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

UK Geoenergy Observatories Programme

Open Report OR/21/031

BRITISH GEOLOGICAL SURVEY

UK GEOENERGY OBSERVATORIES PROGRAMME

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Part of optical core image from 180 m drilled depth

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- Sarah Hannis – validating depth shift to MSCL-S data, applying to XRF core scan data
- Tim Kearsey – minor update to sedimentology log
- Alison Monaghan – coordinating final data release

Contributions to the intermediate data release (September 2019) that is incorporated into this final data release were:

- 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 Damaschke, Simon Wylde – core scanning and data processing
- Mark Fellgett, Andy Kingdon – core scanning, workflow and results
- Alison Monaghan – coordinating intermediate data release

Contributions to the initial data release (March 2019) that is incorporated into this final data release were:

- Vanessa Starcher: Technical overview, wireline log data acquisition
- Kirsty Shorter: Fluid and geomicrobiology samples, tracer information, field measurements
- 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

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Borehole imaging figures and interpretation generated in Schlumberger Techlog Version 2017.2

Geophysical wireline log plots showing MSCL-S and XRF data generated in Lloyd's Register Interactive Petrophysics software (IP 2018, Version 4.5.2019.2902).

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Summary

This report provides an overview of information contained in the final data release for the UK Geoenergy Observatories Glasgow borehole GGC01. This final data release supersedes the initial and intermediate data releases (Starcher et al. 2019; Kearsey et al. 2019). It includes additional information on core scan data and core-wireline depth integration.

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 have been used to collect along core datasets. This final data release includes optical images (whole core and slabbed core), radiographic images, MSCL-S (geophysical), NIR and XRF (mineralogical and chemical) core scan data.

Also included in this final release is the material from the previous releases including sedimentary, discontinuity and engineering logs, wireline/geophysical downhole logs, drillers' logs and sample information.

1 Introduction

This report provides an overview of the final data release for the UK Geoenergy Observatories Glasgow borehole GGC01. 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 final data release includes contractors and BGS drilling and sampling information, geophysical (wireline) log data, BGS core scan data including whole and slabbed core optical images and radiographic images, BGS depth-shift information for core-log integration as well as BGS sedimentary, discontinuity and engineering logs (Figure 1).

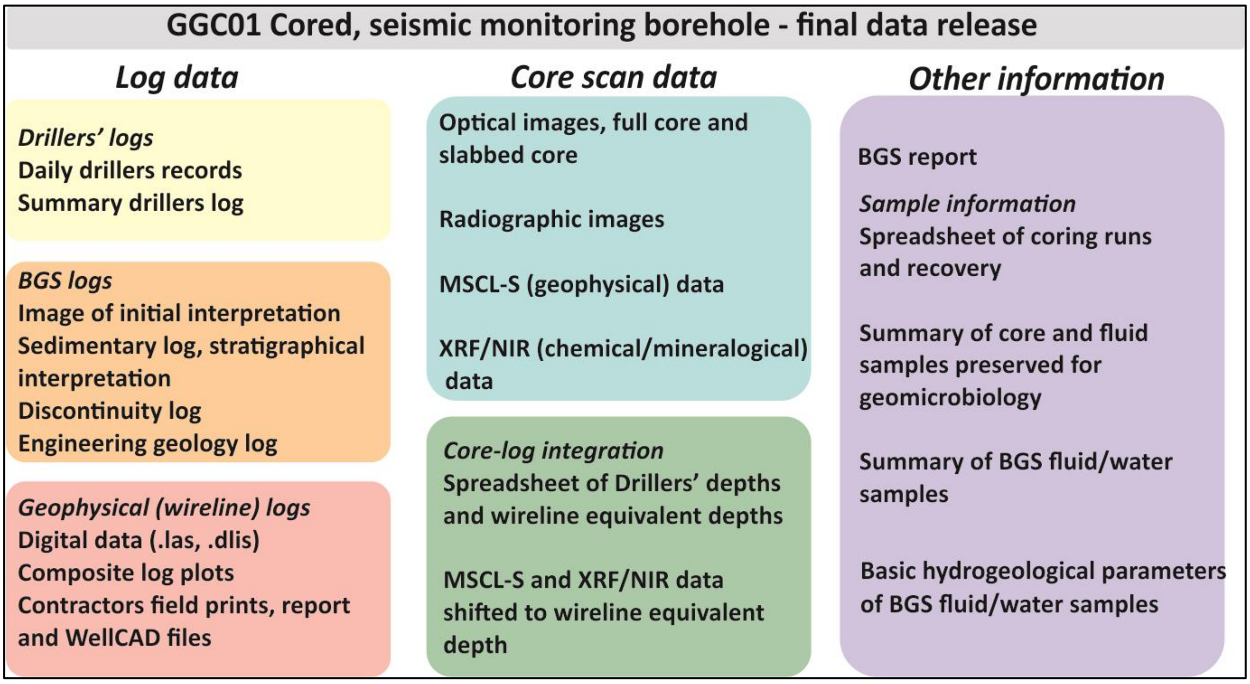


Figure 1 Visual summary of data files within the final data release for the UK Geoenergy Observatories cored, seismic monitoring borehole GGC01.

A full list of files within the data release is given in Appendix A.

1.1 DEPTH REFERENCING

Two depth referencing systems are used in this data release:

i. Drillers' Depth was measured on site during the drilling process and for the core recovered from the borehole.
ii. Wireline Depth was measured on site using downhole wireline logs taking measurements of the in-situ depths of the rock mass down the borehole. Wireline equivalent depths have been calculated for each the core boxes to account for core loss and overlength core and used to depth shift selected core data for integration with the wireline data.

Details of the depth shifting methodology used and wireline equivalent depths spreadsheet per core box is given in section 7. Table 1 summarises which depth reference system has been used in each dataset within this release.

Table 1 The depth reference used by each dataset in this data release.

Dataset	Drilled depth	Wireline or wireline equivalent depth
Drillers' log	x	
Geophysical/wireline downhole logs		x
Optical and radiographic images (full and slabbed core)*	x	
MSCL-S core scan data	x	x
XRF/NIR core scan data	x	x
Used in National Geological Repository (NGR = 'BGS core store')	x	
BGS Sedimentology log	x	
BGS Engineering log	x	
BGS Discontinuity log	x	

*****a spreadsheet is also provided of measured core lengths as seen on the images including overlength sections*

1.2 CITATION GUIDANCE

Any use of the data should be cited to:
DOI: Monaghan A A, Damaschke M, Starcher V, Fellgett M W, Kingdon A, Kearsey T, Hannis S, Gillespie M, Shorter K, Elsome J, Barnett M. (2021) UKGEOS Glasgow GGC01 Final Borehole Information Pack. NERC EDS National Geoscience Data Centre. (Dataset). https://doi.org/10.5285/e38c58a6-48ec-4ad1-a996-6c6144968d7d
and this report cited as:
Monaghan A A, Damaschke M, Starcher V, Fellgett M W, Kingdon A, Kearsey T, Hannis S, Gillespie M, Shorter K, Elsome J, Barnett M. 2021. UK Geoenergy Observatories Glasgow: GGC01 cored, seismic monitoring borehole – final data release. British Geological Survey Open Report, OR/21/031. 64pp.

2 Drillers' logs

2.1 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 drillers' 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.

Drilling was advanced using a rotary-cored method with water flush. This involves rotation of the core barrel as it goes down and the retrieval of a core of material when the barrel is pulled back to the surface. The Geobore-S system was used with a borehole diameter of 151 mm, producing a core of 102 mm. Core was recovered in three metre runs and sawn into one metre length sections. The core was within an opaque core liner and stored in wooden core boxes.

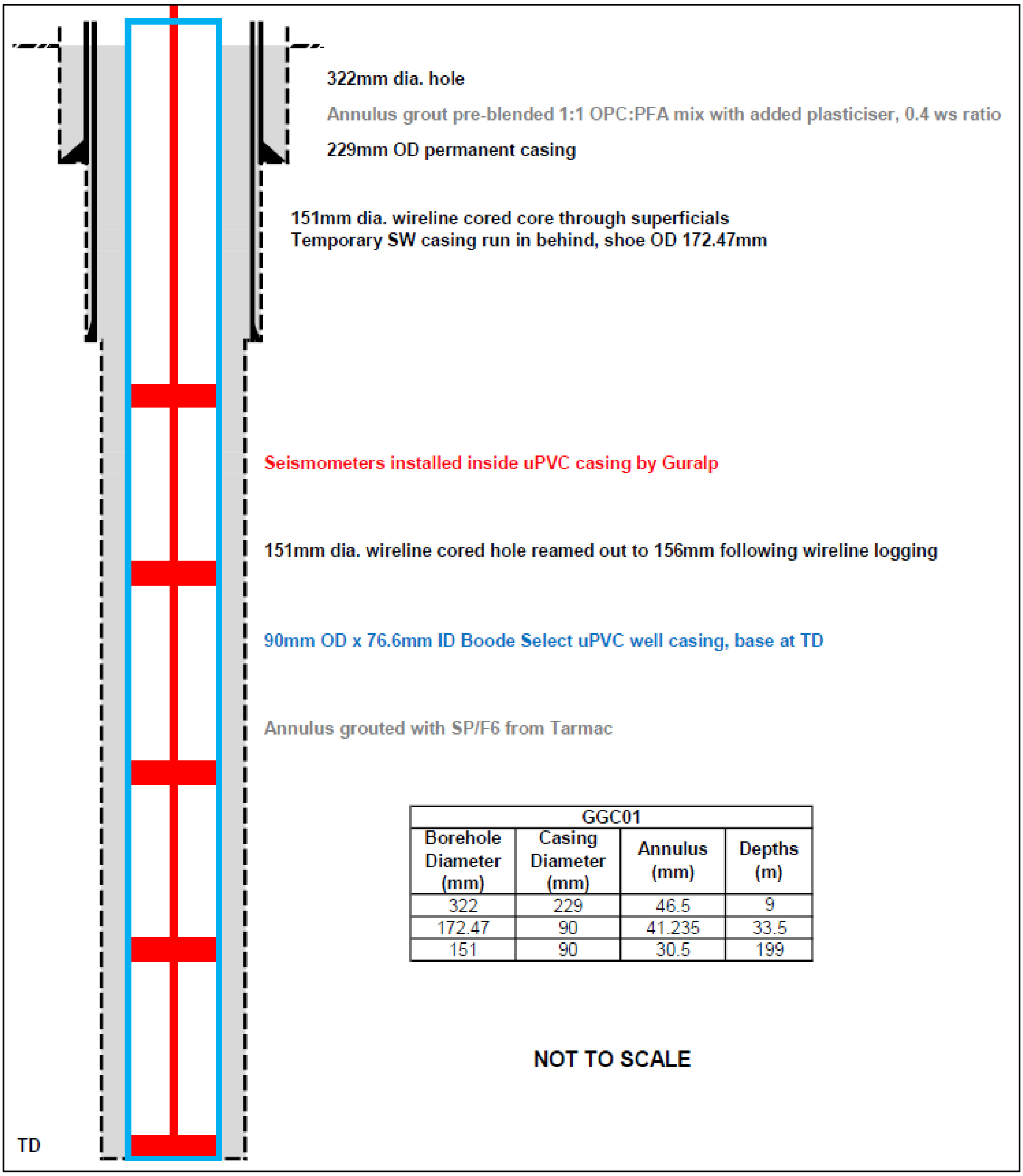
2.2 SUMMARY DRILLERS' LOG AND FINAL INFORMATION SHEET

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.

2.3 AS-BUILT BOREHOLE DESIGN

Following completion of drilling, borehole flushing, open hole wireline logging and reaming out of the borehole to 156 mm diameter, a 76.6 mm ID uPVC Boode casing was installed and the annulus was grouted (Figure 2). Subsequently a string of 5 seismometers was installed by Guralp inside the uPVC casing and connected to a surface cabinet with power and broadband connection. Time-series data has been streamed from the seismometers since 2019 and is available from https://ukgeos.ac.uk/glasgow/seismic-monitoring . The headworks of the borehole were installed within a secure below ground chamber, with the final borehole start height datum being 8.96 m above Ordnance Datum.



GGC01			
Borehole Diameter (mm)	Casing Diameter (mm)	Annulus (mm)	Depths (m)
322	229	46.5	9
172.47	90	41.235	33.5
151	90	30.5	199

Figure 2 Schematic of as-built seismic monitoring borehole GGC01 at Site 10

3 Summary initial BGS borehole information from drill site

3.1 SPREADSHEET OF DRILL DEPTHS/DATES/CORE RECOVERY

File name: GGC01 Coring data_V6.xlsx

The information presented on the summary Drillers' log is provided in 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 in section 1.1, depth shifting of core intervals is needed for detailed comparison with the geophysical (wireline) logs.

3.2 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 shifting 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 mostly 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 8-9 in this final data release.

4 Sample Information

A range of samples were collected during borehole construction including drilling fluids, and borehole water/groundwater. Some preserved samples were taken immediately at drill site (core barrel fluids) or within 1-2 hours of the core being extracted (geomicrobiology core samples; academic during-drilling core samples) at the University of Strathclyde geomicrobiology laboratory. Following NERC data policy, academic sample datasets will be deposited at a NERC data centre.

4.1 SUMMARY SPREADSHEET OF CORE AND FLUID SAMPLES PRESERVED FOR GEOMICROBIOLOGY

File name: GGC01_geomicrobiology_externalversion_V4.xlsx

This Excel workbook details sub-samples collected from rock cores immediately after core recovery and preserved for geomicrobiology analysis, and which is available to the science community via a request form. 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 5 cm 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
- '1 g count' denotes crushed core material preserved in glutaraldehyde fixative

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

File name: GGC01_fluidsamples_fieldparameters_externalversion_V5.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 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 have been analysed for a suite of water chemistry parameters; data is described in Shorter et al. (2021) and the accompanying data release.

4.3 SUMMARY OF TRACER AND ADDITIVE INFORMATION

4.3.1 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 2 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 2 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

4.3.2 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.

5 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. (1999) 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].

5.1 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).

5.2 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'

5.3 LOG ACQUISITION METADATA

Three LAS files are supplied with a standard metadata package defining the well metadata and acquisition (Table 3).

