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Bedrock Sandstone channel subsurface mapping for the Gateshead area - Project Groundwater Northumbria

National Geoscience Programme

Commercial Report CR/24/080

BRITISH GEOLOGICAL SURVEY

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Bedrock Sandstone channel subsurface mapping for the Gateshead area - Project Groundwater Northumbria

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Summary

This report has been produced by the British Geological Survey (BGS) on behalf of Project Groundwater Northumbria, the Flood and Coastal Resilience Innovation Programme (FCRIP) project led by Gateshead Council. It provides background and methodological information on the development of maps of the possible locations of major bedrock sandstone channels in the subsurface for the Gateshead area.

The development of these maps was undertaken through the analysis of 139 boreholes logs which were coded for the project along with mine plan information and academic literature.

An analysis of all the borehole data coded for the project shows that 41% of the rock recorded in the borehole logs in boreholes were sandstone in the Lower and Middle Pennine Coal Measures formations. The median thickness of sandstone is 2.1 m, which is to say half of the sandstones are below that thickness. Using the deposit thickness interpreted by Fielding (1986) it is possible to suggest that 70-80 % of the sandstones are in sandstone bodies with a width <400 m rather than in major channels. This would suggest that sandstones are present even in the areas where no major sandstone channel has been mapped based on the distribution and thicknesses seen in borehole.

The number and distribution of major distributary channel sandstones varies significantly between coal seams. Above the High Main Coal and above the Durham Low Main Coal there are extensive channel sandstones across the whole area. This may suggest that the channels have amalgamated into channel belts at these levels. Through most of the stratigraphic slices the sandstones are in beds <10m thick which is too thin to assume that they are associated with the major distributary channels.

There is a high degree of uncertainty with all major distributary channel sandstones mapped because it is impossible to positively identify the facies in the borehole data due to the age and method of borehole logging. It is suggested that the maps cannot be used to identify where specific sandstones are underground or indicate areas of mudstone. Also, they should not be used in any flow simulations without accounting for the fact that there are more, but smaller sandstones in the areas that are not part of channels. The mapped sandstone bodies comprise only 10% of the total sandstone within the rock volume, indicating that fluid flow will also occur in areas beyond the mapped sandstones.

1 Introduction

1.1 BACKGROUND AND SCOPE

The British Geological Survey (BGS) has interpreted the possible locations of major sandstone units in the subsurface for the Gateshead area as part of commissioned work for Project Groundwater Northumbria (PGN), the Flood and Coastal Resilience Innovation Programme (FCRIP) project led by Gateshead Council. These sandstone channels are likely to influence the movement of groundwater in the bedrock aquifers.

The PGN project work is intended to help project partners including the Environment Agency and Gateshead Council understand both spatial variations in recharge to the bedrock aquifers and highlight areas where outflow from sandstone units or historic mine workings may increase risks of groundwater flooding and/or interact with surface water systems and shallow superficial aquifers.

This report details the methodology for the development of the maps of the possible locations of major sandstone channels in the subsurface and accompanies the delivery of these datasets as Geographical Information System compatible files (shapefiles). This work also includes the interpretation and digital transcription of bedrock boreholes, these will also be used in the construction of a 3D geological model for part of the project area.

1.2 ROLE OF BEDROCK ON GROUNDWATER FLOW

Carboniferous strata are dominated by interbedded units with grain sizes that range from claystone (>63 µm) to occasional conglomerate units which have grains up to 60 mm in size (Kearsey *et al*, 2019). Recent studies on the hydrology of the Coal Measures have shown that the transmissivity of the strata which has been unaffected by mining can range from 100–700 m^2 / day (Graham *et al*, 2009). The unmined bedrock has been strongly indicated to provide effective connectivity to provide pathways between abandoned flooded mine workings. It has been observed that the groundwater levels in boreholes in abandoned mine workings and the overlying unmined bedrock show synchronous fluctuations during pumping tests and over the long term in response to rainfall (Gonzalez Quiros *et al*, 2024).

It is therefore important to try and quantify the pathways in the bedrock as far as possible and calculate the variation in lithology that cannot be mapped. This study does not assess the role that faults and fractures have on transmissibility, although these are thought to have a major control on flow in the unmined bedrock (O Dochartaigh *et al*, 2015).

1.3 GEOLOGY AND SEDIMENTOLOGY THE AREA

The bedrock geology in the study area comprises of the Lower, Middle and Upper Pennine Coal Measures formations and the Permian Yellow Sands Formation (**Figure 1**, **Figure 2**). This area is covered by two 1: 50 000 scale map sheets (21 Sunderland, 1978 and 20 Newcastle upon Tyne, 1978) which show sandstone units in the Pennine Coal Measures. Some of these have been given stratigraphic names, such as the Grindstone Post Member and the Seventy Fathom Post Member. However, many have not been stratigraphically correlated or projected into the subsurface in the cross-sections.

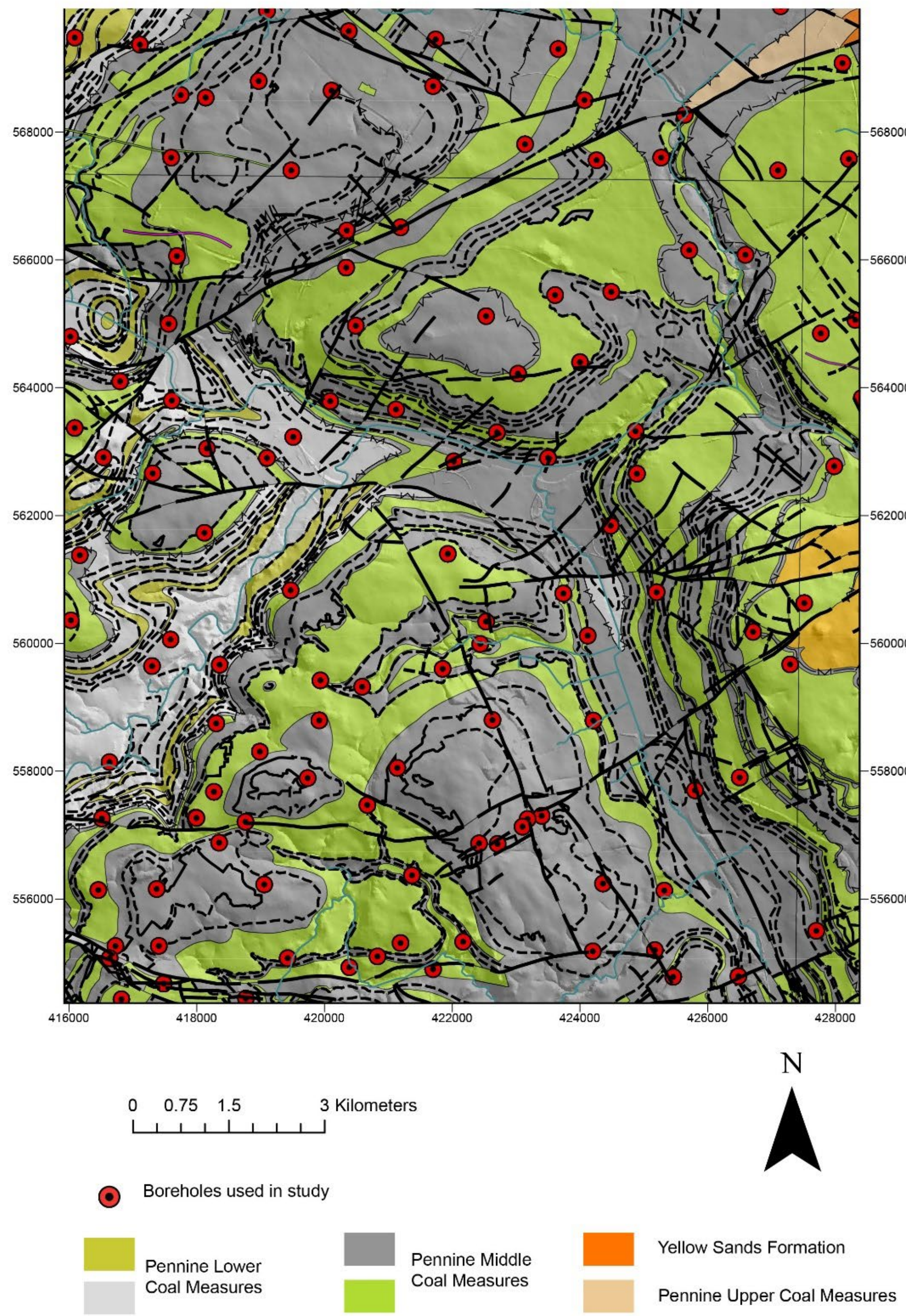


Figure 1 Bedrock Geological map (1:50 000 scale) of the study area with interpreted boreholes shown. BGS © UKRI 2024 Contains OS data © Crown Copyright and database right 2024.

