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UK Geoenergy Observatories Glasgow: GGC01 cored, seismic monitoring borehole – intermediate data release

T Kearsey, M Gillespie, D Entwisle, M Damaschke, S Wylde, M Fellgett, A Kingdon, J Burkin, V Starcher, K Shorter, H Barron, J Elsome, M Barnett, A Monaghan

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Summary

This report gives an overview of information related to an intermediate data release of the borehole information pack for UK Geoenergy Observatories: Glasgow borehole GGC01.

The cored, seismic monitoring borehole GGC01 (BGS SOBI number NS66SW BJ 3754, BGS ID 20650619) was drilled between 19 November and 12 December 2018 producing a core of 102 mm diameter. The borehole was wireline logged in December 2018 and a string of 5 seismometers were installed in February 2019.

The core was transported to the National Geological Repository (NGR) at BGS Keyworth and was curated into 1 m core boxes. State-of-the-art core scanners are being used to collect radiographic, CT, optical images, geophysical log and XRF along core datasets. Optical images and radiographic images are included in the intermediate release. Also included are sedimentary, discontinuity and engineering logs.

Contributions to this report and the intermediate data release are as follows:

- Tim Kearsey, Joel Burkin – sedimentary log and stratigraphical interpretation
- Martin Gillespie – discontinuity log
- David Entwisle – engineering geology log, Suzanne Self – drawing up engineering log
- Magret Damascke, Simon Wylde – core scanning and processing
- Mark Fellgett, Andy Kingdon – core scanning, workflow and results
- Alison Monaghan – coordinating intermediate data release

The datasets and descriptions from the initial data release are included in this data release to form the definitive dataset for this borehole. Authorship for the initial dataset was as follows:

- Vanessa Starcher: Technical overview, wireline log data acquisition
- Kirsty Shorter: Fluid and geomicrobiology samples, tracer information, field measurements, photo metadata
- Hugh Barron: On-site core and data acquisition, initial geological interpretation
- Joel Burkin; Geomicrobiology samples, on site core management and initial geological interpretation
- Jack Elsome: Fluid and geomicrobiology samples
- Mark Fellgett: Wireline log data checking and documentation
- Andy Kingdon: Wireline log data checking and documentation
- Megan Barnett: Geomicrobiology samples
- Alison Monaghan: Coordinating initial data pack, initial geological interpretation

IMPORTANT – Note that core and borehole depths given in this intermediate and the initial data release are 'drillers' depths' and have not been depth-shifted to account for intervals of non-recovery. These 'drillers' depths' used for the sedimentary, discontinuity and engineering logs, sample depths, core scan images and labelling of core boxes in the National Geological Repository (NGR) core store (BGS Keyworth) are internally consistent. There are some mismatches of up to *c.*1 m with the downhole geophysical (wireline) log data due to non-recovery intervals and oversized core stick lengths.

Depth-shifts to align log, core box and sample depths with downhole geophysical (wireline) depths are being undertaken such that the final borehole data pack will contain reference to drillers' depths and corrected depths, for studies that require this core-downhole log integration.

1 Introduction

This report gives a short overview of information related to the intermediate data release for UK Geoenergy Observatories; Glasgow borehole GGC01, as well as information included in the initial data release. The cored, seismic monitoring borehole GGC01 (BGS SOBI number NS66SW BJ 3754, BGS ID 20650619, British National Grid reference 260915, 663109) was drilled between 19 November and 12 December 2018 producing a core of 102 mm diameter. The borehole was wireline logged in December 2018 and a string of 5 seismometers were installed in February 2019. A range of fluid, water and core samples were taken during the drilling process.

This intermediate data release includes optical images and radiographic images from core scanners at BGS Keyworth, as well as sedimentary, discontinuity and engineering logs (Figure 1).

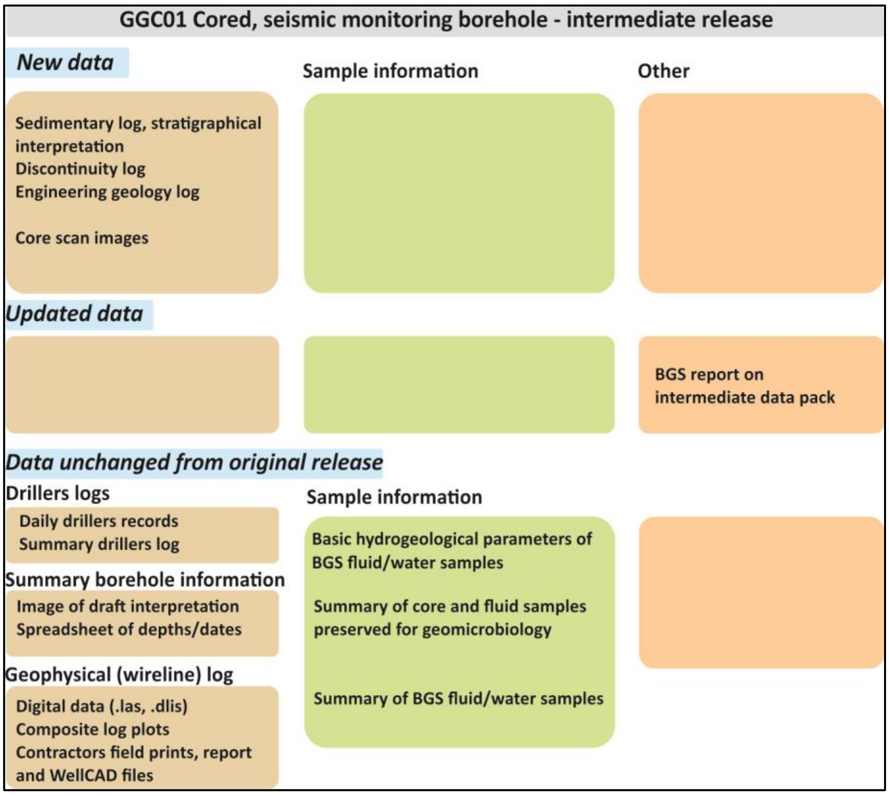

Figure 1 Visual summary of data files within the intermediate data release for the UK Geoenergy Observatories cored, seismic monitoring borehole GGC01.

2 Sedimentary log and initial stratigraphical interpretation

Authors: Tim Kearsey, Joel Burkin

File names: Composite Log GGC01.pdf –overview of sedimentary log, facies interpretation and wireline log (Figure 2 below)

Sedimentary log GGC01.pdf – detailed log with observational descriptions of each interval

Sedimentary log GGC01.xlsx – Excel table of observational descriptions of each interval, used to create the detailed log, plus dictionaries on separate worksheet.

2.1 METHOD

Core GGC01 was made available for sedimentology logging on 8–16 May 2019. The objective was to complete a sedimentological log of the core and to identify the position of stratigraphic boundaries. The core was laid out in the National Geoscience Data Centre (NGDC), at the BGS offices in Keyworth, Nottinghamshire. The core was intact (not sawn) at the time it was examined, and presented in 1-metre sticks sitting in plastic sleeves. The sleeves had been cut lengthwise, so that when the core was laid out horizontally the bottom half of each sleeve supported a core stick and the top half could be removed. Thus, only the top half of each core stick was generally visible. Spacers and labels had been placed in/on the core to note the positions of short (<10 cm) sections of core that had already been removed for testing. There were several other short sections of missing core. Observation of breaks in the sedimentary succession suggest that there is likely to only have been up to ~3m of core loss over the entire length of the bedrock succession in the core. The preservation of the superficial deposits was poorer - commonly present as a wet slurry in the core tubes.

All depths were recorded with reference to the drillers' depths (D.D.) shown on the core boxes.

The objective was to input a sedimentological log description directly into a dictionary-controlled spreadsheet based on the sedimentary logging methodology described by Tucker (2011). Table 1 shows the features that were described for each bed in the logging spreadsheet. This original spreadsheet was then modified for import in to graphical logging software such as SedLog (Zervas *et al.* 2009) and Strater® (Figure 2).

Table 1 Summary of fields used in sedimentary logging spreadsheet. Those with * are dictionary controlled.

Column title	Explanation
Base boundary*	Nature of the base of bed (e.g. erosional, graded etc.).
Bed angle*	Tectonic dip of bedding (e.g. horizontal, gentle etc.).
Lithology*	Bulk lithology of bed (e.g. mudstone, sandstone, coal etc.).
Grading*	Whether the bed is exhibiting normal, reverse or no grading.
Grain-size*	Grainsize of sandstones and mudstones using Wentworth grainsize scale (clay to boulder).
Angularity*	The shape of the dominant clasts in the bed.
Sorting*	Overall sorting of bed from very well sorted to very well sorted
Feature*	Sedimentary features such as symmetrical ripples, trough cross bedding, rip-up clasts, root structurers, siderite nodules etc. Up to five sedimentary features can be recorded per bed.
T Foss*	Trace fossils. Described as being either dominantly, vertical, inclined or horizontal. If specific ichnofauna were identified this was recorded in the notes.
Fossils*	Body fossils only described at class level (e.g. bivalve, brachiopod etc.).
Notes	More detailed description of other features identified in the bed.
Stratigraphic notes	Identification of key marker horizons.

