OR/19/049 Sedimentary log and initial stratigraphical interpretation

From Earthwise

Kearsey, T, Gillespie, M, Entwisle, D, Damaschke, M, Wylde, S, Fellgett, M, Kingdon, A, Burkin, J, Starcher, V, Shorter, K, Barron, H, Elsome, J, Barnett, M, and Monaghan, A. 2019. UK Geoenergy Observatories Glasgow: GGC01 cored, seismic monitoring borehole — intermediate data release. *British Geological Survey Internal Report*, OR/19/049.

Authors: Tim Kearsey, Joel Burkin

File names: Composite Log GGC01.pdf – overview of sedimentary log, facies interpretation and wireline log (Figure 2 below)
Sedimentary log GGC01.pdf – detailed log with observational descriptions of each interval
Sedimentary log GGC01.xlsx – Excel table of observational descriptions of each interval, used to create the detailed log, plus dictionaries on separate worksheet.

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 ~3 m 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)[1]. Table 1 shows the features that were described for each bed in the logging spreadsheet. This original spreadsheet was then modified for import in to graphical logging software such as SedLog (Zervas et al. 2009[2]) and Strater® (Figure 2).

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

Column title	Explanation
Base boundary*	Nature of the base of bed (e.g. erosional, graded etc.).
Bed angle*	Tectonic dip of bedding (e.g. horizontal, gentle etc.).
Lithology*	Bulk lithology of bed (e.g. mudstone, sandstone, coal etc.).

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

Summary sedimentary log

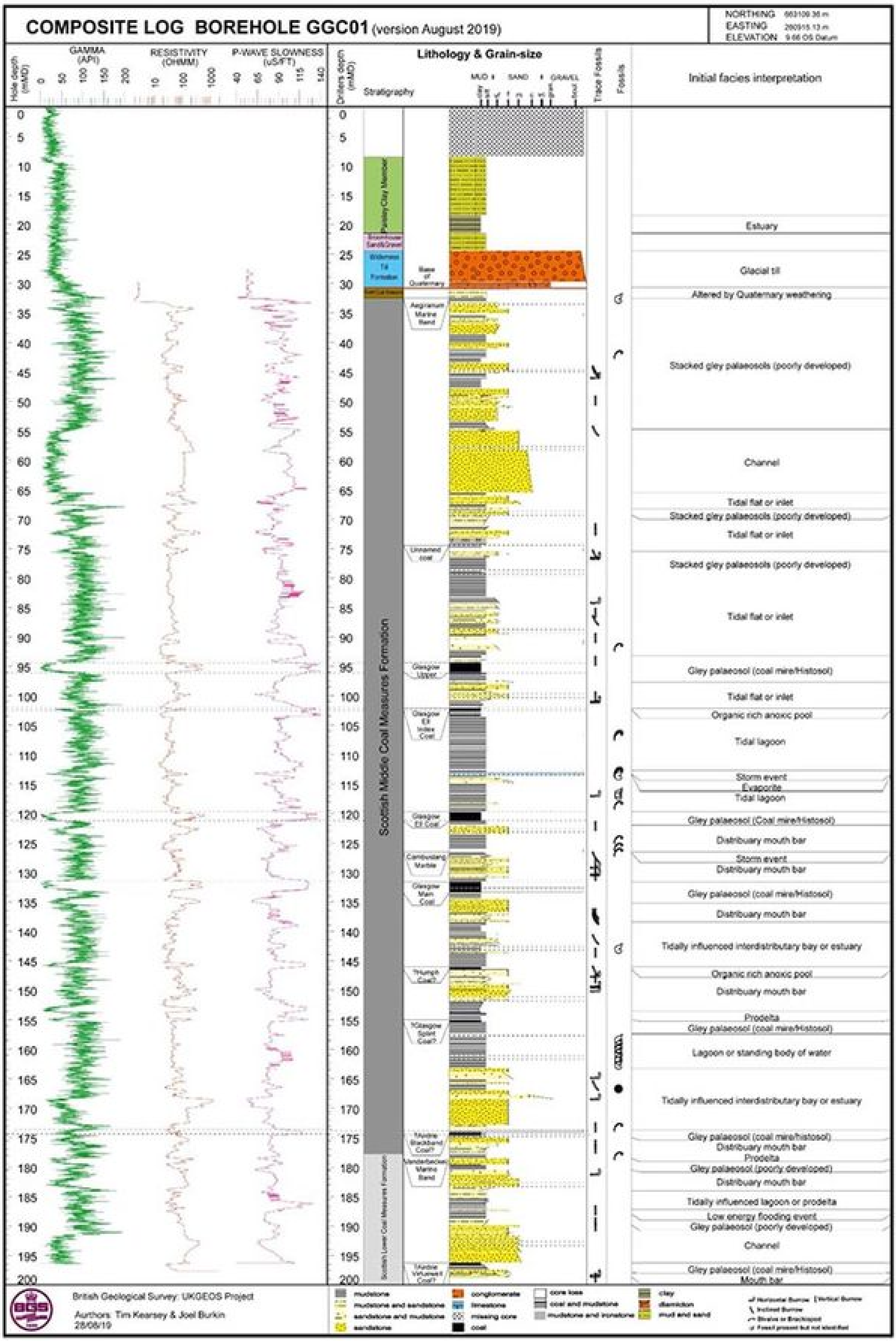

Figure 2 Summary sedimentary log and stratigraphical interpretation of borehole GGC01 measured against drillers' depth used in core logging. Geophysical (wireline) log data against hole depth. An A3 pdf version of this figure is included within the data release.

