**The Geology of Clifton and Durdham Downs** by Andrew Mathieson

There are many accounts of the geology of the Avon Gorge, which is hardly surprising since it is nationally important for both the exposed rock sequence and the landform of the gorge itself, but much less has been written about that of the Downs, even though they have a number of special geological features. The two sites are very closely linked since most of the rocks seen in the Gorge also lie under the Downs. However there are several younger rocks which are only found on the Downs themselves, and these add greatly to our understanding of the geological history of the area.

**The Rock Succession**

The oldest group of rocks on the Downs is the Carboniferous Limestone, and this underlies most of the area. It is a thick sequence of some 760 m (2,500 ft) of rock, and is mostly made up of different types of limestone, but there are also dolomites, mudstones and sandstones. These all contain the fossil remains of brachiopod shellfish, corals and crinoids, clearly indicating that the rocks formed beneath the sea. The presence of corals and limestone suggest that the water was shallow and warm, and this is supported by studies of palaeomagnetism, which indicate that these rocks formed close to the equator. Radiometric evidence shows that they are between 359 to 326 million years old.

The sequence of Carboniferous Limestone is divided into a series of units, which are mostly named after exposures seen along the Gorge (Kellaway and Welch, 1955). These units were created by the Geological Survey to replace a system of zones based on fossil corals and brachiopds (Vaughan, 1905) which, although revolutionary at the time, had been found to be difficult to use outside the Bristol area. The new system is based on units of types of rock which can be traced across the area from the Mendips to South Gloucestershire. The Gorge is famous as the reference site for both of these methods of dividing the limestone succession (Bradshaw and Frey, 1987; Hawkins, 1987).

The main Geological Survey units present on the Downs are:

1. **Black Rock Limestone** is the oldest unit, and it can be traced in a band across the north of the Downs from Sea Walls to Badminton School, and it forms the northern edge of the high ground. It takes its name from Black Rock Quarry in the Gorge, where it is very well exposed, and is a dark grey, well bedded limestone with many fossil crinoids, corals and brachiopods.
2. **Gully Oolite** outcrops across the Downs to the south and parallel to the Black Rock Limestone from near the top of the Gully. It is a light grey coloured oolitic limestone, with few fossils and little evidence of bedding. The rock is best seen in the Gully Quarry in the Gorge. Modern day oolite sediments are found in shallow seas subject to bottom currents.
3. **Clifton Down Mudstone** is a relatively softer rock and its course across the Downs runs parallel to the other older rocks, starting from where it was eroded out to form the top of the Gully. The rock is poorly exposed in the Gorge but its base can be seen at the top of the Gully Quarry. The contact with the Gully Oolite beneath is irregular, suggesting that erosion took place at that time and the junction between the units is interpreted as a fossil soil. The presence of mudstones indicates that mud was washed into the sea by rivers from nearby land, but there are also beds of limestone which show that the seawater cleared at times.
1. **Clifton Down Limestone** is found both on Durdham and Clifton Downs, since it was displaced by large scale faulting. It is rich in fossils and is sometimes oolitic. There are also some fossil algal structures which suggests an inter-tidal origin for some of the rock.
2. **Hotwells Limestone** is again found on both Durdham Down and on the south side of Clifton Down due to the action of the same faulting. It is a well bedded limestone, rich in fossil corals and shellfish, and is well exposed around the foot of the Old Zigzag and beside the entrance to the former Clifton Rocks Railway.

All these rocks in the Gorge and on the Downs were subjected to enormous forces during a major period of earth movements at the end of the Carboniferous period. They were compressed and became part of a massive arched fold (the Westbury-on-Trym Anticline), which extended from Clifton northwards to Kingsweston and Henbury. In addition a number of faults were formed and the largest of these, the Great Fault, can be seen at the bottom of Bridge Valley Road. Here Clifton Down Limestone is pushed up over Cromhall Sandstone with the result that the upper part of the rock sequence in the Gorge (and on the Downs) is repeated to the south. The movement of this major fault is calculated as 335 m (1,100 ft), and it has had the effect of extending the length of the Downs (and the Gorge) by about a third.

These earth movements also created sets of joints in the rocks and some of these have since been filled with younger rocks or mineral veins.

The fold must have also included a thick sequence of younger Carboniferous rocks which once covered the Limestone on the Downs. These Coal Measure rocks are found beneath Ashton Vale, where coal seams are found in mudstones and sandstones, and must have been deposited in the equivalent of the tropical rain forest of 300 million years ago. The local Coal Measures are some 600 m (2,000 ft) thick, but much more was probably once present and when they lay on top of the limestones in the fold, the Downs area must have been on the southern slope of a mountain which could have been over 3,000 m (10,000 ft) high at Westbury on Trym.

