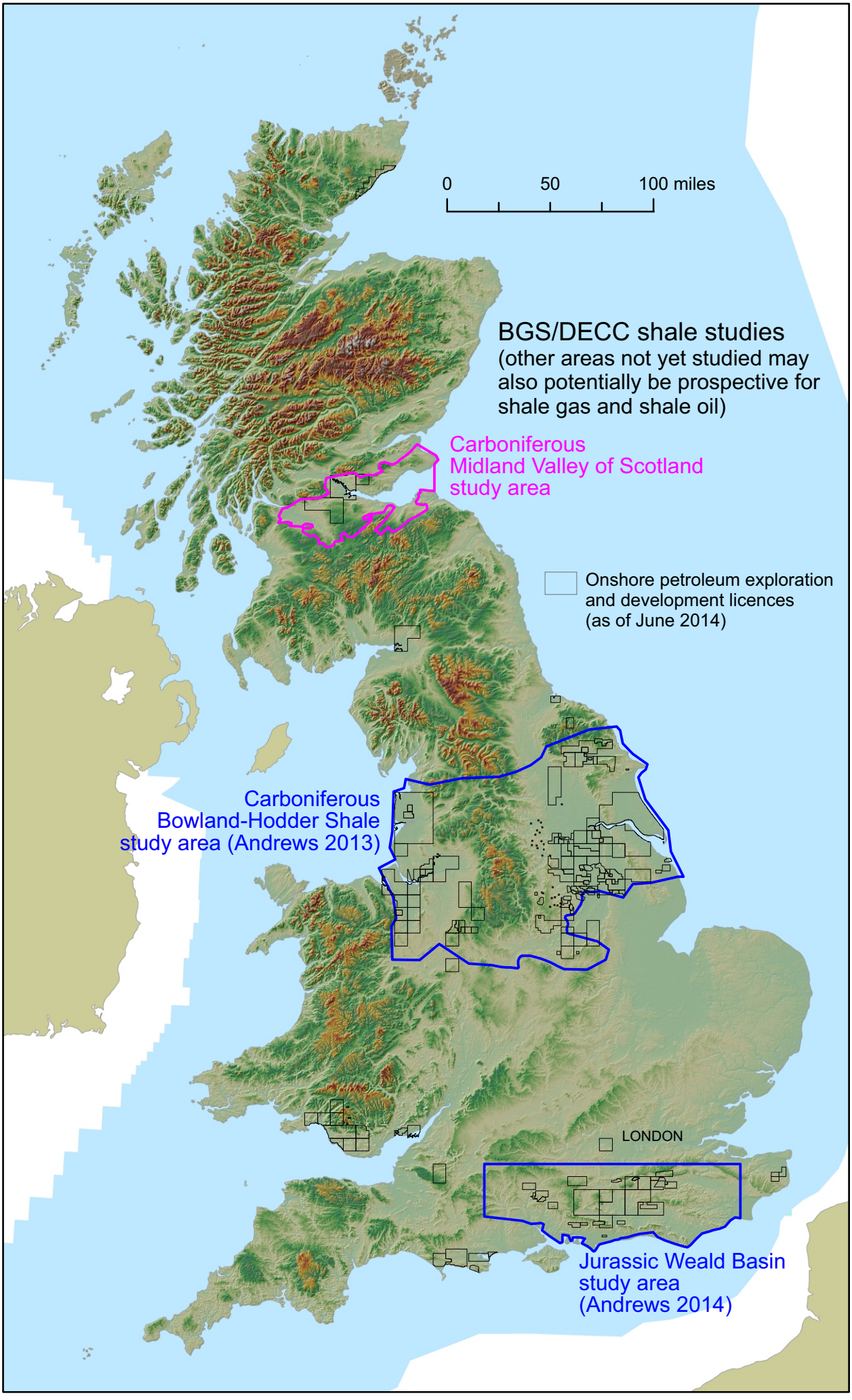

Figure 1. Location of the BGS/DECC Midland Valley of Scotland study area, together with areas assessed for their prospectivity for shale gas in northern Britain and for shale oil in southern Britain, together with currently licensed acreage.

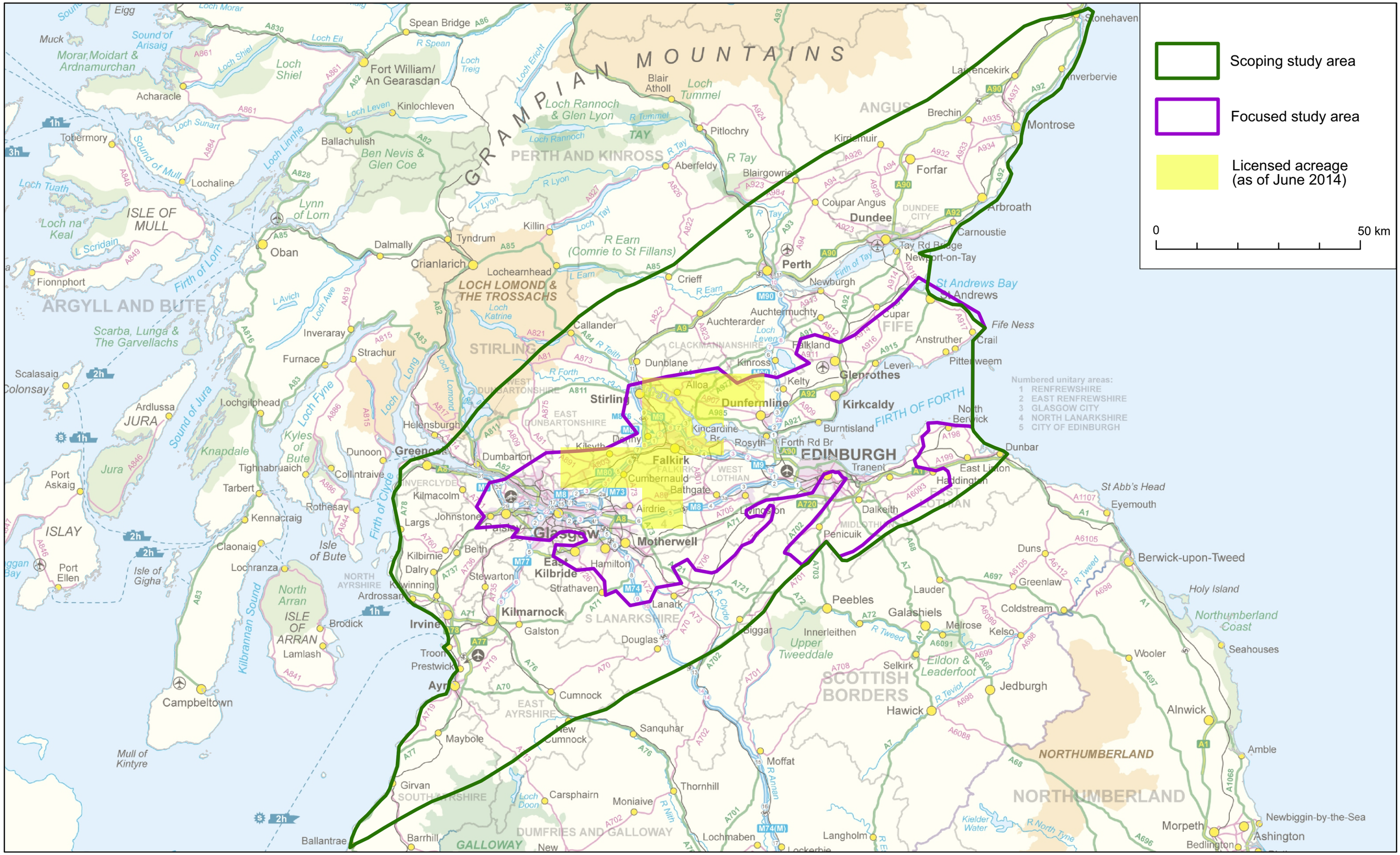

Figure 2 Extent of Midland Valley of Scotland scoping study area and Midland Valley of Scotland focused study area, shown with currently licensed acreage. Ordnance Survey data © Crown copyright 2014

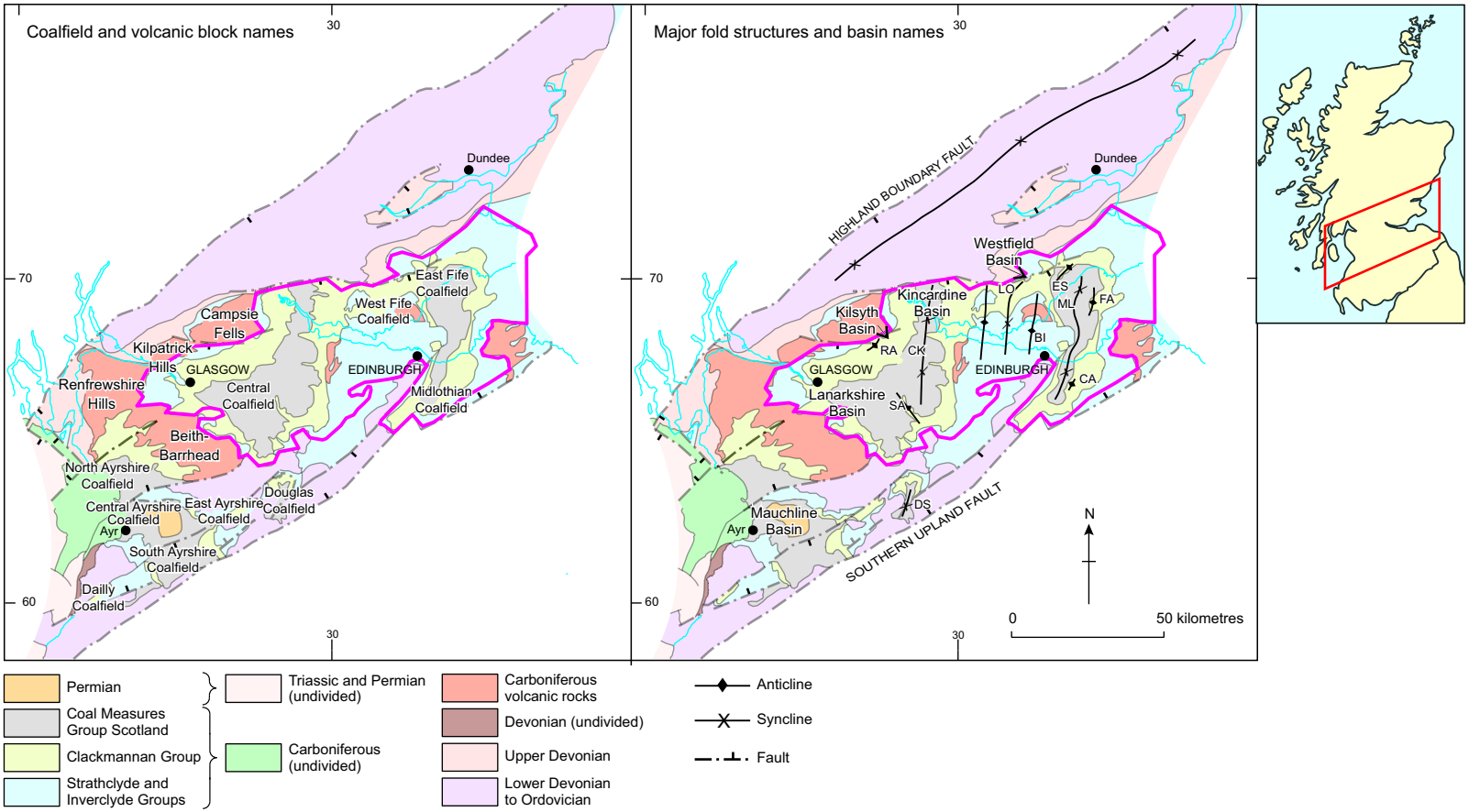

Figure 3 Outcrop geology and main structural elements of the Midland Valley of Scotland using nomenclature adapted from numerous BGS memoirs and from Read (1988).
Key: CA = D'Arcy – Cousland Anticline, ML = Midlothian – Leven Syncline, ES = Earl's Seat Anticline, BI = Burntisland Anticline, LO = Lochore Syncline,
CK = Clackmannan Syncline, RA = Riggin Anticline, SA = Salsburgh Anticline, DS = Douglas Syncline, FA = Forth Anticline.

