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UK Geoenery Observatories Glasgow: express data release, mine water and environmental baseline monitoring boreholes at Cuningar Loop (updated June 2020)

UK Geoenery Observatories Programme

Open Report OR/20/02



BRITISH GEOLOGICAL SURVEY

UK GEOENERGY OBSERVATORIES PROGRAMME

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UK Geoenery Observatories Glasgow: express data release, mine water and environmental baseline monitoring boreholes at Cuningar Loop (updated June 2020)

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1 Introduction

Drilling of six mine water and five environmental baseline monitoring boreholes at Cuningar Loop was completed in December 2019 at the UK Geoenergy Observatory in Glasgow. This document and accompanying files provide an initial overview of the ‘as-built’ borehole infrastructure available for research and innovation.

Individual borehole data releases provide a comprehensive data pack for each borehole including:

- Drillers log
- BGS log
- Wireline and optical camera data (selected boreholes only)
- Summary report
- Spreadsheet of archived rock chip samples

Datasets from the twelfth Glasgow borehole, a 199 m deep cored, seismic monitoring borehole located in Dalmarnock are openly available at <https://www.ukgeos.ac.uk/data-downloads/glasgow/seismic-borehole-information-pack>

1.1 AS-BUILT BOREHOLE LOCATIONS AND DEPTHS

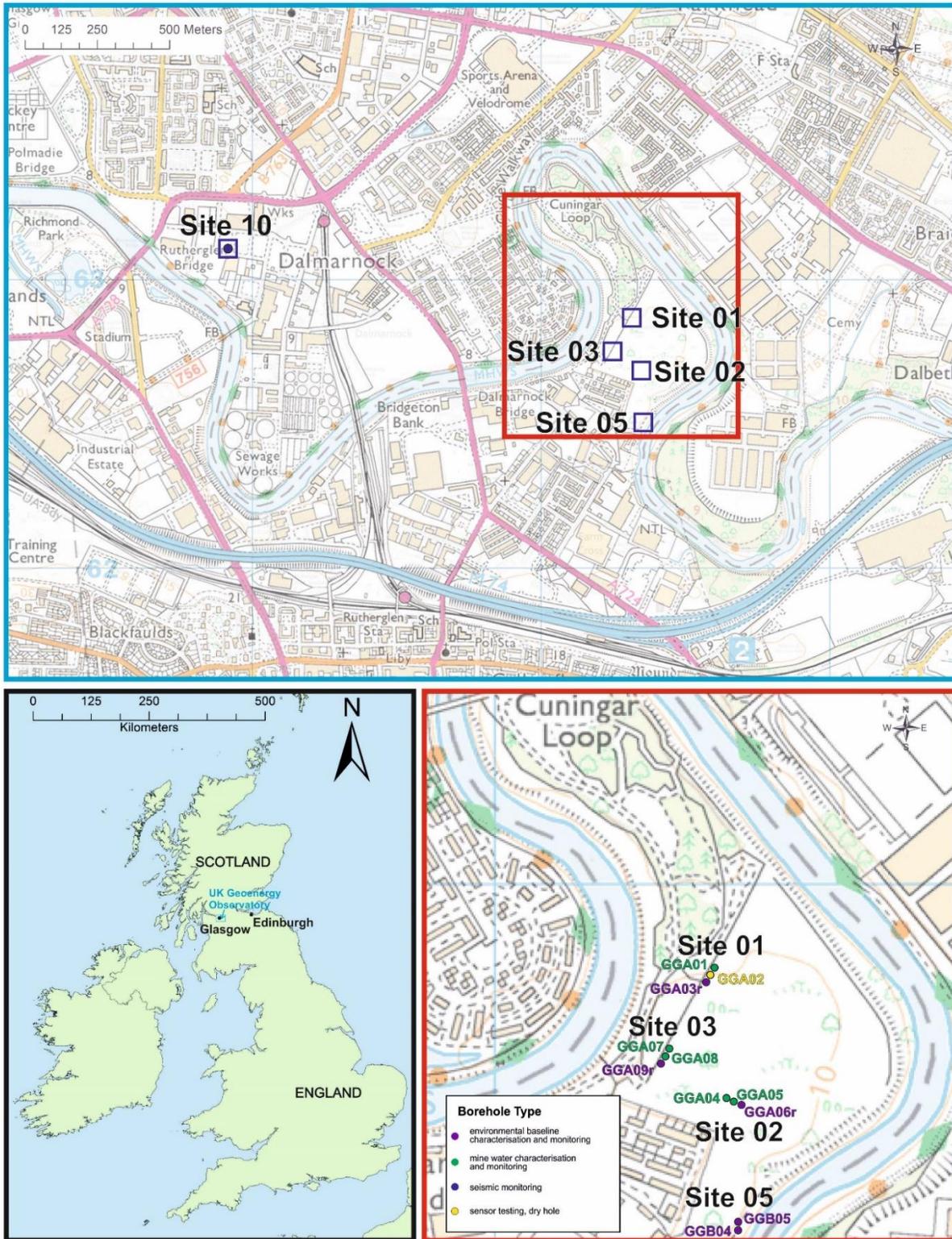


Figure 1 Location maps of the UKGEOS Glasgow borehole locations, including detail of the mine water and environmental baseline boreholes at Cuningar Loop (in red box). Contains Ordnance Survey data © Crown copyright and database rights. All rights reserved [2020] Ordnance Survey [100021290 EUL].

Borehole number	GGERFS Site number	Easting	Northing	Drilling Platform Level AOD	Total drill length, from drill platform
		British National Grid	British National Grid	metres above Ordnance Datum	metres
GGA01	GGERFS01	262318.712	662877.923	10.88	52.0
