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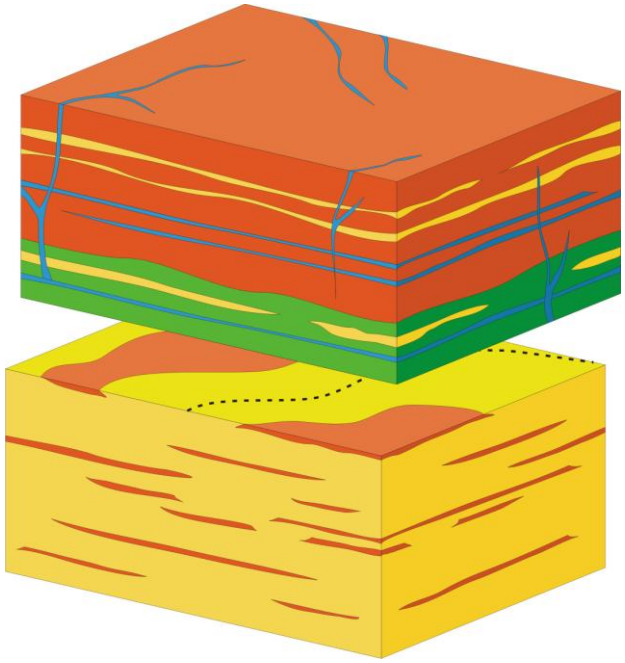
Lithological Heterogeneity of the Mercia Mudstone and Sherwood Sandstone Groups in the Yorkshire-Lincolnshire Region, and Knox Pulpit Sandstone, Kinnesswood and Ballagan Formations in the Forth Region - Additional Information for CASSEM Work Package One

Responsive Surveys Scotland Programme

Internal Report CR/09/053



Scottish Centre for Carbon Storage

BRITISH GEOLOGICAL SURVEY

RESPONSIVE SURVEYS SCOTLAND PROGRAMME

INTERNAL REPORT CR/09/053

Lithological Heterogeneity of the Mercia Mudstone and Sherwood Sandstone Groups in the Yorkshire-Lincolnshire Region, and Knox Pulpit Sandstone, Kinnesswood and Ballagan Formations in the Forth Region - Additional Information for CASSEM Work Package One

J R Ford and A A Monaghan

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Front cover

Schematic representation of lithological variability in the Sherwood Sandstone and Mercia Mudstone groups; not to scale.

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Summary

This report describes the anticipated lithological heterogeneity in the region of the 3D bedrock geology modelling covered by the Yorkshire and Forth modelling components of the CASSEM Work Package One. The Yorkshire 3D geological model represents parts of the Permian and Triassic strata within an area of eastern England designated for the purpose of methodological research as a potential site for the long-term geological storage of CO_2. The CO_2 source is designated as the Ferrybridge Power Station.

The Forth 3D geological model represents parts of the Upper Devonian and Carboniferous strata within an area of eastern Scotland designated for the purpose of methodological research as a potential site for the long-term geological storage of CO_2. The CO_2 source is designated as the Longannet Power Station.

1 Introduction

Ford *et al.* (2008) describes the Yorkshire-Lincolnshire 3D geological modelling component of CASSEM Work Package One, providing a summary of the geological framework, including general lithofacies characteristics of the modelled succession. Monaghan *et al.* (2008) describes the Forth 3D geological modelling component of CASSEM Work Package One, providing a summary of the geological framework, including general lithofacies characteristics of the modelled succession. Further detailed work on the physical characteristics of the succession is given in Milodowski and Rushton (2008).

This brief report responds to the request from the CASSEM consortium for additional information on lithological heterogeneity within the primary aquifer and seal units considered in the study: the Sherwood Sandstone (SSG) and Mercia Mudstone (MMG) groups respectively in Lincolnshire, and the Knox Pulpit Sandstone (KPF), Kinnesswood (KNW) and Ballagan (BGN) formations in Forth. Specifically, this report aims to quantify the relative proportion of low-permeability marl seams within the SSG, and high-permeability horizons within the MMG, the amount of low permeability mudstone and limestone in the KPF and KNW, and high permeability sandstones within the BGN.

2 Sherwood Sandstone Group

To approximate the incidence of mudstone and siltstone horizons within the SSG, a lithological summary of the Cleethorpes borehole (BGS ref: TA30NWBJ51.) was created. Although the Cleethorpes borehole is located outwith the area covered by the 3D geological model (see Figure 1), it may be considered as a representative record of the SSG succession in the modelled area. It should be noted that this summary is based on the graphic log of the borehole, and will be subject to generalisations based on the scale at which the graphic log was produced (it is likely that mudstone/siltstone horizons below an estimated minimum thickness of 0.5 m may be underrepresented and that recognised horizons of less than 1 m may be exaggerated for graphic purposes on the log). It should also be noted that the lithological classification shown on the log is in largely based on indirect observation (i.e. geophysical response). A numerical record of the lithological log for the 397 m of SSG intersected in the Cleethorpes borehole is shown in Appendix 1. Figure 2 shows a graphic representation of the data from Appendix 1.

Based on the figures presented in Appendix 1, the total thickness of sandstone is recorded as 373.67 m (94.12% of the SSG) and the total thickness of mudstone is 23.33 m (5.88% of the SSG). The number of recorded mudstone horizons is 27. The thickest undivided intersections of sandstone and mudstone are 34.12 m and 1.72 m respectively. The vertical distribution of mudstone units is shown in Figure 2.

Several "clusters" of mudstone horizons are apparent (see the intervals 140 to 180 m and 260 to 275 m below the top of the SSG). No detailed/statistical study is given here to determine if this trend is regular or predictable.

The lateral extent of individual or clustered mudstone horizons is not known with any degree of certainty. However, based on field observation in the Midlands and Northwest of England, it is estimated that the aerial extent of individual mudstone horizons is no greater than 200 to 300 m, with a typical extent of less than 100 m. This is an estimate based on informal feedback from BGS geologists with experience of the succession. At the time of deposition, it is likely that individual mud horizons would have formed extensive spreads between major sand-filled channels. However, erosion associated with subsequent channel migration would have incised and dissected the mud horizons. The geometry or alignment of individual mudstone horizons (or sandstone channels) is not known. Figure 3 shows a thematic representation of the expected morphology of mudstone horizons within the SSG.

As described in Ford *et al.* (2008), the upper and lower boundary of the SSG is characterised by a gradational boundary with the MMG and Roxby Formation respectively. Although this relationship is not apparent in the Cleethorpes borehole log, it may be assumed that the upper and lower 2 to 5 m of the SSG is represented by a gradual increase in mudstone/siltstone content, up to 50%.

Please note, the information given above relates to a single borehole. Significant variability is expected within this part of the succession in terms of the position, thickness and lateral persistence of individual horizons and overall ratio of mudstone to sandstone. A comprehensive review of additional borehole records may provide additional or contrasting information. Further detailed information on lithological characteristics of the SSG is given in Milodowski *et al.* 1987.

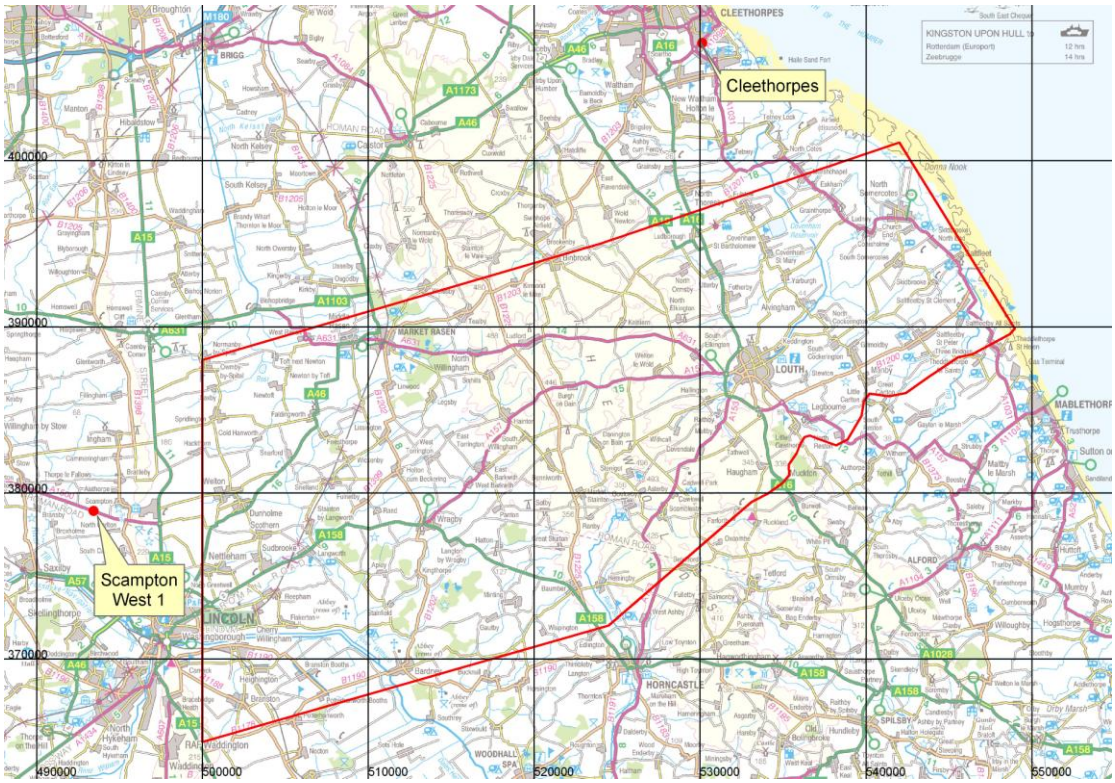

Figure 1 - Location map showing position of boreholes referenced in this document. CASSEM Yorkshire-Lincolnshire region of study shown in red. OS © Topography Crown Copyright

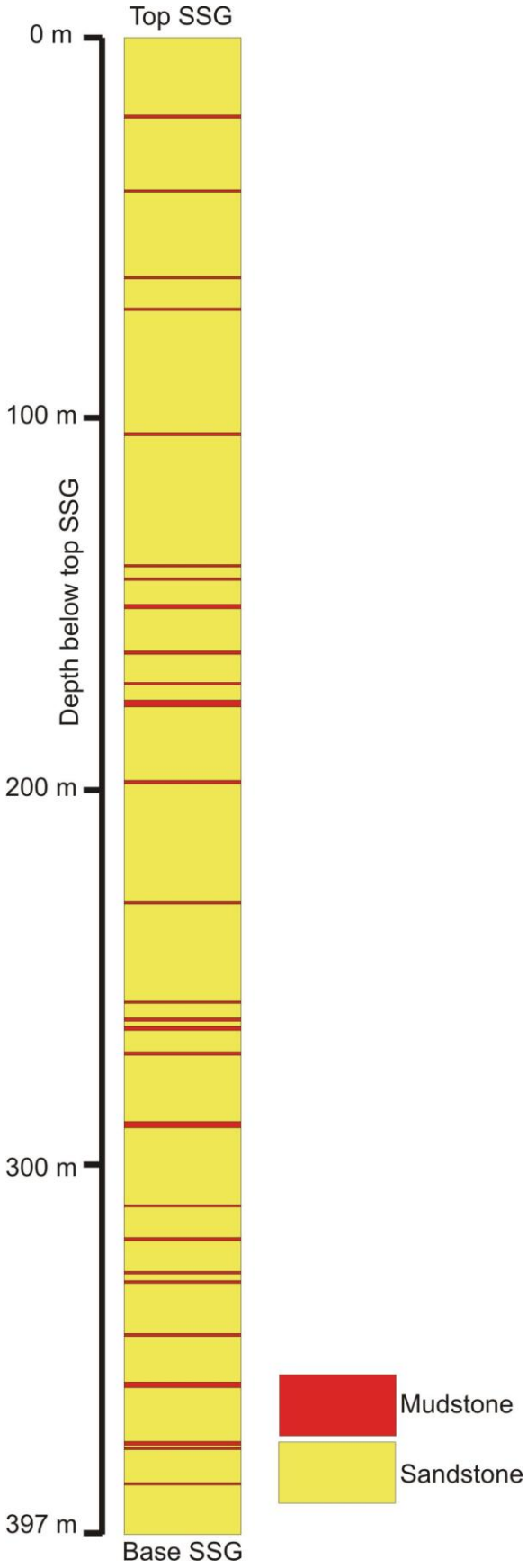

Figure 2 - Summary graphic log of the SSG intersection recorded in the Cleethorpes borehole (BGS ref: TA30NWBJ51.)

