Appendix C. Well and borehole interpretations and correlations

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Well correlation

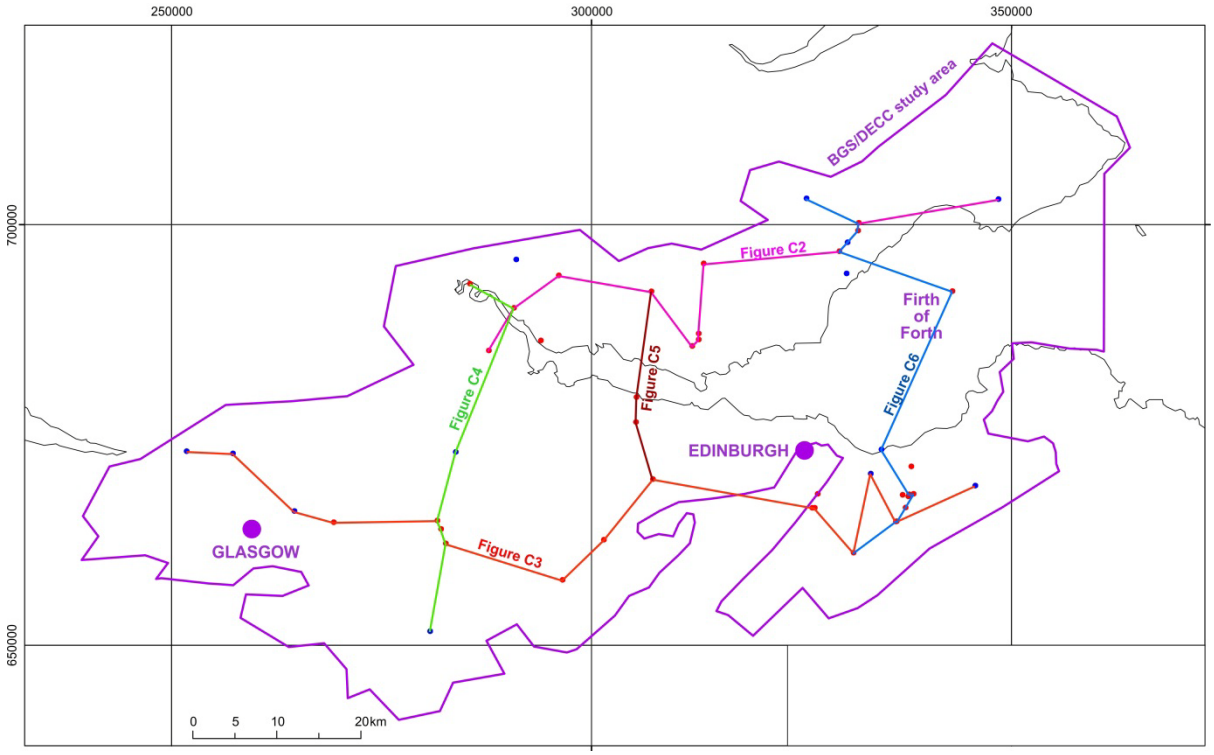

Figure C1 Location of the well/borehole correlation panels

Well correlation panels hung on the base of the Lower Limestone Formation (Hurlet Limestone) highlight the differing stratigraphic intervals drilled and the lateral variability of the Carboniferous succession (Figures C2-C6). The influence of igneous activity is striking, with numerous igneous sills and volcanic intervals encountered. Table 2 summarises the depths and thicknesses in key wells and boreholes used in this study.

The correlation of the Limestone Coal and Lower Limestone formations above the Hurlet Limestone is usually fairly straightforward, well studied and well constrained by data, though the precise assignments of named limestone and coal beds can be problematic where there is faulting and a lack of macrofaunal data. Lateral thickness variations are common, for example the Black Metals Member marine band reaches 164 ft (50 m) thick on the northern side of the Central Coalfield contrasting with less than ten feet (a few metres) thick in parts of the Midlothian Coalfield.

Correlation in the Strathclyde Group is more challenging due to laterally variable sedimentary and volcanic strata, laterally changing nomenclature, less constraining data and the possible effects of volcanism on biostratigraphically important faunas and floras.

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Some of the volcanic strata are fairly well defined spatially by map, borehole/well and geophysical (magnetic) data (e.g. parts of the Kinghorn and Bathgate Hills volcanic formations) and some ashes are observed semi-regionally (e.g. Barracks Ash). However, as a result of limited data and likely complex volcanic geometries, in most cases the lateral extent of volcanic formations in the subsurface is poorly defined.

Stratigraphic interpretations

Given the importance of stratigraphic interpretations to the modelled depth surfaces and eventual rock volumes of prospective shale resource, the interpretations on well composite logs and in well reports were examined. In some cases a revised stratigraphic interpretation to that on the composite log was made using biostratigraphy information (from the well report or in BGS records), extensive BGS knowledge of Carboniferous stratigraphy or core logging of wells at the time of drilling (e.g. South Fod 1) and BGS or published information on the character and age of igneous rocks. A summary of where BGS interpretations differ from the company composite log, or where particular interpretations are emphasised is given in Table 1.

In addition the well correlations utilise the most recent rather than historical terminology (see Appendix B for equivalence).

