information for development planning purposes alongside other strategy documents which are being produced in relation to archaeology, biodiversity and landscape in Hertfordshire.

The Hertfordshire RIGS Group was formed in 1990, with a membership drawn from organisations with an interest in the county's geology along with individuals able to make a specialist contribution. The organisations currently represented in the group include English Nature, Hertfordshire Geological Society, Herts & Middlesex Wildlife Trust, Hertfordshire County Council, North Hertfordshire District Council and University of Hertfordshire.

The Hertfordshire sites currently designated as geological SSSIs and those biological SSSIs with an earth science interest, are described in Appendix II. In addition, a number of sites in Hertfordshire have been designated as RIGS by the Hertfordshire RIGS Group and these are described in Section 6 below. The location of both the SSSI and RIGS sites is shown on the accompanying map of Geological Conservation Sites in Hertfordshire (Figure 1).

Information concerning relevant conservation organisations and initiatives in Hertfordshire is contained in Appendix III.

1.3 The Purposes of this Document

The purposes of this Strategy Document are to:

- Outline in non-technical terms the geology of Hertfordshire (*Section 2*).
- Give an account of Hertfordshire's geological resources (including physical landscape), its recording, conservation, management and use in education (*Section 3*).
- Identify threats affecting these resources (*Section 4*).
- Provide criteria for the selection of important geological sites (*Section 5*).
- Identify and briefly describe known geological sites and certain physical landscape features (*Section 6 and Appendix II*) and relevant specimen collections (*Section 3.9 and Appendix IV*).
- Formulate the principal objectives of the Geological Strategy for Hertfordshire (see *Strategy Objectives-Mission Statement*, *Section 7*).

Figure 1

GEOLOGICAL CONSERVATION SITES IN HERTFORDSHIRE

Legend

RIGS

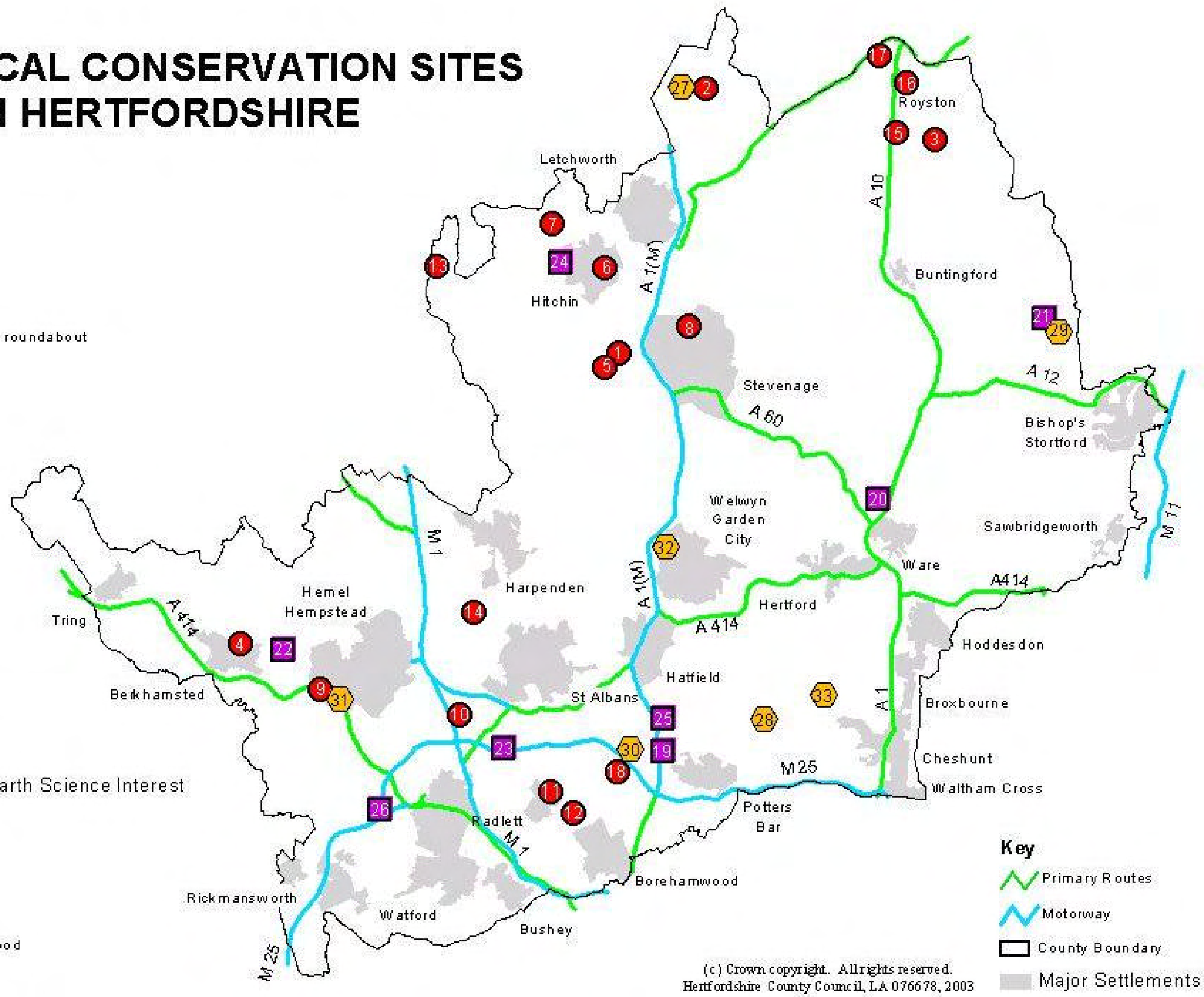
1 Almshoe Bury Swallowhole
2 Ashwell Quarries
3 Barkway Chalk Pit
4 Castle Hill, Berkhamstead
5 Hill End Farm Pit
6 Hitchin Railway Cutting
7 Holwell Gravel Pits
8 Martins Way / Canterbury Way roundabout
9 Moorend Farm Meadows
10 Potters Crouch Pit
11 Radlett Field
12 Radlett Plantation
13 Ravensburgh Castle
14 Redbournbury Chalk Quarry
15 Reed Chalk Pit
16 Royston Chalk Pit
17 Royston Erratic
18 Shenley Chalk Mine

Geological SSSIs

19 Castle Lime Works Quarry
20 Downfield Pit, Westmill
21 Hillcollins Pit
22 Little Heath Pit
23 Moor Mill Quarry West
24 Oughtonhead Lane
25 Water End Swallowholes
26 Westwood Quarry

Biological SSSIs with Earth Science Interest

27 Ashwell Springs
28 Northaw Great Wood
29 Patmore Heath
30 Redwell Wood
31 Roughdown Common
32 Sherrardspark Wood
33 Wormley-Hoddesdonpark Wood



- Outline action plans required to secure those strategy objectives (*Section 8)*.

2. HERTFORDSHIRE'S GEOLOGY - AN OUTLINE

The earliest of Hertfordshire's rocks, the **Gault Clay** and the **Upper Greensand,** were deposited just over 100 million years ago and today form much of the low-lying country at the foot of the Chiltern Chalk **escarpment**. At the time when these rocks were deposited, Hertfordshire was covered by sea. Mud carried from the land lying to the north and south was deposited in relatively deep water as the Gault Clay. Nearer the shore, the sediments were predominantly sandy and formed the Upper Greensand. Both contain abundant fossils of marine organisms, especially ammonites and other molluscs.

The **Chalk** extends throughout most of Hertfordshire, providing much of the prominent relief of the Chiltern Hills. Between 100 and 65 million years ago Britain was further south, approximately where North Africa now lies (35ºN - 40ºN) and much closer to America as the Atlantic had not yet fully opened. Southern Britain was submerged under a warm sea about 300 metres deep. As there was no nearby land to contribute mud or silt, the seas were clean, warm and clear. Tiny calcareous plants (algae) and animals (**foraminifera**) flourished in the sea and when they died their remains sank to the seabed to form calcium carbonate mud. Slowly, over millions of years, this mud increased in thickness and solidified to form the Chalk. Only part of the Chalk is preserved in Hertfordshire. Its maximum thickness in the county is 207 metres, although locally much of it has been removed by erosion. Periods of slow accumulation during the deposition of the Chalk resulted in the hardening of the sea floor by precipitation of **minerals** within the carbonate mud, to form hard nodular layers known as **hardgrounds**. Some of these are so hard that they are difficult to penetrate and form the floors of quarries (e.g. Redbournbury and possibly Codicote). Some hardgrounds were previously used to divide the Chalk into Lower, Middle and Upper parts (see Table 3 in Appendix VII). The **Chalk Rock** was used to separate the Middle from the Upper Chalk and the **Melbourn Rock** the Lower from the Middle Chalk. A layer of **freestone** (**Totternhoe Stone**) within the Lower Chalk at Totternhoe (Bedfordshire) was quarried in the Mediaeval period to provide stone for carving statues, doorframes and windowframes in many Hertfordshire churches, including St. Albans Abbey.

There are many visible fossils in the Chalk; the commonest are sea urchins (**echinoids**) such as *Micraster* and *Echinocorys*; **sponges** such as *Ventriculites*; **brachiopod** shells such as *Cretirhynchia* and *Gibbithyris*; **gastropods**, **bivalves** and **crinoids**. The Chalk also comprises countless microscopic fossils, which provide much information regarding its age and origin.

The Chalk has been extensively quarried and mined in Hertfordshire since Roman times to produce agricultural lime, building stones, flint and, until very recently, cement. Finely ground chalk (**whiting**) is now being used for many purposes by numerous British industries.

Flint is a very hard form of **silica** found in parts of the Chalk, either as rounded nodules or in flat sheets. The nodules occur in a variety of shapes often determined by the form of animal burrows in which the silica was deposited. Exactly how flint was formed is still a controversy but it is generally accepted that the silica originally came from the remains of marine sponges, **radiolarians** and **diatoms**, which lived in the Chalk sea and had skeletons composed of silica (Clayton, 1986).

Nodules of the mineral **marcasite** are also found in parts of the Chalk. Their dark brown crusts are composed of **limonite** (hydroxide of iron) and when broken they exhibit radiating, brassy-looking crystals of iron disulphide.

After the formation of the Chalk there were major movements in the Earth's crust, which caused the sea level to fall so that most of Britain emerged as land with a sub-tropical climate. Then about 58 million years ago a brief marine transgression trimmed the surface of the Chalk and deposited two thin layers of sandy clay known as the **Thanet Sand** and **Upnor Formations** (see Table 4 in Appendix VII). The Thanet Sand Formation occurs only in eastern Hertfordshire, but the Upnor Formation originally extended across the whole county. The marine erosion surface cutting across the Chalk is known as the sub-Palaeogene surface, because it is overlain by various Lower Tertiary (**Palaeogene**) formations in southern England. After the marine episode resulting in the Upnor Formation the sea retreated and a 15 metre thick layer of sands, flint pebbles and clays was deposited by rivers flowing eastwards across Hertfordshire. These sediments now form the **Woolwich/Reading Formation** (Table 4 in Appendix VII). In places water containing silica in solution percolated through the beds of sand and cemented them into a very hard sandstone known as **sarsen stone.** Sarsen stone was extensively quarried in the Chiltern Hills in the nineteenth century and sarsen sets and curbstones can be seen in many of the older Hertfordshire towns. There is also a large piece of sarsen stone outside the St Albans Museum in Hatfield Road.

Where bands of flint pebbles occurred in the Woolwich/Reading Formation, the silica-cemented rock forms a conglomerate known as the **Hertfordshire Puddingstone** (Figure 2). Puddingstone and sarsen stone are both forms of an unusual rock type known as **silcrete.** This may have originally formed an extensive layer across the Chilterns, most of which has been eroded away, leaving only relic boulders scattered throughout Hertfordshire and neighbouring counties. The boulders range in size from a few centimetres across to large masses over 2 metres in diameter. A large boulder of puddingstone can be seen in St Albans beside Kingsbury Mill in St Michaels. Puddingstone and sarsen have been used as foundation and building stones in many Hertfordshire churches and as boundary markers and local monuments.

Where the Upnor and basal part of the Woolwich/Reading Formations form a thin (less than 5 metres) layer over the Chalk, water has percolated through it into the Chalk, transforming it into **Clay-with-flints** (Catt, 1986). The water has also dissolved the Chalk underneath to form cavities (solution pipes) into which the Clay-with-flints has collapsed (Figure 8). Where streams disappear down the pipes they are known as **swallow holes.**

Figure 2. Hertfordshire Puddingstone at Radlett (photo by Chris Wood)

Further earth movements then lowered the land in relation to the sea, so that a shallow subtropical sea spread over south-east England and deposited the **Harwich Formation** (3-4 metres of greenish-grey silty clay) and up to 100 metres of dark bluish-grey **London Clay Formation** (see Table 4 in Appendix VII) over the Woolwich/Reading Formation**.** The London Clay Formation contains rich and historically important fossil remains of subtropical land plants washed by rivers from adjacent land areas into the sea and buried along with the remains of marine animals. At the top of the London Clay, the sediments are more sandy and are known as the **Claygate Member** (see Table 4 in Appendix VII). These are the youngest of Hertfordshire's solid (pre-Quaternary) bedrock deposits: they are about 52 million years old.

There is then a long gap in the known geological history of the county until the end of the Pliocene Period or early **Pleistocene** Period about 2.5 – 2.6 million years ago. At this time the North Sea seems to have invaded parts of the emerging Chiltern Hills. The main evidence for this marine episode is a few blocks of iron oxide-cemented sandstone found in 1926 at Rothamsted Experimental Station, Harpenden. The blocks contained marine molluscs, which Dines and Chatwin (1930) equated with a well known assemblage of fossils from the Plio-Pleistocene Red Crag in Suffolk. Both deposits accumulated in shallow water. However, the Red Crag in Suffolk occurs up to 30 metres above present sea level, but the deposit at Rothamsted was at 130 metres, suggesting that Hertfordshire has been uplifted by at least 100 metres compared with Suffolk over the last 2.5 million years.