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

Table 3 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

5.3.1 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 4 Contents of GGC01_Composite_Certified

Parameter	Units	Description
DEPT	M	Measured Depth
INC	DEG	Borehole Inclination
CONDUCTIVITY	US/CM	Conductivity
TEMPERATURE	DEGC	Temperature
CAL_X	MM	X Caliper
CAL_Y	MM	Y Caliper
GAMMA	API	Gamma Ray
AZ	DEG	Borehole Azimuth
DENSITY	GM/CC	Density
BRD	CPS	Far-positioned detector measuring gamma ray counts per second
HRD	CPS	Mid-positioned detector measuring gamma ray counts per second
PORS	LPU	Neutron Porosity
NEAR	CPS	Near
FAR	CPS	Far
TX1-RX1	µS	Transit Time TX1-RX1
TX1-RX2	µS	Transit Time TX1-RX2
SLOWNESS	µS/FT	Sonic Slowness
RESISTIVITY	OHMM	Resistivity

5.3.2 GGC01_Flowmeter_Certified.LAS

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

Table 5 Contents of GGC01_Flowmeter_Certified.LAS

Parameter	Units	Description
DEPT	M	DEPTH
RATE_D4	RPM	Number of rotations per minute, 4 metres/ minute downward run
CABL_D4	M/MIN	Speed of deployment 4 metres/ minute downward run
RATEU4	RPM	Number of rotations per minute, 4 metres/ minute upward run
CABLU4	M/MIN	Speed of deployment 4 metres/ minute upward run
RATEU6	RPM	Number of rotations per minute, 6 metres/ minute upward run
CABLU6	M/MIN	Speed of deployment 6 metres/ minute upward run
RATED6	RPM	Number of rotations per minute, 6 metres/ minute downward run
CABLD6	M/MIN	Speed of deployment 6 metres/ minute downward run
RATED8	RPM	Number of rotations per minute, 8 metres/ minute downward run
CABLD8	M/MIN	Speed of deployment 8 metres/ minute downward run
RATEU8	RPM	Number of rotations per minute, 8 metres/ minute upward run
CABLU8	M/MIN	Speed of deployment 8 metres/ minute upward run

5.3.3 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 6 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

5.4 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 release at scales of 1:200 and 1:500.

5.5 BOREHOLE IMAGING INTERPRETATION

File Name: GGC01_Borehole_Image_Interpretation.las

As part of the work to calculate a wireline equivalent depth for the core scanner data (see sections 6 and 7) Andrew Kingdon (BGS) produced a borehole image interpretation from the acoustic borehole imaging data.

As the depth shifting was the primary focus, more weight was given to characterising the faults and fractures. As a result, not all sedimentary features such as erosional surfaces and cross bedding may have fully characterised. This interpretation was undertaken independently of the sedimentary and discontinuity logging described in sections 8 and 10.

The data provides a record of the true and apparent Dip and Strike of each interpreted feature in-situ. As the GGC01 borehole is near vertical, the values for apparent and true dip and strike are similar.

There are 997 interpreted features in the file including representative bedding, coal seams, faults, open and closed fractures. As bedding planes dominate the number of features observed in borehole imaging in sedimentary sequences, not all bedding planes are picked.

Table 7 Feature Classification for Borehole Imaging Interpretation

Feature Classification	Number of features
Bedding	596
Closed Fracture	174
Coal Seam	19
Cross Bedding	5
Erosional Surface	6
Fault	12
Induced Fracture	2
None	4
Open Fracture	205

6 Core scan data

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 core scanners which are listed below.

- Geotek Multi-Sensor Core Logger Standard (MSCL-S)
- Geotek Rotating X-Ray Computed Tomography Scanner (MSCL-RXCT)
- Geotek Core Workstation (MSCL-XYZ)
- Itrax Multi Core (ITRAX-MC)

The core scan data contained in this data release comprises all planned open data collected on the GGC01 core. This includes optical images collected from the MSCL-XYZ scanner, 2D radiographic images collected using the MSCL-RXCT scanner, geophysical property data collected on the MSCL-S scanner and X-ray fluorescence (XRF) and near infrared (NIR) data collected on the MSCL-XYZ scanner.

In some core boxes, particularly ones which were sampled at drill site, the core may have moved inside the liner. As a result, it is strongly advised that any dataset is used alongside the radiographic and optical images to ensure they are spatially aligned. To optimise visualisation and interpretation, the light intensity of the images collected by the scanners have been manually scaled in the processed images supplied in the data release, and as a result they may not be suitable for automated processing or machine learning techniques.

The XRF and NIR sensors on the MSCL-XYZ require a flat surface in order to maximise the data quality. To address this BGS designed and built a prototype core clamp which allowed the core to be slabbed and scanned while minimising the disruption to the core (section 6.5). Overall only approximately 10 % of the recovered GGC01 core was unsuitable for XRF/NIR scanning (and was not scanned) following slabbing.

The clamps were designed to fit inside the MSCL-XYZ and all NIR and XRF data were collected in this fashion. An additional set of optical images were also collected at this time (slabbed core optical images) and should be used alongside the XRF and NIR datasets. All other core scanner datasets were acquired on whole, cylindrical core.

Scan settings were consistent across the entire length of the core for all machines. However, in order to provide a working dataset many of the outputs have been processed to remove artefacts. The MSCL-S, XRF and NIR datasets were depth shifted to a wireline equivalent depth (Section 7) in order to make them comparable with the wireline logging datasets (Section 5).

All raw data from the core scanners will be retained by BGS and can be requested from ukgeosenquiries@bgs.ac.uk.

6.1 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. An index spreadsheet *GGC01_Corebox_Depths_Final.xlsx* has been provided to link the core box number to drillers' depth and wireline equivalent depth.

For the image data, 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. Information is provided in *Imaged_overlength_core_sections.xlsx*

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

The point datasets collected on the MSCL-S and -XYZ scanners are referenced to a section number which represents the order in which the core was scanned. For example, the first core scanned in a day is section one, the second is section two, and so on. These section numbers have been converted to core box numbers and referenced to both wireline equivalent depth and drillers' depth for ease of use.

6.2 2D RADIOGRAPHY DATA

File names:

High resolution .tif files are available in the large file size (56 GB zipped) download UKGEOS Glasgow GGC01 Intermediate Borehole Information Pack - Part Two , https://doi.org/10.5285/0b49f25b-a5d6-401c-98ff-397ad9ee9ed1

They can be viewed online at https://ukgeos.ac.uk/data-downloads/glasgow/seismic-borehole-information-pack/core-scanning-images.

The 2D radiography data was collected using the 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 Degree – Source directly above core and detector below
- 45 Degree – Source and detector at 45 degree angle to the core
- 90 Degree – Source and detector horizontally 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.

Examples of radiographic data can be seen in Figure 8 to Figure 12 below.

6.2.1 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 radiographic images in isolation, but to view them with the optical images.

The scaled images are included as .tif files, 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 as separate 'Radiographic scans- coal'.

6.3 OPTICAL DATA

File names:

High resolution .tif files of the whole core are available in the large file size (56 GB zipped) download 'UKGEOS Glasgow GGC01 Intermediate Borehole Information Pack - Part Two' https://doi.org/10.5285/0b49f25b-a5d6-401c-98ff-397ad9ee9ed1

High resolution .tif files of the slabbed core are available in the large file size UKGEOSGlasgowGGC01_slabbedhighresimages.zip in the final data release

In UKGEOSGlasgow_GGC01_Final.zip, the folder '*Processed_Core_Scan_Data/ Optical Scans' contains JPG images of the whole and slabbed core at lower resolution in the final data release.*

The optical images were collected at a resolution of 50 microns. Scanning of the whole core took place immediately following the radiographic scans, after the opaque core liner had been opened and before discontinuity and sedimentary logging in order to reduce core disturbance. The light intensity of the images collected by the scanners have been manually scaled in the processed images supplied in the data release to allow for interpretation and are included as one .jpg file per core box in the 'Optical scans' folder. Given the very large file sizes, these images have also been made available in an online viewer https://ukgeos.ac.uk/data-downloads/glasgow/seismic-borehole-information-pack/core-scanning-images.

The lengths of core shown in the optical images, and where additional pieces of core have been included in the image are listed in '*Imaged_overlength_core_sections.xlsx'*

Examples of optical images data can be seen in Figure 8 to Figure 12 below.

6.4 PHYSICAL PROPERTY DATA

File name: MSCL-S_DD_processed_final.xlsx

Following acquisition of the optical images, the whole cylindrical cores from GGC01 were scanned for physical property data using the MSCL-S core scanner. This included gamma attenuation density and volumetric magnetic susceptibility at 1 cm increments and natural gamma ray at 5 cm increments (Table 8).

The dataset was then processed to remove data points over cracks, missing core intervals and heavily fractured sections of core where no reliable data could be collected. The final dataset has been aggregated and is presented in drillers' depth and wireline equivalent depth. Figure 3 provides an illustration of the MSCL-S data.

Table 8 List of parameters collected by the MSCL-S scanner and included in the data release

MSCL-S sensor	Parameter (unit)
Gamma Attenuation	Den1 (g/cc)
Magnetic Susceptibility	MS1 (SI x 10 ^-5)
Natural Gamma	API
potassium	K (%)
uranium	U (ppm)
thorium	Th (ppm)

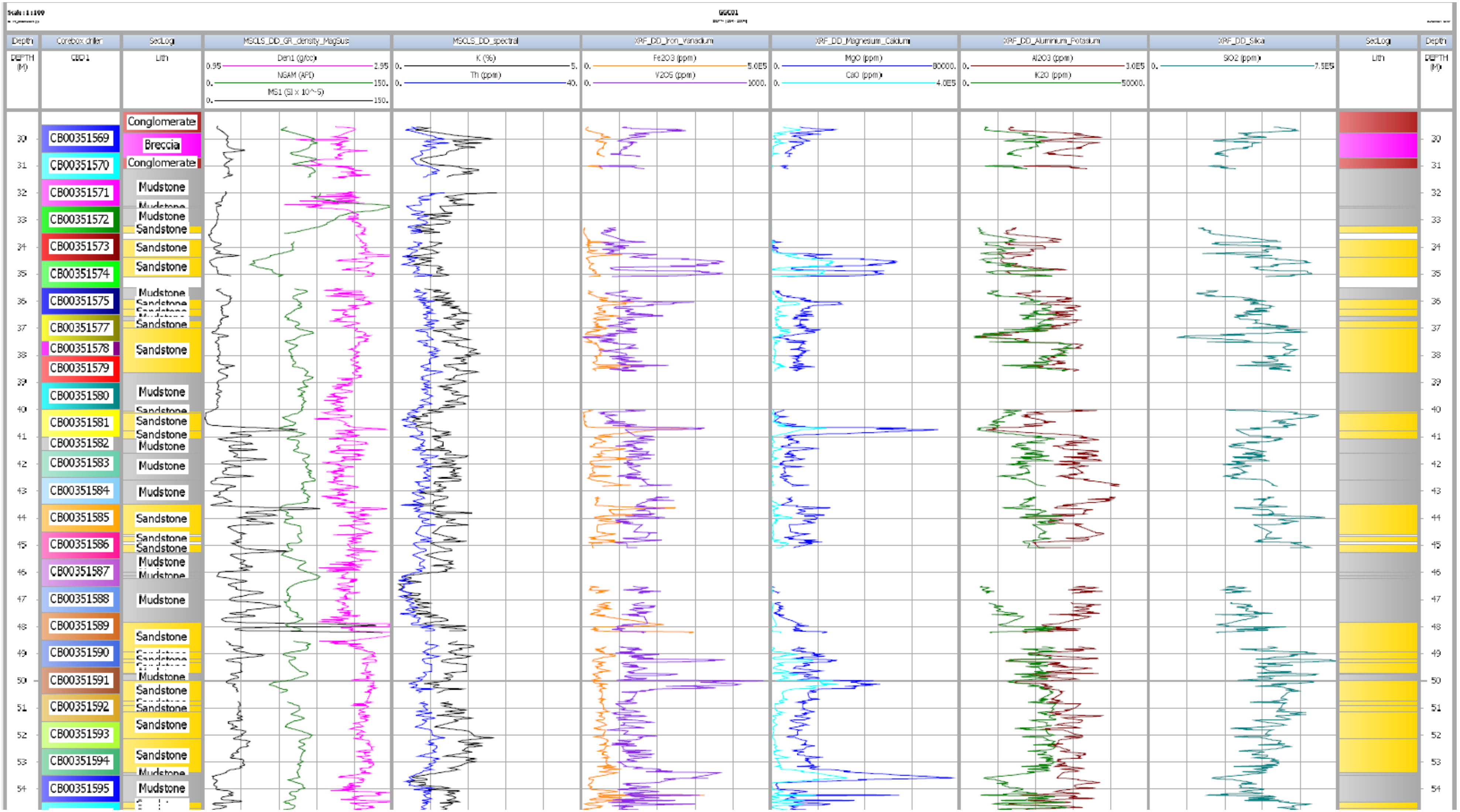


Figure 3 Example of selected core scanner MSCL-S and XRF data plotted against the sedimentary log (drillers' depth) for the top part of the dataset (29 - 55 m). The full plot image *GGC01_XRF_MSCL-S_SedLog_1to100Scale.pdf* is included in the data release.

6.5 ASYMMETRIC CORE SLABBING AND CLAMPING

It was necessary to slab the core in order to create a flat surface prior XRF and NIR core scanning. A flat surface greatly improves the quality of the core scan data, whereas whole cylindrical core reduces the quality of data collected using these techniques.

In order to slab the core, whilst preserving the majority of its volume for sampling, the decision was taken to slab the core 1/3 to 2/3 down its length.

The slabbing process can be destructive resulting in loss of material, so in order to mitigate loss of material while slabbing the core asymmetrically, a new technical solution was devised. A team from the BGS Research and Design Engineering Facility designed a prototype core clamp which would not only allow asymmetric core slabbing but would also fit inside the MSCL-XYZ scanner (Figure 4).