Summary of observed bedrock sedimentary features

Sandstones

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

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

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

Coals and palaeosols

Ten separate stratigraphic named coal beds, ranging from 0.07 m to 1.75 m 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[3]) Only the Glasgow Upper Coal sits on well developed (>1 m) clay rich seatearth where pedogenesis has completely destroyed any primary lamination.

Overall 18% of the bedrock showed some evidence of pedogenesis (e.g. Figure 4), often in the form of carbonised root traces. Most of the palaeosols, including those that are not associated with coals, are very weakly developed and would probably be classified as Inceptisols using the classification proposed by Retallack (1994)[4]. 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.

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

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

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

Marine bands

Several marine bands were identified in the core, although it is highly likely that some have been missed because the core has not been broken up to retrieve all of its fossil content. The marine bands (as opposed to mussel bands, see below) were all found in the same facies. The bivalves in the marine bands are distributed through up to 40 cm of the mudstone units and are found on many different bedding planes. This suggests they are found close to life position and have not been transported far (Figure 5). The mudstones in which the fossils are found in are parallel laminated and do not show any evidence of bioturbation. As such they may represent a bay or prodelta depositional environment (c.f. Thomas 2013[3]).

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

Mussel bands

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

The Cambuslang Mussel Band sits directly above a coal-rich palaeosol which it appears to have eroded part of. It contains disarticulated bivalve shells of 1–4 cm size. The shells are normally graded, flow aligned and occasionally show imbrication. This suggests they were deposited by a flow event, or events, which may have carried the shells a considerable distance. The Cambuslang Mussel Band is also called the Cambuslang Marble (Hall et al. 1998[5]), but in this core the matrix is dominated by carbonaceous siltstone rather than carbonate.

Figure 6 Cambuslang Mussel Band.

Bioturbation

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

Figure 7 *Diplocraterion* burrows in core.

Stratigraphical interpretation

Bedrock stratigraphy

The stratigraphic positions of the Glasgow Upper Coal, Glasgow Ell Index Coal, Glasgow Ell Coal and the Glasgow Main Coal were all confidently identified in the borehole (Table 2). Also the position of the Aegiranum Marine Band, which marks the base of the Scottish Upper Coal Measures Formation was confidently identified by comparing the material from GGC01 with the that from the Prospecthill borehole (BGSID: 1068691) which is the stratotype borehole for this boundary in this area (Hall et al. 1998[5]). Although individual fossil species were not identified in the band the general fossil assemblage of sponge spicules, foraminifera, and ostracods were diagnostic enough to confidently identify this bed (Figure 8). The interpretation of the Aegiranum Marine Band signifies the base of the Upper Coal Measures and means that a 1.8 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)[6].

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

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

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

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

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

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

Airdrie Virtuewell Coal	196.60	196.60	Airdrie Blackband Coal

Superficial deposits stratigraphy

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

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

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

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

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

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

Comparison with predictions from pre-drill 3D geological models

Table 5 shows the difference between the predicted pre-drill depths from 3D geological modelling (Arkley, 2018[7]; Burkin and Kearsey, 2018[8]) and the measured drillers' depths. Depth-shifting after core-downhole log integration may reduce the difference by up to c. 1 m.

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

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

Base of Glasgow Ell Coal	110	121.22	-12
Base of Glasgow Main Coal	116	132.60	-17

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

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

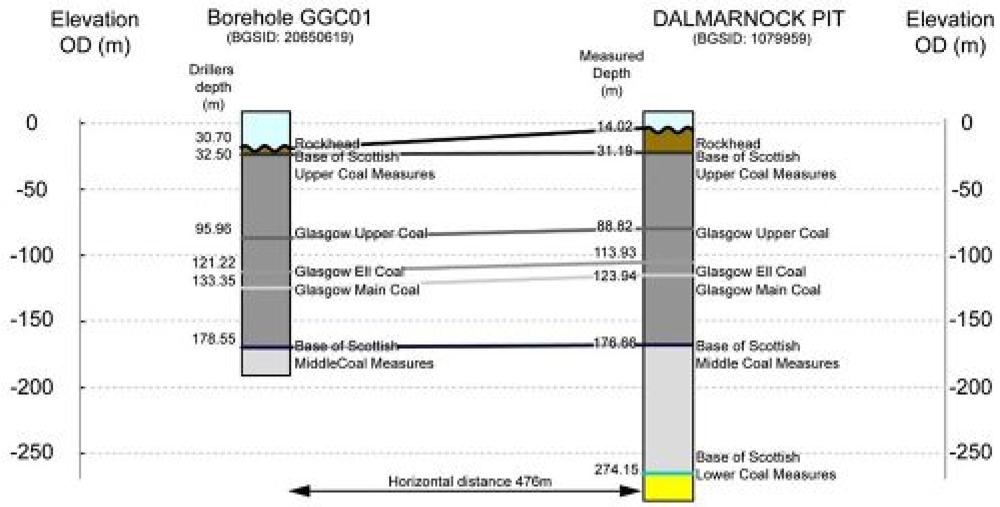

Figure 9 Comparison of depth of key stratigraphic horizons between GGC01 and Dalmarnock Pit shaft record around 500 m away.

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