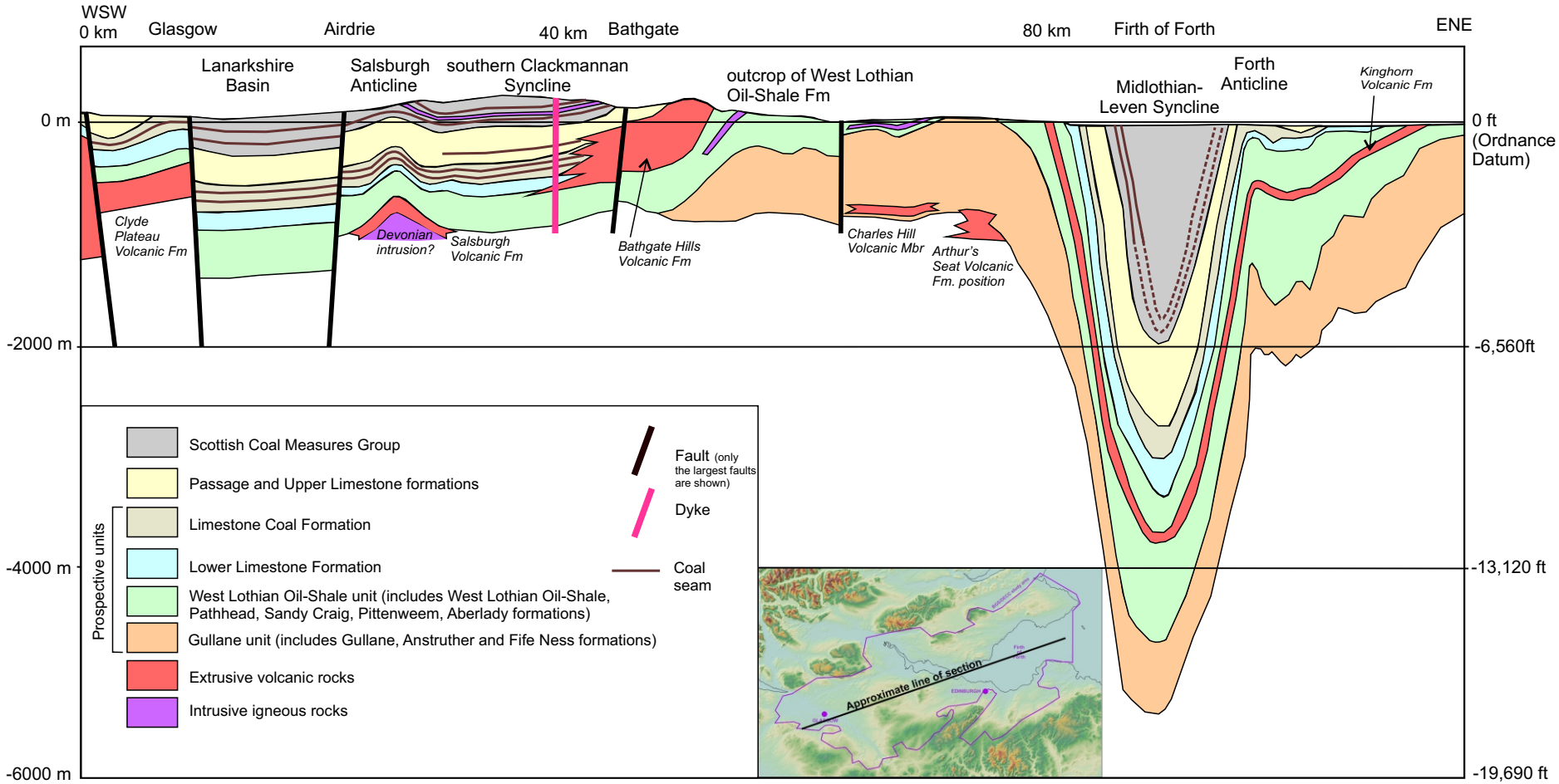

Figure 4 Schematic cross-section across the Midland Valley of Scotland to illustrate some of the main geological features. Note the significant vertical exaggeration x10.

250000
300000
350000
700000
650000
Scottish Coal Measures Group
Clackmannan Group
Strathclyde Group
Inverclyde Group
Pre-Carboniferous strata
Carboniferous extrusive volcanic rocks
Intrusive igneous rocks
BGS/DECC study area
MILTON OF BALGONIE 1
KELTY BRIDGE 1
INCH OF FERRYTON 1
LATHALMOND 1
SOUTH FOD 1
CALAIS 3
ROSYTH 1
Firth of Forth
FIRTH OF FORTH 1
BLACKNESS 1
EASTER PARDOVAN 1
EDINBURGH
PUMPHERSTON 1
COUSLAND 1
3
2
6
5
4
MIDLOTHIAN 1
STEWART 1
STRAITON 1
SALSBURGH 1A
2
BARGEDDIE 1
GLASGOW
CRAIGHEAD 1
WEST CALDER 1
CARRINGTON 1
LEVEN SEAT 1
0 5 10 20 km
No oil shows
Oil shows
Oil produced to surface
Oil produced economically

Figure 5 Map depicting historic oil shows, oil produced to surface and oil produced economically within the study area, based on commercial well reports and available references to oil shows in the literature. Geological information ©BGS/NERC.

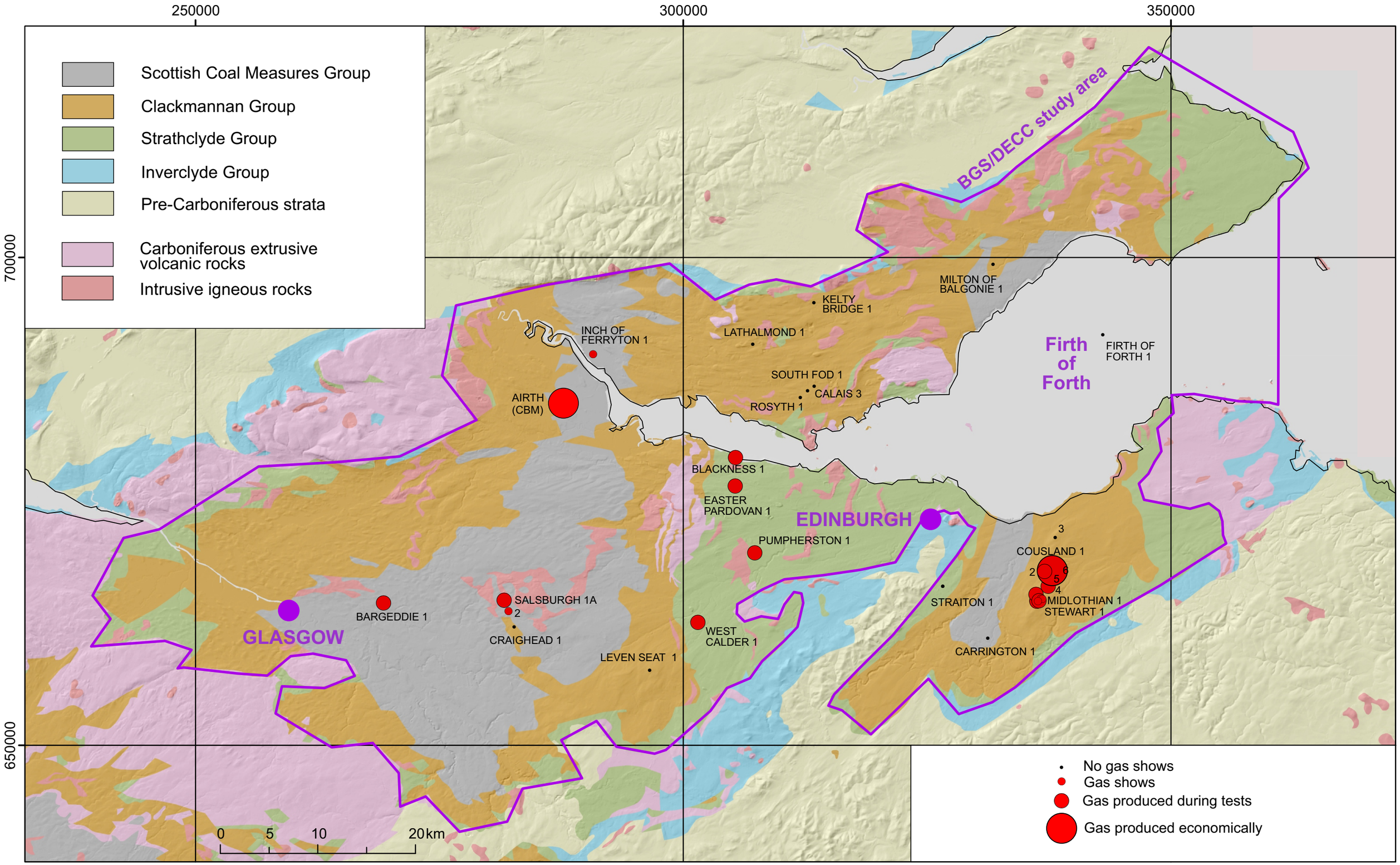

Figure 6 Map depicting historic gas shows, gas produced during tests, and gas produced economically within the study area, based on commercial well reports and available references to gas shows in the literature. Geological information ©BGS/NERC.

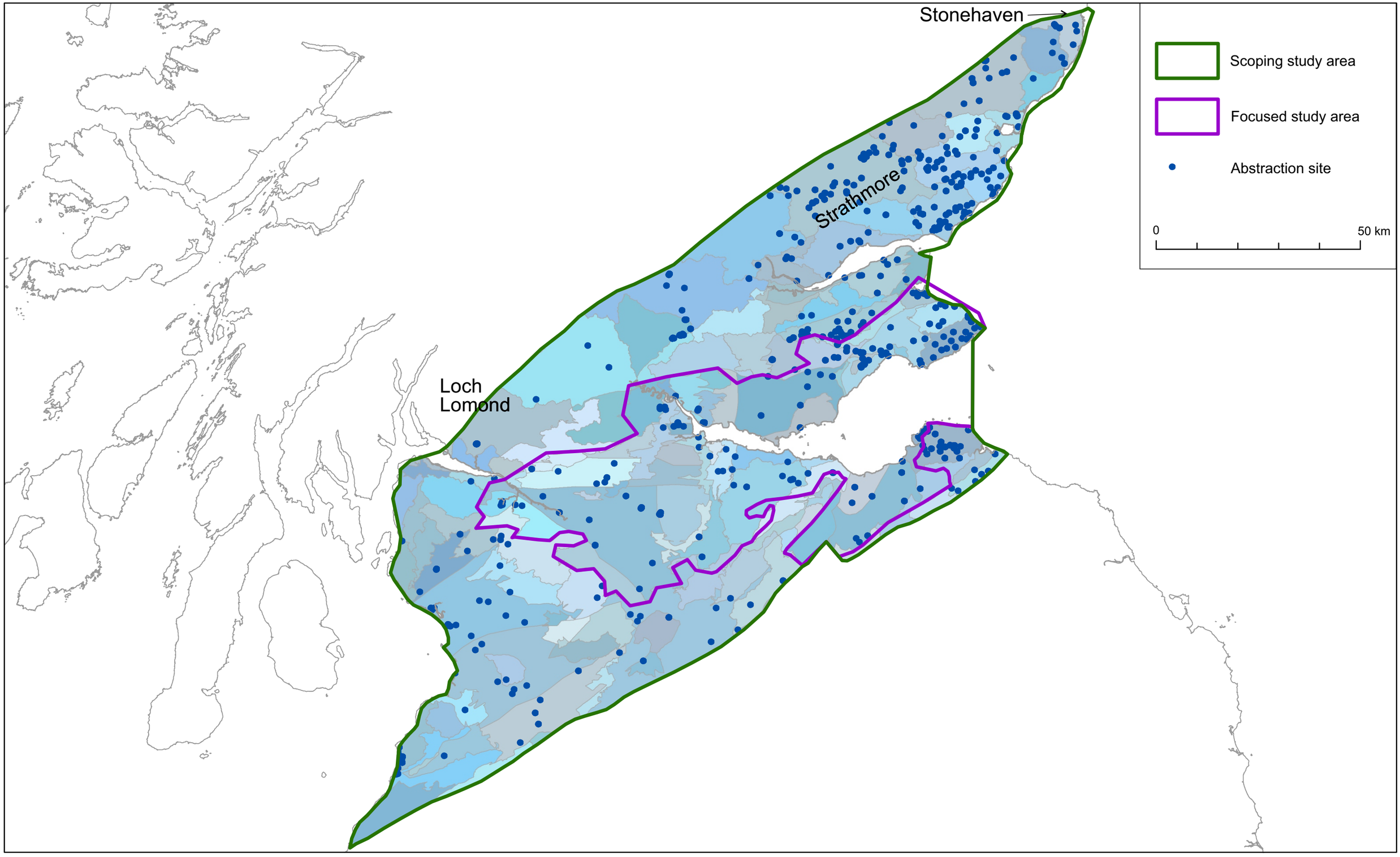

Figure 7 Groundwater bodies (bedrock only; coloured in various blue-grey shades) in the Midland Valley of Scotland from Ó Dochartaigh et al. (in press). Groundwater abstractions in the study area are shown as dots, from SEPA. Ordnance Survey data © Crown Copyright 2014