2.2 SUMMARY SEDIMENTARY LOG

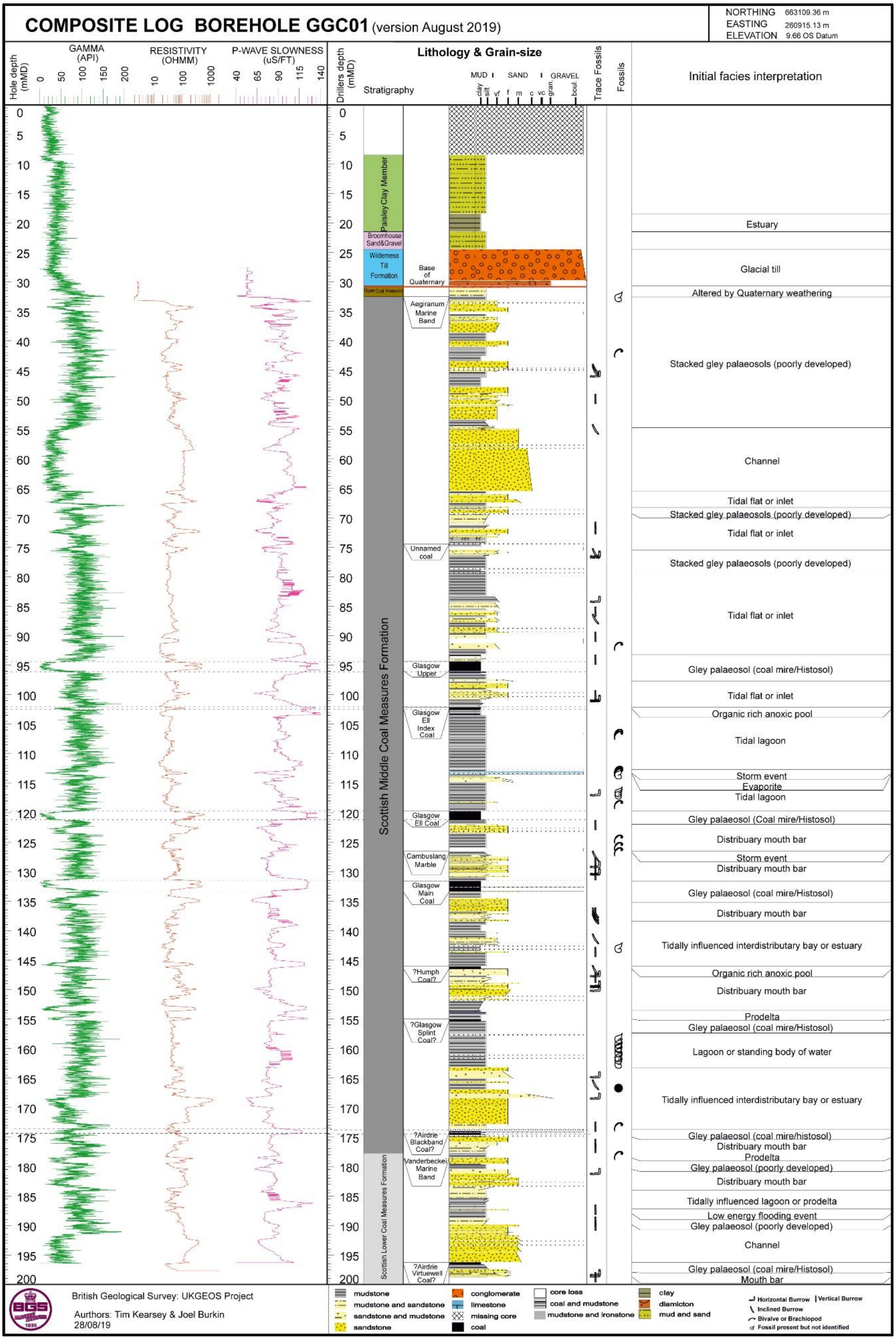

Figure 2 Summary sedimentary log and stratigraphical interpretation of borehole GGC01 measured against drillers' depth used in core logging. Geophysical (wireline) log data against hole depth. An A3 pdf version of this figure is included within the data release.

2.3 SUMMARY OF OBSERVED BEDROCK SEDIMENTARY FEATURES

2.3.1 Sandstones

In the Middle Coal Measures Formation, the vast majority of the sandstones are part of coarsening upward sequences of about 1m thickness, which were not part of channels. These probably represent distributary and distal mouth bars. They are dominated by fine grained sandstone. Flow rolls (Figure 3) are common just below reverse-graded sandstone units which probably formed on a distal bar or prodelta setting (c.f. Thomas, 2013). The tops of the coarsening upward sequences showed evidence of wave reworking and mud drapes suggesting they may have been affected by tidal action.

Figure 3 Flow rolls seen in a sandstone unit in GGC01 core

There are three examples of channelised sandstones in the GGC01 core at 190-196.4 m, 169-173 m, and the most developed at 55-65.5 m (Figure 2). All are normally graded and show a progression from large scale trough cross beds. These present in the core as planar cross beds with foresets up to 30 cm size but show occasional trough cut-offs and thus are identified as trough cross beds. These pass upwards in to trough cross beds and then trough cross ripples. The abandonment facies of the channels, which can be both sandstone and mudstones often is highly bioturbated with a diverse ichnofauna.

2.3.2 Coals and palaeosols

Ten separate stratigraphic named coal beds, ranging from 0.07 m to 1.75m thick were identified in the core. There were also four other minor unnamed coal horizons and six horizons which comprised of a mixture of coal and organic rich mudstones. Many of the coals showed changes in the silt composition throughout and could be divided into separate 'leaves' suggesting changes in the zonation of the coal-forming mire through its evolution (c.f. Thomas 2013) Only the

Glasgow Upper Coal sits on well developed (>1m) clay rich seatearth where pedogenesis has completely destroyed any primary lamination.

Figure 4 Examples of gleyed palaeosols in the core. A) shows examples of carbonized root traces in a gleyed mudstone. B) shows a typical example of well-developed gleyed palaeosol profile. Note the 5cm wide siderite nodules at between 98 cm and 105 cm on the tape measure.

Overall 18% of the bedrock showed some evidence of pedogenesis (e.g. Figure 4), often in the form of carbonised root traces. Most of the palaeosols, including those that are not associated with coals, are very weakly developed and would probably be classified as Inceptisols using the classification proposed by Retallack (1994). There are only a couple of examples of palaeosol B sub-horizons where all primary lamination has been destroyed by soil forming processes (pedogenesis) and these are not all associated with coals, for example the ‘seatearth’ at 43 m.

Siderite and pyrite nodules were common throughout the core but are mostly associated with pedogenesis and tend to be found in palaeosol B horizons which can extend for metres below coal deposits (Figure 4B).

All the coals were intact and there was no sign of mining observed in the core.

2.3.3 Marine bands

Several marine bands were identified in the core, although it is highly likely that some have been missed because the core has not been broken up to retrieve all of its fossil content. The marine bands (as opposed to mussel bands, see below) were all found in the same facies. The bivalves in the marine bands are distributed through up to 40 cm of the mudstone units and are found on many different bedding planes. This suggests they are found close to life position and have not been transported far (Figure 5). The mudstones in which the fossils are found in are parallel laminated and do not show any evidence of bioturbation. As such they may represent a bay or prodelta depositional environment (c.f. Thomas 2013).

Figure 5 Pyritised bivalve shells in a marine band, close to life position.

2.3.4 Mussel bands

Two mussel bands were observed in the core; the deepest being the Cambuslang Mussel Band at 126.55 - 126.72 m (Figure 6) and an unnamed mussel band at 113.03-113.50 m.

The Cambuslang Mussel Band sits directly above a coal-rich palaeosol which it appears to have eroded part of. It contains disarticulated bivalve shells of 1-4 cm size. The shells are normally graded, flow aligned and occasionally show imbrication. This suggests they were deposited by a flow event, or events, which may have carried the shells a considerable distance. The Cambuslang Mussel Band is also called the Cambuslang Marble (Hall *et al.* 1998), but in this core the matrix is dominated by carbonaceous siltstone rather than carbonate.