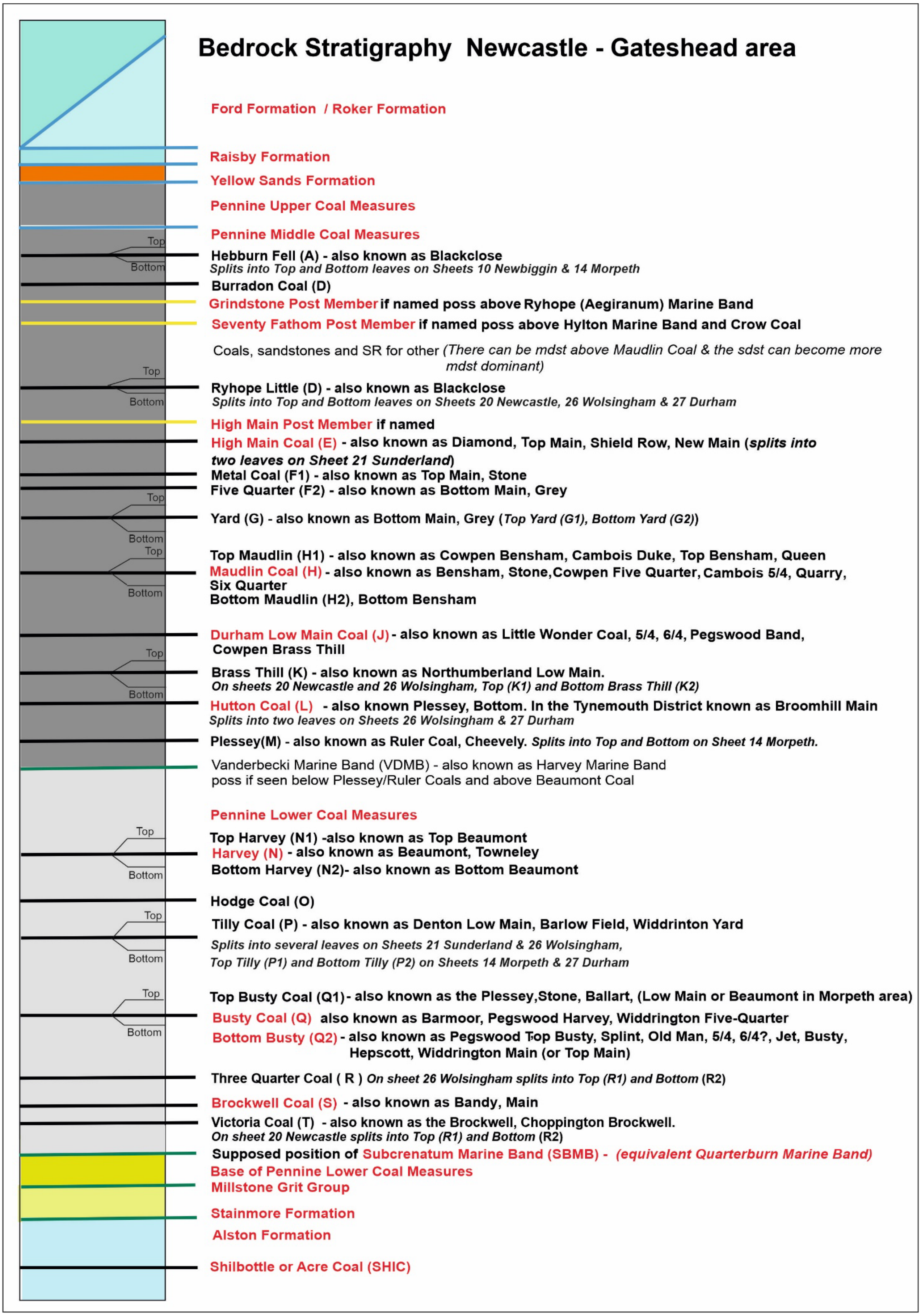


Figure 2 Bedrock stratigraphy in the study area. Coals and formations highlighted in red have been interpreted into the regional and detailed cross-sections completed in a previous study for Project Groundwater Northumbria (Kearsey *et al*, 2023). BGS © UKRI 2024.

BGS does not normally project sandstones into cross sections on maps in the Carboniferous. This is because there needs to be a detailed sedimentological study to determine the geometry and size of the sandstones in the system. This requires the use of outcrops and detailed sedimentary logging which is not normally available for most map areas. However, Fielding (1984,1986) has conducted such a study for this area. In these papers they identify 16 different sedimentary facies in the coal measures (**Table 3** in Appendix 2).

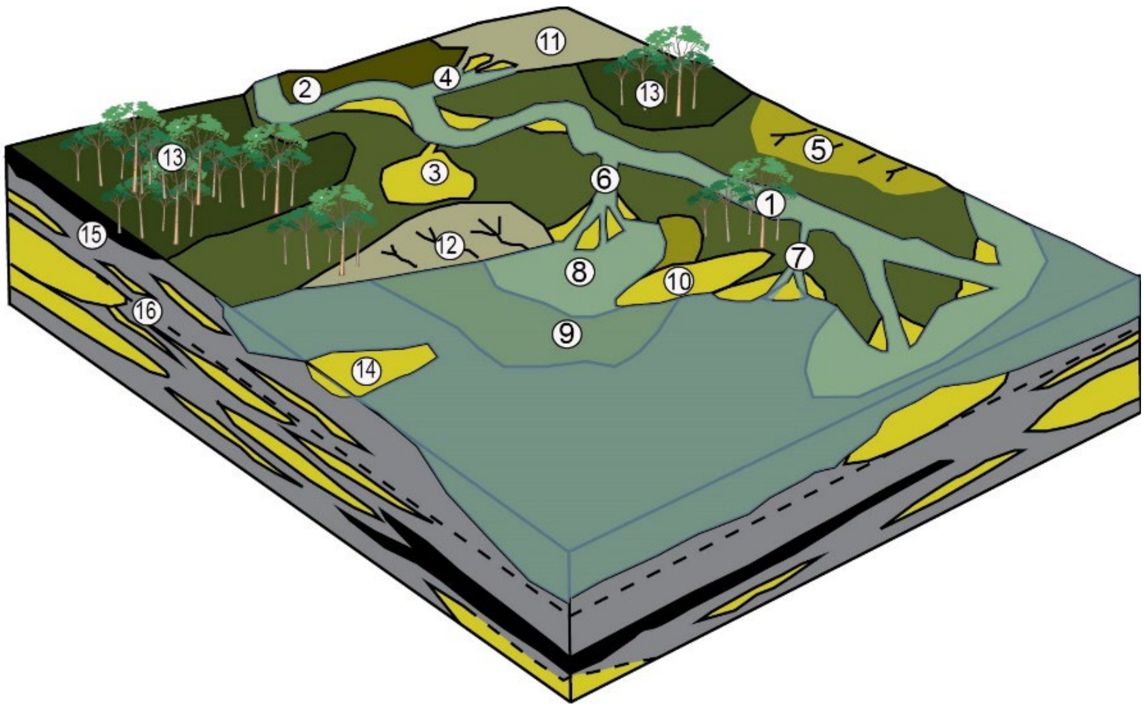


Figure 3 Facies identified by Fielding (1984,1986) in the Pennine Coal Measures within the project area. 1) Major distributary channel; 2) Coarse-grained overbank deposits; 3) Proximal, major crevasse channel; 4) Minor distributary channel; 5) Siltstone-dominated over bank deposits 6) Minor crevasse channel; 7) Distal feeder channel 8) Medial crevasse splay/ minor delta; 9) Distal crevasse splay/ minor delta; 10) Outer minor delta / overbank; 11) Anoxic lake/bay floor; 12) Passive lake/bay margin; 13) coal mire; 14) Reworked shoreline/ shallow marine sandstone; 15) Pedogenically formed 'ganister'; 16) Marine band. (adapted from Kedzior *et al*, 2007)

Lithofacies a body of rock with a distinct physical and compositional characteristics that differentiate it from adjacent rock units. These characteristics can include grain size, sedimentary structures, mineral composition, colour, and fossil content. Lithofacies are used in sedimentology and stratigraphy to interpret depositional environments and geological history. Fielding (1986) identify 5 different sandstone bodies in the Pennine Coal Measures (**Table 1**) which range in thickness between 1 – 20 m and between 20 – 5000 m in width. Given the distribution of boreholes (**Figure 1**) in the study area it is likely that only the major distributary channels will be able to be mapped in the subsurface because these are likely to be the largest channels. This is because most of the other sand bodies have an area of <400 m^2 so would need boreholes drilled every 200 m to give an approximate location (**Figure 4**).