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Well	Revised stratigraphic interpretation
Salsburgh 1A	As in BGS Falkirk Memoir (Cameron *et al*. 1998), but with the interpretation of Devonian microgranodiorite intrusion at base of well after Phillips & Browne (2000).
Leven Seat 1	Nearly 1,970 ft (600 m) thick, fine-grained basalt (hawaiite to trachybasalt) and tuffs containing interbedded TC zone sedimentary strata interpreted as Salsburgh Volcanic Formation and Gullane Formation equivalents. Presence of the top part of the Calders Member shows volcanism ended before that in Salsburgh 1A and 2. ?Pu zone strata beneath volcanic rocks correlated with the Inverclyde Group (Clyde Sandstone/ Ballagan Formation).
West Calder 1	The large proportion of ash in the mudstones at same stratigraphic level as the Salsburgh Volcanic Formation in Leven Seat 1 (7 km to SW) are interpreted as basinward equivalent of active extrusive volcanism.
Rashiehill (BGS borehole)	The interpretation of the volcanic rocks follows Anderson & Francis (1963) and Cameron *et al*. (1998), i.e. rocks of the Clyde Plateau Volcanic Formation at the base of the borehole are overlain by younger rocks of the Bathgate Hills Volcanic Formation.
Inch of Ferryton 1	Interpretation taken from an unpublished BGS petrology report to include Pathhead Formation between 5,663 - 5,898 ft and to correlate the Strathclyde Group (5,898 - 6,360 ft) with the Sandy Craig Formation. Strata from 6,800 to 7,800 ft dominated by Devonian volcanic rocks.
South Fod 1	Beneath the Burdiehouse Limestone – part of the Calders Member, faulted to TC zone Gullane Formation at 2,860 ft. Below this the strata are similar to that in the Rosyth-Dalgety Bay area, including the Charles Hill Volcanic Member at 4,600 ft. An undifferentiated Strathclyde Group is interpreted between the Charles Hill Volcanic Member and the tuff/basalt of Carboniferous character at the base of the well.
Rosyth 1	The top of the Gullane Formation is interpreted at 2,490 ft based on BGS palaeontology records and regional stratigraphic correlations.
Lathalmond 1	Re-interpretation of the well beneath 374 ft to West Lothian Oil-Shale strata, with numerous intrusive sills, plus volcanic strata correlative of the Kinghorn Volcanic Formation. Due to the thick igneous succession, the lack of available biostratigraphy, and thickness of Visean successions to the south-east, the base of the well is interpreted to remain in the Strathclyde Group (not reaching the Inverclyde Group as indicated on the company composite log).
Milton of Balgonie 1	The basal part of the well has been re-interpreted with changes in base Pathhead, Sandy Craig and Pittenweem formations, and the inclusion of Anstruther Formation compared to the composite log. This was based on advice and a graphic log drawn by M. Browne who was present at the time of drilling, and incorporating all the palynology and biostratigraphy.
Firth of Forth 1	The Pittenweem Formation is believed to extend from 4,877 ft to the TD of the well (i.e. the Anstruther Formation is not reached).
Blackness 1 and Easter Pardovan 1	The top of the Gullane Formation has been re-interpreted in both wells. Towards the base of both wells are volcanic rocks which could correlate with the Charles Hill Volcanic Member as seen in the South Fod well and on the Fife coast.
Carrington 1 & Stewart 1	The position of the top Gullane Formation has been estimated by correlation with Midlothian 1 (the latter being biostratigraphically constrained, Neves *et al*. 1973).

Table 1 Summary of stratigraphic interpretations in wells used in this study, where revised from those on well composite logs or where a particular interpretation is emphasised.

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Summary table of well and borehole stratigraphical interpretations