During the **Quaternary Period**, which began about 2.5 million years ago, there have been many rapid climatic changes. Relatively long (up to about 100,000 years) cold stages created a cold, bleak landscape with stunted arctic vegetation. Animals tolerant of very cold conditions, such as the woolly mammoth, woolly rhinoceros and wolf, were the only ones to inhabit Britain in these harsh conditions. During one such cold stage (the **Anglian**), which occurred about 470,000 - 420,000 years ago, a large ice sheet about 1 km thick invaded Hertfordshire from the north-east. It reached about as far west as St Albans and deposited till (a stony clay containing many chalk fragments), which is known locally as the **Chalky Boulder Clay** (see Table 5 in Appendix VII).

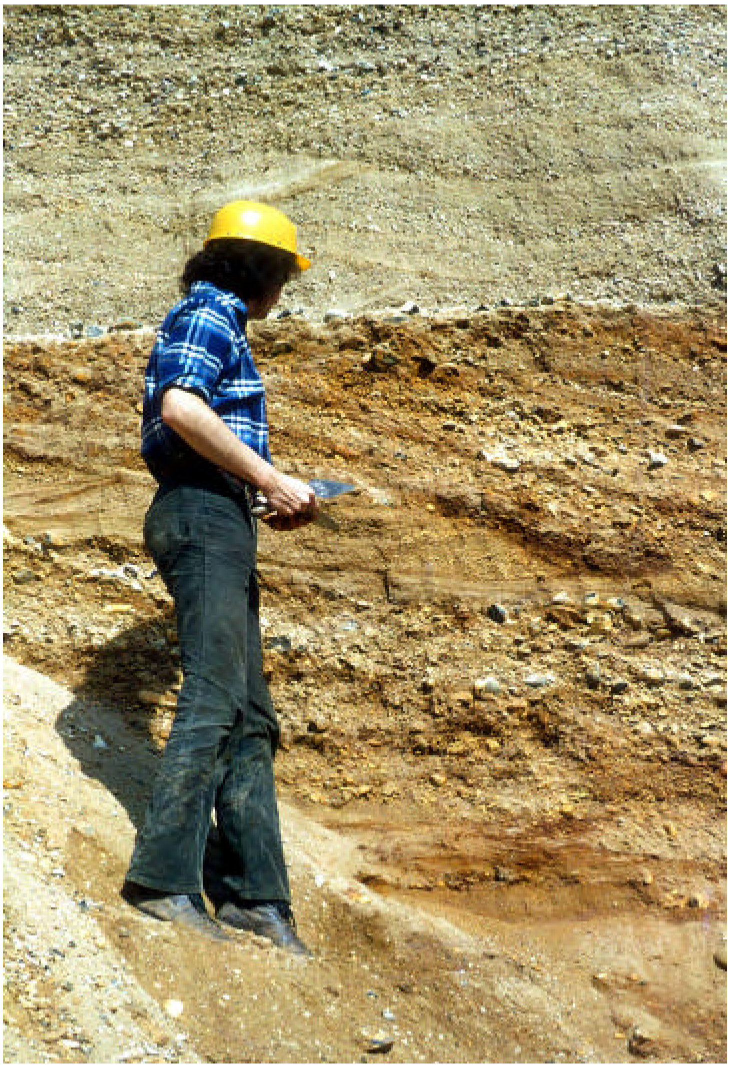


Figure 3. Section in Westmill Pit showing chalky glacial outwash gravel of Anglian age overlying river gravel of proto-Thames (photo by John Catt)

Before the advance of this ice sheet, the River Thames flowed from the Goring Gap through the Vale of St Albans to enter the North Sea via Norfolk, Suffolk and later Essex. This ancient river is known as the proto-Thames. The advancing ice blocked the proto-Thames, diverting the river into its present course through London. Along its old course, the proto-Thames deposited flinty gravels in all the cold stages of the Quaternary. These now form a sequence of terraces created as the river repeatedly incised its bed in response to slow uplift of the land. The Anglian glacier also deposited gravels as it melted (Figure 3), and together with the proto-Thames terrace gravels these constitute one of the county's main natural resources, which are today extensively quarried as **aggregate** for the building industry.

Larger fragments of rock transported by the ice sheets, sometimes many miles from their source, are known as **erratic** boulders. A good example can be found in Royston town centre where a boulder of **Millstone Grit**, originating in Derbyshire or Yorkshire, has been mounted on a concrete plinth.

The cold stages of the Quaternary were separated by shorter (about 10,000 years), warmer **interglacial stages.** Large areas of forest then covered the county and supported herds of grazing animals, at times including large mammals such as elephant, rhinoceros, hippopotamus, bison and deer. Predators such as hyena, lion and sabre-toothed cat also preyed upon them. The **Hoxnian** Interglacial, which followed the Anglian cold stage, is represented by lake deposits at numerous sites in Hertfordshire, including several in the Hatfield and Stevenage areas (Figure 4). At Oughtonhead Lane, Hitchin, an important deposit of **tufa** accumulated in a spring-fed marshy area during the Hoxnian. The tufa is rich in mammal bones and fresh water molluscs.

Figure 4. Hoxnian Interglacial peat and lake deposits, Roe Hyde Pit (now under the A1(M)), Hatfield (photo by John Catt)

The last 10,000 years of geological time (the **Holocene period**) is probably equivalent to an interglacial. The main Holocene deposits are the alluvial muds and peaty sediments deposited in and beside the county's rivers (see Table 5 in Appendix VII). In the last few thousand years man has exerted an increasing influence on the landscape through agriculture and other industries.

Further details of the geological history of Hertfordshire are given by Sherlock and Pocock (1924), Catt (1978a; 1981), Millward *et al*. (1987), Shephard-Thorn *et al*. (1994) and Hopson *et al*.(1996).

3. HERTFORDSHIRE'S GEOLOGICAL RESOURCES

3.1 The Hard Rock

Hertfordshire has virtually no natural hard rock exposures. Consequently, geologists have to rely on man-made exposures, such as pits, quarries, road and railway cuttings, and temporary excavations such as trenches for gas pipelines, to provide evidence of the county's geology. Museum and other collections and library archive material are also an important geological resource and play a key part in research and raising public awareness.

Chalk	• Chilterns scarp (cover photograph and Figure 5). • Coombes such as Coombe Bottom, Kelshall, Tring Park and Therfield Heath. • Spring sources as at Ashwell, Oughtonhead, Lemsford, and Chadwell near Ware.
Woolwich/Reading Formation and London Clay Formation	• Swallow holes at Water End and Northaw Great Wood. • Shenley Ridge. • Patmore Heath. • Exposed Hertfordshire Puddingstone at Radlett (Figure 2).
Pleistocene	• Boulder Clay Plateau of East Hertfordshire. • Hitchin Gap. • Vale of St Albans (marking the route of the proto-Thames and now containing the major rivers of Hertfordshire).
Holocene	• Alluvial flood-plain at Kings Mead, Hunsdon Mead, Panshanger Park Valley. • Bournes at Braughing, Wareside (Nimney Bourne).

Table 1. Examples of Landscape Features in Hertfordshire

3.2 Physical Landscape and Geomorphology

The physical landscape, the study of which is known as **geomorphology**, results from the interaction between the underlying bedrock geology and processes of erosion and deposition under various climatic conditions during the Quaternary. The same interaction produces the river network and also the various **soil** types, which in turn influence the patterns of vegetation and agriculture. Hertfordshire's relatively soft, easily eroded geological deposits are the main reason for its gently undulating landscape. There are few hills above 200 metres in height and these are confined mainly to the Chalk escarpment of the Chilterns in the north-west of the county.

Figure 5. Aerial view of a typical scene on the Chalk scarp, looking east along the scarp from over Therfield towards Reed (right centre) and Barkway (top right), showing till with chalk rafts emplaced by glacial tectonics (photo by Brian Sawford).

3.3 Soils

Weathering and other modifications of the various geological deposits occurring at the land surface have produced a diversity of soil types in Hertfordshire, ranging from the thin, highly calcareous soils of the Chalk escarpment to the deep, acid soils found on the flinty proto-Thames terrace gravels in the south of the county. Between these extremes are many more soil types whose characteristics are largely related to the parent material and the processes responsible for their formation.

Where the Chalk lies within about 23 cm below the surface, the soil type known as a **rendzina** occurs. This is found mainly on the slopes along the Chiltern scarp and on the sides of many Chiltern valleys. It is a well-drained, dark coloured calcareous soil associated with beech woods and chalk grassland with a rich flora of lime-tolerant species.

Thin carbonate-rich soils (rendzinas) are also found on the Chalky Boulder Clay in the east and the Gault Clay in the north-west. These soils are well structured but only slowly permeable; they are extensively cultivated for pasture and with a wide range of arable crops. Uncultivated areas have a semi-natural vegetatation of oak-hazel-hornbeam woodland, with rush and sedge communities in the damper areas.

During the Holocene and some interglacials, **argillic brown earths** have developed on Clay-with-Flints, Chalky Boulder Clay and glacial and river terrace gravels. They are deep, well-drained, loamy soils and are either under mixed woodland or are cultivated mainly for cereals. The argillic brown earths on Clay-with-flints, proto-Thames and glacial gravels have reddened and strongly clay-enriched subsoils formed in interglacials and are known as **palaeo-argillic brown earths**. Large areas of these acidic soils are under pasture, semi-natural woodland or commons. Their acidity has to be counteracted by applications of ground chalk for arable farming. In the past this was usually excavated from "dell holes" at the edges of fields.

On the **Woolwich/Reading Formation** and **London Clay Formation,** clay-rich acidic soils occur. Because they are poorly drained and heavy to cultivate, they are used mainly for pasture or are under oak-hornbeam woodland. The deposits of Holocene alluvium on the river flood-plain give rise to **alluvial soils**. These are often composed of calcareous silt and clay and are rich in organic matter. The **water table** is usually near ground level and the land has been used as water meadow pasture or watercress and osier beds.

Further details of the soils of Hertfordshire in relation to geology are given by Avery (1964) and Catt (1978b).

3.4 Water

Hertfordshire has two main sources of water: rivers and the **aquifers** which feed wells and springs. Many of Hertfordshire's small streams are **bournes** with predominantly gravel or chalk beds, in which water levels rise and fall according to seasonal flow i.e. they flow in winter but are often dry in the summer.

Larger rivers have tended to remain stable throughout the year, but by the 1990s over-abstraction and prolonged drought conditions had lowered the water table considerably (sometimes by 7 metres) and this left some of their stretches almost permanently dry. This was true of the River Ver until abstraction at Friars Wash Pumping Station (near Markyate) was replaced by surface recharge.

Ephemeral **swallow holes**, formed where streams disappear into fissures in the Chalk, are common in Hertfordshire. A famous and much-studied example is at Water End near Hatfield where the Mimmshall Brook disappears into the Chalk at the edge of the Woolwich/Reading Formation outcrop and reappears ten miles away at Chadwell Spring near Ware. Water End is the only area of permanent sinkholes in the Chalk of Hertfordshire and it drains into the largest known subsurface **karstic** drainage network in England (approximately 32 square kilometres). It has been designated as a Site of Special Scientific Interest (Appendix II).

3.5 Pits and Quarries

Hertfordshire makes important contributions to the country's demands for sand and gravel for use as aggregate in the building industry. The county also produces chalk mainly for use in the production of agricultural lime and clay for use in brick making. In the past, the county has also provided chalk for use in cement production. As well as providing raw materials, pits and quarries also provide excellent geological **exposures**, which form a valuable record of the geology that underpins the mineral prosperity of our county. However, quarrying is essentially a temporary land use with pits having a limited working life. Many Chalk quarries provide good exposures long after work has ceased, but other geological exposures remain only during the working life of a site, unless their longer term retention can be secured, perhaps as part of the final restoration of the site. Accordingly, quarries and pits can provide both temporary and permanent exposures of geological features, depending on individual circumstances. Key quarry and pit sites retaining geological interest in 2003 include:

- Anstey Quarry – Chalk.
- Ashwell Chalk Pit – Chalk.
- Bedwell Park Quarry – Chalk and Upnor Formation.
- Codicote Quarry – Chalk.
- Hillcollins Pit – proto-Thames gravels.
- Great Westwood Quarry - proto-Thames gravels.
- Pitstone Quarry 2.
- Springview Quarry, Flaunden – Chalk.
- Ware Road Chalk Quarries – Chalk.
- Westmill Quarry – sand and gravel.

Of the above sites, only Pitstone Quarry 2 has provision for the permanent retention of an exposure. Other sites, such as Anstey Quarry, Great Westwood Quarry and Westmill Quarry, provide examples of temporary exposures. Some, such as Codicote Quarry and Springview Quarry, Flaunden, also provide temporary exposures but may provide opportunity for permanent exposures to be incorporated in any future restoration proposals for the sites.

3.6 Road/Rail Cuttings

Hertfordshire includes many important transport corridors between London, the Midlands, East Anglia and northern Britain. These corridors require acceptable gradients and have, accordingly, resulted in the creation of cuttings providing exposures which are invaluable in the study of geology. Examples of these man-made exposures can be seen in the Hitchin Railway Cutting , the Royston Bypass (Figure 6) and the A41 trunk road (all Chalk). However, many past exposures, such as the Little Wymondley Bypass (Glacial Gravels), are now concealed, making it necessary to rely on chance temporary exposures in the future to reveal geological features.

3.7 Temporary Exposure Sites

In recent decades, there have been numerous major pipeline excavations for gas and water and for housing/industrial development. Many have cut through areas of great geological interest, exposing sequences which may provide valuable clues to the geological history of the county. Such exposures are more short lived than those created in pits and quarries, although their importance can be considerable if they are logged or studied by specialists when freshly dug.

Figure 6. Road cutting in the Chalk, Royston Bypass (photo Brian Sawford)

3.8 Archaeology

Hertfordshire is particularly rich in archaeological remains. The combination of good soils, favourable climate and adequate water supplies made it a favoured area for settlement from the end of the last Ice Age (the **Devensian** Stage) around 10,000 years ago (Hertfordshire County Council Environment Department, 1997a). Before Britain finally became separated from the continent by the English Channel about 6000 years ago, there were several invasions of people from the continent across southern Britain. In Hertfordshire, about 10,000 years ago, the Mesolithic people spread into the drier lands of the upper reaches of what is now the Lea and Colne river systems and began to colonise some of the more heavily wooded areas of the county such as the Chiltern Hills where the Chalk and the Clay-with-Flints provided abundant supplies of flint for tool-making.