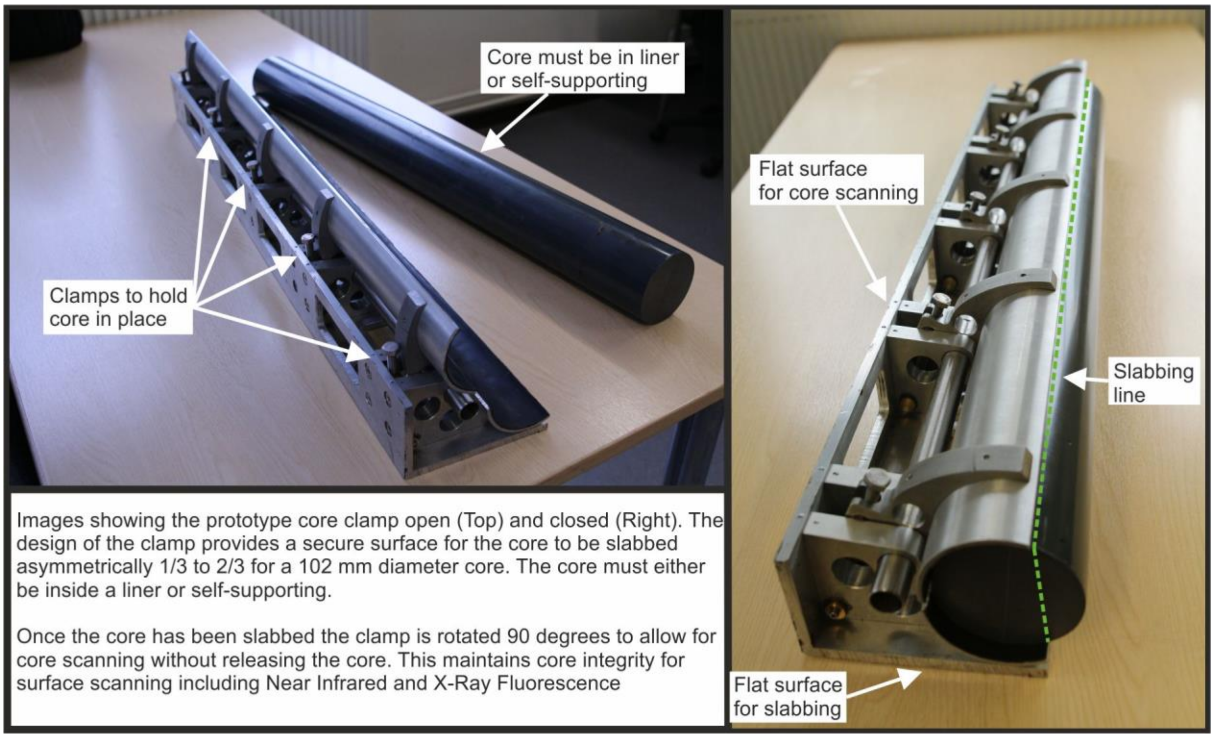


Figure 4 Prototype Core Clamp

This new design allowed core to be slabbed and scanned while maintaining its physical integrity, both improving the quality of the scan data and preserving a greater volume of core for scanning and subsequent subsampling (Figure 5).

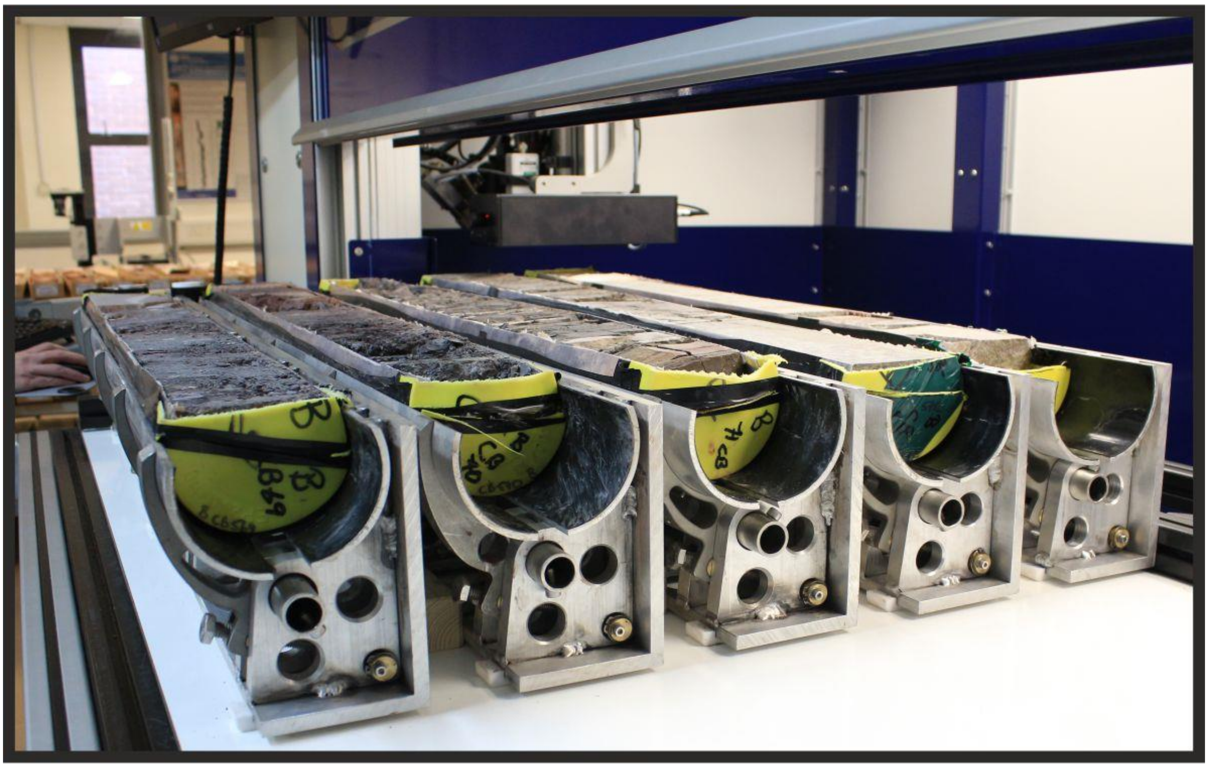


Figure 5 Photograph showing prototype core clamps holding slab core in the MSCL-XYZ scanner, ready for scanning.

6.6 XRF/NIR DATA

File name: MSCL-XYZ_DD_processed_final.xlsx

X-ray Fluorescence (XRF) and Near Infrared (NIR) data was collected at 2 cm intervals and 5 second exposure down the slabbed GGC01 core surface (Table 9). For this data release the XRF and NIR data are supplied as data points. The equivalent spectral data can be requested from ukgeosenquiries@bgs.ac.uk.

The NIR data provides reflectance, absorption, colour and mineralogical information across a series of wavelengths from 350-2500 nm. The XRF data was acquired at two modes of 10kV and 40kV enabling automated fitting and calibration of ~21 elements using XRS-FP (Amptek), an integrated quantitative analysis software package. As a result, the elemental concentrations in ppm are, at best semi quantitative.

The error value associated with each measured element is calculated as a relative error from the uncertainty of the line intensity and the uncertainty of the background intensity at the line position. This uncertainty is then expressed in ppm as per the instrument calibration, to 2σ.

In addition, replicate scans as well as reference sample point scans have been performed to ensure consistent acquisition conditions. Replicate scans can be used to identify poor core condition, and corresponding poor XRF data quality. Replicate data can be requested from ukgeosenquiries@bgs.ac.uk.

The dataset was processed to remove data points over cracks, missing core intervals and heavily fractured sections of core where no reliable data could be collected. The fragmentation state of the core was evaluated using a fragmentation chart (*Fragmentation_chart_GGC01.xlsx*). An increase of core fragmentation results in a decrease of XRF/NIR data quality. The data from highly fragmented core, fragmentation state >3, has been removed. The data from partly fragmented core, fragmentation state 2&3, has been partly removed and should be treated with caution.

The final dataset has been aggregated and is presented in drillers depth and wireline equivalent depth. Figure 3, Figure 6 and Figure 7 provide an illustration of some of the XRF data.

After the XRF/NIR data was collected a second set of optical images was acquired using the same technique as detailed in section 6.3. These are available in the Optical_Scans/ SlabbedCore_lowResJPG folder.

Table 9 List of parameters collected by the MSCL-XYZ scanner and included in the data release

MSCL-XYZ sensor	Parameter (unit)
NIR	Greyscale Reflectance (%)
	CIE XYZ Colour Space
	CIE L*a*b* Colour Space
	Reflectance (nm)
XRF	Calibrated* XRF Elements (ppm)
	Calibrated* XRF Oxides (ppm)
	Uncertainty in the calibrated concentration* (Error) (ppm, 2σ)

*calibrated using integrated XRS-FP software (Amptek)

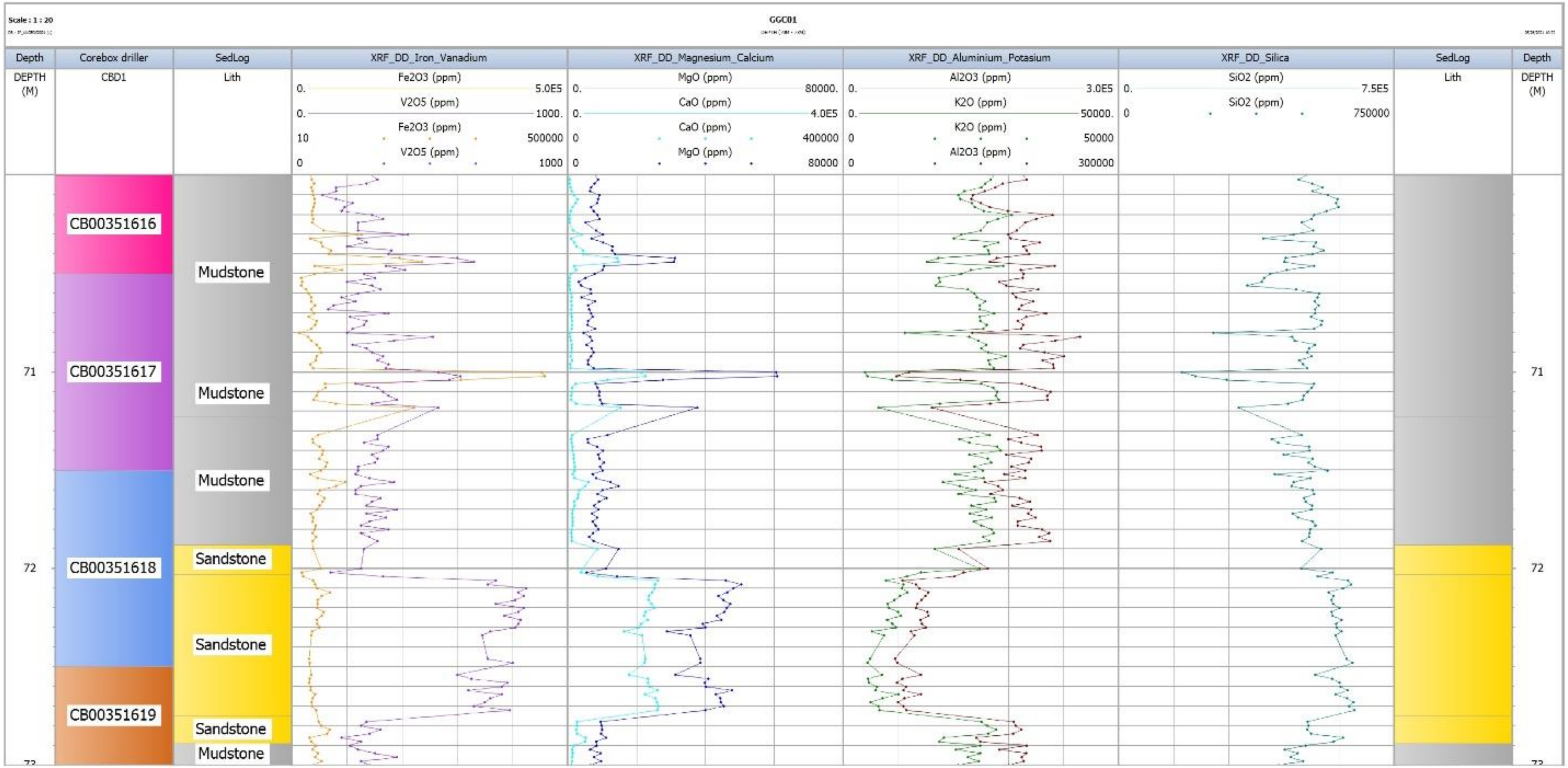


Figure 6 Example of selected XRF core scan data in a sandstone and mudstone interval around 72 metres

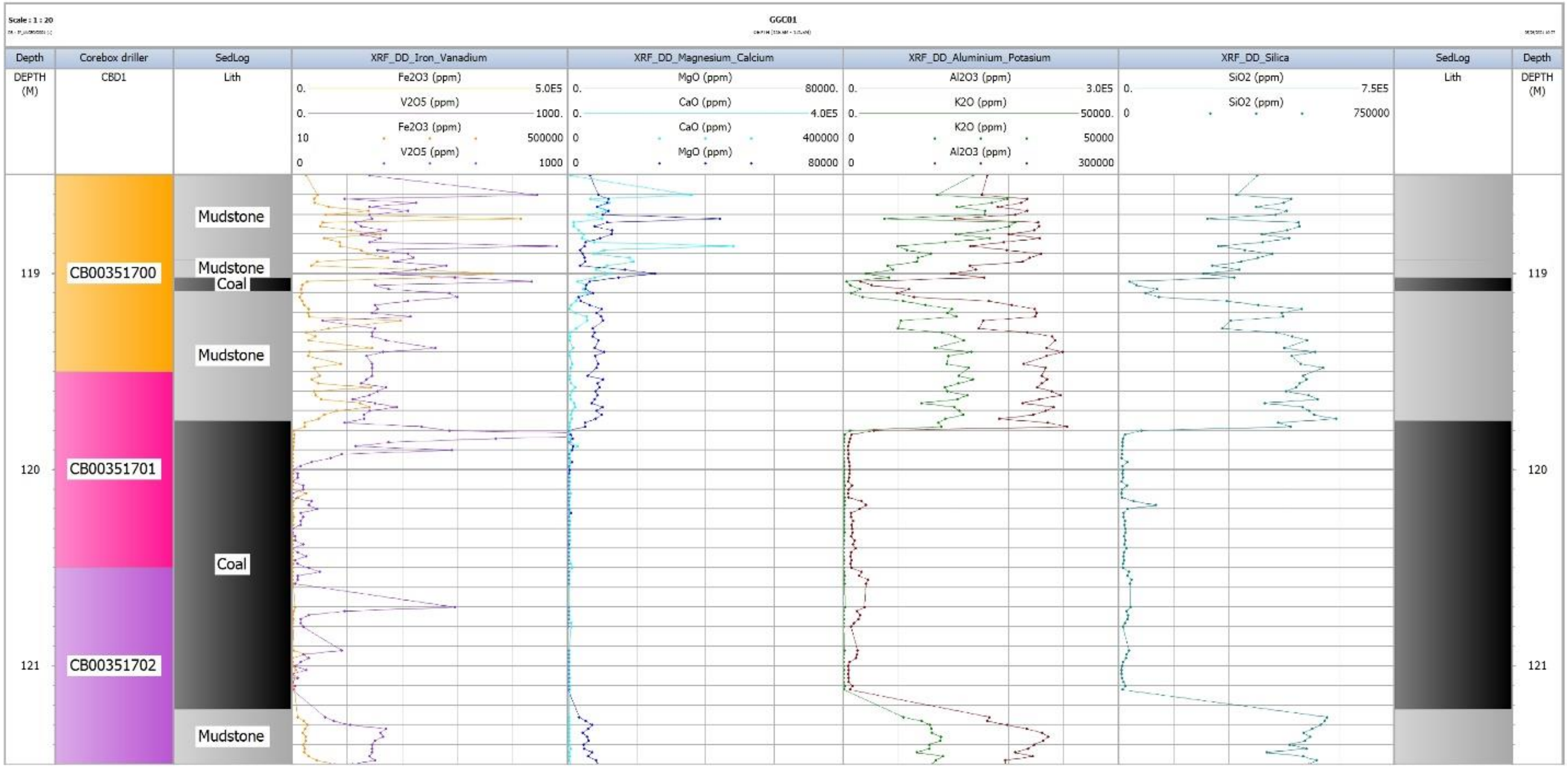


Figure 7 Example of selected XRF core scan data in a coal and mudstone interval around 120 metres

7 Depth shift methodology for wireline equivalent depths (core – log integration)

File names:

GGC01_Corebox_Depths_Final.xlsx includes wireline equivalent depths

MSCL-S_WED_processed_final.xlsx

MSCL-XYZ_WED_processed_final.xlsx

Many of the datasets provided with this data pack are referenced to the drillers' depth which was measured on site during the drilling and coring process. For upscaling and data integration it is advantageous to correlate core information with data from downhole wireline logs, particularly outputs from the BGS Core Scanning Facility (CSF).

