YORKSHIRE GEOLOGICAL SOCIETY

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Field Guide
to the
Geology of Graves Park, Sheffield

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View of the base of the Greenmoor Rock at Waypoint 13 of the itinerary.

Introduction

This excursion provides the opportunity to examine the stratigraphy, sedimentation and provenance of sandstones in the middle part of the Pennine Lower Coal Measures Formation in the Sheffield area. The excursion is presented as a series of Waypoints that visit the most significant exposures in Graves Park and also demonstrate the various landscape features formed by the underlying geology that enable detailed and precise geological mapping.

Waypoints are presented with Ordnance Survey National Grid references, and shown on Figure 5. The route and waypoints can also be viewed in the OS Maps™ web app on a Windows or Mac computer. This map can be printed out for use in the field. Alternatively, for smartphone users (Apple or Android), open this pdf guide in your phone web browser then click here . This opens a map of the itinerary and waypoints that can be used for navigation in the field using your phone. Note that this map works best in your phone's web browser rather than the bespoke OS Maps smartphone app. There is normally good mobile phone reception in most parts of the Park.

Recommended Maps and Apps

BGS 1:50,000 series Sheffield Sheet 100, Bedrock and Superficial Geology, published 2011. Click here to view online.

Ordnance Survey 1:50,000 Landranger™ Sheet 110 Sheffield and Huddersfield or Sheet 111 Sheffield and Doncaster.

Ordnance Survey 1:25,000 Explorer™ Sheet 278 Sheffield and Barnsley

British Geological Survey iGeology app

Ordnance Survey OS Maps™ (opens the free online OS Maps™ web app allowing the route to be viewed on OS mapping)

About Graves Park

Graves Park is located in the south-western suburbs of Sheffield and is the city's largest municipal park. Formerly part of the Norton Estate (https://en.wikipedia.org/wiki/Norton_Hall), the Park was purchased by the Alderman J G Graves in 1925 and immediately presented to the Sheffield Corporation as a gift to the City for use as a public park. Much of the original landscaping of the Norton Estate was carried out by the Shore family (http://www.gravespark.org/history.html) in the early 19th century, including the damming of the upper courses of the brook that flows through the park to create a series of ornamental lakes. Prior to World War 2 the Park was expanded by additional purchases and recreational facilities were developed including sports pitches, a rose garden, children's play areas and an open air theatre. According to local residents, areas of the park were turned over to allotments as part of the World War 2 'Dig for Victory' campaign. The animal farm in the north-east of the park opened in 1977 and provides both an educational amenity for children and a centre for protection of rare farm animal breeds.

For many decades, the Pennine Lower Coal Measures in the Dronfield and Chesterfield areas were used as a training ground for new recruits to the British Geological Survey's mapping teams. In 2001, when the Foot and Mouth epidemic prohibited access to these favoured areas, Graves Park was introduced as a 'stop gap' training ground. It was subsequently used for training for many years, partly because of ease of access but also because it provided more realistic experiences for BGS geologists working on urban geology projects, which figured largely in the BGS programme at the time. The Park was also used to familiarise other, experienced geoscience specialists in BGS with the techniques of high-precision geological mapping and as a proving ground for development of digital field data capture methods using tablet computers, which are now widely used in BGS national and international programmes.

Geological Setting

The bedrock geology of Graves Park (Fig. 1) is mainly formed from two sandstone units, the Greenmoor Rock and the Grenoside Sandstone, and their associated mudstones and siltstones.

