The Building Stones of Bedfordshire

Bedfordshire & Luton RIGS

bringing landscape to life

Dr. Jill Eyers and the Bedfordshire & Luton RIGS Group

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RIGS: Regionally **I**mportant **G**eological and **G**eomorphological **S**ites

Most people are aware of the need to conserve our natural environment – whether that involves the landscape or the plants and animals that live on it. Media attention on global warming, pollution or extinction of species has heightened our awareness of how fragile life can be and the need to protect it. But the distribution of plants and animals depends not simply on climate or their individual natural habitats, but also upon the natural geology and landscape. In this respect every part of the British Isles is quite unique in the rocks that lay beneath, and in what geological events have sculpted those rocks to the form we see today. However, much of our landscape is hidden from view and much of it is in danger of being destroyed. RIGS (Regionally Important Geological and Geomorphological Sites) is a conservation network which aims to record and conserve our rock heritage.

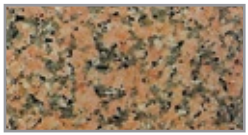
Rock on!

The rocks that underlie Britain have a very strong influence on its environment. They determine the distribution of hills, valleys and mountains, where rivers flow and where springs emerge. They also influence the nature of the soils, and therefore what is able to grow on them and hence the animals that can live there. The availability of water, good soils, stone and later other raw materials for tools, all influenced where our early ancestors were able to settle. In addition to all this, we use rock for buildings – as cut building stone, clay for bricks, gravel and lime for cement, and much more.

Three Bedfordshire landscapes. Left: Grassland covers the steep slopes of the chalk downs. Centre: Flat, fertile arable fields on the Gault clay. Right: Trees almost conceal one of the sand quarries on the Greensand Ridge.

Geologists recognise only three major categories of rock: igneous, sedimentary and metamorphic:

Igneous rocks (the Latin *ignis* means 'fire') form when molten rock known as *magma* cools and solidifies. They are easily recognisable as they are made from interlocking crystals that are in random orientation. Sometimes the crystals are too small to see, as in a lava flow. But you can still recognise this as 'lava', an igneous rock, as it is black, hard, heavy (and often has little holes in it formed by escaping gases). Granite is another example of an igneous rock.



Peterhead granite

Sedimentary rocks are made from eroded remnants of other rocks stuck together with what geologists call 'cement'. The types of cement are: quartz, iron-oxide, calcite and occasionally clay minerals. Examples of sedimentary rocks are: limestone, sandstone and mudstone.

Sandstone from the Lower Greensand

Metamorphic rocks (meaning 'changed form') are rocks that have literally 'morphed' from a sedimentary or igneous rock. With increasing heat and pressure the minerals of the original rock change to new minerals. For instance, a limestone will become a marble, a sandstone becomes a quartzite, and even a plain old mudstone can become a beautiful schist!

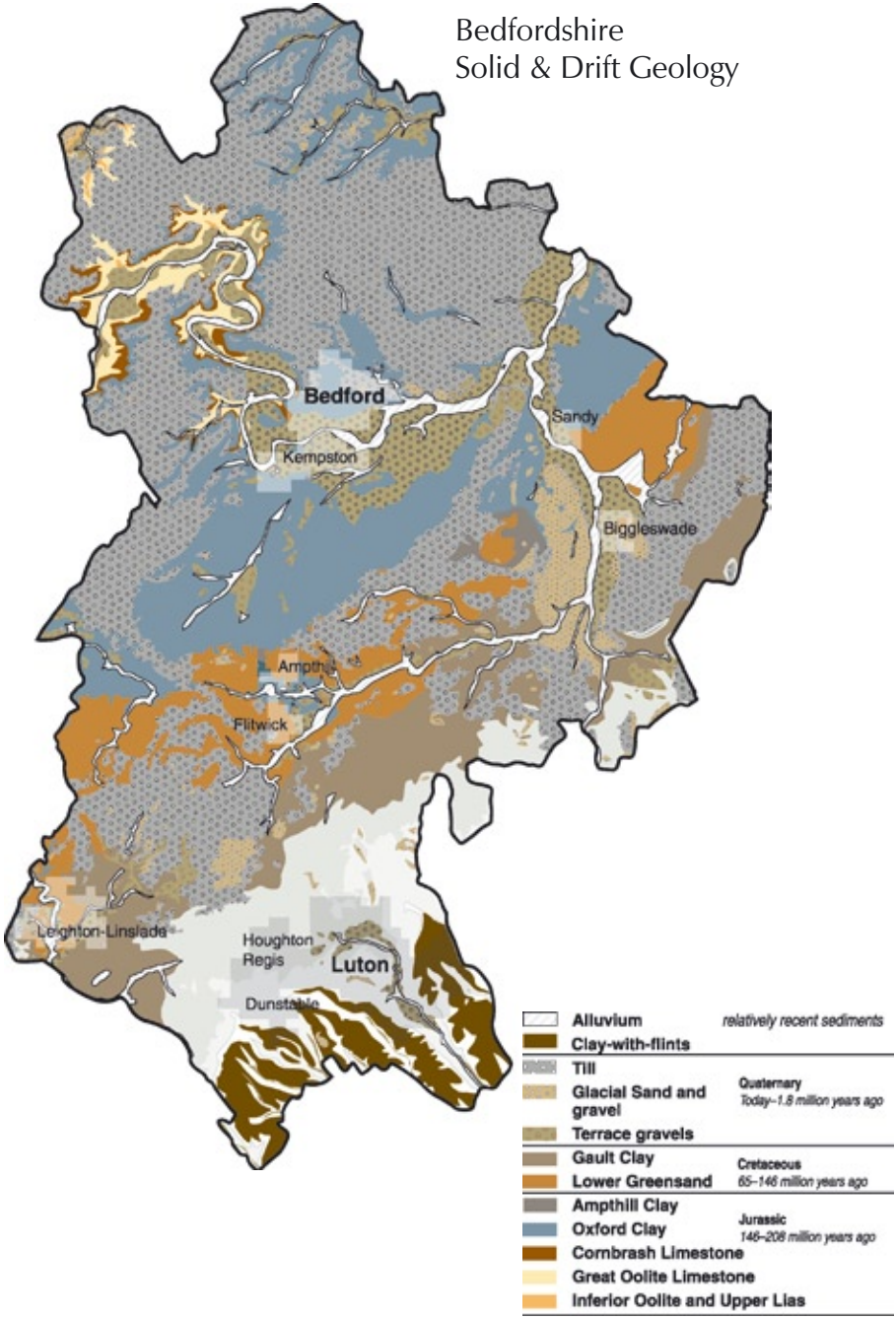
Heat and pressure transform a mudstone (left) into glittering schist (right).