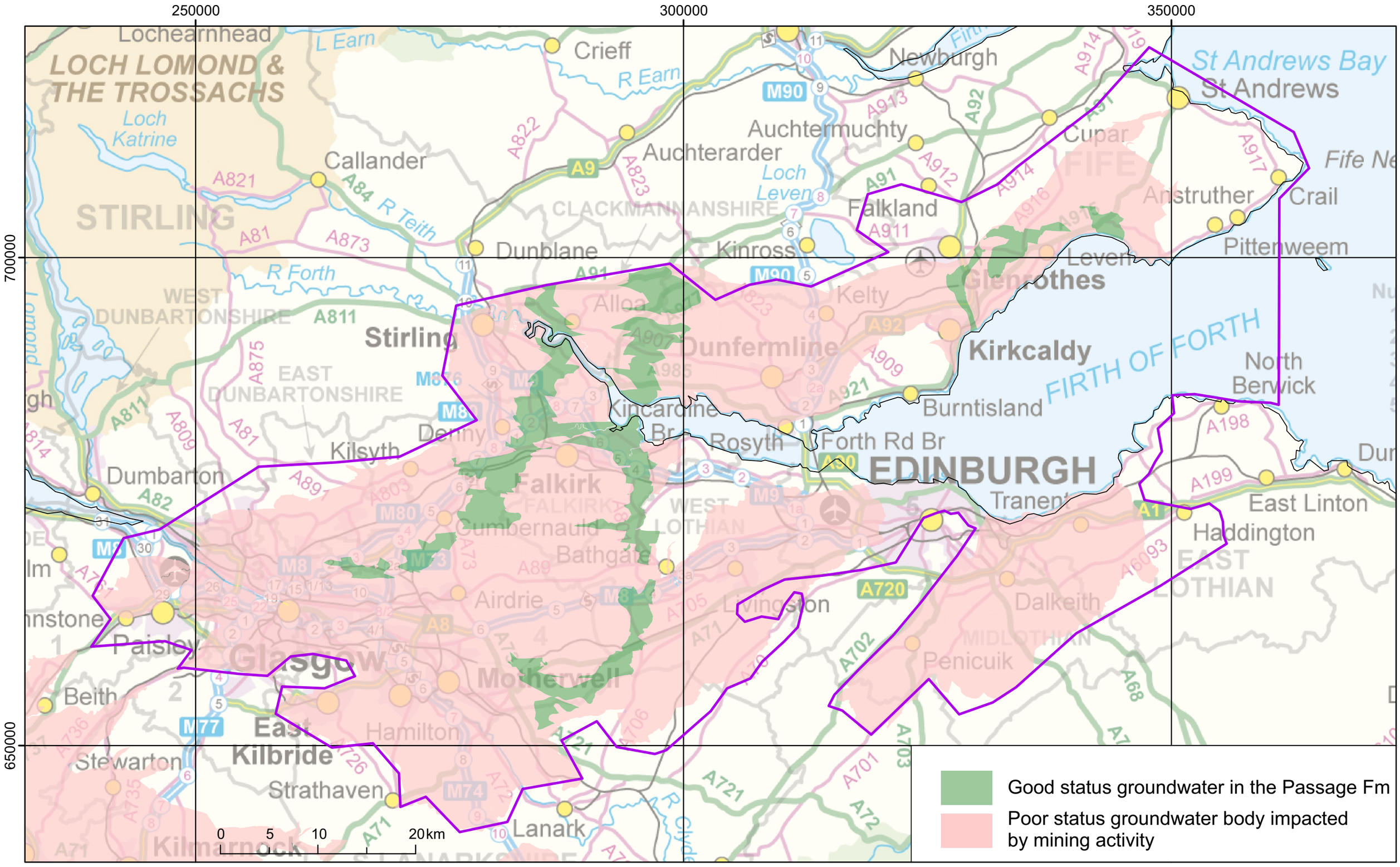

Figure 8 Poor status groundwater bodies impacted by mining activity (red)and good status Passage Formation groundwater bodies (green, from SEPA 2013 Water Framework Directive Classification) Ordnance Survey data © Crown Copyright 2014

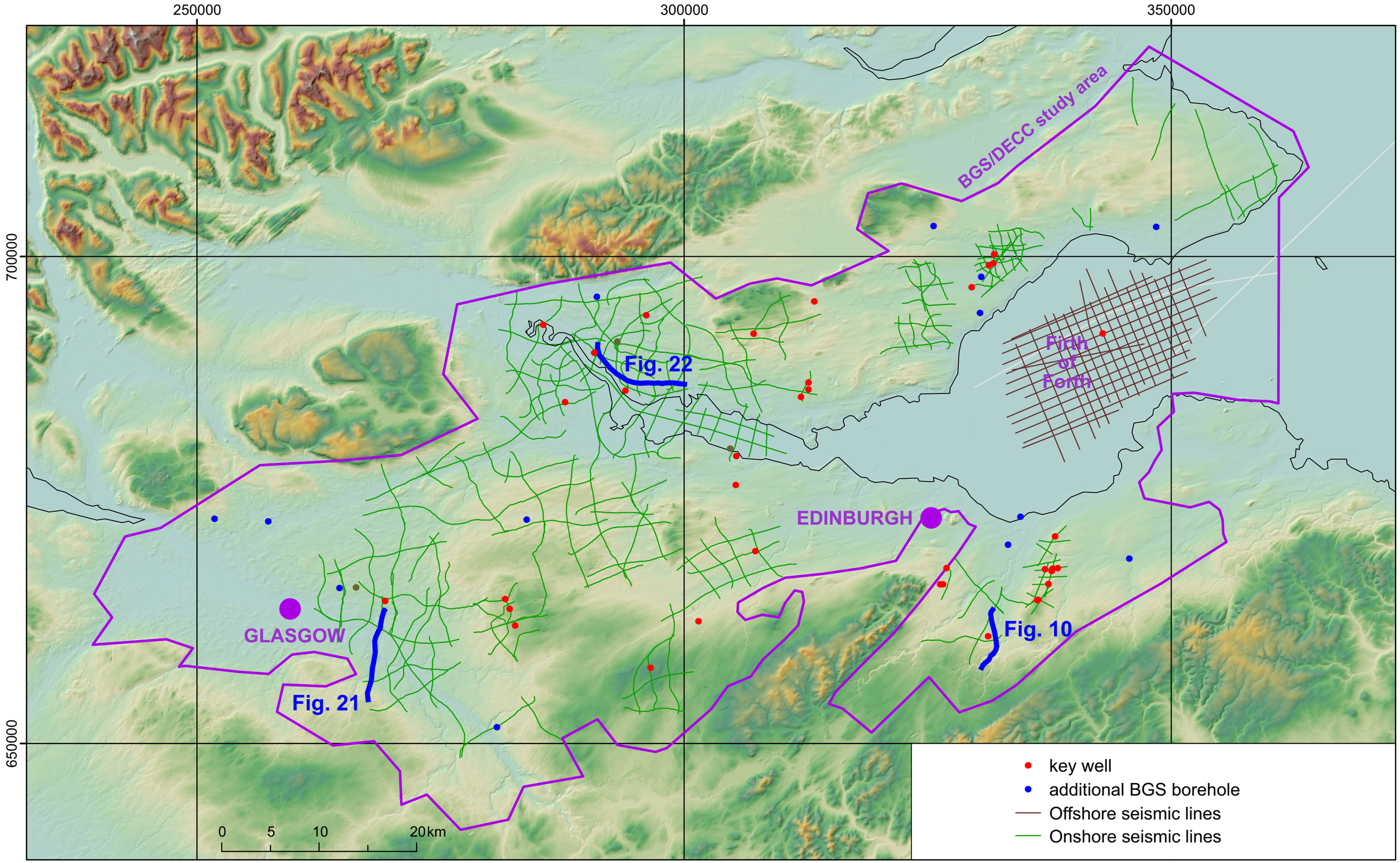

Figure 9 Location of 2D seismic profiles used to assess the shale potential of the Midland Valley of Scotland study area. The locations of the seismic examples illustrated in this report are highlighted in blue.

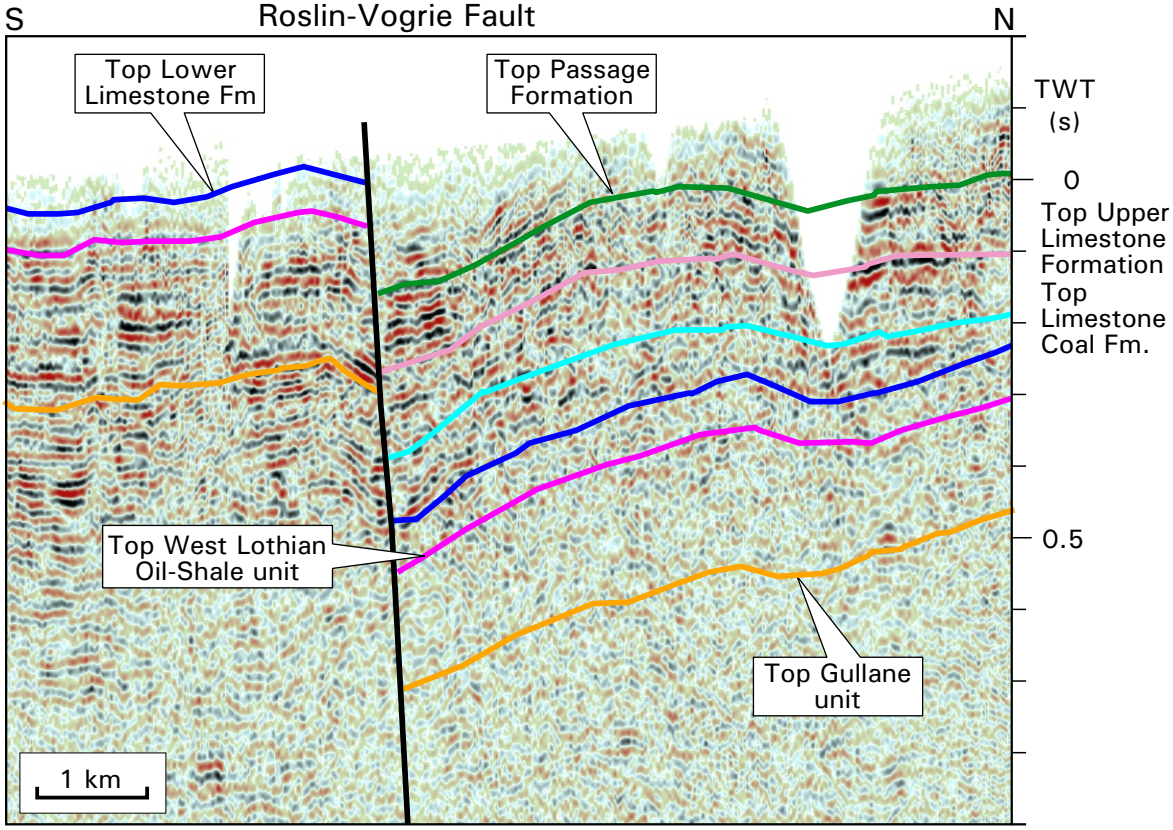

Figure 10 Seismic line LV82-04 along the Midlothian syncline and across the Roslin-Vogrie Fault, the Carrington well is some way up-dip of the line.