Much of the south of the Downs is underlain by Dolomitic Conglomerate, a rock composed of pebbles and boulders of limestone in a matrix of sandstone and mudstone. This was created from the eroded remains of the Carboniferous Limestone. The best exposure of this rock is in a cutting on Bridge Valley Road, where it can be seen to lie in horizontal layers. This appears to represent the infill of a fossil valley cut into the relatively softer Cromhall Sandstone. The rock was formed between 250 and 200 million years ago, in the Triassic period of geological time, when the Downs are thought to have been an area of high ground in an arid desert.

There are some areas of younger Triassic rocks on the Downs. Westbury Beds are found around Clay Pit Road, where the rock was quarried in the 1780's (Savage, 1999), and near the centre of Durdham Down. This black coloured mudstone contains fossils which indicate a marine origin, and provides evidence that at least some of the eroded surface of the desert landscape was covered by the sea about 200 million years ago.

**The Downs Island**

The fossil remains of the “Bristol Dinosaur” *Thecodontosaurus antiquus* were found in a fissure in a limestone quarry on the edge of the Downs, near the top of Blackboy Hill, in 1834. Some quarrymen took samples of the fossils to the Bristol Institution (which later became Bristol City Museum) where they were examined by the curator and by a number of experts. The men were employed to find more fossils and a large collection was made. This dinosaur was only the fourth named in England, and perhaps the world (Benton, 2012). Sadly some of the fossils were destroyed by bomb damage in the Second World War but many are still safely stored in the Geology Department of the City Museum and Art Gallery. It was generally thought that the bones were preserved in Dolomitic Conglomerate which had formed in the fissure, but recent research has found evidence that the fissure fill is equivalent in age to the Westbury Beds. This is based on the presence of some fossil shark teeth and the similarity of many of the fossils to those found in South Gloucestershre where evidence of Westbury Bed was established. The same research revealed fossil evidence for a number of other dinosaurs and terrestrial reptiles which must have lived alongside *Thecodontosaurus* on the Downs Island of the time (Foffa, 2014)

Near the Bristol entrance to the Suspension Bridge there is a small deposit of more Triassic, and possibly also Jurassic rock, which appears to have been deposited in a cave or fissure in the Carboniferous Limestone. Tawney (1867) described this deposit as:

*a wide fissure (or pocket) in which blocks of Cotham-marble are found imbedded. Lias Septaria too were dug out of it in making the road to the bridge and the excavations for the bridge chains. The bulk of the infilling material seems to be greenish marl, with a little red marl such as occurs in the Rhaetics.*

Cotham Marble is found in the Cotham Beds, which are of Triassic age, and younger than the Westbury Beds. The Marble is a well known local limestone formed by fossil algae, suggesting inter-tidal conditions. The Cotham Beds have not been recorded elsewhere on the Downs. The Lias mentioned by Tawney is the lowest division of the local Jurassic rocks. These occurences imply that the site was on the shoreline of an island, sited where the Downs are today, which existed from the time when the Cotham Beds were deposited through to the early Jurassic period.

Charles Moore (1881) later wrote about the same site:

*Close to the toll house, on the Clifton side, there is a deposit of considerable interest, having a face of about forty feet, in which the Rhaetic bone-bed and its asscociated remains are present. It is partly composed of irony and yellow sandy looking marl, with many free crystals of carbonate of lime .. and there are patches of finely lamintated rock, similar to the Rhaetic "White Lias".... The bone-bed is two inches thick, with teeth of Saurichthys apicalis, Lophodus minimus, and many fish scales, and the clay on either side contains fish-remains of the same age.*

The Bone Bed with its various fossil fish remains is found in the Westbury Beds, which shows that the coast existed from before the Cotham Beds were formed.

It is thought that the Island was completely drowned by the sea later in the Jurassic period, since pieces of Lias limestone with fossil *Gryphaea* and *Spiriferina* have been found on the Downs (Donovan and Kellaway, 1984). These are presumably derived from Jurassic deposits hidden beneath the soil.