A geological timeline. The periods that feature in Bedfordshire's landscape are highlighted in colours that reflect their colour on the ground (very different to the colours on the traditional geological map). Each also has a symbol representing a fossil found in that rock.

These three major rock categories make up what geologists call the **Solid Geology**. If you look on any geological map the key will list the solid geology, giving each rock its period name, for example Jurassic, Cretaceous and Tertiary. These are the layers that make up the Earth's crust and every area has a different set of layers, telling different stories. These rocks are always more than 2.6 million years old (that is, Tertiary or older). If you look again at the geological map you will see another key alongside the solid geology. This one is called the 'Drift'. Why is it called Drift? Well, back in the Victorian era geologists thought these layers were deposited by drifting icebergs! Looking in the list of this key there are sediments listed such as sands, gravels, river terrace deposits, till, alluvium and much more. These deposits are relatively young, less than 2.6 million years old (Quaternary to Recent). If the Solid Geology is thought of as 'the cake' then the Drift is the icing on that cake. It is a thinner veneer of sediments all laid down during the Ice Age or in recent times. Bedfordshire's solid & drift geology is shown on the next page; compare it with the map on p12 to see how much of our rocks lie hidden beneath the relatively young sediments.

The River Ivel looking north. The foreground is a landscape of Quaternary sediments (alluvium and glacial gravels); in the background are the Cretaceous sediments of the Greensand Ridge.

Bedfordshire
Solid & Drift Geology



The geology of buildings

Building stones

Whether stone can be used in buildings, and to what purposes it can be put, depends crucially on its hardness. Rock must have a compressive strength suitable for the structure, as well as being durable and resistant to weathering. Ideally it will also be affordable and attractive. If cost is a very important factor then local building materials will usually be the cheapest as there is no excessive transportation costs. In general, the older a building is, the more likely it is to be made from local materials. Difficulty with transportation was the main factor influencing this choice. In later eras stone could be transported from further afield. Bath Stone, for example, appears in many 18th and 19th century buildings. This can be directly linked to the canal system opening up transportation routes. Similarly, during the mid-1800s the railway network opened up a vast range of new sources for building stones, ranging from Scotland to Wales, York, Portland and Cornwall.

Igneous rocks are very tough and make hard-wearing building stones. However, the sources closest to Bedfordshire are Scotland or Devon and Cornwall. These rocks are difficult to work into small blocks or intricate forms, but they can take a good polish. The durability of igneous rocks is due to their interlocking crystalline texture. With every crystal intimately locked to the others, there are no spaces between them for water to penetrate and attack the rock. However, they are expensive. So they tend to be used as facings to buildings (thin veneers which are pegged into place over the inner structure). Common types in town centres (such as Bedford) are: Peterhead Granite, Dartmoor Granite, Larvikite (from Norway) and gabbro from many sources.

Metamorphic rocks do not make tremendously good building stones in general, as they have weaknesses along the planes where the minerals align. However, there are exceptions and marble is a famous one, beautiful and strong, but very expensive, so it is usually only used for statues or small areas of veneer inside buildings. Slate is another exception. A very useful roofing material, its use exploits the weakness between layers of minerals which ensures it splits into thin sheets.

Bedfordshire's rocks are **sedimentary rocks**, and good quality building stone from local sources are few and far between. Commonly limestones and sandstones, there can be a huge range of types and appearances. These rocks are more easily quarried and worked than the other types. As a result they are often cheaper and they form the largest amount of stone in faced buildings almost anywhere in the country for these reasons. However, some sedimentary rocks are prone to attack by weathering. They are often porous and allow water to soak into the pore spaces. This is a problem with limestones as it allows a large area for acid rainwater to penetrate react with the calcite making up most

of the rock. The result is rock that crumbles or flakes, literally turned to clay and dissolved ions.

Bricks

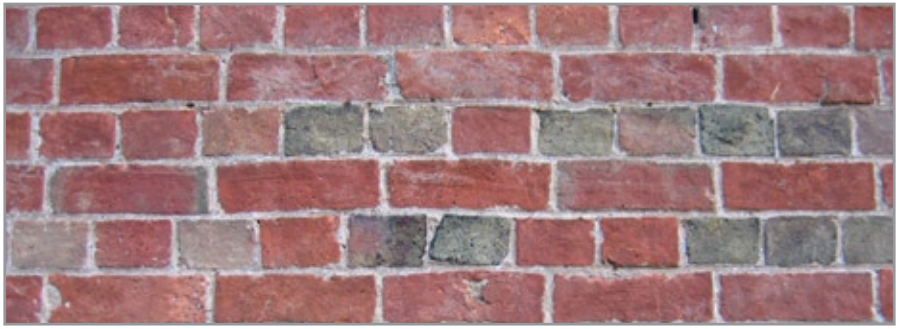
Clay is one of the most common sediments, and bricks are made from clay. Bricks can be described in terms of the clays making them, or by the way they are made, or sometimes by their purpose or appearance. For instance, classification by purpose:

- *Facing bricks*, used where appearance is important.
- *Engineering bricks*, used for strength or where low water absorption is required.
- *Common bricks*, used for everyday purposes, where strength or special appearance is not critical.

Some of the very strong engineering bricks seen in structures such as railway bridges are known as 'Staffordshire Blues' not surprisingly because they come from Staffordshire and are a deep blue-grey colour.

Classification by place of manufacture or clay type

The name *Fletton* comes from the London Brick Company works in Fletton, near Peterborough, where bricks have been made from Oxford Clay since 1882. In Buckinghamshire Oxford Clay produces 'Bucks multis', multi-coloured bricks, usually deep red and blue. In Bedfordshire the Oxford Clay which underlies much of the county produces deep-red flettons frequently used in Bedfordshire buildings. These bricks are very economical to make because the clay has a high carbon content and literally 'self-fires' once started (which saves fuel and money). For instance, the Oxford Clay bricks need only 70 kg of coal to fire 1000 bricks compared to other types of brick, which need 250-300 kg of coal.