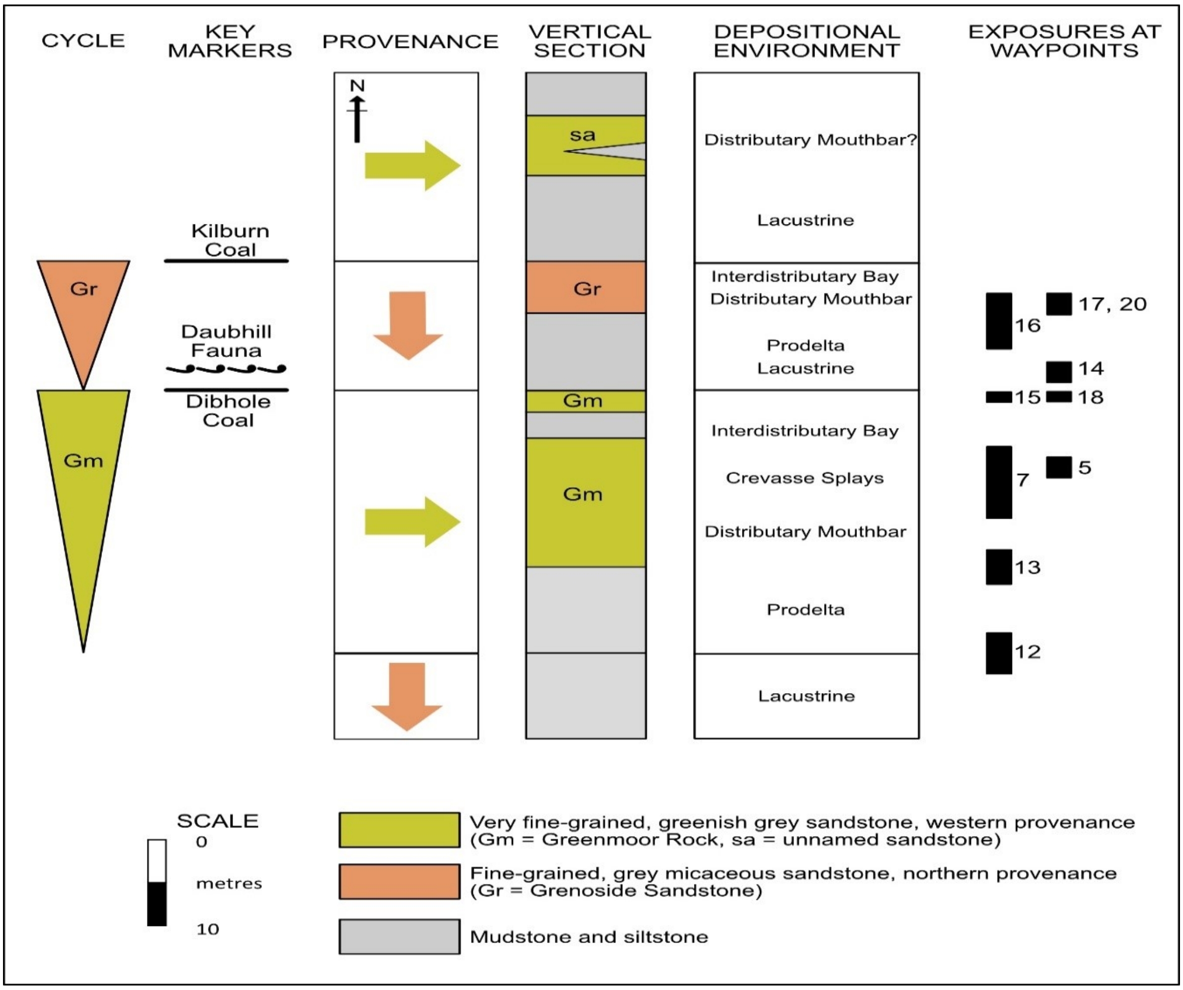

Figure 1*. Geological succession exposed in Graves Park. Key markers occur in correlative exposures elsewhere but are not seen in the Park. Cycles, markers and provenance after Chisholm (1990) and, Hallsworth and Chisholm (2000, 2008). Waypoints correspond to locations in the itinerary.*

Stratigraphically, the sandstones occur in the lower half of the Pennine Lower Coal Measures of Langsettian (Westphalian A) age, internationally recognised as part of the Bashkirian stage of the Pennsylvanian (Upper Carboniferous) sub-system. The Grenoside Sandstone is overlain locally by the Grenoside Sandstone Coal, which is the locally named equivalent of the Kilburn Coal of the East Midlands, the Better Bed Coal of West Yorkshire and Arley Coal of Lancashire. This was the lowest coal in the Pennine Coal Measures succession to be extensively worked in deep pits in the East Pennines Coalfield, though lower coals were mined locally, especially close to outcrop.

The Greenmoor Rock, Grenoside Sandstone and other interbedded and overlying sandstone units are resistant beds that form a series of escarpments ascending in a general NW to SE direction across the Park, illustrated well by the oblique aerial imagery available in Google Earth™ (Fig. 2). The Greenmoor Rock and Grenoside Sandstone form the major escarpments, which have extensive, southward-facing dip slopes that underlie much of the area of the Park. Thinner sandstones between and above these two units form smaller-scale escarpments. The Greenmoor Rock was formerly quarried for walling stone and flagstone in the Park and is locally exposed in these former excavations. A larger, former flagstone and building stone quarry in Greenmoor Rock (Fig. 7) is located immediately to the west of the Park at Meadowhead, now occupied by a large (Morrisons) supermarket. The Greenmoor Rock, Grenoside Sandstone and underlying/intervening mudstones are intermittently exposed in the deep ravine between the ornamental lakes and Cobnar Wood, and in the tributary gullies, though there are many unexposed gaps. Strata above the Grenoside Sandstone crop out in the south of the Park but are not exposed.

***Figure 2**. Eastward oblique Google EarthTM image of Graves Park showing outcrop of sandstone beds (Gm = Greenmoor Rock, Gr = Grenoside Sandstone, sa = un-named sandstone units). Image from Google Earth App, iPadOS version, Copyright Google.*

The Pennine Coal Measures Group of the Sheffield area is deformed into a series of WNW-ESE trending anticlines and synclines with generally gentle dips of less than 10 degrees (Fig. 3). Faults follow a similar WNW-ESE trend and have displacements of a few tens of metres or less. Steeper dips are associated with the SW-NE trending, SE facing Don Monocline, a Variscan inversion structure with an inherited basement control on its orientation. Graves Park is located on the southern limb of the Norton-Ridgeway Anticline, with typical dips of 5-7 degrees to the south or SSE. Faulting is minor, with one small normal fault mapped in the Park with a maximum downthrow to the east of about 4 metres.

