East Anglia and adjoining areas region

This account provides a broad perspective of the geology of East Anglia and adjoining areas region, which includes the counties of Norfolk, Suffolk, Cambridgeshire and parts of Lincolnshire and Bedfordshire. Figure 1 provides a geological sketch map of this region showing the rock types occurring in relation to the major towns and cities. East Anglia’s relatively flat and rolling landscape, mainly less than 100 m above sea-level, provides a rich agricultural setting and contains an interesting geological story. This account sketches out the geology to a depth of at least a kilometre and summarises the current and historical use of the geological resources in the region.

The surface geology of the region is known from quarries, coastal cliffs and shallow boreholes. At greater depths, below about 250 m, our direct knowledge comes from about 50 deep boreholes spread fairly evenly across the region. The deepest of these go down over a kilometre, and most were drilled to explore for water or coal. Geophysical surveys, carried out on land or by low flying aircraft, reveal patterns of the Earth’s gravity and magnetic field, and these also give us clues as to the deeper geology of the region. East Anglia is not known to contain oil, gas, coal or metal resources at depth, and there has been no deep mining within the region. As a result detailed information on the deep geology is sparse.

Geologically recent surface deposits

East Anglia has widespread geological deposits of relatively recent origin, formed over the past 2 to 3 million years and spanning the Ice Ages and Interglacial periods. These are known as superficial deposits and include sands, clays and peat deposits which were laid down by former ice-sheets, in rivers, swamps and marshes, or along the margins of the North Sea. At times over the past 3 million years the North Sea has extended inland, covering the eastern part of region, while at other times it was more restricted and the land area extended across much of the present southern North Sea. The superficial deposits are less than 100 m in thickness and are not shown on Figure 1, examples include the peat deposits of the Fenlands and the Broads, the boulder clays of central East Anglia and the ‘Crag deposits’, sands that are often full of fossil seashells, found in the eastern parts of Suffolk and Norfolk. These Crag deposits (Figure 2) are a useful shallow source of groundwater; water is present in the pore spaces and flows freely between the individual sand grains, enabling it to be pumped out easily. Deposits like this are known as aquifers and are used to provide drinking water. Most of the superficial deposits are soft and easily eroded, as they have not been deeply buried and consolidated to form strong rocks.
Figure 1  Geological map and key showing the range and distribution of different bedrock types in East Anglia and adjoining areas. The extent of The East Anglia and adjoining areas is identified on the inset map of the United Kingdom.
**Figure 2** The Crag, a soft shelly sand deposit that forms an important shallow aquifer in eastern Norfolk and Suffolk.

**Geology at depth**

Below the superficial deposits, or with just a cover of soil where such deposits are absent, are older rocks which geologists broadly split into two distinct types:

- The *sedimentary bedrock geology* is composed of quite hard rocks formed from tens to a few hundred millions of years ago as layers of sediments which were deposited in shallow seas, deserts and vast river systems in times when Britain lay closer to the Equator and the climate and landscape were very different from those of today.

- The *basement geology*, which underlies the whole region, is over 410 million years old and mainly comprises harder and denser rocks which have been strongly consolidated, fractured and folded. They include both rocks originally deposited as sediments and others that are products of volcanic activity or formed from the solidification of molten rock below ancient volcanoes.

In the course of the past 550 million years there have been periods when parts of the UK formed a landmass and was being eroded, whilst parts were sinking and new layers of sediment were being deposited. The history of erosion and deposition has not been the same in all parts of the UK. In the East Anglia region the oldest sedimentary bedrock are red sandstones (Old Red Sandstone) overlain by Carboniferous sandstones, mudstones and limestones that are similar to the rocks occurring at the surface in parts of northern England. These rocks are all referred to here as the *older sedimentary bedrock*. 
Subsequently, a younger sequence of sedimentary rocks, including limestones, sandstones and clays, was laid down and are known as the *younger sedimentary bedrock*. As one travels across the region from west to east the rocks at the surface become younger in age because the layers are slightly tilted down toward the east. These include in the west Jurassic rocks, comparable to those seen along the coast of Dorset and North Yorkshire, they also extend at depth across north Norfolk. They are overlain by Cretaceous rocks, including the widespread Chalk that occurs at the surface over much of the eastern part of the region, These Cretaceous rocks rest on different types of older rock including the basement rocks when traced across the region, this situation is what geologists call an unconformity, it represents a period of uplift and erosion.

Figures 3 and 4 provide vertical sections through the geology, referred to as geological cross-sections.

**Figure 3** Schematic cross-section the underlying geology of part of East Anglia and the adjoining areas. The section alignment and key are shown in Figure 1.

**Figure 4** Schematic cross-section of the underlying geology of part of East Anglia and the adjoining areas. The section alignment and key are shown in Figure 1.
Individual areas
From a geological perspective, the region can be divided into three; in the west lies the Fenland and adjacent areas, whilst farther east the region can be split into Suffolk and south Norfolk, and north Norfolk.