It is common to see depth mismatches between drillers' depths and wireline depths when examining borehole data (Figure 8). In this case, depth mismatches are the result of sections of core loss, as well as over length and under length core sections due to natural breaks in the core. Typically core depths are corrected to a wireline equivalent depth as the wireline logs preserve an in-situ record of the rock mass in the borehole after drilling. In contrast, core can be disturbed through cutting, handling and transportation and core recovery is commonly less than 100%.

The calculated depth shift has been generated on a core run by core run basis for the entire borehole. There may still be small discrepancies (<10 cm) between core scanner data and borehole imaging data. There are a small number of larger discrepancies which are a result of core loss being shifted to the start or the end of a coring run. As a result, users may wish to apply further depth shifts on specific intervals of interest.

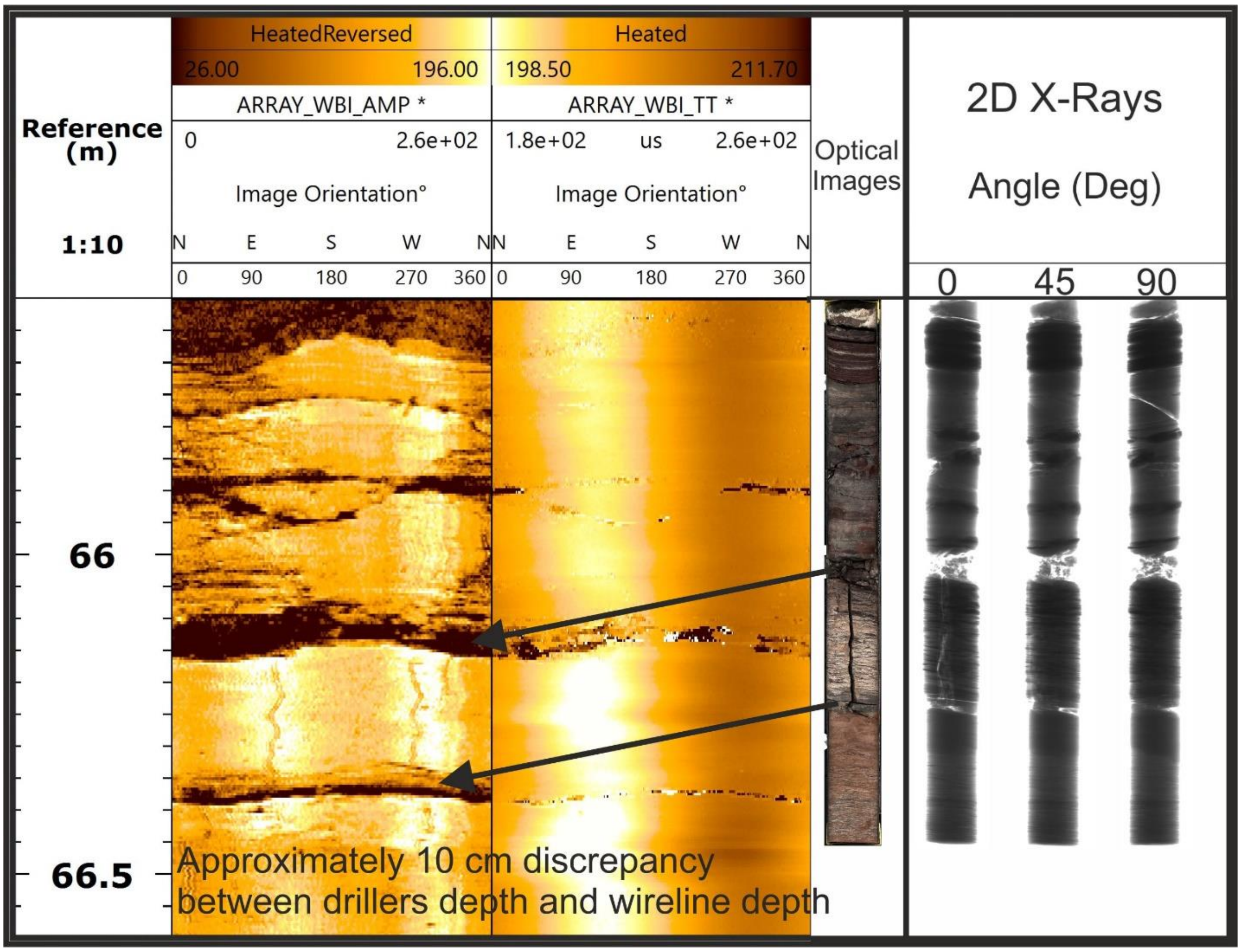


Figure 8 Image showing small depth discrepancy between drillers' depth and wireline depth. Left; Wireline depth in m, Centre Left; Acoustic Amplitude Image from wireline logging, Centre; Acoustic Travel Time Image. Centre Right; Optical image of core acquired using the MSCL-XYZ. Right 2D X-Ray images of core acquired at 0, 45 and 90 degrees to the core using the MSCL-RXCT.

For GGC01, the core was acquired using a 3 m length core barrel and then split into one metre sections for transportation to the National Geological Repository (NGR) at Keyworth. Core recovery was very good for GGC01, frequently up to 100 % (see GGC01 Coring data_V6.xlsx) with a few intervals of poor or non-recovery.

However, on arrival at the NGR it became apparent that there were a number of overlength sections which had a drillers' depth that indicated that the core was 1 m long, when the length was >1 m. When this occurred, it created an overlap in the actual core lengths compared to the documented core boxes. This happened both within and between coring runs (Figure 9). Further information on core lengths is provided in file *Imaged_overlength_core_sections.xlsx*.

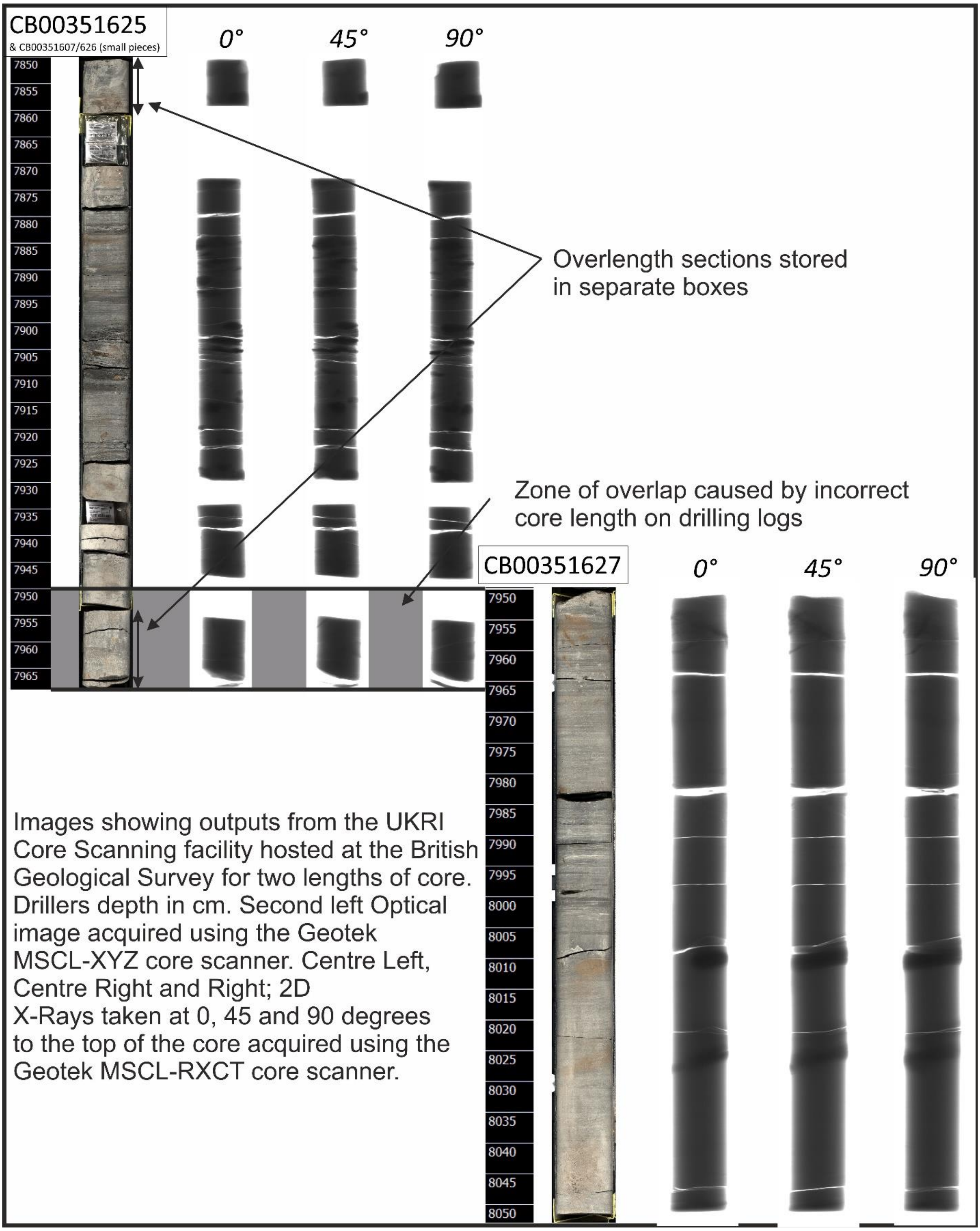


Figure 9 Image showing overlaps created by overlength sections when using drillers' depth

These overlap sections pose a problem for any continuous dataset acquired from core such as core scanning data. In addition to this, depth mismatches between drilling and wireline data can also be the result of core loss. Where sections of core loss do occur, it can cause material spread across several metres to shift in the barrel to appear as a single metre-long core stick (Galliot *et al*., 2007).

In order to remove the overlaps and account for core loss and overlength sections, core - log integration was undertaken using the images from the CSF and the wireline acoustic borehole imaging. The goal of this work was to calculate a depth shift that could be applied to each core box so core datasets can be presented in wireline equivalent depth as well as drillers' depth.

7.1 INITIAL DEPTH SHIFT METHODOLOGY

There is substantial information in the literature on using borehole imaging as a basis for core log integration work. A brief description is included below. For more information on borehole imaging and its applications see Paillet *et* al. (1990) and Prensky (1999). An example of depth shifting methodology can be seen in Galliot *et al*. (2007).

Due to the acquisition of wireline acoustic borehole imaging there was a continuous record of the structural and stratigraphic features downhole for GGC01. These features included sedimentary features such as bedding and cross bedding alongside interpreted faults and fractures. In total 996 features were interpreted between 34 and 194 m wireline depth from the acoustic borehole images.

To calculate a wireline equivalent depth for each core box, the optical images and 2D X-Ray images acquired from the Core Scanning Facility were compared against the wireline acoustic borehole imaging. The acoustic borehole imaging tool is sensitive to changes in acoustic impedance and damage to the borehole wall. This does not necessarily correspond to stratigraphic features such as bed boundaries or mineralised zones. This is why the acoustic borehole imaging can sometimes appear as though there is less variability in the borehole imaging than in the optical images of the core (Figure 8).

Interpreters then identified common features on the borehole imaging with those present in the core. Clear features which were matched to a high degree of certainty were labelled as "key features". Once these key features were identified in both core and wireline they could be used to calculate the depth discrepancy between the wireline and drillers' depth (Figure 8). In some cases, there was good agreement between drillers' depth and wireline depth (Figure 10).