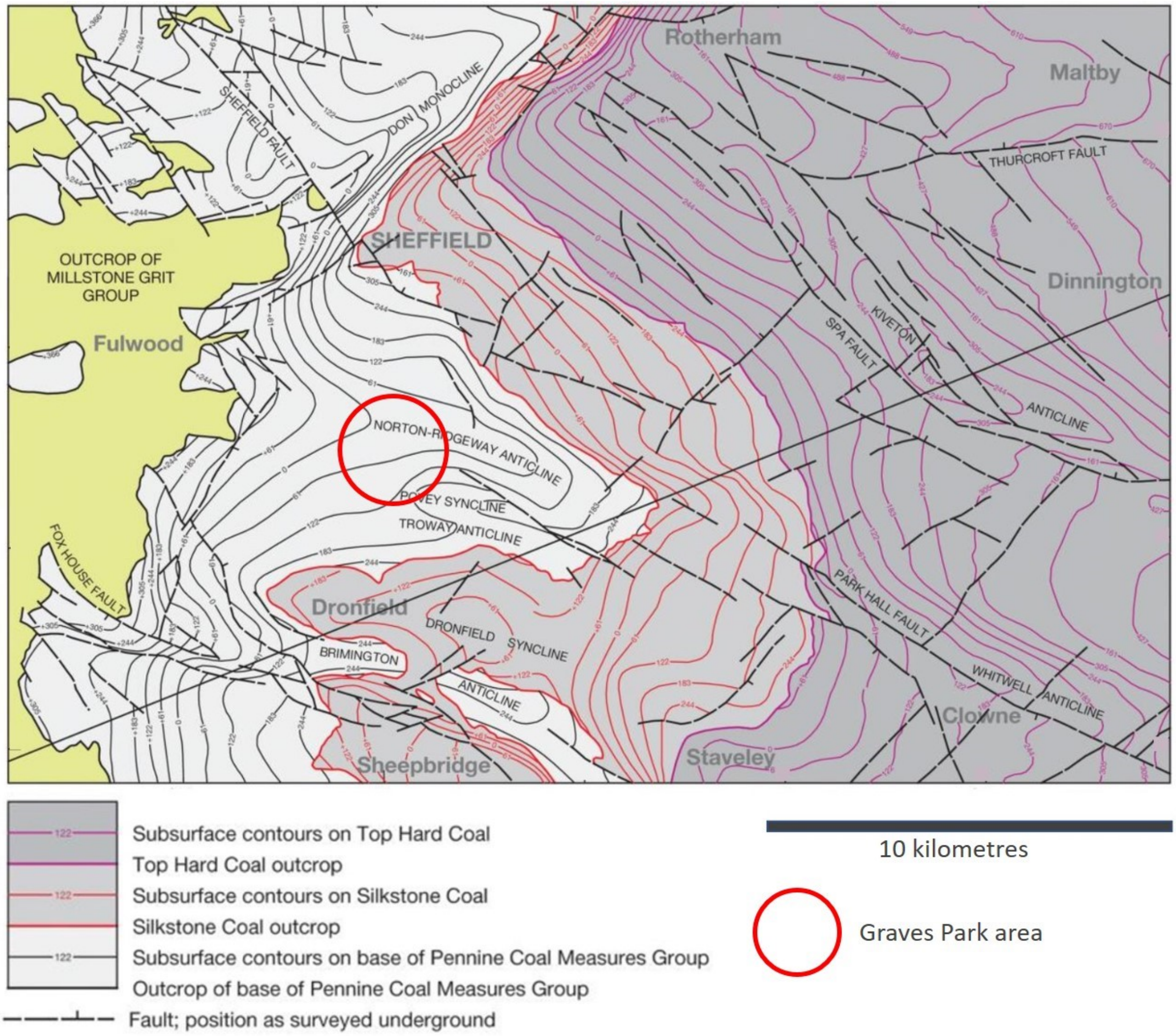

Figure 3. *Geological structure of the Sheffield area, circle shows location of Graves Park. Contours in metres relative to sea level, '+' prefix denotes above sea level. Modified from British Geological Survey England and Wales- 1:50,000 Sheet 100 (Sheffield), with permission of the BGS © UKRI CP20/081* *https://webapps.bgs.ac.uk/data/maps/maps.cfc?method=viewRecord&mapId=9315*

Drainage in this part of Sheffield typically follows a classic trellised pattern, with strike-parallel drainage flowing between sandstone escarpments subsequently captured by headward erosion of springs and deeply incised streams that exploited local zones of weakness (jointing and/or faulting) in the steep, sandstone scarps. The principal brook that drains Graves Park is one such example, initially flowing to the SSW along strike before turning sharply to a north-westerly course through the deep ravine in the Greenmoor Rock scarp in Cobnar Wood.

The Sheffield area was not glaciated during the last (Late Devensian) glacial episode but was subject to cold climate, periglacial processes. Periglacial slope deposits ('Head') mantle the lower scarp and dip slopes of the Greenmoor Rock and Grenoside Sandstone escarpments, and locally floor the deep ravine in Cobnar Wood. A landslide in the north west corner of the Park was probably initiated during late glacial or early post glacial freeze thaw, but shows signs of recent mudslide activity (see below). Man-made deposits in the park include spoil from quarrying of the Greenmoor Rock, dams to retain the ornamental ponds and terracing for sports pitches, tennis courts, bowling greens and pitch and putt golf. Ridge and furrow to the south of Bolehill Farm and in the lower ground in the north-western part of the park probably originates from medieval farming practices and pre-dates the extensive landscaping of the Norton Estate.

Sedimentology and provenance of the Greenmoor Rock and Grenoside Sandstone

Patterns of sedimentation in the early Carboniferous (Visean) in northern England were controlled by active rifting, with shallow water carbonate platforms forming on fault-bounded 'blocks' and deeper water clastic sediments deposited in intervening 'basins'. Active rifting had ceased by the Namurian, to be replaced by regional, thermal sag subsidence. The Namurian succession records the successive southwards infilling, by prograding deltas, of the block and basin seafloor topography inherited from Visean rifting. By the end of the Namurian, this inherited topography had largely been filled, so that Westphalian strata do not display the major lateral changes in thickness and sedimentary facies seen in the earlier Carboniferous succession. The Westphalian Pennine Coal Measures Group accumulated in a more gradually subsiding regional depocentre, the Pennine Basin, in which lateral thickness variations were largely controlled by differential compaction of underlying strata. The Basin lay at equatorial latitudes with a hot and wet climate, and sedimentation of the mudstones, sandstones and coals of the Coal Measures took place in a mosaic of freshwater lakes, river channels and mires on a perennially waterlogged delta plain. Rivers drained through the Basin and have been proposed to exit into a contemporary southern North Sea basin where they interacted with fluvial systems flowing from the north (Rippon, 1996). During periods of higher sea level, the sea appears to have transgressed westwards from eastern Europe (Rippon, 1996), possibly from a marine basin located in western Russia, and the Basin was flooded to form marine bands.