Well or borehole registration number	Name	Easting (British National Grid)	Northing (British National Grid)	Start height or KB elevation (m)	Base Upper Lmst Fm (ft)	Base Upper Lmst Fm (m)	Base Lmst Coal Fm (ft)	Base Lmst Coal Fm (m)	Thickness Lmst Coal Fm (m)	Base Lower Lmst Fm (ft)	Base Lower Lmst Fm (m)	Thickness Lower Lmst Fm (m)	Base West Lothian Oil-Shale unit(ft)	Base West Lothian Oil-Shale unit (m)	Thickness West Lothian Oil-Shale unit (m)	Base Gullane unit (ft)	Base Gullane unit (m)	Thickness Gullane unit (m)
LF/26- 1	AIRTH 6	287789	685063	31.7	2930	893	3485+	1063+	170+	np	np	np	np	np	np	np	np	np
LG/05- 1	BARGEDDIE 1	269318	664649	81.8	2182FT	665FT	2252	687	21.5FT	2559	780	94	3430+	1045.5+	np	np	np	np
LH/03- 2	BLACKNESS 1	305380	679530	25.9	np	np	np	np	np	np	np	np	1457	444	np	2454+	748+	304+
LH/05- 25	CARRINGTON 1	331220	661030	156.4	2048	624	2612	796	172	2940FT	896FT	100FT	4555	1388	492	5561+	1695+	307+
LH/01- 2	CRAIGHEAD 1	282670	662120	248.7	865	264	1549	472	208	1957	596	124	2969+	905+	309+	np	np	np
LH/03- 3	EASTER PARDOVAN 1	305310	676570	78	np	np	np	np	np	np	np	np	1043	318	np	3182+	970+	652+
L25/26- 1	FIRTH OF FORTH 1	342978	692116	32.6	np	np	656	200	np	1146	349	149	4877	1487	1137	6801+	2073+	586+
LF/27- 1	INCH OF FERRYTON 1	290777	690150	9.8	2624	800	4885	1489	689	5663	1726	237	5898FT	1798FT	72FT	6360	1939	141
LF/28- 8	LATHALMOND 1	307160	692080	184.1	np	np	np	np	np	374	114	np	3073	937	823	np	np	np
LH/07- 1	LEVEN SEAT 1	296577	657795	340.1	np	np	4885	164	np	1079	329	165	2398	731	402	np	np	np
LF/27- 10	MEADOWHILL 1	296125	694000	66.02	1879	573	3280+	978+	406+	np	np	np	np	np	np	np	np	np
LH/05- 2	MIDLOTHIAN 1	336250	664730	235	np	np	np	np	np	144	44	np	1722	525	481	3668+	1118+	593+
LF/25- 5	MILTON OF BALGONIE 1	331733	699336	64.9	1740	530	2550	777	247	3885	1184	407	6290	1917	733	6594+	2010+	93+
LH/03- 4	PUMPHERSTON 1	307338	669793	127.6	np	np	np	np	np	np	np	np	213	65	np	2970	905	840
LF/28- 1	ROSYTH 1	312010	685610	69.1	np	np	np	np	np	np	np	np	2490	759	np	2707+	825+	66+
LH/01- 1A	SALSBURGH 1A	281660	664869	223.4	1055	322	1726	526	205	2075	632	106	3650	1113	480	np	np	np
LH/01- 3	SALSBURGH 2	282110	663850	228.3	1017	310	1575	480	170	1919	585	105	3525	1074	490	np	np	np
LF/28- 3	SOUTH FOD 1	312790	687080	102	np	np	np	np	np	250	76	np	2860FT	872FT	796FT	4740+?	1445+	573+
LH/05- 15	STEWART 1	336330	664760	235.6	np	np	np	np	np	157	48	np	1624	495	447	3097+	944+	449+
LF/26- 3	BANDEATH 1	285539	693013	9.1	1175	358	2062+	628+	270+	np	np	np	np	np	np	np	np	np
LF/28- 6	CALAIS 3	312764	686386	90.8	np	np	np	np	np	200	61	np	600+	183+	122+	np	np	np
L33/01- 1	COUSLAND 1	337809	667982	170	np	np	np	np	np	198	60	np	1127	344	283	2917+	889+	545+
L33/01- 8	COUSLAND 6	338352	668017	169.65	np	np	np	np	np	54	16	np	1625	495	479	1909+	582+	87+

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LF/29- 5	KELTY BRIDGE	313384	695400	147.98	np	np	np	np	np	380	116	np	np	np	np	np	np	np
LF/27- 9	LONGANNET 1	293978	686252	7.4	2490	759	3950+	1204+	445+	np	np	np	np	np	np	np	np	np
LF/25- 6	MILTON OF BALGONIE 2	331821	700235	53.34	1729	527	2795	852	325	3976	1212	360	np	np	np	np	np	np
LH/05- 24	STRAITON 1	326592	666385	151.4	np	np	np	np	np	np	np	np	771	235	np	2864+	873+	638+
LF/30- 1	THORNTON 1	329521	696867	52.1	2059	628	2770+	844+	217+	np	np	np	np	np	np	np	np	np
LH/03- 1	WEST CALDER 1	301500	662590	191.7	np	np	np	np	np	np	np	np	1686	514	np	3901+	1189+	675+
NS99NW19 1	BLACKFAULDS BORE NO1	291055	695875	49.59	1739	530	3681+	1122+	592+	np	np	np	np	np	np	np	np	np
NT39SW44	BORELAND BORE DYSART	330394	694222	62.5	2536	773	3304+	1007+	234+	np	np	np	np	np	np	np	np	np
NT37SW31	ESKMOUTH BORE	334530	673320	4	2664	812	3369	1027	215	3422+	1043+	16+	np	np	np	np	np	np
NT39NW16	MACKIES MILL FARM BORE	330510	697940	47	2448	746	3219	981	235	4101+	1253+	272+	np	np	np	np	np	np
NS87SW22	RASHIEHILL (GS) BORE	283860	673005	152	1296	395	2329	710	315	2598	792	82	np	np	np	np	np	np
NO20SE385	GLENROTHES	325617	703144	158.85	np	np	np	np	np	538	164	na	673	205	41	np	np	np
NS57SE50	MILNGAVIE NO 5	257345	672845	33.55	739	225	1799	548	323	2344	714	166	2481+	756.2+	42+	np	np	np
NO40SE26	KILCONQUHAR MAINS NO 1	348448	703046	22.9	np	np	np	np	np	np	np	np	2726+	831+	np	np	np	np
NT46NE73	SPILMERSFORD	345694	669019	72.45	np	np	np	np	np	72	22	na	420	128	106	942	287	159
NT37SW43	MONKTON HOUSE BORE NO 37	333250	670440	34	2582	787	3261+	994+	207+	np	np	np	np	np	np	np	np	np
NS85SW355	BROWNLEE BORE	280787	651714	123	2176	663	2405+	733+	70+	np	np	np	np	np	np	np	np	np
NS57SW162	LAWMUIR 1A	251825	673095	90.83	np	np	np	np	np	39	12	na	877	267	255	np	np	np
NS66NW32 6	QUEENSLIE NO 4 BORE	264640	665975	78.2	1839	560	2406+	732+	191+	np	np	np	np	np	np	np	np	np

Table 2 Well and borehole interpretations; drilled depths to stratigraphic boundaries. np = not present or not possible to calculate a thickness, + signifies base of stratigraphic unit not reached so full unit will be thicker, FT signifies a fault recorded at that level.