Figure 6 Cambuslang Mussel Band

2.3.5 Bioturbation

Bioturbation was common in the coarsening upward sandstone sequences. Good examples of *Asterosoma*, and *Diplocraterion* (Figure 7) were found. *Zoophycos*, was common in the top of the distributary bar sequences. It was noticed that the bioturbation was restricted to specific facies and when the organic carbon content of the beds increased past a certain point, there was no longer any evidence of bioturbation, possibly suggesting localized anoxic conditions.

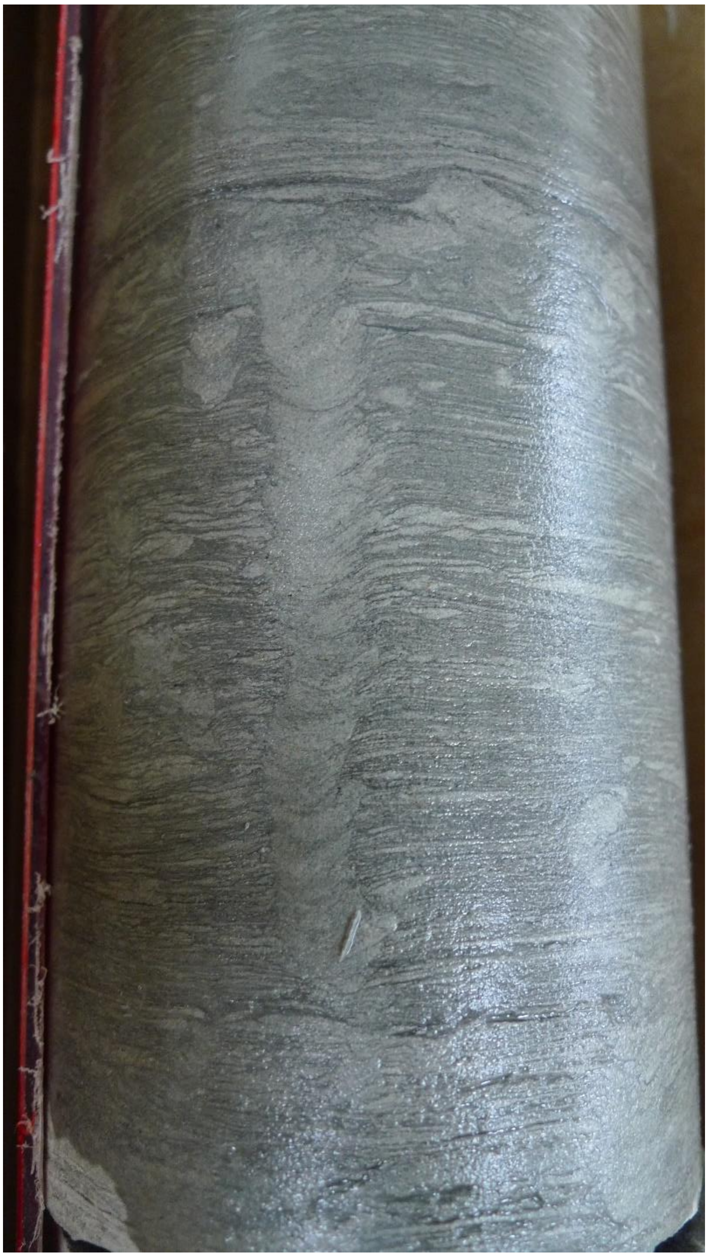

Figure 7 *Diplocraterion* burrows in core.

2.4 STRATIGRAPHICAL INTERPRETATION

2.4.1 Bedrock stratigraphy

The stratigraphic positions of the Glasgow Upper Coal, Glasgow Ell Index Coal, Glasgow Ell Coal and the Glasgow Main Coal were all confidently identified in the borehole (Table 2). Also the position of the Aegiranum Marine Band, which marks the base of the Scottish Upper Coal Measures Formation was confidently identified by comparing the material from GGC01 with the that from the Prospecthill borehole (BGSID: 1068691) which is the stratotype borehole for this boundary in this area (Hall *et al.* 1998). Although individual fossil species were not identified in the band the general fossil assemblage of sponge spicules, foraminifera, and ostracods were diagnostic enough to confidently identify this bed (Figure 8). The interpretation of the Aegiranum Marine Band signifies the base of the Upper Coal Measures and means that a 1.8m short section of Upper Coal Measures is present in GGC01 immediately beneath rockhead. This is consistent with the BGS 1:10,000 scale map (2008)

Table 2 Positions of the bedrock stratigraphic boundaries that were confidently identified in GGC01 (drillers' depths DD),

Horizon	Top depth (m DD)	Base depth (m DD)
Aegiranum Marine Band	32.50	32.56
Glasgow Upper Coal	94.38	95.96
Glasgow Ell Index Coal	102.11	102.40
Glasgow Ell Coal	119.75	121.22
Cambuslang Mussel Band	126.55	126.72
Glasgow Main Coal	131.60	132.60

Figure 8. The Aegiranum marine band in the GGC01 and Prospecthill borehole core.

Below the Glasgow Main Coal, the stratigraphy in the GGC01 borehole becomes harder to resolve. It is noted that in this area the coals below the Glasgow Main Coal often thin, pinch out and split in two separate leaves (Clough et al. 1926). The interpretation presented in Table 3 is based on the projection of the mine workings of the Glasgow Splint and Airdrie Virtuewell approximately 250 m away from the borehole and on correlations with Dalmarnock Pit shaft records (BGS ID 1079959, NS66SW BJ236) from 500 m away. There is an alternative interpretation which would put the lowest coal in the borehole as being the Airdrie Blackband Coal. This difference in interpretation could be resolved if the lowest marine band in the borehole (at 177.73-178.55 m DD) contains fossils that allow it to be confirmed as the Vanderbeckei Marine Band which marks the boundary between the Middle and Lower Scottish Coal Measures .

Table 3 Positions of the bedrock stratigraphic boundaries that were tentatively identified in GGC01 (drillers' depths).

Horizon	Top depth (m DD)	Base depth (m DD)	Alternative interpretation
Humph Coal	146.07	146.50	Minor coal listed on GVS but not named
Glasgow Splint Coal	155.00	155.35	Humph Coal
Virgin Coal	Missing	Missing	
Airdrie Blackband Coal	174.00	174.60	Glasgow Splint Coal
Airdrie Virtuewell Coal	196.60	196.60	Airdrie Blackband Coal

2.4.2 Superficial deposits stratigraphy

In general, the superficial deposits were in a poorer state of preservation than the bedrock and so their interpretation is more difficult (Table 4). At time of logging, the sand units often presented as a wet slurry in the core tubes. The glacial till had fared much better, although radiographic core scans were used to identify boundaries due to the amount of mud covering the outside of the core tubes.

The base of the Quaternary succession was identified using the radiographic core scans. The top 4 cm of the bedrock showed evidence of in-situ frost heave and brecciation.

The glacial till (Wilderness Till Formation) comprised of two separate packages, the lower package being dominated by clasts of mudstone while the upper package being dominated by very poorly sorted sandstone clasts in a sandy matrix. The Paisley Clay Formation was tentatively identified, its thickness possibly underestimated due to the state of the core. Between the Paisley Clay Formation and the Wilderness Till Formation there a sandier unit which in a borehole (BGS ID 1084293) 100 m to the east contains similar unit that has been interpreted as the Broomhouse Sand and Gravel Formation.

Above 8.50m the borehole was open holed drilled so there was no core recovered above this point.

Table 4 Positions of the superficial deposits stratigraphic boundaries that were confidently identified in GGC01 (drillers' depth)

Horizon	Top depth (m DD)	Base depth (m DD)
Paisley Clay Formation	8.50	21.50
Wilderness Till Formation	24.50	29.80
base of Quaternary	-	29.80

2.5 COMPARISON WITH PREDICTIONS FROM PRE-DRILL 3D GEOLOGICAL MODELS

Table 5 shows the difference between the predicted pre-drill depths from 3D geological modelling (Arkley, 2018; Burkin and Kearsey, 2018) and the measured drillers' depths. Depth-shifting after core-downhole log integration may reduce the difference by up to c.1 m.

Table 5 Model prediction versus drillers' depths for key correlative units.

Horizon	Predicted depth (m)	Drillers' depth in core (m)	Difference between predicted and drillers' depth (m)
Top of Wilderness Till	25	24.50	-1
Base of Quaternary (rockhead)	29	30.70	-2
Base of Glasgow Upper Coal	81	95.96	-15
Base of Glasgow Ell Coal	110	121.22	-12
Base of Glasgow Main Coal	116	132.60	-17

The superficial deposits 3D model was reasonably well constrained by legacy borehole data in the vicinity of GGC01 and so it is reassuring that there is a small difference between predicted and drilled depths. The bedrock 3D model was poorly constrained by legacy borehole and mining datasets in the vicinity of GGC01, nevertheless the size of the difference between predicted and drillers' depths for coals is surprising.