The Fenland and beyond
This area includes the low lying Fenland and adjacent countryside extending from the Wash in the north, southwestwards through Huntingdon to the districts around Biggleswade and St. Neots. Other important settlements within this area include Holbeach, Wisbech, Downham Market, Ely and Cambridge. This area is bounded to the east by a prominent ridge, formed by Chalk, that extends from Hunstanton due south to Soham and then southwestwards through Cambridgeshire to the south western limits of the region.

Younger Sedimentary Bedrock
The bedrock in this part of the region consists of a variety of sedimentary rocks, their overall shape, thickness and sequence are quite well known because there are widespread boreholes. The stack of layers are only 100 to 200 m thick in the south of this area but they get progressively thicker going north and are about 500 m thick around the Wash. These sedimentary rocks are formed of distinct layers of limestone, mudstone and sandstone which geologists group together into distinctive units or formations which can be traced for long distances, often over hundreds of kilometres. The individual layers or beds vary from a few metres to tens of metres thick and are very gently tilted towards the southeast. Throughout the area there are Jurassic rocks, 200 to 150 million years old, which were laid down in warm shallow seas. These include the famous brick clays that are dug to the west of the region around Bedford and thick grey mudstone known as the Lias which is famous for its fossil marine reptiles such as Plesiosours and Ichthyosaurs.

Farther north the sedimentary bedrock layers are thicker and descend to greater depths while the lowest part of the rock sequence is composed of still older sandstones, overlain by mudstones, both with a reddish colouration due to iron oxide stains formed when they were deposited in very dry desert-like conditions between 250 and 210 million years ago. These red rocks do not crop out at the surface within the East Anglia region but around the Wash the sandstones (New Red Sandstone, Sherwood Sandstone) are up to 100m thick and are used as a minor aquifer. The red mudstone (Mercia Mudstone) above is up to 100 m thick around Spalding and forms a barrier or seal preventing the water within the sandstone from moving upwards.
Older Sedimentary Bedrock and Basement Rocks

Underlying the sequence of younger sedimentary layers lies the older sedimentary bedrock deposited from about 410 to 300 million years ago, and the even older basement rocks. These older rocks are present within 100 to 200 m of the surface in the southwest of the area, but farther north towards the Wash they lie deeper, typically at depths of about 500 m or more. The Older Sedimentary Bedrock is quite well known from drill holes in the south of this area and mainly comprises red mudstones and sandstones, popularly known as the Old Red Sandstone. The available information indicates that they are several hundred metres thick and are overlain by thin Carboniferous Limestone. The basement rocks are mainly grey mudstones and sandstones that are weakly metamorphosed so that they are much harder, and denser than the sedimentary rocks above them. They have been tightly folded and tilted at steep angles during ancient earth movements, when they were buried much deeper than they are today. While the rocks themselves are less porous than the younger sediments they are cut through by fractures that do contain groundwater and include geological faults where the rocks on each side of the fracture have moved relative to one another. The basement rocks were originally deposited between 550 and 410 million years ago, similar rocks underlie much of England, and occur at the surface farther west, forming much of the hill country of Cumbria and Wales.

Geophysical surveys reveal local anomalies in the magnetic field and the force of gravity in some parts of this area including the countryside north and northwest of Cambridge, also to the north of Wisbech, and south of Hunstanton. Such anomalies are common in areas where there are buried pillar-shaped bodies of granite or similar rocks, known as igneous intrusions. These intrusions are the solidified remains of chambers of molten rock or magma, that lie beneath many active volcanoes today. The anomalies occur because the granite is lighter than the surrounding basement rocks and so gives a low or negative gravity anomaly. The granite also contains more magnetic minerals than the rest of the basement rocks producing highs or spikes in the magnetic signal. The presence of these granite masses has only been proven by a single borehole near Wisbech. The interpretation of the geophysical signals is consistent with what has been found where similar basement rocks occur near the surface or buried in other parts of the UK.

Suffolk and south Norfolk

Our second area of East Anglia comprises Suffolk and southern Norfolk. The main settlements are Ipswich, Bury St Edmunds, Newmarket, Thetford and Lowestoft. This area starts in the west at the ridge of Chalk referred to above and extends from there eastwards to the coast. This area possesses more uniform geology than that described from the Fenland area, and in particular the Chalk either occurs at the surface or beneath a thin cover of young sedimentary rocks throughout the area.
Younger Sedimentary Bedrock
In Suffolk and south Norfolk the younger sedimentary bedrock consists mainly of a sequence of sedimentary layers including the Chalk, dipping gently to the southeast. These rest on the younger sedimentary bedrock layers that occur at the surface farther west in the Fenland, but those layers only extend eastwards beneath the Chalk for a short distance. The younger sedimentary bedrock in this area is up to about 400 m thick and ranges in age from about 150 to 50 million years old. The main elements of the sequence are sandstones and mudstones up to 30 m thick, overlain by the Chalk, which reaches 300 m in thickness, and capped near the coast by younger sands and clays up to 50 m thick; so the Chalk is the dominant sedimentary layer of this stack.