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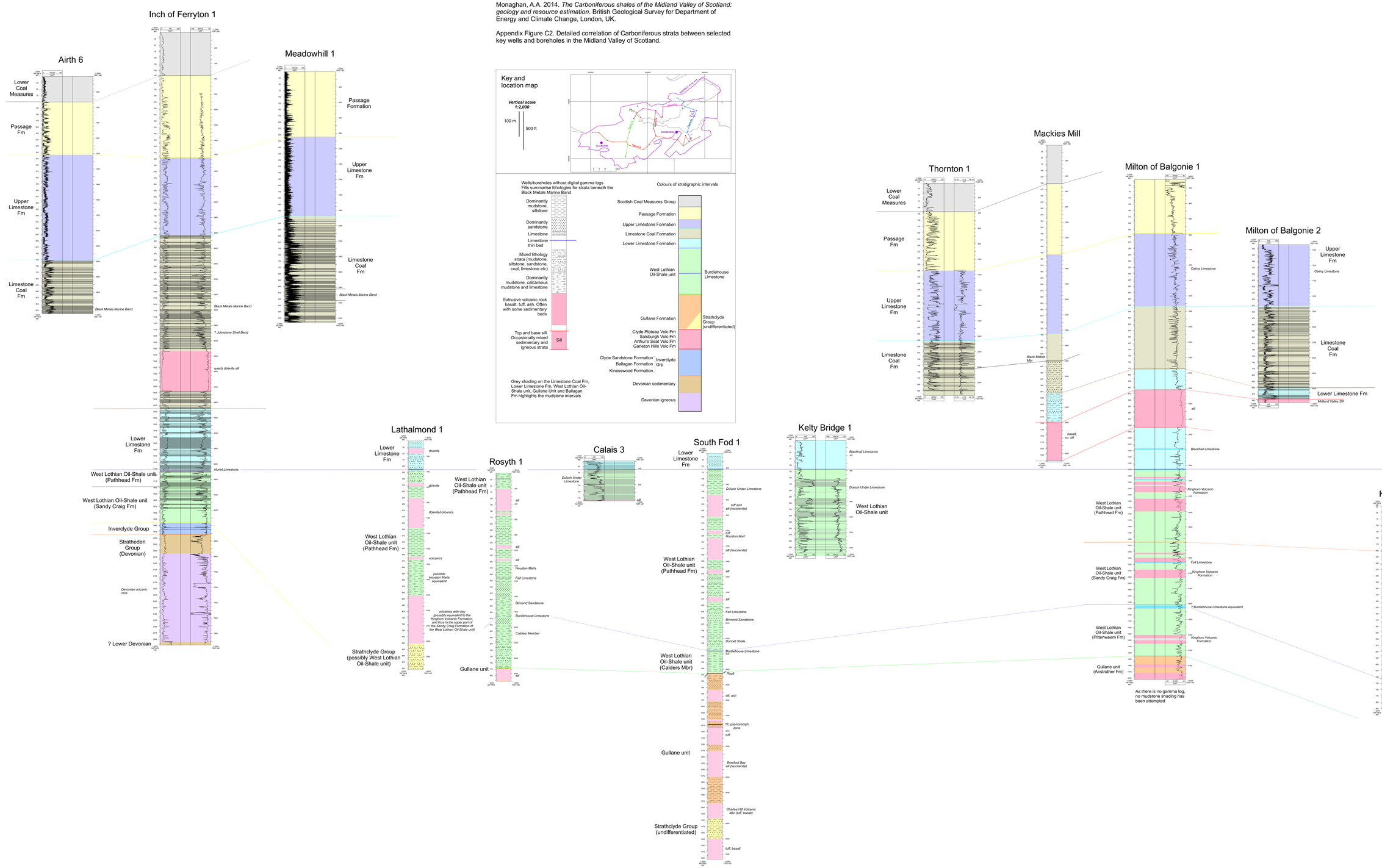
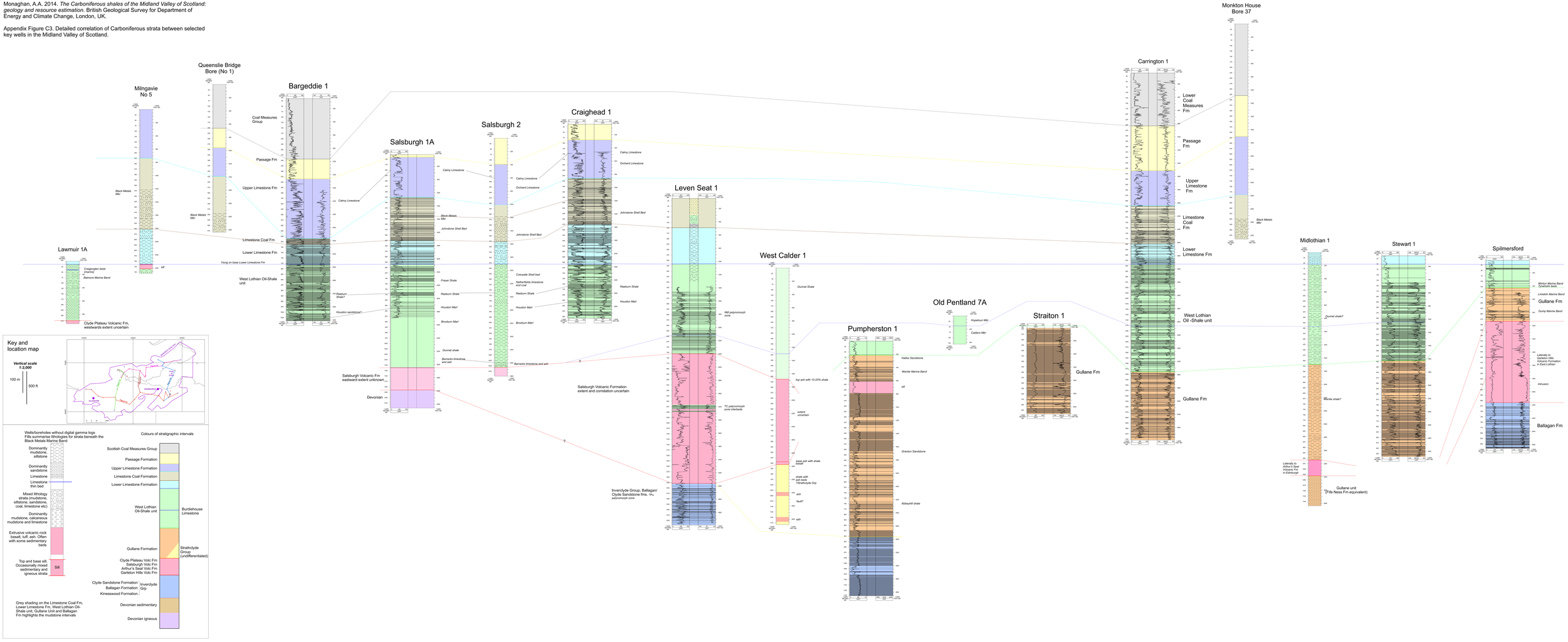
Appendix Figure C2. Detailed correlation of Carboniferous strata between selected key wells and boreholes in the Midland Valley of Scotland.