The large deposits of alluvium and peat within the valleys of Hertfordshire contain important prehistoric (e.g. Mesolithic) archaeological remains. These deposits are likely to contain some of the best preserved archaeological sites in the county and, in addition, a wide range of information relating to past environments and developments leading to the present environment. However, such deposits are very vulnerable to degradation as a result of hydrological change and have, in many places, been extensively destroyed by quarrying (e.g. Rye Meads).

3.9 Earth Science Collections of Material from Hertfordshire

Hertfordshire Museums and other institutions

The wealth of geological material within the Hertfordshire museum collections represents an important part of the geological heritage of the county and a major, but under-used, resource for research, display and educational use.

Surveys by Timberlake (1988) and McLean (1991) suggested that there are over 25,000 geological specimens within Hertfordshire Museums. This includes the collections of the Environmental Sciences Department of the University of Hertfordshire, although over three-quarters of the specimens are stored in local authority museums, in particular those at Hitchin, St.Albans and Hertford.

Collections in the Hertfordshire museums have been made over more than 180 years. Some of the older material is of historical importance. Their true scientific merit remains unknown, although the potential research value of some of the better-documented material is considerable. There is no 'type' material among the collections in Hertfordshire, but many specimens are referred to or figured in the literature. Examples include ammonites from the Chalk Rock at Hill End Farm Pit and foraminifera from the Top Rock at Redbournbury Quarry.

A list of Museums and other institutions in Hertfordshire containing geological collections can be found in Appendix IV**.**

Museums and other institutions outside Hertfordshire

One of the most important collections of Hertfordshire Chalk fossils is that held by the British Geological Survey (BGS) at Keyworth, Nottinghamshire. This comprises fossils and archives collected at the time of the surveys of the Hertford and, latterly, the Hitchin geological sheets, and also the most comprehensive collections ever made of Chalk Rock fossils (all groups) from the two key Hertfordshire localities, namely the Hill End Farm Pit and the Reed Chalk Pit RIGS sites. The ammonite collections alone in the BGS and Natural History Museum, London from these two localities (particularly Hill End) contain 73 figured and/or type specimens (see Section 6 and Appendix VI).

Most of the important Pleistocene mammal finds are housed in the Natural History Museum, London, though there is also some material in BGS, Keyworth.

3.10 Urban Geology: Building Stones etc

Before the twentieth century, buildings, especially churches, and memorials were often constructed of stone taken from local quarries. Important local examples are Totternhoe Stone and Hertfordshire Puddingstone. Later, ease of transport and changes in public taste often led to stone being imported from other parts of the country or indeed from overseas. This has lent colour and texture to the urban landscape and has become an important part of our geological heritage.

After many years of neglect many older buildings e.g. churches, cathedrals, town halls etc. and also gravestones have recently been cleaned and returned to their former glory so that the rich variety of stone types used in their construction can be appreciated.

Over 80% of the population live in urban areas, and in the light of the limited access to both natural and man-made exposures in the county the role of building stones in raising awareness of geology is of great importance (Bennett *et al.*, 1996). The built environment is so rich in geology that it provides a superb opportunity to promote the county's geological heritage and increase awareness of the value of geology in our everyday lives (English Nature, 1992).

Where importance is attached to quality in urban conservation and design, the contribution made by natural stone deserves to be recognised.

4. THREATS AFFECTING THE GEOLOGICAL RESOURCES

In the previous section, the county's geological resources were outlined. In this section, threats to those resources are briefly examined.

4.1 Modifications to Landscape

Considerable economic and development pressure exists within Hertfordshire due, in no small part, to its proximity to London. As a result, the need for new built develop-ment and the accompanying supply of construction aggregates gives rise to continuing pressure for the use of 'green field' sites for these purposes. This pressure can conflict with other concerns such as the protection of natural features within the landscape and can, therefore, pose a potential threat to the resource.

In the context of this threat, there is a need to be clear about the importance of landscape features from a geological perspective and to understand the connection between geology, development opportunities and landscape. The fate of the Hertfordshire landscape rests in the hands of a host of organisations and individuals, including local authorities, private and corporate land owners, developers, conservation organisations and others. Similarly, the minerals industry, geologists and geomorphologists and all those who may be associated with the creation, study and protection of geological features need to work together to clarify the links between landscape features and the geology beneath. This is a major concern of the Hertfordshire RIGS Group.

4.2 Degradation of Soils

There are six principal threats to our soil resource (Taylor *et al.,* 1996): intensive agriculture, forestry, industrial emissions, waste disposal, expansion of the built environment and recreational use of land.

Hertfordshire is one of the more intensively cultivated of British counties and contains large areas of "Best and Most Versatile Land" as identified by the Agricultural Land Classification (ALC) system. Government land use policy centres on the protection of these higher grades of agricultural land from irreversible development (Planning Policy Guidance 7, paragraph 2.6; see Appendix I). The ALC system is based on assessments of the natural characteristics of soils and the practical limitations on their use for agriculture, which when taken together, confer a value for agricultural use. The physical characteristics of the soil are largely inherited from the underlying geology which provides the soil parent materials. To aid the protection of soils in general, the former Ministry of Agriculture, Fisheries and Food (MAFF, now part of DEFRA) published a code of good practice (Ministry of Agriculture, Fisheries and Food and Welsh Office Agriculture Department, 1993), providing guidance on how to minimise loss and degradation of soils. The former Department of Environment, Transport and the Regions (DETR) also published for consultation a *Draft Soil Strategy for England* which explores further issues around the identification and protection of soil resources.

It is important to recognise the need for sustainable land use and management and to encourage all to give full support to it. The protection of natural resources, including the soil resource, is an important aspect of geological conservation, in which geologists, soil scientists and others can play an important role in developing appropriate policies.

4.3 Depletion of the Chalk Aquifer, the Source Rock of our Water

Since the last ice sheets melted from the highlands of Britain 10,000 years ago, major rivers in the county, such as the Lea, have deposited fine alluvium and are still playing an important role in the formation of Hertfordshire's landscape but, unfortunately, they are vulnerable to a wide range of threats.

There has been concern in recent years about low flow in some chalkland rivers, caused by over-abstraction of water from the Chalk and by persistent drought conditions, resulting not only in the decline of river quality, but also in the physical degradation of the river course. The management of these rivers is closely related to the wider systems in which they are found, and the Environment Agency is addressing the need for a holistic approach through the production of Local Environment Agency Plans (LEAPs) and, previously, Catchment Management Plans (CMPs).

4.4 Destruction of Exposures Through the Restoration of Mineral Sites

Deposits exposed by mineral extraction processes provide an important geological resource, which can give vital clues to the geological structure and history of the area. These exposures can provide an invaluable opportunity to study the local geology at locations that would otherwise have remained hidden. They may also provide the opportunity, in some circumstances, to identify features which may on completion of mineral extraction be retained in the landscape as part of the final restoration of the site. However, wider considerations such as those of future land use, health and safety, and planning, may mean that geological interests are not always regarded as overriding, such that some features may not be retained in the long term. Such conflicts of interest are unavoidable on occasions, thus making it essential that the issues are thoroughly considered during every stage of the planning process. It is for these reasons that the Hertfordshire Structure Plan and Hertfordshire Minerals Local Plan both address the issue of RIGS sites within their policies. Accordingly, liaison between the Hertfordshire RIGS Group, local planning authorities, quarry operators and others is needed to ensure that, wherever possible, critical features are preserved upon restoration for future study.

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4.5 Loss of Geological Sites in Road/Rail Cuttings

There have been several major road-building programmes in the last 20 years and various environmental consultancies were commissioned to identify the environmental issues associated with their construction and operation. The usual mitigation measures to protect the landscape, wildlife and archaeological sites formed an integral part of the proposals, but little has ever been done to ensure the retention of any important geological features exposed by the works (Larwood and Markham, 1995).

Much of Britain's branch line railway network has become disused and overgrown and some sites have become obscured by vegetation or degraded through collapse. These can, however, often be recovered by judicious excavation although, as with mineral sites, there may be wider issues, such as those of health and safety, which should be taken into account.

4.6 Temporary Exposures in Service Pipeline Trenches

The collection of data and material from temporary excavations such as the trenches for new pipelines for water, gas and cables, can significantly increase our knowledge and understanding of the underlying geology. Liaison with key interest groups for wildlife and archaeology has already been established by the service industries, but there is a need to ensure that geologists are also part of that partnership to gain the maximum scientific and educational benefit.

4.7 Archaeological Sites

There is an intimate relationship between archaeology and the local geology in patterns of human settlement, development and landscape (Glasser, 1994). Recognising this joint interest at an early stage in the planning system should ensure effective monitoring and conservation of both natural and historic environments. With threats to these environments from commercial workings of minerals, road schemes and gas pipelines, it is important to establish an effective line of communication between archaeologists and geologists, so that joint efforts can be made to assess the scientific importance of sites proposed for commercial working.

4.8 The Deterioration of Geology Collections in Hertfordshire Museums

Most geological collections were put together during the last two centuries when collectors were able to visit the numerous pits and quarries being worked throughout the county. Today, many sites have been lost due to subsequent changes in land use. The specimens that were collected in the past provide valuable material for research, because historic sites cannot always be revisited. They are an irreplaceable part of our scientific heritage, and better provision for the care of Hertfordshire's geological collections should be considered as a priority alongside site conservation and research. Doughty (1981) revealed a frightening picture of disorder, neglect, mismanagement and decay of geological collections in the UK and the situation has improved little over the past 20 years; indeed, there is now no geological curator in the county. On the positive side, however, local museums have become more active in recent years in involving the public. One innovative example can be seen in the "Geology Wall" in Stevenage and there is scope for other initiatives of this kind. It is a Hertfordshire RIGS Group strategy objective to encourage museum authorities to take better care of geological collections (Section 7).

4.9 Modernisation of Old Buildings

Throughout many of the older towns in Hertfordshire shops and banks are being modernised and town centres pedestrianised. This has involved the removal of large quantities of indigenous and imported stone cladding, kerbstones and cobbles.

At a time when interest in natural stone as a building material is high, we lack a comprehensive policy on the preservation of building stones. We should assemble a collection of specimens of the building stones in the county. Efforts are required to make architects, planners and teachers aware of the importance of old buildings, such as churches, as historical and educational resources (English Nature, 1992). St Albans is an example of a town where great care has been taken to make best use of traditional, local material in refurbishment work.

5. SITE SELECTION

In setting out criteria for the selection of geological sites for protection, two contrasting types of site are distinguished. They are not mutually exclusive, but each group requires a broadly different approach.

The two types have been called "Integrity Sites" and "Exposure Sites" (Nature Conservancy Council, 1990) and can be identified as follows:

5.1 Integrity Sites

Integrity sites are sites whose educational and scientific value is based on their containing a finite deposit or landform that is irreplaceable if destroyed. They include glacial, periglacial and fluvial landforms and their associated deposits, and the unique mineral, fossil, stratigraphic or structural aspects of other geological features. Conservation of these sites is weighted heavily in favour of preservation and restricting man-made changes via the planning system. Sites in Hertfordshire that come within this category include **swallow holes** and **naleds** or **icings**.

5.2 Exposure Sites

Exposure sites are those whose scientific or educational value lies in deposits which are extensive or plentiful beyond the margin of the site. The usual situation is that the deposits seen at the site continue laterally where they almost certainly contain features similar to those exposed at the worked face. However, in practical and economic terms the deposit is not available for study other than at the exposed face or by remote sensing or investigation (e.g. drilling or geophysical exploration). Exposure sites are numerically the most common and include most quarries, cuttings, outcrops and mines. Examples of Exposure Sites in Hertfordshire are given in Table 2.

Type of site	Potential threats
Active quarries and pits e.g. Anstey Quarry and Codicote Quarry.	Quarry extension or (as quarry reaches the end of its economic life) landfill and restoration.
Disused quarries and pits e.g. Holwell Pit.	Landfill, restoration, flooding.
Road cuttings e.g. Royston bypass.	Slope stabilisation, hydroseeding.
Chalk mines and tunnels e.g. Shenley, Roughdown Common.	Infilling.

Table 2. Examples of Exposure Sites in Hertfordshire

The conservation of Exposure Sites depends mainly on protecting the exposure from burial or becoming overgrown. However, the actual material that is exposed at a face at any time does not need to remain provided fresh material can be exposed to form equivalent or better exposures. Quarrying may, indeed, be welcome because it creates fresh exposures. Exposure Sites may be created where none existed before, and man's activities are in general more compatible with their conservation than is the case for Integrity Sites. It must be stressed that Exposure Sites are no less important than Integrity Sites. In fact they are critically important because of the huge cost and difficulty of creating new sites to replace them.

5.3 Selection Criteria

The basic criteria used by the Hertfordshire RIGS Group in selecting sites as RIGS are the nationally agreed criteria set out in Section 1.1 of this document. In applying these criteria, the Hertfordshire RIGS Group has developed a standard site assessment form which addresses the following aspects:

Scientific Importance

Petrology

- Does the site expose rocks representative of Hertfordshire?

Stratigraphy

- Does the site show stratigraphic features representative of Hertfordshire?
- Is the site important for stratigraphic correlation?

Palaeontology

- Is the site important for a particular fossil species or assemblage?
- Is the site important palaeo-ecologically?

Mineralogy

- Is the site important for a particular mineral or assemblage of minerals?

Structure

- Does the site demonstrate any important structural features (e.g. faults, folds) ?

Geomorphology

- Is the site an important landscape feature in Hertfordshire?
- Does the site demonstrate important geomorphological features or processes?

Other Scientific interests

- Does the site have any wildlife significance?
- Has the site any archaeological significance?
- Is the site protected for its wildlife or archaeological significance?

Educational/research value

- Is the site suitable for teaching the Earth Science components of the National Curriculum?
- If so, at what level?
- Is the site suitable for teaching the Earth Sciences at undergraduate level?
- Is the site suitable for other educational users (e.g. adult classes)?
- Is the site important for post-graduate research?
- Is the site physically accessible?
- Is the site safe?
- Is access to the site permitted for education/research?

Historical associations

- Is the site historically important in terms of advances in geological/geomorphological knowledge?
- Has the site any associations with culture, folklore or religion?