GGA02	GGERFS01	262314.012	662869.175	10.91	94.16
GGA03r	GGERFS01	262309.311	662860.227	10.95	41.72
GGA04	GGERFS02	262337.727	662687.960	12.41	53.63
GGA05	GGERFS02	262347.102	662684.932	12.22	88.5
GGA06r	GGERFS02	262356.555	662681.402	12.23	16.0
GGA07	GGERFS03	262252.230	662759.869	11.63	56.9
GGA08	GGERFS03	262247.655	662751.008	11.82	91.37
GGA09r	GGERFS03	262242.640	662742.276	11.72	16.0
GGB04	GGERFS05	262352.976	662500.043	12.40	16.0
GGB05	GGERFS05	262353.098	662510.136	12.35	46.0
GGC01	GGERFS10	260915.13	663109.36	9.66	199.0

Table 1 British National Grid reference locations for each UKGEOS borehole, drilling platform level and drilled length. Note: drilling platforms have been subsequently remediated and borehole headworks installed; final borehole datums/start heights differ.

Borehole location information is available in this summary release pack as an Excel table and a GIS shapefile (*UKGEOSGlasgowboreholes_AsBuilt_Location_Depth_v3updateJune2020.xlsx* and *UKGEOSGlasgowboreholes_AsBuilt_Jun20.shp* and *.lyr*). In addition, these digital files contain the top and base height of the screened intervals, along with the BGS_SOBI borehole reference numbers and as-built borehole datums/start heights.

1.2 NOTE ABOUT PLATFORM LEVELS AND START HEIGHTS

The drilling platform levels (metres, above Ordnance Datum) listed in this summary release were measured from hard core platforms that had been built up to provide level ground. These platforms have been remediated post-borehole construction and the final borehole start heights are from headworks that have been installed for future site users. The final as-built borehole datums/start heights are included in the accompanying Excel and shapefile.

2 Summary of screened intervals, borehole diameter and purpose

A summary of the borehole depth, screened interval, borehole diameter, installation of electrical resistivity tomography (ERT) and direct temperature sensing (DTS) fibre optic cables, and geology/purpose of the target interval is given in Table 2 below.