An early 1800s Bedfordshire house wall built in 'English Bond'. Bricks can be laid in many patterns.

This wall in Potton is built of typical Oxford Clay bricks with their variation in colour, due in this instance to different oxygen levels in the kiln during firing.

Gault Clay (as present at Arlesey) makes a distinctive cream-coloured brick. Another light-coloured brick is the 'London Stock', made from a slurry of London Clay, ground chalk and water, all mixed with sifted town rubbish! Huge quantities of these yellow bricks went to all counties around London and up the Thames estuary.

A typical brick made from Gault clay dug from the quarry at Arlesey. These bricks are always pale lemon or cream colour and coarse in texture.

A house in Potton featuring London Stock bricks.

Brick-making clays are widespread throughout Bedfordshire. Brick and tiles were used extensively during the Roman period, but went out of manufacture by the 4th and 5th centuries when the Roman empire was in decline. Brick-making was revived in the 15th century; Someries Castle (AD1448) is a fine example. But bricks remained a high status building material for some time, until technology improved the kilns and made it more affordable.

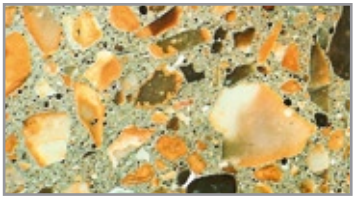
A fragment of Roman brick with a layer of Roman mortar (made with fragments of brick instead of aggregate) on the upper surface.

Someries Castle is the earliest brick-built building in Bedfordshire.

Concrete

Concrete is a mixture of chalk, clay and aggregate (sand or gravel) invented by the Romans and we have used it in various forms ever since. Though we are seldom aware of it, concrete plays a vital role in our daily lives. It is part of every structure we use: our homes, schools, work places, sports centres, bridges rely on it. It is often unseen in foundations, pipes and tunnels or holding up some other building material such as brick or glass. Concrete's main attributes are its strength, durability, fire resistance, versatility and price – it's cheap!

A cross-section through modern concrete showing large angular pieces of aggregate.



Aggregates

Aggregates can be loosely defined as rock and mineral fragments that can be compacted to a firm mass to fill a space; they are often bound with cement to make concrete. The best aggregates are made from a mixture of different size particles, as this gives the most stable mass with a lower porosity when it is compacted. Much Bedfordshire aggregate comes from the valleys of the Ouse and the Ivel. Aggregates may be sand, gravels or cobbles. Sands are mostly made up of quartz, while gravels are composed of rocks of various types and are usually angular in shape, whereas cobbles are large and rounded. To make a good aggregate the deposit must not contain much clay, as clay will compact over time and cause collapse or crumbling of structures.

What are aggregates used for and how much do you need?

Most of the UK's aggregate goes into roads (32%) with houses in second place (25%). Here are some more statistics:

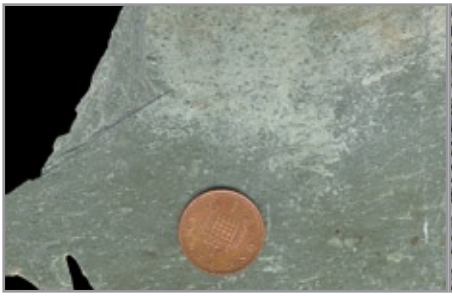
To construct:	You need:
• 1 cm^3 of concrete	2 tonnes
• 3-bedroom house	50 tonnes
• multi-storey car park	17 000 tonnes
• major road	7 500 tonnes per km
• airport runway	15 000 tonnes per km
• the Channel Tunnel lining	1.5 million tonnes

How did the aggregate get into the river valleys? These sediments are just some of the layers of 'Drift' lying on top of the Solid geology on geological maps.All the drift is less than 2.6 million years old, and most deposits have not been cemented or consolidated. All the drift sediments have been produced by the processes of weathering and erosion, and most of these deposits were formed during the melt of the ice sheets during the last ice age. The aggregates often have at least a two-stage history: first they were eroded and broken up by ice and then, when the ice melted, the torrential waters carried the broken fragments, sorting them into sands, gravels or cobbles.

Gravels overlain by a bed of sand in an ancient river terrace of the Ouse. The water currents that deposited these gravels flowed from right to left in this photo (indicated by the inclined lines tilting down to the left).

Roof materials

There are many kinds of natural roofing material: thatch, tile, slate or other slab-like stone. It simply has to be waterproof, naturally formed or man-made as relatively thin sheets, be light enough to put on the roof and they must be affordable. Tiles (made from local clays) have been used since the Roman period. Several types of rock are suitable for use as roof materials: for instance, some limestones or slate for instance. If available nearby, the Romans might use thinly bedded limestone, such as the Cornbrash, for roofing material. This can be heavy and it is not always good quality – but it did the job when there were no alternatives. Slate really only became popular for roofing once the Victorians had established a rail connection to transport the slate from its source areas in Wales or the Lake District.



Green slate from the Lake District. Slate is a metamorphic rock that has formed from a very fine-grained sedimentary rock such as mudstone.

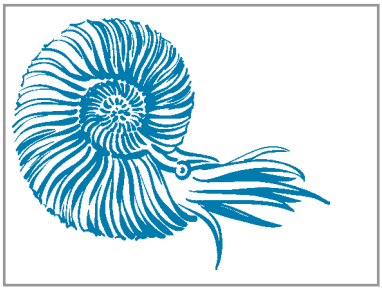
A stack of old roofing slates shows how they split cleanly to form thin sheets. The cleavage plane (the line on which they split) often bears no relationship to the original bedding plane (the surface of the sea floor on which the sediment was deposited).

Thatch and slate side by side on houses of oolitic limestone in Harrold.

Geology of Bedfordshire

Jurassic

The rocks in Bedfordshire tell an amazing story – a story that starts around 190 million years ago with the oldest rocks in the northwest of the County called the Inferior Oolite and Upper Lias.