The Westphalian succession in the Pennine Basin records several major changes in fluvial drainage patterns and sediment provenance over time (Hallsworth and Chisholm, 2000; 2008, Waters *et al.* 2020) (Fig.4). The succession in Graves Park displays one of these major changes, which took place just before the deposition of the Kilburn Coal and its equivalents, around mid-Langsettian times (Fig.1). Earlier Langsettian sandstone beds are predominantly grey in colour, contain abundant mica flakes and plant fragments and contain a suite of detrital heavy minerals indicating derivation from denudation of highly metamorphosed Caledonide Terranes lying distantly to the north. This detritus was then transported southwards, ultimately entering the Pennine Basin via distributary river channels flowing from the north or locally from the east. This pattern changed with the incoming of the Greenmoor Rock, which represents the first incursion during the Langsettian of detritus derived from lower grade (greenschist facies) metasediments to the west – similarly sourced sediments had entered the western part of the basin and were deposited as the Haslingden Flags during the earlier Yeadonian (late Namurian). These westerly sourced sands have a pale greenish grey tint due to the presence of chloritic clay minerals, and are generally finer grained and contain fewer and smaller mica flakes and plant fragments than the northerly derived sandstones, with a markedly different heavy mineral suite. Palaeocurrent measurements generally confirm flow directions from the west. The Grenoside Sandstone marks a brief return of sediments of northern provenance in the northern part of the East

Pennines Coalfield, though equivalent strata in the East Midlands including the Bole Hill Sandstone maintain deposits of western provenance. Western provenance sediments became firmly established throughout the remainder of the Langsettian and much of the overlying Duckmantian (Westphalian B).

This major change in sandstone provenance also broadly coincided with a basin-wide change in depositional setting, associations of sedimentary facies and style of sedimentary cyclicity. Below the Kilburn Coal, marine bands are common and coals are generally thin, discontinuous and of poor quality. A lower delta plain environment is inferred (Guion and Fielding, 1988), subject to more frequent, glacio-eustatic marine incursions. Above the Kilburn Coal, marine bands become much less common, and coal seams are abundant, thick and of good quality, though with many splits. An upper delta plain environment is inferred (Guion and Fielding, 1988), which was more distant from marine influence. A return to a lower delta plain environment in the late Duckmantian, above the Maltby Marine Band, likewise coincided with another major change in sediment source, in this case to a south-easterly provenance (Fig.4).

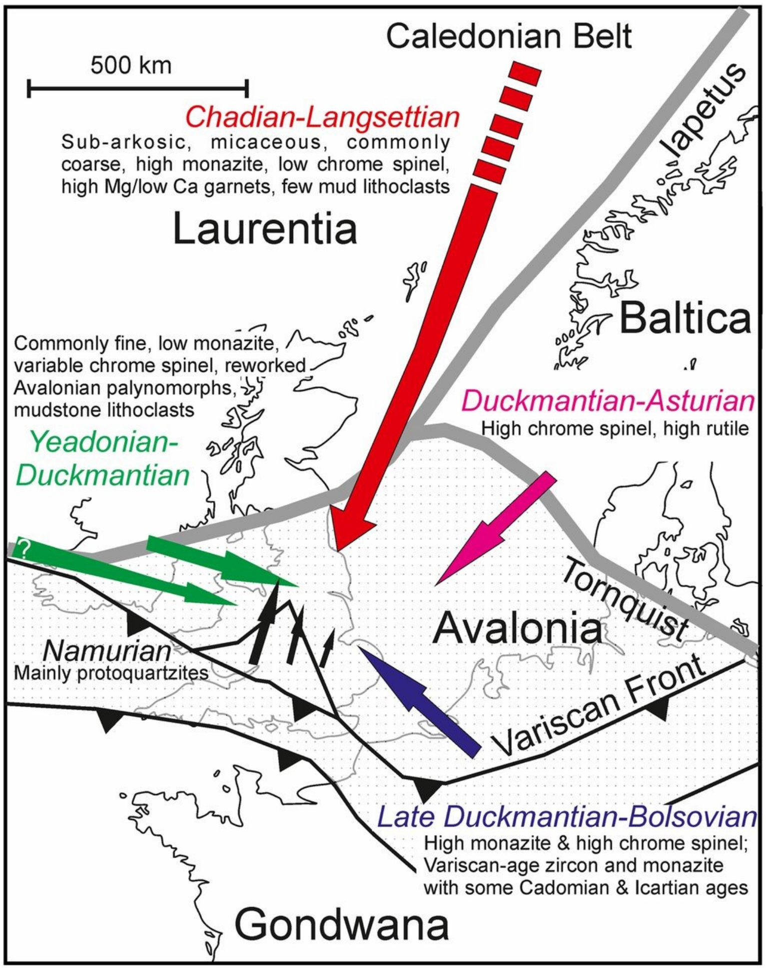

Figure 4*. Plate tectonic reconstruction during the later parts of the Carboniferous showing key changes in sediment provenance over time. Reproduced from Waters et al. 2020 Figure 5 and sources referenced therein, by permission of the Council of the Yorkshire Geological Society.*

Glacio-eustatic sea level change influenced sedimentation throughout the Carboniferous, but became an important driver in the Westphalian as the influence of tectonics declined. Sea level change drove the development of cyclic patterns (‘cyclothems’) of sedimentation that can be correlated throughout the basin. A classic, glacio-eustatic Pennine Coal Measures cyclothem commences at the base with a marine band, typically an organic rich, dark mudstone with goniatites, marine bivalves and Lingulid brachiopods. Marine bands represent maximum flooding surfaces when the rate of relative sea level rise was at its highest. When relative sea level began to fall slowly and the sea retreated, brackish and freshwater lacustrine environments took over and mudstones with non-marine bivalves, fish and crustaceans ('*Estheria*') were deposited. As relative sea level began to fall more quickly, delta lobes prograded into the lakes, with prodelta silts passing up into distributary mouth sands to form an upward coarsening succession. If relative sea level fall was sufficiently rapid, distributary channels were incised into the underlying prodelta and mouth bar sediments. As relative sea-level reached its lowest point, a suite of fluvial deposits including channel sands, crevasse splays and overbank flood deposits were laid down on the delta plain, overlain in turn by palaeosols with roots (seatearth and ganister). As sea level started to rise again, base level and water tables also rose, denudation rates declined and thick peats accumulated in bogs and mires, which were eventually buried and compressed to form coal.