Table 1 Summary of channel and channel belt dimensions from Fielding (1986)

	Major Distributary Channel	Major Crevasse Splay	Minor distributary Channel	Minor Crevasse Splay	Distal feeder channel
Morphology	Straight to sinuous	Straight	Straight to sinuous	Straight	Straight
Channel belt width	Mostly up to 5 km	Up to 400 m	Up to 100-200 m	Mostly up to 20 m	Up to 200 m
Channel width	Mostly 1-2 km	Up to 400 m	Up to 150 m	Mostly up to 20 m	Up to 200 m
Deposit thickness	Mostly 10-20 m	Up to 7 m	Up to 6 m	Mostly up to 1-5 m	c 1 m
Channel bankfull depth	Mostly 10-12 m	Up to 6 m	Mostly up to 6 m	Mostly up to 0.7 m	c 2 m

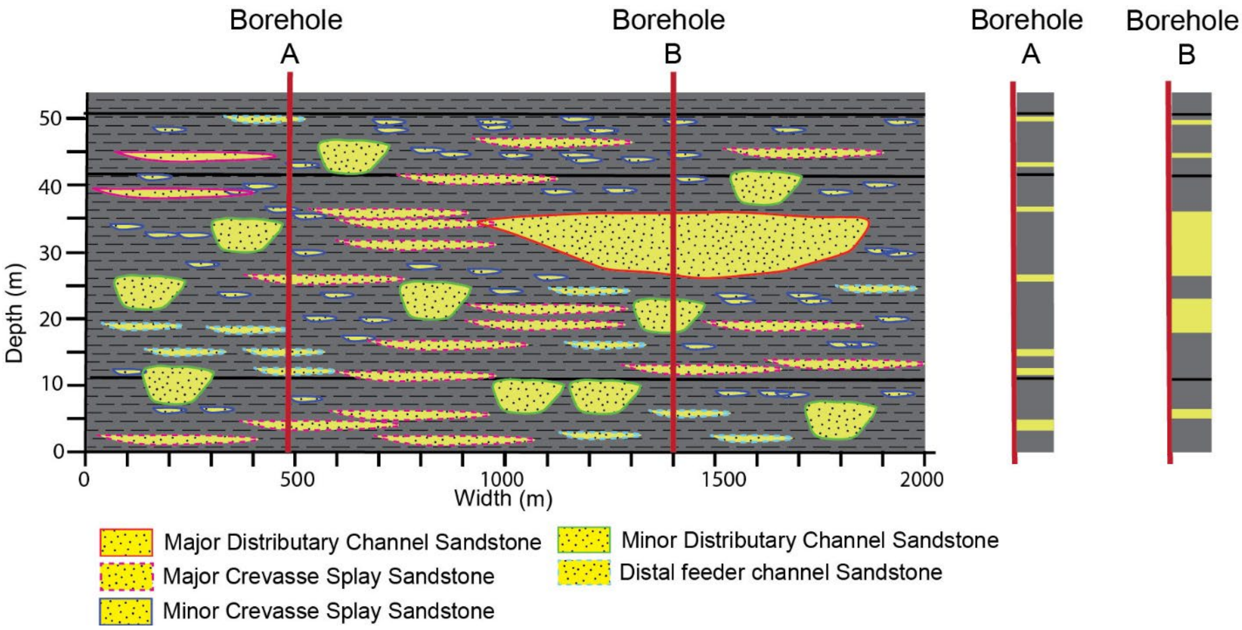


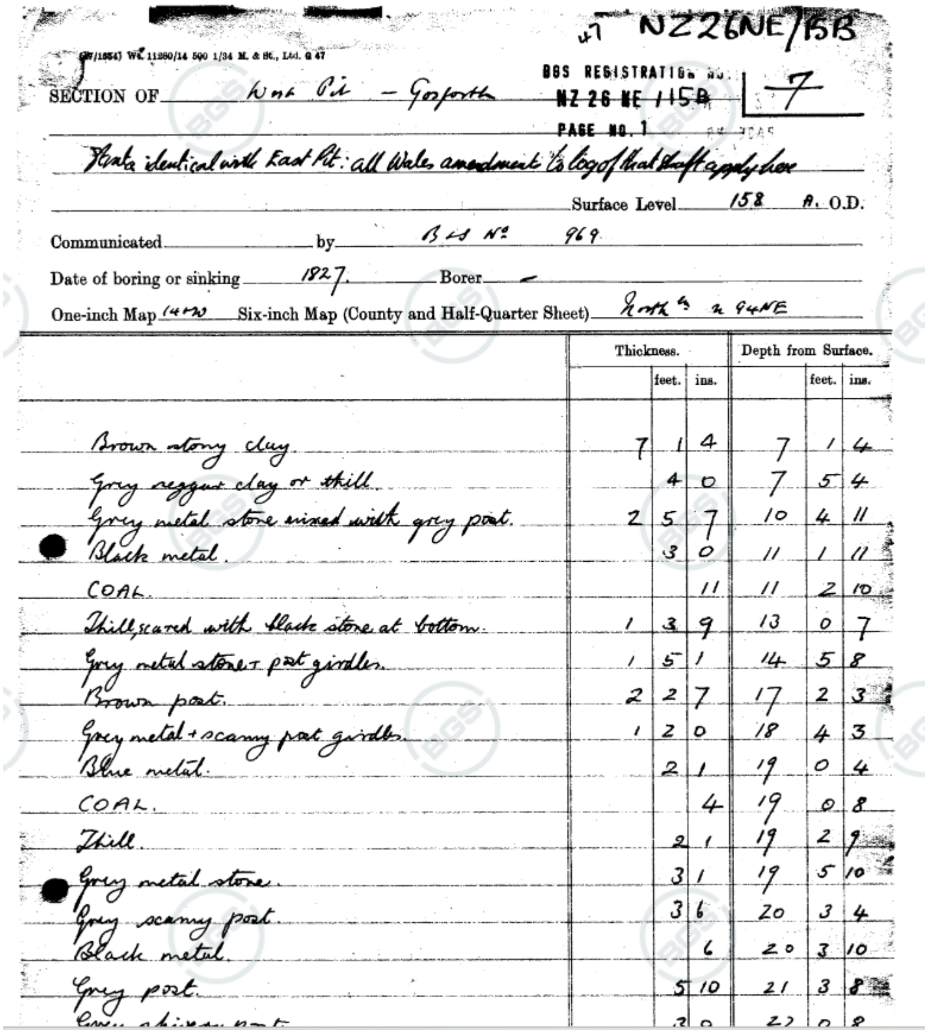
Figure 4 The distribution of channel and channel belt dimensions in conceptual cross section. BGS © UKRI 2024.

2 Methodology

2.1 BOREHOLES

In the study area 139 boreholes were interpreted and coded for the project. They were selected on the following criteria: 1) they were greater than 100 m in length and 2) had coal seams named on the borehole log. To try an ensure an even spread of data within the project area, where there were no boreholes greater than 100 m, shorter boreholes were coded but still fulfilling criteria 2).

Most of the boreholes are former coal mining bores and have limited information about the sandstone units (**Figure 5**). For instance, they often mention "*Grey Post*" for the sandstone beds which when compared to a modern sedimentary description of a sandstone such as "*Sandstone, coarse-sand grainsize grading to medium-sand, moderately sorted. With planar cross bedding and rip-up clasts and trough cross bedding. Erosional base and normal grading*" do not contain the information need to reliably conduct a facies analysis. Instead, bed thickness would have to be used a proxy.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SECTION OF

Surface Level 158 ft. O.D.

Communicated by

Date of boring or sinking 1827

Borer

One-inch Map

Six-inch Map (County and Half-Quarter Sheet)

	Thickness feet	Thickness ins.	Depth from Surface feet	Depth from Surface ins.
Brown stony clay	7 1	4	7 1	4
Grey reggur clay or thill	4	0	7 5	4
Grey metal stone mixed with grey post	2 5	7	10 4	11
Black metal	3	0	11 1	11
COAL		11	11 2	10
Thill scared with black stone at bottom	1 3	9	13 0	7
Grey metal stone & post girdles	1 5	1	14 5	8
Brown post	2 2	7	17 2	3
Grey metal + scamy post girdles	1 2	0	18 4	3
Blue metal	2	1	19 0	4
COAL		4	19 0	8
Thill	2	1	19 2	9
Grey metal stone	3	1	19 5	10
Grey scamy post	3	6	20 3	4
Black metal		6	20 3	10
Grey post	5	10	21 3	8
[illegible]	3	0	22 0	8

Figure 5 Example of a borehole record in Coal Measures in Gateshead. BGS © UKRI 2024.

Boreholes were coded using the BGS Rock Classification Scheme (https://www.bgs.ac.uk/technologies/bgs-rock-classification-scheme/) in total 49 codes were used. These were then simplified into 18 codes which were used in the analysis (Table 2).