The boreholes have been constructed with 2 or 3 casing strings to isolate the made ground, superficial deposits and bedrock – only the internal casing diameter is listed in Table 2. Individual borehole data packs

include the full details of the various casing sizes, depths and annulus grouting, as well as a cased-hole gamma wireline log dataset from the three deepest mine water boreholes, and an open-hole optical camera downhole image and open-hole caliper/gamma wireline dataset from a few of the mine water boreholes.

Temperature, pressure, conductivity groundwater data loggers were installed into the boreholes. A set of step- and constant-rate pumping tests was completed to determine some basic hydraulic properties.

In the case of boreholes GGA02 and GGA08, the planned borehole design had to be adapted during borehole construction. A summary of the main changes is provided in sections 2.1 and 2.2 below.

Site	Site GGERFS01			Site GGERFS02			Site GGERFS03			Site GGERFS05	
Borehole number	GGA01	GGA02	GGA03r	GGA04	GGA05	GGA06r	GGA07	GGA08	GGA09r	GGB04	GGB05
Screen depth from drill platform (drilled depth, m)	45.7 - 49.3	<i>cased hole to 67.2 m</i>	37.91 - 40.72	47.7 - 51.3	83.7 - 86.4	11.92 - 13.89	51.2 - 53.9	85.53 - 88.23	11.71 - 13.61	10.63 - 12.53	43.0 - 44.8
Screen type and internal casing diameter	4 mm slotted with pre-glued gravel pack, 248 mm ID	248 mm ID	3 mm slotted with pre-glued gravel pack, 146 mm ID	4 mm slotted with pre-glued gravel pack, 248 mm ID	4 mm slotted no gravel pack, 248 mm ID	1 mm slotted with pre-glued gravel pack, 103.8 mm ID	4 mm slotted pre-glued gravel pack, 248 mm ID	4 mm slotted pre-glued gravel pack, 248 mm ID	1 mm slotted with pre-glued gravel pack, 103.8 mm ID	1 mm slotted with pre-glued gravel pack, 103.8 mm ID	3 mm slotted with pre-glued gravel pack, 146 mm ID
Description of screened interval	Overlying sandstone roof and Glasgow Upper mine working waste (47.60 - 48.86 m)	n/a. Grout filled Glasgow Main target interval/screen inside casing up to 67.2 m	Sandstone below rockhead, above Glasgow Upper mine working	Overlying sandstone roof (fractured?) and Glasgow Upper mine working position 49.46 - 50.60 m (coal and mudstone)	Overlying sandstone roof and Glasgow Main mine working, void (84.66 - 85.36 m), to mudstone floor	Sand and gravel in superficial deposits	Overlying mudstone and Glasgow Upper mine working, coal pillar and void (52.2 - 53.9 m)	Overlying sandstone/siltstone and Glasgow Main mine roadway 87.7 - 90.7 m (screen is above obstruction)	Sand and gravel in superficial deposits	Sand and gravel in superficial deposits	Sandstone below rockhead, above Glasgow Upper mine working
Total drilled depth (m) from drill platform	52.0	94.16	41.72	53.63	88.5	16.0	56.9	91.37	16.0	16.0	46.0
ERT/Fibre optics	Yes, bedrock section. Active DTS heating possible	Active DTS in superficial section. Passive DTS to 72.65 m and ERT to 85.58 m in bedrock section	No	Yes, bedrock section	Yes, bedrock section	No	Yes, bedrock section	Yes, bedrock section. DTS above seal above 83.7 m only	No	No	No
Initial hydrogeological indications from test pumping	<i>Very high yielding</i>	n/a	<i>Low yielding</i>	<i>High yielding</i>	<i>Very high yielding</i>	<i>Low yielding</i>	<i>Very high yielding</i>	<i>Very high yielding</i>	<i>Low yielding</i>	<i>Very low yielding</i>	<i>Moderately yielding</i>
Headline science outcomes	Mine water borehole for testing flow, heat response in a waste with <i>very high yield</i> . Spatial response in same seam in 3D with GGA04 and GGA07	ERT/fibre optic monitoring in response to GGA01 or GGA03r pumping. Active heating in superficial deposits. Borehole for sensor testing	Environmental baseline monitoring in bedrock. Depth connectivity and response with pumping etc. in GGA01	Fractured rock and mine working affected rock mass research. Depth response between mined seams with GGA05. Spatial response in same seam in 3D from GGA01 and GGA07	Mine water borehole for testing flow, heat etc response in a void with significant water flow. Depth response between mined seams with GGA04. Spatial response in same seam with GGA08.	Environmental baseline monitoring in superficial deposits. Depth connectivity and response with pumping etc. in GGA04 and GGA05	Mine water borehole for testing flow, heat etc response in a void. Depth response between mined seams with GGA08. Spatial response in same seam 3D with GGA01 and GGA04.	Mine water borehole for testing flow, heat etc response in a roadway/void. Depth response between mined seams with GGA07. Spatial response in same seam with GGA05.	Environmental baseline monitoring in superficial deposits. Depth connectivity and response with pumping etc. in GGA07/GGA08	Environmental baseline monitoring in superficial deposits, some distance from mine water boreholes. Depth connectivity and response with pumping	Environmental baseline monitoring in bedrock, some distance from mine water boreholes. Depth connectivity and response with pumping etc.