Chalk is a fine grained white, or grey rock composed of fragments and microfossils of calcium carbonate; it is a special type of limestone. In its upper parts, black flint nodules (Figure 5) are common. Flint is a very fine grained form of silica and flint nodules were dug from the Chalk in prehistoric times, for example at Grimes Graves near Thetford, and used by early man to fashion stone implements.

Figure 5 A massive vertical flint nodule within the Chalk, its length is about one metre.
The Chalk is a very important aquifer, not just in East Anglia but in adjacent parts of southern and eastern England. Unlike the other aquifers referred to in this account (the Crag and the Sherwood Sandstone) most of the water flow in the Chalk is not through the pore spaces between the grains of the rock but along the fractures within it. These fractures are both horizontal and vertical and connect together to make pathways for water to flow through. Because the Chalk is composed of calcium carbonate which can be slowly dissolved by groundwater, the fractures become wider over long periods of time leading to the quite rapid flow of water through some parts of the Chalk. The bottom of the Chalk is rich in clay and the thin layer immediately below is a clay layer, the Gault Clay. Water trickling through the Chalk cannot percolate downwards any further when it reaches these clay layers and so flows along the top of the clay until it emerges at the surface forming springs. The water from the Chalk is rich in dissolved calcium carbonate and is referred to as ‘hard’. When this water boils, for example in a kettle, the calcium carbonate is precipitated as “scale”.

**Older Sedimentary Bedrock and Basement Rocks**

Occurring directly beneath the Gault Clay over most of the area, these rocks occur at depths of about 200m around Cambridge and descending gradually eastwards to depths of about 400 to 500 m below sea level along the coast. These rocks are only known from scattered deep boreholes and most of these penetrated only the very top part of them, there is no geophysical evidence of granites at depth. The Older Sedimentary Bedrock is similar to that of the area to the west being composed of Old Red Sandstone and is mainly confined to the southwestern and northern parts of this area. Its’ thickness is uncertain. In the rest of the area the younger sedimentary bedrock rest directly on basement rocks comprising hard fractured grey mudstones and sandstones that are inclined at steep angles. These rocks originated as sediments on the deep sea floor over 410 million years ago.

**North Norfolk**

North Norfolk can broadly be equated with an area north of a line drawn from Kings Lynn through Norwich to Great Yarmouth; the other principal towns in this area include Hunstanton, Fakenham, Aylsham, North Walsham and Cromer. The coastline here is dominated by low cliffs (Figure 6) with intervening stretches of sand spits, marshes and dunes.
Figure 6 The base of the Chalk in the cliffs at Hunstanton, it rests on a layer of bright red sediment known as locally as the ‘Red Chalk’.

Sedimentary Bedrock

In this area there is a thick sequence of sedimentary bedrock layers which exceeds 1000 m in total between Cromer and Great Yarmouth in northeast Norfolk. As a result, the top of the underlying basement rocks is well below 1 km depth in that part of the area.

The same easterly-tilted younger sedimentary bedrock layers described from the rest of Norfolk and Suffolk continue through this area but are even thicker, reaching over 500 m in parts of northeast Norfolk. They comprise interbedded sandstones and mudstones including the Gault Clay overlain by Chalk, which in places in the east is covered by further sands and clays. The lower sandstones and clays are thickest where they are exposed at the surface between Kings Lynn and Hunstanton reaching up to 75m, however they thin out quickly when traced eastwards beneath the Chalk. The Chalk locally exceeds 450 m in thickness with the overlying sand and clay layers reaching 80 m thick but restricted to the fringes of the east Norfolk coast.
The further sedimentary bedrock layers described from the Fenland also continue eastwards beneath the Chalk and are not pinched out as they are to the south. Instead, they form a thickening sequence of layers to the east along the Norfolk coast.

Between Wells next the Sea and Great Yarmouth, Older Sedimentary Bedrock layers are also present at depth. These include sandstones, mudstones, and limestones of the Carboniferous Limestone and the Coal Measures. Elsewhere in Britain some of these layers are encountered nearer the surface and form important aquifers, however little is known about their water content beneath the North Norfolk coast and evidence from similar geological settings elsewhere in the UK suggest that it is likely to be saline.

Basement rocks
The basement rocks in this area are similar to those encountered below the other areas with grey mudstones and sandstones which have been changed by high temperatures and pressures in the long time since they were formed; thin layers of volcanic lavas have also been found in some boreholes. There may be a single granite intrusion in the area north of Fakenham based on the gravity and magnetic data, although other possible interpretations have also been suggested.

<table>
<thead>
<tr>
<th>Version</th>
<th>Description of change</th>
<th>Date of release</th>
<th>Updated by</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>First released version</td>
<td>Dec 14</td>
<td>Steve Mathers</td>
</tr>
<tr>
<td>2</td>
<td>Updated Figure 1 legend, new logo, version control</td>
<td>Dec 18</td>
<td>Fiona McEvoy</td>
</tr>
</tbody>
</table>