**Durdham Down Bone Cave**
The youngest deposits on the Downs were found in the famous Durdham Down Bone Cave. According to Latimer (1887, pp 265-266):

*An interesting geological discovery was made in November 1842, in one of the quarries which then worked in the middle of Durdham Down, the workmen having found an opening into a cavern containing a quantity of the remains of animals for ages extinct in this country. The cavity though narrow, was of some extent, being traceable to a depth of ninety feet. The bones had belonged to about twelve hyenas, a bear, two rhinoceros, several hippopotami, numerous examples of wild bulls, about five deer, and five or six elephants, besides the relics of animals of later date. The bones were nearly all fractured into small pieces, and the proportion of teeth and horns to other parts of the body greatly preponderated. Taking this fact into consideration, together with the marks of gnawing on the bones, and the certainty that the cave could not have accommodated more than a small fraction of the animals represented by the vestiges, scientific observers concluded that the den had been the retreat of hyenas, which had carried to it portions of their prey.*

This fauna represents animals which lived in the last warm phase of the Ice Ages (Ipswichian interglacial, between 128,000 and 116,000 years ago). The fossils are largely from extinct animals, which today are known as spotted hyena ( ), cave bear (*Ursus* etc.
A model of the cave is preserved in the Geology Department of the City Museum and Art Gallery.

**Natural Landscape**
The Downs plateau is a remarkable feature which extends across the area at a hieght of around 100 m (330 ft) above sea level, and can be seen to continue across the other side of the Gorge. Most geologists have concluded that it is an ancient surface formed following the very long period of erosion after the late Carboniferous earth movements. They consider that it was planed off at the end of the Triassic and beginning of the Jurassic periods, as the sea advanced across the area. There is certainly evidence for marine sediments of this age on and around the edge the Downs. The area is then thought to have been covered with a very thick sequence of younger Jurassic and possible Cretaceous rocks, which would have completely hidden the erosion surface. These would have been affected by earth movements in the Tertiary period with the result that they dip at a low angle towards the south east. Subsequent erosion has removed most of these rocks and exhumed the buried Triassic landscape.

It is likely that this long period of erosion had some effect on the Downs plateau, and also possible that the postulated presence of an ice sheet during the Ice Ages made further changes. The erosion of the Gully and the New Zigzag valleys must have taken place when the Gorge was created. Given that these are now dry valleys, and that any rainwater that falls on the Downs sinks down through the limestone, it probably required the ground to be frozen to allow water to run across the land surface to erode the features. This could have happened during any of the cold phases of the Ice Ages, but the present shape of the valleys was no doubt completed in the last, the Devensian, between 116,000 and 11,000 years ago.

There are a number of caves in the area but most are found in the sides of the Gorge. However the Observatory Hill Cave entrance is on Clifton Down. Its entrance has been blocked up, but it was reported to be 9 m (30 ft) long, 1.5 m (5 ft) high and 3 m (10 ft) wide. There is no known evidence of when it was formed. The Durdham Down Bone Cave was discovered in a quarry but must have once had an entrance on the Downs. There may well be more undiscovered caves and solution cavities on the Downs which were formed as rainwater found its way down through joints and other openings in the limestone. There are several small depressions on the Downs which could be sink holes, but which may turn out to be unrecorded mineral workings. One pit is thought to be a Second World War bomb crater.

It has been suggested that much of the surface of the Downs was formerly covered by limestone boulders and griked bedrock, and that this was mostly removed by lime burners or as ornamental stone for use in rockeries (Kellaway and Welch, 1993). Clearly the natural landscape has been considerably altered by quarrying and mining.

**Quarrying**
There have been many quarries which extracted Carboniferous Limestone on the Downs (see the map in Greenacre, The Downs History Trails No. 1). In 1754 it was reported that locals were permitted to take what stone they required from the Downs, and that much was burnt in kilns to make lime for mortar (Savage, 1999). Some was also used as building stone, with the Observatory, for example, almost entirely built of this rock. The only two quarries which have survived are around Observatory Hill.

In addition to the many small quarries there were four much larger:

1. Quarry north of Westbury Road and marked by the Seven Sisters fir trees
2. Quarry to the north west of the junction of Stoke Road and Ladies Mile
3. Chain Quarry, north of Belgrave Road
4. Pembroke Road Quarry, north of Clifton Down

Quarry 1 was was reported as being nearly 1.2 hectares (3 acres) in area with an average depth of 9 m (30 ft). Quarry 2 is thought to be the site of the Durdham Down Bone Cave, and had an area of nearly 1.6 hectares (4 acres) and also an average depth of 9 m (30 ft). This appears to be the quarry depicted in a watercolour by William Arnee Frank (1862), and, if so, seems to have been much deeper in part. The Clifton and Durdham Downs (Bristol) Act of 1861 established a number of duties, including the closure and infilling of existing quarries. One of the Downs Committee's first actions was to give notice to all quarry users to quit by October 1862. In 1866 the Docks Engineer proposed to the Downs Committee that these now didused quarries should be infilled with the material to be excavated when straightening the course of the River Avon and constructing a new lock at the entrance to Cumberland Basin. This was agreed and the Dock Spoil Tramway was built to carry the excavated material up onto the Downs.