However, part of this difference can be explained by significant, locally variable inter-coal seam thickness variations. If the depth of key stratigraphic horizons in GGC01 are compared with the shaft record from the Dalmarnock Pit (NS66SW BJ236, BGSID 1079959) 476 m from GGC01 (Figure 9), surfaces such as the top and base of the Middle Coal Measures are 1-2 m different, yet the coal seams depths differ by 7-9 m. Possible explanations include unrecorded minor faulting or a greater degree of palaeotopography, and thickness variation between units than expected resulting from the relative depositional positions within clinoforms or delta lobes.

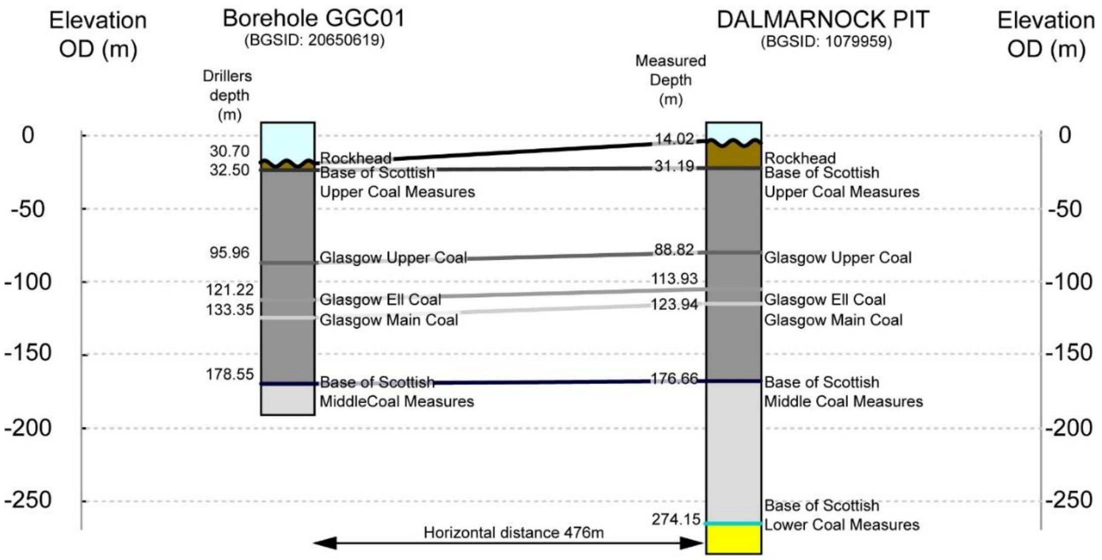

Figure 9 Comparison of depth of key stratigraphic horizons between GGC01 and Dalmarnock Pit shaft record around 500 m away.

3 Engineering geology log

Authors: David Entwisle, Suzanne Self

File names: EngineeringLog_GGC01_1_25scale_v03.pdf – drawn up log

Engineering_core_description_GGC01_V03.xlsx – spreadsheet log

3.1 METHOD

The engineering geology logging took place at the same time as the discontinuity logging at the NGR, Keyworth (section 4 below). Limitations on the handling of, and damage to, core material were in place with the standard field engineering description of BSI (2018a,b) followed as much as was possible.

3.2 SUMMARY OF DATA RELEASE

The data is released both in a spreadsheet and as a log. Note that due to the differing style of logging of boundaries and rock type classification, the sedimentological and engineering log bed boundary depths do not always match exactly.

4 Discontinuity log

Author: Martin Gillespie

File name: Discontinuity_log_GGC01.xlsx

4.1 INTRODUCTION

Core GGC01 was made available for discontinuity logging in two stages: 0–140 m was examined on 20–22 March 2019, and 140–198.69 m (terminal depth) was examined on 10–11 April 2019. The core was laid out in Viewing Lab 5 of the National Geological Repository (NGR), at the BGS offices in Keyworth, Nottinghamshire. The core was intact (not sawn) at the time it was examined, and presented in 1-metre sticks sitting in plastic sleeves. The sleeves had been cut lengthwise, so that when the core was laid out horizontally the bottom half of each sleeve supported a core stick and the top half could be removed. Thus, only the top half of each core stick was generally visible. The core was not orientated, and lacked a core reference line. Lighting (artificial light provided by strip lights) was good.

Core quality in general was reasonably good, though parts of the core (notably those formed of mudstone and coal) are affected by multiple induced and natural breaks and are clearly deteriorating faster than other parts. Spacers and labels had been placed in/on the core to note the positions of short (<10 cm) sections of core that had already been removed for testing. There were several short sections of missing core; some of these appeared to be due to drilling problems, but the cause was not obvious in some cases.

The objective was to prepare a spreadsheet log of natural discontinuities (specifically fractures) in core GGC01, and make a preliminary record of their character. The log spreadsheet is included in the accompanying data release. The logging methodology is described in section 4.2, and a summary of the key observations of discontinuity character arising from this brief examination of the core is presented in section 0.

4.2 METHODOLOGY

The visible part (i.e. top half) of the core was examined visually, using a 10x hand lens where necessary. Core pieces were lifted out of their supporting plastic sleeves temporarily to allow the bottom half to be examined, where this was considered useful and it could be done easily; less than half the core was examined in this way. A solution of 10% HCl was used sparingly to test for reactive minerals (particularly calcite).

The log was created in a Microsoft Excel spreadsheet, with entries in most individual cells controlled by drop-down menus (controlled vocabularies). In most cases, an individual record (row) in the log corresponds to a single discontinuity in the core. However, in some cases, an individual record in the log is used to describe multiple discontinuities (a *set*, *system* or *network*) within a discrete interval of core, usually because the high density of fractures in the interval made it impractical to record each one separately; this was the case in all beds of coal, for example. A summary of the headings and contents of all columns in the spreadsheet is provided in Table 6. The terms used throughout the log, and their definitions, are consistent with Gillespie *et al*. (2011).

Depth information recorded in the log was calculated by measuring the distance (obtained using a tape measure) from the top of a core stick to the logged feature and adding this to the 'drillers' depth' for the top of the stick. 'Drillers' depths' are uncorrected depths assigned by the borehole drillers, which are written on each core box in the National Geological Repository and indicate the top and bottom depth of the core stick.

The depth of logged features was recorded in several ways:

- the mid-point of the top and bottom depths of intersection was recorded for individual features that cut across the core (i.e. do not terminate within it);
- the top and bottom depths were recorded for individual features whose shallowest and deepest limits are contained within the core;
- the shallowest and deepest limits were recorded where details for multiple features (e.g. fracture systems and sets) were included in a single record.

The positions of several short sections of missing core are noted in the log. Unless stated otherwise in the log, it is considered unlikely that previously sampled and missing sections of core contain significant natural discontinuities.

Table 6 Summary of fields used in the Discontinuity Log spreadsheet

Column heading	**Explanation**
No.	The record number, assigned sequentially from the top of the core.
Depth (m)	The depth, in metres, of the logged feature, based on 'Drillers' depths' (see text for explanation).
Discontinuity type	Indicates the type of discontinuity that has been logged. Terms in the controlled vocabulary are: *fracture (undifferentiated)*; *joint*; *slip surface*; *fault*; *deformation-band*; *array*; network; *set*; *system*.
Discontinuity origin	Indicates whether the feature is *natural* or *induced*, based on available evidence.
Dip (º)	The dip of the feature, with respect to horizontal (taken to be 90º to the core axis). In most cases, both a term denoting a bin (a given range) and a measured value are recorded. Terms used in the 'Bin' column are: *horizontal* = 0–5º, *gentle* = 5–30º, *moderate* = 30–60º, *steep* = 60–85º, and *vertical* = 85–90º. The 'Direction' column is for dip direction; this has not been measured, as the core was not orientated, and had no reference line, at the time the log was prepared.
Width (mm)	Indicates the average width of the logged feature, in mm. The option to record a bin (a given range) and a measured value is given, but in most cases only a bin has been recorded. Terms used in the 'Bin' column are: <1, 1–10, 10–100, and >100.
Filling history	Indicates whether the filling history (i.e. mineralization ± dissolution) and/or the displacement history of the logged feature is *simple* (formed through a single operation) or *compound* (formed through multiple operations), based on available evidence.
Filling type	Indicates the type of filling in the logged feature. Terms in the controlled vocabulary are: *vein*, *crust*, *dendrite*, *layer*, *patch*, *spot*, *sediment*, *breccia*, *fault-rock* and *none*.
Filling components	Indicates the components comprising the filling in a logged feature. The controlled vocabulary includes a range of mineral names, terms for different classes of fault-rock, and the term *void*.
P±S	Indicates whether polishing and/or striations (slickenlines) produced by deformation are developed on slip surfaces and other places where the core has parted.
PFF	Indicates (using Y = yes, N = no, and ? = not known) whether the logged feature is considered to be a Potentially Flowing Feature (PFF; following the nomenclature used in Milodowski *et al*., 1995), i.e. a discontinuity that is unsealed, and therefore may be permeable and transmissive.
Comment	Additional, discretionary information, in free text.