Table 2 Simplification of lithological codes

	Lithology summary	Description	Equivalent codes
1	SEAT	Seat-earth	SEATM
2	IGRU	Igneous rock	MFIR, MFIRSA
3	COAL	Coal	
4	ROCKW	Waste, rock	ASHFIL, FILLU
6	NOCO	No core recovered	
7	MDSD	Mudstone and sandstone	MDSA, MDSS, MDSS, MSCI, MSDI, SASLST, SR, MDFEST
8	SDSR	Sandstone, rooted	
9	SDMDSL	Sandstone, mudstone and siltstone	SDMDC
10	MDSTC	Mudstone and coal	
11	OPHO	Open hole	
12	BREC	Breccia	BRSM
13	FEST	Ironstone	
14	CONG	Conglomerate	SDCON
15	SDST	Sandstone	CSST, MCASST, MDSST, SDIR, STMD
16	MDST	Mudstone	MDSI, CMDST, MDCO, SAMDST, MIMDST, MISLST, SASLST, SLMDST, SIMD, SLST
17	LSSM	Limestone, sandstone, siltstone and mudstone	
18	FBRC	Fault-breccia	

The borehole data was then combined into a single shapefile in ArcPro GIS and then separated into slices using the base of major coal seams shown below:

- Major distributary channel sandstones above the High Main Coal
- Major distributary channel sandstones above the Maudlin Coal
- Major distributary channel sandstones above the Durham Low Main Coal
- Major distributary channel sandstones above the Hutton Coal
- Major distributary channel sandstones above the Harvey Coal
- Major distributary channel sandstones above the Busty Coal
- Major distributary channel sandstones above the Brockwell Coal

2.2 OTHER INPUT DATA

Other input data used in construction of the channel sandstone maps include the BGS Geology 1:50 000 digital geological map; the abandoned underground mine working plans provided by the Coal Authority. Also, the palaeogeographical maps from Fielding (1984 fig 4) and Fielding (1986 fig 8) were used as reference.

The abandoned underground mine working plans were used to identify areas where major sandstone channels could not be. As it was assumed that the major distributary channels would have eroded the coal seams leaving ‘wants’, also known as washouts. This assumes Walther's Law; “any vertical progression of facies is the result of a succession of depositional environments that are laterally juxtaposed to each other” is appliable in this case.

3 Results

3.1 ANALYSIS OF THE BOREHOLE DATA.

All the boreholes are in the Lower and Middle Pennine Coal Measures formations and therefore the Upper Pennine Coal Measures and the Permian Yellow Sands Formation are not considered in this investigation. An analysis of all the borehole data coded for the project shows that 41% of the rock seen in boreholes were sandstone in these formations (**Figure 6**). However, 15% of the rock seen in boreholes did not differentiate between sandstones and mudstones. Coal made up 5% of the rock volume, although given the age of some of the borehole logs (see **Figure 5**) it is likely that they pre-date the coal mining in the area so this should not be taken as the percentage of coal remaining today. There is also 1% igneous rock in the boreholes which probably represents unmapped dykes and sills. These may impact on groundwater flow in these strata by introducing impermeable boundaries into the rock. The proportion of mudstone to sandstone is about 50:50 in the Lower and Middle Pennine Coal Measures formations.

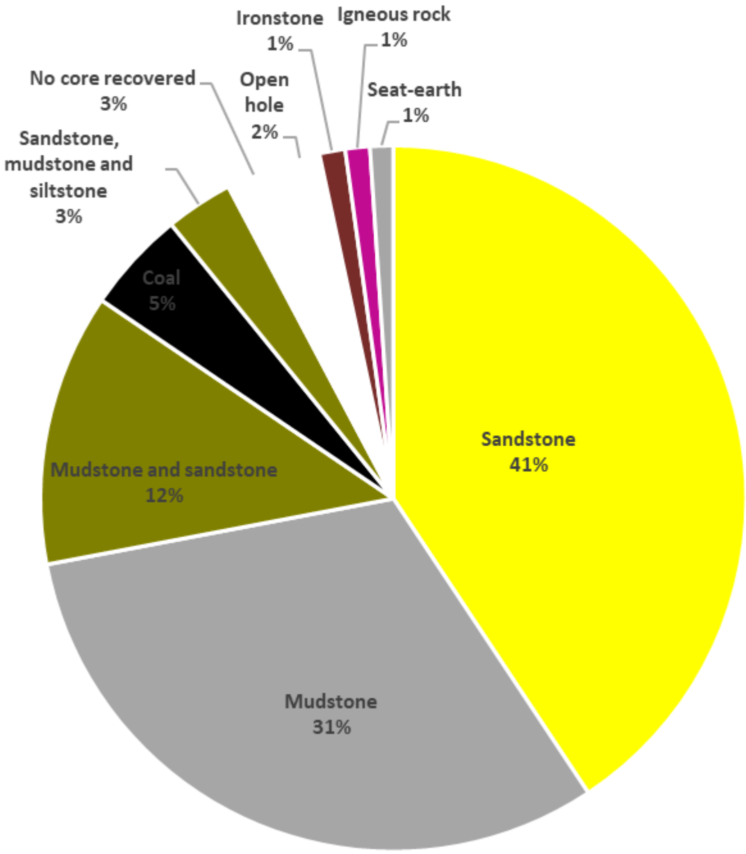

Figure 6 Bulk analysis of all the simplified lithologies found in the boreholes in the Middle and Lower Pennine Coal Measures in the study area. BGS © UKRI 2024.

The median thickness of sandstone is 2.1 m, which is to say half of the sandstones are below that thickness (**Figure 6**). Using the deposit thickness interpreted by Fielding (1986) it is possible to suggest that 70-80% of the sandstones identified in the borehole data have a thickness consistent with sandstone bodies with a width <400 m rather than in major channels.

This would suggest that even in areas away from channels there will be sandstone pathways and there will be sandstone bodies found throughout the rock volume.

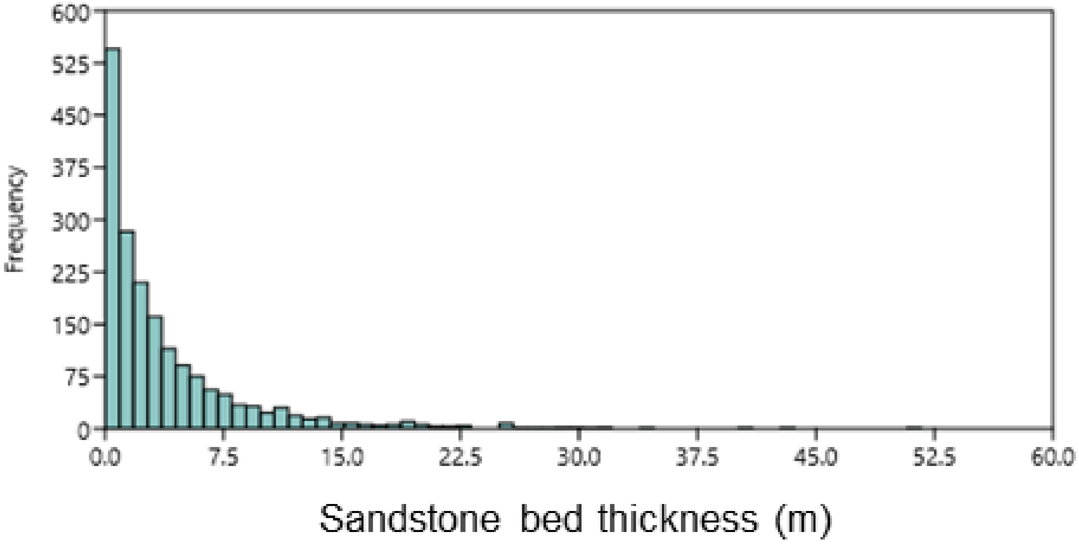

Figure 7 Thickness of sandstone beds found in the boreholes in the Middle and Lower Pennine Coal Measures in the study area. BGS © UKRI 2024.

3.2 MAJOR DISTRIBUTARY CHANNEL SANDSTONE MAPS

The maps of the major distributary channel sandstones show the possible locations of more continuous sandstones in the subsurface. They synthesise the interpretations from Fielding (1984,1986) with the data described in **Section 2**. The strata dip to the east (see Kearsey *et al,* 2023) therefore the youngest strata occur in the east of the study area. This younger stratum is absent to the west due to it been eroded, this is marked with a hatch line. The maps are presented in Appendix 1. The general flow direction of the channels is determined from Fielding (1984,1986). The number and distribution of major distributary channel sandstones varies significantly between slices. Above the High Main Coal (**Figure 9**) and above the Durham Low Main Coal (**Figure 12**) there are extensive channel sandstones across the whole area. This may suggest that the channels have amalgamated into channel belts at these levels. At other levels the more discrete channels can be mapped. There is significant uncertainty with the geometries of these as specific levels, especially above the Maudlin Coal (**Figure 10**); Hutton Coal (**Figure 12**) and Busty Coal (**Figure 14**). This is because at these levels there are fewer boreholes that intersect channel bodies and therefore it harder to connect between major distributary channel sandstones in boreholes. The major distributary channel sandstones also appear to be affected by the 90-Fathom fault above the Harvey Coal (**Figure 13**). This possibly suggests that this fault may have been active, or at least was a topographic barrier when the sediments were deposited.