Aesthetic characteristics

- Is the site an essential component of an attractive or evocative local landscape?
- Could the site be used to promote public awareness and appreciation of geology/geomorphology?

Conservability

- Does the site require management work?

6. HERTFORDSHIRE RIGS

The following sites in Hertfordshire have been designated RIGS sites by the Hertfordshire RIGS Group. A National Grid Reference is given for each site and their general location is shown on the accompanying map of Geological Conservation Sites in Hertfordshire (Figure 1). Supplementary details on many of the Chalk Group RIGS sites and on additional potential Chalk Group RIGS sites are given in Appendix VI.

Almshoe Bury Swallow Hole (North Herts. District) TL 207246. A seasonal bourne leading to a large swallow hole where floodwater percolates through gravels into the Chalk bedrock. The swallow hole area and a blind valley to the south-east flood occasionally.

Ashwell Quarries (North Herts. District) TL 253395. The Totternhoe Stone here was formerly quarried for building stone. It is a Hertfordshire and Middlesex Wildlife Trust Nature Reserve. Only a few small exposures of Chalk can now be seen.

Barkway Chalk Pit (North Herts. District) TL 381366. Section through two glaciotectonically moved blocks of Chalk containing the Chalk Rock and beds immediately above and below (Hopson, 1995, Fig. 4). The succession in the larger block extends down to the sub-Chalk Rock Reed Marl. This block is traversed by a fault that repeats the higher part of the succession. The two blocks are separated by Anglian till and are faulted against till (Figure 7). This is one of a group of pits (including Reed Chalk Pit) exposing Chalk that is out of position as a result of being displaced by the Anglian glacier impinging on the Chalk scarp. It is a Hertfordshire and Middlesex Wildlife Trust Nature Reserve.

Castle Hill, Berkhamsted (Dacorum Borough Council) SP 993085. A pile of three large boulders of Hertfordshire Puddingstone on the grass verge in Castle Hill. They show good stratification and transition from conglomerate to sarsen.

Hill End Farm Pit (= Hitch Wood Pit)(North Herts. District) TL 197239. This pit is of national stratigraphic and international palaeontological importance, but has lost its original SSSI status and is now very degraded. It is the type locality of the Hitch Wood Hardground at the top of the Chalk Rock. This hardground is exceptionally fossiliferous here, and has probably yielded more fossils of all groups (notably ammonites) than any other Chalk Rock locality apart from the Kensworth Chalk Pit GCR site, Bedfordshire. It is a Hertfordshire and Middlesex Wildlife Trust Nature Reserve.

Figure 7. Barkway Chalk Pit showing till between two rafts of Chalk containing Chalk Rock
(photo by Brian Sawford)

Hitchin Railway Cutting (North Herts. District) TL 196295. This is one of the three original reference sections for the Melbourn Rock at the base of the traditional Middle Chalk, which must have been exposed at track level or in the floor of the adjoining quarry (TL 196294). The present exposures show Chalk above the Melbourn Rock. It was formerly designated a SSSI because of its fossils, and is the type locality of biostratigraphically important bivalves and brachiopods. A noteworthy feature is the occurrence of flinty chalk equivalent to that in the central Chiltern Hills near Totternhoe and in the Steeple Morden Plantation Quarry, just over the county boundary in Cambridgeshire (see section 3 of Appendix VI).

Holwell Gravel Pit (North Herts. District) TL 167318. This important site previously exposed Anglian till and glaciofluvial sands and gravels (Etienne, 2001). Before it was infilled, glaciotectonic structures in the northern pit were photographed in detail and a purpose-drilled borehole has been funded by the landfill company to establish stratigraphic equivalence with Anglian deposits elsewhere in Hertfordshire. The samples from this borehole are currently being analysed.

Martins Way/Grace Way/Canterbury Way Roundabout, Stevenage (North Herts. District) TL 244262. The chalk in this roadside cutting (Figure 8) contains solution pipes filled with typical Woolwich/Reading Formation sediment, which proves that this formation once extended several kilometres north of its present main outcrop. The unworn flint nodules around the edges of the pipes were released by dissolution of the adjacent chalk as the pipes formed.

Moorend Farm Meadows (Dacorum District) TL 037060. Geomorphological site showing naleds or icings (depressions where large masses of ice accumulated on the valley floor because water from a spring froze semi-permanently in the Late Devensian). The depressions are filled with Holocene muds and peat.

Potters Crouch Pit (St. Albans District) TL 116046. Upper Chalk with paramoudra (very large flint) and marl seams.

Radlett Field (Hertsmere District) TL 174999. Abundant fragments of Hertfordshire Puddingstone revealed after ploughing.

Figure 8. Pipe in Chalk filled with Tertiary sands and lined with Clay-with-flints. Roadside cutting, Martins Way, Stevenage (photo by John Hepworth)

Radlett Plantation (Hertsmere District) TL 175995. The only known exposure in the county of Hertfordshire Puddingstone *in situ.* It shows depositional and structural features important for indicating the origin of the rock.

Ravensburgh Castle (North Herts. District) TL 092302. Chalk escarpment with steep-sided coombes and chalk springs.

Redbournbury Chalk Quarry (St. Albans District) TL 124105. Section in the lower part of the traditional Upper Chalk (*Micraster cortestudinarium* Zone) with the Top Rock Hardground visible in a shallow trench on the quarry floor. The lower part of the chalk exposed in the main face contains spectacular sub-horizontal anastomosing sheet flints demonstrating the effects of minor faults. The fossils from the Top Rock and immediately overlying beds indicate the extent of condensation of the Top Rock and also enable correlations with successions in northern Europe and North America. The Top Rock has yielded more fossils than almost any other Top Rock locality in Britain. Currently there is no public access.

Reed Chalk Pit (North Herts. District) TL 359370. This pit has lost its original SSSI status and is now very degraded, but has considerable stratigraphical, palaeontological and glaciotectonic importance. It is a potential GCR site and should not be allowed to disappear through lack of conservation. The highly fossiliferous Chalk Rock exposed here is the source of numerous figured specimens of ammonites and has also yielded many brachiopods and well preserved sponges. The beds below the Chalk Rock (no longer exposed) contain well preserved uncrushed echinoids. The pit is also important in that it is one of a group, including the Barkway Chalk Pit RIGS site, which expose glaciotectonically disturbed Chalk that is out of its correct position and shows unusually high dips (Jukes-Browne and Hill, 1904, Fig. 57; Hopson, 1995). It is a Hertfordshire and Middlesex Wildlife Trust Nature Reserve.

Royston Chalk Pit (North Herts. District) TL 361403. Middle Chalk with exposure of the Reed Marl, which is no longer seen at Reed.

Royston Erratic (North Herts. District) TL 356407. Glacial erratic boulder of Millstone Grit (Carboniferous sandstone), probably derived from Derbyshire or Yorkshire.

Shenley Chalk Mine (Hertsmere District) TL 203014. Disused chalk mine with extensive tunnels and gigantic caverns. It is reputed to be one of the largest unsupported chalk mines in the world. It is now an important bat hibernaculum.

7. STRATEGY OBJECTIVES – MISSION STATEMENT

To contribute to the quality of life for all who live, work and play in Hertfordshire through the conservation and management of our geological heritage and landscape and to fulfil the aims set out in the Structure Plan regarding sustainability.

In order to achieve these objectives the Hertfordshire RIGS Group needs to:

1. ***Promote the appreciation and enjoyment of Hertfordshire's geological heritage.***

2. ***Ensure wherever possible that Hertfordshire's geological and geomorphological heritage is safeguarded throughout the planning process.***

3. ***Support UKRIGS to standardize site evaluation techniques, notification procedures and data recording systems.***

4. ***Safeguard Hertfordshire's geological heritage by identifying sites needing active management and enhancement.***

5. ***Secure effective curation of, and access to, geological collections and archives in Hertfordshire.***

8. ACTION PLANS

To achieve the strategy objectives listed above, the following actions will be taken by the Hertfordshire RIGS Group in partnership with other relevant organizations including, as appropriate, English Nature, The Geologists' Association, Hertfordshire Biological Records Centre, Hertfordshire County Council, Hertfordshire District and Borough Councils, Hertfordshire Geological Society, Hertfordshire and Middlesex Wildlife Trust and the University of Hertfordshire.

1. Audit of all existing RIGS sites. This will include evaluation and recording of:

   - The current physical state of the site.
   - Any rescue work required as a matter of urgency.
   - The educational potential of the site.
   - Current ownership/management of the site and arrangements regarding access.

2. Develop site recording, assessment and notification procedures and data recording systems in conjunction with UKRIGS.

3. Develop site monitoring and conservation procedures and, where appropriate, management and enhancement plans for each site.

4. Increase public awareness of the geological heritage of Hertfordshire by developing plans for:

   - Dissemination of site information.
   - Site information boards.
   - Site trails with descriptive material.
   - Guided site visits.

5. Ensure that new policy proposals in the Hertfordshire County Structure and Local Plans are commensurate with the strategy objectives stated in Section 7 of this document.

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APPENDIX I

SOME RELEVANT INTERNATIONAL AND NATIONAL GEOLOGICAL CONSERVATION INITIATIVES

1. The Malvern International Task Force for Earth Heritage Conservation

The Malvern International Task Force was established at the Second Conference on Geological and Landscape Conservation held at Malvern in July 1993. The conference was attended by 150 delegates from 30 countries, who supported the following resolution:

'The Malvern International Conference 1993:

- believes that there is a need for an international Earth Science conservation convention;
- recognises that the justification for, potential scope of, and objectives of such a convention should be examined in depth;
- supports the establishment of an international task force which will pursue, and report back on, these opportunities.

The Task Force members believe that a crucial step towards achieving an international convention is the establishment of an international organisation for earth heritage conservation. To this end, it is establishing a network of contacts around the globe who will promote the need for earth heritage conservation, and form the foundation on which an international organisation will be built.'

2. National Planning Policy Guidance

Planning Policy Guidance 9: Nature Conservation (PPG 9) (Department of the Environment, 1994) covers the legal framework for nature conservation in England, the treatment of nature conservation in development plans, and development control criteria for SSSIs and sites with additional national and international designations. PPG 9 identifies a formal hierarchy of sites:

Internationally important

- Special Protection Areas (SPAs).
- Special Areas of Conservation (SACs).

Nationally important

- National Nature Reserves (NNRs).
- Sites of Special Scientific Interest (SSSIs).

Regional and local sites

- Local Nature Reserves (LNRs).

- Sites of importance for nature conservation (SINCs)/ County Wildlife Sites.
- Regionally important geological and geomorphological sites (RIGS).

The Government expects development plan policies and development control decisions to respect the relative importance of these levels of designation. Their significance for earth science conservation was discussed by Culley (1995).

Other PPGs relevant to geological site conservation include

- The Countryside - Environmental Quality and Economic and Social Development (PPG 7).
- Archaeology and Planning (PPG 16).
- Transport (PPG 13).
- Tourism (PPG 21).

3. Local Agenda 21

At the Earth Summit held in Rio de Janeiro in June 1992, over 150 countries, including the UK, expressed a shared belief that action must be taken to halt the loss of the world's limited natural resources. Geological conservation sites are by nature a limited resource.

One of the principal policies resulting from this Earth Summit was Local Agenda 21, through which local communities are evolving programmes of action for the 21st century. Theoretically these should cover features of geological interest that are vulnerable and contribute to the quality of life, but the low profile of geology and geomorphology generally, and in school curricula, means that there is likely to be a low level of awareness of important sites.

4. The Natural Areas Map

English Nature and the Countryside Commission, with assistance from English Heritage, examined the local distinctiveness of all parts of England, to identify their characteristic wildlife and other natural features, and used this to define a comprehensive series of Natural Areas (English Nature, 1993). The boundaries are based on land use patterns and human history as well as the distribution of wildlife and other natural features. Consequently they offer a more effective framework for the planning and achievement of nature conservation objectives than do administrative boundaries. The map is being used as a strategic framework to help the Countryside Agency and English Nature to achieve their objectives (English Nature and Countryside Commission, 1996). It will also act as an essential reference for everyone working at a regional or local level. In particular, it forms the basis for Hertfordshire's Landscape Strategy Volumes 1 and 2 (Hertfordshire County Council Environment Department, 1997b; 2001).

The definition and characterization of Natural Areas required a considerable input from geology, and provided a major opportunity to bring the practices of wildlife conservation and geological conservation much more closely together (English Nature, 1997). This played a major part in ensuring that the processes which drive the development of the characteristic land management activities are well understood, and that the nature of the rocks and soils which constrain the development of the vegetation is properly appreciated.

English Nature has published descriptive profiles for all the Natural Areas. The one of greatest relevance to Hertfordshire geology is for the Chilterns (English Nature Thames and Chilterns Team, 1997).

5. Local Biodiversity Action Plan: the UK Steering Group Report

Biodiversity is the name given to the whole variety of life on Earth, including the different ways that plants and animals live together in communities. An international agreement on the conservation of biodiversity was an outcome of the Earth Summit at Rio de Janeiro in 1992.

In January 1994 the UK Government published its Biodiversity Action Plan in response to the commitment it gave at the Rio Summit. As a result, the question of biodiversity conservation has now been placed squarely on the agenda at both national and local level through Local Agenda 21, in particular through the production of the Biodiversity UK Steering Group's Action Plan (Bendall *et al*., 1994) and Report (Department of the Environment, 1995).

The Action Plan included an analysis of the 37 broad habitats in the UK, to see how many species of conservation concern each contained. Fifteen broad habitat types were identified as primary habitats for the greatest number of species of conservation concern. In order of priority, broadleaved woodland came first and standing open water second. Of note, however, were the third, fourth and fifth habitats: natural rock exposures and caves, calcareous grassland and maritime cliffs and slopes. The underlying geology exerts a powerful influence without which these three habitats and the plants and animals they include would simply not exist.

One aim of the geological conservation strategy for Hertfordshire is to emphasize the fundamental importance of geology and landscape as the essential framework upon which all other conservation issues rest. In the Hertfordshire chalklands many sites combine a significant wildlife interest with importance for geological conservation. Often the objectives of biological conservation and geological conservation go hand-in-hand, though sometimes they may be diametrically opposed. Clearly, biological and geological strategies must be integrated (Hopkins, 1994).