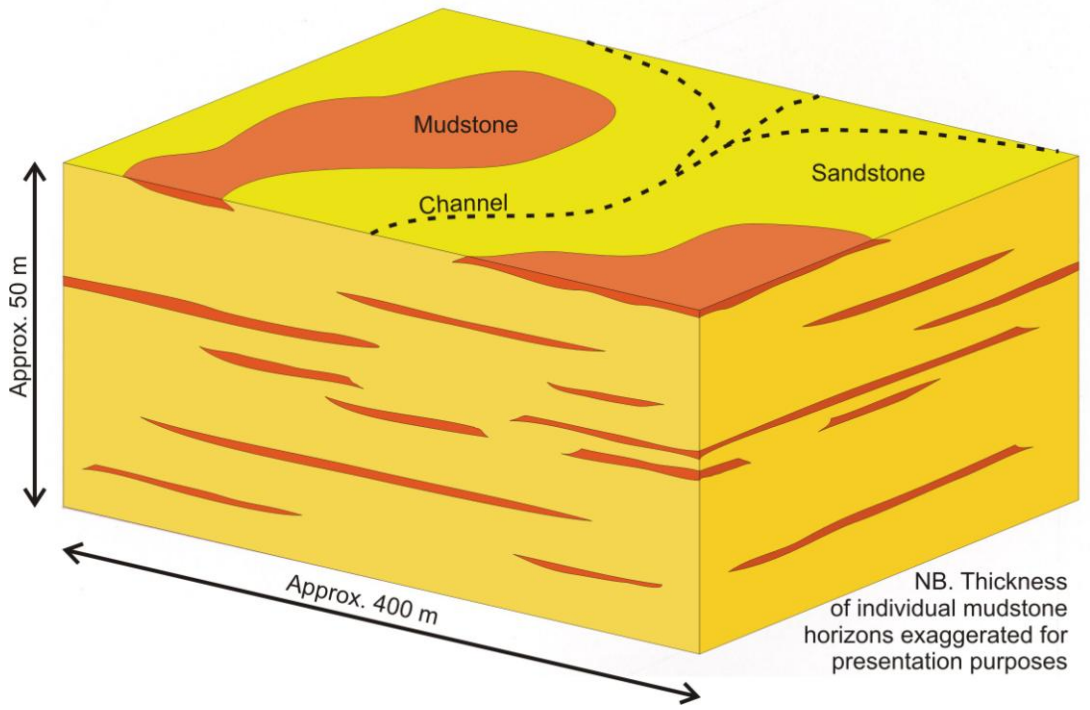

Figure 3 - Schematic block diagram showing expected distribution of mudstone horizons within the Sherwood Sandstone Group. This block represents an arbitrary position within the vertical succession, and is subject to a vertical exaggeration.

3 Mercia Mudstone Group

A review of the formational framework for the MMG, based on a synthesis of published material and borehole information is given in Howard et al. (2008). This report (available from http://www.bgs.ac.uk/downloads/start.cfm?id=866) considers the MMG on a national scale, and provides regional lithostratigraphic summaries.

For the purpose of the CASSEM project, the 3D geological model represents the MMG at group level. Insufficient detailed borehole information was available throughout the area of study to constrain a more detailed subdivision. However, an indication of the formation-level classification of the succession and corresponding lithological variability is presented in Appendix 2 and Figure 4. This information is based on the Scampton West 1 borehole (ARCO British Limited, 1988; BGS ref: SK97NWBJ31.), located approximately 7 km to the west of the region of study (see Figure 1). NB. This appraisal of the MMG is subject to equivalent limitations to those described above for the SSG study of the Cleethorpes borehole. In addition, it should be noted that BGS geologists' experience of the succession suggests a high likelihood that many of the "sandstone" units classified on the Scampton West 1 borehole represent "skerries" (harder, cemented patches or beds within friable mudstone); rather than "sandstone", these may be more accurately classified as very fine grained sandstones or siltstones. Similarly, it is likely that parts of the succession classified on the log as "siltstone" may be more accurately defined as mudstone, and that any "mudstone" unit shown on the log may contain common inclusions of siltstone. Therefore, it is suggested that the information presented in respect of Scampton West 1, including Figure 4, Figure 5, Appendix 2 and the summary below is used as a guide in subsequent work in the full understanding of the limitations described here.

The Scampton West 1 borehole records 253 m of MMG. Based on the figures presented in Appendix 2, the total thickness of mudstone is recorded as 116.33 m (46% of the MMG), the total thickness of siltstone is 81.74 m (32% of the MMG), the total thickness of sandstone is

39.11 m (15% of the MMG) and the total thickness of anhydrite/gypsum (undifferentiated on the log) is 19.16 m (7% of the MMG). The number of recorded sandstone horizons is 18. The thickest undivided intersections of mudstone and sandstone are 21.62 m and 3.18 m respectively.

The lateral extent of lithological variability in the MMG is not known with any degree of certainty. However, it is likely that individual packages of siltstone and mudstone may be traceable over distances of several tens of kilometres (i.e. some units may be present throughout the region of study). This is an estimate based on informal feedback from BGS geologists with experience of the succession. Individual anhydrite/gypsum horizons may be traced over equivalent distances, although it is likely that the anhydrite/gypsum intersections recorded in the log represent a combination of horizontal beds and sub-vertical veins; the latter may be expected to have very limited lateral persistence (<1 m). A schematic representation of the lithological relationships that may be expected in the MMG is given in Figure 5.

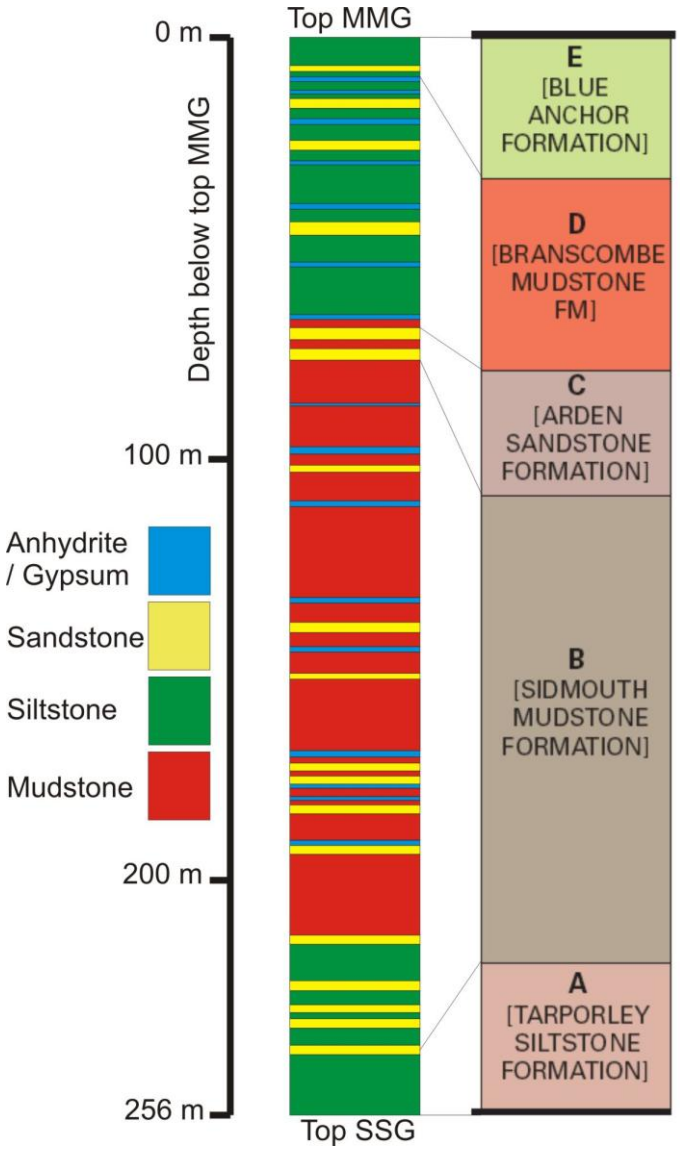

Figure 4 - Lithological summary of MMG recorded in Scampton West 1 (ARCO British Limited, 1988; BGS ref: SK97NWBJ31.). Please refer to main text for further information on the potential limitations of this information. Tentative lithostratigraphic correlation to formation level based on Generalised Vertical Section taken from Howard *et al.* 2008.

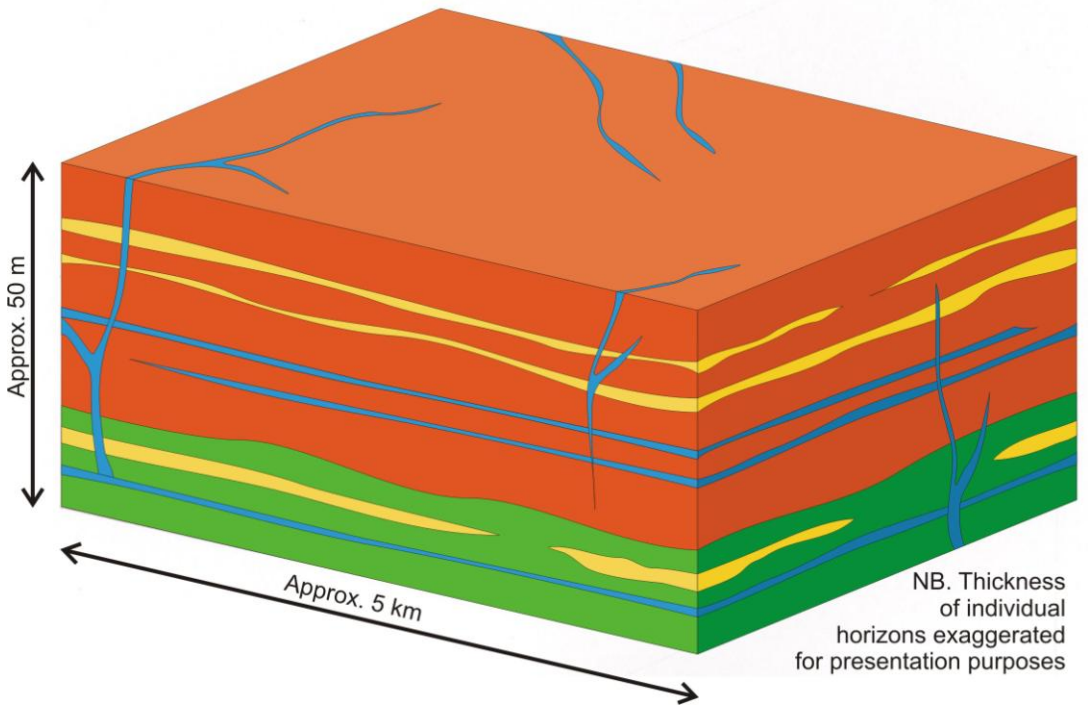

Figure 5 - Schematic block diagram showing expected distribution of lithological heterogeneity within the Mercia Mudstone Group. Please refer to main text for further information on the potential limitations of this information. This block represents an arbitrary position within the vertical succession, and is subject to a vertical exaggeration. See Figure 4 for legend.

4 Forth dataset

To approximate the incidence of sand bodies within the Ballagan Formation and the incidence of mudstone, limestone and siltstone horizons within the Knox Pulpit Sandstone and Kinnesswood formations, lithological summaries of five boreholes were examined (Figure 6). These boreholes could be considered as representative of the Fife (Glenrothes and Fife water boreholes) and Lothian (Spilmersford) successions. However, note they represent only a few point observations in a complex geological succession. Significant variability is expected within the succession in terms of the position, thickness and lateral persistence of individual horizons and in the ratio of lithologies. A comprehensive review of additional borehole records and field exposures may provide contrasting information.