Table 2 Summary of as-built mine water and environmental baseline monitoring boreholes at Cuningar Loop. Where minor changes have been made from the February 2020 version of this report in response to information received from the drilling contractor, these have been shown in *italic text*. All drilled depths/lengths are given from drilling platform level, see Table 1 and section 1.2.

2.1 GGA02

Borehole GGA02 was drilled as a mine water borehole to a depth of 94.16 m. ERT and DTS cables were installed across the screened section at 79.1-83.6 m. Unfortunately in the final stages of borehole construction, during the grouting of the borehole annulus, cement (grout) entered the inside of the screen and casing and the DTS cable was damaged. The result is that GGA02 is a 'dry', cased hole to around 67.2 m. The ERT cable is functioning, facilitating cross-hole monitoring with the ERT cable in GGA01. The DTS cable is functioning only in passive (not active, heating) mode to 72.65 m.

2.2 GGA08

Borehole GGA08 is believed to have entered a roadway in the Glasgow Main mine working from 87.7-90.7 m. During the final stages of drilling the sump below the roadway a large, high angle, block was encountered that deviated the drill string and prevented the permanent casing from being emplaced to the target depth. The borehole casing was therefore terminated and screened within the roadway and above the obstruction. Due to the length of the sump needed to accommodate the DTS termination unit, the DTS cable was terminated above the seal at 83.7 m. The ERT cable extends to the base of the casing, with the lowest sensor at 88.0 m.

3 Initial interpretive summary geological images

Figures 2-4 below have been prepared as an illustrative representation of the initial BGS interpretation of the bedrock boreholes and mine workings encountered. These are based on observations from drilling (e.g. drop of drill rods, smell of H₂S), BGS on-site logs of the returned rock chips, mine plan information, wireline (caliper) and optical camera open-hole data (selected boreholes only). The interpretations are subject to change with further interpretation of the datasets.