Marine bands only formed during the most extreme sea level highstands and are the most common component to be missing from a cyclothem; more than 80% of the 100 or so cycles recognised within the East Pennines Coalfield contain non-marine shales at their base. It is probable that deposition in these cyclothems occurred in areas distant from marine influences in the upper delta plain association, with the cyclicity reflecting delta lobe switching, augmented by local compactional influences. Those cyclothems generated in response to sea-level rise are on average 50% thicker than lacustrine cycles, suggesting that the sea-level rise provided greater accommodation space for the deltaic sediments to accumulate. The succession in Graves Park includes two major cyclothems which, although devoid of marine bands, can be correlated throughout the Pennine Basin (Chisholm, 1990). The lowest, termed the Greenmoor cycle by Hallsworth and Chisholm (2000), includes the Greenmoor Rock and is capped by a thin coal seam, the Dibhole Coal. The upper cycle, termed the Grenoside Cycle by Hallsworth and Chisholm (2000), includes the Grenoside Sandstone and is capped by the Grenoside Sandstone (= Kilburn) Coal. Figure 1 illustrates the succession proved by mapping in Graves Park and the parts of the succession that are currently exposed and described in this itinerary.

Introduction to the itinerary

The itinerary typically takes about 3-4 hours to complete, and follows a series of Waypoints (click here to view an online map) around Graves Park, starting at the Bunting Nook Car Park (pay and display) (Grid Reference SK 3579 8258). A smaller (currently free) car park can be accessed via Charles Ashworth Road, though is usually full at evenings and weekends.

Refreshments and toilets are available within the Park at the Rose Garden Café, at the neighbouring Morrisons superstore at Meadowhead, and at a Costa Coffee outlet near the Cobnar Road entrance to the Park.

Most of the itinerary follows tarmac paths or mown grass, though the ground may be uneven and slippery near some of the exposures so walking boots are recommended. There are no high faces and hard hats are not required. There is ample loose scree material at most of the exposures that enables lithologies to be examined. Please do not hammer or remove in situ material.

The Park is often very busy, especially at weekends when sports matches and other recreational events may be held. Local park users will often take an interest in visiting geological parties and may be very knowledgeable about the history of the Park.

Itinerary (see Fig. 5 for map)

From Bunting Nook Car Park (**Waypoint 1, SK 35787 82583**), walk south-westwards along the tarmac path towards the Rose Garden Café (**Waypoint 2, SK 35569 82490**). The steep wooded slope to the north of the path is a scarp formed by the Grenoside Sandstone and underlying mudstones. To the south, the remarkably even and smooth dip slope of the Grenoside Sandstone extends southwards as far as a series of ornamental ponds. The 5 metre-spaced contours on this slope on the OS Explorer™ Map are a near approximation to structure contours on the upper surface of the Sandstone. The contours are spaced at 55 metre intervals, indicating a dip slope inclination of 1 in 11 or 5 degrees, approximately towards the south.

Looking directly down the dip slope along the top surface of the sandstone indicates that the boundary with the overlying mudstone is likely to crop out below water level in the ornamental ponds. It may formerly have been exposed in the valley side before the ponds were filled when the Park was landscaped in the 19th century.

From the Café, take the steep wooded path towards the north-west, down the scarp slope of the Grenoside Sandstone. Once on open ground, take the tarmac path that heads north-westwards towards the Cobnar Road exit/entrance to the Park. Ridge and furrow and the remnants of former field boundaries are visible in the ground to the west of the path.