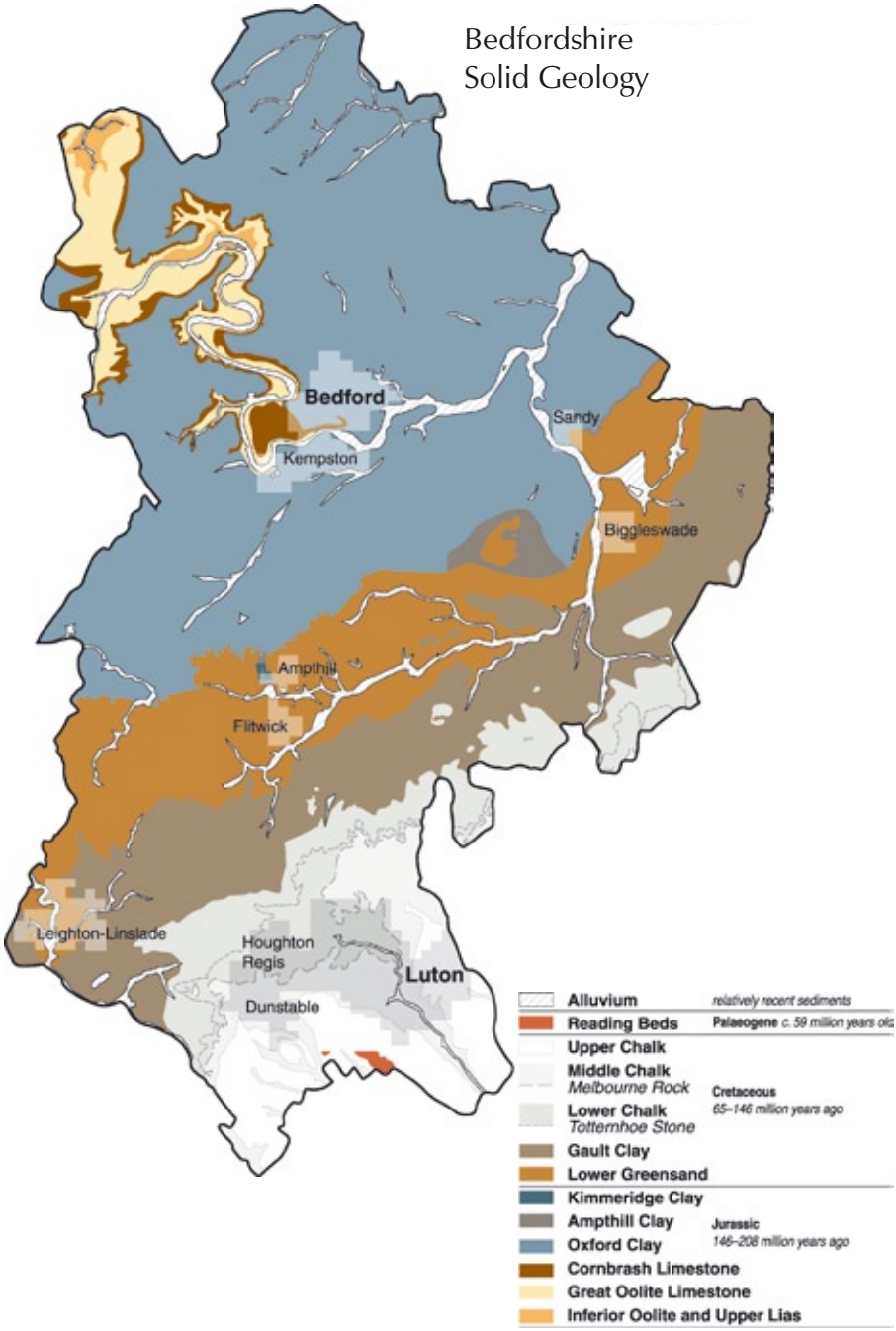


Ammonites are one of the main markers for different periods in the fossil record, as the species present in the rocks change over time. This is what one might have looked like, a bit like the modern Nautilus.

The **Upper Lias** is the oldest rock of all in Bedfordshire, a series of silty muds and muddy limestones that were laid down in the sea around 190 million years ago. This sea was warm and teemed with life including abundant ammonites. Uplift and subsequent erosion means there is a gap between this and the overlying **Inferior Oolite**, so these rocks were deposited up to around 175 million years ago. The little *oolites* are tiny balls of calcium that tell us they formed in a warm, shallow (*c.* 5 to 10m or so) sea. Waves rolled particles backwards and forwards on the seafloor, giving them an even coating of calcite. Oolitic limestones are very good building stones, although the Inferior Oolite is a bit too muddy for this purpose (mud means a poorly cemented limestone). Both these ancient formations lie at the surface on either side of the River Ouse, but in very patchy, tiny areas. This makes finding them difficult to predict.

The **Great Oolite** is a much harder rock, again an oolitic limestone formed in warm, shallow waters, but containing far less clay. Ammonites, sea urchins and bivalves are common fossils in this rock. , This rock can be found lying at the surface in a thin strip of land on the valley sides of the River Ouse between Bromham, Oakley, Pavenham and Milton Ernest and also along the section starting at Harrold to Chellington southwards. The Great Oolite is a good building stone and the buildings of Harrold are excellent examples.

Oolitic limestone in the walls of St Paul's, Bedford. Note the round 'balls' of calcite, tiny spheres made by rolling particles backward and forward in tropical seas.


Bedfordshire
Solid Geology
Bedford
Kempston
Sandy
Biggleswade
Ampthill
Flitwick
Leighton-Linslade
Houghton
Regis
Luton
Dunstable
Alluvium
relatively recent sediments
Reading Beds
Palaeogene c. 59 million years old
Upper Chalk
Middle Chalk
Melbourne Rock
Lower Chalk
Totternhoe Stone
Cretaceous
65–146 million years ago
Gault Clay
Lower Greensand
Kimmeridge Clay
Ampthill Clay
Oxford Clay
Jurassic
146–208 million years ago
Cornbrash Limestone
Great Oolite Limestone
Inferior Oolite and Upper Lias

The **Cornbrash** is a sequence of thin beds of rubbly limestone containing lots of completely smashed fossil shells, the result of strong wave action near a shoreline 170 million years ago. In Roman times it was occasionally used as roofing material, but it is not a good building stone. It does make a fertile, well-drained soil (hence the name *Cornbrash*, 'a site where good corn is grown'.)