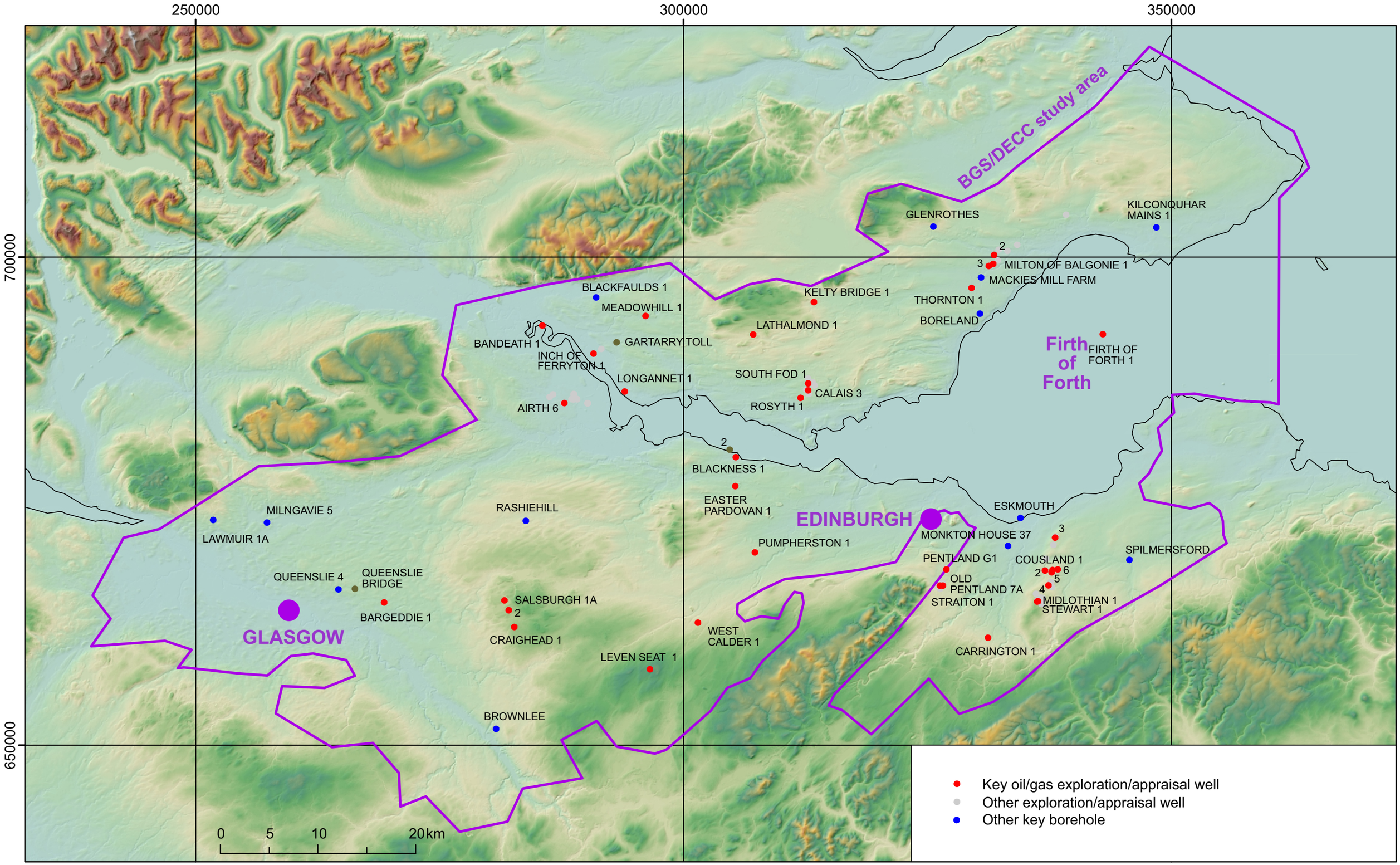

Figure 11 Distribution of the key wells and other deep boreholes used in the study.

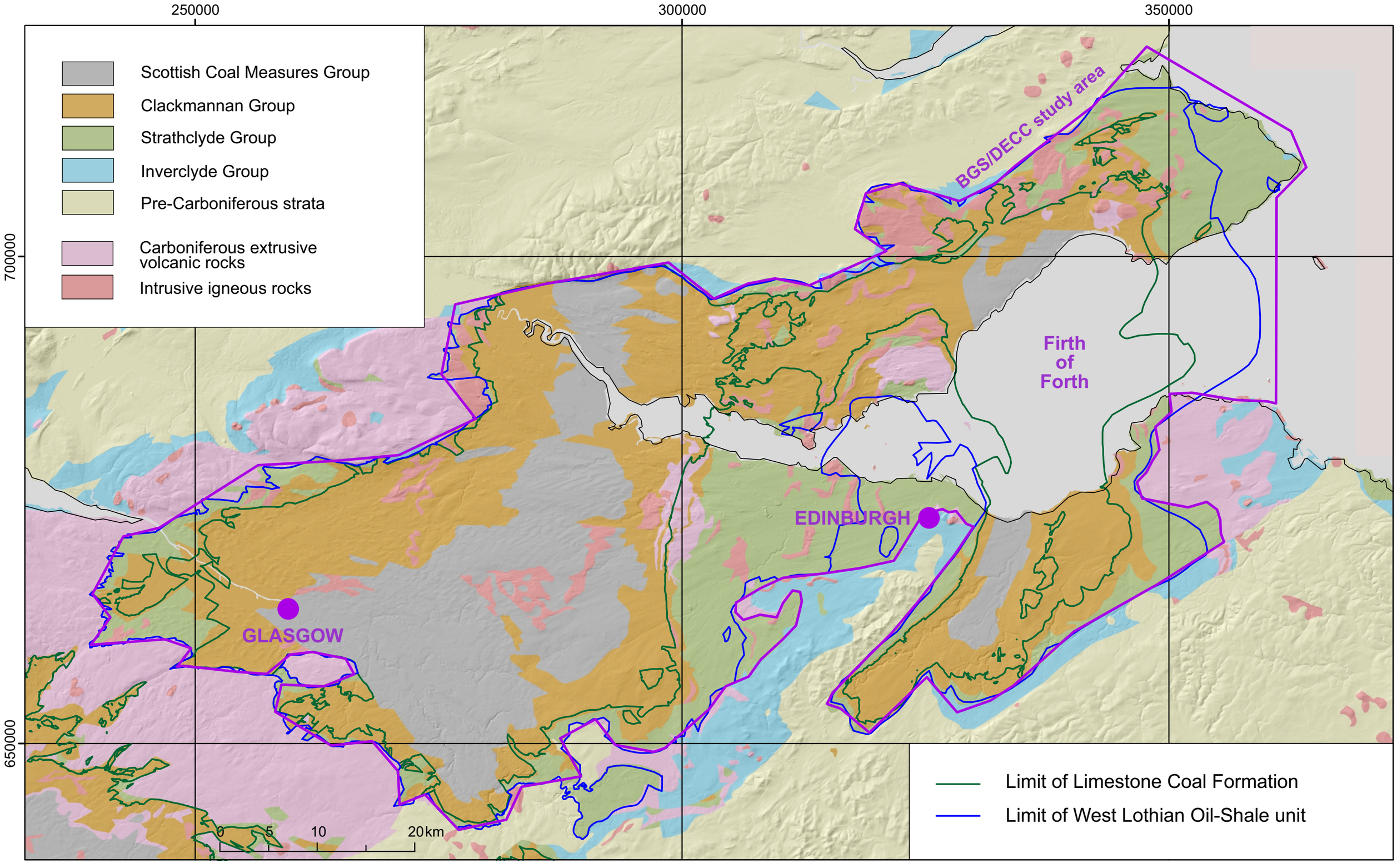

Figure 12 Geological map at 1:625 000 scale (BGS 2008) together with the extent of the Limestone Coal Formation and West Lothian Oil-Shale unit extracted from BGS DigMap 1:50,000 (BGS 2013a). Geological information ©BGS/NERC.

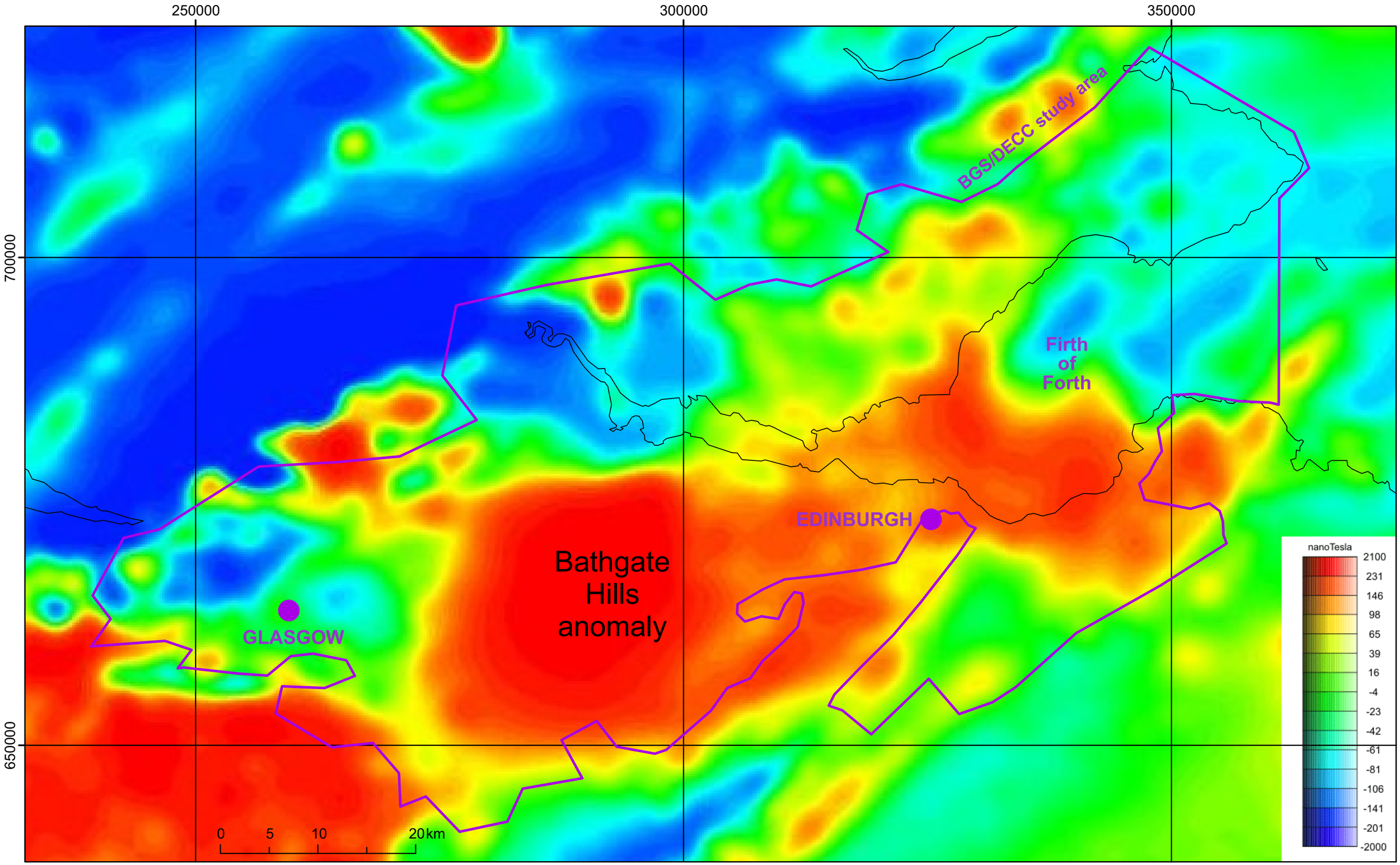

Figure 13 BGS Magnetic anomaly map for the BGS/DECC study area of the central and eastern Midland Valley. Red-yellow = high, blue = low. Geophysical information ©BGS/NERC.