On behalf of the forerunners of the Hertfordshire Rural Forum, the Hertfordshire and Middlesex Wildlife Trust (1998) produced a Local Diversity Action Plan entitled *A 50 Year Vision for the Wildlife and Natural Habitats of Hertfordshire*.

6. The Geological Curators Group

The Geological Curators Group of the London Geological Society was founded in 1974 to:

- Improve the status of geology as a science in museums throughout the UK.
- Improve the standard of care of geological collections.

- Promote the documentation and conservation of geological sites.

The Group supports the work of those curators in Hertfordshire (currently there are none) responsible for the hands-on care of collections, and seeks to advance their training and proficiency.

APPENDIX II

HERTFORDSHIRE GEOLOGICAL SSSIs

Castle Lime Works Quarry (Hertsmere District) TL 229026. This site is a disused and largely backfilled chalk quarry, one face of which has been retained to show the boundary between the Chalk and overlying deposits. Large vertical pipe-shaped solution cavities in the top of the Chalk are filled with Palaeogene sands and clays modified by soil development processes (Thorez *et al*., 1971). It was the finest exposure of solution pipes in the Chalk landscape of England. Unfortunately, the quarry face was susceptible to erosion and, as a result, the foundations of the adjoining 12th century motte and bailey castle have partly collapsed into the quarry. The castle is a Scheduled Ancient Monument and English Heritage have demanded that backfilling of the SSSI quarry should be completed to protect the castle from further erosion.

Downfield Pit, Westmill (East Herts. District) TL 349165. This former gravel pit contains a complex sequence of gravels and boulder clays (tills) laid down during the Pleistocene by the ancestral River Thames (proto-Thames) and Anglian glacier. The deposits are important for interpreting conditions when the proto-Thames was diverted from the Vale of St. Albans into its modern course through London. More specifically, the gravels from this site and others in the area indicate that the river diversion resulted from the first Anglian glacial advance, which deposited the Ware Till. Subsequent gravels and tills are much richer in chalk and were deposited in the newly created Lea catchment. The site is now very degraded, but the sequence of deposits could be demonstrated by drilling a borehole on the site. Parts of the same sequence are currently visible in the nearby Westmill Pit (TL 344158), which is described in detail by Bridgland and Cheshire (1994).

Great Westwood Quarry (Three Rivers District) TQ 071993. This a key site for understanding the early history of the River Thames before the Anglian glaciation, when the river flowed through the Vale of St. Albans towards east Hertfordshire and East Anglia (McGregor and Green, 1983). The gravels contain pebbles of volcanic rocks which originated in north Wales, suggesting that at this time (800,000 – 900,000 years ago) the Thames drained a much larger area than at present or there was a glacier in higher parts of the catchment. The site is discussed in detail by Bridgland (1994, pp. 117-121).

Hillcollins Pit (East Herts. District) TL 442267. This small pit exposes the earliest gravels (Westland Green Gravels) laid down by the ancestral River Thames (proto-Thames) about 1,600,000 – 1,800,000 years ago. The extent of these gravels indicates that the proto-Thames flowed from Oxford through the Goring Gap and then north-eastwards to Norwich. The original site where these deposits were first found has become completely degraded, so the Hillcollins Pit is of considerable significance for reconstructing the evolving geography of southern Britain. The site is discussed in detail by Bridgland (1994, pp. 115-117).

Little Heath Pit (Dacorum District) TL 017082. Moffat and Catt (1983) suggested that the pebbly gravel and sand seen at this site were originally deposited on a Pliocene or

Pleistocene beach about 2.5 million years ago. However, their exact age is uncertain. Despite this, the sediments here will continue to attract considerable interest in future years because of their importance with respect to the early landscape history of the Chilterns. The site is discussed in detail by Bridgland (1994, pp. 94-101) and Moffat and Catt (1983).

Moor Mill Quarry West (St. Albans District) TL 145027. The gravels and clays in this excavation show the diversion of the Thames during the Anglian Stage of the Middle Pleistocene (Gibbard, 1977; Bridgland, 1994, pp. 129-134). The lowest beds of gravel (the Westmill Lower Gravel) were deposited in the period 470,000 - 500,000 years ago when the ancestral Thames (proto-Thames) flowed through the Vale of St. Albans. The ice sheet moving south-westwards then blocked the Vale and formed a large lake, in which the finely bedded clays seen here were deposited. Subsequently, a layer of boulder clay (the Ware Till) was deposited when the ice advanced further south-west. This caused the lake to overflow, creating the present course of the Thames through London. When the ice melted the present day River Colne was formed and deposited the top layer of gravels. Moor Mill is the only remaining site where this complete sequence can be studied; it is therefore a key site for understanding an important aspect of Britain's geological history. Unfortunately the exposure is subject to flooding.

Oughtonhead Lane, Hitchin (North Herts. District) TL 172299. The main research interest of this site (an interglacial tufa) is not currently visible, and a shallow trench is required to expose it. The tufa probably dates from the Hoxnian Interglacial (Kerney, 1959; Holyoak *et al*., 1983) about 300,000 – 420,000 years ago. It is of special interest because it contains fossil land snails and mammal bones indicating the climate and local environmental conditions during this period.

Water End Swallow Holes (Welwyn-Hatfield District) TL 230043. These are the only permanent swallow holes in Hertfordshire (i.e. water flows continuously into them). The site covers a group of more than 15 swallow holes, where two streams draining areas of the London Clay and Woolwich/Reading Formations sink close to the boundary of the Chalk outcrop. At times of flood a lake accumulates in the basin and may overflow into the River Colne via a channel through North Mymms Park, but it eventually drains back into the swallow hole basin. Beneath the surface is the largest known enclosed karstic drainage system in England (approximately 32 km^2).

BIOLOGICAL SSSIs WITH SOME ELEMENTS OF GEOLOGICAL/GEOMORPHOLOGICAL INTEREST

Ashwell Springs (North Herts. District) TL 270398. A series of springs arising from near the base of the Chalk form a source of the River Cam.

Northaw Great Wood (Welwyn-Hatfield District) TL 280043. Close to the Cuffley Brook, where the Chalk lies below thin permeable beds, such as Pleistocene Valley Gravel and sands of the Woolwich/Reading Formation, the surface water percolates into the Chalk through numerous swallow holes. Pieces of Hertfordshire Puddingstone may be found near the swallow holes, and in higher parts of the wood there are exposures of gravel that was probably deposited during an early stage of the proto-Thames**.**

Patmore Heath (East Herts. District) TL 443258. Variations in the thickness of gravels overlying the London Clay bring the water table close to the surface, so that areas of wet heathland have developed.

Redwell Wood (Welwyn-Hatfield District) TL 213025. Temporary swallow holes fed by seasonal woodland streams occur where the streams cross the boundary between the Woolwich/Reading Formation and Chalk.

Roughdown Common (Dacorum District) TL 047057. An old chalk quarry and an extensive chalk mine form part of the site, which is currently gated and in use as a bat hibernacule.

Sherrardspark Wood (Welwyn-Hatfield District) TL 230139. Temporary swallow holes fed by seasonal woodland streams occur where the streams flow off outcrops of the Ware Till and Woolwich/Reading Formation onto Chalk.

Broxbourne and Hoddesdonpark Woods (East Herts. and Broxbourne Districts) TL 325075 to TL 352085. In this extensive area of ancient woodland numerous streams developed on proto-Thames gravels overlying London Clay show natural meanders.

APPENDIX III

SOME RELEVANT GEOLOGICAL CONSERVATION ORGANIZATIONS AND INITIATIVES IN HERTFORDSHIRE

1. Local Nature Reserves

Local Nature Reserves (LNRs) are set up and managed by local authorities under Section 21 of the National Parks and Access to the Countryside Act 1949. The aim of LNRs is to protect places of special interest and/or those which provide opportunities for research and education or the enjoyment of nature by the public. There are now over 500 LNRs in England which were established because of their wildlife interest. However, many also hold unappreciated geological interest and could be managed better to help preserve this interest (English Nature, 1997).

2. Hertfordshire's Development Plan

By determining local land use policy, District/Borough planners have the most important role in the successful conservation of geological/geomorphological sites in Hertfordshire. Besides safeguarding individual sites through Local Plans, planners can play a positive role in promoting the use, management and enhancement of geological sites based upon advice provided by appropriate bodies. Earth science conservation needs to be an integrated part of any Local Plan, both in terms of policies adopted and of specific plans for future use.

The support for geological conservation through the Structure Plan has already been mentioned (Section 1.2). The adoption of the Landscape Character approach by Hertfordshire County Council will further support conservation of local physical landscape features.

3. Thames Northern Tributaries Project

The recent and older alluvial deposits of the middle Thames northern tributaries, the Rivers Colne, Lea and Rodin, have produced prehistoric, archaeological, environmental and geological evidence of exceptional quality. Despite their demonstrable potential, these alluvial deposits are under increasing threat of destruction. Large tracts of deposits in the middle and lower reaches of the valleys have been destroyed or are under threat from:

- Mineral extraction.
- Reservoirs.
- Large infrastructure development (e.g. roads and sewage works).
- Commercial redevelopment.
- Urban development.

In 1994 a steering committee was set up by Hertfordshire County Council archaeologists to investigate the need for a project to aid the research and management of these important alluvial deposits. The project, the **Middle Thames Northern Tributaries Project**, focuses on the prehistoric period from the Late glacial (13,000 years ago) to the Roman occupation from about 50 AD. Recognizing the joint interest in the deposits of these river valleys, the Hertfordshire RIGS Group gives its full support to the project.

4. Hertfordshire and Middlesex Wildlife Trust

The Hertfordshire and Middlesex Wildlife Trust safeguards and manages over 40 nature reserves across the two counties. In Hertfordshire three are mainly of value for their geological features. These are the Royston Chalk Pit, Barkway Chalk Pit and Hill End Farm Pit. Other Trust reserves also contain notable geomorphological features, such as the spring line fen at Ridlins Mire, Stevenage. It is part of the Hertfordshire RIGS Group strategy to assist the Trust wherever possible.

In partnership with the Hertfordshire RIGS Group, the Trust has recently installed a new information board at Hill End Farm Pit to celebrate the rich biodiversity of the site and its palaeontological importance (Figure 9).

Figure 9. Hill End Farm Pit Information Board (photo by John Facer)

5. Hertfordshire Geological Society

This society is affiliated to the Geologists' Association and Hertfordshire Natural History Society and Field Club. Its primary aim is to study and raise awareness of geology and related sciences with particular, but not exclusive, reference to Hertfordshire and adjacent parts of surrounding counties.

There is an opportunity for members to raise the profile of geology and geomorphology by keeping a watchful eye on developments and by commenting on Local Plans through the Local Agenda 21 process and liaison with the Hertfordshire RIGS Group.

6. Landowners and Managers

As with much of the remainder of the county's heritage, sites of geological and geomorphological interest and buildings showing geologically interesting stonework are largely in the hands of private owners. Resources are available through English Nature and the Geologists' Association to assist owners with site management. Through public consultation processes, lobbying via Local Agenda 21 or organizations like the Country Landowners Association, there are opportunities for the Hertfordshire RIGS Group to influence policy.

7. Countryside Forum and Countryside Management Service

The Hertfordshire Countryside Forum (the predecessor to the present Hertfordshire Rural Forum), comprising representatives of key organizations in the county with an interest in landscape and heritage, identified a number of actions in the Hertfordshire Countryside Strategy 1996-2001 (including notably the production of this strategy document) which, when implemented, should help with the conservation and promotion of the geological resource. In particular, the Countryside Management Service has agreed to organize guided walks to explore, and practical projects to conserve, the county's heritage. Traditionally these have included at least some initiatives concerning geological features.

APPENDIX IV

HERTFORDSHIRE MUSEUMS AND OTHER INSTITUTIONS WITH GEOLOGICAL COLLECTIONS

Ashridge Management College. Grotto with fossils and minerals embedded in the walls, a rockery with many large pieces of Hertfordshire Puddingstone and an ice house built partly of puddingstone and sarsen.

Ashwell Village Museum. Many non-local rocks and minerals; a small number of local Pleistocene/Holocene mammal specimens.

Hertford Museum. Over 5000 specimens of local and non-local rocks, fossils and minerals. Local Pleistocene mammals are well represented.

Lowewood, Broxbourne. Approximately 300 specimens, mostly local fossils. Local Pleistocene mammals are well represented.

Museum of St. Albans. Approximately 6000 specimens of rocks, fossils and minerals. Good collections of fossils from the Chalk, Cambridge Greensand and London Clay.

North Hertfordshire Museums Resources Centre, Hitchin. Between 5000 and 10,000 specimens of rocks, fossils and minerals, including the combined collections of Hitchin and Letchworth Museums. Most are local, with strengths in Pleistocene mammals, glacial erratics and Chalk fossils.

Rothamsted Experimental Station. Collection of wax impressions of fossils obtained by BGS from the Red Crag at Rothamsted (Dines and Chatwin, 1930).

Stevenage Museum. Over 1500 specimens, mostly from the local Chalk and glacial deposits. The collection is mainly recent and of educational importance only.

University of Hertfordshire. Approximately 2000 specimens of rocks, fossils and minerals used for teaching and research. Many are from Hertfordshire Pleistocene sites.

Watford Museum. Small number of local Chalk fossils, some glacial erratics and pieces of Hertfordshire Puddingstone.

Scots Park Grotto, Ware. 18^{th} century grotto with fossils and minerals embedded in the walls.