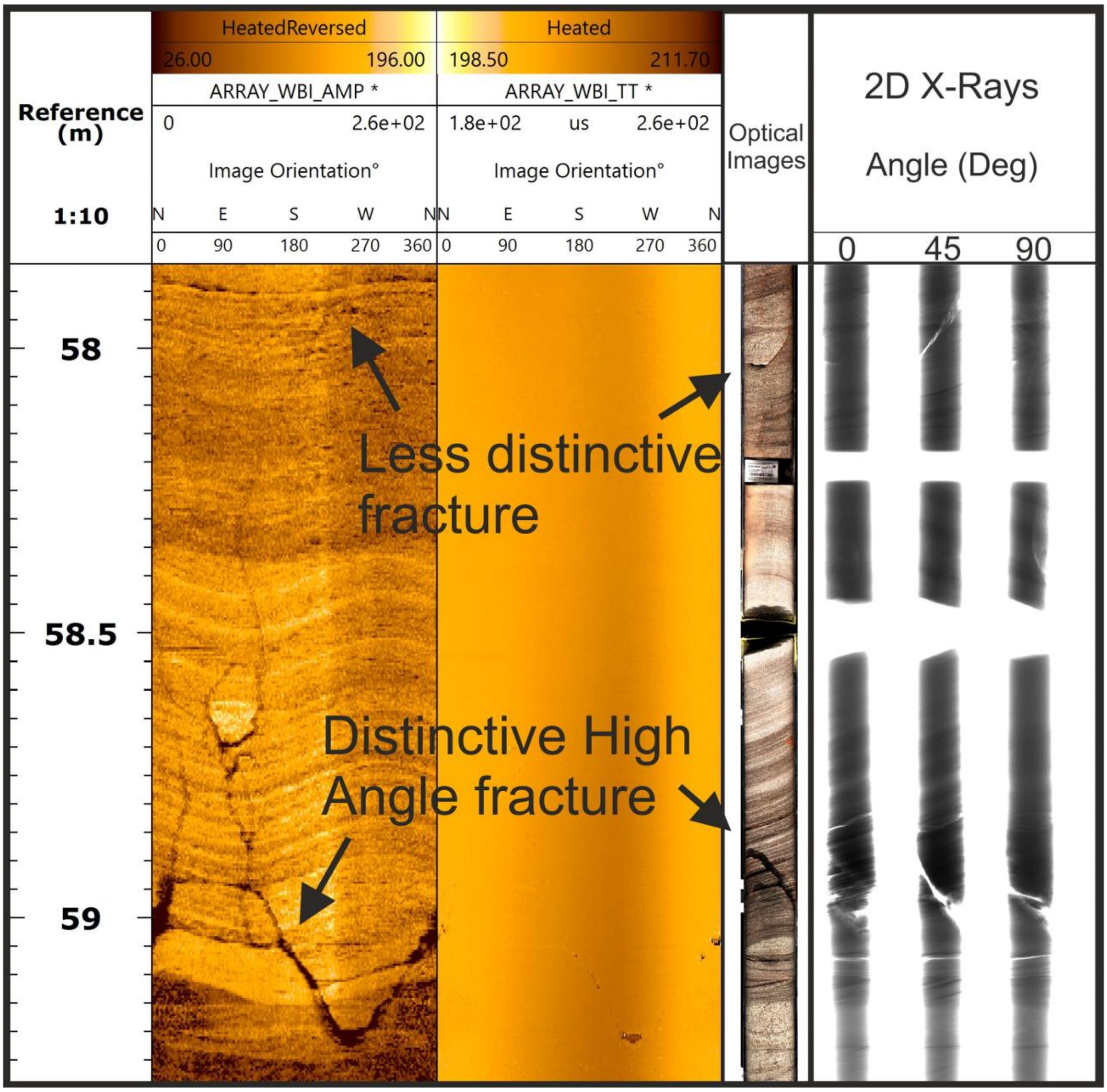


Figure 10 Image showing small depth discrepancy between drillers' depth and wireline depth. Left; Wireline depth in m, Centre Left; Acoustic Amplitude Image from wireline logging, Centre; Acoustic Travel Time Image. Centre Right; Optical image of core acquired using the Geotek MSCL-XYZ. Right 2D X-Rays of core acquired at 0, 45 and 90 degrees to the core using the Geotek MSCL-RXCT.

Depth discrepancies in the core increase the chances of mismatching features when comparing the core against the borehole imaging. This is a particular problem when individual features are not distinct. The Scottish Coal Measures Group drilled by GGC01 is dominated by lower angle features, such as bedding planes (Figure 11). Over 90% of the interpreted features on the borehole imaging had a dip of < 35 degrees (12573 features). The result is that there is a greater chance of mismatching low angle features identified on borehole imaging to core unless they are distinctive for example, for example a coal seam.

In addition, there were sections of the borehole where there were no clear high angle features on the borehole imaging. This can make depth matching difficult and increase the chance of mismatching features identified in borehole imaging to core (Figure 11).

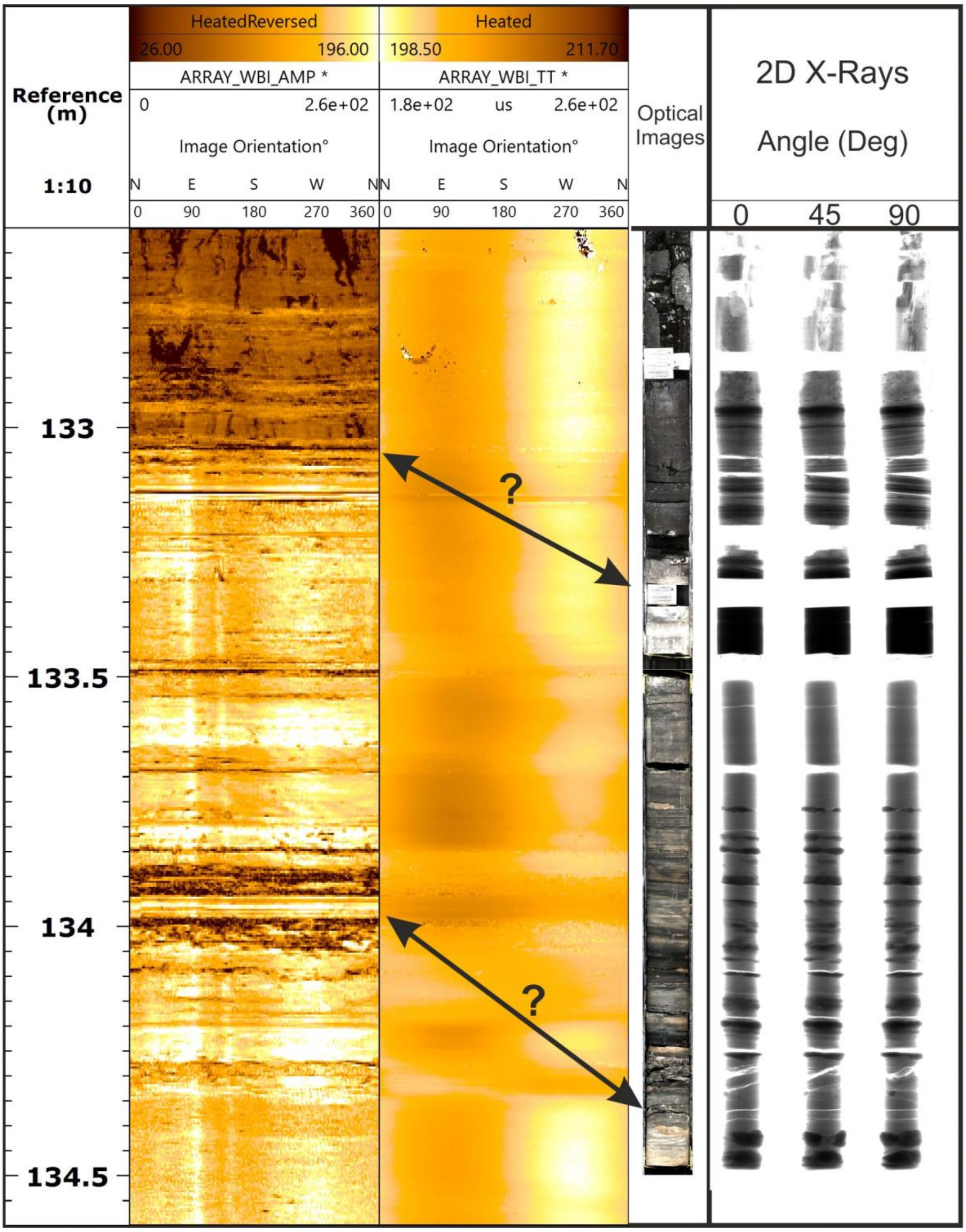


Figure 11 Image showing area with no clear features to match core data to wireline data. Left; Wireline depth in m, Centre Left; Acoustic Amplitude Image from wireline logging, Centre; Acoustic Travel Time Image. Centre Right; Optical image of core acquired using the Geotek MSCL-XYZ. Right 2D X-Rays of core acquired at 0, 45 and 90 degrees to the core using the Geotek MSCL-RXCT.

To reduce the likelihood of mismatching features from the borehole imaging only a small number of distinct features were used in the depth matching process. In total 51 key features were used.

These key features were chosen as there was a high degree of confidence that the features could be mapped from core to borehole imaging. Additional factors that were taken into consideration included the depth of the feature and whether it was proximal to zones of core loss. The reason core loss was considered was that cores were assumed to be continuous within and between runs unless there was clear core loss or zones of damage on the images (Figure 12).

Of these 51 features 16 were used as depth control points. While the depth shift was being calculated a further 35 features were used to provide a validation on the depth check (Figure 11). This highlighted areas where features had been misidentified and also showed areas where core loss was incorrectly attributed.

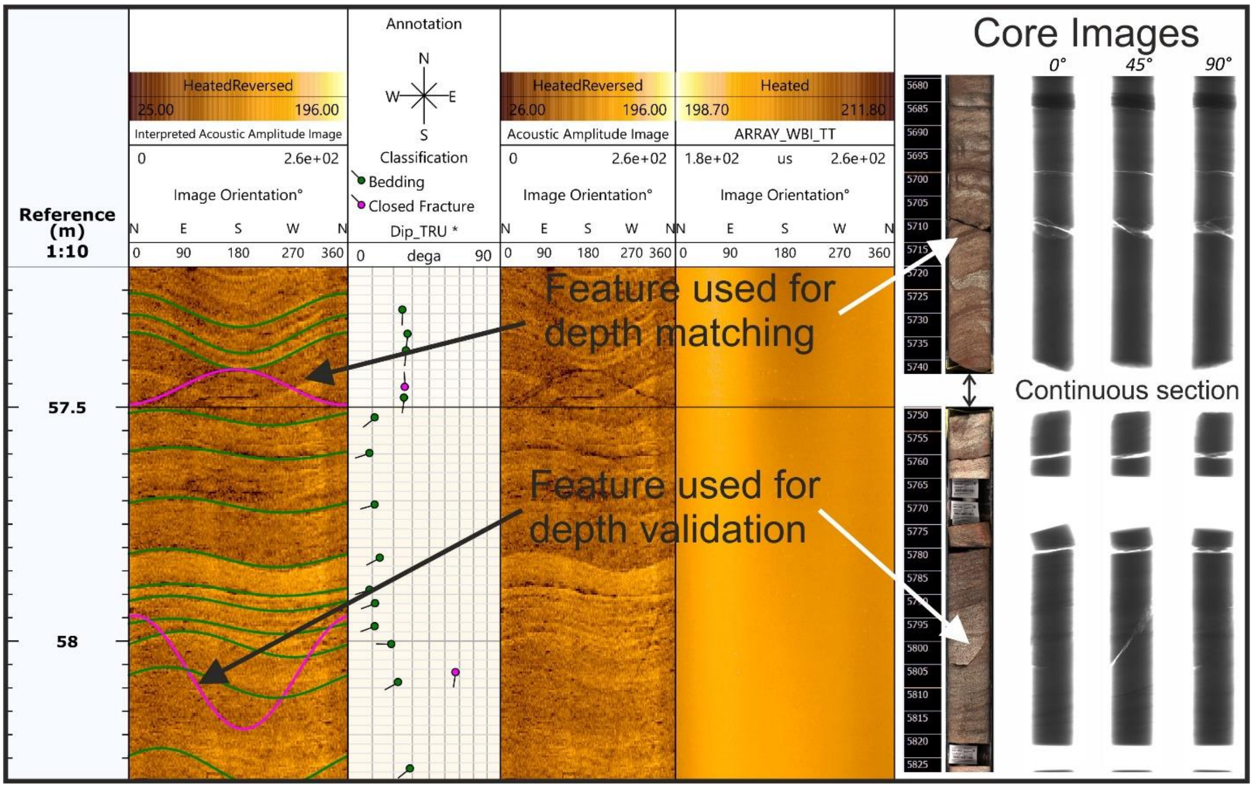


Figure 12 Image showing an example of the depth matching methodology with distinctive features which can be mapped from the core to the borehole imaging being used to calculate and validate the depth shift. Left; Interpreted Acoustic Amplitude Image, Centre Left; Tadpoles from borehole imaging interpretation, Centre; Acoustic Amplitude Image from wireline logging, Right; Acoustic Travel Time Image. Optical image of core acquired using the Geotek MSCL-XYZ and 2D X-Rays of core acquired at 0, 45 and 90 degrees to the core using the Geotek MSCL-RXCT.

7.2 VALIDATION OF DEPTH SHIFT USING CORE SCANNER DATA

Once the depth shift had been calculated for each core, it was used to shift the core scanner data from the MSCL-S scanner to wireline equivalent depth. The MSCL-S scanner records core density and natural gamma ray, which are directly comparable to the density and gamma ray data from the wireline logging (Section 5), albeit at different sampling intervals. Therefore, these two datasets were compared to provide an independent validation of the depth shift. Full details on the core scanner data can be found in Section 6.

This validation step showed that in some places the depth shift applied to the MSCL-S data improved the match to the wireline logs, though in some cases had not completely corrected it (Figure 13, Figure 14). It also became apparent that in some cases the depth shift applied to the MSCL-S data had decreased the match to the wireline data (Figure 15).

This decrease is likely to be the result of mismatches between features identified in the core and features identified on the borehole imaging. There are a number of possible causes for this, the most likely being the lack of clear features across certain intervals and potentially zones of core loss (Figure 11).

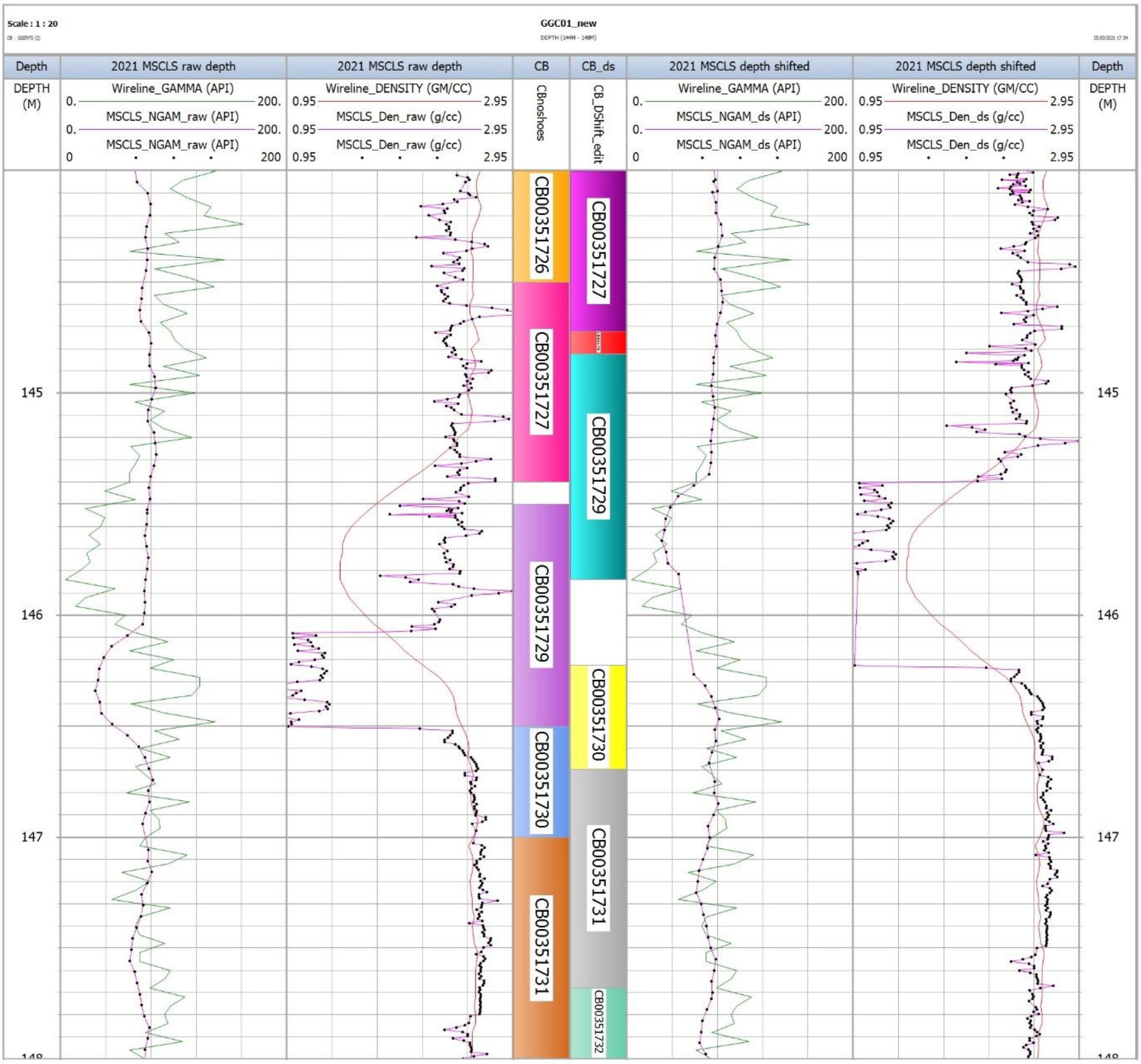


Figure 13 An example where the depth shift applied has improved the MSCL-S to Wireline fit. Left; Unshifted MSCL-S data (drillers' depth) on the left in pink lines/black dots. Right; Shifted MSCL-S data to match the wireline data (wireline equivalent depth). Wireline density and Gamma Ray data shown in red and green respectively.