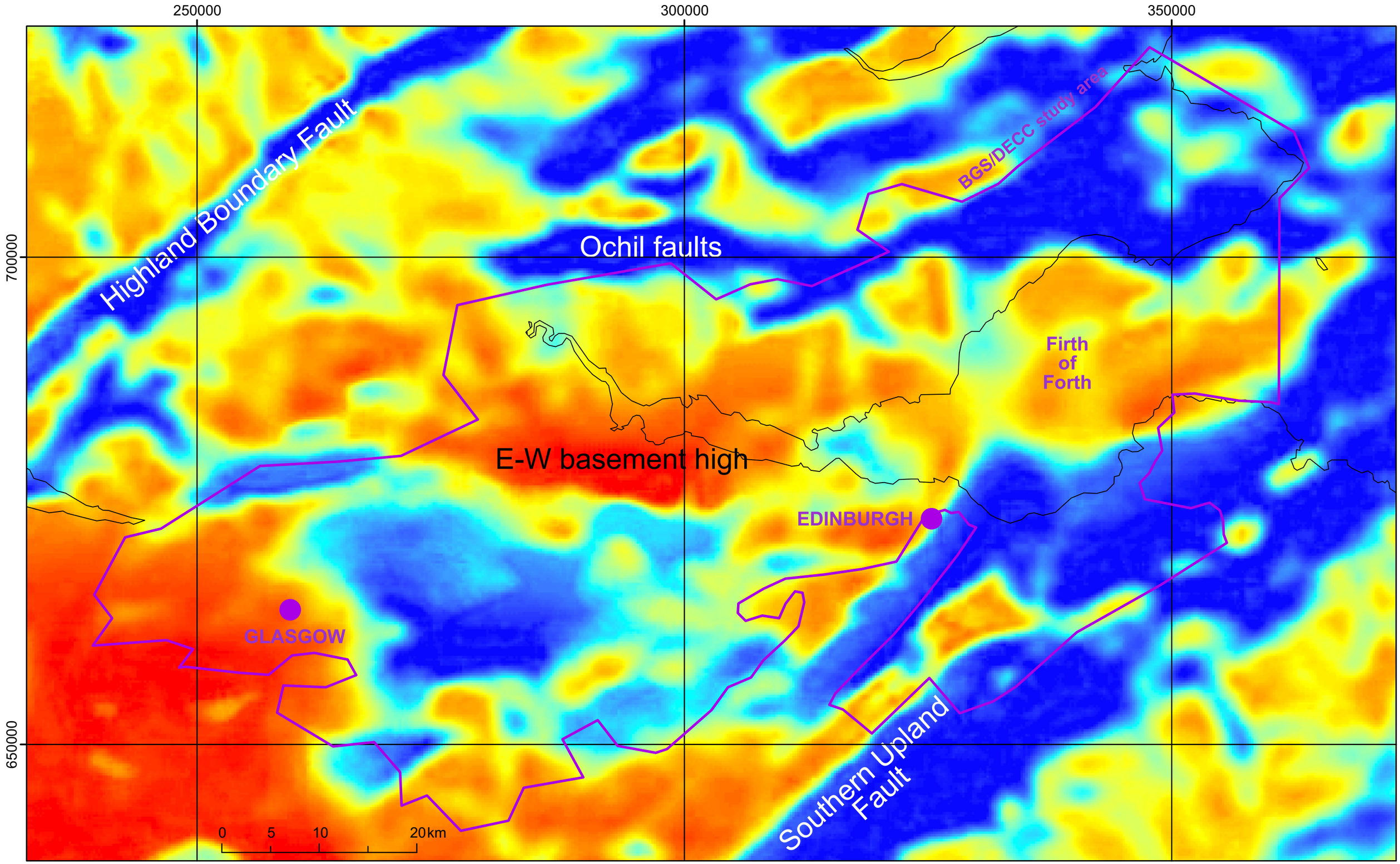

Figure 14 BGS Gravity anomaly map for the BGS/DECC study area of the central and eastern Midland Valley. Red-yellow = high, blue = low. Geophysical information ©BGS/NERC.

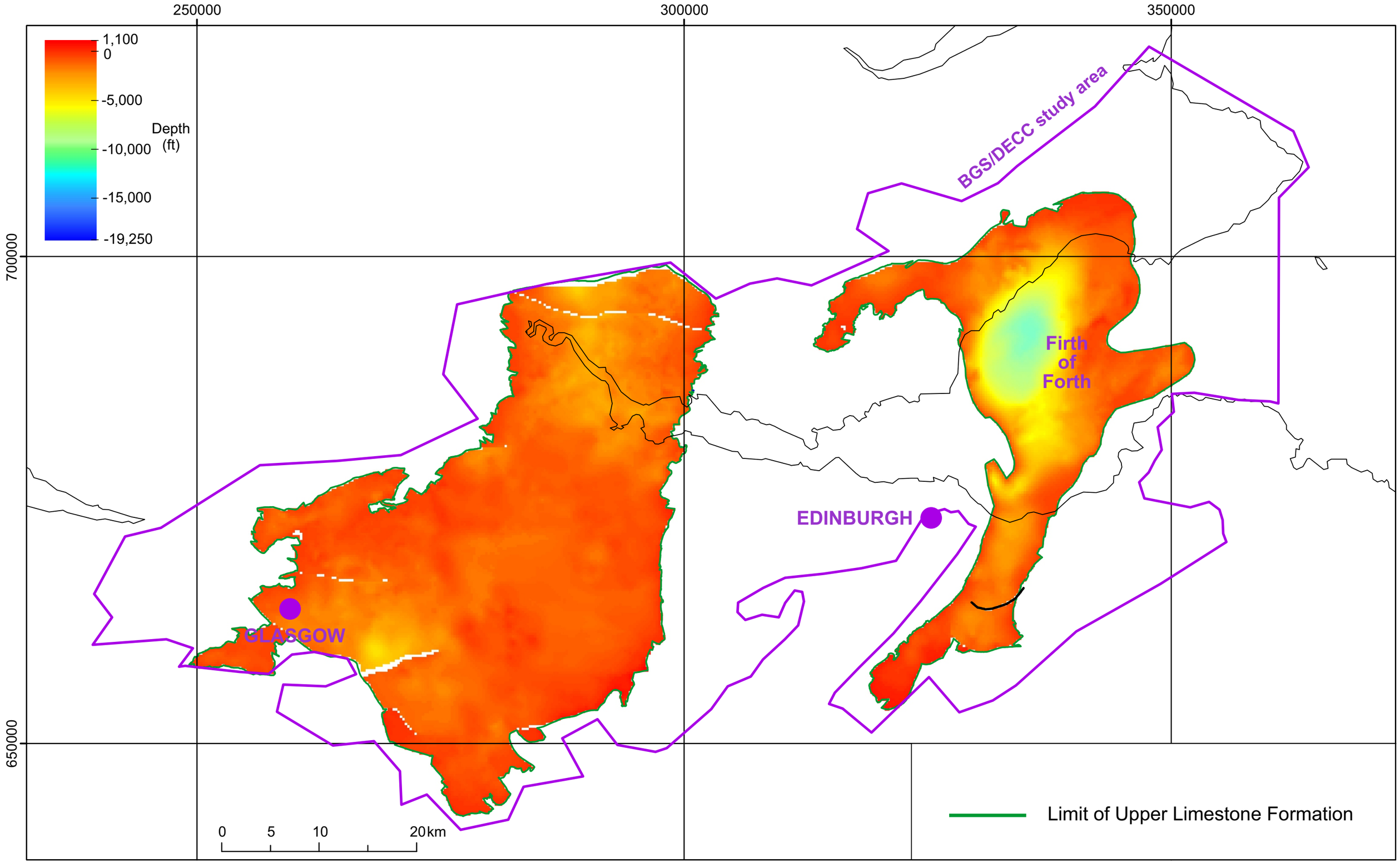

Figure 15 Depth map to the base of the Upper Limestone Formation (top Limestone Coal Formation) in feet relative to Ordnance Datum.

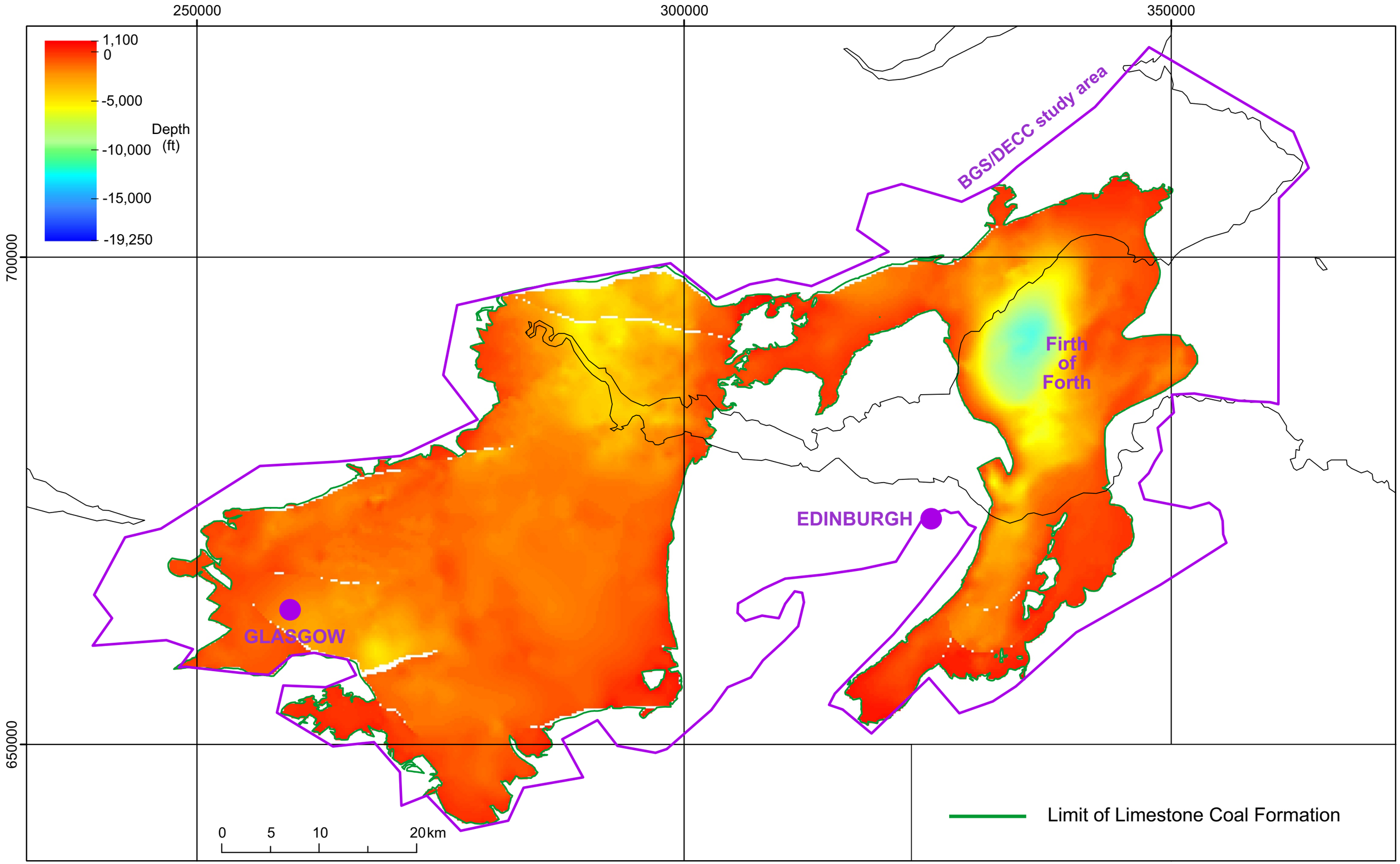

Figure 16 Depth map to the base of the Limestone Coal Formation in feet relative to Ordnance Datum.