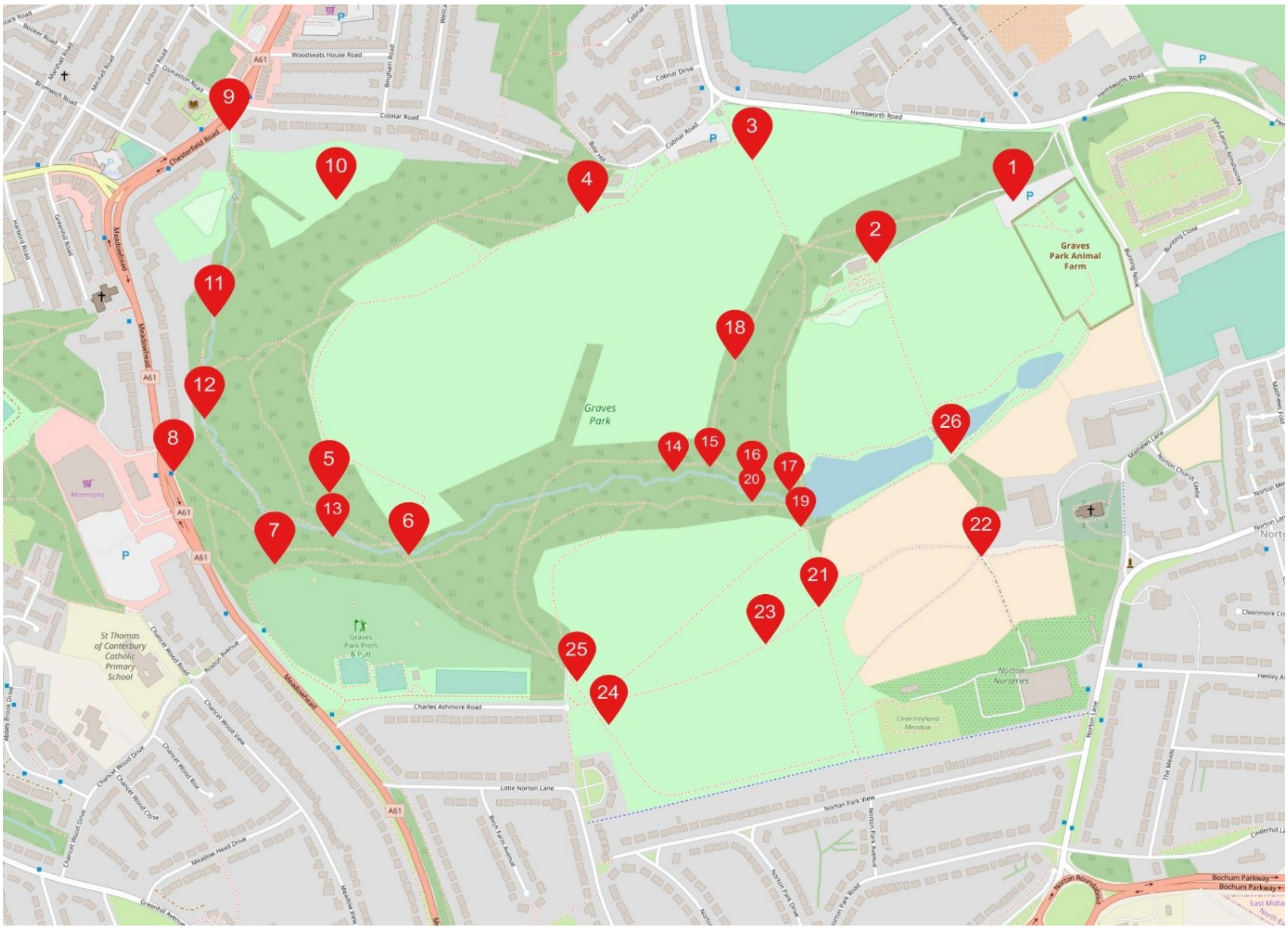

Figure 5*. Map showing location of waypoints flowed by the itinerary. Base map [© OpenStreetMap contributors](). Waypoints can also be viewed in the [OSMaps™ App]().*

Before reaching the exit, a display board beside the path (**Waypoint 3, SK 35432 82621**) summarises the history of the Park. Turn around and look back south-eastwards along the path. A subtle cuesta feature is developed on either side (north-east and south-west) of the path but becomes more cryptic as it crosses the path itself. This scarp is formed by a thin unit of flaggy sandstone that forms the uppermost bed of the Greenmoor Rock and lies close to the top of the Greenmoor Cycle (Fig. 1).

Resume your walk towards the Cobnar Road entrance, turn left (southwest) along the path in front of the large brick and concrete pavilion and proceed past the former Bolehill Farmhouse (**Waypoint 4 SK 35197**

82548). On passing the farmhouse, the steep, wooded scarp slope of the Greenmoor Rock becomes evident to the north-west of the path. Continue south-westwards along the path. The dip slope of the Greenmoor Rock extends southwards from the path for a distance of about 250 metres, but is substantially more uneven than that of the Grenoside Sandstone seen at Waypoint 1 and 2. This is partly due to the dip slope being formed on resistant sandstone beds at various different levels at or near the top of the Greenmoor Rock. Attempts have been made to terrace and flatten the football pitches on the dip slope but substantial gradients remain, no doubt to the considerable home advantage of the local teams.

Head south-westwards along the path for about 300m and then continue to follow the path as it descends into Cobnar Woods. The path swings towards the south and south east as it descends the scarp of the Greenmoor Rock. There are numerous small sandstone quarries on the slopes above the path (**Waypoint 5, SK 34824 82247**) that exploited the Greenmoor Rock for walling and flagstone. There is little exposure in situ but the spoil provides ample opportunity to examine the lithology of the Rock. The sandstone is typically very fine-grained and weathers pale brownish grey, but fresh samples are pale grey with a (subjective) greenish tint. The sandstone can easily be split along planar laminated surfaces, some of which may be slightly micaceous with very small flakes and small plant fragments. Some blocks have current rippled surfaces with rib and furrow structure on bedding planes.

Continue downslope along the path into Cobnar Wood ravine until you reach the brook (**Waypoint 6, SK 34957 82117**). Ignore the first path to the right (west) before the brook. Cross the brook, turn sharp right and continue westwards along an unmade path (marked as a public footpath on the OS Explorer™ and Landranger™ Maps). This leads to a former quarry (**Waypoint 7, SK 34794 82105**) (Fig. 6), once used as an open air theatre. The upper beds (about 5m) of the Greenmoor Rock are exposed. Please do not hammer the in situ exposures. Flaggy, planar and current ripple laminated, slightly greenish grey sandstones pass upwards by alternation into thinner bedded, silty and argillaceous sandstones with low amplitude ripples. Siltstones with thin sandstone beds are exposed in places towards the top of the face. The succession in the quarry probably represents the gradual filling of an interdistributary bay, initially by mouth-bar sands of a distributary channel, with overlying crevasse splay sheet sands gradually passing up into lower energy overbank flood deposits.