APPENDIX V

USEFUL ADDRESSES

British Geological Survey, Keyworth, Nottingham NG12 5GG

Countryside Management Service, Environmental Department, Hertfordshire County Council, County Hall, Hertford SG13 8DN

Countryside Agency (South East), 4th Floor, 71 Kingsway, London WC2B 6ST

English Heritage, 23 Savile Row, London W1X 1AB

English Nature (National Office), Northminster House, Peterborough PE1 1UA

English Nature (Essex, Hertfordshire and London Team), Harbour House, Hythe Quay, Colchester CO2 8JF

Environment Agency, Apollo Court, 2 Bishops Square Business Park, St. Albans Road West, Hatfield AL10 9EX

The Geological Society of London, Burlington House, Piccadilly, London W1V 0BG

Geological Curators Group, c/o Mandy Edwards, Department of Geology, University of Manchester, Manchester M13 9PL

Geologists' Association, Burlington House, Piccadilly, London W1V 9AG

Groundwork Hertfordshire, Mill Green, Hatfield AL9 5PE

Hertfordshire Biological Records Centre, Environment Department, Hertfordshire County Council, County Hall, Hertford SG13 8DN

Hertfordshire County Council Environment Department, County Hall, Hertford SG13 8DN

Hertfordshire Geological Society, c/o Linda Hamling, 17 Rye Hill Road, Harlow CM18 7JF

Hertfordshire and Middlesex Wildlife Trust, Grebe House, St. Michaels, St. Albans AL3 4SN

Hertfordshire Museums Development Office, The Seed Warehouse, Maidenhead Yard, The Wash, Hertford SG14 1PX

Hertfordshire RIGS Group, c/o John Facer, Hall Farm House, Langley, Hitchin SG4 7PN

Hertfordshire Rural Action, Community Development Agency, 2 Townsend Avenue, St. Albans AL1 3SG

Hertfordshire Rural Forum, Environment Department, Hertfordshire County Council, County Hall, Hertford SG13 8DN

National Trust, 36 Queen Anne's Gate, London SW1H 9AS

Rockwatch Club for Young Geologists, The Wildlife Trusts, The Green, Witham Park, Waterside South, Lincoln LN5 7JR

Rothamsted Experimental Station, Harpenden AL5 2JQ

Three Valleys Water, P.O.Box 48, Bishops Rise, Hatfield AL10 9HL

University of Hertfordshire, College Lane, Hatfield AL10 9AB

APPENDIX VI

SUPPLEMENTARY NOTES ON SOME EXISTING AND POTENTIAL CHALK RIGS SITES

1. Existing RIGS sites

Ashwell Quarries TL 253395. This extensive overgrown site has not been investigated recently to ascertain whether there are any useful exposures. Jukes-Browne and Hill (1903, p. 189) stated that "The Totternhoe Stone, with from 30 to 35 ft of the overlying grey chalk, may be seen in a quarry nearly a mile west of Ashwell, where the stone was formerly quarried". However, there is no note of any exposures in the BGS Hitchin Memoir (Hopson *et al*., 1996).

Hill End Farm Pit TL 197239. The currently exposed section (Lewes Nodular Chalk Formation, *Sternotaxis plana* Zone and base of *Micraster cortestudinarium* Zone) extends from just above the Chalk Rock up to 1.6 metres above the Top Rock (Hopson *et al*., 1996, Fig. 17). The Chalk Rock normally has to be exposed by trenching. The underlying beds are covered by talus, but include the Reed (i.e. Caburn) Marl and probably also the Southerham Marl. The Reed Marl is seen at the Royston Chalk Pit RIGS site and was formerly exposed at its type locality at the Reed Chalk Pit RIGS site. All of these localities link to the Kensworth Chalk Pit GCR site in Bedfordshire (Mortimore *et al*., 2001, pp. 342-347), where both of these two key marker marl seams and a considerable thickness of underlying chalk are exposed.

Hill End Farm Pit is the type locality of the Hitch Wood Hardground of the Chalk Rock (Bromley and Gale, 1982; Gale, 1996), the terminal pebble bed of which is exceptionally fossiliferous. It is the type locality of, and gives its name to, the siliceous sponge genus *Hillendia*, which forms part of the rich sponge fauna known from this pit (Reid, 1954-64). The occurrence of very well preserved ammonites here was first recorded by Billinghurst (1927), a local schoolmaster, who described as new species *Prionocyclus* (now *Subprionocyclus*) *hitchinensis* and *Prionotropis cristatus* (now *Subprionocyclus branneri*). These figured specimens are in the Natural History Museum, London, and Billinghurst's plate of ammonites was reproduced by Bloom (1934) in Hine's classic work *The Natural History of the Hitchin Region*. Many fossils from Hill End Farm Pit are in the British Museum (Natural History) and British Geological Survey. It has yielded 22 out of the 24 species constituting the rich Chalk Rock ammonite fauna including, in addition to numerous figured and/or cited specimens, the **holotype** and **paratypes** of *Allocrioceras strangulatum*, the holotype of *Anisoceras reidi* (now *Allocrioceras schlueteri*), the holotype of *Lewesiceras woodi*, a paratype of *Otoscaphites reidi* (*Yezoites bladenensis*), paratypes of *Scaphites diana*, the holotype of *Scaphites kieslingswaldensis doylei* and figured specimens of the rare species *Pseudojacobites farmeryi* and *Tongoboryceras rhodanicum* (see Wright, 1979; Kaplan *et al*., 1987; Kaplan, 1989).

Hitchin Railway Cutting TL 196295. This site was previously a geological SSSI because of exposures of fossiliferous Lower Turonian *Inoceramus labiatus* Zone sensu lato (i.e. *Mytiloides* spp. Zone) and Middle Turonian *Terebratulina lata* Zone in the cutting faces and the adjoining quarry. It should probably be regarded as the type locality of the **lectotype** of the biostratigraphically important bivalve *Inoceramus apicalis* and of the brachiopod *Orbirhynchia cuvieri* sensu Pettitt non d'Orbigny.

The sections in the southern wall of the cutting (TL 197293) are stratigraphically important and are described in Hopson *et al*. (1996, pp. 49-51 and Fig. 15). They expose the junction of the shell-detrital Holywell Nodular Chalk Formation with the overlying smooth New Pit Chalk Formation, and provide a key link with the more extensive sections at Steeple Morden Plantation and Steeple Morden Station Quarries, which are situated just outside the county boundary in Cambridgeshire. These quarries provide the type sections for the Odsey Marl, which occurs immediately above the base of the New Pit Chalk Formation and is also seen in the cutting sections. The occurrence in the cutting sections, and also in part of the Steeple Morden Plantation Quarry (Hopson *et al*., 1996, Fig. 14), of flints in the highest part of the Holywell Nodular Chalk Formation is noteworthy and is similar to the development of flinty chalk in the central Chiltern Hills near Totternhoe. Macrofossils from this site are in the collections of the BGS, Keyworth.

Redbournbury Chalk Pit TL 124105. This section extends from a short distance above the Top Rock to a level close to the top of the upper Lewes Nodular Chalk Formation (*Micraster cortestudinarium* Zone). The Top Rock itself and less than 1 metre of the underlying chalk (*Sternotaxis plana* Zone) are visible in a trench cut into the floor of the pit. The highest beds contain the trace fossil *Zoophycos* and can accordingly be assigned to the Beachy Head Zoophycos in the higher part of the *Micraster cortestudinarium* Zone (Mortimore *et al*., 2001).

Past observations on the biostratigraphical importance of the Top Rock and overlying succession at this site (Shephard Thorn *et al*., 1994) need to be updated in the light of subsequent research on the inoceramid bivalves of Europe and North America and the introduction of a new zonal scheme broadly applicable to both areas (Walaszczyk and Wood, 1999). Because of this the assemblage in the Top Rock takes on an even greater significance than hitherto. The identification of North American species shows that the condensed Top Rock includes elements of both the basal Lower Coniacian *Cremnoceramus deformis erectus* Zone and the overlying *Cremnoceramus waltersdorfensis hannovrensis* Zone of the new scheme. The occurrence of *Cremnoceramus waltersdorfensis waltersdorfensis* in the Top Rock of the Kensworth Chalk Pit GCR site (Mortimore *et al*., 2001) suggests that the condensed succession represented by the Top Rock at Redbournbury may also include the terminal Upper Turonian *Cremnoceramus waltersdorfensis waltersdorfensis* Zone. Specimens of *Cremnoceramus crassus crassus* (formerly *Cremnoceramus schloenbachi*) and *Tethyoceramus* sp. from the white chalk with flints a short distance above the Top Rock indicate the *Cremnoceramus crassus crassus – Cremnoceramus deformis deformis* Zone.

Another important feature of the Redbournbury section is that the Top Rock seen in the trench was exposed to weathering in the Late Cretaceous, and is consequently much less indurated than in the M40 road-cutting GCR site at Aston Rowant, the Kensworth Chalk Pit GCR site and the Hill End Farm Chalk Pit and Reed Chalk Pit RIGS sites. In these sections, it is difficult to split the rock in such a way that the fossils can be removed without damage; also the Top Rock is exposed in vertical faces.

The Top Rock at Redbournbury has also yielded the only specimen of the biostratigraphically important benthic foraminiferid *Stensioeina granulata levis* (Bailey *et al*., 1984) so far recorded in the UK.

Reed Chalk Pit TL 359370. The currently exposed section (upper Lewes Nodular Chalk Formation) extends from just below the Chalk Rock to 8.5 metres above the Top Rock (*Micraster cortestudinarium* Zone), and is described in Hopson *et al*. (1996, pp. 59-60. Fig. 17 and Plate 6). The lowest part of the section formerly exposed the Reed (= Caburn) Marl, which is now seen in the Royston Chalk Pit RIGS site, and for which the Reed Chalk Pit is the type locality.

Like Hill End Farm Pit, this is a highly fossiliferous Chalk Rock locality, but here the Chalk Rock is developed in an expanded nodular facies, rather than as a single chalkstone bed with a terminal pebble bed. The single pebble bed of the Hitch Wood Hardground has split into a lower glauconitized (green) surface and a higher phosphatized (brown) surface, each with associated fossils. It is the source of Chalk Rock ammonites figured by Wright (1979) and Kaplan *et al*. (1987), notably the fragment of the rare species *Neocrioceras multinodosum* (Wright, 1979, Plate 2 and Fig. 5) and the apparently undescribed *Subprionocyclus* sp. (Wright, 1979, Plate 5 and Fig. 11). The latter is a phosphatized clast from above the higher of the two mineralized surfaces, and may well be younger than most of the ammonites in the Chalk Rock composite assemblage. The Chalk Rock has also yielded many brachiopods, including the rhynchonellid *Orbirhynchia reedensis,* which takes its name from this pit (Etheridge, 1881, Plate 3, Fig. 12), and the unusually large figured specimen of *Kingena elegans* (Owen, 1970, Plate 6 and Fig. 1). *K. elegans* is common in the Chalk of Lincolnshire and Yorkshire at this level, but here it is probably at the southern limit of its range. The sponges, as from Hill End Farm Pit, are very well preserved. Echinoids from the beds below the Chalk Rock that are no longer exposed (*Micraster corbovis* of *lata* Zone type, the zonal index fossil *Sternotaxis plana*) and the figured ammonites and brachiopods cited above are now in the collections of the BGS, Keyworth.

The two RIGS sites, Hill End Farm Pit and Reed Chalk Pit, and the intervening sections at Weston (TL 272300), Clothall Bury (TL 274325) and Wallington (TL 288337), are crucial to the understanding of the complex stratigraphy of the Chalk Rock and its lateral variation (Bromley and Gale, 1982; Gale, 1996; Hopson *et al*., 1996, Fig. 17). They also provide a link with the key Kensworth Chalk Pit GCR site.

Potters Crouch Pit TL 116046. The record of marl seams suggest that this pit exposes the Belle Tout Beds at the base of the Seaford Chalk Formation (Middle Coniacian, basal *Micraster coranguinum* Zone).

Royston Chalk Pit TL 364405. This section exposes Chalk high in the traditional Middle Chalk (lower Lewes Nodular Chalk Formation, *Terebratulina lata* Zone). It is described under the name Royston School Pit by Hopson *et al*. (1996, pp. 51-52, Fig. 16), and provides the only remaining exposure of the sub-Chalk Rock Reed (= Caburn) Marl in its type area. The section extends from *ca*. 3 metres below the Reed Marl to a flint band situated *ca*. 7 metres above the marl and inferred to be at the base of the Chalk Rock.

2. Potential RIGS sites

Anstey Quarry TL 395329. This section in the lower part of the traditional Upper Chalk is described in detail in Hopson *et al*. (1996, p. 61), albeit without the graphic log that is included in BGS open file reports. Macrofossils, including inoceramid bivalves and echinoids, found here are in the collections of the BGS Keyworth. There is currently a proposal to backfill this pit progressively over several years. The exposed section is essentially comparable with that at Codicote Quarry, although at Anstey only a single marl seam corresponding to one of the Shoreham Marls has been identified at the top of the section. However, the exposure is of critical importance to interpretation of the outstanding wireline (resistivity) logs of nearby water wells and the glaciotectonically disturbed sections at the Reed Chalk Pit and Barkway Chalk Pit RIGS sites (Hopson, 1995). The available data lead to the contradictory conclusions that the base of Anstey Quarry is either only a few metres above the Top Rock or 24 metres above this datum. A borehole drilled in the floor of the pit would be valuable to both BGS and the water companies. The quarry would also be of considerable use as an educational resource since, in addition to chalk with marl seams, flints and fossils can be seen and the faces are relatively safe.

Ashwell Chalk Pit TL 268394. This disused and partly backfilled quarry on the edge of Ashwell village exposes a section of national stratigraphical importance, and must be urgently considered for notification as a RIGS site or even higher status. With the loss of two of the original three type sections of the Melbourn Rock, namely Melbourn Quarry in Cambridgeshire and the base of Hitchin Railway Cutting (Hill and Jukes-Browne, 1886), this remaining section becomes the type section of the Melbourn Rock. It is thus critical to the interpretation of Melbourn Rock sections outside the original type area of north Hertfordshire and south Cambridgeshire, notably in other parts of southern England where this part of the Chalk is significantly different (Wood, 1993).

The section extends from the base of the Plenus Marls Member of the Holywell Nodular Chalk Formation up to a level several metres above the inferred top of the original concept of the Melbourn Rock. The inaccessible topmost bed is inferred to equate with the Morden Rock of the Steeple Morden Quarries (see section 3 of this Appendix). Hopson *et al*. (1996, pp. 41-47, Figs 12 and 13, Plate 4) described the section in detail and reviewed its correlation with sections exposed in trenches dug in the floor of Steeple Morden Plantation Quarry. Macrofossils and a full sequence of slabbed rock samples from the pit are in the collections of BGS Keyworth.