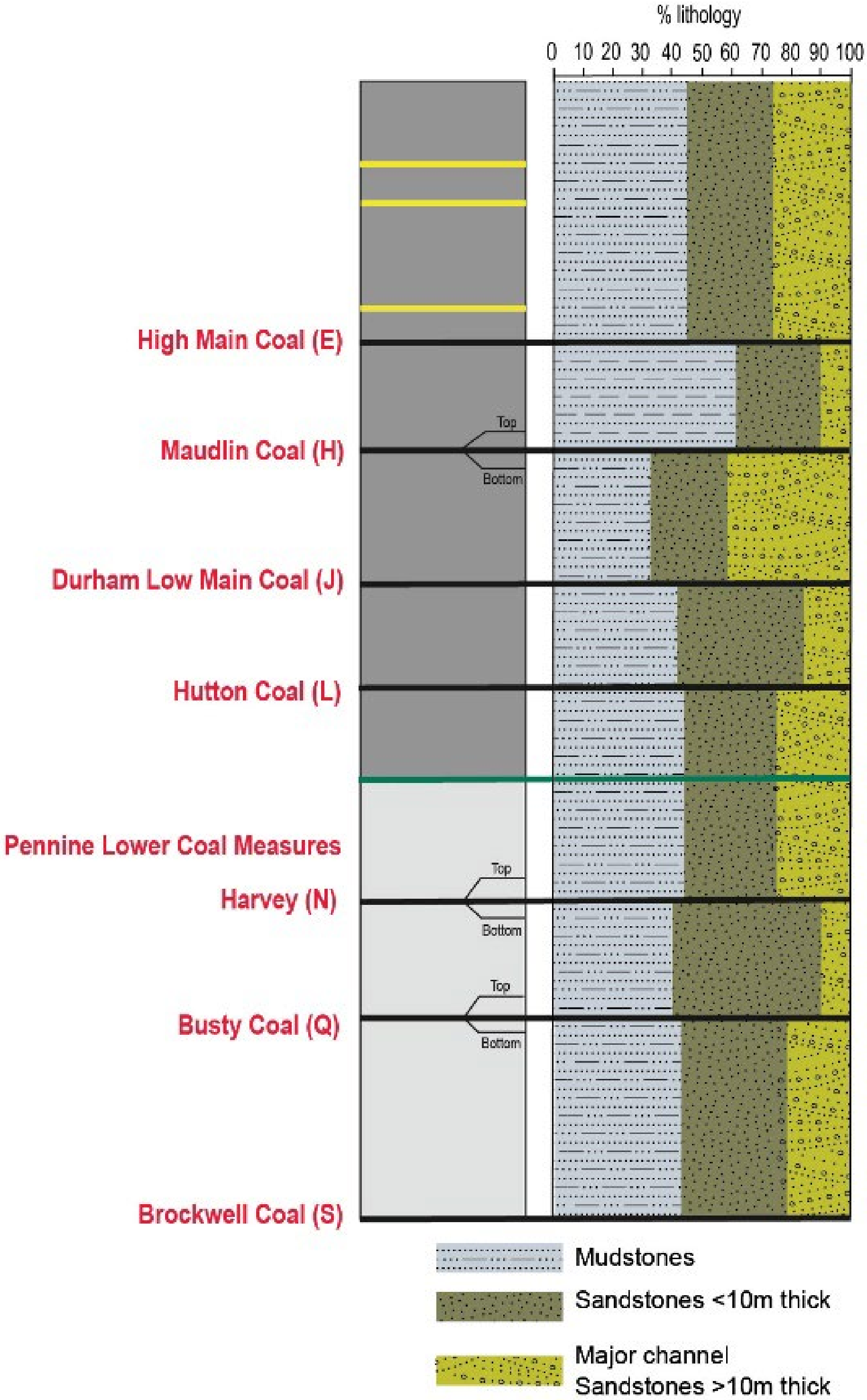

Figure 8 Variation in sandstones and mudstones from boreholes at each slice through the stratigraphy. BGS © UKRI 2024.

Through most of the stratigraphic slices the sandstones are in beds <10 m thick which is too thin to be positive that they are associated with the major distributary channels (**Figure 8**). This suggest that majority of the sandstones are in sandstone bodies with a width <400 m rather than in major channels. However, with detailed sedimentological analysis this association might change. There is an exception to this pattern; above the Durham Low Main Coal (**Figure 11**) where there appears to be more sandstones associated with the major distributary channels than thinner sandstones.

4 Limitations

The sandstone interpretations are reliant on being able to identify the High Main Coal, Maudlin Coal, Durham Low Main Coal, Hutton Coal, Harvey Coal, Busty Coal and Brockwell Coal in the borehole logs. The boreholes used included the seam names on the logs, but no attempt was made to assess the accuracy of these interpretations in 3D. If the 3D bedrock geological modelling reinterprets these seams in the boreholes this would mean the channels may need to be reinterpreted.

There is high a degree of uncertainty with all the major distributary channel sandstone maps because it is impossible to positively identify the facies (**Table 3**) in the borehole data due to the age and type of logging (e.g. **Figure 5**). Therefore, the maps cannot be used to identify where specific sandstones are underground or indicate areas of mudstones. Also, they should not be used in any flow simulations without accounting for the fact that there are more, but smaller sandstones in the areas that are not part of channels (see **Figure 4**). However, they can be used to understand the amount of channel sands in each slice and to indicate the general direction of pathways that may influence groundwater flow.

5 Recommendations

Future work, to improve the understanding of the sandstone units in the study area would include detailed sedimentary logging of new boreholes in the Coal Measures Group. Also reassessing the interpretation of the named coal seams in boreholes using the thickness maps derived from the 3D bedrock geological model to test these results of this study against. There may be geophysical techniques that may be helpful, but they are normally limited in effectiveness by working in an urban area.

The other flow pathway that was not considered in this work is the faults. Faults like the 90-Fathom fault have a damage zone of 80 m wide and have evidence of fluid flow along them. They are a major control on flow in the unmined bedrock (cf. O Dochartaigh *et al,* 2015).

Appendix 1

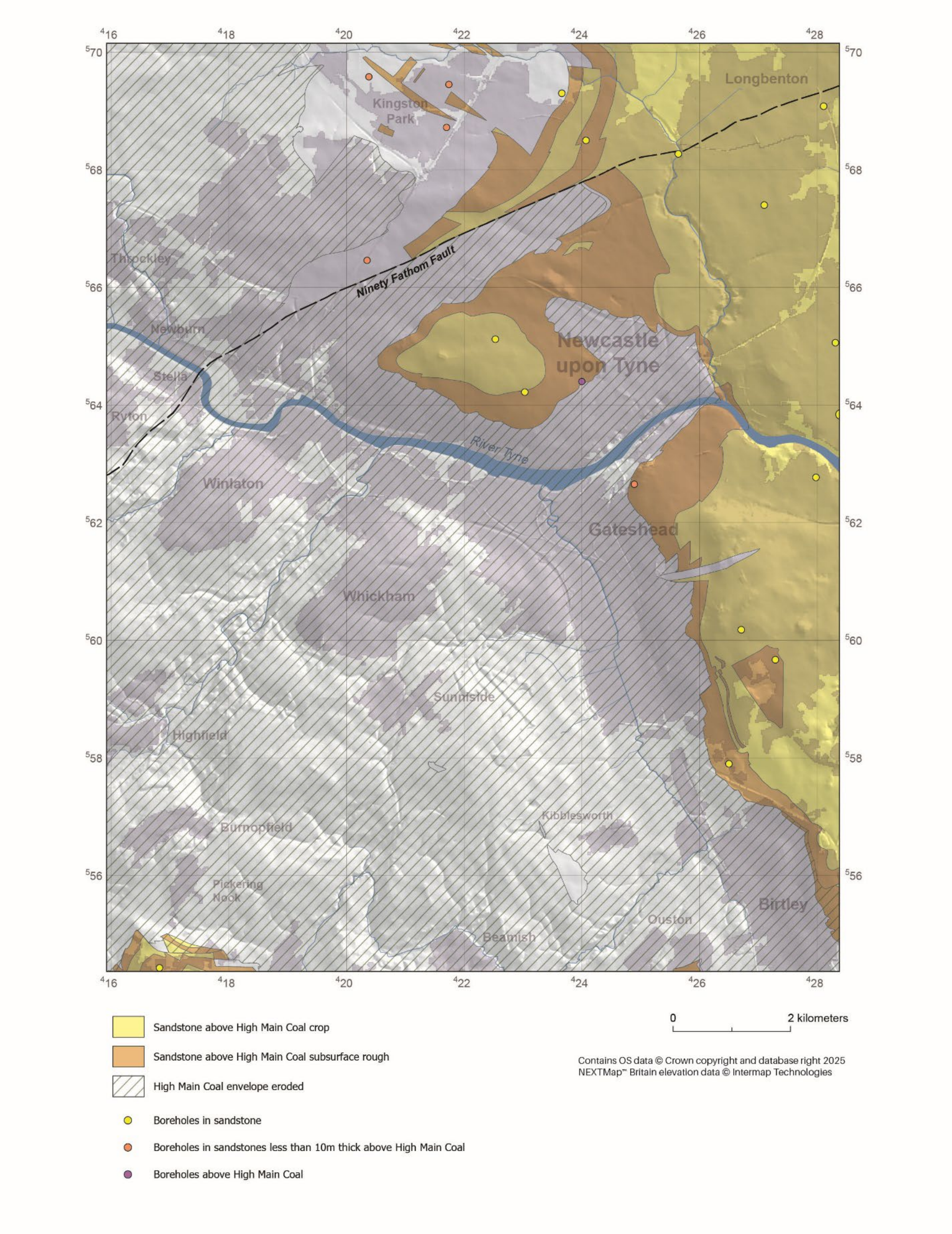

Figure 9 Major distributary channel sandstones above the High Main Coal. BGS © UKRI 2024.