4.3 SUMMARY OF OBSERVATIONS

The following summary of observations is based on a brief examination of core. The distribution of key features in the core is illustrated in Figure 10.

- The boundary between Quaternary materials and bedrock was placed at 30.7 m, so the total length of examined core below rockhead was approximately 168 metres.
- Natural discontinuities are distributed unevenly due to an obvious lithological control. Every bed of coal contains numerous thin veins that have exploited the coal cleat system (a dense, subregular network of subvertical and subhorizontal natural fractures). By contrast, natural discontinuities in all other lithologies are sparse; only 97 records of discontinuities, most describing a single feature, were made in 160 metres of core formed of lithologies other than coal.
- In coal beds, veins up to 3 mm thick consist of calcite, an unidentified white mineral (possibly a carbonate mineral that does not react to 10% HCl), and a subordinate proportion of Fe-sulphide, which is fresh or tarnished (Figure 11a).
- Of the 97 ‘features’ recorded outwith the coal beds, 38 are mineralised joints, 18 are non-mineralised joints, 28 are slip surfaces, 10 are faults, and 3 are other types of feature.
  - Mineralised joints are typically <1 mm thick; the thickest simple vein is c.6 mm thick. Calcite is by far the most common filling. Only rare traces of sulphide mineral were recorded outwith the coal beds. An orange mineral – possibly a carbonate mineral or anhydrite – occurs locally (Figure 11b); nodules formed of, or including, the same orange mineral are scattered locally in the host rock. Most veins appear to have a simple filling history; only three were described as ‘compound’ in character (i.e. formed through more than one stage of mineralisation). Mineralised joints are scattered more or less evenly in the core, though concentrated locally. A set of subhorizontal calcite veins occurs between 31.93 and 32.58 m.
  - Non-mineralised joints (core partings with non-mineralised surfaces, which are likely to be natural rather than induced because they are discordant to bedding and/or have slightly weathered-looking surfaces) are relatively common down to 60 m, sparse between 60 and 163 m, and apparently absent below 163 m. This distribution probably reflects a general reduction with depth in the degree to which calcite and other soluble minerals have been dissolved by modern meteoric groundwater. Iron and manganese oxide and oxyhydroxide minerals, which typically are residual products of carbonate dissolution in oxidising water, seem to be largely absent.
  - All but one of the features classified as a fault are of similar character: bands of rock up to 70 cm thick within which cm-scale offsets are discernible and protobreccia (fault-rock formed by very weak cataclasis) may be developed (Figure 11c). All such features, which are a product of very weak cataclasis, are healed, though the offset surfaces in some cases have been exploited by calcite veins. Nine of the ten features described as faults occur between 140 and 180 m, suggesting some or all of them are related. The features probably formed at an early stage in the rock history (during burial?). The apparent dip of such features can be difficult to discern, but there appears to be no consistent or dominant dip amount (steep, moderate and gentle dips were all recorded). One feature, at 178.62 m, consists of a c.3 cm-thick, subhorizontal band of protomylonite developed at the interface between layers of mudstone (above) and sandstone (below). Within this band, flattish 'augen' and variably fragmented layers of sandstone (forming clasts) are enclosed in a dark 'matrix' of deformed mudstone

and organic matter, and the mylonitic fabric undulates but is broadly subhorizontal. The feature is a product of brittle-ductile deformation, but probably due to relatively weak strain in materials of strongly contrasting character.

  - Slip surfaces are partings in the core on which there is evidence for displacement, in the form of tectonic polish and/or striation, but without visible fault-rock. They generally are developed in mudstone beds, which appear to have accommodated much of the (relatively insignificant) strain that has affected the heterolithic sequence. Many partings in the core have formed where the borehole has intersected fossil plant matter lying on a bedding plane, and these surfaces commonly display a striated character that is due to the structure of the plant rather than accommodation of strain. Two clusters of slip surfaces were recorded, one between 32 and 70 m and the other between 140 and 180 m. Both intervals correlate broadly with the position of faults in the core, suggesting a genetic relationship. However, slip surfaces are only observed on core partings, and as such are likely to form a strongly biased dataset in the log.

- Following the nomenclature used in Milodowski *et al*. (1995), any discontinuity that is unsealed, and therefore may be permeable and transmissive, has been labelled a Potentially Flowing Feature (PFF) in the log and on Figure 10. Ten PFFs and twenty possible PFFs were identified. The PFFs are mainly mineralised joints that are either largely mineralised but locally gapped (Figure 11d), or largely non-mineralised but with crusts of euhedral, fine- or very-fine-grained calcite crystals. In the latter case, the calcite crusts form discontinuous patches or scattered spots (giving joint surfaces a weakly spotted character). The possible PFFs are mainly non-mineralised joints. Many PFFs and possible PFFs are 'Type D' structures in the sense of Milodowski *et al*. (1995); that is, they have formed by brittle fracturing adjacent to, and commonly between, one or more sub-parallel slip surfaces (Figure 11e,f). Typically, the brittle fracturing has occurred in sandstone and the slip surfaces have formed in mudstone. The PFFs are distributed broadly evenly throughout the core, while the possible PFFs are mainly between 40 and 60 m, where most of the non-mineralised joints were recorded.

- Very few cross-cutting relationships were observed, from which a fracture paragenesis can be interpreted. However:
  - hairline veins of calcite locally exploit, and therefore post-date, thin deformation bands in some of the features logged as faults;
  - a vein comprising early orange carbonate(?) and later calcite has exploited an earlier hairline vein of calcite;
  - euhedral calcite crystals have grown on the surfaces of some unsealed joints.

- This evidence supports the following tentative fracture paragenesis:
  1. Early weak faulting, possibly associated with development of slip surfaces.
  2. Formation of calcite veins, at least some of which may be contemporaneous with the faults and slip surfaces.
  3. Formation of rare veins of carbonate/anhydrite (?) and later calcite.
  4. Localised dissolution of soluble minerals in fractures (and probably in the rock matrix), most extensively in the near-surface zone, creating PFFs; this is likely to be geologically recent.
  5. Formation of new, euhedral calcite crystals in some PFFs; dissolution of soluble minerals and precipitation of new calcite may be ongoing in different parts of the rock mass.
- Rock matrix permeability was not tested systematically, but much of the sandstone may be permeable. Given the small number of PFFs, and their generally very small apertures,

it seems likely that matrix permeability is more important than fracture permeability in controlling transmissivity in the rock mass. The sandstone seems mainly to be calcite-free, but is calcite-bearing locally around some calcite veins.