The **Oxford**, **Ampthill** and **Kimmeridge** clay sequence reveals a deepening of the Jurassic sea from 175 to 150 million years ago. As the waters of the Oxford Clay deepened the sea became unstable, with frequent algal blooms. When great numbers of algae died, sometimes the mass of organic matter collected on the sea floor when little or no oxygen was available, decaying to form muds rich in organic compounds. These compounds are the reason for the excellent firing quality of these brick-making clays. The very flat landscape of the clays makes it impossible to see where one clay ends and another begins, but most of northern Bedfordshire, surrounding the town of Bedford, is composed of these clays.

Bedfordshire then became dry land once more, and lost rocks to erosion.

Cretaceous

About 115 million years ago the sea flooded across parts of southern England, creating a narrow seaway from the Wash to the Isle of Wight. The result of this invasion by the sea was the sands of the **Lower Greensand**. It lies at the surface from Sandy to Leighton Buzzard and is easy to spot as it produces a very dry, sandy soil in those areas. It is largely loose sands, but there is a notable bed of hard sandstone that forms a topographic feature called the Greensand Ridge.

This sea gradually deepened as a result of massive global warming, eventually covering the whole of Britain and Europe. The sands of the Lower Greensand give way to the clays of the **Gault**. The Gault contains lots of small marine fossils such as ammonites, belemnites, bivalves, shark and ichthyosaur teeth and vertebrae and many others. At the very top of the Gault is a very distinctive

The Jurassic Oxford Clay landscape north of Bedford. Ditches are essential to drain water from the heavy soil.

bright green sandstone known as the **Upper Greensand**. This has been exploited in several places (small pits dug into the ledge at the base of the Chalk where it is at the surface). It is quite a hard stone and can be used in buildings; it is not easy to find, but it can be seen in Husborne Crawley church.

By 95 million years ago sea level was the highest it had ever been, more than 20m above present sea-level. The result was the very pure limestone we call the **Chalk**. There are hundreds of metres of chalk, but only a couple of beds are suitable for exploiting as building material, for instance, the Totternhoe Stone or 'Clunch'.

Tertiary

When global temperatures finally fell again (65 million years ago), sea level fell too. The landscape of Bedfordshire was a flat chalky wasteland. Although we known a lot happened here over the next 63 million years, including huge rivers criss-crossing the landscape and the sea returning on more than one occasion, we do not have any useful evidence of this period, known as the Tertiary. Bedfordshire has one tiny Tertiary outcrop in the very south of the County, a splodge of **Reading Beds**. These contain a mottled clay overlain by sands. The clay represents a fossil waterlogged soil deposited around 40 million years ago, and which became swamped by an estuary, represented by the sands. The clays are famous for producing excellent quality bricks, but are better known and more plentiful in the Reading area of Berkshire.

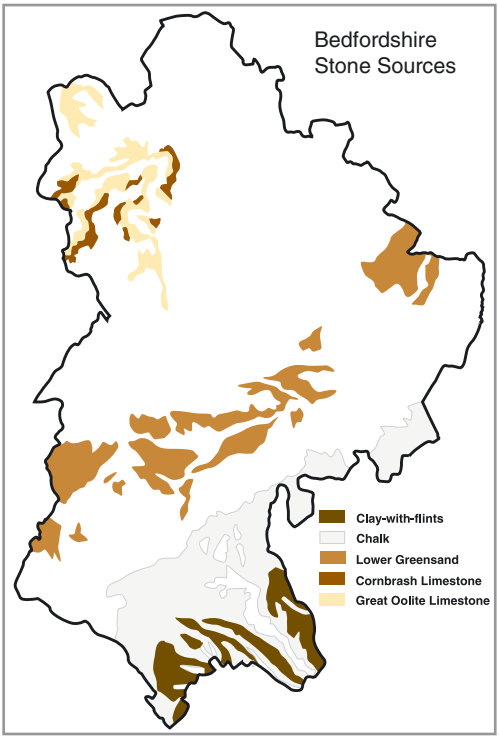
A Quaternary landscape: the Ouse Valley at Felmersham, full of glacial gravels and more recent sediments.

The building stones of Bedfordshire (and where to see them)

Geological maps tell you what rock is at the surface if all the surface soil and vegetation were removed. They are made by geologists, who travel parts of the country, identify what rocks are where, and 'colour in' the rock colours onto an Ordnance Survey map. William Smith was the first person to develop this idea, and without it geologists would find it very hard to work. In respect of his work, geologists call him the 'father of geology'.

Oolitic limestone

This fairly good quality building stone was quarried from the Ouse Valley and sent to many parts of Bedfordshire and beyond as facing blocks used together with other building stones. The 'limestone villages' of Harrold, Pavenham and Stevington are given their unique character by the use of this oolitic limestone.



Sources of building stones in Bedfordshire. Much of the rest of the county can supply various brick clays.

Bromham Bridge is a Scheduled Ancient Monument dating from the 13th century with extensive 15th and 19th century repairs. It is built of the local oolitic limestone with some 19th century Portland Limestone and brick.

Lower Greensand

Most of the Lower Greensand is a sequence of loose sands that are used for the construction industry or other purposes. Distinct beds of sandstone are found in at least two horizons within the sands, but the best for building stone is the hard bed at the top of the Silver Sands. The Lower Greensand outcrops from Sandy down to Leighton Buzzard. Sandstone is frequently used in older buildings in both towns, and in neighbouring villages.

The sands are cemented into stone by quartz or by iron oxide. Quartz is the hardest common mineral we have, so sandstone cemented with quartz is extremely durable and resistant to the effects of weathering. Iron oxide in the sandstone is mostly in the form of red-brown haematite (although orange-red limonite is also present). Iron oxide can be a strong cement, but in the Lower Greensand it tends to make a more friable building stone that suffers after 20 years or so in a structure. Even if the sandstone is held together by a quartz cement it is still a deep red-brown colour as the grains are stained by iron oxide, even if there is not enough to hold it together.

Above: larger blocks of sandstone have been used to build Wilkes Almshouses in Leighton Buzzard. The quartz cementing the sands produces a very strong stone, darker in colour than the iron oxide alone.

Right: old St Mary's Church, Clophill, fell into disuse after the new church was built in 1848.

Above: a wall at Potton typical of many on the Lower Greensand outcrops. Slabs of red-brown sandstone are held together with mortar.

Upper Greensand

The bright green colour makes this a distinctive rock. It is very restricted in its use in buildings, not because it is not a good building stone (it is very durable indeed), but because it is limited in size and distribution, and therefore difficult to locate and quarry in significant quantities.