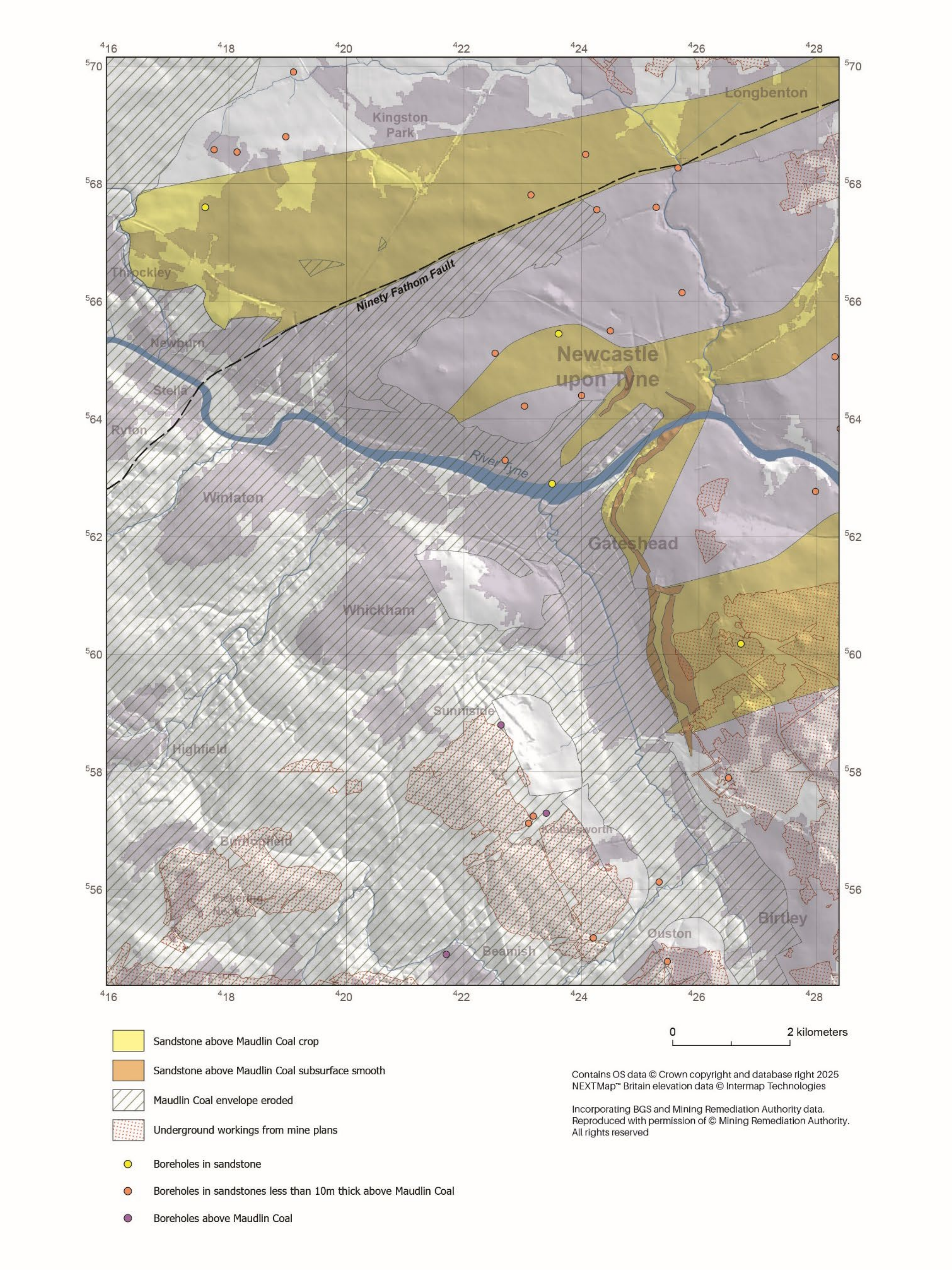

Figure 10 Major distributary channel sandstones above the Maudlin Coal. BGS © UKRI 2024.

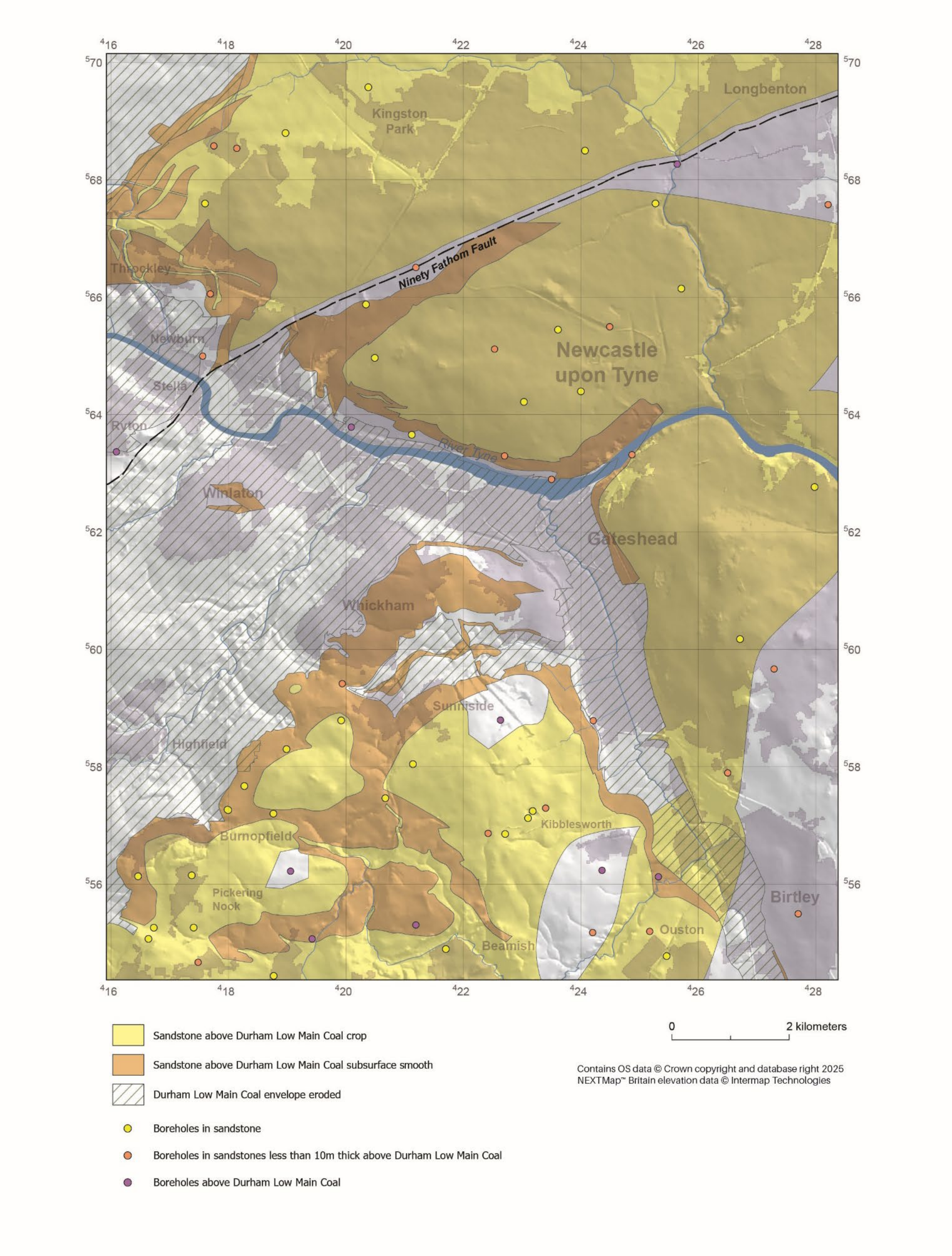

Figure 11 Major distributary channel sandstones above the Durham Low Main Coal. BGS © UKRI 2024.