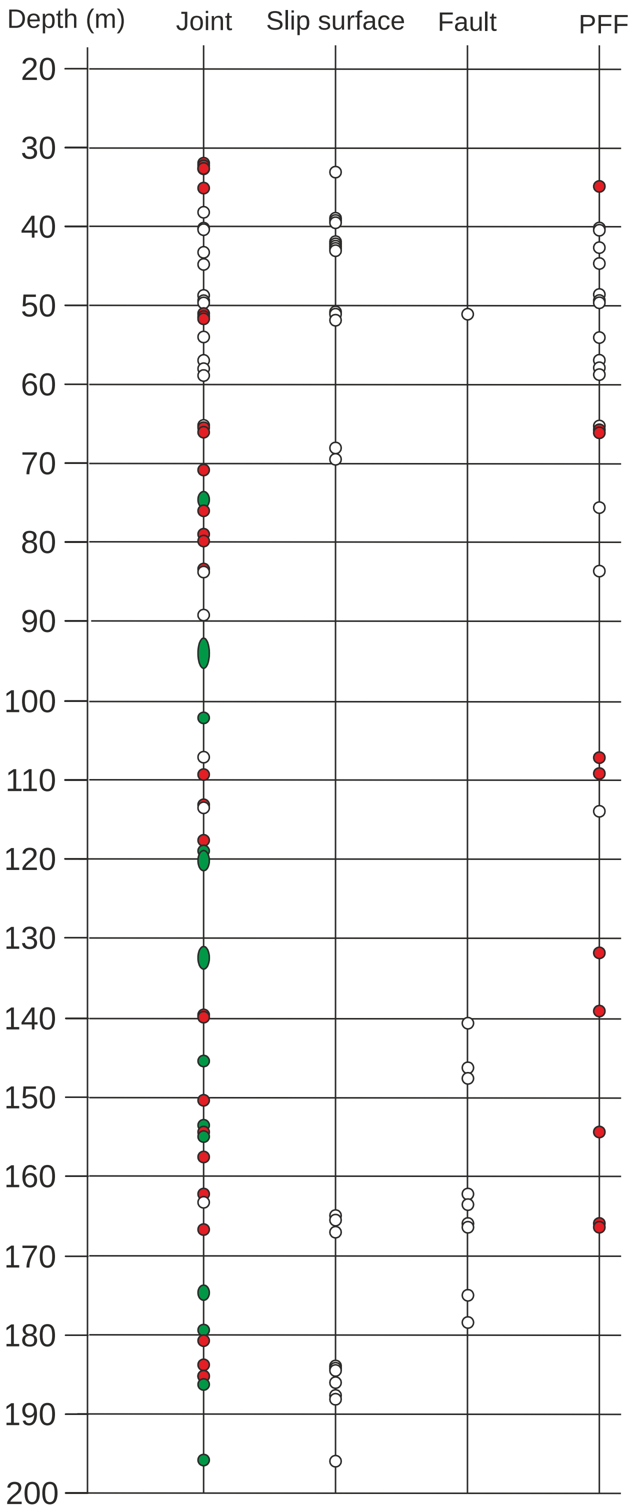

Figure 10 Distribution of logged discontinuities in GGC01 core

PFF = Potentially Flowing Feature. Circle colour denotes feature type: colourless = a single, non-mineralised feature; red = a single, mineralised feature; green = a system of mineralised joints in a coal bed.

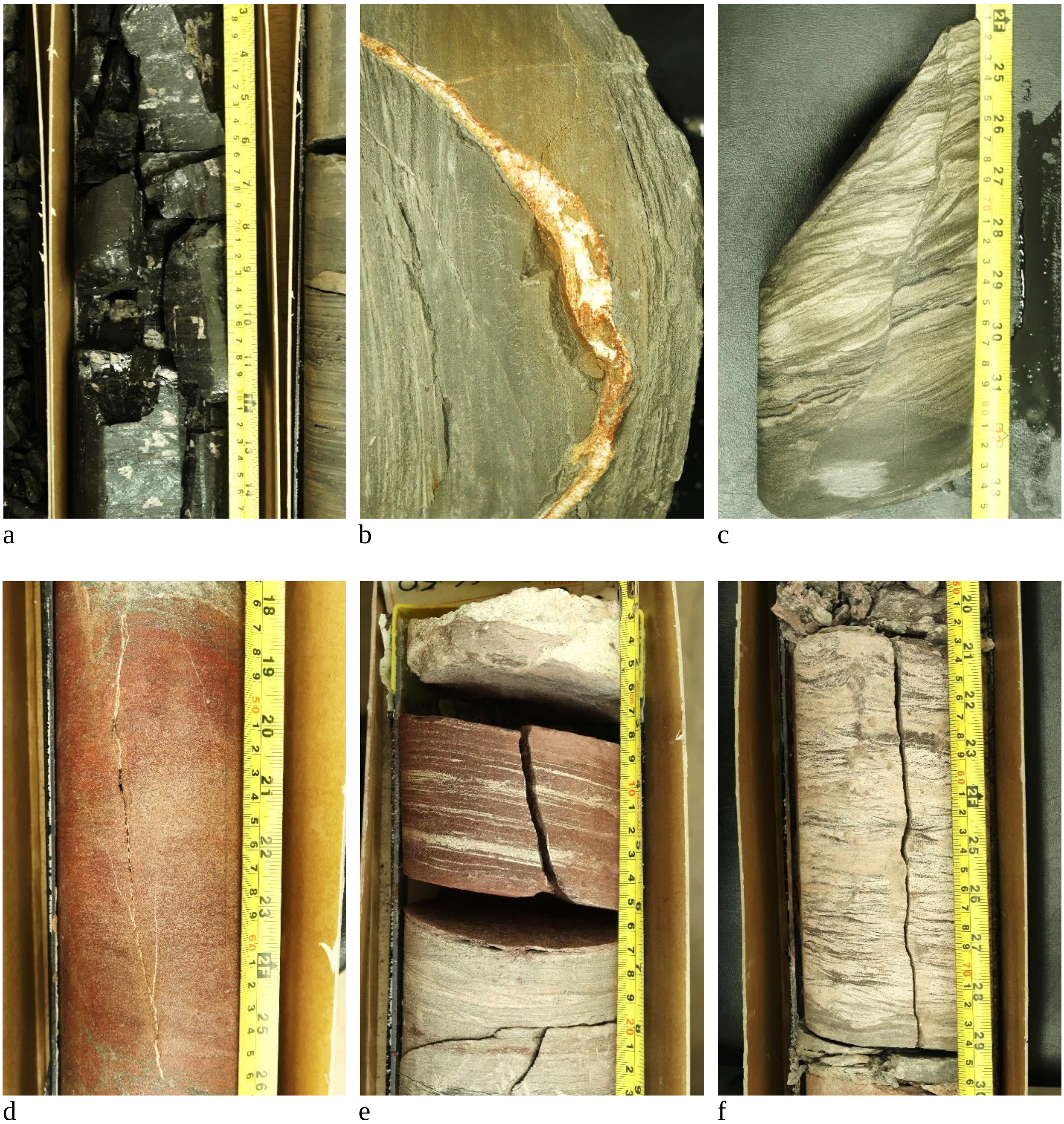

Figure 11 Character of discontinuities in core GGC01

a. A typical coal bed, showing disaggregated core with thin veins of white calcite and Fe-sulphide developed on numerous joint surfaces within the coal cleat system. Log feature no. 78, 132.45-132.63 m. b. A vein of early orange carbonate (or anhydrite?) and late white calcite, which has exploited an earlier hairline calcite vein. Log feature no. 61, 83.06 m. c. A small, healed fault bounded by dark grey deformation bands and containing weakly cataclastic fault-rock (protobreccia), developed in thinly interlayered sandstone and mudstone. Log feature no. 41, 51.20 m. d. A thin, subvertical vein with partial calcite filling, which is naturally gapped in places with possible calcite euhedra developed locally on surfaces, and therefore is classified as a potentially flowing feature (PFF). Log feature no. 16, c.35.0 m. e. A steep joint with moderately rough, weathered-looking surfaces on which dip-parallel slickenlines are developed locally with possible later calcite on top. The joint terminates abruptly against subhorizontal bedding planes, indicating it is a 'Type D' PFF in the sense of Milodowski *et al*. (1995). Log feature no. 50, 65.57-65.64 m. f. A subvertical joint with rough surfaces on which patches of small calcite crystals are scattered. The feature terminates abruptly at both ends against subhorizontal bedding planes, indicating it is a 'Type D' PFF in the sense of Milodowski *et al*. (1995). Log feature no. 51, 66.00-66.22 m.

5 Core scan data

Authors: Magret Damaschke, Simon Wylde, Mark Fellgett, Andy Kingdon

File name: GGC01_Coreboxes_All.xlsx   Index of core box numbers to depths, needed to use the images

Folders containing images:
-Optical images
-Radiographic images
-Radiographic images- coal

The core scan data are a series of measurements and images taken of the GGC01 borehole core using the Core Scanning Facility (CSF) at BGS Keyworth. The CSF contains four scanners which are listed below with links to the technical specifications:

- Geotek Multi Sensor Core Logger Standard (MSCL-S)
- Geotek rotating X-Ray, CT Scanner (MSCL-RXCT)
- Geotek Multi Sensor Core Logger XYZ
- Itrax Multi Core (ITRAX-MC)

The core scan data contained in this intermediate data release comprises the optical imaging collected from the MSCL-XYZ scanner and the 2D radiography collected using the MSCL-RXCT scanner.

In some coreboxes, particularly ones which were sampled at drill site, the core shifted inside the liner. As a result it is strongly advised that the radiography images are used alongside the optical images.

Scanner settings were consistent across the entire length of the core. However to optimise visualisation and interpretation the outputs have been manually scaled and as a result they may not be suitable for automated processing or machine learning techniques. The raw unscaled image data can be requested from (ukgeosenquiries@bgs.ac.uk).

5.1 NAMING AND IMAGE CONVENTIONS

When core arrives at the National Geological Repository (NGR) at BGS Keyworth it is accessioned. This process records the standard core metadata and assigns a core box number to each core stick. The core box number is a unique identifier and links the core box metadata to borehole datasets. The core scan images are named using the core box number. A spreadsheet (*GGC01_Coreboxes_All.xlsx*) has been provided to link the core box number to core depth.