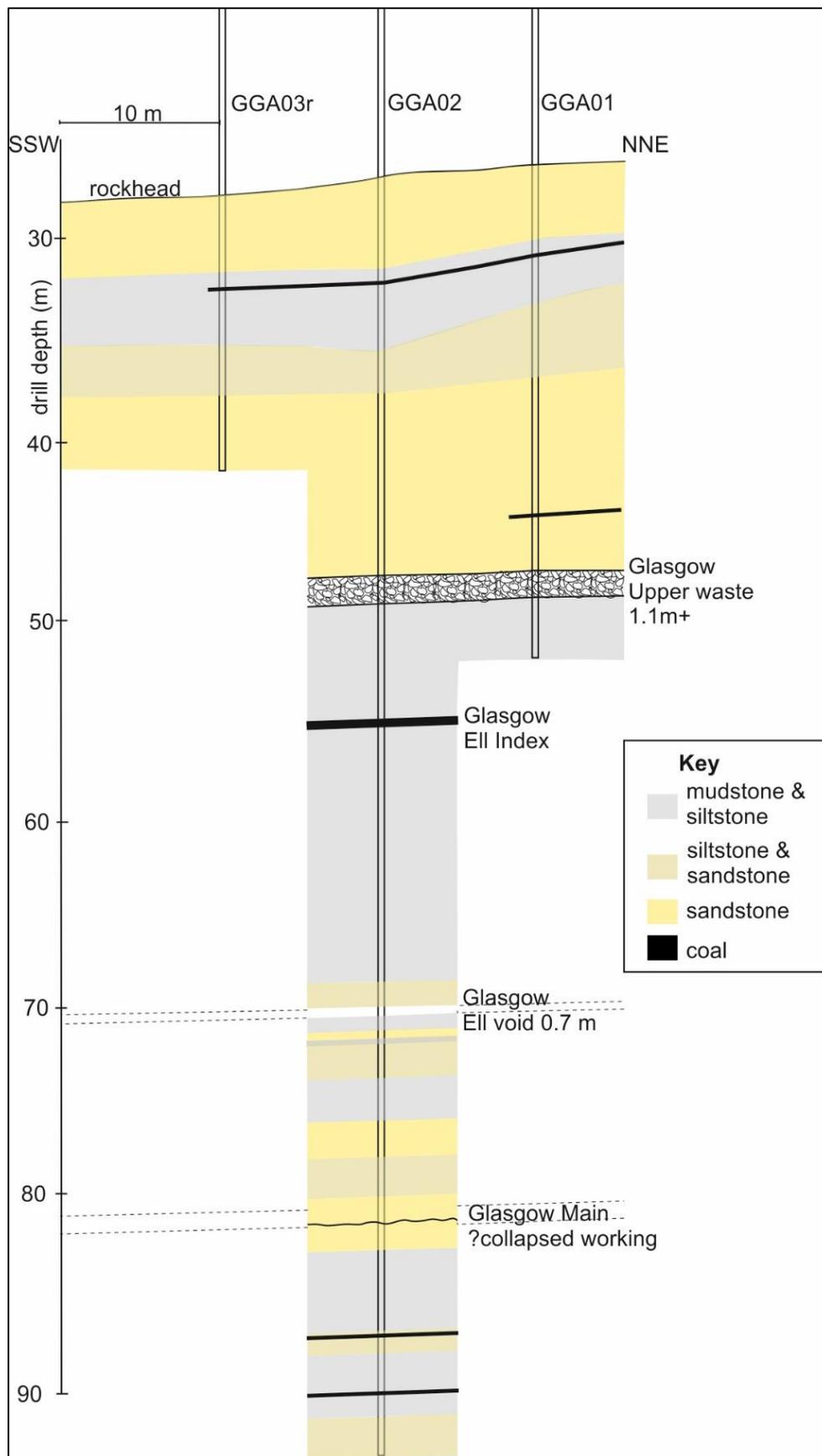


Figure 2 Initial interpretive summary of boreholes GGA01, GGA02 and GGA03r from field logs at January 2020. Superficial deposits not shown, borehole width not to scale. GGA01 is screened at the Glasgow Upper mine working, GGA02 is now a cased hole to c. 69 m, GGA03r is screened in sandstone.