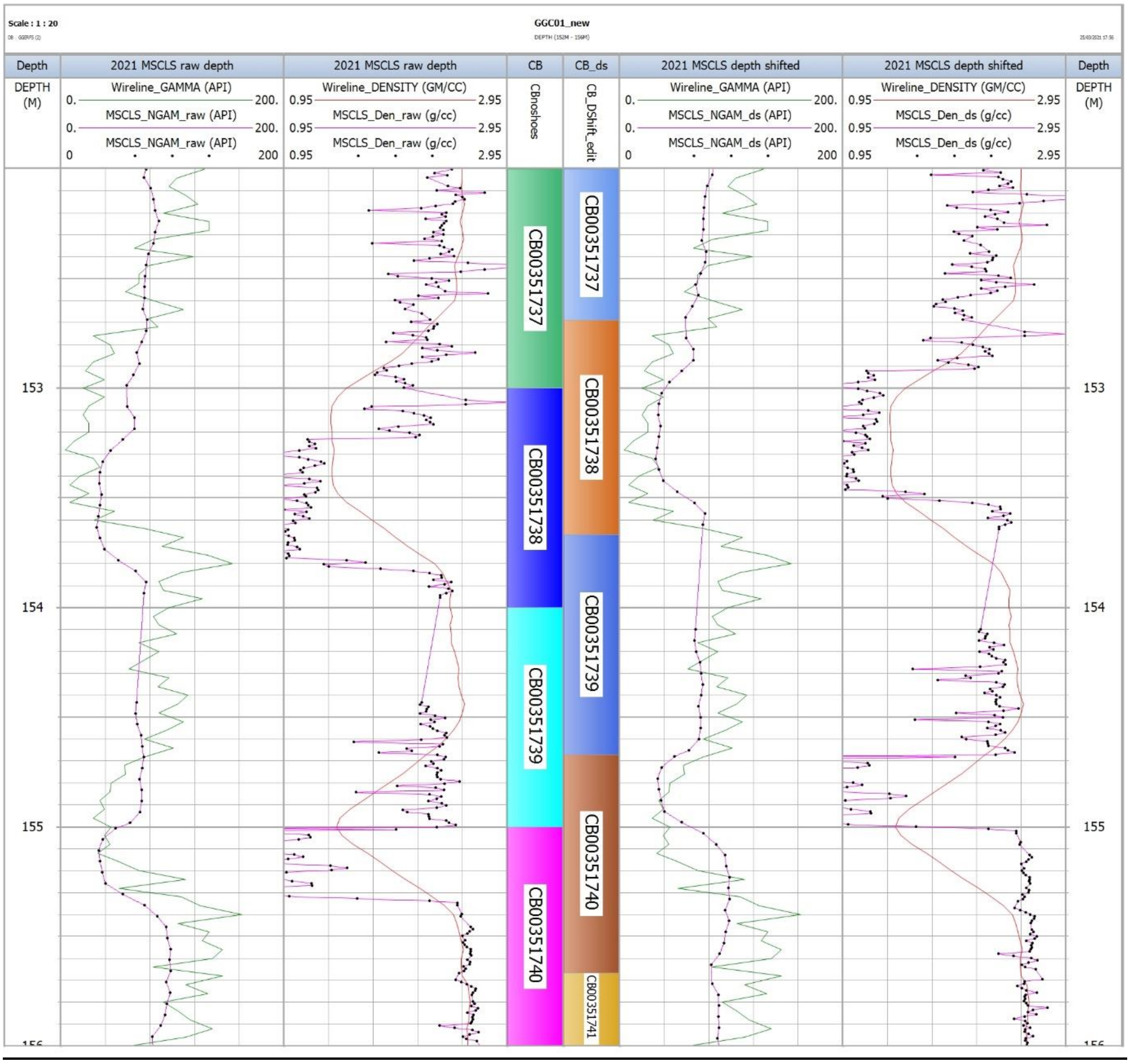


Figure 14 An example where the depth shift applied has improved the MSCL-S-Wireline fit with a small mismatch remaining. Left; Unshifted MSCL-S data (drillers' depth) on the left in pink lines/black dots. Right; Shifted MSCL-S data to match the wireline (wireline equivalent depth). Wireline density and Gamma Ray data shown in red and green respectively.

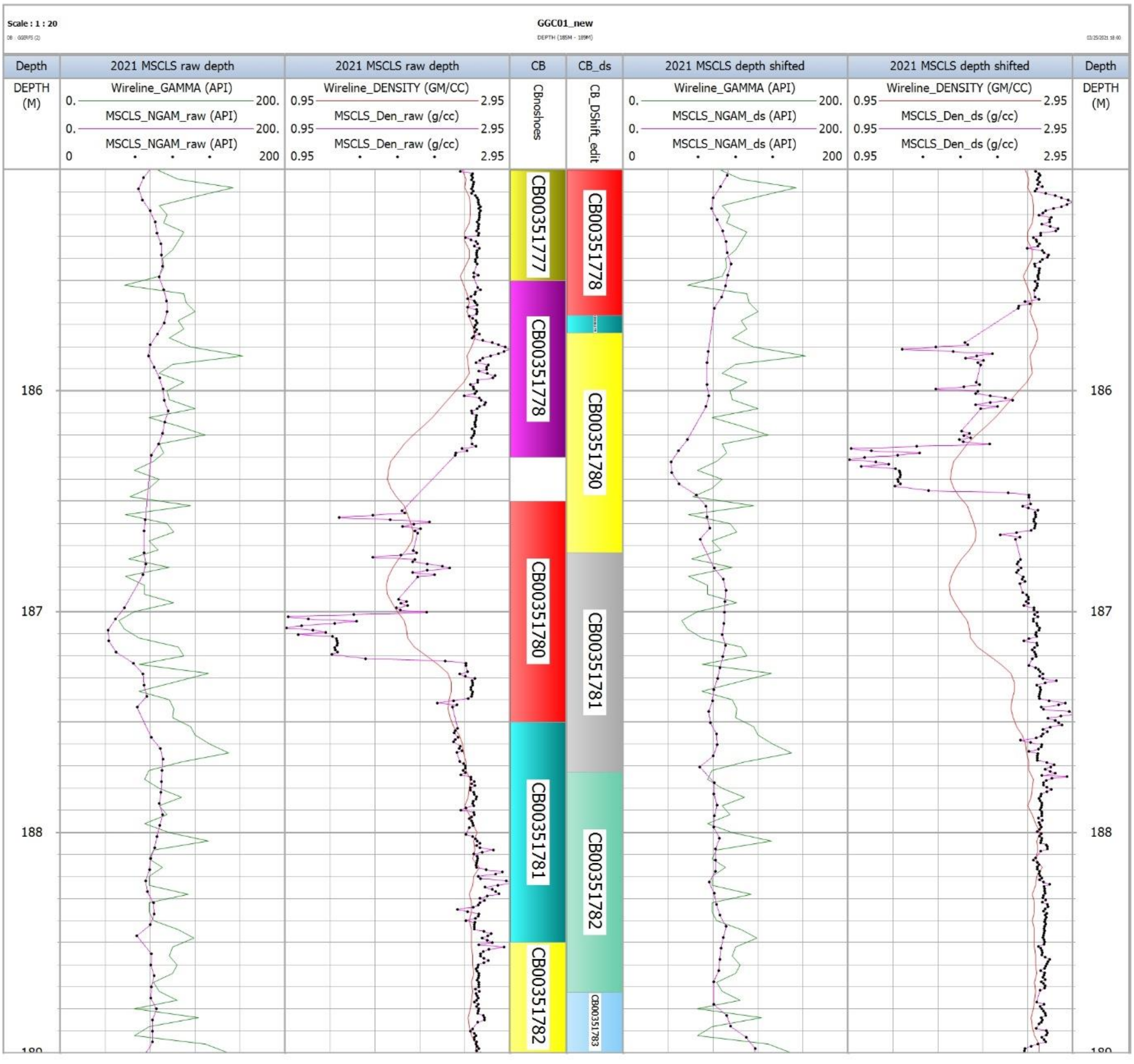


Figure 15 An example where the depth shift applied has decreased the MSCL-S-Wireline fit. Left; Unshifted MSCL-S data (drillers' depth) on the left in pink lines/black dots. Right; Shifted MSCL-S data to match the wireline (wireline equivalent depth). Wireline density and Gamma Ray data shown in red and green respectively.

7.3 FINALISED DEPTH SHIFT

After assessment of the shifted and unshifted MSCL-S data it was concluded that between 28 m and 173.28 m wireline depth, the depth shift improved the match between the core scanner MSCL-S and wireline geophysical data.

To address the remaining mismatch at the base of the borehole (Figure 15) the calculated depth shift from the borehole imaging was further shifted by 0.5 m. This additional shift was calculated by matching the gamma ray and density data from the MSCL-S to the wireline density and gamma ray logs.

This has created a finalised depth shift for each core box which can be used to display all core scanner datasets to driller depths or to wireline equivalent depth for comparison with wireline data. It also accounts for all overlength and no-recovery core sections.

A spreadsheet (GGC01_Corebox_Depths_Final.*xlsx*) showing all of the core boxes for GGC01, the drillers' depth and wireline equivalent depths can be found in the accompanying data release. The depth shift provided can now be applied to other core data sets, where they are referenced to the corebox code, to make it comparable to the wireline data depths and allow meaningful scientific comparisons between data types at common depths.

The core scanner MSCL-S and XRF/NIR data are provided in both drillers' depth and wireline equivalent depths for this data pack. An overview of the depth reference system for each dataset can be found in Table 1.

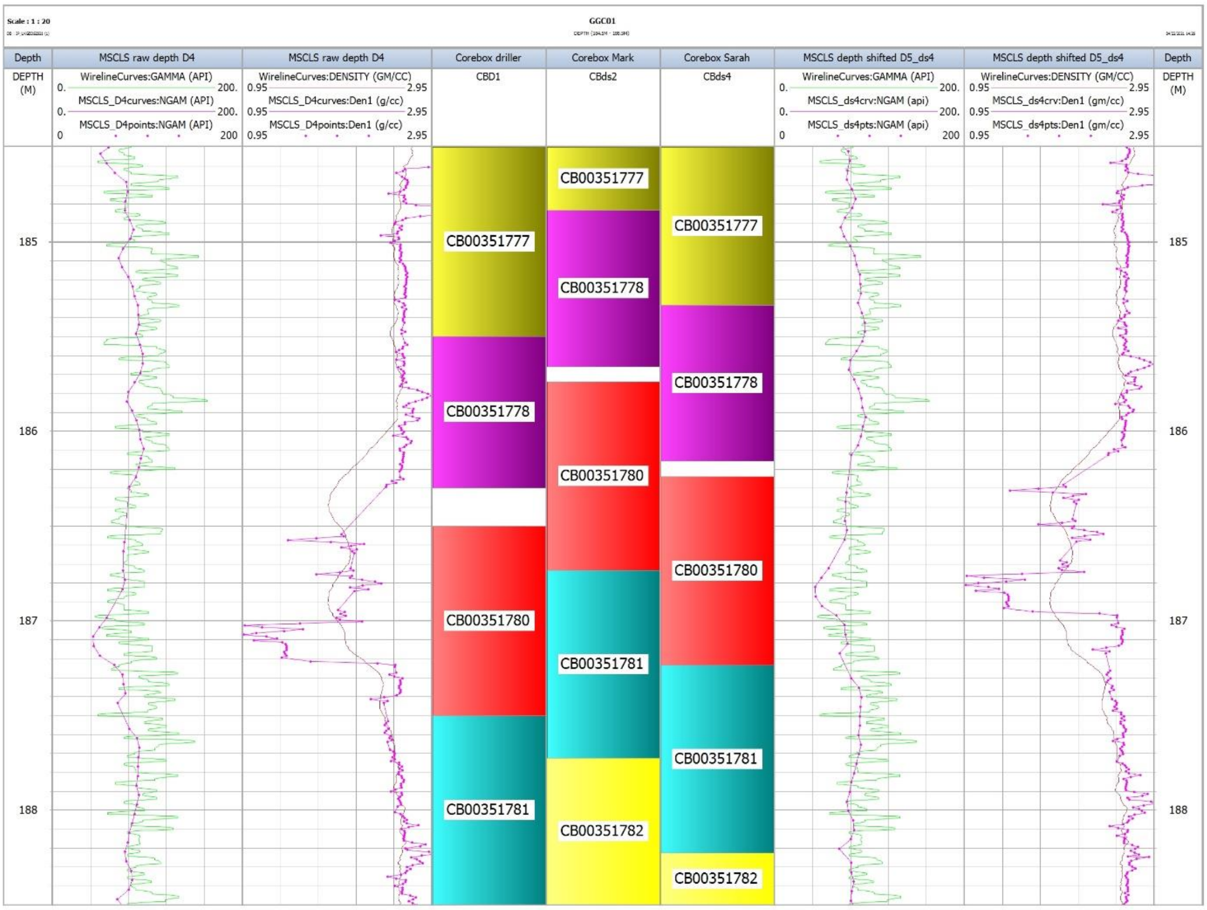


Figure 16 An example where the depth shift applied has improved the MSCL-S-Wireline fit after an additional 0.5 m shift was applied to borehole imaging wireline shift. Left; Unshifted MSCL-S data (drillers' depth) on the left in pink lines/black dots. Right; Shifted MSCL-S data to match the wireline (wireline equivalent depth). Wireline density and Gamma Ray data shown in red and green respectively.