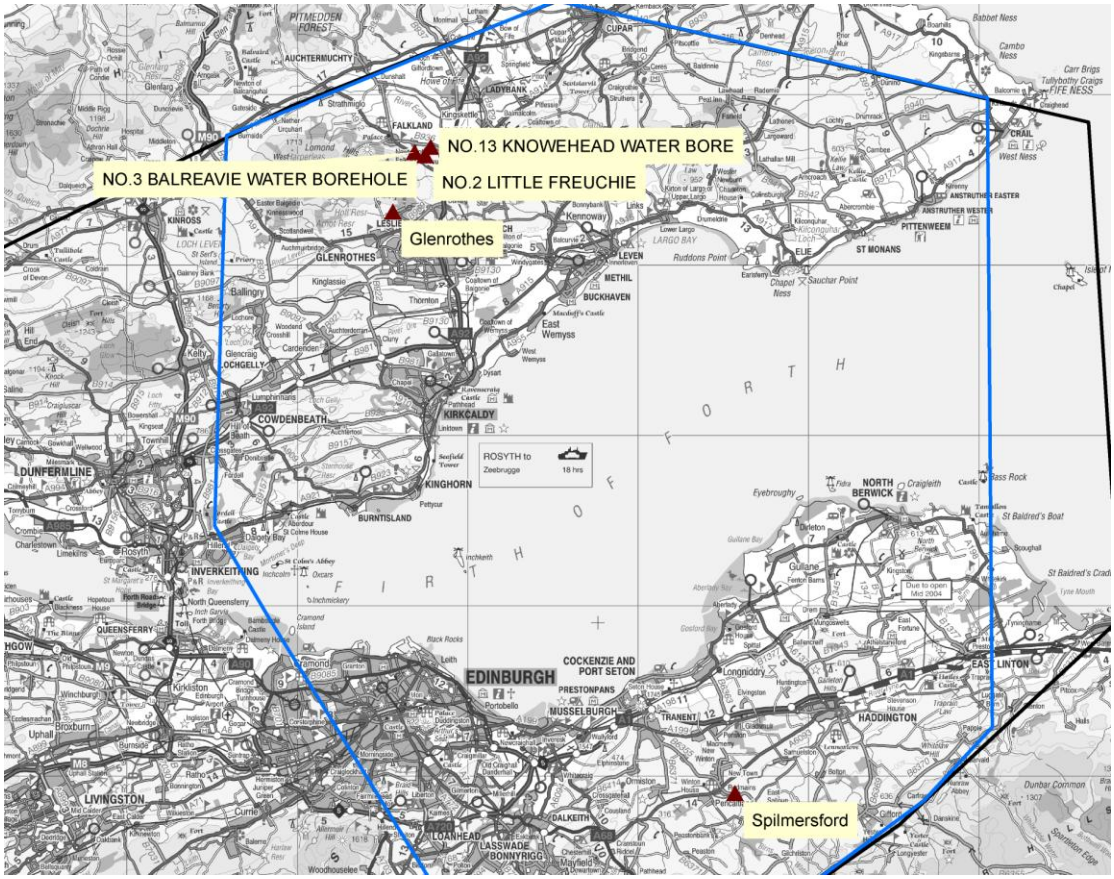

Figure 6 Location map showing position of boreholes referenced in this document. Forth detailed inner study area shown in blue and target area in black. OS © Topography Crown Copyright

It should be noted that these summaries are based on the borehole log recorded at the time of drilling. This log contains an element of interpretation and personal judgement. It is likely that in non-BGS logged boreholes thin beds of mudstone and siltstone under 0.3 m thickness may not have been recorded individually and will be underrepresented.

The estimates of lateral extent of horizons are based on the knowledge and experience of the BGS regional geologist (Mike Browne). Field exposures in these rocks are generally of small outcrops (less than tens of metres wide) and there are not enough closely spaced borehole records to undertake log correlations.

5 Knox Pulpit Sandstone Formation

The Knox Pulpit Sandstone Formation comprises soft, weakly cemented, white and cream-coloured, very fine- to coarse-grained feldspathic sandstones. The most characteristic feature is a marked variation in grain-size between adjacent laminae which may be 1–10 mm thick. This is known as pin-stripe lamination and is aeolian in origin. The rarity of pebbles is another distinctive feature with small masses of ochreous decomposed caliche/calcrete (cornstone) near the top of the formation and greenish grey silty claystone laminae and thin beds near the base (Figure 7).

The Knox Pulpit Sandstone Formation passes laterally to the fluviatile facies of the Glenvale Sandstone Formation and equivalents (see Monaghan et al., 2008 Figure 41). In the Fife area, the Glenvale Sandstone Formation (GEF; Chisholm and Dean, 1974), up to 350 m thick, consists of white, yellow, brown, red and purple, fine- to coarse-grained, feldspathic sandstones, with rare siliceous pebbles. Pebbles of red, green and cream-coloured mudstone up to 0.15 m across are common. Subsidiary beds of greenish grey and red silty claystone and siltstone are also present, and some form the upper parts of upward fining cycles. This unit was probably deposited by braided streams.

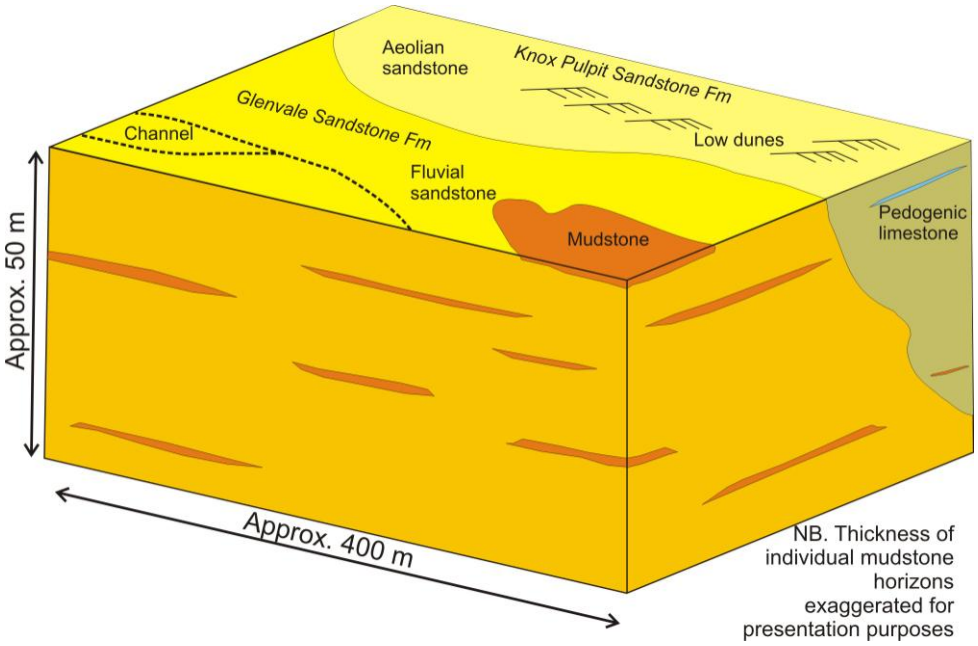

Figure 7 Schematic block diagram showing expected distribution of mudstone and pedogenic limestone horizons within, and interpreted depositional setting of, the Knox Pulpit Sandstone and Glenvale Sandstone formations. This block represents an arbitrary position within the vertical succession, and is subject to a vertical exaggeration. The passage laterally between the two units has been drawn much simplified.

Sandstone is the very dominant lithology for the Knox Pulpit Sandstone Formation (Table 1 below; Figure 7). A thin mudstone seen at the base of the Knox Pulpit Sandstone Formation is localized (likely less than 10 m lateral extent) and pedogenic limestones (calcretes) towards the top of the formation are commonly less than 20 cm thick and believed to be perhaps a few hundred metres in lateral extent.

Other very rare intercalations of siltstone or silty mudstone towards the top of the Formation are 14 cm or less in thickness and would be expected to be localized to tens of metres or less lateral extent.

Mudstone and siltstone lenses within the Glenvale Sandstone Formation are thought to be up to about 30 cm thick and with lateral extents less than 200 m. There is no borehole data to quantify this statement which was derived from regional geological knowledge.

Glenrothes Borehole Knox Pulpit Sdst Fm	Percentage of Lithology
Limestone	0.3
Sandstone	99.2
Mudstone, silty	0.1
Siltstone	0.4

Table 1 Percentage of recorded lithologies in Glenrothes Borehole, Fife NO20SE 385 NGR [325617,703144]. In approximately 120 metres of Knox Pulpit Sandstone Formation strata with top Formation seen and then terminal depth of borehole reached.

100% sandstone is recorded in borehole NO20NE_17 in approximately 9m of Knox Pulpit Sandstone Formation drilled beneath Kinnesswood Formation to borehole terminal depth. 100% sandstone is also recorded in a confidential water borehole in the Falkland-Freuchie area in over 50 m of Knox Pulpit Sandstone Formation drilled from rockhead to terminal depth of borehole.

6 Kinnesswood Formation

The Kinnesswood Formation consists predominantly of purple-red, yellow, white and grey-purple, fine- to coarse grained sandstones which are mostly cross bedded and arranged in upward-fining units. Fine-grained, planar or poorly bedded sandstones, red mudstones and nodules and thin beds of pedogenic limestone (calcrete) also occur (Figure 8). The cross-bedded sandstones were deposited in river channels and the fine-grained sandstones and mudstones represent overbank deposits formed on the associated floodplains. The calcretes, which characterise the formation, were developed in soil profiles on the floodplains under the influence of a fluctuating water table in a semi-arid climate. The calcretes range from immature, in which the sandstones have a partly carbonate matrix with ill-defined concretions, to mature, in which well-defined nodules (glaebules) are elongated in a vertical sense and are overlain by laminar and pisolitic structures.

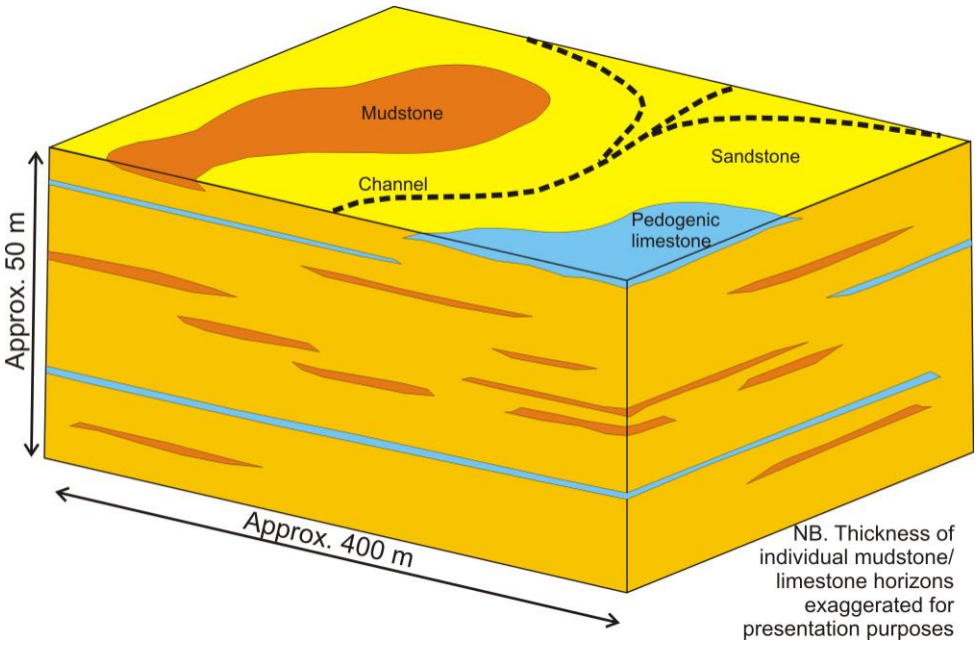

Figure 8 Schematic block diagram showing expected distribution of mudstone and pedogenic limestone horizons within, and interpreted depositional setting of, the Kinnesswood Formation. This block represents an arbitrary position within the vertical succession, and is subject to a vertical exaggeration.