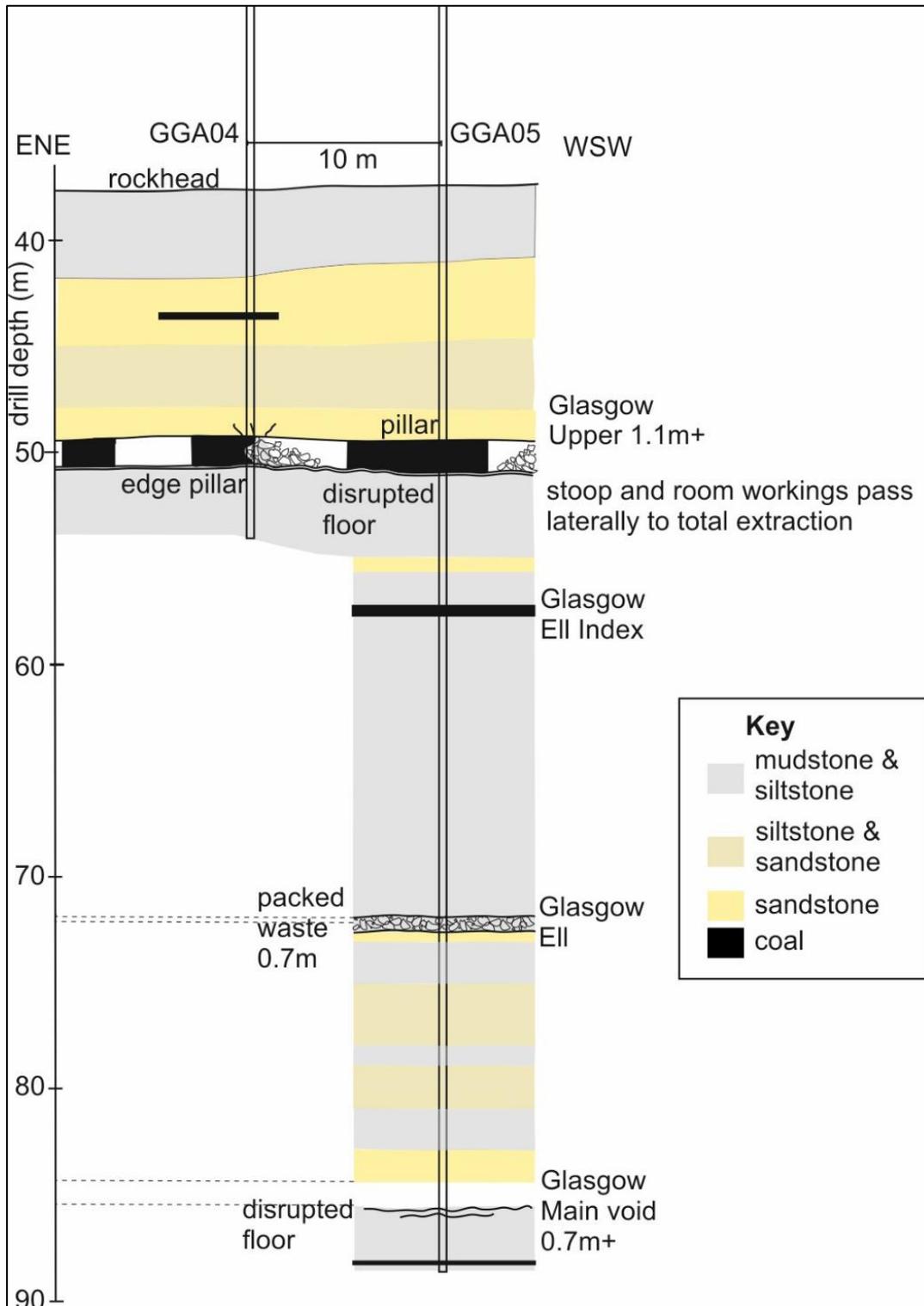


Figure 3 Initial interpretive summary of boreholes GGA04 and GGA05 from field logs at January 2020. Superficial deposits not shown, borehole width not to scale. GGA04 is screened at the Glasgow Upper mine working, GGA05 is screened at the Glasgow Main mine working.