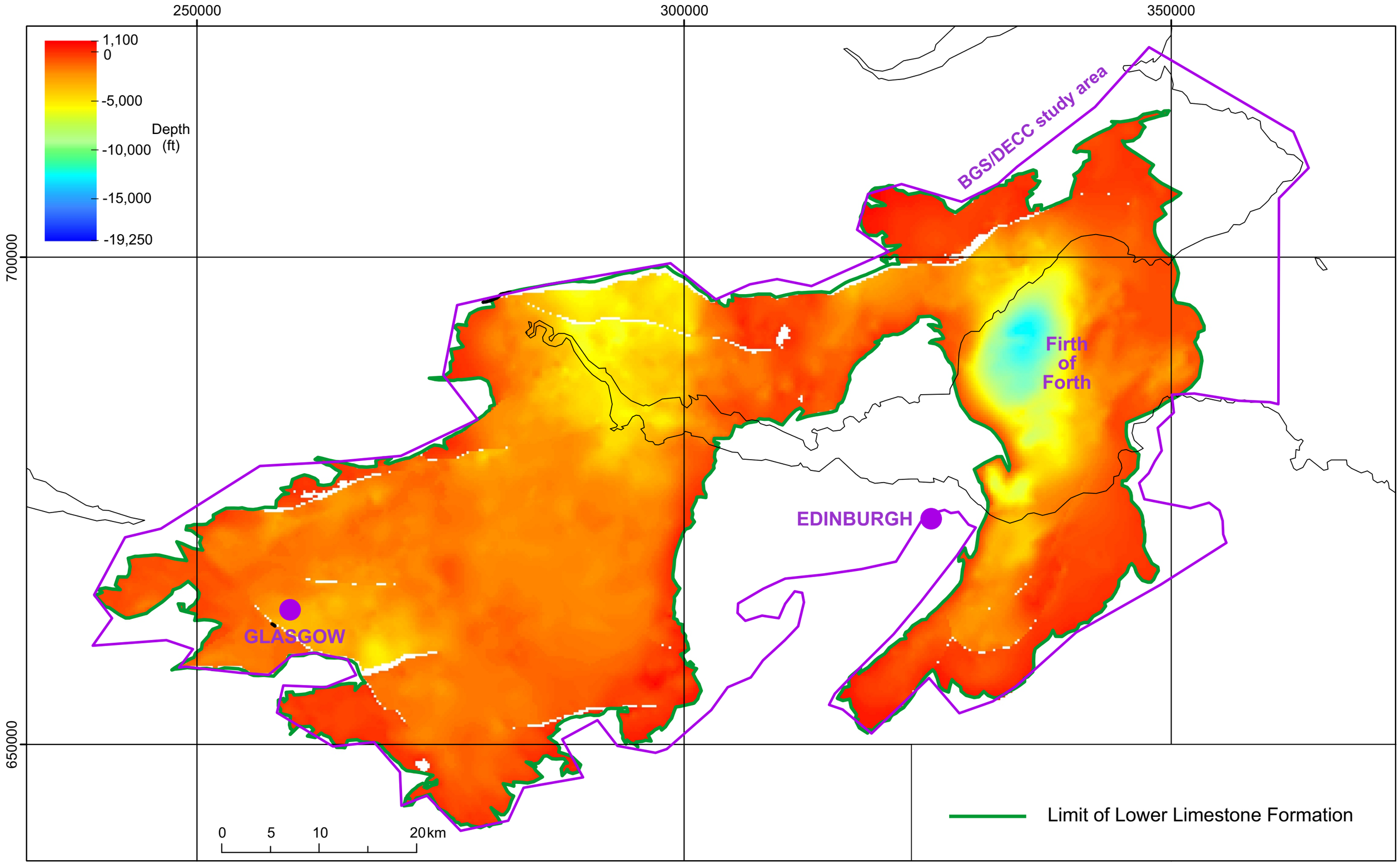

Figure 17 Depth map to the base of the Lower Limestone Formation in feet relative to Ordnance Datum.

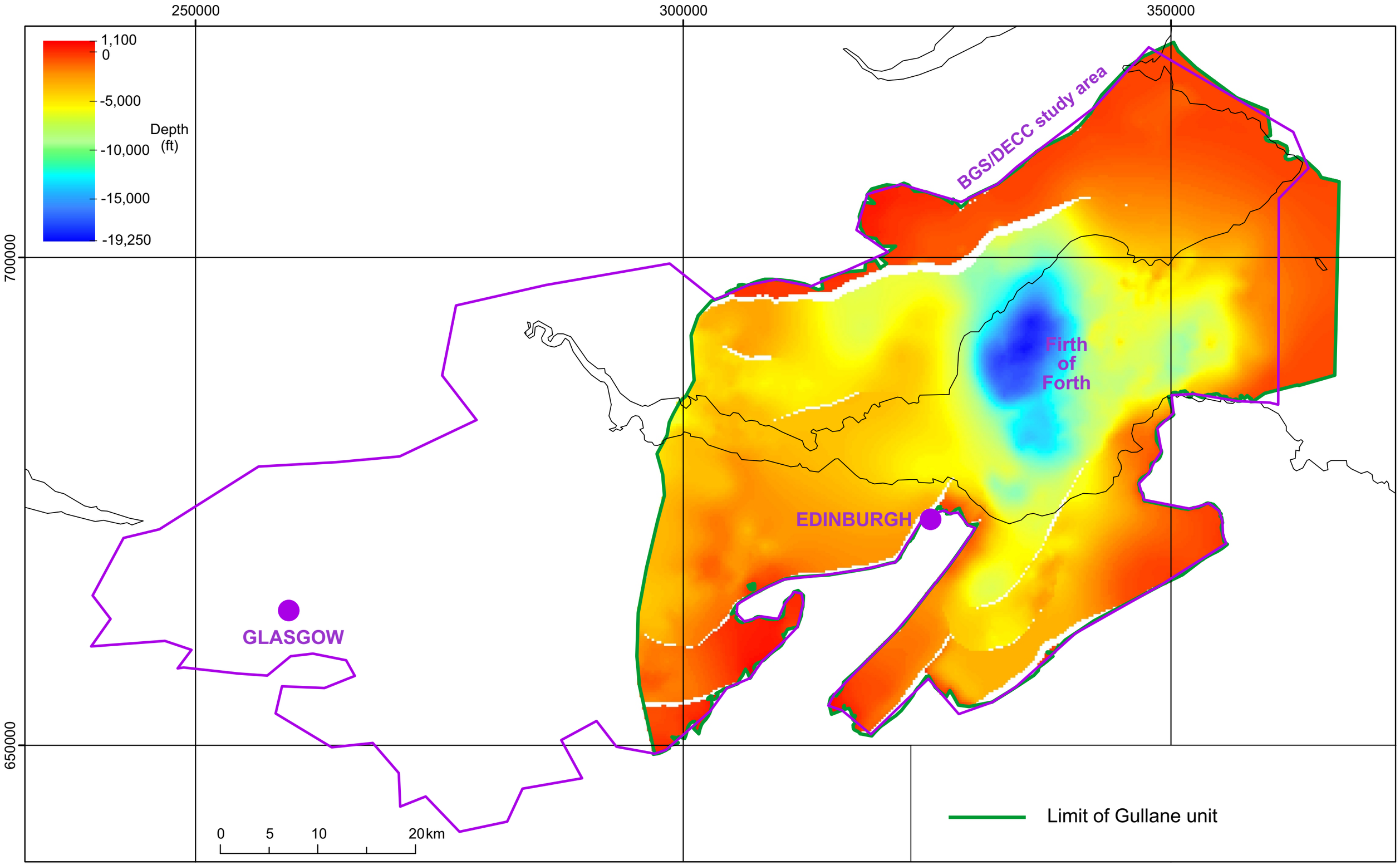

Figure 18 Depth map to the base of the Gullane unit in feet relative to Ordnance Datum.

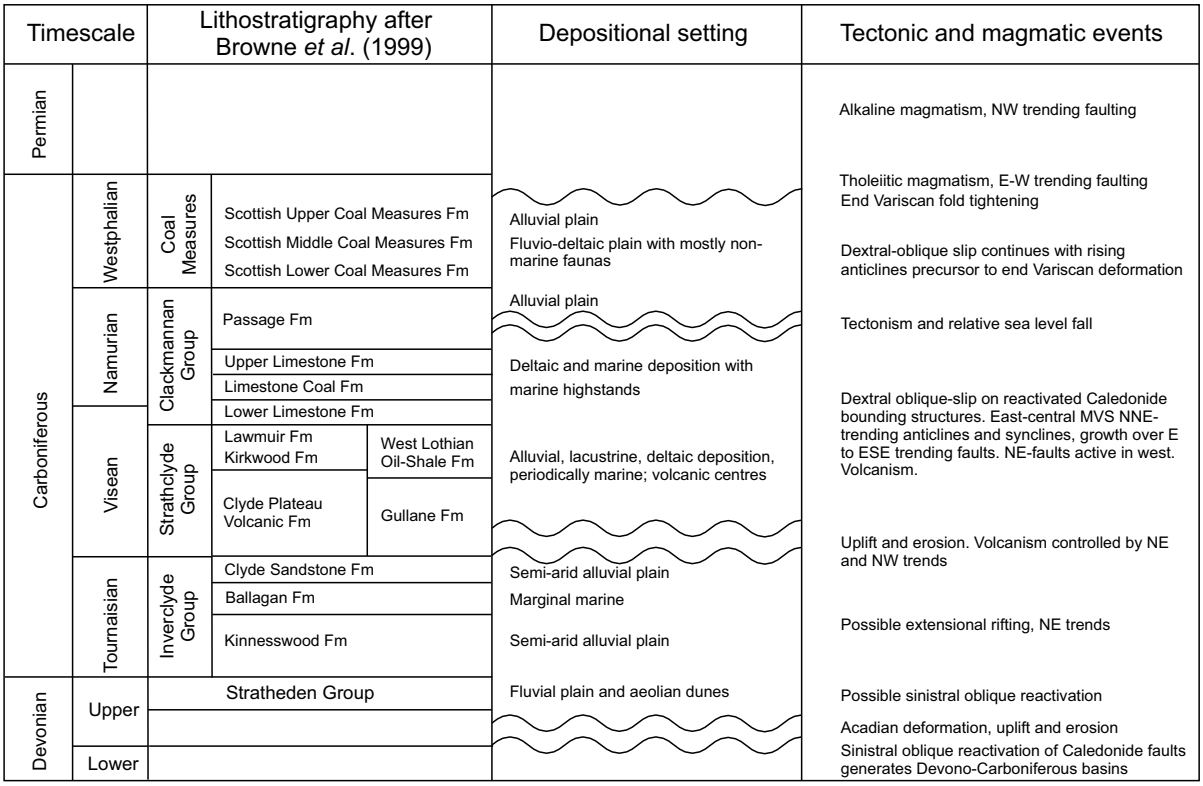

Figure 19 Summary chart of Midland Valley of Scotland Carboniferous tectonic, magmatic and depositional history.