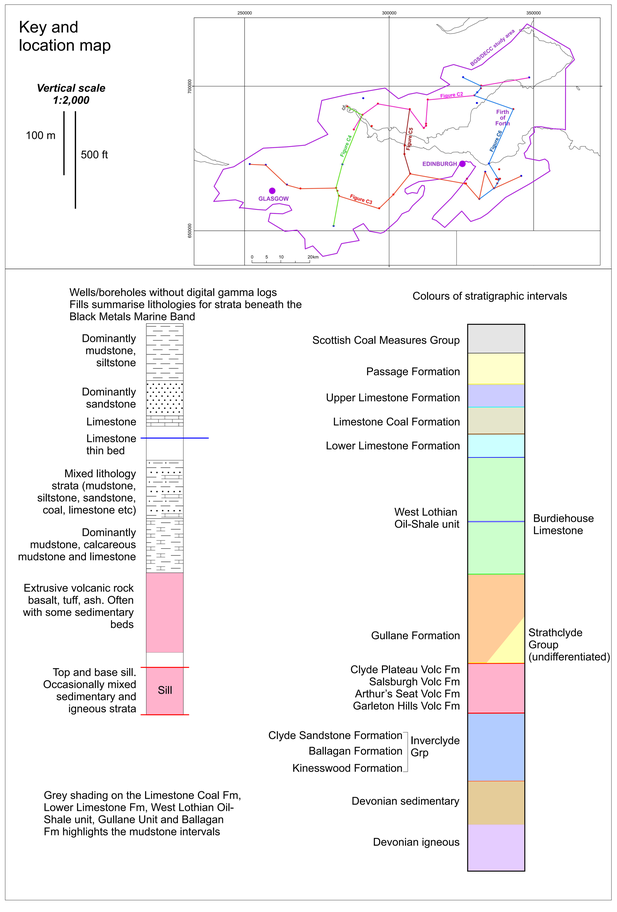
Monaghan, A.A. 2014. *The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation*. British Geological Survey for Department of Energy and Climate Change, London, UK.