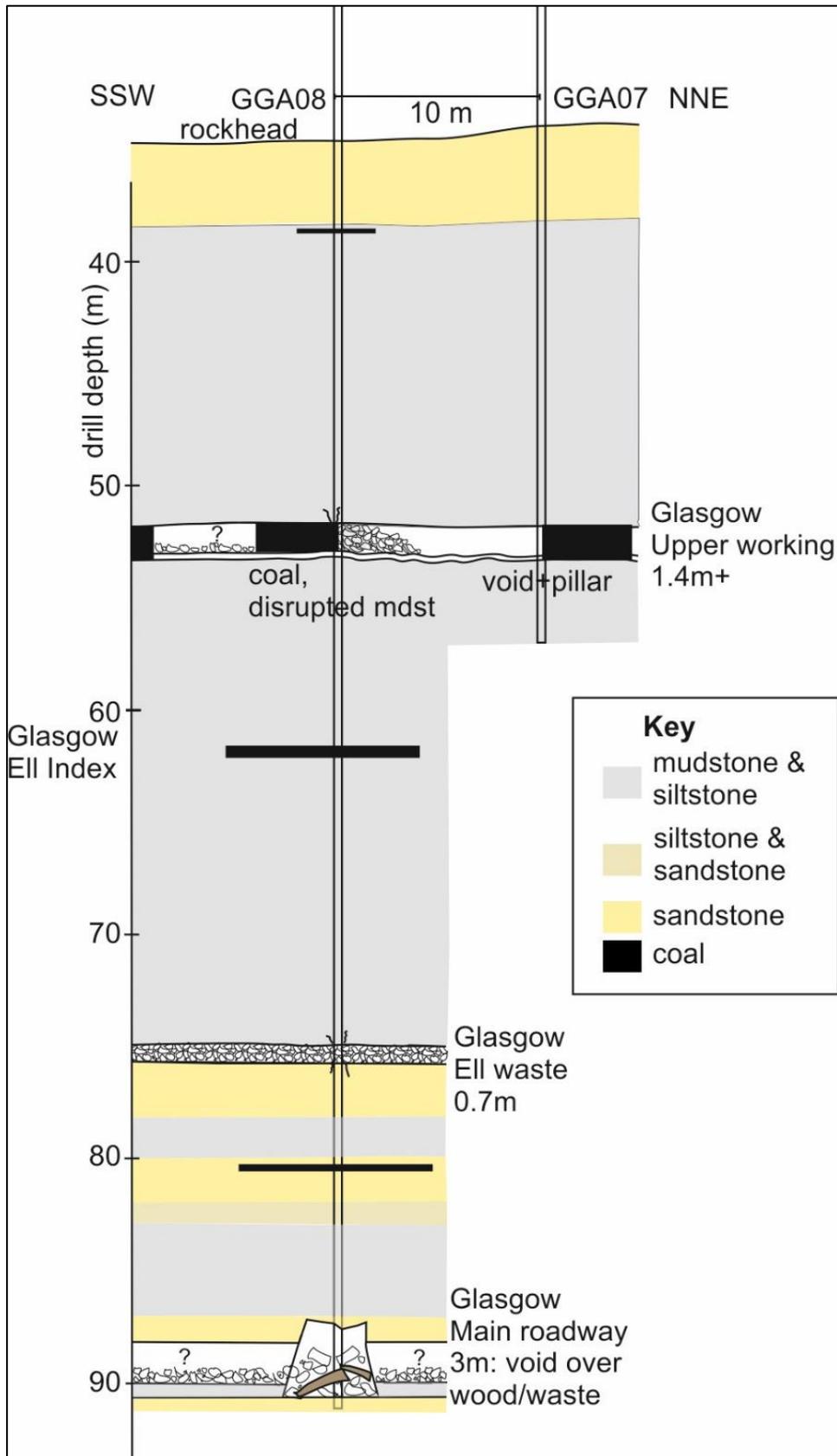


Figure 4 Initial interpretive summary of boreholes GGA07 and GGA08 from field logs at January 2020. Superficial deposits not shown, borehole width not to scale. GGA07 is screened at the Glasgow Upper mine working, GGA08 is screened in the top part of the Glasgow Main mine working.