7.4 EXAMPLE OF WIRELINE DEPTH EQUIVALENT XRF DATASET

Interpretation of core scan data is outside the scope of this report. However, an illustration of the correlation between datasets is shown in: Figure 17.

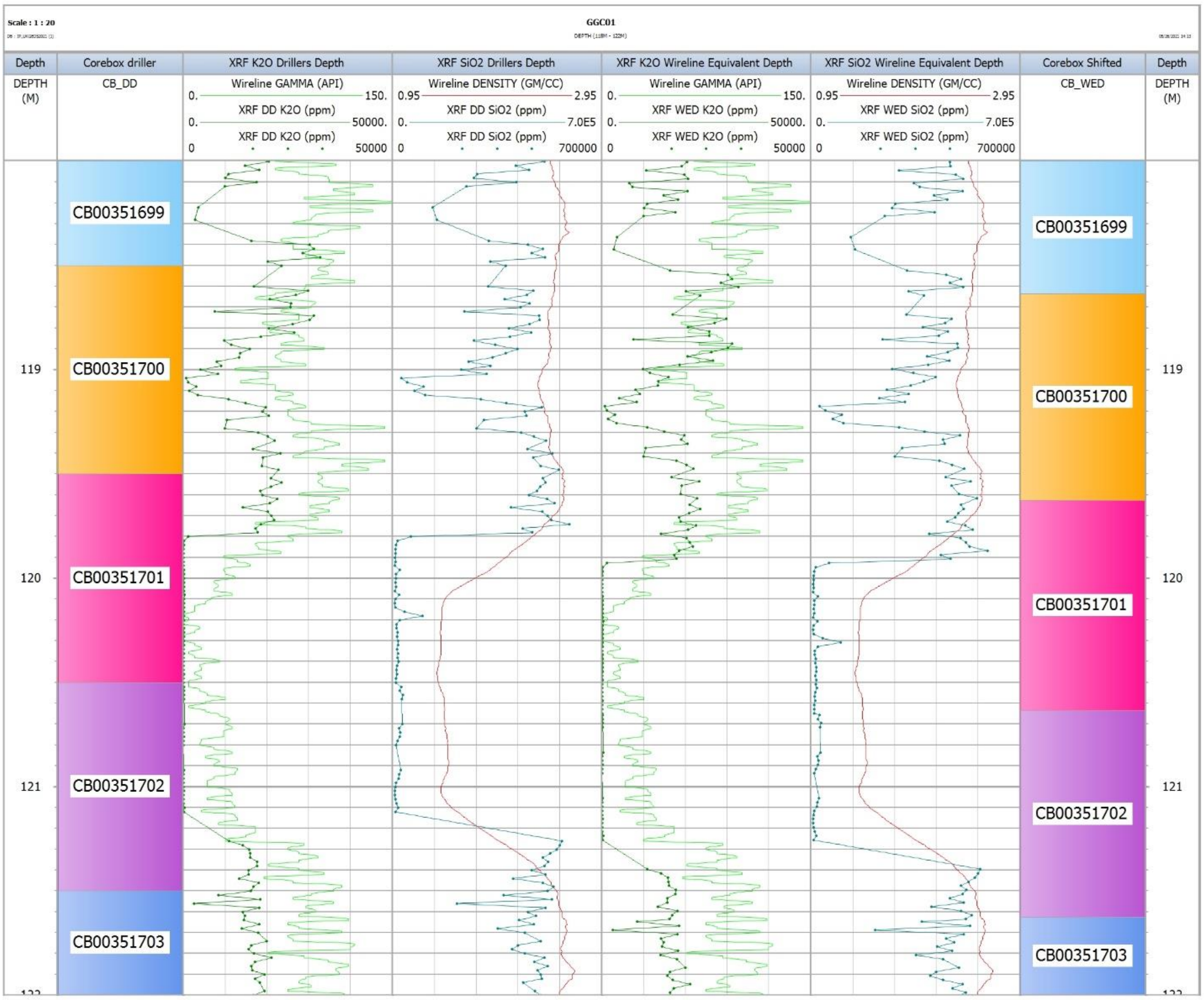


Figure 17 Example of XRF core scan data displayed at drillers' depth (left two tracks) and wireline equivalent depth (right two tracks) for a 4 m interval.

8 Sedimentary log and initial stratigraphical interpretation

File names:

*Composite Log GGC01c.pdf –overview of sedimentary log, facies interpretation and wireline log (*Figure 18 *below) - a minor update to Quaternary interpretation compared to the intermediate data pack.*

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.

8.1 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 10 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 18).

Table 10 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.

8.2 SUMMARY SEDIMENTARY LOG

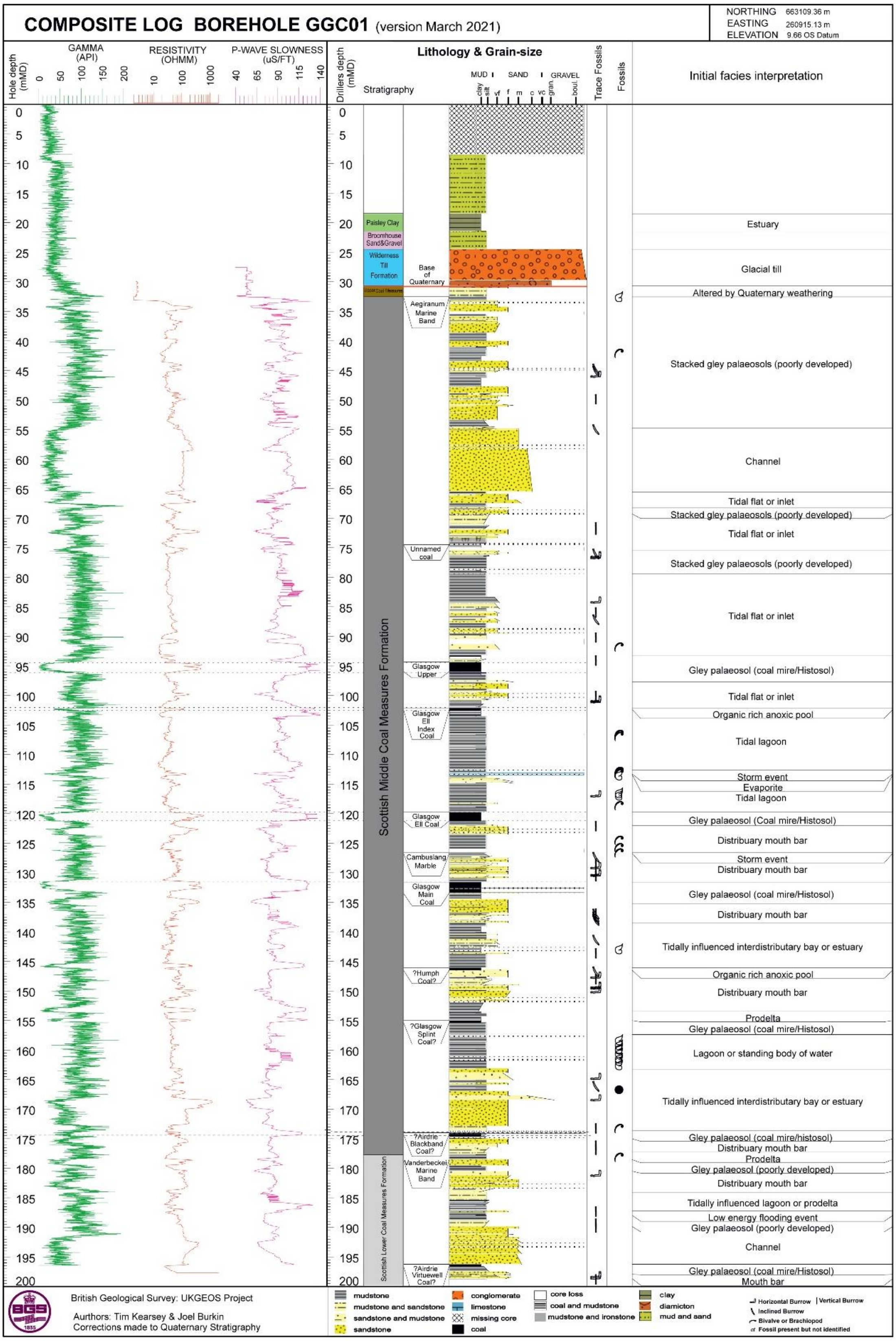


Figure 18 Summary sedimentary log and stratigraphical interpretation of borehole GGC01 measured against drillers' depth used in core logging. Geophysical (wireline) log data is displayed at wireline depths. Updated version March 2021   A pdf version of this figure is included within the data release.

8.3 SUMMARY OF OBSERVED BEDROCK SEDIMENTARY FEATURES

8.3.1 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 19) 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 19 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 18). 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.

8.3.2 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 20 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 5 cm 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 20), 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 20B).

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

8.3.3 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 21). 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 21 Pyritised bivalve shells in a marine band, close to life position.

8.3.4 Mussel bands

Two mussel bands were observed in the core; the deepest being the Cambuslang Mussel Band at 126.55 - 126.72 m (Figure 22) 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 22 Cambuslang Mussel Band

8.3.5 Bioturbation

Bioturbation was common in the coarsening upward sandstone sequences. Good examples of *Asterosoma,* and *Diplocraterion* (Figure 23) 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.

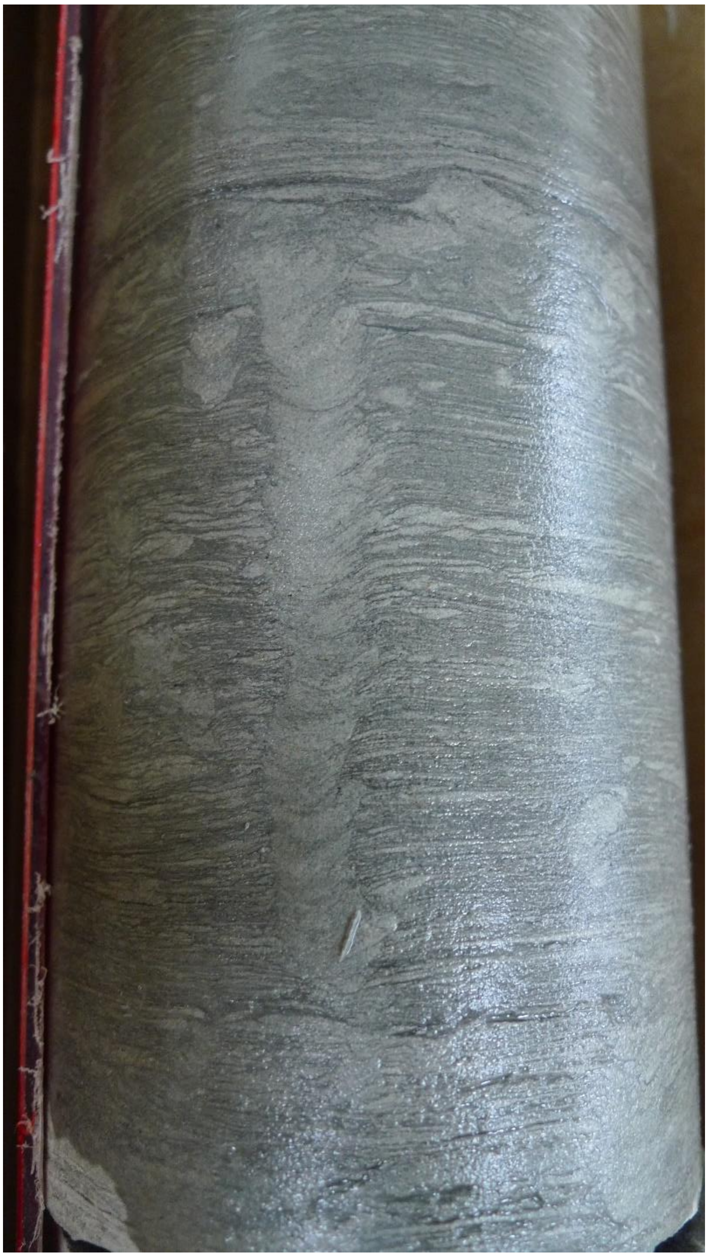


Figure 23 *Diplocraterion* burrows in core.

8.4 STRATIGRAPHICAL INTERPRETATION

8.4.1 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 11). 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 24). The interpretation of the Aegiranum Marine Band signifies the base of the Upper Coal Measures and means that a 1.8 m 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 11 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 24. 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 12 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 12 Positions of the bedrock stratigraphic boundaries that were tentatively identified in GGC01 (drillers' depths).Correction made in March 2021 to the top Airdrie Virtuewell.

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	196.25	196.60	Airdrie Blackband Coal

8.4.2 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 13). 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 8.50 m the borehole was open holed drilled so there was no core recovered above this point.

Table 13 Positions of the superficial deposits stratigraphic boundaries that were confidently identified in GGC01 (drillers' depth). Correction to top Paisley Clay, base Wilderness Till and base Quaternary depths made in March 2021.

Horizon	Top depth (m DD)	Base depth (m DD)
Paisley Clay Formation	18.50	21.50
Wilderness Till Formation	24.50	30.70
Base of Quaternary	-	30.70

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

Table 14 shows the difference between the predicted pre-drill depths from 3D geological modelling (an earlier version of the models described in Arkley, 2019; Burkin and Kearsey, 2019) and the measured drillers' depths.

Table 14 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 used for the borehole prognosis, an earlier version than that described in Burkin and Kearsey (2019), 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 25), 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.