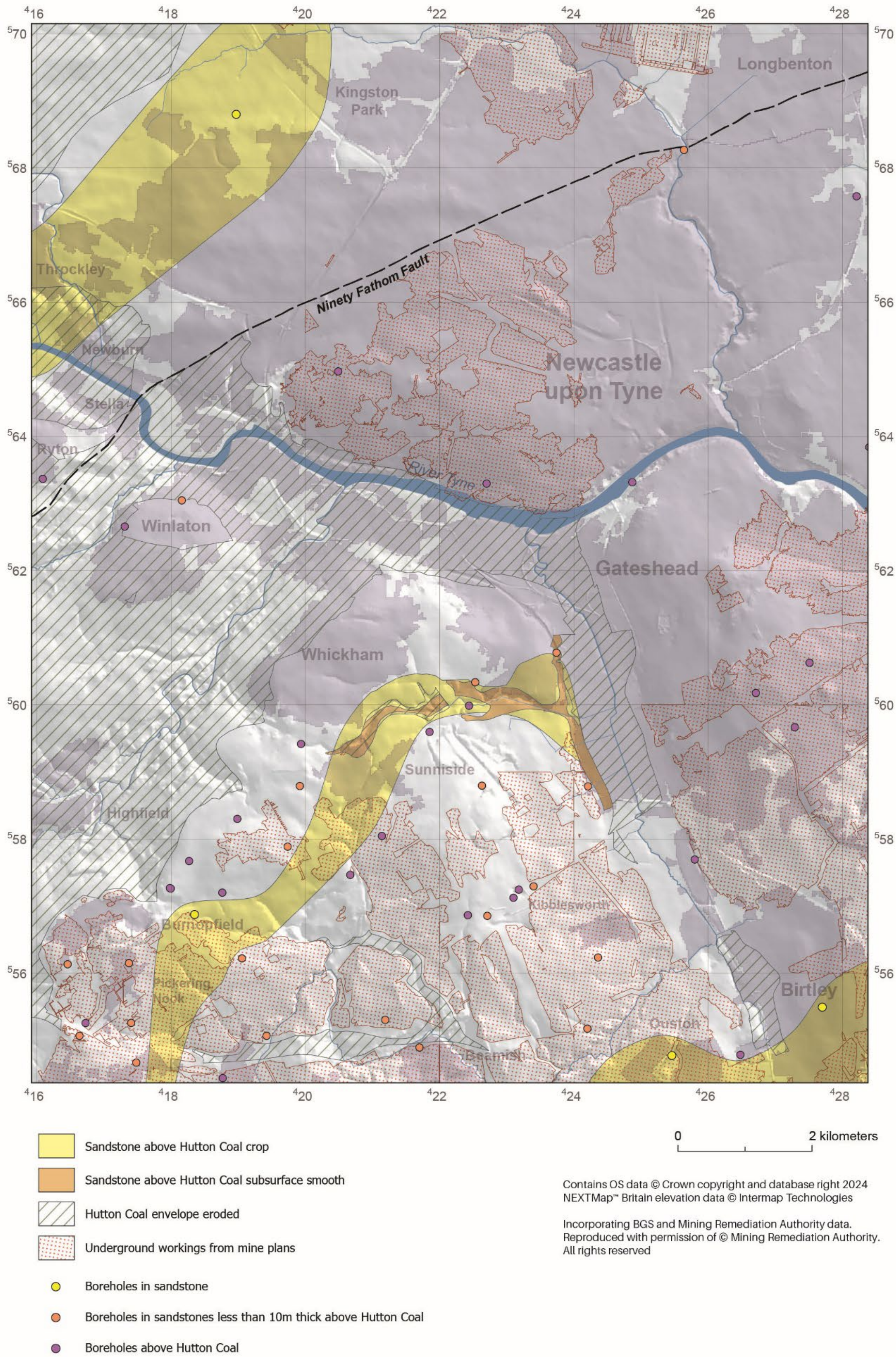

Figure 12 Major distributary channel sandstones above the Hutton Coal. BGS © UKRI 2024.

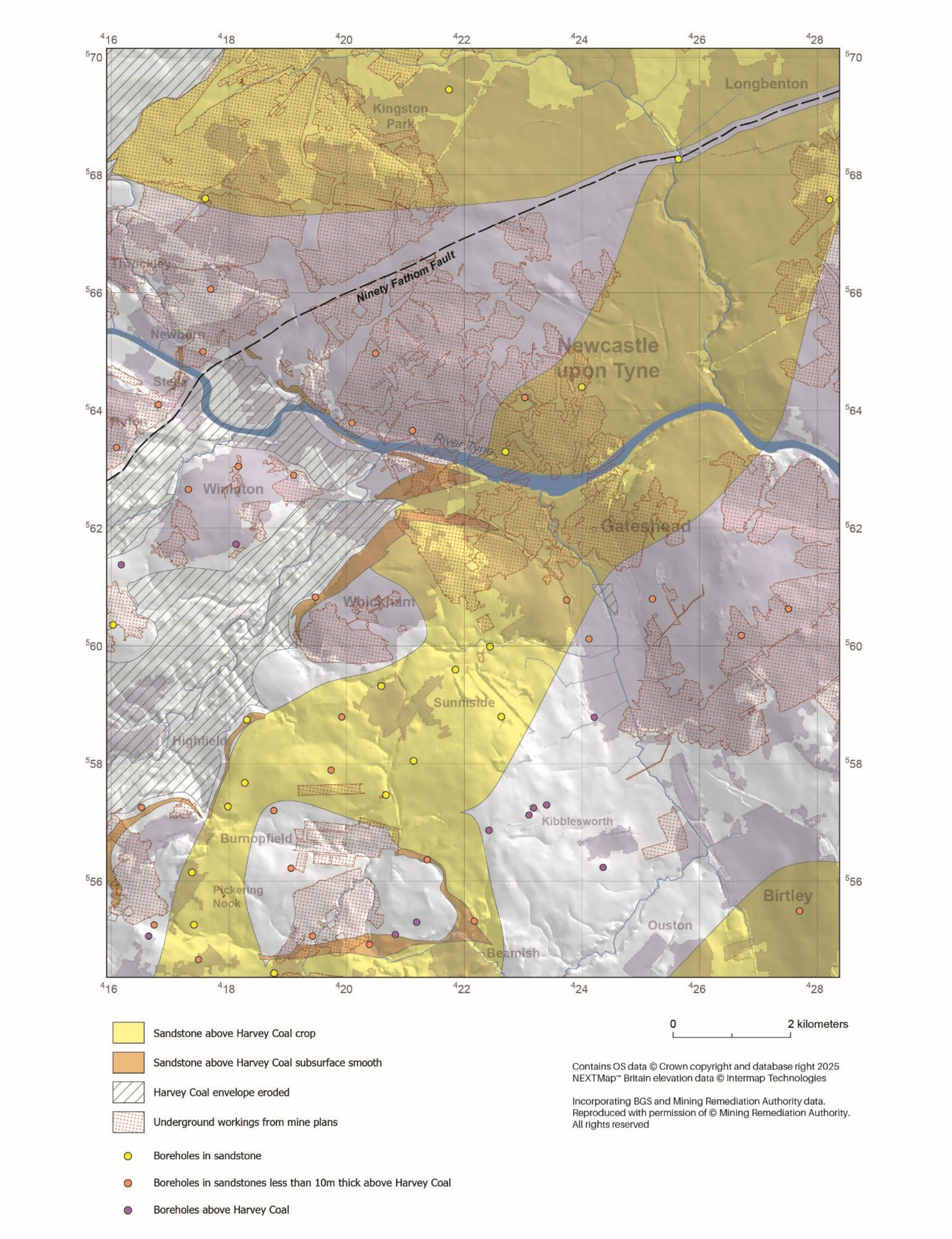

Figure 13 Major distributary channel sandstones above the Harvey Coal. BGS © UKRI 2024.