Pedogenic limestones could form local barriers to fluid flow. The thickest (*c.*1-4 m thick) could have regional extents (i.e. kilometres lateral extent) . Mudstone and siltstones are likely to have lateral extents of tens to a few hundred metres. Mudstone intervals are commonly less than 0.3 m thick, though they can be up to 1 m and some silty mudstones up to *c.* 2 m have been recorded. In the Glenrothes Borehole, the pedogenic limestones appear relatively evenly distributed throughout the formation, with thicker limestones and more abundant conglomerate in the top 20 m of the formation. The Kinnesswood Formation in the Glenrothes Borehole also shows a relatively even distribution of mudstone/siltstone interbeds throughout.

The percentage of sandstone within the Kinnesswood Formation varies from 82-86 % in boreholes in Fife and 50 % in the Spilmersford Borehole (Tables 2-5). In the Spilmersford Borehole, conglomerate makes up the other 50 %, whereas in Fife the Glenrothes and other boreholes have up to 10% pedogenic limestone and up to 6 – 8 % mudstone/siltstone as well as very minor amounts of conglomerate (Tables 2-5).

Glenrothes Borehole Kinnesswood Fm	Percentage of lithology
Conglomerate	0.3
Dolostone	0.2
Limestone	10.7
Sandstone	81.8
Mudstone, silty	5.8
Siltstone	1.2

Table 2 Percentage of recorded lithologies in the Glenrothes Borehole, Fife NO20SE 385, NGR [325617,703144]. In approximately 87 metres of Ballagan Formation strata with top and base Formation seen.

Spilmersford Borehole Kinnesswood Fm	Percentage of lithology
Conglomerate	49.7
Sandstone	50.3

Table 3 Percentage of recorded lithologies in the Spilmersford Borehole, Lothian NT46NE 73, NGR [345694, 669019]. In around 10 m of strata at the base of the borehole, to terminal depth.

NO20NE_21 Kinnesswood Fm	Percentage of lithology
Sandstone	86
Pedogenic limestone	8
Siltstone	2
Mudstone	4

Table 4 Percentage of recorded lithologies in the No 13 Knowehead Water Borehole NO20NE_21 near outcrop, Fife NGR [327840, 706960]. In approximately 82 m of strata drilled from rockhead to the top of the Knox Pulpit Sandstone Formation.

N020NE_17 Kinnesswood Fm	Percentage of lithology
Pedogenic limestone	10.0
Mudstone	1.5
Sandstone	82.2
Siltstone	6.3

Table 5 Percentage of recorded lithologies in the No 3 Balreavie Water Borehole NO20NE_17 near outcrop, Fife NGR [326900, 706640]. In approximately 58 m of strata drilled from rockhead to the top of the Knox Pulpit Sandstone Formation.

7 Ballagan Formation

From the known exposures and borehole occurrences, the Ballagan Formation is likely to be present across the study area but is locally absent in the Lomond Hills by unconformity. The rock types are likely to change laterally (e.g. sandier in the Edinburgh area, see below). The Ballagan Formation is characterised by generally grey mudstones and siltstones, with nodules and beds of ferroan dolostone (cementstone), the beds are generally less than 0.3 m thick (Figure 9). Gypsum, and to a much lesser extent anhydrite, and pseudomorphs after halite occur. Desiccation cracks are common and the rocks frequently show evidence of brecciation during diagenesis. Both these features are associated with reddening of the strata.

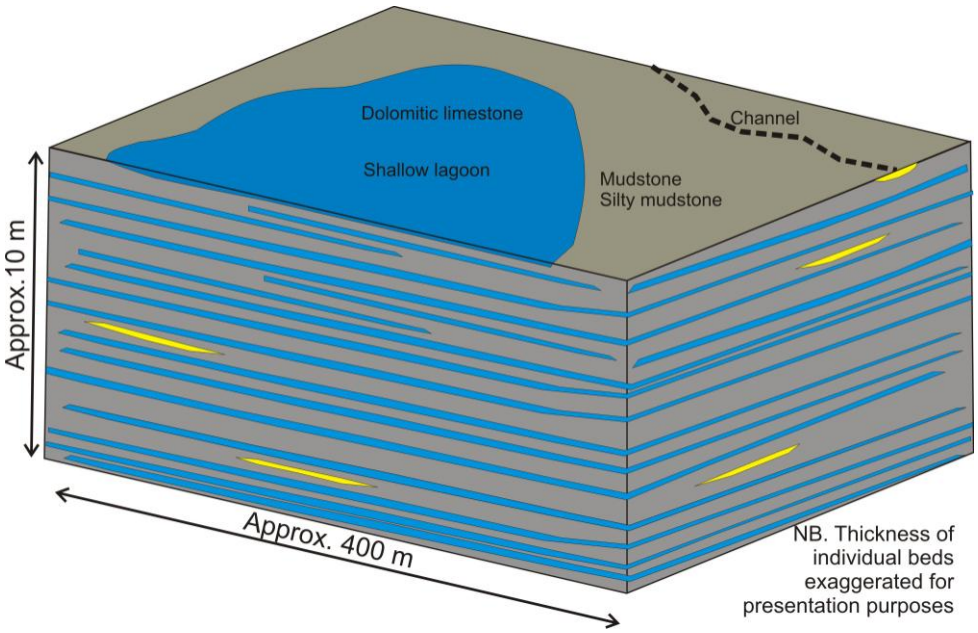

Figure 9 Schematic block diagram showing expected distribution of sandstone horizons within, and interpreted depositional setting of, the Ballagan Formation. This block represents an arbitrary position within the vertical succession, and is subject to a vertical exaggeration.

Beds of mudstone, siltstone and ferroan dolostone are likely to be laterally continuous over tens to hundreds of metres (or perhaps kilometres). Commonly the intervals of each interbedded lithology are less than 0.3 m thick, though they may range up to 10 m. Sand bodies within the Ballagan Formation are likely to be rare in Fife with thicknesses of up to 2.5 m and lateral extents less than a few hundred metres (Figure 9). In the Edinburgh area, sandstones make up a greater proportion of the succession (e.g. up to 67 % in the Water of Leith section near the Edinburgh Bypass, 31 % in the Spilmersford Borehole more commonly up to 15 %) and whilst individual sand bodies are likely to exceed a few hundred metres in lateral extent, the sand bodies could be interconnected.

In the Glenrothes Borehole, the Ballagan Formation is relatively mudstone- versus ferroan dolostone-rich in the bottom 30 m, and a little more sandstone-rich in the uppermost 10 m, but otherwise exhibits fairly uniformly bedded mudstone, dolostone and siltstone intercalations. In the Spilmersford Borehole, the Ballagan Formation succession is more variable with intervals of 10-30 m that are more mudstone-dolostone rich and intervals of 10-30 m that are more sandstone rich, both throughout the succession.

Mudstone, ferroan dolostone and silty mudstone form the bulk of the rock with the amount varying between 46 – 99 % in the boreholes examined for this report (Tables 6-8).

Glenrothes Borehole Ballagan Fm	Percentage of lithology
Gypsum	0.7
Limestone (=ferroan dolostone)	17.1
Mudstone	36.6
Sandstone	8.8
Mudstone, silty	7.8
Siltstone	29.0

Table 6 Percentage of recorded lithologies in the Glenrothes Borehole, Fife NO20SE 385 NGR [325617,703144]. In approximately 160 m of Ballagan Formation strata with top unconformity and base formation seen.

Spilmersford Borehole, Ballagan Fm	Percentage of lithology
Breccia	0.1
Calcareous mudstone	0.1
Limestone (=ferroan dolostone)	0.5
Mudstone	41.3
Sandstone	31.4
Mudstone, silty	5.0
Siltstone	20.4
Tuffaceous rock	1.1

Table 7 Percentage of recorded lithologies in the Spilmersford Borehole, Lothian NT46NE 73 NGR [345694, 669019]. In approximately 260 m of Ballagan Formation strata with top and base Formation seen.

NO20NE_16 Ballagan Fm	
Dolostone	15.6
Siltstone	34.2
Mudstone	49.6
Sandstone	0.7

Table 8 Percentage of recorded lithologies in the No 2 Little Freuchie Borehole, Fife NO20NE 16 NGR [327510, 706450]. In approximately 53 m of the Ballagan Formation from rockhead to terminal depth of the borehole.

Appendix 1

Lithological summary of the SSG intersection as depicted on the Cleethorpes graphic log (BGS ref: TA30NWBJ51.).

Unit top depth in m (from top SSG)	Unit base depth in m (from top SSG)	Unit thickness in m	Lithology
0.00	20.50	20.50	Sandstone
20.50	21.49	1.00	Mudstone
21.49	40.33	18.83	Sandstone
40.33	41.05	0.72	Mudstone
41.05	63.43	22.38	Sandstone
63.43	64.03	0.61	Mudstone
64.03	71.79	7.75	Sandstone
71.79	72.45	0.67	Mudstone
72.45	104.80	32.35	Sandstone
104.80	105.63	0.83	Mudstone
105.63	139.76	34.12	Sandstone
139.76	140.42	0.67	Mudstone
140.42	143.36	2.94	Sandstone
143.36	143.97	0.61	Mudstone
143.97	150.28	6.31	Sandstone
150.28	151.50	1.22	Mudstone
151.50	162.69	11.19	Sandstone
162.69	163.52	0.83	Mudstone
163.52	171.05	7.53	Sandstone
171.05	171.72	0.66	Mudstone
171.72	175.82	4.10	Sandstone
175.82	177.53	1.72	Mudstone
177.53	197.03	19.50	Sandstone
197.03	197.92	0.89	Mudstone
197.92	229.22	31.30	Sandstone
229.22	229.82	0.61	Mudstone
229.82	255.47	25.65	Sandstone
255.47	256.19	0.72	Mudstone
256.19	260.01	3.82	Sandstone
260.01	260.90	0.89	Mudstone
260.90	262.23	1.33	Sandstone
262.23	263.28	1.05	Mudstone
263.28	269.04	5.76	Sandstone
269.04	269.93	0.89	Mudstone

Unit top depth in m (from top SSG)	Unit base depth in m (from top SSG)	Unit thickness in m	Lithology
269.93	287.60	17.67	Sandstone
287.60	289.09	1.50	Mudstone
289.09	309.59	20.50	Sandstone
309.59	310.20	0.61	Mudstone
310.20	318.29	8.09	Sandstone
318.29	319.23	0.94	Mudstone
319.23	327.17	7.94	Sandstone
327.17	327.93	0.76	Mudstone
327.93	329.75	1.83	Sandstone
329.75	330.47	0.72	Mudstone
330.47	343.77	13.29	Sandstone
343.77	344.49	0.72	Mudstone
344.49	356.62	12.13	Sandstone
356.62	358.00	1.38	Mudstone
358.00	372.41	14.40	Sandstone
372.41	373.40	1.00	Mudstone
373.40	373.93	0.53	Sandstone
373.93	374.51	0.58	Mudstone
374.51	383.32	8.80	Sandstone
383.32	383.87	0.55	Mudstone
383.87	397.00	13.13	Sandstone

Appendix 2

Lithological summary of the MMG intersection as depicted on the Scampton West 1 (ARCO British Limited, 1988; BGS ref: SK97NWBJ31.) graphic log.