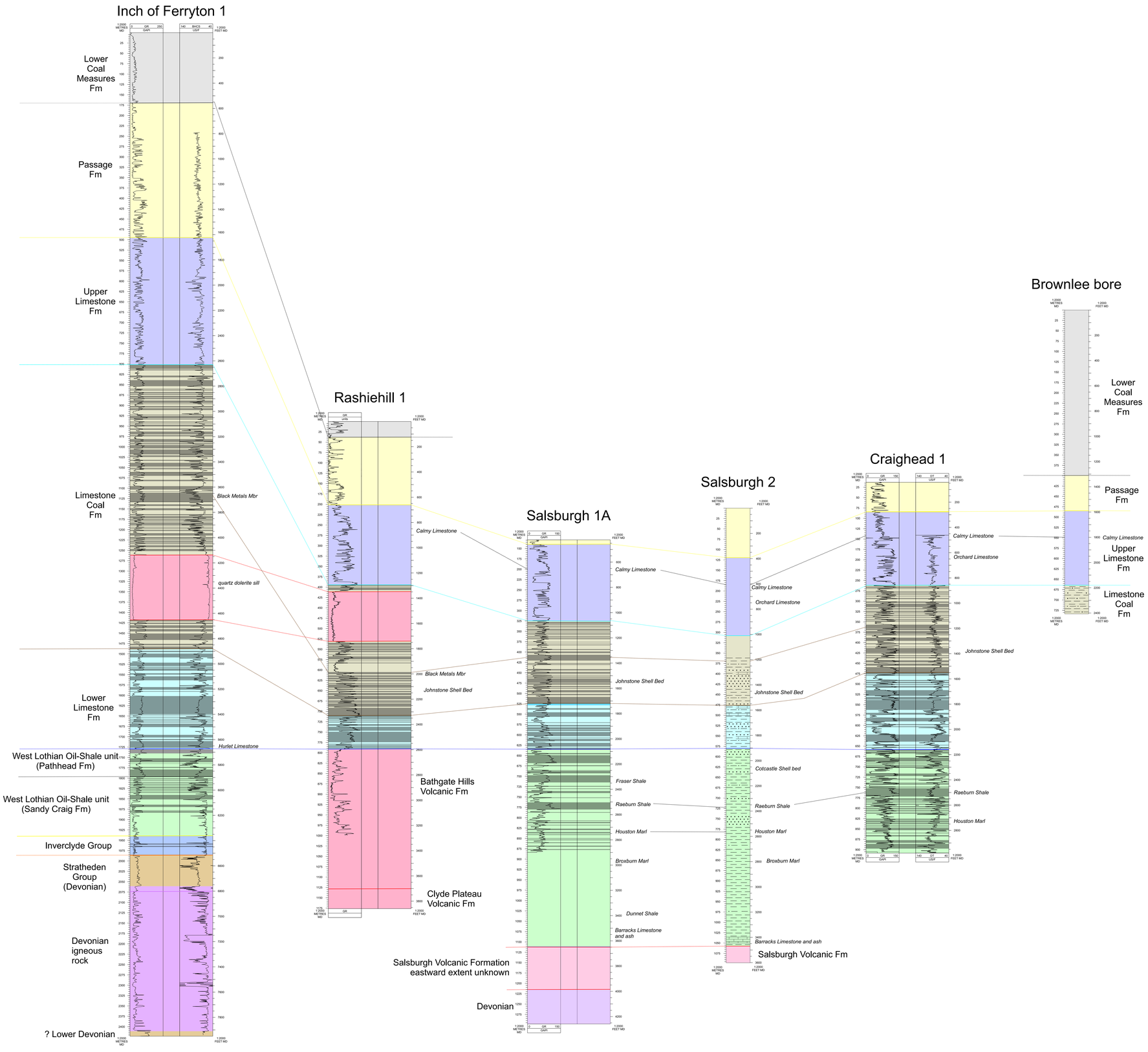
Appendix Figure C3. Detailed correlation of Carboniferous strata between selected key wells in the Midland Valley of Scotland.



Monaghan, A.A. 2014. *The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation*. British Geological Survey for Department of Energy and Climate Change, London, UK.