Bedwell Park Chalk Quarry, Essendon TL 285089. The former Bedwell Quarry ['large pit by the avenue' in the Hertford Memoir (Sherlock and Pocock, 1924, p. 17)] provided an excellent and extensive section in what was probably nearly the stratigraphically highest part of the traditional Upper Chalk in Hertfordshire (Seaford Chalk Formation: Lower Santonian part of the *Micraster coranguinum* Zone), overlain by Palaeogene sediments belonging to the Upnor and Woolwich/Reading Formation of the Lambeth Group. Unfortunately, there is no log available of this now backfilled section, although macrofossils collected in the 1960s still exist. Fossils from here, collected at the time of the original survey of the Hertford Sheet, are in BGS, Keyworth. Colour photographs taken in the late 1990s of a section close to, or possibly part of, the original quarry are held on file by the Hertfordshire RIGS Group. In addition, Dr. H. W. Bailey holds some microfaunal samples collected from this section at the time when it was photographed. 12 m of Seaford Chalk Formation (*Micraster coranguinum* Zone) with sheet and nodular flints were logged in July 2002 beneath the contact with the Upnor Formation. Photographs were taken, and 12 samples were collected by Dr.H.W.Bailey for microfaunal and nannofloral analysis. Just above the base of the visible section, there is a shell-bed of pink-coloured, thin-shelled inoceramid bivalves: these are reminiscent of the *Cladoceramus* floods at the base of the Santonian portion of the *M. coranguinum* Zone. Foraminiferal data, however, suggested that the basal sample was probably in the higher part of the Coniacian, while the topmost sample (just below the contact with the Upnor Formation) was definitely in the lower part of the Santonian, but below the level of the Whitaker's 3" Flint Band of southern England successions. The nannofloras from both of these samples were essentially comparable, i.e. Santonian.

Codicote Quarry TL 214171. This currently working quarry exposes upper Lewes Nodular Chalk Formation (Lower Coniacian, *Micraster cortestudinarium* Zone) overlain by basal Seaford Chalk Formation (Middle Coniacian, *Micraster coranguinum* Zone). The Shoreham Marls at the junction of the two formations are clearly seen near the top of the section. The section has not been logged in detail. From the outcrop characteristics, the Top Rock either forms the floor of the quarry or is just below it. The section thus overlaps with the main face of the Redbournbury RIGS site and with the Anstey section, although at Anstey the position of the Top Rock is uncertain. It also provides a link with the M40 Aston Rowant road cutting GCR site, which exposes the Shoreham Marls near the top, and with an abandoned quarry (TQ 042918) in the Colne Valley north of Uxbridge, immediately outside the county boundary, which exposes chalk of the *Micraster coranguinum* Zone and the higher Shoreham Marl at the base. The chalk at Codicote Quarry is overlain by 2-3 metres of weathered Anglian till.

Springview Quarry, Flaunden TL 005008. This quarry exposes a 13 m accessible section in upper Lewes Nodular Chalk Formation (Lower Coniacian, *Micraster cortestudinarium* Zone) with anastomosing sheet, tabular and nodular flints. The sheet flints are particularly well developed and apparently reflect low amplitude banks in the Chalk. There are two hardgrounds *ca.*10 m apart, of which the lower is situated only 0.8 m above the quarry floor. The higher is underlain by a bed of chalk rich in echinoderm debris, particularly spines of the regular echinoid *Tylocidaris clavigera*. Neither hardground exhibits the strongly mineralised (glauconitised and phosphatised) characters of the Top Rock, which is probably located a short distance below the existing quarry floor and may well have formed the floor to the original quarry. Photographs were taken recently (July 2002) of different parts of the succession and these, together with 11 samples taken for microfaunal and nannofloral analysis, are held by Dr.H.W.Bailey. The higher part of the quarry section, which may be at least 13m thick, is inaccessible. Inspection through binoculars suggests that thin sheet flints are present. Although there is no unequivocal evidence for the marl seams (Shoreham Marls) that mark the boundary between the upper Lewes Nodular Chalk Formation and the basal beds of the overlying Seaford Chalk

Formation (Middle Coniacian, *Micraster coranguinum*) Zone, as at Codicote Quarry, the very highest beds contain relatively large nodular flints, suggestive of the basal beds of the Seaford Chalk. Foraminifera collected from flint meals within hollow flint nodules from this pit were recorded by Curry (1982)

Ware Road Chalk Quarries, Hertford. Now that the Bedwell Park Quarry has been almost completely backfilled, these disused quarries along the Ware Road between Ware and Hertford constitute the last remaining significant sections in Hertfordshire of the Seaford Chalk Formation (*Micraster coranguinum* Zone), and probably represent the highest part of the traditional Upper Chalk exposed anywhere in the county. The sections provide an upward continuation of the succession exposed in Anstey and Codicote Quarries.

The lowest sections (TL 352137), now almost completely degraded, are situated behind a housing estate above the Chadwell Spring and may well be as low as upper Lewes Nodular Chalk (*Micraster cortestudinarium* Zone). Adjacent to this section and at a slightly higher topographic level, a section behind a bungalow (TL 351136) exposes chalk with shell-beds of inoceramid bivalves (*Platyceramus*, *Volviceramus*) near the base. These shell beds belong to the Belle Tout Beds at the base of the Seaford Chalk Formation (Middle Coniacian part of the *Micraster coranguinum* Zone). This is probably the pit described by Sherlock and Pocock (1924, pp. 16 and 17) as the Barrowfield Limekiln Quarry, where the base of the *coranguinum* Zone was exposed. At an even higher topographic level, a line of disused quarries behind garages (TL 346134), known as Lines Pit and Green's Pit, expose vertical and virtually inaccessible sections of chalk with nodular flints and several horizons with sheet flints. These probably belong to the Cuckmere Beds (Upper Coniacian).

3. Additional information on Steeple Morden Quarries, Cambridgeshire

Two working quarries just over the county boundary into Cambridgeshire, Steeple Morden Plantation Quarry (TL 298402) and Steeple Morden Station Quarry (TL 301388), expose lower parts of the traditional Middle Chalk. The sections show the junction of flinty, shell-detrital Holywell Nodular Chalk Formation with the overlying New Pit Chalk Formation, and link with the sections in the Hitchin Railway Cutting RIGS site and Ashwell Chalk Pit. They are the type localities for the Morden Rock, Morden Flint and Odsey Marl, and are described in detail in Hopson *et al*. (1996, pp. 47-51 and Fig. 14). The higher part of the Holywell Nodular Chalk in the Plantation Quarry contains several flint bands, one of which (the Morden Flint) contains well preserved, three-dimensional inoceramid bivalves (*Mytiloides*) (Figure 10). The flinty chalk thins and passes laterally into flintless chalk within the quarry over an inferred structure. The equivalent beds in the Station Quarry are also virtually flintless.

Figure 10. Fossil bivalves (*Mytiloides* sp.) from Morden flint band in the Holywell Nodular Chalk, Steeple Morden Plantation Quarry, near Ashwell (photo by John Catt)

APPENDIX VII

LITHOSTRATIGRAPHICAL NOMENCLATURE OF THE CHALK GROUP, TERTIARY AND QUATERNARY IN HERTFORDSHIRE

1. Chalk Group Lithostratigraphy

The traditional classification of the Chalk into Lower, Middle and Upper Chalk is no longer used in a formal sense, although these subdivisions can still be used informally. In the new standard lithostratigraphical scheme (see Table 3, based on Rawson *et al*., 2001), the Chalk Group is divided into two Subgroups: in ascending order the Grey Chalk Subgroup and the White Chalk Subgroup.

AGE		Sub-Group	Formation	Member/ Bed	Traditional lithostratigraphy used in Hertfordshire
LATE CRETACEOUS	CAMPANIAN (part)	WHITE CHALK	Portsdown Chalk		Section not preserved in Hertfordshire
			Culver Chalk		
	SANTONIAN		Newhaven Chalk		
	CONIACIAN		Seaford Chalk		Upper Chalk
	TURONIAN		Lewes Nodular Chalk	Top Rock Chalk Rock	
			New Pit Chalk		Middle Chalk
			Holywell Nodular Chalk	Melbourn Rock Plenus Marls	
	CENOMANIAN	GREY CHALK	Zig Zag Chalk	Totternhoe Stone	Lower Chalk
			W.Melbury Mly Ch		

Table 3. Revised Lithostratigraphy of the Chalk Group (after Rawson *et al.*, 2001

The Grey Chalk Subgroup is co-extensive with the traditional Lower Chalk, but excludes the Plenus Marls. It is divided into the West Melbury Marly Chalk Formation (with a basal

Glauconitic Marl Member) and the Zig Zag Chalk Formation. In Hertfordshire, the boundary between these two formations is taken at the base of the Totternhoe Stone.

The White Chalk Subgroup comprises the traditional Middle and Upper Chalk. It is divided in southern England into seven formations, of which the first four – Holywell Nodular Chalk (with a basal Plenus Marls Member), New Pit Chalk, Lewes Nodular Chalk and Seaford Chalk – are preserved in Hertfordshire below the sub-Palaeogene erosion surface. So far as is known, the stratigraphically highest preserved Chalk in Hertfordshire below this surface lies in the higher part of the Seaford Chalk Formation, as it does under London. The Melbourn Rock, at the base of the traditional Middle Chalk, comprises the basal part of the Holywell Nodular Chalk Formation above the Plenus Marls Member. The boundary between the traditional Middle and Upper Chalk in Hertfordshire is taken at the base of the Chalk Rock, which falls within the Lewes Nodular Chalk Formation of the present classification.

2. Tertiary Lithostratigraphy

The traditional classification of the Lower Tertiary (Palaeogene) deposits is also no longer used. In the new standard lithostratigraphical scheme (Table 4), the Palaeogene rocks are, in ascending order: the Thanet Sand Formation, the Lambeth Group (comprising the Upnor Formation and Woolwich/Reading Formation) and the Thames Group (comprising the Harwich Formation and the London Clay Formation, with the Claygate Member at the top). The London Clay Formation is overlain by the Bagshot Beds Formation.

AGE	Group	Formation	Member/ Bed
TERTIARY/PALEOGENE		Bagshot	FORMATION NOT PRESENT IN HERTFORDSHIRE
	THAMES	London Clay	Claygate
		Harwich	
	LAMBETH	Woolwich/Reading	Puddingstone
		Upnor	
		Thanet Sand	

Table 4. Summary of Revised Lithostratigraphy of the Lower Tertiary

3. Quaternary Lithostratigraphy

The Quaternary lithostratigraphy of the Hertfordshire area is described in the GCR volume The Quaternary of the Thames (Bridgland, 1994) and the London Geological Society's Special Report No. 23 (Lewis, 1999). A simplified sequence of Quaternary Stages is shown in Table 5.

Unlike the Cretaceous and Tertiary deposits, the Quaternary deposits of Hertfordshire were deposited in relatively small terrestrial basins of sedimentation that are limited in lateral and vertical extents. Their patchy distribution makes lateral correlation of deposits particularly difficult, and Quaternary lithostratigraphies frequently apply only to limited areas. Where the basins of sedimentation are relatively large, as in central Hertfordshire during the Anglian Stage, lithostratigraphies may be developed with more confidence (Cheshire, 1983; Allen *et al.*, 1991: Bridgland and Cheshire, 1994; Lewis, 1999). Only the Anglian Stage deposits of this basin are described here, but Table 5 also summarizes the main deposits of other Quaternary Stages.

The Anglian Stage opened with the proto-Thames flowing ENE through the Vale of St. Albans and into the mid-Essex depression in deteriorating climatic conditions. The river was braided, as are many arctic rivers today, and deposited a major gravel, the Westmill Lower Gravel (Bridgland and Cheshire, 1994) or Westmill Member (Lewis, 1999). This gravel contains durable clasts, including flint, quartzites, chert and quartz pebbles, and is largely devoid of clay and silt, so that it is the county's most extensive good quality gravel resource.

Ice advanced initially from the north and north-east and blocked the proto-Thames, thus creating lakes in the Ware area (the Watton Road Lake) and in the Vale of St. Albans between Colney Heath and Uxbridge (the Moor Mill Lake). The waters of the Moor Mill Lake overspilled near Uxbridge into a valley now recognizable as the modern Lower Thames valley, effectively diverting the Thames from Hertfordshire. The deposit of this ice advance is known as the Ware Till (Bridgland and Cheshire, 1994) or Ware Member (Lewis, 1999), and extends as far south-west as Bricket Wood. It is a dark grey, slightly chalky boulder clay. After this ice had melted, drainage to the south-west was initiated in the modern Colne basin and drainage eastwards towards Ware commenced in the modern Lea basin. The lower Lea valley towards London was also excavated at this time. The resulting gravel deposits, the Smug Oak Gravel (Bridgland, 1994) in the Colne basin and the Westmill Upper Gravel (Bridgland and Cheshire, 1994) or Hertford Member (Lewis, 1999) in the Lea basin, contain both durable and non-durable rocks. The latter include chalk, soft Jurassic limestones, Jurassic and Cretaceous fossils and some boulder clay clasts, making these gravels of lower quality as aggregate.

During the accumulation of the Westmill Upper Gravel (Hertford Member), two further ice advances from the north-east occurred in north-east Hertfordshire. These deposited the Stortford Till (Bridgland and Cheshire, 1994) or Stortford Member (Lewis, 1999) and the Ugley Till (Cheshire and Bridgland, 1994) or Ugley Member (Lewis, 1999). Both tills are more chalky and less sandy than the Ware Till, and are usually weathered to a yellowish brown colour.

The final advance of Anglian ice into Hertfordshire was again from the north-east and extended as far as Hatfield. This deposited a chalky boulder clay similar in appearance to the Stortford and Ugley Tills known as the Westmill Till (Bridgland and Cheshire, 1994) or Wadesmill Member (Lewis, 1999). This till caps many of the interfluves in north-east Hertfordshire, providing a semi-permeable cover to the underlying sediments.

The Anglian glacial stage was succeeded by the Hoxnian interglacial stage, recorded in freshwater lake deposits at sites near Hatfield and Fishers Green (Stevenage), and in the tufa at Oughtonhead Lane, Hitchin. The lake deposits fill small basins known as kettle-holes, which were created when blocks of ice buried in the Anglian glacial deposits melted as the climate became warmer.