Unit top depth in m (from top MMG)	Unit base depth in m (from top MMG)	Unit thickness in m	Lithology
0	6.76	6.76	Siltstone
6.76	8.17	1.41	Sandstone
8.17	9.40	1.23	Siltstone
9.40	10.59	1.19	Anhydrite/Gypsum
10.59	12.62	2.02	Siltstone
12.62	13.48	0.87	Anhydrite/Gypsum
13.48	14.60	1.12	Siltstone
14.60	16.92	2.31	Sandstone
16.92	19.38	2.46	Siltstone
19.38	20.79	1.41	Anhydrite/Gypsum
20.79	24.55	3.76	Siltstone
24.55	26.86	2.31	Sandstone
26.86	29.43	2.57	Siltstone
29.43	30.37	0.94	Anhydrite/Gypsum
30.37	39.58	9.22	Siltstone
39.58	40.89	1.30	Anhydrite/Gypsum
40.89	43.92	3.04	Siltstone
43.92	47.10	3.18	Sandstone
47.10	53.47	6.36	Siltstone
53.47	54.66	1.19	Anhydrite/Gypsum
54.66	65.97	11.31	Siltstone
65.97	67.13	1.16	Anhydrite/Gypsum
67.13	69.08	1.95	Mudstone
69.08	71.94	2.86	Sandstone
71.94	74.07	2.13	Mudstone
74.07	76.78	2.71	Sandstone
76.78	87.05	10.27	Mudstone
87.05	87.70	0.65	Anhydrite/Gypsum
87.70	97.39	9.69	Mudstone
97.39	99.12	1.74	Anhydrite/Gypsum
99.12	101.80	2.67	Mudstone
101.80	103.42	1.63	Sandstone
103.42	110.26	6.83	Mudstone
110.26	111.63	1.37	Anhydrite/Gypsum

Unit top depth in m (from top MMG)	Unit base depth in m (from top MMG)	Unit thickness in m	Lithology
111.63	133.25	21.62	Mudstone
133.25	134.58	1.34	Anhydrite/Gypsum
134.58	139.14	4.56	Mudstone
139.14	141.60	2.46	Sandstone
141.60	144.92	3.33	Mudstone
144.92	146.23	1.30	Anhydrite/Gypsum
146.23	151.29	5.06	Mudstone
151.29	152.66	1.37	Sandstone
152.66	169.65	16.99	Mudstone
169.65	171.17	1.52	Anhydrite/Gypsum
171.17	172.61	1.45	Mudstone
172.61	174.49	1.88	Sandstone
174.49	175.72	1.23	Mudstone
175.72	177.60	1.88	Sandstone
177.60	178.62	1.01	Anhydrite/Gypsum
178.62	180.57	1.95	Mudstone
180.57	181.51	0.94	Anhydrite/Gypsum
181.51	182.59	1.08	Mudstone
182.59	184.69	2.10	Sandstone
184.69	190.98	6.29	Mudstone
190.98	192.21	1.23	Anhydrite/Gypsum
192.21	194.30	2.10	Sandstone
194.30	213.54	19.23	Mudstone
213.54	215.70	2.17	Sandstone
215.70	224.38	8.68	Siltstone
224.38	226.77	2.39	Sandstone
226.77	230.09	3.33	Siltstone
230.09	231.97	1.88	Sandstone
231.97	233.42	1.45	Siltstone
233.42	235.66	2.24	Sandstone
235.66	239.71	4.05	Siltstone
239.71	241.95	2.24	Sandstone
241.95	256.34	14.39	Siltstone

Appendix 3

Bed by bed summary of the Ballagan to Knox Pulpit Sandstone formations from the Glenrothes Borehole, extracted from the BGS.Borehole.Geology database on 1/4/08. This is a existing BGS interpretation and constitutes BGS background information, to be used only for the CASSEM project under the terms of the CASSEM Collaboration Agreement. Note yellow highlighted horizons are repeated rows due to additional property information.

Codes

CMST = cementstone = fine grained dolomitic limestone
MDST = mudstone
SLST = siltstone
SDST = sandstone
SLMDST = mudstone, silty
DOLO = dolostone
LMSTN = limestone
SAF = sand, fine grained
SAFV = sand, very fine grained
SAM = sand, medium grained
SAC = sand, coarse grained
SACV = sand, very coarse grained
(yellow highlights indicate repeated bed for property information)
BGN =Ballagan Fm
KNW = Kinnesswood Fm
KPF = Knox Pulpit Sandstone Fm

Lithology	Lithostratigraphy	Drilled depth top	Drilled depth base	Thickness	Property	Property value
SLST	BGN	205	205.2	0.2		
SLMDST	BGN	205.2	205.83	0.63		
CMST	BGN	205.83	205.87	0.04		
MDST	BGN	205.87	206.02	0.15		
CMST	BGN	206.02	206.15	0.13		
MDST	BGN	206.15	206.28	0.13		
CMST	BGN	206.28	206.35	0.07		
MDST	BGN	206.35	207.41	1.06		
SDST	BGN	207.41	209.35	1.94	GRSZE	SAF
MDST	BGN	209.35	209.74	0.39		
CMST	BGN	209.74	209.77	0.03		
MDST	BGN	209.77	209.81	0.04	FOSSIL_01	FISH
CMST	BGN	209.81	209.95	0.14		
MDST	BGN	209.95	210.01	0.06		
CMST	BGN	210.01	210.09	0.08		
MDST	BGN	210.09	210.15	0.06		
SLST	BGN	210.15	210.87	0.72		
SDST	BGN	210.87	212.1	1.23	GRSZE	SAF
SLST	BGN	212.1	212.69	0.59		
SDST	BGN	212.69	213.37	0.68	GRSZE	SAF
MDST	BGN	213.37	213.39	0.02		
CMST	BGN	213.39	214.03	0.64		
SLMDST	BGN	214.03	214.53	0.5		
SLST	BGN	214.53	214.69	0.16		

SDST	BGN	214.69	214.8	0.11		
SLST	BGN	214.8	215.22	0.42		
SDST	BGN	215.22	215.28	0.06	GRSZE	SAF
SLST	BGN	215.28	215.52	0.24		
SDST	BGN	215.52	216	0.48		
MDST	BGN	216	216.07	0.07		
CMST	BGN	216.07	216.44	0.37		
SLMDST	BGN	216.44	216.54	0.1		
SDST	BGN	216.54	217.12	0.58	GRSZE	SAF
SLST	BGN	217.12	217.58	0.46		
SLMDST	BGN	217.58	217.77	0.19		
CMST	BGN	217.77	218.14	0.37		
SLMDST	BGN	218.14	218.46	0.32	FOSSIL_02	FISH
SLMDST	BGN	218.14	218.46	0.32	FOSSIL_01	OSTRACODA
SLST	BGN	218.46	219.67	1.21		
MDST	BGN	219.67	220.47	0.8		
SLST	BGN	220.47	221.02	0.55		
SDST	BGN	221.02	221.74	0.72		
SLST	BGN	221.74	221.93	0.19		
CMST	BGN	221.93	222	0.07		
SLST	BGN	222	222.15	0.15		
MDST	BGN	222.15	222.23	0.08		
SLST	BGN	222.23	222.65	0.42		
SLMDST	BGN	222.65	223.34	0.69		
SLST	BGN	223.34	223.55	0.21		
CMST	BGN	223.55	223.73	0.18		
MDST	BGN	223.73	224.08	0.35		
CMST	BGN	224.08	224.32	0.24	FOSSIL_01	ANNELIDA
MDST	BGN	224.32	224.36	0.04	FOSSIL_01	ANNELIDA
MDST	BGN	224.32	224.36	0.04	FOSSIL_02	OSTRACODA
CMST	BGN	224.36	224.51	0.15	FOSSIL_01	OSTRACODA
CMST	BGN	224.36	224.51	0.15	FOSSIL_02	ANNELIDA
CMST	BGN	224.36	224.51	0.15	LITH2	GYPS
SLMDST	BGN	224.51	224.6	0.09		
SDST	BGN	224.6	224.64	0.04	LITH2	SLST
SLST	BGN	224.64	224.74	0.1		
CMST	BGN	224.74	224.86	0.12		
MDST	BGN	224.86	225	0.14	FOSSIL_01	SHELL
SLMDST	BGN	225	225.1	0.1		
SLST	BGN	225.1	225.33	0.23	LITH2	SDST
MDST	BGN	225.33	225.77	0.44		
CMST	BGN	225.77	225.85	0.08		
MDST	BGN	225.85	225.99	0.14	LITH2	GYPS
CMST	BGN	225.99	226.17	0.18	LITH2	GYPS
MDST	BGN	226.17	226.21	0.04	FOSSIL_01	BIVALVIA
SDST	BGN	226.21	226.32	0.11	GRSZE	SAF
SLST	BGN	226.32	226.67	0.35		
SLMDST	BGN	226.67	226.96	0.29		
CMST	BGN	226.96	227.11	0.15		
SLST	BGN	227.11	227.25	0.14		
CMST	BGN	227.25	227.36	0.11		
SLST	BGN	227.36	227.41	0.05		
CMST	BGN	227.41	227.51	0.1		
SLST	BGN	227.51	227.82	0.31		

CMST	BGN	227.82	227.88	0.06		
SLMDST	BGN	227.88	228.1	0.22		
SLST	BGN	228.1	228.5	0.4	TRACE_FOSS_01	Planolites
SDST	BGN	228.5	228.72	0.22	GRSZE	SAF
CMST	BGN	228.72	228.78	0.06		
SDST	BGN	228.78	229.65	0.87	GRSZE	SAF
SLST	BGN	229.65	230	0.35	TRACE_FOSS_01	Planolites
MDST	BGN	230	230.12	0.12		
CMST	BGN	230.12	230.25	0.13		
MDST	BGN	230.25	230.31	0.06		
CMST	BGN	230.31	230.45	0.14	LITH2	GYPS
MDST	BGN	230.45	230.85	0.4		
CMST	BGN	230.85	230.9	0.05		
MDST	BGN	230.9	231.19	0.29		
CMST	BGN	231.19	231.52	0.33	FOSSIL_01	ALGAE
MDST	BGN	231.52	231.64	0.12		
CMST	BGN	231.64	231.71	0.07		
MDST	BGN	231.71	232.08	0.37		
CMST	BGN	232.08	232.14	0.06	LITH2	GYPS
MDST	BGN	232.14	232.2	0.06		
SLST	BGN	232.2	233	0.8		
CMST	BGN	233	233.19	0.19	LITH2	GYPS
SLST	BGN	233.19	235.67	2.48	TRACE_FOSS_01	Planolites
SDST	BGN	235.67	236	0.33		
SLST	BGN	236	236.24	0.24		
SLST	BGN	236.24	236.52	0.28	TRACE_FOSS_01	Planolites
SLMDST	BGN	236.52	236.64	0.12		
CASLST	BGN	236.64	236.87	0.23		
LMST	BGN	236.87	237	0.13		
SLMDST	BGN	237	237.53	0.53	FOSSIL_01	BIVALVIA
SLMDST	BGN	237	237.53	0.53	LITH2	CAMDST
CASLST	BGN	237.53	237.8	0.27		
MDST	BGN	237.8	238.08	0.28	LITH2	CAMDST
MDST	BGN	237.8	238.08	0.28	LITH3	LMST
SDST	BGN	238.08	238.31	0.23	GRSZE	SAF
SLST	BGN	238.31	238.85	0.54		
MDST	BGN	238.85	239	0.15	FOSSIL_01	SHELL
SLST	BGN	239	239.7	0.7	LITH2	CASLST
SLMDST	BGN	239.7	240.2	0.5		
SLST	BGN	240.2	240.5	0.3		
MDST	BGN	240.5	240.83	0.33		
SLST	BGN	240.83	241.19	0.36		
SDST	BGN	241.19	241.26	0.07	GRSZE	SAF
SLST	BGN	241.26	242	0.74		
SLMDST	BGN	242	242.48	0.48		
SDST	BGN	242.48	242.58	0.1	GRSZE	SAFV
SLST	BGN	242.58	242.74	0.16		
CMST	BGN	242.74	242.77	0.03		
MDST	BGN	242.77	243.14	0.37		
CMST	BGN	243.14	243.17	0.03		
MDST	BGN	243.17	243.22	0.05		
CMST	BGN	243.22	243.57	0.35	LITH2	MDST
CMST	BGN	243.22	243.57	0.35	LITH3	GYPS
MDST	BGN	243.57	243.65	0.08		