Figure 6*. Exposure of the Greenmoor Rock in a former sandstone quarry at Graves Park, Sheffield (Waypoint 7).*

In winter months when there is no deciduous leaf cover, the dip slope of the Greenmoor Rock is clearly visible on the opposite side of the Cobnar Wood ravine. Take the path westwards from the quarry and leave the Park via a small gateway onto the main A61 Chesterfield Road (**Waypoint 8, SK 34670 82216**). On the opposite side of the road, the Morrisons supermarket occupies a large, former quarry in the Greenmoor Rock. The former exposures in the car park are screened by mesh and exposure is now poor, but 10m faces of sandstone were formerly exposed with minor N-S oriented faults (Fig. 7).

Figure 7. *Photograph P201122 – Former Flagstone Quarry in the Greenmoor Rock, Meadowhead, Sheffield, looking NW. The site is now occupied by Morrisons supermarket. From British Geological Survey Geoscenic imagebase, [Photograph P201122], date May 1911, reproduced by courtesy of the British Geological Survey (N.B. the image in Geoscenic is reversed).*

Head northwards and downhill for about 500m along the pavement on the east side of the A61 road. The road descends the scarp slope formed by the Greenmoor Rock. Re-enter Graves Park via the entrance immediately before the junction with Cobnar Road (**Waypoint 9, SK 34744 82646**). The scarp slope of the Greenmoor Rock rises steeply to the south-east of the entrance. Ascend the grass-covered lower slopes of the scarp. These have a gentle hummocky morphology with ridge and furrow, and are underlain by landslip deposits. Near the foot of the tree line (**Waypoint 10, SK 34871 82548**), a lobate mudslide deposit overlies (and hence post-dates) the ridge and furrow. The landslide backscarp forms a broad amphitheatre on the steeper and tree-covered upper scarp.

Re-trace your steps back downslope, re-join the path and head southwards into the Cobnar Wood ravine. Downstream of the first footbridge, small exposures of steeply dipping mudstone in the brook indicate the effects of valley bulging (**Waypoint 11, SK 34717 82300**). About 100m upstream, between 2 footbridges, mudstone and siltstone are exposed in a 5m high face (**Waypoint 12, SK 34703 82285**). The lower half of the face is formed of moderately fissile, dark grey mudstone. About half way up the face there is an abrupt change to paler grey silty mudstone with a greenish tint. This transition marks the first incoming of sediments with westerly provenance within the Greenmoor Cycle (Fig. 1), and the base of the upward-coarsening succession culminating in the Greenmoor Rock.

Figure 8*. Lower beds within the Greenmoor Rock, displaying climbing ripple lamination deposited in a pro-grading distributary mouth bar setting. Graves Park, Sheffield, Waypoint 13.*

Continue up the brook side path as it swings south-eastwards. At **Waypoint 13** (**SK 34879 82128**) (Frontispiece), the sharp base of the Greenmoor Rock is exposed in a low face adjacent to the path, at an elevation about 5m below the exposure in the quarry previously described at Waypoint 7. Below the sandstone, an upwards coarsening 1.5m succession of laminated, very fine sandy siltstone probably represents pro-delta deposits. The overlying Greenmoor Rock consists of about 1.5m of very fine pale grey sandstone with excellent examples of climbing ripple lamination inclined towards the east (Fig. 8), indicating rapid deposition of sand by eastward-directed, heavily sediment laden flows. This sandstone represents the basal part of the eastwards pro-grading, distributary mouth bar seen at Waypoint 7.

Proceed eastwards along the footpath for a further 500m. The floor of the ravine widens in places and is mantled by aprons of poorly drained Head deposits. At **Waypoint 14** (**SK 35331 82213**), a low cliff exposes about 3m of mudstone disrupted by a fault, though the amount and direction of throw on the fault cannot be determined. At **Waypoint 15** (**SK 35357 82219**), a small tributary gully enters the main brook from the north. **The section between Waypoints 15 and 17 described below can be very slippery underfoot and is not recommended for persons with mobility difficulties, or more generally if the weather has been wet and the brook is in spate. In summer months this part of the ravine may be overgrown with vegetation. If these circumstances pertain, users of this guide should proceed direct to Waypoint 18.**

Bedding planes of very fine-grained wave ripple marked sandstone, some with root traces, are exposed in the bottom of the brook at **Waypoint 15**. At this locality a very thin smutty coal can, with some searching, be found resting upon the sandstone, though it is typically obscured by stiff clay of downslope wash material (Head). This probably represents the local equivalent of the Dibhole Coal of Lancashire. These sandstones are also seen at Waypoint 18 (see below). Continue carefully along the foot of the ravine to **Waypoint 16** (**SK 35412 82199**), where a succession of about 5m of mudstone and siltstone within the lower part of the Grenoside Cycle (Fig. 1) are exposed in a steep face below a stone footbridge (Fig. 9). The mudstone is grey in colour and becomes progressively more silty, micaceous and rich in plant fragments upwards towards the base of the Grenoside Sandstone, which is exposed immediately below the footbridge (accessible at Waypoint 20 see below). The mudstones towards the base of the Grenoside Cycle have not been extensively collected here, but equivalents at a comparable stratigraphical level elsewhere in the Pennine Basin yield a copious fauna of non-marine bivalves, known as the Daubhill Mussel Fauna (Chisholm, 1990).