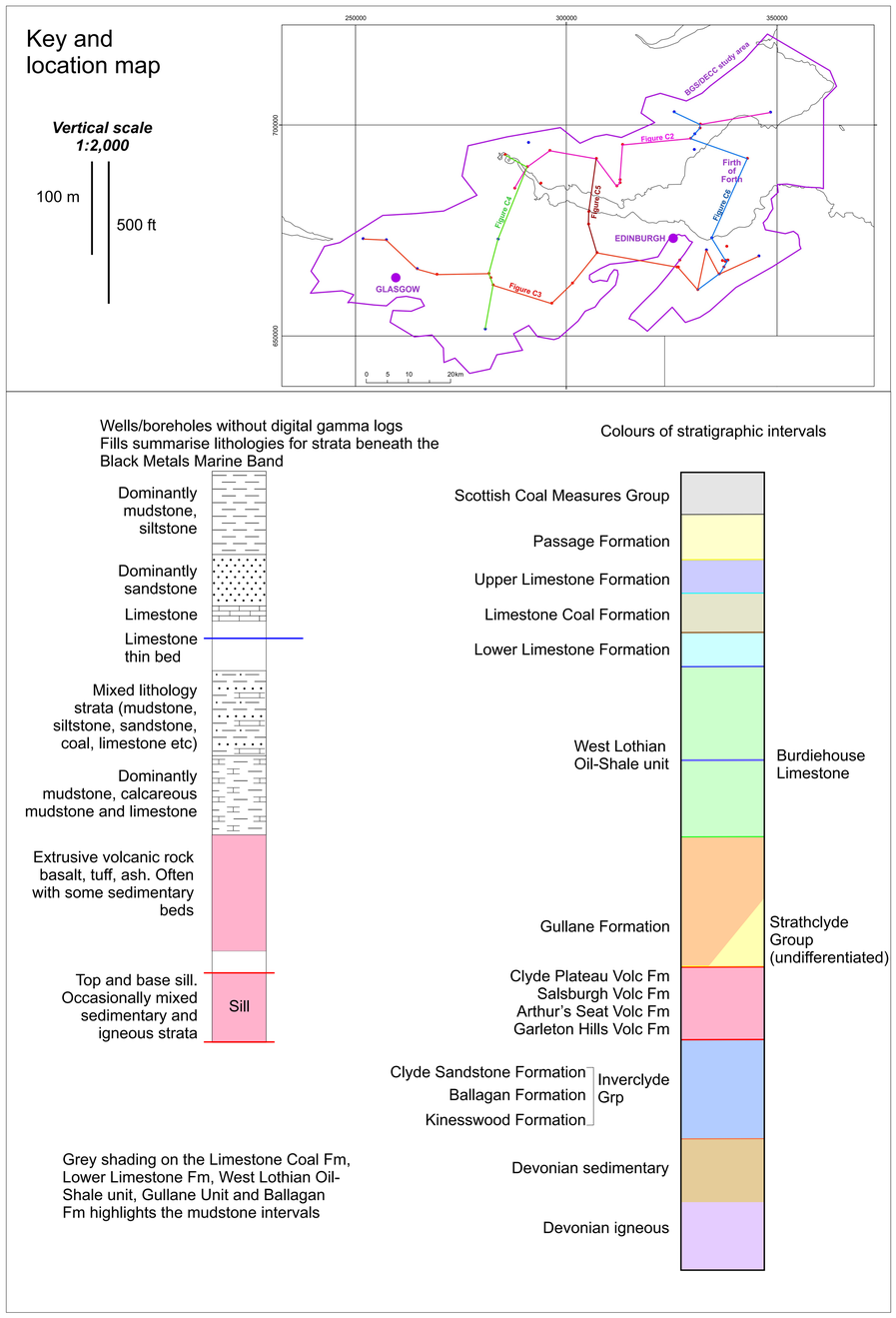
Appendix Figure C4. Detailed correlation of Carboniferous strata between selected key wells in the Midland Valley of Scotland.