CMST	BGN	243.65	243.79	0.14		
SLMDST	BGN	243.79	243.94	0.15	FOSSIL_01	BIVALVIA
CMST	BGN	243.94	244.13	0.19	LITH2	GYPS
SLMDST	BGN	244.13	244.15	0.02		
CMST	BGN	244.15	244.17	0.02		
SLMDST	BGN	244.17	244.2	0.03		
CMST	BGN	244.2	244.32	0.12		
MDST	BGN	244.32	244.54	0.22		
MDST	BGN	244.54	244.81	0.27	FOSSIL_01	FISH
MDST	BGN	244.54	244.81	0.27	FOSSIL_02	OSTRACODA
CMST	BGN	244.81	244.86	0.05		
MDST	BGN	244.86	245.32	0.46	FOSSIL_01	Estheria
MDST	BGN	244.86	245.32	0.46	FOSSIL_02	FISH
CMST	BGN	245.32	245.55	0.23		
SLMDST	BGN	245.55	245.57	0.02		
CMST	BGN	245.57	245.71	0.14		
MDST	BGN	245.71	246	0.29		
CMST	BGN	246	246.2	0.2		
MDST	BGN	246.2	246.44	0.24		
SLST	BGN	246.44	246.85	0.41		
MDST	BGN	246.85	246.96	0.11		
CMST	BGN	246.96	247	0.04		
SDST	BGN	247	247.04	0.04	GRSZE	SAF
SLST	BGN	247.04	247.47	0.43		
SDST	BGN	247.47	249.97	2.5	GRSZE	SAM
SDST	BGN	247.47	249.97	2.5	GRSZE	SAF
MDST	BGN	249.97	250.24	0.27		
CMST	BGN	250.24	250.41	0.17		
MDST	BGN	250.41	250.58	0.17		
CMST	BGN	250.58	250.62	0.04		
MDST	BGN	250.62	250.9	0.28		
CMST	BGN	250.9	251.03	0.13		
MDST	BGN	251.03	251.1	0.07		
CMST	BGN	251.1	251.15	0.05		
SLST	BGN	251.15	251.86	0.71		
CMST	BGN	251.86	251.89	0.03		
MDST	BGN	251.89	252.14	0.25		
SLST	BGN	252.14	252.24	0.1		
MDST	BGN	252.24	253.17	0.93		
CMST	BGN	253.17	253.24	0.07		
MDST	BGN	253.24	253.46	0.22		
LMST	BGN	253.46	253.55	0.09		
MDST	BGN	253.55	253.65	0.1		
CMST	BGN	253.65	253.76	0.11		
MDST	BGN	253.76	253.87	0.11		
CMST	BGN	253.87	254	0.13		
MDST	BGN	254	255.6	1.6		
CMST	BGN	255.6	255.64	0.04		
MDST	BGN	255.64	255.81	0.17		
CMST	BGN	255.81	255.89	0.08		
MDST	BGN	255.89	255.94	0.05		
CMST	BGN	255.94	256	0.06		
MDST	BGN	256	256.2	0.2		
CMST	BGN	256.2	256.24	0.04		

SLMDST	BGN	256.24	256.69	0.45		
CMST	BGN	256.69	256.8	0.11		
MDST	BGN	256.8	257.19	0.39		
CMST	BGN	257.19	257.34	0.15		
SLMDST	BGN	257.34	257.39	0.05		
SDST	BGN	257.39	257.64	0.25	GRSZE	SAF
MDST	BGN	257.64	257.88	0.24		
CMST	BGN	257.88	258.01	0.13		
MDST	BGN	258.01	258.62	0.61		
SLST	BGN	258.62	258.94	0.32		
SLMDST	BGN	258.94	259.52	0.58		
CASLST	BGN	259.52	260.14	0.62		
MDST	BGN	260.14	260.6	0.46		
SDST	BGN	260.6	260.66	0.06	GRSZE	SAF
CMST	BGN	260.66	260.73	0.07		
SLST	BGN	260.73	261.26	0.53		
CMST	BGN	261.26	261.48	0.22		
MDST	BGN	261.48	261.69	0.21		
SLST	BGN	261.69	261.81	0.12		
CMST	BGN	261.81	262.1	0.29		
MDST	BGN	262.1	262.2	0.1		
CMST	BGN	262.2	262.3	0.1		
SLMDST	BGN	262.3	262.81	0.51		
CMST	BGN	262.81	263.03	0.22		
MDST	BGN	263.03	263.69	0.66		
CMST	BGN	263.69	263.93	0.24		
MDST	BGN	263.93	264.64	0.71		
SLST	BGN	264.64	265.26	0.62		
MDST	BGN	265.26	266.6	1.34		
SLST	BGN	266.6	266.67	0.07		
LMST	BGN	266.67	266.83	0.16		
MDST	BGN	266.83	267.06	0.23		
CMST	BGN	267.06	267.25	0.19		
SLMDST	BGN	267.25	267.62	0.37		
CMST	BGN	267.62	267.68	0.06		
MDST	BGN	267.68	267.76	0.08		
CMST	BGN	267.76	267.93	0.17		
MDST	BGN	267.93	268	0.07		
CMST	BGN	268	268.03	0.03		
MDST	BGN	268.03	268.08	0.05		
CMST	BGN	268.08	268.24	0.16		
MDST	BGN	268.24	268.42	0.18		
CMST	BGN	268.42	268.49	0.07		
MDST	BGN	268.49	268.6	0.11		
SLST	BGN	268.6	268.9	0.3		
SLMDST	BGN	268.9	269.04	0.14		
CMST	BGN	269.04	269.09	0.05		
SLST	BGN	269.09	269.25	0.16		
GYPS	BGN	269.25	270.06	0.81		
CMST	BGN	270.06	270.24	0.18		
SLMDST	BGN	270.24	270.58	0.34		
SLST	BGN	270.58	270.86	0.28		
CMST	BGN	270.86	270.9	0.04		
SLST	BGN	270.9	271.6	0.7		

LMST	BGN	271.6	271.67	0.07		
SLST	BGN	271.67	272	0.33		
MDST	BGN	272	272.43	0.43		
LMST	BGN	272.43	272.46	0.03		
SLST	BGN	272.46	272.48	0.02		
LMST	BGN	272.48	272.5	0.02		
SLST	BGN	272.5	272.76	0.26		
CMST	BGN	272.76	272.84	0.08		
MDST	BGN	272.84	273	0.16		
SLST	BGN	273	273.36	0.36		
CMST	BGN	273.36	273.51	0.15		
SLST	BGN	273.51	274.2	0.69		
CMST	BGN	274.2	274.36	0.16		
SLST	BGN	274.36	275	0.64		
CMST	BGN	275	275.51	0.51		
MDST	BGN	275.51	275.54	0.03		
CMST	BGN	275.54	275.57	0.03		
SLST	BGN	275.57	275.98	0.41		
CMST	BGN	275.98	276.02	0.04		
SLST	BGN	276.02	276.33	0.31		
CMST	BGN	276.33	276.45	0.12		
MDST	BGN	276.45	277.2	0.75		
SLST	BGN	277.2	277.66	0.46		
CMST	BGN	277.66	277.92	0.26		
SLST	BGN	277.92	277.95	0.03		
CMST	BGN	277.95	278.05	0.1		
SLST	BGN	278.05	279.6	1.55		
CMST	BGN	279.6	279.64	0.04		
SLST	BGN	279.64	279.74	0.1		
CMST	BGN	279.74	279.86	0.12		
SLST	BGN	279.86	280.01	0.15		
CMST	BGN	280.01	280.1	0.09		
SLST	BGN	280.1	280.29	0.19		
CMST	BGN	280.29	280.4	0.11		
SLMDST	BGN	280.4	280.8	0.4		
SLST	BGN	280.8	281.16	0.36		
CMST	BGN	281.16	281.23	0.07		
SLMDST	BGN	281.23	281.29	0.06		
LMST	BGN	281.29	281.43	0.14		
MDST	BGN	281.43	281.97	0.54		
SLST	BGN	281.97	282.6	0.63		
MDST	BGN	282.6	283.85	1.25		
SDST	BGN	283.85	283.88	0.03	GRSZE	SAF
SLST	BGN	283.88	284	0.12		
SDST	BGN	284	284.04	0.04	GRSZE	SAF
MDST	BGN	284.04	284.2	0.16		
SLST	BGN	284.2	284.44	0.24		
SDST	BGN	284.44	284.5	0.06		
MDST	BGN	284.5	284.73	0.23		
CMST	BGN	284.73	284.77	0.04		
GYPS	BGN	284.77	284.96	0.19		
MDST	BGN	284.96	285.22	0.26		
SLST	BGN	285.22	285.6	0.38		
MDST	BGN	285.6	285.87	0.27		

CMST	BGN	285.87	286.37	0.5		
MDST	BGN	286.37	286.64	0.27		
SLST	BGN	286.64	287.05	0.41		
MDST	BGN	287.05	287.57	0.52		
LMST	BGN	287.57	287.8	0.23		
SLST	BGN	287.8	288.24	0.44		
MDST	BGN	288.24	288.47	0.23		
CMST	BGN	288.47	288.51	0.04		
MDST	BGN	288.51	288.74	0.23		
CMST	BGN	288.74	288.8	0.06		
MDST	BGN	288.8	288.87	0.07		
CMST	BGN	288.87	288.95	0.08		
MDST	BGN	288.95	289.05	0.1		
SLST	BGN	289.05	289.43	0.38		
MDST	BGN	289.43	289.55	0.12		
CMST	BGN	289.55	289.69	0.14		
SLST	BGN	289.69	289.75	0.06		
CMST	BGN	289.75	289.83	0.08		
SLMDST	BGN	289.83	289.85	0.02		
CMST	BGN	289.85	289.92	0.07		
SLST	BGN	289.92	291.19	1.27		
CMST	BGN	291.19	291.51	0.32		
MDST	BGN	291.51	291.7	0.19		
CMST	BGN	291.7	291.82	0.12		
MDST	BGN	291.82	291.92	0.1		
CMST	BGN	291.92	292.08	0.16		
MDST	BGN	292.08	292.14	0.06		
SLST	BGN	292.14	292.26	0.12		
GYPS	BGN	292.26	292.28	0.02		
SLST	BGN	292.28	293.15	0.87		
CMST	BGN	293.15	293.21	0.06		
SLST	BGN	293.21	294.55	1.34		
CMST	BGN	294.55	294.63	0.08		
SLST	BGN	294.63	294.69	0.06		
MDST	BGN	294.69	295.1	0.41		
SLST	BGN	295.1	295.47	0.37		
CMST	BGN	295.47	295.6	0.13		
SLST	BGN	295.6	295.63	0.03		
CMST	BGN	295.63	295.79	0.16		
SLST	BGN	295.79	295.98	0.19		
SDST	BGN	295.98	296.35	0.37	GRSZE	SAF
SLST	BGN	296.35	296.42	0.07		
MDST	BGN	296.42	296.58	0.16		
SLST	BGN	296.58	297.81	1.23		
SDST	BGN	297.81	297.85	0.04	GRSZE	SAF
SLST	BGN	297.85	297.99	0.14		
CMST	BGN	297.99	298.05	0.06		
SLMDST	BGN	298.05	298.06	0.01		
CMST	BGN	298.06	298.52	0.46		
MDST	BGN	298.52	298.57	0.05		
SLST	BGN	298.57	298.71	0.14		
CMST	BGN	298.71	298.97	0.26		
SLST	BGN	298.97	299.06	0.09		
CMST	BGN	299.06	299.14	0.08		