4 Science opportunities from the as-built boreholes

The as-built UKGEOS Glasgow boreholes will provide a range of opportunities for scientific research and innovation and will be available for science community users in 2020. In summary, the as-built infrastructure comprises:

- 5 wide (248 mm casing ID) diameter mine water boreholes: 3 screened at the Glasgow Upper mine working and 2 screened at the Glasgow Main mine working
 - Mine water boreholes are equipped with down hole and cross-hole continuous sensor cables for electrical resistivity tomography (ERT) and direct temperature sensing (DTS)
- 5 environmental monitoring boreholes:
 - 2 screened boreholes in the top of the sandstone bedrock above the Glasgow Upper mine working (146 mm casing ID, screened at 37.91–40.72 m & 43.0–44.8 m)
 - 3 screened boreholes in superficial deposits above the bedrock (103.8 mm casing ID, screened at 11.92–13.89 m; 11.71–13.61 m; 10.63–12.53 m)

Initial results from test pumping indicate high to very high aquifer yield in the mine water boreholes, with several of them yielding 20 l/s over a 5-hour test for drawdowns of <2 m. Mine water temperatures are commonly around 12°C with initial indications of relatively good mine water quality.

By way of example, this infrastructure could support the following research/ innovation activities:

- Research into the characteristics and hydraulic properties of different types of legacy mine working:
 - Void
 - Roadway
 - Waste
 - Pillar
 - Fractured rock
- Development of new tools and approaches for mine water characterisation and monitoring
- Modelling of mine system behaviour using data from field studies and the continuous pressure-temperature-conductivity downhole data loggers
- Characterisation of any physical/ chemical interactions between the flooded mine workings and the shallow bedrock and superficial monitoring boreholes.
- Baseline monitoring for any effect of mine water pumping operations on surface water quality, ground gas emissions, ground motion and seismicity.

Design work is ongoing to install additional infrastructure to support abstraction and re-injection of mine water. In the interim period the Glasgow Observatory is available for research to establish the baseline geology, hydrogeology and microbiology etc., ahead of any major subsurface heat perturbations.

Further information on accessing the UK Geoenery Observatory in Glasgow is available on the website <https://www.ukgeos.ac.uk/research> or contact ukgeosenquiries@bgs.ac.uk

5 Useful publications and datasets

Background information on the geology, hydrogeology, soil geochemistry etc. of the area can be found within:

MONAGHAN, A A, Ó DOCHARTAIGH, B E, FORDYCE, F M, LOVELESS, S, ENTWISLE, D, QUINN, M, SMITH, K, ELLEN, R, ARKLEY, S, KEARSEY, T, CAMPBELL, S D G, FELLGETT, M, MOSCA, I. 2017 UKGEOS: Glasgow Geothermal Energy Research Field Site (GGERFS): initial summary of the geological platform. Nottingham, UK, *British Geological Survey Open Report*, OR/17/006. <http://nora.nerc.ac.uk/id/eprint/518636/>

The infrastructure as was planned is described in:

MONAGHAN, A A, STARCHER, V, Ó DOCHARTAIGH, B E, SHORTER, K M, BURKIN, J. 2019. UK Geoenergy Observatories : Glasgow Geothermal Energy Research Field Site: Science Infrastructure Version 2. Nottingham, UK, British Geological Survey Open Report, OR/19/032 <http://nora.nerc.ac.uk/id/eprint/522814/> <http://nora.nerc.ac.uk/id/eprint/518636/>

Further publications can be found at <https://www.ukgeos.ac.uk/data/publications>.

Datasets are available on the individual boreholes, bedrock and superficial deposits geological models, the cored, seismic monitoring borehole GGC01 and links to the seismic monitoring data at <https://www.ukgeos.ac.uk/data-downloads>