Each image supplied corresponds to one core box of approximately 1 m length. Some core boxes clearly show less than 1 m of core, some contain gaps where during drilling samples were taken and some show core runs slightly longer than 1 m.

The top of the image is the top of the core box, the base of the image is the base of the core box.

5.2 2D RADIOGRAPHY

The 2D radiography data was collected using the Geotek MSCL-RXCT immediately after it was accessioned. Opaque core liners were not opened prior to radiography being taken. The MSCL-RXCT has a rotating source detector arrangement. This allows the core to remain undisturbed during scanning. Three angles were chosen for radiograph acquisition in GGC01.

- 0 Degrees – Source directly above core and detector below

- 45 Degrees – Source and detector at 45 degree angle to the core
- 90 Degrees – Source and detector either side of the core

The three angles give the user information on how fractures propagate through the core, as high angle fractures may not be clear on some orientations.

5.2.1 Density Contrasts

Where there are large density contrasts between materials in the same core box it is not possible to properly image all material. For GGC01, a decision was made to set a source power and current to provide the maximum amount of information over the whole cored section. The result is that rocks with high and low densities are not optimally imaged. For the denser material this problem has been addressed by manually scaling the images to give more information.

Where there are high and low density rocks within the same core box, the scaling process can remove low density material from the image. This is a particular problem with coals and as a result they can appear as sections of core loss. For this reason users are strongly encouraged not to use the radiography images in isolation, but to view them with the optical images.

The scaled images are included as .tiff files in the '*Radiographic images'* folder, three images per core box labelled with the acquisition angle_A0, A45 or A90.

To ensure that the coal sections are properly represented, each box which contained over 15 cm of coal was rescanned with a different source power and current. These images are contained within the '*Radiographic images- coal'* folder.

5.3 OPTICAL IMAGING

The optical images were collected at a resolution of 50 microns. Scanning took place immediately following the radiography scanning, after the opaque core liner had been opened and before discontinuity and sedimentary logging in order to reduce core disturbance. The images have been scaled to allow for interpretation and are included as one .tiff file per core box in the 'Optical images' folder

5.4 FUTURE CORE SCAN DATASETS

The remaining core scan datasets (MSCL-S and XRF) will be included in a final data pack. The core scan images will be re-supplied with a length scale.

______________The information below formed the initial data release (Starcher et al. 2019) and is included in this in intermediate data release for completeness ___________________

6 Drillers' logs

6.1 DAILY DRILLERS' RECORDS

File names: BAA4202-GGC01_DL_page 8(2018-12-04).pdf and similar (17 files)

The daily drillers records were compiled by BAM Ritchies, the drilling contractors, and provide a summary of the operations that take place on the rig during one day. The reports contain information about the amount of rock that was drilled and cored during the day as well as the driller's basic description of the lithology that was encountered – note that this is approximate, as it was through an opaque core liner. Information regarding hole diameter and casing diameter for each section drilled is also shown. The records are produced in the field and have not been reviewed. There are no records for the days where drilling did not take place.

All drilling was advanced using a rotary-cored method with water flush. This involves rotation of the core barrel as it is goes down and the retrieval of a core of material when the barrel is pulled back to the surface.

6.2 SUMMARY DRILLERS' LOG AND FINAL INFORMATION SHEET

File names: GGC01 Final Log 070319.pdf and GCC01 Final info sheets 070319.pdf

The summary drillers' log is a compilation by the drilling contractor of the daily drilling records. Please note the caveats above – that this was an on-site record through an opaque liner (only the ends of the rock core being visible). The final information sheet summarises the information from the daily drillers' records and includes information on the depth of the seismometers installed.

7 Summary initial BGS borehole information

7.1 SPREADSHEET OF DRILL DEPTHS/DATES/CORE RECOVERY

File name: GGC01 Coring data_V6.xlsx

The same information as is presented on the summary drillers' log is contained within a BGS spreadsheet summarising the core runs, basic recovery information and approximate lithology as recorded at the drill site. The depth intervals of the 1 m cores sub-sampled straight after drilling for geomicrobiology and geochemistry investigations are highlighted.

Note that as highlighted above depth correction of some core intervals will be needed in the poor recovery zones to align features visible in the geophysical (wireline) logs and core scans. Revised depth information will be included in the final borehole data pack.

7.2 IMAGE OF DRAFT BOREHOLE INTERPRETATION

File name: BoreholePrognosis_GGERFS10_draft_v9_Preliminary_v2.pdf

This image compares the anticipated geology with the initial interpretation from the drillers'/ BGS record. This interpretation has been greatly improved by subsequent core scanning, core logging and depth matching with the geophysical (wireline) log and is included only as a record of pre- and during-drilling information, for completeness. The depths of the geomicrobiology core samples are shown.

The drilled superficial deposits succession and depth of the lithological rockhead surface was much as expected (these parts of the geological prognosis being well constrained by existing borehole data). The bedrock part of the succession is typical of the Scottish Coal Measures Group. Coal mining is not recorded by mine abandonment plans in the vicinity of GGC01, but mine workings were considered 'possible' based on the records to the east of the site. On drilling, no evidence of mining was encountered in the borehole and several thick intact coals were cored.

Initial comparison of the drillers/ BGS lithological records and the wireline logs indicated that there are additional coals present that were not observed during drilling operations (being inside the opaque core liner). These were confirmed on the full logging of the core, as presented in sections 2-4 above in this intermediate data release.

8 Geophysical (wireline) logs

Geophysical logging is the process of measuring the properties of a formation using sensors attached to a winch cable (wireline) suspended in the borehole. Measurements are made continuously down the borehole by raising or lowering the sensor tools. The property measurements are then converted to a standard series of geophysical logs including: Density, P-Wave Transit Time, Neutron Porosity etc.

Description of geophysical logging technology is beyond the scope of this report, there are a number of textbooks which cover the acquisition and interpretation of wireline logs including: Serra (1983); Hearst et al. (2000) and Ellis and Singer (2007). Wireline logs have also been used extensively as part of the Integrated Ocean Drilling Program with a number of resources available online[1].

8.1 LAS FORMAT FOR CONVENTIONAL LOG DATA

File name: GGC01_Composite_Certified.las and 6 similar named files

Conventional geophysical logs are provided in LAS format[2], version 2.0. This is a column separated ASCII format. Almost all specialist logging software is capable of loading and interpreting geophysical log data in LAS format. In addition to this LAS files can also be viewed in any software capable of manipulating an ASCII text file, including Notepad (Windows), VI (Unix) or spreadsheets (e.g. Microsoft Excel).

8.2 DATA PROVISION OF BOREHOLE IMAGING DATA IN DLIS FOMAT

File name: GGC01_Acoustic_2.dlis

Acoustic borehole image logging was acquired for borehole GGC01. When processed using specialist software this file provides an unwrapped interior borehole wall image. The image facilitates visualisation of the physical condition of the borehole's wall, such as presence of breakouts, open fractures etc. and also some details of geological features visible on the borehole wall, such as intersections of some beds with the borehole and some types of discontinuity which are not open.

Borehole imaging data is provided in the form of Digital Log Interchange Standard (DLIS) files. This binary format cannot be read with anything other than specialist borehole imaging software, which is required to interpret the data files. The file was acquired and processed by Robertson Geo Ltd using the WellCAD software and the associated DLIS file integrity has been checked by BGS scientists using Schlumberger Techlog borehole imaging software.