SLMDST	BGN	299.14	299.73	0.59		
CMST	BGN	299.73	299.92	0.19		
SLST	BGN	299.92	300.71	0.79		
MDST	BGN	300.71	301	0.29		
SLST	BGN	301	301.65	0.65		
CMST	BGN	301.65	301.75	0.1		
SLST	BGN	301.75	302	0.25		
MDST	BGN	302	302.38	0.38		
SLST	BGN	302.38	302.92	0.54		
MDST	BGN	302.92	303.02	0.1		
CMST	BGN	303.02	303.43	0.41		
MDST	BGN	303.43	303.93	0.5		
SLST	BGN	303.93	304.11	0.18		
SLMDST	BGN	304.11	304.64	0.53		
SLST	BGN	304.64	304.97	0.33		
CMST	BGN	304.97	305.65	0.68		
SDST	BGN	305.65	305.69	0.04	GRSZE	SAF
SLST	BGN	305.69	306.25	0.56		
CMST	BGN	306.25	306.51	0.26		
MDST	BGN	306.51	306.57	0.06		
CMST	BGN	306.57	306.67	0.1		
SLST	BGN	306.67	306.92	0.25		
CMST	BGN	306.92	306.95	0.03		
SLST	BGN	306.95	307.21	0.26		
CMST	BGN	307.21	307.43	0.22		
SLST	BGN	307.43	307.64	0.21		
MDST	BGN	307.64	308.45	0.81		
SLST	BGN	308.45	308.96	0.51		
MDST	BGN	308.96	309.09	0.13		
CMST	BGN	309.09	309.85	0.76		
MDST	BGN	309.85	310	0.15		
LMST	BGN	310	310.1	0.1		
SLST	BGN	310.1	310.45	0.35		
SLMDST	BGN	310.45	310.88	0.43		
SDST	BGN	310.88	310.96	0.08	GRSZE	SAF
CMST	BGN	310.96	311.21	0.25		
SLST	BGN	311.21	312.2	0.99		
CMDST	BGN	312.2	312.34	0.14		
SLST	BGN	312.34	312.39	0.05		
LMST	BGN	312.39	312.51	0.12		
SLST	BGN	312.51	313.4	0.89		
CMST	BGN	313.4	313.47	0.07		
MDST	BGN	313.47	314.35	0.88		
CMST	BGN	314.35	314.59	0.24		
MDST	BGN	314.59	314.7	0.11		
SLST	BGN	314.7	315.4	0.7		
MDST	BGN	315.4	316.95	1.55		
SLST	BGN	316.95	317.31	0.36		
MDST	BGN	317.31	317.46	0.15		
CMST	BGN	317.46	317.51	0.05		
SLMDST	BGN	317.51	317.93	0.42		
SLST	BGN	317.93	317.99	0.06		
CMST	BGN	317.99	318.38	0.39		
MDST	BGN	318.38	318.43	0.05		

CMST	BGN	318.43	318.62	0.19		
MDST	BGN	318.62	318.7	0.08		
SLST	BGN	318.7	319.72	1.02		
CMST	BGN	319.72	319.93	0.21		
MDST	BGN	319.93	320.16	0.23		
SLST	BGN	320.16	320.84	0.68		
MDST	BGN	320.84	321.42	0.58		
CMST	BGN	321.42	321.56	0.14		
MDST	BGN	321.56	321.64	0.08		
CMST	BGN	321.64	321.71	0.07		
SLST	BGN	321.71	322.22	0.51		
MDST	BGN	322.22	322.41	0.19		
CMST	BGN	322.41	322.52	0.11		
MDST	BGN	322.52	323.18	0.66		
CMST	BGN	323.18	323.45	0.27		
MDST	BGN	323.45	323.6	0.15		
CMST	BGN	323.6	324.25	0.65		
SLST	BGN	324.25	324.61	0.36		
SLMDST	BGN	324.61	324.69	0.08		
CMST	BGN	324.69	324.85	0.16		
MDST	BGN	324.85	325	0.15		
SLST	BGN	325	325.24	0.24		
CMST	BGN	325.24	325.53	0.29		
MDST	BGN	325.53	325.94	0.41		
SLST	BGN	325.94	326.01	0.07		
CMST	BGN	326.01	326.36	0.35		
SLST	BGN	326.36	326.6	0.24		
CMST	BGN	326.6	326.8	0.2		
MDST	BGN	326.8	327.07	0.27		
SLST	BGN	327.07	327.44	0.37		
MDST	BGN	327.44	327.82	0.38		
SLST	BGN	327.82	327.87	0.05		
MDST	BGN	327.87	328.23	0.36		
CMST	BGN	328.23	328.65	0.42		
SLST	BGN	328.65	329.18	0.53		
CMST	BGN	329.18	329.28	0.1		
SLMDST	BGN	329.28	330.2	0.92		
CMST	BGN	330.2	330.8	0.6		
MDST	BGN	330.8	333.17	2.37		
CMST	BGN	333.17	333.3	0.13		
MDST	BGN	333.3	333.56	0.26		
CMST	BGN	333.56	334.23	0.67		
MDST	BGN	334.23	338	3.77		
SLST	BGN	338	338.05	0.05		
MDST	BGN	338.05	338.99	0.94		
CMST	BGN	338.99	339.09	0.1		
MDST	BGN	339.09	339.3	0.21		
CMST	BGN	339.3	339.44	0.14		
MDST	BGN	339.44	341.74	2.3		
CMST	BGN	341.74	342.45	0.71		
MDST	BGN	342.45	343.15	0.7		
CMST	BGN	343.15	343.45	0.3		
SLMDST	BGN	343.45	343.74	0.29		
CMST	BGN	343.74	343.8	0.06		

MDST	BGN	343.8	344.5	0.7		
CMST	BGN	344.5	345.2	0.7		
SLMDST	BGN	345.2	345.85	0.65		
CMST	BGN	345.85	346.15	0.3		
MDST	BGN	346.15	356.8	10.65		
CMST	BGN	356.8	357	0.2		
MDST	BGN	357	357.4	0.4		
CMST	BGN	357.4	357.44	0.04		
MDST	BGN	357.44	358.75	1.31		
CMST	BGN	358.75	358.8	0.05		
MDST	BGN	358.8	358.82	0.02		
CMST	BGN	358.82	359.47	0.65		
SDST	BGN	359.47	359.76	0.29	GRSZE	SAF
MDST	BGN	359.76	359.8	0.04		
SDST	BGN	359.8	361.97	2.17	GRSZE	SAF
CMST	BGN	361.97	362	0.03		
SLMDST	BGN	362	362.43	0.43		
SDST	KNW	362.43	363.47	1.04	GRSZE	SAF
SDST	KNW	362.43	363.47	1.04	GRSZE	SAM
LMSTN	KNW	363.47	363.99	0.52		
SDST	KNW	363.99	364.38	0.39	GRSZE	SAM
SDST	KNW	363.99	364.38	0.39	GRSZE	SAF
LMSTN	KNW	364.38	365.51	1.13		
SDST	KNW	365.51	366.23	0.72	GRSZE	SAF
SDST	KNW	365.51	366.23	0.72	GRSZE	SAM
SDST	KNW	366.23	366.9	0.67	GRSZE	SAM
SDST	KNW	366.9	366.92	0.02		
SDST	KNW	366.92	370.11	3.19		
SDST	KNW	370.11	370.33	0.22	GRSZE	SACV
CONG	KNW	370.33	370.42	0.09		
LMSTN	KNW	370.42	371	0.58		
SDST	KNW	371	373.48	2.48	GRSZE	SAF
SLMDST	KNW	373.48	375.38	1.9		
SDST	KNW	375.38	376.78	1.4	GRSZE	SAF
LMSTN	KNW	376.78	381.34	4.56		
SDST	KNW	381.34	381.49	0.15	GRSZE	SAF
LMSTN	KNW	381.49	381.99	0.5		
SDST	KNW	381.99	383.38	1.39	GRSZE	SAF
SDST	KNW	383.38	384.24	0.86	GRSZE	SAM
SDST	KNW	383.38	384.24	0.86	GRSZE	SAF
SDST	KNW	384.24	385.1	0.86	GRSZE	SAFV
SDST	KNW	384.24	385.1	0.86	GRSZE	SAF
SDST	KNW	385.1	388.81	3.71	GRSZE	SAM
CONG	KNW	388.81	388.97	0.16		
SLMDST	KNW	388.97	389.15	0.18		
SLST	KNW	389.15	389.24	0.09		
SLMDST	KNW	389.24	389.3	0.06		
SDST	KNW	389.3	389.99	0.69	GRSZE	SAF
SLMDST	KNW	389.99	390.29	0.3		
SDST	KNW	390.29	391.38	1.09		
SLMDST	KNW	391.38	391.58	0.2		
SDST	KNW	391.58	394.03	2.45	GRSZE	SAF
SDST	KNW	391.58	394.03	2.45	GRSZE	SAM
LMSTN	KNW	394.03	394.42	0.39		

SDST	KNW	394.42	396.43	2.01	GRSZE	SAF
SDST	KNW	394.42	396.43	2.01	GRSZE	SAM
SLMDST	KNW	396.43	396.46	0.03		
SDST	KNW	396.46	400.38	3.92	GRSZE	SAM
SDST	KNW	396.46	400.38	3.92	GRSZE	SAF
SDST	KNW	400.38	402.75	2.37	GRSZE	SAF
LMSTN	KNW	402.75	402.98	0.23		
SDST	KNW	402.98	404.48	1.5	GRSZE	SAF
SDST	KNW	402.98	404.48	1.5	GRSZE	SAM
SDST	KNW	404.48	404.59	0.11	GRSZE	SAF
SDST	KNW	404.59	404.9	0.31	GRSZE	SAC
SDST	KNW	404.59	404.9	0.31	GRSZE	SAM
SDST	KNW	404.9	406.99	2.09	GRSZE	SAM
SDST	KNW	404.9	406.99	2.09	GRSZE	SAF
SLST	KNW	406.99	407.25	0.26		
SDST	KNW	407.25	407.51	0.26	GRSZE	SAF
SDST	KNW	407.25	407.51	0.26	GRSZE	SAM
SLST	KNW	407.51	407.55	0.04		
SDST	KNW	407.55	408.58	1.03	GRSZE	SAF
SDST	KNW	407.55	408.58	1.03	GRSZE	SAM
SLST	KNW	408.58	408.63	0.05		
SDST	KNW	408.63	410.03	1.4	GRSZE	SAF
SLMDST	KNW	410.03	410.38	0.35		
SDST	KNW	410.38	410.62	0.24	GRSZE	SAF
SDST	KNW	410.62	411.26	0.64	GRSZE	SAF
SDST	KNW	410.62	411.26	0.64	GRSZE	SAM
SDST	KNW	411.26	411.58	0.32	GRSZE	SAF
SDST	KNW	411.58	413.55	1.97	GRSZE	SAM
SLST	KNW	413.55	413.61	0.06		
SDST	KNW	413.61	414.62	1.01	GRSZE	SAM
SDST	KNW	414.62	415.33	0.71	GRSZE	SAF
SDST	KNW	415.33	416.74	1.41	GRSZE	SAM
SDST	KNW	415.33	416.74	1.41	GRSZE	SAC
SDST	KNW	416.74	420.61	3.87	GRSZE	SAF
SDST	KNW	416.74	420.61	3.87	GRSZE	SAM
SLST	KNW	420.61	420.62	0.01		
LMSTN	KNW	420.62	420.83	0.21		
SLST	KNW	420.83	420.9	0.07		
SDST	KNW	420.9	421.38	0.48	GRSZE	SAM
LMSTN	KNW	421.38	421.44	0.06		
SDST	KNW	421.44	421.6	0.16	GRSZE	SAF
SDST	KNW	421.6	421.74	0.14	GRSZE	SAM
SDST	KNW	421.74	422	0.26	GRSZE	SAF
SDST	KNW	422	424.27	2.27	GRSZE	SAM
SDST	KNW	422	424.27	2.27	GRSZE	SAC
SDST	KNW	424.27	425.83	1.56	GRSZE	SAM
SDST	KNW	425.83	425.94	0.11	GRSZE	SAFV
SDST	KNW	425.94	428.05	2.11	GRSZE	SAM
LMSTN	KNW	428.05	428.24	0.19		
SDST	KNW	428.24	429.18	0.94	GRSZE	SAC
SDST	KNW	428.24	429.18	0.94	GRSZE	SAM
SDST	KNW	429.18	429.3	0.12	GRSZE	SAFV
SDST	KNW	429.3	430.66	1.36	GRSZE	SAM
SDST	KNW	430.66	430.88	0.22	GRSZE	SAF