Figure 9*. Exposure of the 'Grenoside Cycle' at Waypoint 16. The prominent resistant bed in the lower part of the section is formed by a strongly cemented calcareous siltstone, grading to very fine-grained sandstone. The Grenoside Sandstone is exposed below the stone footbridge at the top of the section.*

Proceed eastwards along the eastern bank of the brook to **Waypoint 17** (**SK 35465 82197**), where the brook descends a 4m high waterfall formed by the damming of the largest ('Boating Lake') of the three ornamental ponds upstream (NB. this section may be difficult to access if the banks are slippery and overgrown, or if the brook is in spate - care is advised). A low face up the bank to the left (north-west) of the waterfall exposes the lowest 2m of the Grenoside Sandstone (Fig. 10). The sandstone is grey in colour, weathering brown, and is fine-grained with prominent lamination coated by abundant mica flakes and plant fragments. Planar lamination and current ripple lamination dominate, wave ripples and climbing ripple lamination occur but are less common. The trace fossil *Lockeia* isp. (formerly '*Pelecypodichnus*'), which represents the resting trace of a semi- infaunal bivalve, has also been observed here. The underlying siltstones are also highly sandy with mica and plant fragments. The upward-coarsening succession here was deposited by the progradation of a delta lobe, with the lower beds of the Grenoside Sandstone representing distributary mouth bar deposits. Higher beds within the Grenoside Sandstone, which is locally about 6m thick, are not exposed in the Park but elsewhere in the Sheffield area preserve a suite of delta plain deposits including channel levees, crevasse splay sand lobes and abandoned channel fills (Chisholm, 1990). The overlying Grenoside Sandstone Coal, marking the top of the Grenoside Cycle, is also not exposed in the Park.

***Figure 10**. Grenoside Sandstone with gradational base and underlying sandy siltstones at Waypoint 17.*

Looking across the ravine from the exposure above, the basal beds of the Grenoside Sandstone can be traced visually through the face behind the waterfall and along the upper part of the opposite bank. A minor fault adjacent to the waterfall displaces the base of the Sandstone by about 1m down to the east. This fault may represent, or be a splay from, a fault with an eastwards downthrow of about 4m that is mapped in the southern part of the Park (see Waypoint 23).

Re-trace your steps carefully along the brook back to **Waypoint 15.** From here, take the path northwards. This path follows the foot of the wooded scarp slope of the Grenoside Sandstone, located to the east. At **Waypoint 18** (**SK 35390 82316**), if the weather is dry, bedding planes of sandstone can be examined in the gully that runs along the western side of the path. Some bedding planes display ripple marks and higher beds (upstream) contain rootlets. The sandstone lithology is comparable to the Greenmoor Rock, and this sandstone probably lies close to the top of the Greenmoor Cycle. These sandstones give rise to the small cuesta between the Greenmoor Rock and Grenoside Sandstone, previously observed from the vantage point of Waypoint 3. From the path, the southwards facing dip slope formed on the top of this sandstone is visible to the west, through the hedgerow.

Continue along the path as it curves around towards the northeast. Return to the Rose Garden Café, re-ascending the scarp of the Grenoside Sandstone. Take the path south-westwards from the Café. This path follows the crest of the Grenoside Sandstone as it curves around to the south. The southerly dip slope of the Sandstone is visible to the east, the wooded scarp slope to the west. Continue to the largest of the three ornamental ponds, formerly a boating lake, and enjoy a rendezvous with the ducks. Cross the dam. At the southern end of the dam (**Waypoint 19, SK 35502 82158**), turn right (west) and proceed along a narrow tarmac path. After about 50m, cross a small footbridge. About 1.5m of Grenoside Sandstone, including its base, is exposed in the gully below the bridge (**Waypoint 20, SK 35415 82177**). This overlies the succession previously described at Waypoint 16.

Retrace your steps back to the boating lake dam at Waypoint 19. Take the path that heads uphill to the south. The path ascends two distinct crest features, most likely formed by two relatively resistant, unnamed sandstone beds separated by less resistant mudstone or siltstone (though none of these lithologies are proved by exposures in or near the Park). At a 'crossroads' in the path at **Waypoint 21** (**SK 35522 82045**), take the path to the northeast which follows the crest of the second (upper) sandstone feature. The scarp slope lies to the north of the path. A dip slope, inclined at about 5 degrees down to the south, extends southwards from the crest for a distance of about 100m. At **Waypoint 22** (**SK 35730 82112**), turn sharply south-westwards to proceed along another path. The inflection at the foot of the dip slope, marking the outcrop of the top of the sandstone bed, crosses this path obliquely about 150m south east of Waypoint 22.

Continue south-westwards along to the path for a further 150m, then turn right (northwards) to walk back up the dip slope, returning to the crossroads at Waypoint 21. Turn left (south-westwards) and follow the path along the crest of the sandstone feature. After about 100m **(Waypoint 23, SK 35408 81969)**, the crest dies out quite sharply. This marks the outcrop of a minor fault, shown on the BGS 1:50,000 Sheffield Sheet 100 (British Geological Survey, 2011). The fault trends approximately N-S, with a downthrow to the east of about 4 metres. The fault may join that exposed at Waypoint 14, with a splay exposed at Waypoint 17. On the west (relatively upthrown) side of the fault, the outcrop of the sandstone is displaced southwards by about 80 metres. Continue south-westwards along the path. The sandstone crest is hard to follow to the west of the fault, due to the presence of a prominent ridge that follows an old hedgerow and minor landscaping of a cricket pitch. However, at **Waypoint 24** (**SK 35250 81900)**, the crest becomes more prominent below the small cricket pavilion and can be traced from there into adjacent streets.

Return to the path near the small car park at the Charles Ashworth Road entrance to the Park (**Waypoint 25, SK 35198 81923**). Take the path to the north-east. For the first 150m or so, the dip slope formed on the top of the Grenoside Sandstone rises to the north of the path and dips 4 degrees to the south-west. The foot of the dip slope, marking the outcrop of the upper boundary of the Grenoside Sandstone, is slightly gullied. Continue north-eastwards along the path, back to Waypoint 19. Continue along the path that runs along the south-east edge of the 'Boating Lake'. At **Waypoint 26** (**SK 35679 82256**), turn left, cross the dam between the lakes and then proceed north-westwards towards the Rose Garden Café, which ascends the dip slope of the Grenoside Sandstone seen at the start of the itinerary. Treat yourself to a suitable refreshment at the Café (optional) then return to the starting point at the Bunting Nook Car Park.

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