Local rocks from the Lower Greensand, Chalk and Upper Greensand have been used in Husborne Crawley Church. The red-brown Lower Greensand probably came from the Leighton Buzzard area; the bright green Upper Greensand is likely to have been found not far from the village, along the outcrop to the south or east. The Chalk around the door has survived well due to protection from the weather by the porch.

A closer view. The mineral glauconite gives the Upper Greensand its green colour.

Totternhoe Stone

Totternhoe Stone is a bed 2–4m thick of hard cream or greyish-cream rock within the Lower Chalk (see the *Bedfordshire Solid Geology Map*). During the deposition of the Chalk there were pauses in sedimentation that encouraged a greater amount of cement to form on the seafloor. These thinner beds are often called 'hardgrounds' because of this property. The Totternhoe Stone is a bed that has acquired more cement than the usual Lower Chalk (it can also be slightly gritty). Despite being very prone to damage by frost and acid rain, it has been a popular building stone since Roman times – where there are few other building materials! Its popularity for use in buildings near its outcrop lies in the fact that it is easy to locate, easy to quarry, soft enough to make decorative carvings, and cheap. The main quarries are along the slopes between Totternhoe to Sewell, including underground workings of the late 1700s to late 1800s. Where used inside buildings Totternhoe Stone survives the ravages of

time very well. It has often been used inside Church porches or even in the alter back of Westminster Abbey. However, when used within the outside building structure on older buildings, this rock is often badly weathered.

Woburn Abbey is probably the most famous building in Bedfordshire made from Totternhoe Stone.

The Totternhoe Stone is 'spalling' (peeling away in layers). Each winter water that has seeped into the porous rock freezes and expands, forcing off a layer of rock. The acidity of the rain also decomposes the limestone, causing it to crumble.

Flint

Flint is also found within the Chalk, but it is not a limestone: it is pure silica (quartz). It is very durable and resistant to weathering. In fact it is so strong that it always lasts longer than the structure around it – the mortar, bricks or other building stone always crumble first, leaving re-usable flints behind. Flints can be collected directly from the Chalk where they commonly form in bands. This may be easy when Chalk is being quarried for other purposes. Flints are also found in coarse river deposits, or in the 'Clay-with-Flints' where natural weathering of chalk leaves a residue of flints and clay.

Houghton Regis Church. This elegant chequerboard pattern is made up of alternating Chalk Rock and flint.

Cobbles

Cobbles only occur in surface deposits in eastern Bedfordshire, and hence older buildings such as churches in east Beds tend to have them incorporated in their structure. They can be a flattened shape or rounded, and all come from the glacial deposits of the older river terraces. Churches from Little Staughton to Lanford to Old Warden have cobbles in their structure.

Cobbles used in the structure of Segenhoe Church. Local Lower Greensand sandstone also features in the wall. See further photographs of Segenhoe in the Bedrock Trail.

Earth (clay)

Using clay as an outside rendering to buildings was common in 17th century Bedfordshire. Due to its vulnerability to attack from normal British weather it has to have a protective overhang to shield it from rain. During the 18th century the clay was mixed with pebbles and straw and called 'cob'.

Brick and clay tiles

Brick-making clays are found throughout Bedfordshire: the Oxford, Kimmeridge, Ampthill, Gault and Reading Beds clays have all been used to make bricks. Someries Castle, near Luton, was built in 1448; the surviving part of Warden Abbey was made of local brick in the 16th century and Hillersden Mansion (Elstow) and Houghton House both date from the 17th century.

Houghton House, Benington, a Tudor house built before the standardisation of brick size and quality.

These early buildings are all in red brick, and these early bricks are much thinner than our modern bricks. Other types of brick with varying colours then appeared from the 17th century, at the same time as brick standards were imposed by law to set a standard (larger) size and more regular shape.

Some 17th and 18th century bricks were made in a glazed form and when alternated with standard red bricks they produced a fashionable chequerboard pattern.

Decorative bricks in Someries Castle (AD 1448).

By the 19th century the Gault clay was being used for brick-making; the cream-coloured bricks made at Arlesey are very distinctive. Another 19th century brick used briefly in Dunstable is a deep purple-brown colour.

The view from the Greensand Ridge down onto the clays, showing the chimneys and a clay pit (now a public park) of the London Brick brickworks.

Bedrock Trails

Some suggestions for some good afternoons or days out, looking at some of the scenery, rocks and buildings of Bedfordshire:

1: Leighton Buzzard, Heath & Reach and Stockgrove

There is too much to see and do in this area, so select sites which most interest you and split this area into two or more visits. Some walks are directly building stone related; others provide opportunities to see and understand the geology and landscape of Bedfordshire.

Ouzel River Walk, Leighton Buzzard. Ordnance Survey Map Explorer 192
A pretty walk by the side of the Ouzel. Walk north on public footpaths from the bridge over the Ouzel in Leighton Buzzard to pass many features of interest including wildlife, historical features, geology and ice age features (see the RIGS leaflet *The River Ouzel: its wild past*). Veer west and then north again to see the stones of Old Linslade Church.

St Mary's, Old Linslade; Lower Greensand and Totternhoe Stone. This Norman church was largely reconstructed in the 15th and 16th centuries. The Linslade priests used to encourage pilgrimage to a holy well on the line of the present canal until this was banned in 1299 by the Bishop of Lincoln.

Sand Quarry walks in Heath & Reach. Ordnance Survey Map Explorer 192
Use the OS map to plan a route giving you a glimpse into many of the working quarries in this area, such as Stone Lane Quarry (SP 927 290) off the A4146 near the Cock public house, Munday's Hill Quarry (SP 940 280) in Eastern Way, and Reach Lane Quarry (SP 933 284). See the RIGS leaflets on the Lower Greensand and

A view from a public footpath into Stone Lane Quarry, Heath & Reach.

site leaflets for Munday's HIll and Stone Lane.

These are working quarries: you must not enter without permission. Binoculars will often allow you to see the sequence of sands and clays from the footpaths. The Beds RIGS group may offer official fieldtrips to these quarries.