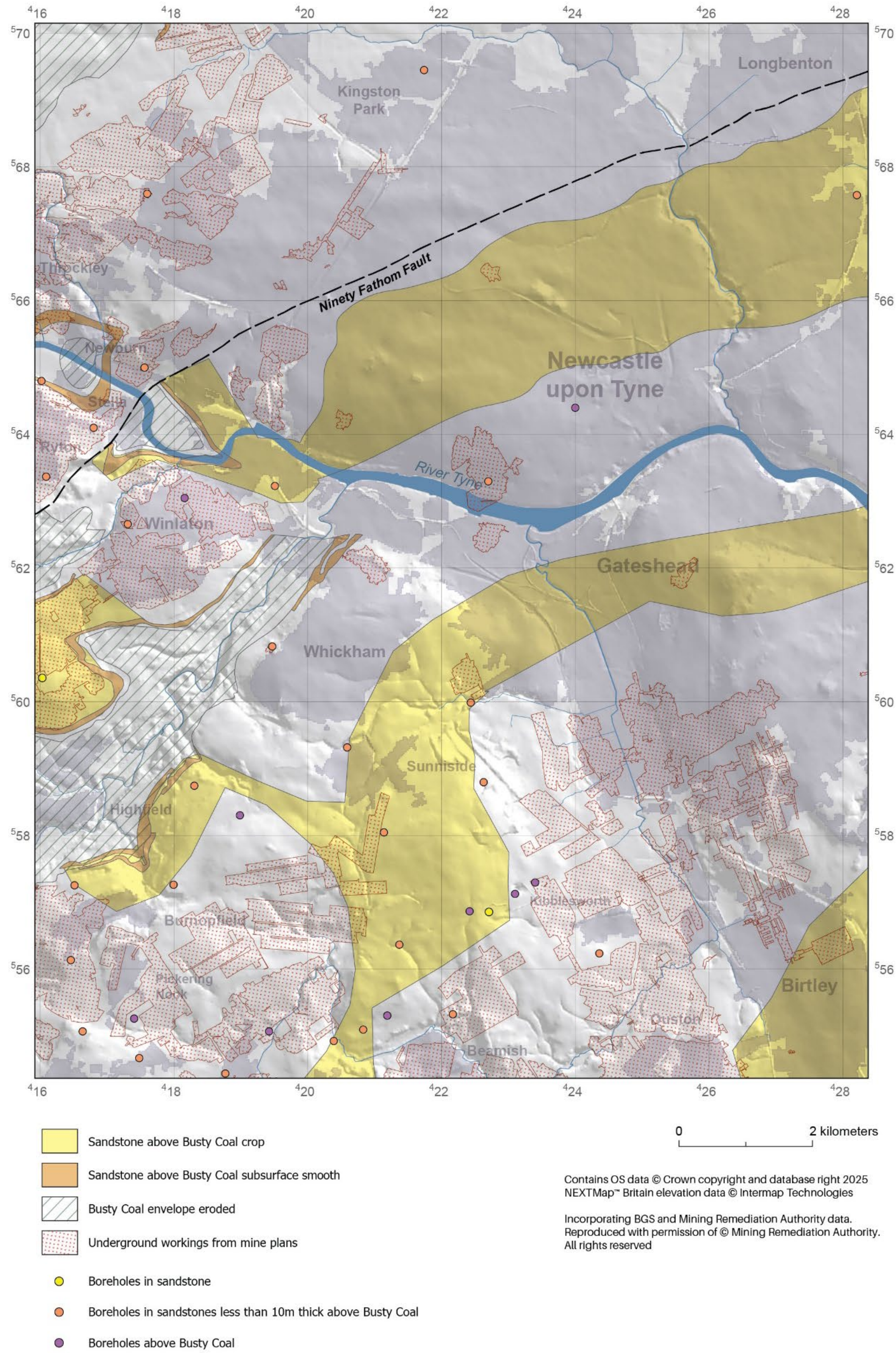

Figure 14 Major distributary channel sandstones above the Busty Coal. BGS © UKRI 2024.

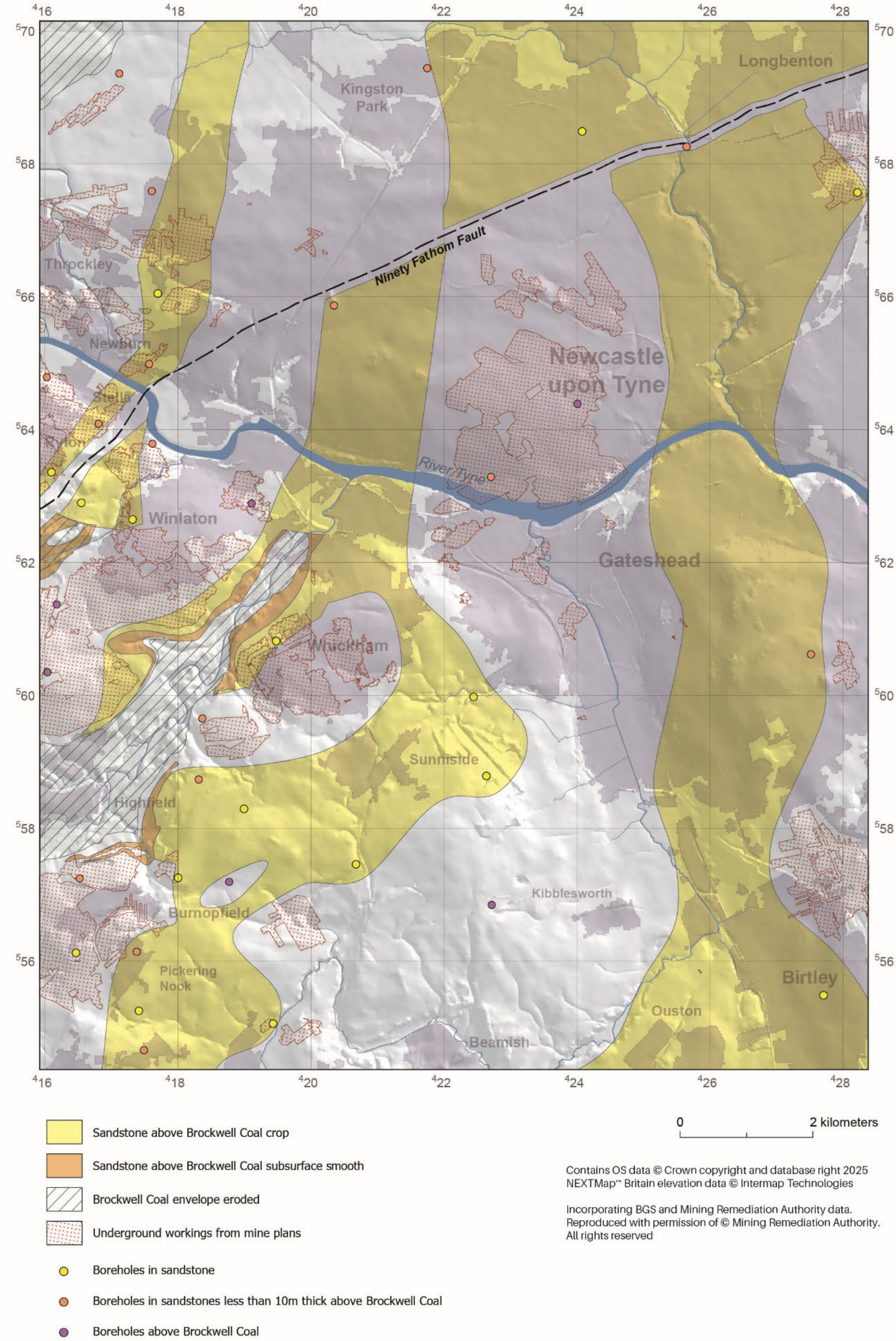

Figure 15 Major distributary channel sandstones above the Brockwell Coal. BGS © UKRI 2024.

Appendix 2

Table 3 Sedimentary Facies identified Fielding (1984,1986) in the study area

	Facies	Lithology	Habitat
1	Major distributary channel (Facies 10 of Fielding, 1984b	Thick (< 35 m), erosively-based sandstone	Occupies entire inter-coal seam intervals, or overlies fluviolacustrine facies (3-9 of Fielding, 1984a), in elongate belts, kilometres wide
2	Coarse-grained overbank deposits	Thinly interbedded sandstone and siltstone/claystone	Occurs in elongate belts bordering major (and in a few cases minor) distributary channel deposits
3	Proximal, major crevasse channel	Channelized, erosively based sandstone	Occurs as elongate belts perpendicular to major belts perpendicular to major Channel margins
4	Minor distributary channel	Variable, erosively based sandstones	Occurs as a component part of fluviolacustrine elongate 'shoestring' sediment bodies
5	Siltstone-dominated over bank deposits	Siltstone, with occasional thin (0.01 m) claystone partings	Occurs in elongate belts bordering minor distributary channels
6	Minor crevasse channel	Massive or structured sandstone	Occurs as a component part of fluviolacustrine
7	Distal feeder channel	Siltstone and claystone with thin (0.1 m) sandstone beds	Occurs as a component part of fluviolacustrine Facies 5
8	Medial crevasse splay/ minor delta	Interbedded sharply based sandstones, coarsening-upward sequences and fine-grained beds	Occurs in irregular tracts down-paleocurrent
9	Distal crevasse splay/ minor delta	Single or multiple coarsening- upwards sequences sandstones and siltstones	Occurs in lobe-shaped areas, in many cases coalesced to form irregular tracts, down paleocurrent from minor crevasse splay
10	Outer minor delta / overbank	Massive or laminated claystones	Occurs as irregular sheets
11	anoxic lake/bay floor	Thinly laminated, carbonaceous claystones	Occurs as irregular sheets
12	passive lake/bay margin	Thinly laminated, sandstones and mudstones carbonaceous	Occurs in elongate, narrow belts parallel to coal seam spits
13	mire	Coal, rooted coaly claystone	Occurs as irregular sheets, overlying fluviolacustrine sections

	Facies	Lithology	Habitat
14	reworked shoreline/ shallow marine sandstone	Quartz-arenitic sandstone	Occurs as elongate, lozenge-shaped or irregular areas in lower delta plain sequences
15	Pedogenically formed ‘ganister’	Irregularly based quartz-arenitic sandstone	Occurs as elongate, lozenge-shaped or irregular areas in lower delta plain sequences
16	Marine band	Fissile claystones	Occurs as widespread though thin sheets

References

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

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