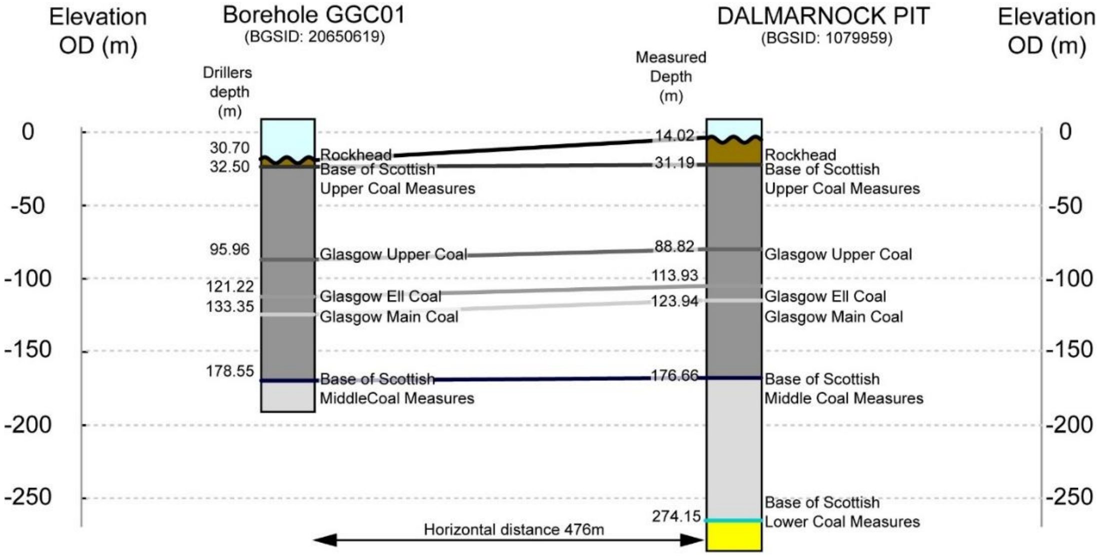


Figure 25 Comparison of depth of key stratigraphic horizons between GGC01 and Dalmarnock Pit shaft record around 500 m away.

9 Engineering geology log

File names:

EngineeringLog_GGC01_1_25scale_v03.pdf – drawn up log

Engineering_core_description_GGC01_V03.xlsx – spreadsheet log

9.1 METHOD

The engineering geology logging took place at the same time as the discontinuity logging at the NGR, Keyworth (Section 10). Limitations on the handling of, and damage to, core material were in place with the standard field engineering description of BSI (2018 a,b) followed as much as was possible.

9.2 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.

10 Discontinuity log

File name: Discontinuity_log_GGC01.xlsx

10.1 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 10.2, and a summary of the key observations of discontinuity character arising from this brief examination of the core is presented in section 0.

10.2 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 15. 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 15 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.

10.3 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 26.

- 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 27a).
- 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 27b); 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 27c). 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 26. Ten PFFs and twenty possible PFFs were identified. The PFFs are mainly mineralised joints that are either largely mineralised but locally gapped (Figure 27d), 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 27e, 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.

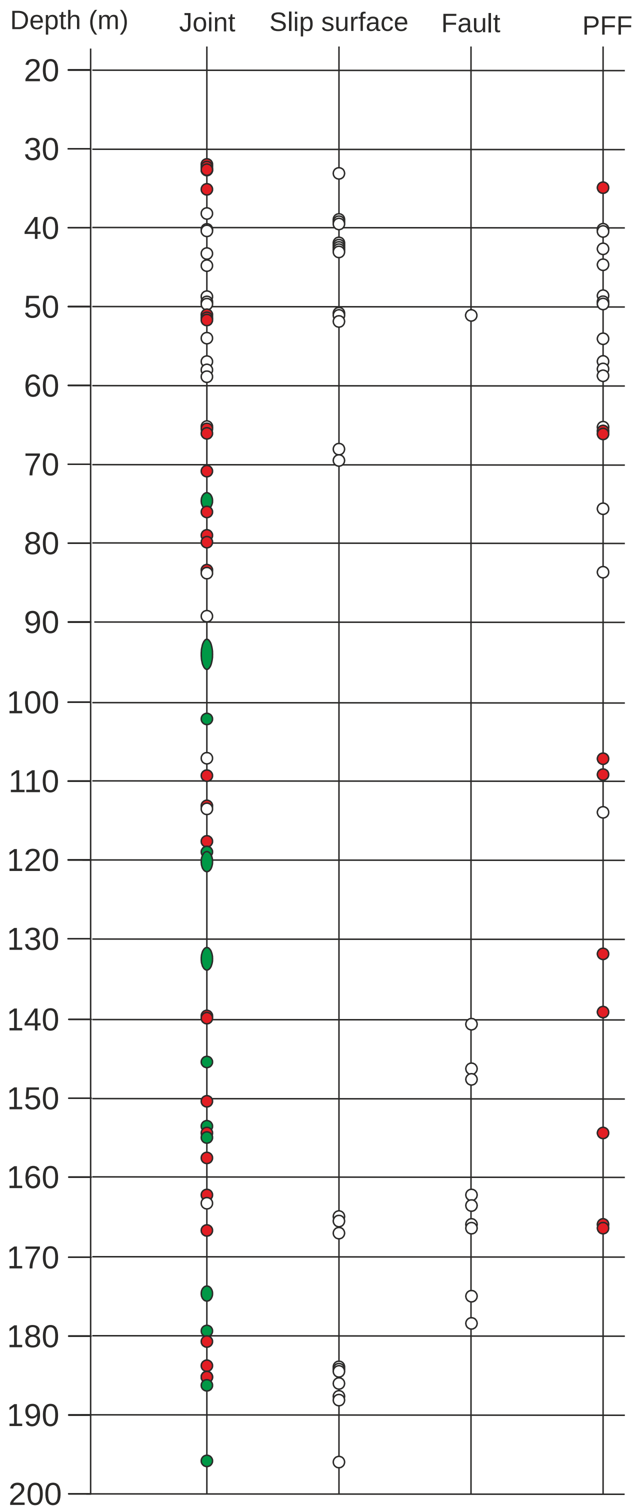


Figure 26 Distribution of logged discontinuities in GGC01 core

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.

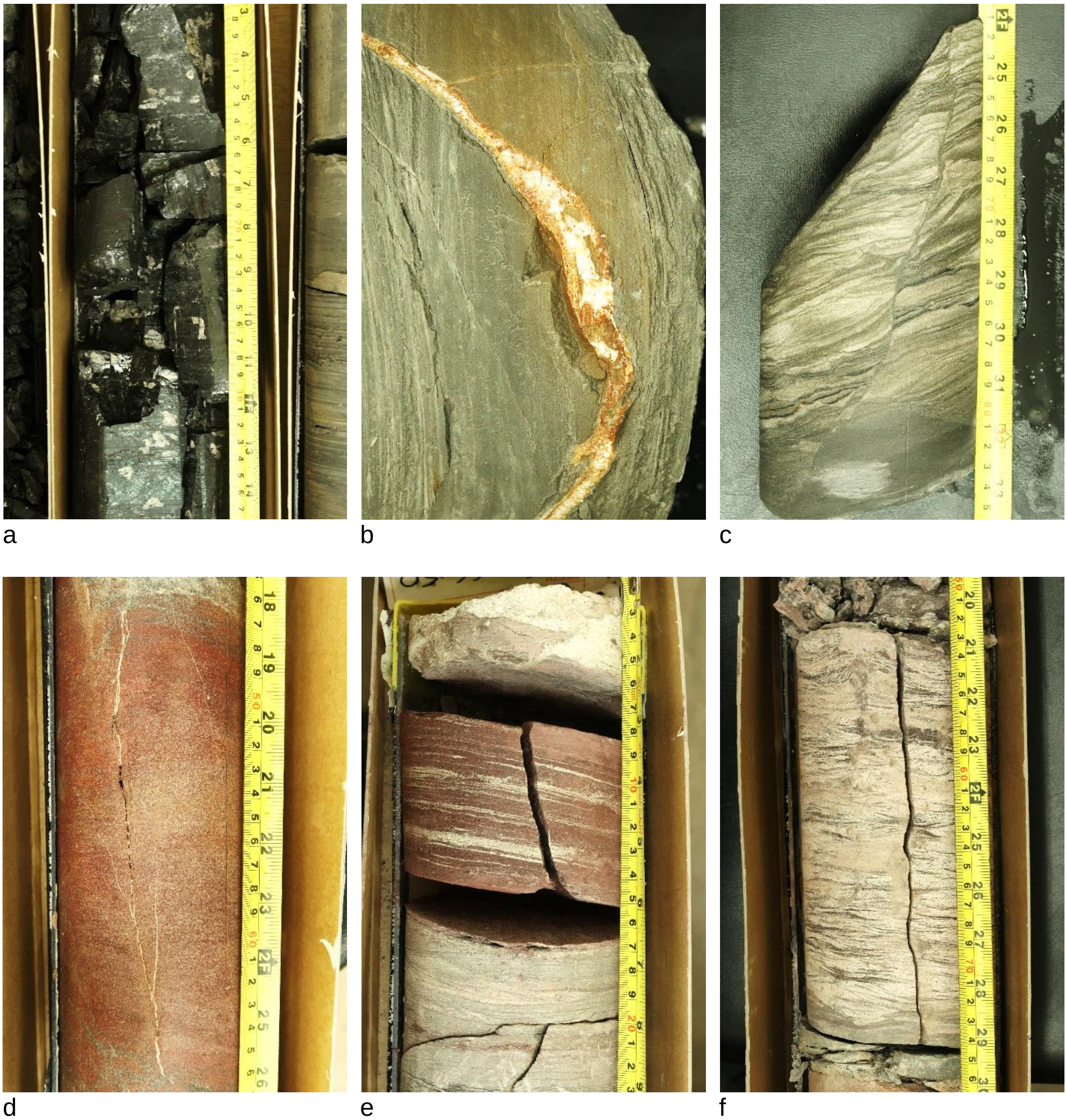


Figure 27 Character of discontinuities in core GGC01

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.

Appendix A Files in the final data release

The data has been packaged into three .zip files, two of these are very large as they contain the high-resolution core scan images (grey and green highlighted rows in Table 16). The file containing the bulk of the data files, as listed in Table 16 below, is *UKGEOSGlasgow_GGC01_Final.zip* .

Table 16 Summary of files in the final data release for GGC01

Folder Name	File Name	Description
GGC01_Final	GGC01_Corebox_Depths_Final.xlsx	Index of core box numbers to depths, needed to use the core scan images, includes columns for Drillers' Depth and Wireline Equivalent Depth
	GGC01_Borehole_Meta_Data.xlsx	Metadata for borehole GGC01
Daily_Drillers_Borehole_Records	BAA4202-GGC01_DL_page 8(2018-12-04).pdf and similar (17 files)	Drillers' daily record
Drillers_Logs	GGC01 Final Log 070319.pdf	Drillers' log
	GCC01 Final info sheets 070319.pdf	Drillers' log information
	BoreholePrognosis_GGERFS10_draft_v9_Preliminary_v2.pdf	BGS first drill site interpretation
Sample_Recovery	GGC01 Coring data_V6.xlsx	BGS drill site data on core runs, recovery and geomicrobiology samples
	GGC01_geomicrobiology_externalversion_V4.xlsx	Summary of geomicrobiology core and core barrel fluid samples taken at drill site
	GGC01_fluidsamples_fieldparameters_externalversion_V5.xlsx	Summary of BGS fluid, water samples and hydrogeological field parameter readings taken at drill site
Wireline_Logging/ Comp_log	GGC01_Comp_Plot_1_200.pdf GGC01_Comp_Plot_1_500.pdf	BGS output composite log plots at two scales
Wireline_Logging/ Digital _data	LAS/GGC01_Composite_Certified.las and 6 similar named files DLIS/ GGC01_Acoustic_2.dlis and one similar named file GGC01_Acoustic_DipData.txt GGC01_Deviationdata.txt	Digital data files from wireline logging
Wireline_Logging/ Field_prints	GGC01_Composite.pdf and 4 other files	Contractors output plots
Wireline_Logging/ Report	GGERFS10_Report.pdf GGC01_Composite_Certificates.pdf	Contractors report and certificates
Wireline_Logging/ WellCAD	GGC01_Composite.WCL and 3 similar files	Digital data files in WellCAD format

Wireline_Logging/ Borehole_Imaging_Interpretation	GGC01_Borehole_Imaging_Interpretation.las	BGS borehole image interpretation from the acoustic borehole imaging data
Processed_Core_Scan_Data/ Optical Scans	SlabbedCore_lowResJPG is a folder of CB00351569.jpg and 171 similar files WholeCore_lowResJPG is a folder of CB00351569.jpg and 171 similar files	Low resolution image files of the slabbed core and whole core
UKGEOS Glasgow GGC01 Intermediate Borehole Information Pack - Part Two	High resolution .tif files (56 GB zipped, 71 GB unzipped) – separate download DOI https://doi.org/10.5285/0b49f25b-a5d6-401c-98ff-397ad9ee9ed1	In existing large file size data release– high resolution core scan images, whole core optical images, radiographic images and radiographic images-coal
UKGEOS Glasgow GGC01 Final Borehole Information Pack	High resolution .tif files (41 GB) – separate .zip *UKGEOSGlasgowGGC01_slabbedhighresimages.zip*	In new large file size data release -high resolution images of the slabbed core
Processed_Core_Scan_Data/	Fragmentation_chart_after_slabbing_GGC01.xlsx Imaged_overlength_core_sections.xlsx GGC01_MSCL_XYZ_MSCL-S_SedLog_1to100Scale.pdf	Spreadsheet of fragmentation state of slabbed core to assist with understanding XRF data Measured lengths and index to images with oversized core length sections added Summary image of MSCL-S and XRF scan data against drillers depth
Processed_Core_Scan_Data/Property_Data/Drillers_Depth	MSCL-S_DD_processed_final.xlsx MSCL-XYZ_DD_processed_final.xlsx	MSCL_S (geophysical) core scan data against drillers' depth XRF/NIR core scan data against drillers' depth
Processed_Core_Scan_Data/Property_Data/Wireline_Equivalent_Depth	MSCL-S_WED_processed_final.xlsx MSCL-XYZ_WED_processed_final.xlsx	MSCL_S (geophysical) core scan data against wireline equivalent depth XRF/NIR core scan data against wireline equivalent depth
Sedimentary_log	Composite Log GGC01_updatedMar2021.pdf	Overview of BGS sedimentary log, facies interpretation and wireline log
	Sedimentary log GGC01.pdf	Detailed BGS log with observational descriptions of each interval
	Sedimentary log GGC01.xlsx	Excel table of BGS observational descriptions of each interval, used to create the detailed log, plus dictionaries on separate worksheet
Engineering_log	EngineeringLog_GGC01_1_25scale_v03.pdf	BGS drawn up log
	Engineering_core_description_GGC01_V03.xlsx	BGS spreadsheet of log
Discontinuity_log	Discontinuity_log_GGC01.xlsx	BGS spreadsheet of log

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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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