Stage names	Approx. duration (years before present)	Deposits in Hertfordshire
Holocene	10,000 to present	River alluvium, swallow holes at Water End, Redwell Wood, etc, Pipes in Chalk at Castle Lime Works, Formation of argillic brown earths and other soils
Devensian	120,000 to 10,000	Loess, valley gravels, formation of naleds at Moorend Farm Meadows
Ipswichian	130,000 to 120,000	Formation of palaeo-argillic brown earth soils
Wolstonian	300,000 to 130,000	Brickearth (loess) at Hitchin, older valley gravels
Hoxnian	420,000 to 300,000	Lake clays and peats at Hitchin, Hatfield, etc, Tufa at Oughtonhead Lane, Hitchin
Anglian	470,000 to 420,000	Glacial outwash gravels (Westmill Upper, Ugley Green and Hoddesdon Gravels), Chalky Boulder Clay at e.g. Downfield Pit, Westmill (Ware, Stortford, Ugley and Wadesmill Tills), Royston erratic, Glacial lake clays at Moor Mill, latest proto-Thames terrace gravel at Westmill
Cromerian	800,000 to 470,000	Valley Farm interglacial soil developed on proto-Thames terrace gravels
Beestonian to Baventian	1.5 million to 800,000	Younger terrace gravels of proto-Thames e.g. Westwood Quarry
Antian to Ludhamian	2.5 million to 1.5 million	Older terrace gravels of proto-Thames e.g. Westland Green Gravels at Hillcollins Pit, Letchworth Gravels
Waltonian	>2.5 million	?Little Heath beach gravels

Table 5. Sequence of Quaternary Stages and Deposits in Hertfordshire

APPENDIX VIII

GLOSSARY: AN EXPLANATION OF SOME TECHNICAL TERMS USED

Aggregate: hard rock particles (gravel or crushed bedrock) used to create part of a building or engineering structure, usually as a component of concrete.

Alluvium or **alluvial deposits**: sediment transported by a river and deposited on its bed or across the floodplain.

Alluvial soils: soils formed in fine-grained Holocene alluvial deposits, usually poorly drained because they occur on valley floors close to rivers and streams.

Ammonite: now extinct group of marine molluscs with a calcareous shell that is usually coiled in a plane spiral; related to cuttle fish, squid and nautilus.

Anglian: a cold stage of the Quaternary period lasting from about 470,000 to 420,000 years ago; the Anglian was the only stage during which an ice sheet reached as far south at Hertfordshire.

Aquifer: a bed of rock containing water of sufficient quality and quantity that can be used for public or private supplies.

Argillic brown earth: loamy soil type formed during the Holocene by decalcification (removal of calcium carbonate) and downward movement of clay particles in percolating water to give a clay-enriched subsurface horizon.

Biodiversity: biological diversity, or life in all its various forms.

Biostratigraphy: subdivision of sediment successions based on their fossil content.

Bivalve: type of mollusc (lamellibranch) with a calcareous shell consisting of two hinged parts or valves, one on the right and the other on the left of the soft body parts.

Blind valley: valley that terminates abruptly where the river flowing over impermeable deposits disappears underground into cavities within a soluble rock such as limestone.

Boulder clay: sediment deposited by an ice sheet and consisting of boulders in a clay-rich matrix; a form of till.

Bourne: a seasonal stream fed by springs, which flows in winter but is dry in summer.

Brachiopod: invertebrate animal in which the soft parts are enclosed in a shell consisting of two parts, one on the dorsal surface and the other on the ventral surface, which may or may not be hinged. Many are attached to the sea floor by a stalk.

Braided river: a river in which the flow is divided between numerous small channels, which divide and rejoin repeatedly and deposit mainly gravels across a broad flat floodplain. In Britain braided rivers were characteristic of cold stages in the Pleistocene, whereas single channel rivers occurred in the warmer interglacial stages.

Calcareous: composed of or containing a significant amount of calcium carbonate.

Chalky Boulder Clay: a type of glacial sediment or till composed mainly of chalk fragments set in a grey clay-rich matrix.

Chert: a microcrystalline form of silica forming concretions or layers in limestone or sandstone.

Clast: a rounded or angular piece of rock occurring in a sediment and derived from an earlier rock.

Coccoliths: minute plates of calcium carbonate formed by single-celled algae living in the ocean; mass deposition of coccoliths formed the bulk of the Chalk sediments.

Conglomerate: sedimentary rock composed mainly of clasts that have been well rounded by movement along a river bed or on a sea shore.

Coombe: steep-sided valley characteristic of the Chalk landscape and formed by river erosion in cold stages of the Pleistocene period.

Crinoid: bottom-living marine animal with a calcareous skeleton composed of plates with a five-fold symmetry that are arranged to form a stem, calyx and movable arms; common name is sea lily.

Devensian: the most recent major cold stage of the Pleistocene lasting from about 120,000 to 10,000 years ago.

Diatoms: microscopic single-celled algae with hard cell walls composed of non-crystalline silica and often perforated by numerous small apertures.

Dip slope: the part of an escarpment that slopes in the same direction as the rock stratification.

Duricrust: layer of soil on or close to the land surface which has been hardened by deposition of calcium carbonate, magnesium carbonate, silica, iron oxide or phosphate.

Earth science: the scientific study of the earth, encompassing the solid earth, oceans and atmosphere. It includes geology, geophysics, meteorology, oceanography, hydrology, pedology and glaciology.

Echinoid: marine animal with a globular, heart-shaped or discoidal calcareous shell covered with spines; common name is sea urchin.

Erratic: large fragment of rock broken off and transported a long distance from its source by a glacier.

Escarpment: ridge consisting of a steep scarp slope and more gently inclined back slope or dip slope cut in gently dipping hard rock (e.g. the Chalk of the Chilterns).

Exposure: a site where hard rock or softer deposits can be studied *in situ* either on the land surface or in excavations such as quarries.

Fault: plane along which a rock has been fractured and the two sides displaced vertically or horizontally relative to one another.

Fen: mire or marsh in which the water is neutral or alkaline and therefore rich in plant nutrients.

Flint: type of chert or microcrystalline silica formed as nodules or sheets in parts of the Chalk succession.

Flint meal: white powder found within hollow flint nodules and composed of silica, often rich in the silicified remains of microscopic animals that lived in the Chalk sea.

Fluvial: related to a river.

Foraminifera: simple microscopic marine animals (protozoans) consisting of a shell containing one or several interconnected chambers and usually composed of calcium carbonate or calcareous-cemented silt grains.

Fossil: the remains of an animal or plant permanently preserved by natural burial usually within sediment.

Freestone: massive hard rock that possesses no natural planes of weakness and so can be carved easily in all directions without cracking.

Gastropods: group of molluscs with calcareous shells that are usually coiled into a screw-like spiral tapering to a point. They inhabit marine, freshwater and terrestrial environments.

Geology: science that deals with the composition, structure, resources, history and evolution of the earth and various applications of this knowledge.

Geomorphology: the study of landscape, landforms and changes in them resulting from natural processes of rivers, glaciers, wind, sea and erosion on slopes.

Geophysics: study of the physical properties of rocks, including gravity, magnetism, electrical resistivity and transmissivity of heat, sound, etc., and the use of these properties to explore remotely the structure of the earth.
Glacial: cold stage of the Pleistocene period when glaciers invaded some parts of the earth's surface.
Glaciation: the invasion of an area by a glacier.
Glaciofluvial: processes and deposits related to meltwater streams flowing beneath, within or beyond the margins of a glacier.
Glaciotectonics: study of the deformation of pre-existing sediments or hard rocks by the advance of a glacier.
Glauconite: green microcrystalline mineral related to mica and formed on the sea bed by reactions between clay and seawater.
Hardground: a hardened or mineralised bed formed during a period of slow or non-deposition by slow continuing reactions between the calcareous mud and seawater.
Holocene: a period of warm climate spanning the last 10,000 years of geological time after the Devensian cold stage.
Holotype: the single, originally described, type specimen of a species.
Horizon: a thin, laterally continuous layer of rock or soil distinguishable from layers above and beneath.
Hoxnian: warm interglacial stage of the Pleistocene period following the Anglian cold stage and lasting from about 420,000 to 300,000 years ago.
Hydrogeology: the scientific study of the movements and reactions of water within rocks or on the earth's surface.
Ice Ages: past geological periods when glaciers repeatedly covered polar and mountain areas; the most recent was during the Pleistocene period (last 2.5 million years).
In situ: Latin term meaning 'in its original place'.
Interglacial: warm stages of the Pleistocene period when glaciers retreated and forest developed in mid-latitude regions that were treeless during the cold (glacial) stages.
Karst: distinctive landscape produced by dissolution of limestone (e.g. chalk) or other soluble rocks; features include swallow holes and caverns.
Kettle-hole: depression formed when a block of glacier ice buried in glacial deposits melted; the depression was subsequently filled with water, in which lake clays and peats accumulated.
Lectotype: a type (name-bearing) specimen, selected from a series of specimens on which the original species description is based.
Limonite: a soft rust-coloured microcrystalline iron mineral (oxide or hydrated oxide).
Listing of buildings: administrative process by which distinctive and architecturally valuable buildings are placed on a register and henceforth fall under protective powers. The register is maintained by District Councils.
Lithostratigraphy: subdivision of rock sequences based upon rock properties alone (colour, particle size distribution, mineralogical composition, character of stratification), but excluding fossil content except where rock forming.
Local plans: plans produced by County and District Council planning authorities covering development of general or specialist activities such as mineral extraction or waste disposal.
Marcasite: iron disulphide forming shiny gold-coloured masses of radiating crystals, often found in the Chalk or soils overlying it.

Mineral: inorganic constituent of rock, sediment or soil with characteristic properties (colour, crystalline form, hardness, etc) resulting from a limited range of chemical composition.
Molluscs: a large group of invertebrate animals often with calcareous shells, inhabiting a wide range of environments (marine, freshwater and terrestrial); they include the lamellibranchs (bivalves), gastropods and cephalopods (e.g. cuttlefish, nautilus and the extinct ammonites).
Naled/Icing: enclosed depression on a valley floor created by a large mass of ice formed on the surface when water from a spring freezes.
Nodule: a hard, rounded or irregularly shaped rock formed within soft sediment by precipitation of carbonate, iron oxides, silica, phosphate, etc. from percolating water.
Outcrop: the total area over which a particular rock unit occurs at the earth's surface - whether visibly exposed or not.
Outlier: an isolated area of younger rocks completely surrounded by older rocks.
Palaeontology: the study of fossils.
Palaeo-argillic brown earth: loamy soil formed during interglacial periods by decalcification (removal of calcium carbonate in solution), downward movement of clay in percolating water to give a clay-enriched subsurface horizon, and weathering of minerals to release iron oxides, which give the soil a reddish colour.
Palaeogene: a period of geological time lasting from the end of the Cretaceous Period about 65 million years ago to about 25 million years ago. It includes the Palaeocene, Eocene and Oligocene Periods, and constitutes the earliest part of the Cenozoic Era.
Paratype: a specimen chosen to illustrate species characters additional to those seen and described from the holotype.
Periglacial: climate and other environmental aspects of the cold regions adjacent to glaciers but excluding the glaciated regions themselves.
Petrology: the study of the composition and origin of rocks.
Pleistocene: the last 2.5 million years of the earth's history, including numerous cold stages leading to glaciation in Britain but excluding the last 10,000 years (the Holocene).
Puddingstone: a form of conglomerate usually cemented into a very hard rock by deposition of silica from percolating water; probably formed as a duricrust on a pre-existing landscape. An example is Hertfordshire Puddingstone.
Quaternary: the fourth and most recent period of geological time, including both the Pleistocene and the Holocene.
Quartz: a crystalline form of silica, which is very widely distributed in rocks such as granite and sediments such as sand.
Quartzite: a hard rock formed by cementation of sand rich in quartz, often with silica precipitated from solution.
Radiolarians: simple microscopic organisms (protozoa), usually with a skeleton composed of non-crystalline silica.
Rendzina: a thin calcareous soil formed directly on limestone (e.g. chalk) and rich in organic matter; usually occurs on steep valley and scarp slopes subject to erosion in periglacial conditions during the Pleistocene cold stages.
Sarsen/sarsen stone: a hard sandstone cemented with silica, probably as a duricrust, and occurring as large blocks and boulders; the origin is similar to that of Hertfordshire Puddingstone.
Silica: oxide of the metal silicon; the main crystalline form is quartz.

Silcrete: very hard silica-rich rock formed as a duricrust by deposition of silica from percolating water within the pores of a soil or sediment.

Soil: the uppermost layers of the earth's crust that have been modified in various ways through contact with the atmosphere and biosphere; soil properties are determined by the nature of the geological parent material, the length of the soil development period and various environmental factors, such as climate, slope, vegetation, animal and human activities.

Sponge: marine animal attached to the seafloor and composed of irregularly folded and perforated walls, the outer layers of which are often strengthened by a skeleton of silica particles known as spicules.

Stratigraphy: the study of rock sequences in relation to time (chronostratigraphy), based upon their composition and field characteristics (lithostratigraphy), fossil content (biostratigraphy) and other properties.

Sustainability: maintaining the environment's natural qualities and characteristics and its capacity to meet the needs of the present without compromising the ability of future generations to meet their own needs.

Swallow hole: a hole in the ground through which surface waters are swallowed into underground channels in a limestone or other soluble rock.

Talus/scree: accumulation of clasts on a slope, often forming a wedge-shaped mass against a valley side.

Terrace: flat or gently sloping land surface created along a river valley by deposition of alluvium or by erosion of bedrock.

Tertiary: geological period extending from the end of the Cretaceous period 65 million years ago until the beginning of the Quaternary/Pleistocene period about 2.5 million years ago; it includes the Palaeogene (65-25 million years ago) and the Neogene (25-2.5 million years ago), the latter divided into the Miocene and Pliocene Periods.

Till: sediment of heterogeneous composition deposited directly from glacial ice without significant sorting of particles by water.

Tufa: deposits of calcium carbonate formed by precipitation from solution around springs or waterfalls.

Type: term used to describe a single typical specimen which has been used to describe a new genus or species of plant or animal; the concept has been extended to include fossils, minerals, rocks and sequences of sedimentary horizons.

Type site: locality where a type section, type species or other type was first described.

Water table: surface within an aquifer below which all the pores in the rock are filled with water.

Whiting: finely ground chalk used as a filler or colorant in foods, paints, medicines, floor coverings, etc.