SDST	KNW	430.88	434.51	3.63	GRSZE	SAF
SDST	KNW	430.88	434.51	3.63	GRSZE	SAM
SDST	KNW	434.51	434.6	0.09	GRSZE	SAF
SDST	KNW	434.6	434.88	0.28	GRSZE	SAC
SDST	KNW	434.6	434.88	0.28	GRSZE	SAM
SDST	KNW	434.88	435.05	0.17	GRSZE	SAF
SDST	KNW	435.05	436.86	1.81	GRSZE	SAM
SLST	KNW	436.86	437.1	0.24		
SDST	KNW	437.1	437.49	0.39	GRSZE	SAF
SDST	KNW	437.49	437.72	0.23	GRSZE	SAM
SDST	KNW	437.72	438.78	1.06	GRSZE	SAM
SDST	KNW	437.72	438.78	1.06	GRSZE	SAF
SLST	KNW	438.78	439	0.22		
SDST	KNW	439	441.88	2.88	GRSZE	SAM
SDST	KNW	439	441.88	2.88	GRSZE	SAF
LMSTN	KNW	441.88	442.39	0.51		
SLMDST	KNW	442.39	443.63	1.24		
SDST	KNW	443.63	445.49	1.86	GRSZE	SAF
SDST	KNW	443.63	445.49	1.86	GRSZE	SAM
LMSTN	KNW	445.49	445.59	0.1		
SDST	KNW	445.59	446.05	0.46	GRSZE	SAF
SDST	KNW	445.59	446.05	0.46	GRSZE	SAM
SLMDST	KNW	446.05	446.12	0.07		
DOLO	KNW	446.12	446.21	0.09		
SLMDST	KNW	446.21	446.56	0.35		
DOLO	KNW	446.56	446.61	0.05		
SLMDST	KNW	446.61	446.8	0.19		
SDST	KNW	446.8	446.98	0.18		
SDST	KNW	446.98	448.74	1.76	GRSZE	SAM
SDST	KNW	446.98	448.74	1.76	GRSZE	SAF
SDST	KNW	448.74	449.32	0.58	GRSZE	SAM
SDST	KNW	449.32	450.4	1.08		
SLST	KPF	450.4	450.46	0.06		
SDST	KPF	450.46	451.54	1.08	GRSZE	SAM
SDST	KPF	451.54	451.77	0.23	GRSZE	SAF
SDST	KPF	451.54	451.77	0.23	GRSZE	SAC
SDST	KPF	451.77	453.27	1.5	GRSZE	SAF
SDST	KPF	451.77	453.27	1.5	GRSZE	SAM
SDST	KPF	453.27	453.69	0.42	GRSZE	SAC
SDST	KPF	453.27	453.69	0.42	GRSZE	SAM
SDST	KPF	453.69	454.74	1.05	GRSZE	SAF
SDST	KPF	453.69	454.74	1.05	GRSZE	SAM
SLST	KPF	454.74	454.95	0.21		
SDST	KPF	454.95	457.52	2.57	GRSZE	SAF
SDST	KPF	454.95	457.52	2.57	GRSZE	SAM
SDST	KPF	457.52	458.66	1.14	GRSZE	SAF
SDST	KPF	458.66	459.26	0.6	GRSZE	SAF
SDST	KPF	458.66	459.26	0.6	GRSZE	SAM
SLST	KPF	459.26	459.33	0.07		
SDST	KPF	459.33	459.4	0.07	GRSZE	SAF
SLMDST	KPF	459.4	459.54	0.14		
SDST	KPF	459.54	460.59	1.05	GRSZE	SAF
SDST	KPF	460.59	461.99	1.4	GRSZE	SAF
SDST	KPF	460.59	461.99	1.4	GRSZE	SAM

SDST	KPF	461.99	462.23	0.24	GRSZE	SAC
SDST	KPF	461.99	462.23	0.24	GRSZE	SAM
SDST	KPF	462.23	462.55	0.32		
SDST	KPF	462.55	464.21	1.66	GRSZE	SAM
SDST	KPF	462.55	464.21	1.66	GRSZE	SAF
SLST	KPF	464.21	464.25	0.04		
SDST	KPF	464.25	464.54	0.29	GRSZE	SAF
LMSTN	KPF	464.54	464.62	0.08		
SDST	KPF	464.62	465.25	0.63	GRSZE	SAF
SDST	KPF	464.62	465.25	0.63	GRSZE	SAM
LMSTN	KPF	465.25	465.35	0.1		
SDST	KPF	465.35	466.16	0.81	GRSZE	SAM
SDST	KPF	465.35	466.16	0.81	GRSZE	SAF
LMSTN	KPF	466.16	466.35	0.19		
SDST	KPF	466.35	466.85	0.5	GRSZE	SAF
SLST	KPF	466.85	466.92	0.07		
SDST	KPF	466.92	468.94	2.02	GRSZE	SAM
SDST	KPF	468.94	473.49	4.55	GRSZE	SAM
SDST	KPF	468.94	473.49	4.55	GRSZE	SAF
SLST	KPF	473.49	473.51	0.02		
SDST	KPF	473.51	476.6	3.09	GRSZE	SAM
SDST	KPF	473.51	476.6	3.09	GRSZE	SAF
SDST	KPF	476.6	478.74	2.14	GRSZE	SAF
SDST	KPF	478.74	478.81	0.07		
SDST	KPF	478.81	479.43	0.62	GRSZE	SAF
SDST	KPF	478.81	479.43	0.62	GRSZE	SAM
SDST	KPF	479.43	483.1	3.67	GRSZE	SAF
SDST	KPF	483.1	486.26	3.16	GRSZE	SAF
SDST	KPF	483.1	486.26	3.16	GRSZE	SAM
SDST	KPF	486.26	491.72	5.46	GRSZE	SAM
SDST	KPF	486.26	491.72	5.46	GRSZE	SAF
SDST	KPF	491.72	491.85	0.13	GRSZE	SAM
SDST	KPF	491.85	492.65	0.8	GRSZE	SAF
SDST	KPF	491.85	492.65	0.8	GRSZE	SAM
SDST	KPF	492.65	492.72	0.07	GRSZE	SAF
SDST	KPF	492.72	494.13	1.41	GRSZE	SAF
SDST	KPF	492.72	494.13	1.41	GRSZE	SAM
SDST	KPF	494.13	494.25	0.12	GRSZE	SAF
SDST	KPF	494.25	494.45	0.2	GRSZE	SAF
SDST	KPF	494.25	494.45	0.2	GRSZE	SAM
SDST	KPF	494.45	494.7	0.25	GRSZE	SAF
SDST	KPF	494.7	495.36	0.66	GRSZE	SAM
SDST	KPF	494.7	495.36	0.66	GRSZE	SAF
SDST	KPF	495.36	495.53	0.17	GRSZE	SAF
SDST	KPF	495.36	495.53	0.17	GRSZE	SAFV
SDST	KPF	495.53	498.23	2.7	GRSZE	SAF
SDST	KPF	495.53	498.23	2.7	GRSZE	SAM
SDST	KPF	498.23	498.42	0.19	GRSZE	SAFV
SDST	KPF	498.42	498.52	0.1	GRSZE	SAM
SDST	KPF	498.42	498.52	0.1	GRSZE	SAF
SDST	KPF	498.52	498.8	0.28	GRSZE	SAFV
SDST	KPF	498.8	505.33	6.53	GRSZE	SAF
SDST	KPF	498.8	505.33	6.53	GRSZE	SAM
SDST	KPF	505.33	508.47	3.14	GRSZE	SAF

SDST	KPF	505.33	508.47	3.14	GRSZE	SAM
SDST	KPF	508.47	511.49	3.02	GRSZE	SAF
SDST	KPF	508.47	511.49	3.02	GRSZE	SAM
SDST	KPF	511.49	512.36	0.87	GRSZE	SAF
SDST	KPF	511.49	512.36	0.87	GRSZE	SAM
SDST	KPF	512.36	515.48	3.12	GRSZE	SAF
SDST	KPF	512.36	515.48	3.12	GRSZE	SAM
SDST	KPF	515.48	519.01	3.53	GRSZE	SAF
SDST	KPF	515.48	519.01	3.53	GRSZE	SAM
SDST	KPF	519.01	519.06	0.05	GRSZE	SAF
SDST	KPF	519.06	524.71	5.65	GRSZE	SAF
SDST	KPF	519.06	524.71	5.65	GRSZE	SAM
SDST	KPF	524.71	526.64	1.93	GRSZE	SAC
SDST	KPF	524.71	526.64	1.93	GRSZE	SAF
SDST	KPF	524.71	526.64	1.93	GRSZE	SAM
SDST	KPF	526.64	529.86	3.22	GRSZE	SAF
SDST	KPF	526.64	529.86	3.22	GRSZE	SAM
SDST	KPF	529.86	530.15	0.29	GRSZE	SAF
SDST	KPF	530.15	530.6	0.45	GRSZE	SAF
SDST	KPF	530.15	530.6	0.45	GRSZE	SAM
SDST	KPF	530.6	530.69	0.09	GRSZE	SAF
SDST	KPF	530.69	532	1.31	GRSZE	SAF
SDST	KPF	530.69	532	1.31	GRSZE	SAM
SDST	KPF	532	532.48	0.48	GRSZE	SAF
SDST	KPF	532.48	532.56	0.08	GRSZE	SAFV
SDST	KPF	532.56	536.09	3.53	GRSZE	SAF
SDST	KPF	532.56	536.09	3.53	GRSZE	SAM
SDST	KPF	536.09	536.95	0.86	GRSZE	SAF
SDST	KPF	536.09	536.95	0.86	GRSZE	SAM
SDST	KPF	536.95	537.79	0.84	GRSZE	SAF
SDST	KPF	537.79	538.33	0.54	GRSZE	SAF
SDST	KPF	538.33	538.58	0.25	GRSZE	SAF
SDST	KPF	538.33	538.58	0.25	GRSZE	SAM
SDST	KPF	538.58	538.94	0.36	GRSZE	SAM
SDST	KPF	538.94	538.98	0.04	GRSZE	SAFV
SDST	KPF	538.98	541.96	2.98	GRSZE	SAF
SDST	KPF	538.98	541.96	2.98	GRSZE	SAM
SDST	KPF	541.96	546.23	4.27	GRSZE	SAF
SDST	KPF	546.23	549.93	3.7	GRSZE	SAF
SDST	KPF	546.23	549.93	3.7	GRSZE	SAM
SDST	KPF	549.93	550.11	0.18	GRSZE	SAFV
SDST	KPF	550.11	551.71	1.6	GRSZE	SAF
SDST	KPF	550.11	551.71	1.6	GRSZE	SAM
SDST	KPF	551.71	551.77	0.06	GRSZE	SAF
SDST	KPF	551.77	552.38	0.61	GRSZE	SAF
SDST	KPF	551.77	552.38	0.61	GRSZE	SAM
SDST	KPF	552.38	555.37	2.99	GRSZE	SAF
SDST	KPF	552.38	555.37	2.99	GRSZE	SAM
SDST	KPF	555.37	555.81	0.44	GRSZE	SAFV
SDST	KPF	555.81	555.95	0.14	GRSZE	SAF
SDST	KPF	555.95	557.26	1.31	GRSZE	SAF
SDST	KPF	555.95	557.26	1.31	GRSZE	SAM
SDST	KPF	557.26	557.41	0.15	GRSZE	SAFV
SDST	KPF	557.41	557.74	0.33	GRSZE	SAF

SDST	KPF	557.41	557.74	0.33	GRSZE	SAM
SDST	KPF	557.74	557.77	0.03	GRSZE	SAF
SDST	KPF	557.77	559.37	1.6	GRSZE	SAF
SDST	KPF	557.77	559.37	1.6	GRSZE	SAM
SDST	KPF	559.37	561.08	1.71	GRSZE	SAF
SDST	KPF	561.08	562.38	1.3	GRSZE	SAF
SDST	KPF	561.08	562.38	1.3	GRSZE	SAM
SDST	KPF	562.38	562.7	0.32	GRSZE	SAF
SDST	KPF	562.7	563.05	0.35	GRSZE	SAF
SDST	KPF	562.7	563.05	0.35	GRSZE	SAM
SDST	KPF	563.05	563.28	0.23	GRSZE	SAF
SDST	KPF	563.28	563.34	0.06	GRSZE	SAF
SDST	KPF	563.28	563.34	0.06	GRSZE	SAM
SDST	KPF	563.34	563.84	0.5	GRSZE	SAF
SDST	KPF	563.84	564.77	0.93	GRSZE	SAF
SDST	KPF	563.84	564.77	0.93	GRSZE	SAM
SDST	KPF	564.77	565.65	0.88	GRSZE	SAF
SDST	KPF	564.77	565.65	0.88	GRSZE	SAM
SDST	KPF	565.65	566.2	0.55	GRSZE	SAF
SDST	KPF	566.2	567.38	1.18	GRSZE	SAF
SDST	KPF	566.2	567.38	1.18	GRSZE	SAM

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