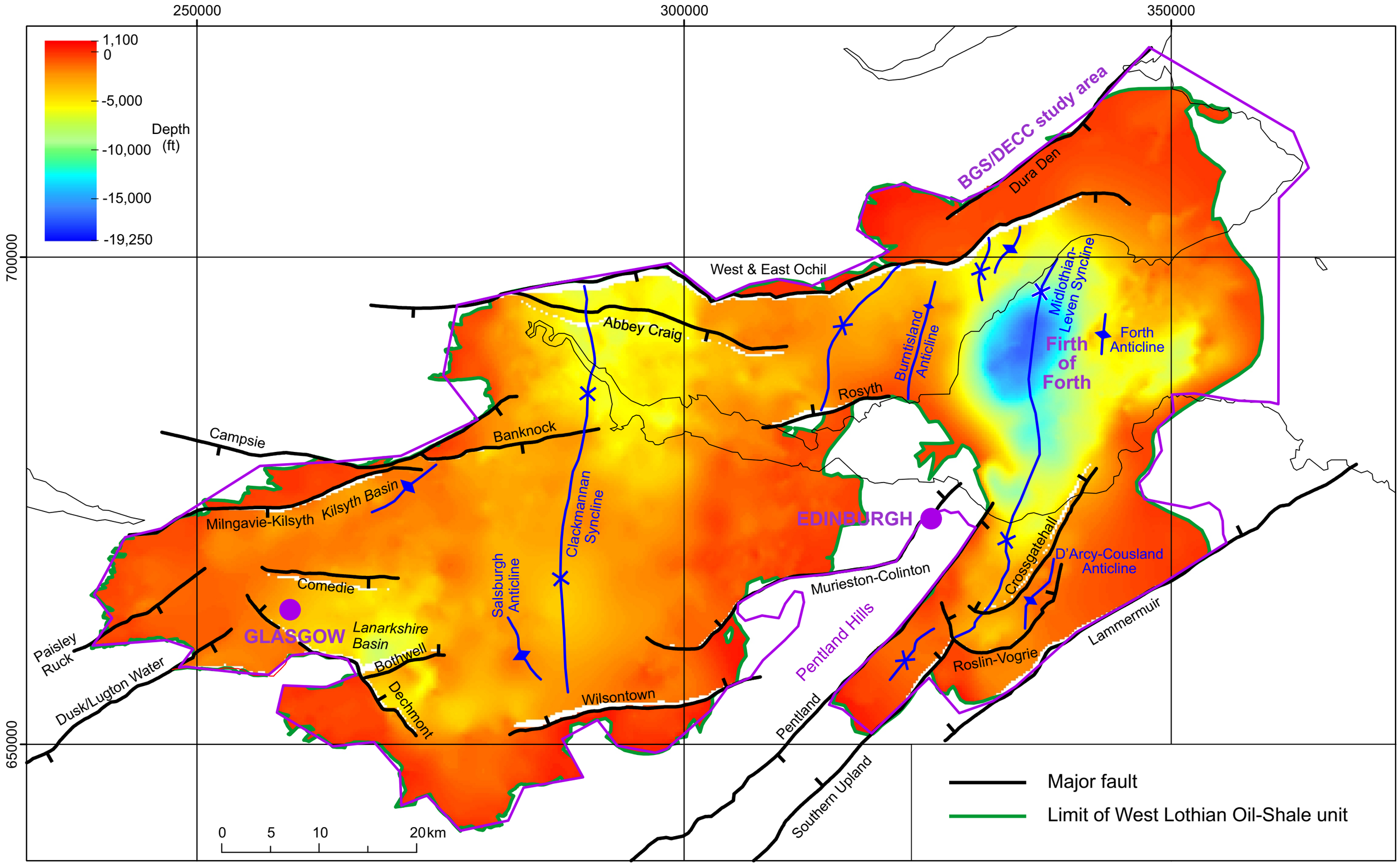

Figure 20 Map showing outcrop position of regional-scale faults included in the geological model, together with the main structural features, using the base of the West Lothian Oil-Shale unit as an illustrative depth map.

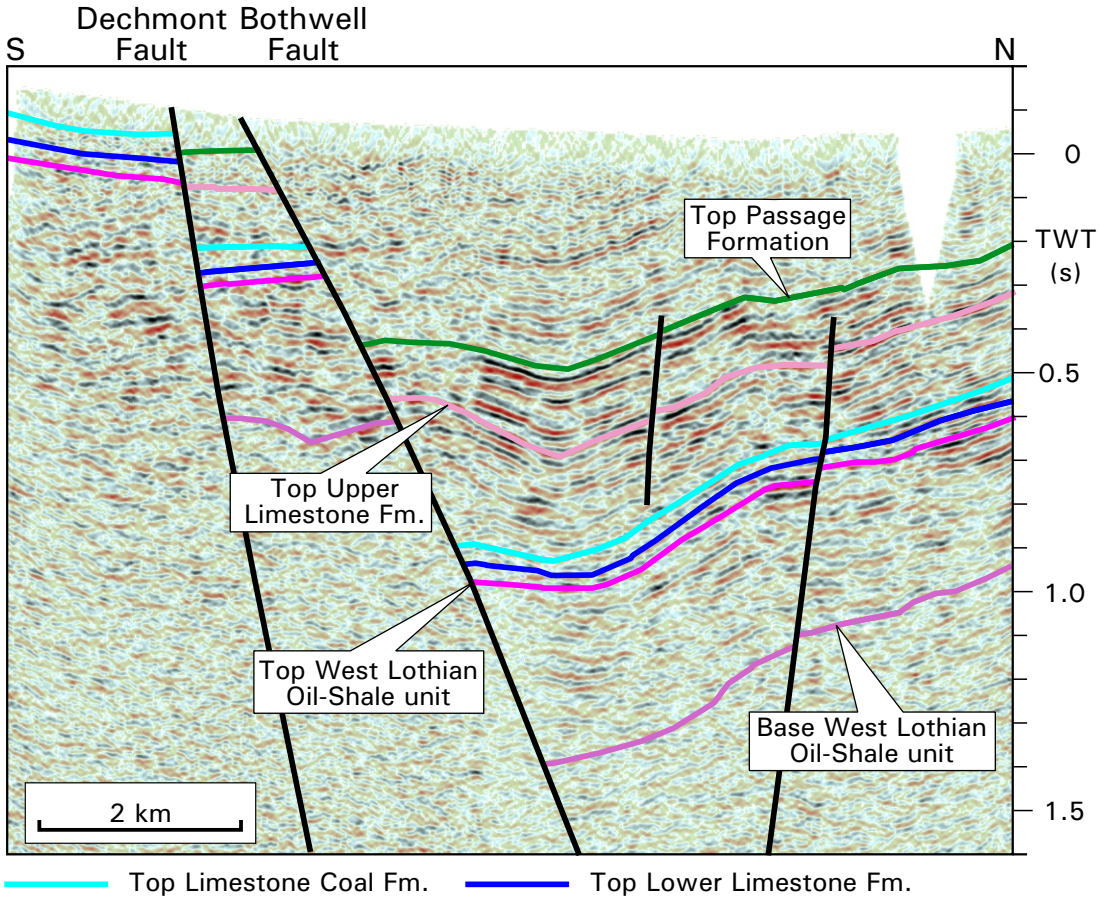

Figure 21 Seismic line SAX-85-06 showing a syn-depositional half-graben bounded by the Bothwell and Dechmont faults in the Lanarkshire Basin

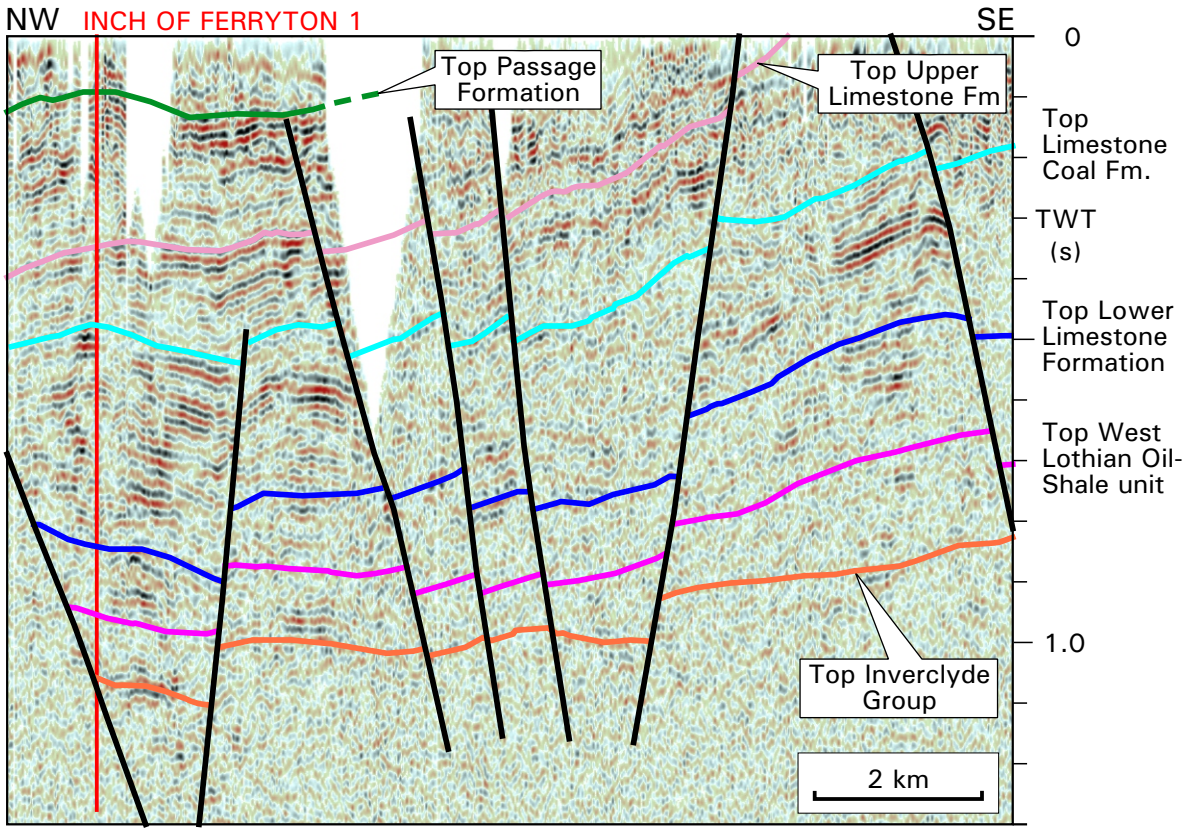

Figure 22 Example seismic line TOC82-V03 tied to Inch of Ferryton 1 well in the centre of the Clackmannan Syncline, with numerous relatively small offset faults interpreted

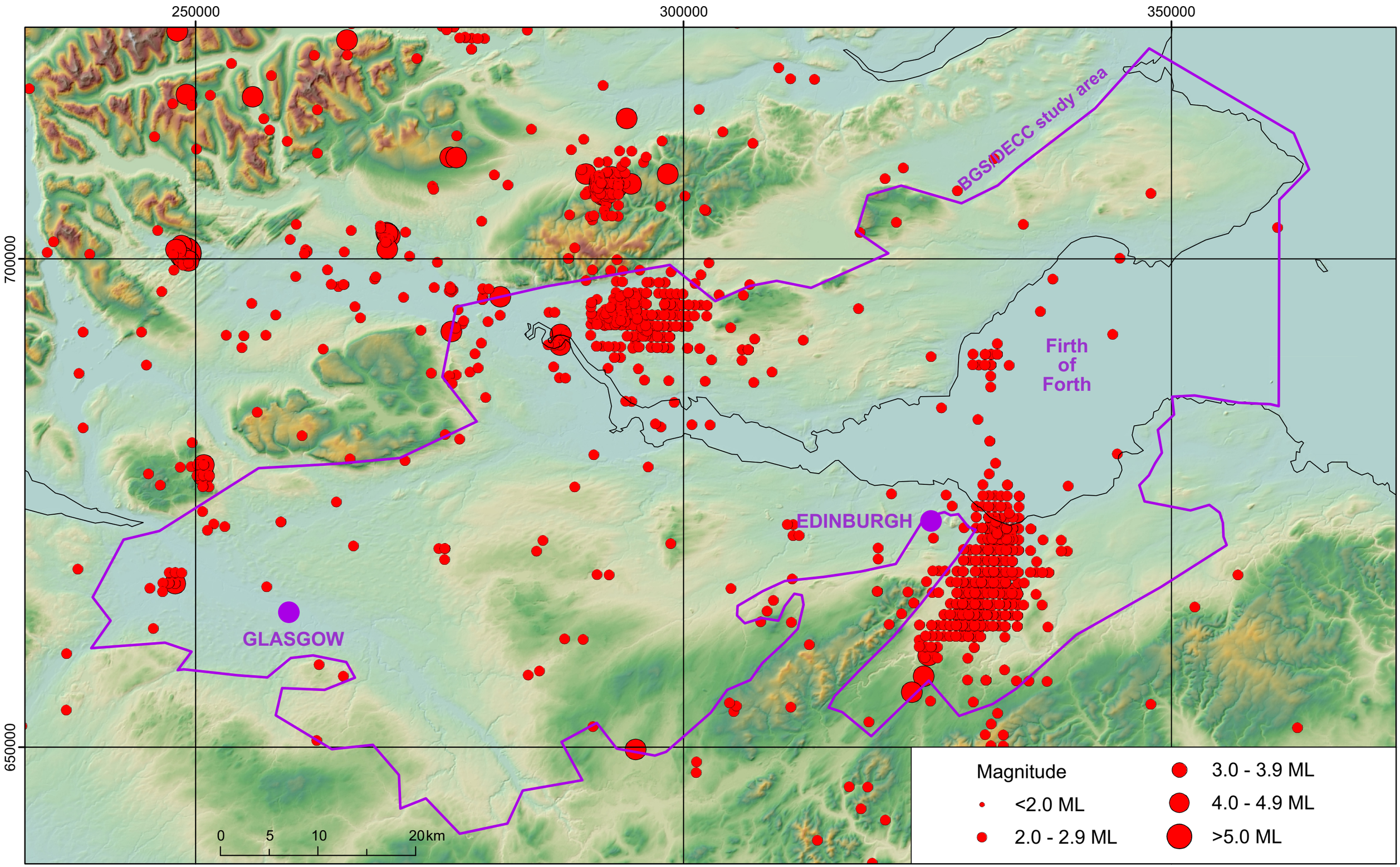

Figure 23 Earthquakes recorded instrumentally by BGS from 1970 to May 2014 across Central Scotland. The clusters of smallest magnitude earthquakes (<2.0 ML) were associated with coal mining activity, which was only detected because temporary monitoring networks were deployed. It is quite possible that there were small mining-induced earthquakes in other coalfields that have not been recorded. The size of the red circle depicts the earthquake magnitude (ML = Richter local magnitude). Information ©BGS/NERC.