Note: The Robertson Geoscience AWS imaging tool DLIS format is not supported by all specialist borehole imaging software and so additional processing stages may be needed to load the data. DLIS files contain array-formatted data, which prevented their conversion into the LAS (Log ASCII Standard) format used to report the other logging parameters. The borehole image logging data can however be viewed in the field prints, 'GGC01_acoustic updated.pdf'

8.3 LOG ACQUISITION METADATA

Three LAS files are supplied with a standard metadata package defining the well metadata and acquisition (Table 7)

[1] http://mlp.ldeo.columbia.edu/log-data-processing/
[2] http://www.cwls.org/las/

Table 7: Simplified well metadata header from LAS files

PARAMETER	UNIT	VALUE	DESCRIPTION
STRT	M	0	First reference value
STOP	M	198.856	Last reference value
STEP	M	0.004	Step increment
NULL		-9999	Missing value
WELL		GGC01	Well name
FLD		Glasgow	Field
LOC		Project_ GGERFSNS66SW BJ 3754BGS ID_ 20650619	Location
PROV		N/A	Province
DATE		17-Dec-18	Date
COMPANY		BGS	Operator
Completion_date		14-Jan-19	DD-MMM-YYYY
CTRY		Scotland	COUNTRY
EGL	M	9.66	Ground Level Elevation
EKB	M	9.66	Datum Elevation
DREF		MSL	Permanent Datum
FL		Glasgow	Geographical area name
LCNM		Robertsons	Logging contractor
LMF		GL	Log Datum
LATI	deg	55.8411448	Latitude
LONG	deg	-4.2213957	Longitude
ORIGINALWELLNAME		GGC01	Well Name
OPER		BGS	British Geological Survey
SPDA		15-Nov-18	Spud Date
TD	M	199	Drillers' Depth
UNKNOWN		GGC01	Full well title
WELL-ID		20650619	UNIQUE WELL IDENTIFIER (BGSID)
WELL-NAME		NS66SW/3754	Single Onshore Borehole Index
Water_depth	M	0	Water Depth
X	M	260915	Easting
Y	M	663109	Northing
TYPE_FLUID_IN_HOLE		Water	Drilling Fluid
TOP_LOGGED_INTERVAL		0.0m	Top Logged Depth
BTM_LOGGED_INTERVAL		198.86m	Bottom Logged Depth
RECORDED_BY		KO	Logging Engineer
WITNESSED_BY		IJ	Observer

8.3.1.1 GGC01_COMPOSITE_CERTIFIED.LAS

This file contains the main geophysical logs that define the geological succession that would typically be included in an industry composite plot.

Table 8: Contents of GGC01_Composite_Certified

Parameter	Units	Description
DEPT	M	DEPTH
INC	DEG	Inc
CONDUCTIVITY	US/CM	Conductivity
TEMPERATURE	DEGC	Temperature
CAL_X	MM	Cal X
CAL_Y	MM	Cal Y
GAMMA	API	Gamma
AZ	DEG	Az
DENSITY	GM/CC	Density
BRD	CPS	BRD
HRD	CPS	HRD
PORS	LPU	Pors
NEAR	CPS	Near
FAR	CPS	Far
TX1-RX1	µS	TX1-RX1
TX1-RX2	µS	TX1-RX2
SLOWNESS	µS/FT	Slowness
RESISTIVITY	OHMM	Resistivity

8.3.2 GGC01_Flowmeter_Certified.LAS

This file contains the flowmeter outputs that show the fluid ingress into the well bore

Table 9 Contents of GGC01_Flowmeter_Certified.LAS

Parameter	Units	Description
DEPT	M	DEPTH
RATE_D4	RPM	RATE d4
CABL_D4	M/MIN	CABL d4
RATEU4	RPM	RATEu4
CABLU4	M/MIN	CABLu4
RATEU6	RPM	RATEu6
CABLU6	M/MIN	CABLu6
RATED6	RPM	RATEd6
CABLD6	M/MIN	CABLd6
RATED8	RPM	RATEd8
CABLD8	M/MIN	CABLd8
RATEU8	RPM	RATEu8
CABLU8	M/MIN	CABLu8

8.3.3 GGC01_Full_Waveform_Sonic_Certified.LAS

This is the full wave form sonic including the interval transit time between the multiple source receiver pairs that allow the detailed sonic profile to be constructed.

Table 10: Contents of GGC01_Full_Waveform_Sonic_Certified.LAS

Parameter	Units	Description
DEPTH	M	Depth
SVEL	µs/ft	5 Interval Transit Time
TA	µs	1 Transit Time TX1-RX1
TB	µs	2 Transit Time TX1-RX2
TC	µs	3 Transit Time TX2-RX1
TD	µs	4 Transit Time TX2-RX2

8.4 SUMMARY COMPOSITE LOG IMAGE FILES

File names: GGC01_Comp_Plot_1_200.pdf and GGC01_Comp_Plot_1_500.pdf

Two composite log image files are included in the data pack at scales of 1:200 and 1:500.

9 Sample Information

9.1 SUMMARY SPREADSHEET OF CORE AND FLUID SAMPLES PRESERVED FOR GEOMICROBIOLOGY

File name: GGC01_geomicrobiology_externalversion_V2.xlsx

This Excel workbook details sub-samples collected from rock cores immediately after core recovery and preserved for geomicrobiology analysis, and which has been made available for the science community via an open sample call. It contains two worksheets: one lists the core samples and the other describes fluid samples that were collected and preserved from around the core barrel.

Each 5cm long subsample of core collected for geomicrobiology analysis was split into four pieces, with the preservation of these pieces being as described in the ‘type of sample’ column:

- ‘-80’ denotes the 2 quarters preserved at -80˚C (for DNA/RNA studies etc.)
- ‘culture’ denotes the 1 quarter preserved at 4 ˚C (for culture studies; 4˚C samples were flushed with nitrogen and sealed).
- ‘counts’ denotes the 1 quarter preserved at 4˚C (from which a portion was been removed and preserved in glutaraldehyde fixative for tracer and cell counts).
- ‘SSK’ denotes the sample number. GMC=geomicrobiology core

In the second worksheet the fluid samples collected are described as follows:

- ‘1 ml fix’ denotes core barrel fluid preserved in glutaraldehyde fixative and frozen at -80˚C
- ‘30 ml drilling fluid’ denotes the remainder of the core barrel fluid collected and preserved at -80˚C
- ‘1g count’ denotes crushed core material preserved in glutaraldehyde fixative

9.2 SUMMARY SPREADSHEET OF BGS FLUID/WATER SAMPLES AND BASIC HYDROGEOLOGICAL PARAMETERS OF BGS FLUID/WATER SAMPLES

File name: GGC01_fluidsamples_fieldparameters_externalversion_V4.xlsx

This spreadsheet records water, fluid and other samples that were taken by BGS over the course of drilling.

Two water samples were taken from the top of the borehole using a hand bailer upon completion of drilling. The first was taken on the 17/12/2018 after the casing had been removed up to the superficial deposits and the borehole had been flushed with clean water and left to settle overnight. The second sample was taken on 07/01/2019 after the borehole had been left open and uncased for two weeks. Samples of mains water (used for borehole flushing) were also taken for comparison. When taking these samples the following water quality parameters were monitored at least three times over an interval of not less than five- minutes: pH, redox (Eh), dissolved oxygen, temperature and conductivity. Alkalinity was also measured, using a Hach Digital Titrator, a minimum of three times.

Post sample collection the redox potential was corrected for temperature and the bicarbonate (HCO_3) value of the water was calculated using the field alkalinity values.

The samples collected are being analysed for a suite of water chemistry parameters; data will be released when available.

9.3 SUMMARY OF TRACER AND ADDITIVE INFORMATION

9.3.1 Geomicrobiology tracer

A geomicrobiology tracer, AFN-09 RADGLO UV Blue, was added daily to the settling tanks containing the re-circulating water used to drill the borehole. The tracer was added to allow the extent of drilling fluid ingress into core material to be assessed. The volumes added, based on BGS records, are summarised in Table 11 below. Various sizes of settling tanks were used throughout the drilling for the re-circulating of drilling water and therefore different amounts of tracer was added to these tanks depending on which one was in use on that day. The original addition of tracer to the settling tanks was based on a ratio of tracer to drilling fluid was 1:40000 and this was attempted to be maintained throughout the drilling process. In order to account for potential losses of water throughout the drilling, additional tracer was added to the settling tanks daily. The tracer data sheet documents it as a mixture of the following chemicals: Ammonium hydroxide (<1% weight), iron (III) sulfate (<0.1% weight) and acrylonitrile (<0.1% weight). A 30 ml sample of the geomicrobiology tracer, AFN-09 RADGLO UV Blue, was taken during the drilling.

Table 11 Volume of tracer added

Date	Volume of re-circulating water (litres)	Volume of tracer added to water (ml)
27/11/2018	13,000*	325^
28/11/2018	13,000	60
29/11/2018	13,000	60
30/11/2018	13,000	60
03/12/2018	7,000** (new tanks)	175
04/12/2018	7,000	30
06/12/2018	13,000* (new tanks)	325
07/12/2018	13,000	60
10/12/2018	13,000	60
11/12/2018	13,000	60
12/12/2018	13,000	60

**based on 6,000 litres in two settling tanks and 1,000 litres in borehole*

***based on 3,000 litres in two settling tanks and 1,000 litres in borehole*

^Added at beginning of day after morning samples were taken

9.3.2 Polymer drilling additive

To aid drilling, a drilling additive called Insta-pac supplied by CETCO Europe, was added by the drilling contractors to the re-circulating water in the settling tanks at various points throughout the drilling. This additive contains Naphtha (petroleum), hydrotreated heavy [low boiling point hydrogen treated naphtha] (<3%). A 60 ml sample was taken by BGS.

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: https://envirolib.apps.nerc.ac.uk/olibcgi.

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