By October 1871 Quarries 1 and 2 were filled and landfill began at the Chain Quarry. The clump of firs known as the Seven Sisters was planted at the site of Quarry 1 in 1872, and the tramway track was removed in 1873, after the completion of the new Cumberland Basin lock. Chain Quarry was finally filled by 1879. In 1890 Pembroke Road Quarry was identified as a landfill site for the material to be excavated during the construction of the Frome Culvert and this was completed in about 1907 (Nichols, 2005). The boundaries of some of these former quarries can be traced due to some settlement of the infill, and no doubt 9 m of river sediment and assorted rocks will have had a significant effect on the type of soil which has developed on these sites.

**Minerals and Mining**
There is an area of disturbed ground known as the Dumps beween Upper Belgrave Road and Ladies Mile. This is unlike any other feature on the Downs and its origin is unknown. It has been suggested that it was a former lead mining area, but the alignment of the workings are quite different from that of the known lead veins nearby. It has also been suggested that it was a former limestone quarry but it does not have the appearance of any other quarry on the Downs. Other suggestions are that the mineral celestite was worked here, or that the trenches were lead workings which were later enlarged by quarrying to supply limestone (Kellaway and Welch 1993).

Several minerals have been found on the Downs. Lead veins found on Clifton Down beneath the Triassic Westbury Beds consist of galena, spaherite and marcasite, with barite and calcite. Elsewhere the veins

in the Carboniferous Limestone show two generations of mineralisation. The first consists of hematite and quartz, followed by galena, barite and calcite, which may be deposited in a central infilling of the vein (Kellaway and Welch, 1993).

Galena was worked as lead ore, and several veins run north westwards from opposite the Zoo. The remains of some of the “grooves” dug by lead miners as they followed the lines of the mineral veins are still visible.The mineral has been recorded at several other sites on the Downs, including in old workings north and south of the White Tree, in the highly mineralised belt at the northern end of Durdham Down (Kellaway and Welch, 1993). The Romans are commonly thought to have worked lead and there is a reference that the mineral was dug on the Downs in the Anglo-Saxon Charter of 883. The first clearly documented record is for 1611 when the Lord of the Manor of Henbury granted a licence to dig for lead on Durdham Down. In 1712 another lease was granted to mine lead ore as a well as iron, manganese and calamine on the Downs (Micklewright and Frost, 1988).

Iron ore was extracted in Clifton, but there is no definite evidence that it was worked on the Downs. In 1872 an iron mine was opened below Royal York Crescent in Clifton and it produced 3,000 tonnes (3,800 tons) of ore in that year. Two beds of hematite, goethite and limonite were worked in red sandstone and shale (Savage, 1999).

Quartz geodes were once extracted from the rocks around Observatory Hill and sold to visitors as “Bristol Diamonds”. Also more prosaically known as Potato Stones, these nodules of quartz are thought to have replaced the mineral anhydrite. The most prized form was a hollow geode with quartz crystals growing in towards the centre. These were very popular with people who came to visit the Hotwells, and could be purchased from shops in the Colonnade. References to Bristol Diamonds go back to 1540 when Camden wrote: *in hills about Bristow be found little stones of divers colours counterfeiting precious stones*. Probably the largest collection of Bristol Diamonds is in the grotto in the garden of Goldney House in Clifton, which was built in the 1740's. The geodes were found in both the Dolomitic Conglomerate and in iron ore veins cutting through the Carboniferous Limestone (Savage, 1999).

Celestite was also found in the Dolomitic Conglomerate, and rich deposits were reported in Clifton (Tawney, 1878). There is no evidence that it was worked on the Downs. However on the other side of the Gorge, in Abbots Leigh, there were extensive workings for the mineral in the late nineteenth and early twentieth centuries.

**Conclusion**

The 1861 Downs Act certainly preserved a green open space for the citizens of Bristol, but it also unfortunately led to the infilling of most of the quarries which once provided information about the geology of the area. Sadly the Bone Cave is completely buried but at least many of the fossils excavated from the site have survived in the City Museum and Art Gallery. The two remaining quarries on Observatory Hill very clearly display the dip of the rocks and this is much appreciated by the younger generation as a slide. The road cutting leading to the Suspension Bridge exposes a splendid array of fossils and mineral veins, as well as a rock which probably once filled a cave on the coast of the Downs Island of just over 200 million years ago. Hopefully these special places will be conserved for future generations to appreciate.