Stockgrove Country Park. Ordnance Survey Map Explorer 192
This nature reserve and park offers lovely scenery, wildlife and archaeology all closely linked to geology (Lower Greensand and the ice age). There are trails and facilities, including a restaurant.
RIGS leaflet *Stockgrove Country Park: Ice Age landforms.*

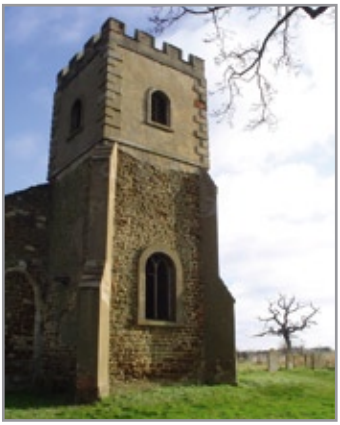
Tiddenfoot Nature Reserve and Ledburn old quarry
Ordnance Survey Map Explorer 192
These sites show us what happens after extraction of our building materials, and how such places can benefit both wildlife and people.
RIGS leaflet *Lower Greensand: Tiddenfoot & Ledburn Quarries.*

2: Husborne Crawley and Segenhoe Churches

Ordnance Survey Map Explorer 192
Two interesting churches that show good use of local building materials, including the Upper Greensand. All Saint's Church (Ridgmont, only a 10 minute walk from Segenhoe) is also worth a visit, with Totternhoe Stone and Lower Greensand sandstones. Don't forget to look at gravestones, which include many different materials including some from far afield such as Dartmoor granite, Marble, Larvikite, Peterhead granite and gabbros.

Segenhoe Church offers the chance to assess the durability of various building materials.

Left, elegantly restrained decoration at All Saints, Ridgmont. Below,



3: Old St Mary's Church, Clophill

Ordnance Survey Map Explorer 193
An attractive ruined church built in sandstone from the Lower Greensand.

4: Ivel Walk, Biggleswade Common

Ordnance Survey Map Explorer 208
Walk through ice age geology, river processes, and landscape history along the banks of the River Ivel. RIGS leaflet *Ice Age Gravels: Ivel Walk, Biggleswade*

Old St Mary's, Clophill. Note the bedding planes in the sandstone (below), showing how currents shifted the sands on the Cretaceous sea floor.

5: Pinnacle Recreation Ground, Sandy and the Lodge, Sandy Warren

Ordnance Survey Map Explorer 208
See the effects of erosion and the plants of sandy soils at the Recreation (with an Iron Age hillfort for good measure), then more wildlife as you walk through the RSPB nature reserve to an old quarry with an excellent exposure of the Lower Greensand. Please note a small charge is levied on non-members of the RSPB wishing to visit the reserve.

RIGS leaflet *Lower Greensand: The Lodge, Sandy Warren Quarry*

The Lower Greensand revealed in the quarry at The Lodge.

6: A day in Bedford

Bedford has much to offer for a day out, including building stones to investigate on your way around the town.

Start at the Information Centre in St Paul's Square, off the High Street, which will supply you with a map of the town.

Immediately opposite the Information Centre is **St Paul's Church**. A church on this site is mentioned in the Domesday Book, but this one was built in the 15th century and much repaired in the 19th century. Take a good look around the church to see all the different building stones:

- cream-coloured shelly limestone
- oolitic limestone
- pale, crumbly blocks of Totternhoe Stone
- dark red-brown sandstone (Lower Greensand)
- green sandstone (Upper Greensand)

St Paul's shelly limestone.

St Paul's Totternhoe Stone.

Some of the limestones and sandstones display sedimentary structures, inclined lines that tell us which way the currents flowed in the tropical waters when these sediments were laid down. Look for the mason's original chisel marks, where he dressed the stone ready for use in blocks many hundreds of years ago. Masons also signed their work – look for the cross and the diamond cut into the rock.

Walk west from St Paul's to the **Town Hall**, which was a grammar school until 1892. The beige, often mottled, blocks are a Jurassic limestone from Ancaster in Lincolnshire known as 'Ancaster Stone'.

Bedford Town Hall (left) and Ancaster Stone (below).

Continue anticlockwise around St Paul's Square (back towards the High Street) to the **drinking fountain** on the church wall. This is typically Victorian in style and materials, including the use of granite, which was readily available in all parts of Britain once the railways had opened up the routes. Some granite has been left rough, while other parts have been polished. Look closely, preferably with a hand lens: the crystals making up this rock are randomly orientated, proving it is an igneous rock. There are three minerals visible: grey glassy quartz, milk-white feldspar and a black mica called biotite. These are the typical 'ingredients' of Dartmoor Granite.

Dartmoor granite

The statue of John Howard near the drinking fountain is another good example of Victorian imports of building stone. The steps and large base of the statue are Portland Limestone, from Portland in Dorset. Victorians loved to use this limestone in their buildings. Look for the fossils, which are mostly oysters and other bivalve shells. The intricate carved area is Carboniferous Limestone from the Pennines. This is easy to identify as it has lots of tiny rings and segmented 'stalks' which are the fossil remains of crinoids or 'sea lilies'. Beneath the intricate carvings on the base are two sandstones, one red and the other cream-coloured. These are splitting apart as a result of water in cracks and crevices expanding as it freezes in cold weather. The red is known as New Red Sandstone, laid down in the Permian/Triassic periods when Britain was a desert in central Pangaea.

The weathered Carboniferous limestone of John Howard's statue.

New Red Sandstone from the Penrith or Halifax area in John Howard's statue.

Despite the name 'sea lilies' crinoids were animals related to starfish and sea urchins. The petals of the 'flower' were arms with fine filaments to trap microscopic food particles and pass them to a central mouth. Their modern relatives 'sea stars' are similar but lack the long 'lily' stem.

As you head north up the High Street look for **exotic rocks** (mostly in shop fronts):

- Larvikite (blue with sparkly large crystals)

Larvikite

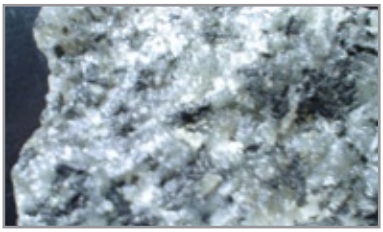
- Peterhead granite (red)
- Shap granite (with large pink crystals[1]
- York Stone paving slabs (grey, dirty-looking fine sandstones)
- Dartmoor granite (black and white crystals)
- Gabbro (black, may be polished)
- Portland limestone (white to beige, fine oolitic limestone, with lots of fossils)
- Travertine (white to cream and has regular layered holes in it)
- Serpentine (green with streaks running through it)[2]
- Marble
- New Red Sandstones (desert origins, look for rounded grains with 'dusty/dull' look)
- Various local bricks

After you have passed St Peter's Street, stop at **St Peter's Church**. This church has an Anglo-Saxon tower and many 19th century repairs to the rest of the building. Oolitic limestone and red-brown Lower Greensand sandstone are the main building stones.