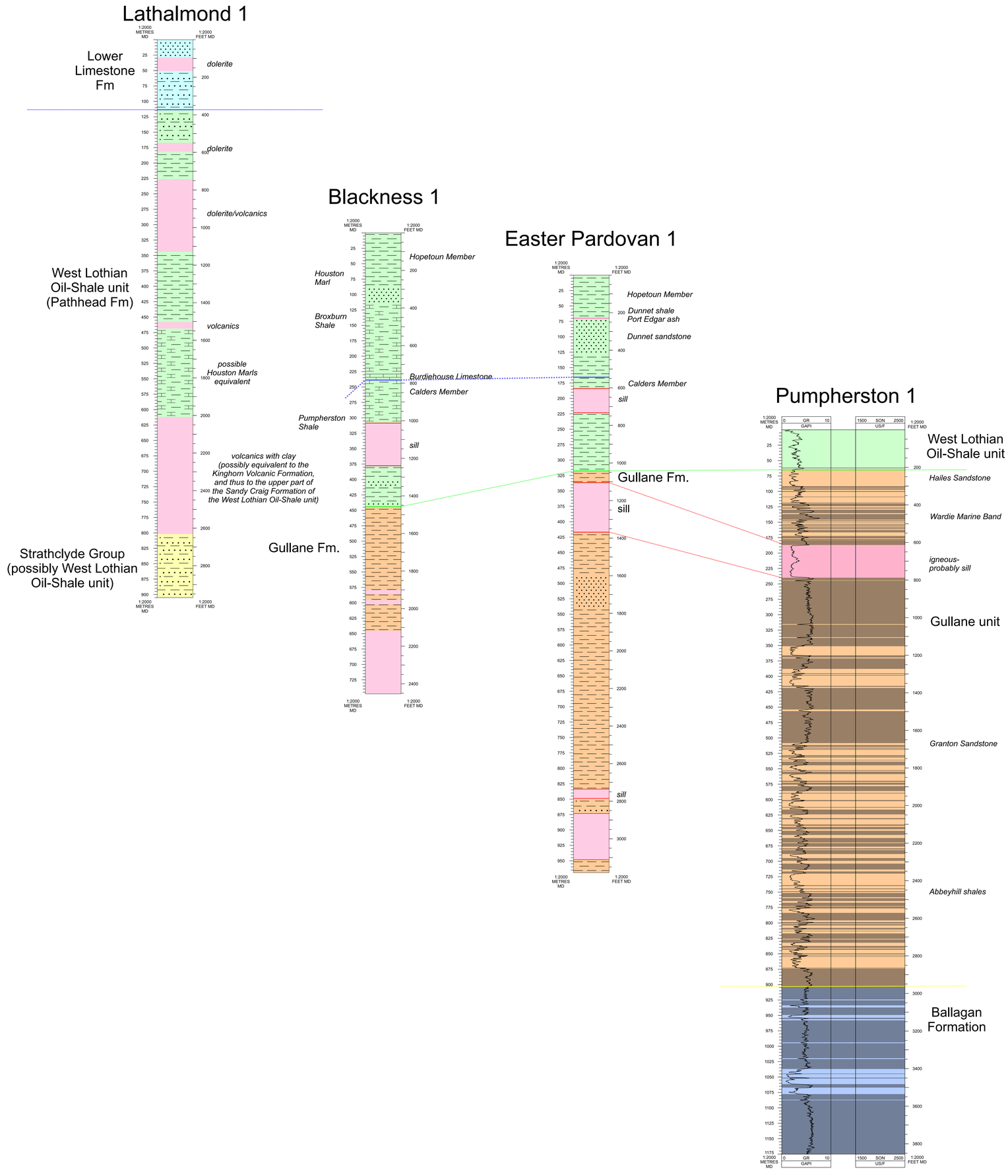




Monaghan, A.A. 2014. *The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation*. British Geological Survey for Department of Energy and Climate Change, London, UK.

Appendix Figure C5. Detailed correlation of Carboniferous strata between selected key wells in the Midland Valley of Scotland.





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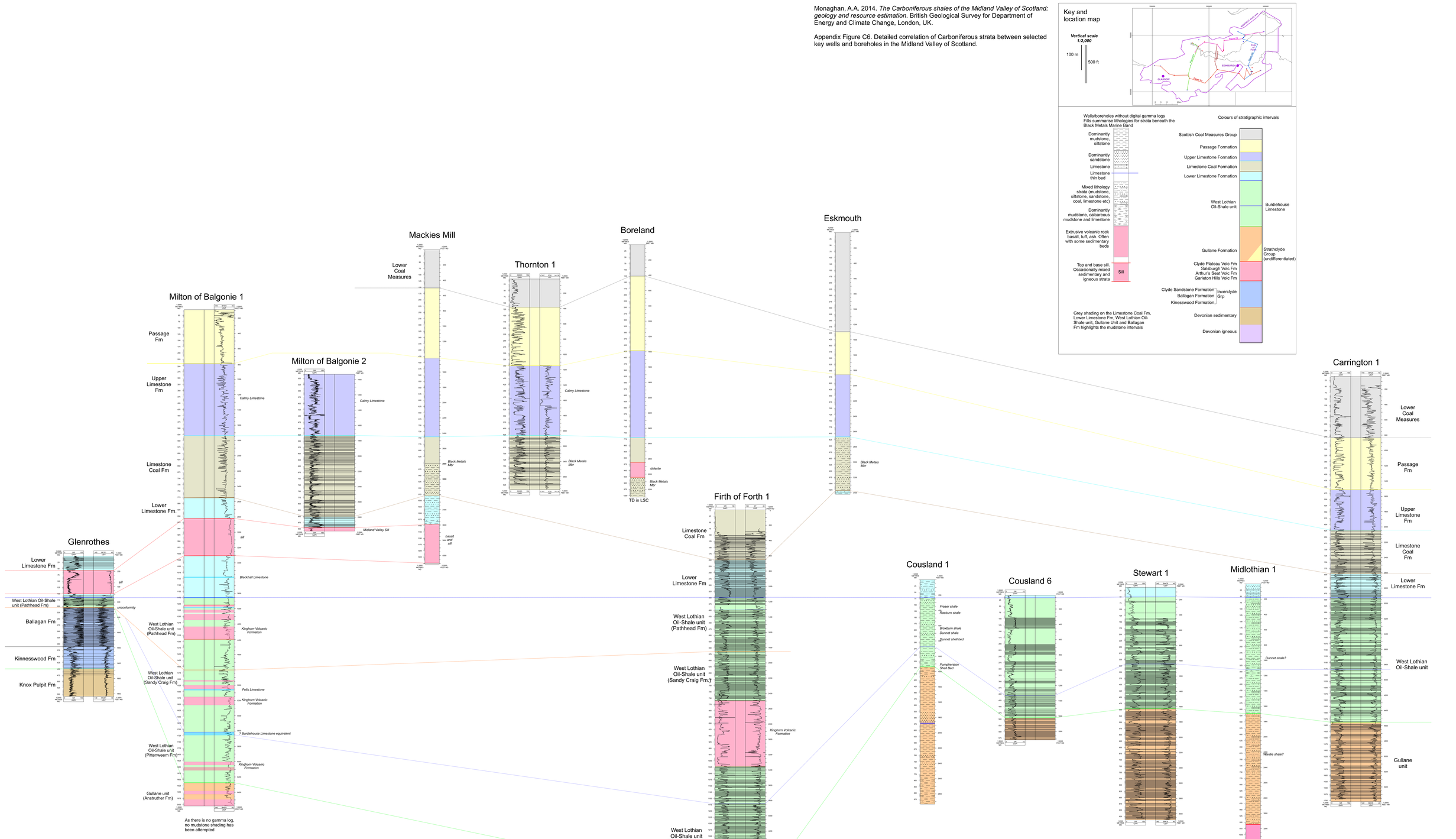
Appendix Figure C6. Detailed correlation of Carboniferous strata between selected key wells and boreholes in the Midland Valley of Scotland.