St Peter's Church

Peterhead granite

Shap granite



gabbro

Portland limestone

1. Look down at your feet on the Mill Street corner.
2. Look for a food shop!

Walk east to **St Luke's United Reform Church** at the end of St Peter's Street. This is a lovely example of the old style of bricks laid in Flemish bond (headers and stretchers laid alternatively to give a long and a short end showing) This style of brickwork is very strong. The clay for these bricks is said to have come from Oakfield, off the Kimbolton Turnpike Road.

Travelling south down St Cuthbert's Street, you see **St Cuthbert's Church**, where again a shelly limestone shows lots of fossils. But continue on, past the Castle, right at the Embankment and over the bridge to get to the lovely **St Mary's Parish Church**. Built in the 11th century you would expect the structure to be made from local stone, and you would be right. The cream-coloured stone is oolitic limestone from the Great Oolite, and church records even tell us that this was quarried at Pavenham in northwest Bedfordshire. The east wall adds other local stones, too: a very dark red-brown and an red-orangey-brown sandstone, both from Leighton Buzzard (Lower Greensand), Totternhoe Stone – and something completely out of place, a block of red granite!

The east wall at St Mary's, Bedford is a hotch-potch of different stones, tiles and re-used building materials.

Left, local sandstone from the Lower Greensand.

Below, a Totternhoe Stone windowsill weathered by rain and frost action.

If you walk back across the bridge and straight on into the High Street, and then turn right into Castle Lane, you can finish the day with a visit to the **Bedford Museum**. In addition to displays of local rocks, they have displays of Bedfordshire's inhabitants before humans, from ichthyosaurs to mammoths (fossils from the Ice Age and the Jurassic are a particular speciality).

Icthyosaurs, pliosaurs and other marine reptiles swam in the ocean above the Jurassic clays from which so many Bedfordshire bricks are made.

Useful addresses and information

Bedfordshire & Luton RIGS *www.bedsrigs.org.uk*

UK RIGS the national website *www.ukrigs.org.uk*

Bedford Museum Castle Lane, Bedford *www.bedfordmuseum.org*

British Geological Survey, Keyworth, Nottingham, NG12 5GG.
For maps, books, and lots of geological information. *www.bgs.org.uk*

Fossils website with rock and timeline information *www.ukfossils.co.uk*

Greensand Trust for sites to visit, conservation and wildlife
www.greensand-trust.org.uk

Rocks Afoot, 13 Pusey Way, Lane End, High Wycombe, HP14 3LG.
For books, courses and tours. *www.rocksafoot.com*

Rocks and how to identify them *www.open2.net/lights/geology/*

BBC Rocks website *www.bbc.co.uk/education/rocks*

Acknowledgements

We are grateful to English Nature, who through their application of the Aggregates Fund, enabled us to found the Bedfordshire RIGS Group and produce this booklet as one of the outputs.

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Thanks are also due to founder members of the Bedfordshire RIGS Group who (with no arm-twisting) set off cross-country to take many of the photographs for this book: Andy Welch, Dick Denton and Martin Day.

Last, but not least, thanks to Sarah Wroot who helped bring the text to life.

Bedfordshire's landscape

Bedfordshire is simply beautiful. The landscape varies from the Chalk hills in the southwest emphasized by the low Gault Clay vale that separates the Chalk from the Greensand Ridge. North of the Greensand's forests and parks the Jurassic clay vales change colour from shades of green to gold as the arable crops ripen. Rivers – the Ouzel, the Great Ouse, the Flit and the Ivel – cut through this landscape, revealing the underlying rocks and depositing sediments to create fertile riverside meadows. The rivers also provided a transport network and permanent water source for early settlers in Bedfordshire.

How rocks make landscape

The landscape of an area is shaped by the rocks that lie beneath the surface, and what has happened to these rocks over millions of years. Weathering and erosion take their toll on different rocks in different ways. In the last 200 million years Bedfordshire has experienced everything from hot and humid tropical climates to freezing cold ice sheets. It's been under the ocean many times and exposed as land many times, too. This has gradually sculpted the rocks into rounded hills and escarpments, ridges and complex river valleys. There is an exciting story for every part of Bedfordshire, and a few stories that are quite unusual. The RIGS group has selected some of the best sites, places that tell these stories for everyone to enjoy. Visit our website *www.bedsrigs.org.uk* for information, including a series of leaflets introducing you to the geology and geomorphology of Bedfordshire.

Looking east from Harrold across the Ouse Valley toward Chellington. The Ice Age Ouse cut this valley, revealing the cream-coloured Jurassic Oolite limestone that features in so many buildings in this area.

What are RIGS?

These are Regionally Important Geological and Geomorphological Sites, places that reveal our geological past and are considered important enough to deserve conservation. They include sites where rocks can be seen (such as quarries and road cuttings) or where the geology or geological processes can be inferred from the shape of the landscape. Even buildings that use local stone in their structure can be RIGS! Official RIGS are recognised by county councils and by English Nature (the statutory nature conservation body of England).

The Bedfordshire & Luton RIGS group

We exist to encourage understanding of the geology and geomorphology of the county and to undertake site recording, interpretation, advice and education. We aim to:

- Protect local geological and geomorphological sites
- Encourage public enjoyment of rocks, fossils and landscape
- Encourage the use of RIGS sites by the public, by schools and local groups
- Keep a listing of RIGS sites in Beds
- Provide information for potential users of sites
- Encourage landowners to participate in the scheme
- Involve landowners and users of RIGS in good practice and management

You can find out more about the geology and geomorphology of your area by visiting our website *www.bedsrigs.org.uk*
You can join trips and help the Beds RIGS group conserve our geological past for the future.

To find out more about the group and events contact:

Chris Andrew c/o Bedford Museum, Castle Lane, Bedford, Bedfordshire MK40 3XD.Tel: 01234 353323; Fax: 01234 273401

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