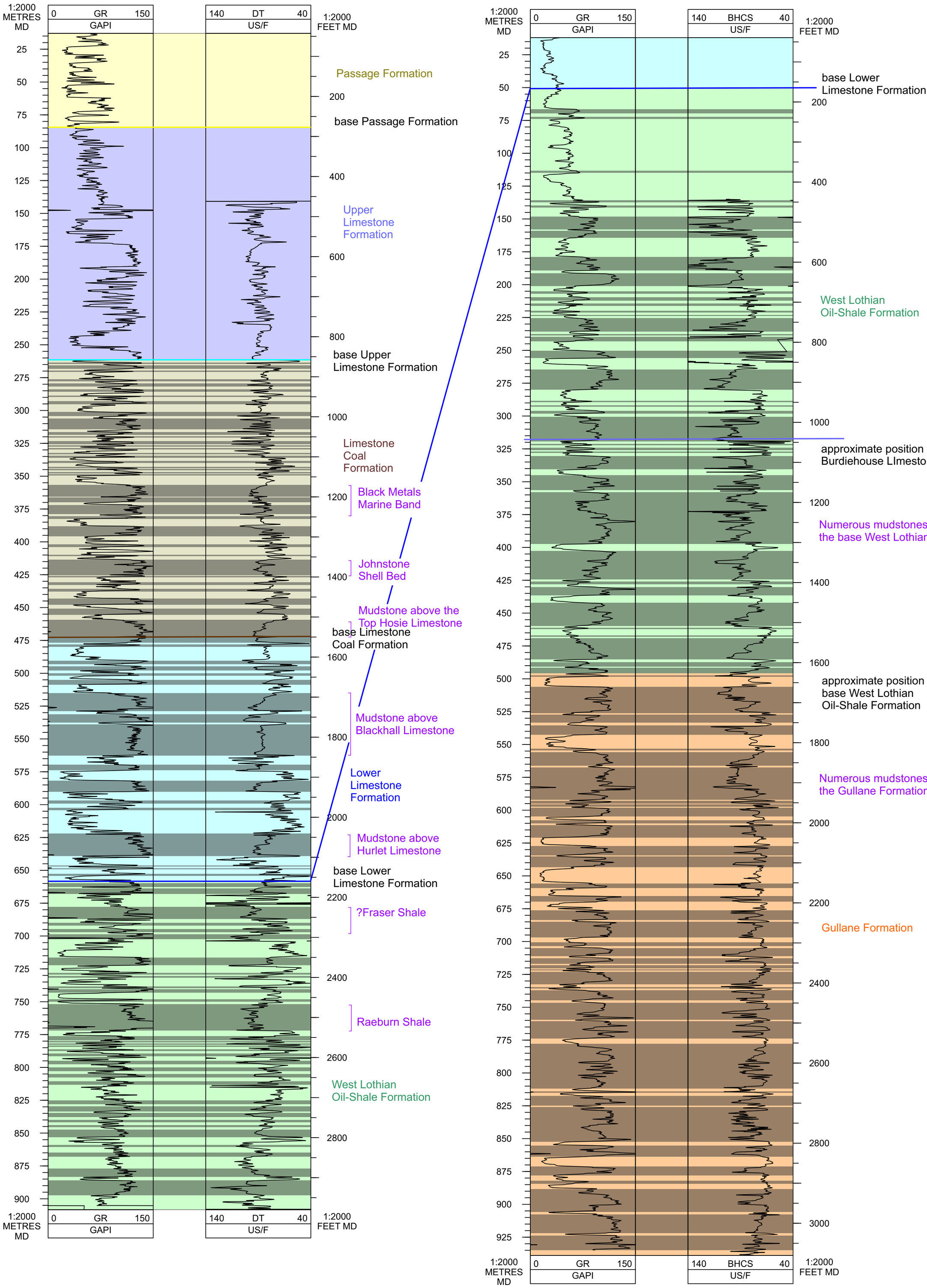

Figure 24 Example of two well logs illustrating the character of the Midland Valley of Scotland prospective shale succession as numerous mudstones (grey) within a stacked sequence. The illustrated section extends from the Passage and Upper Limestone formations (not assessed in this study) and through all four of the prospective shale units.

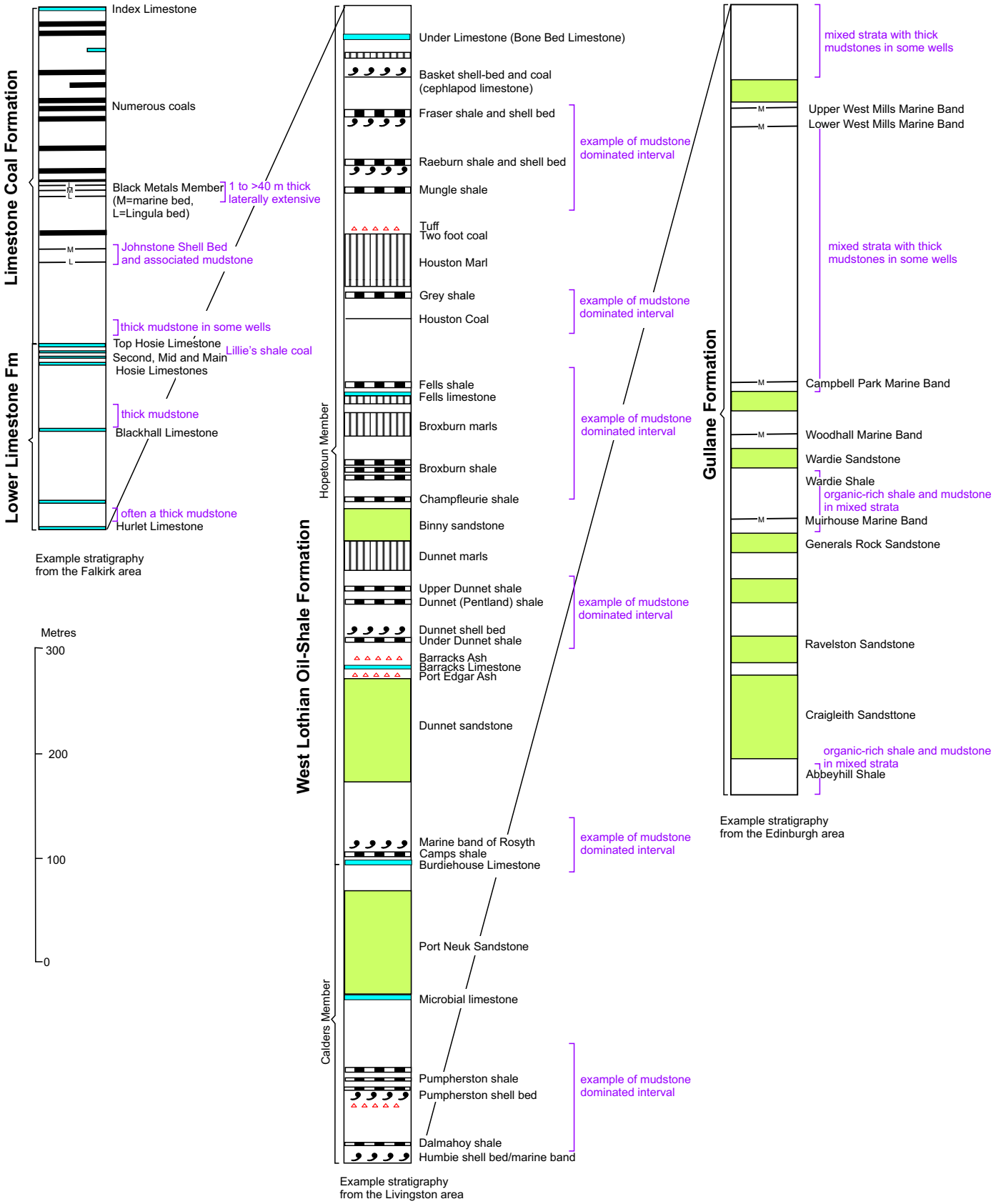

Figure 25 Example of thickness and nomenclature of the main Carboniferous intervals examined for shale prospectivity in the Midland Valley of Scotland, taken from BGS 1:50,000 scale maps and Jones (2007). Examples of potential mudstone-dominated (shale) intervals are shown in purple. Note that white intervals represent mixed lithologies in which mudstones are likely to be a significant proportion. Thicknesses and nomenclature changes laterally from the examples shown here. The shale beds highlighted within the West Lothian Oil-Shale Formation are oil-shales sensu stricto.

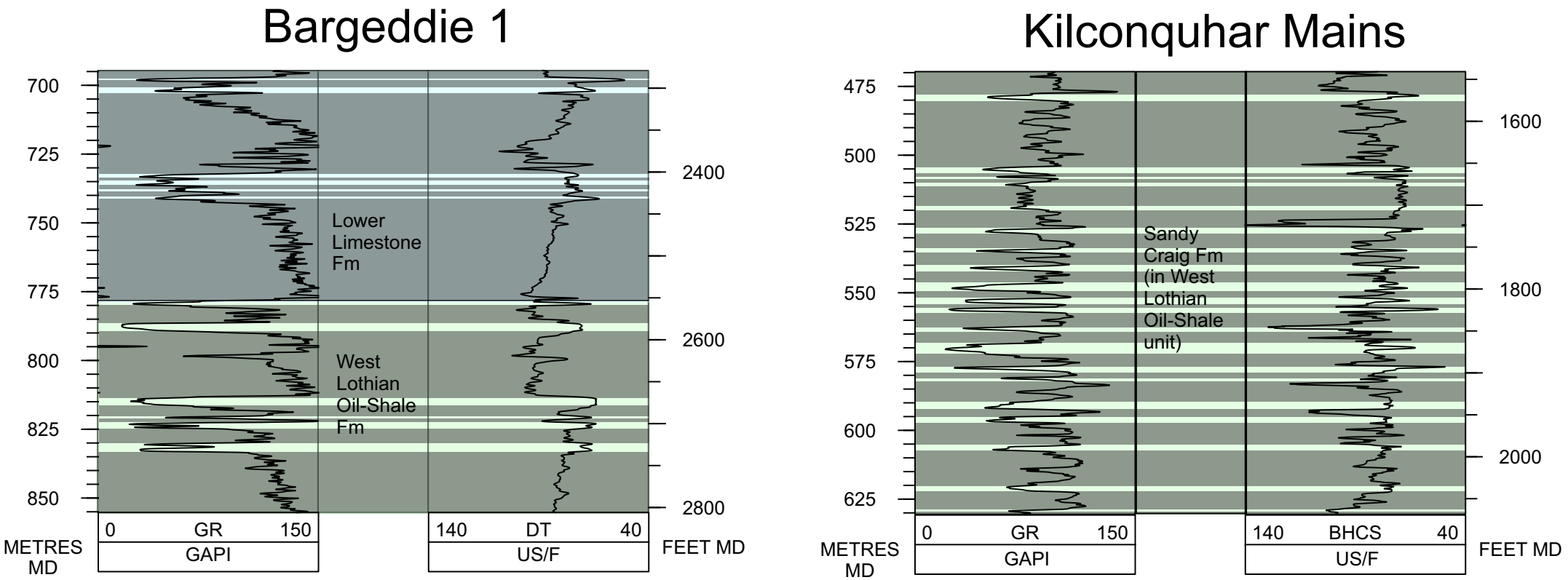

Figure 26 Comparison of gamma and sonic logs for two wells with overall similar percentages of shale, but with differing distributions of shale.

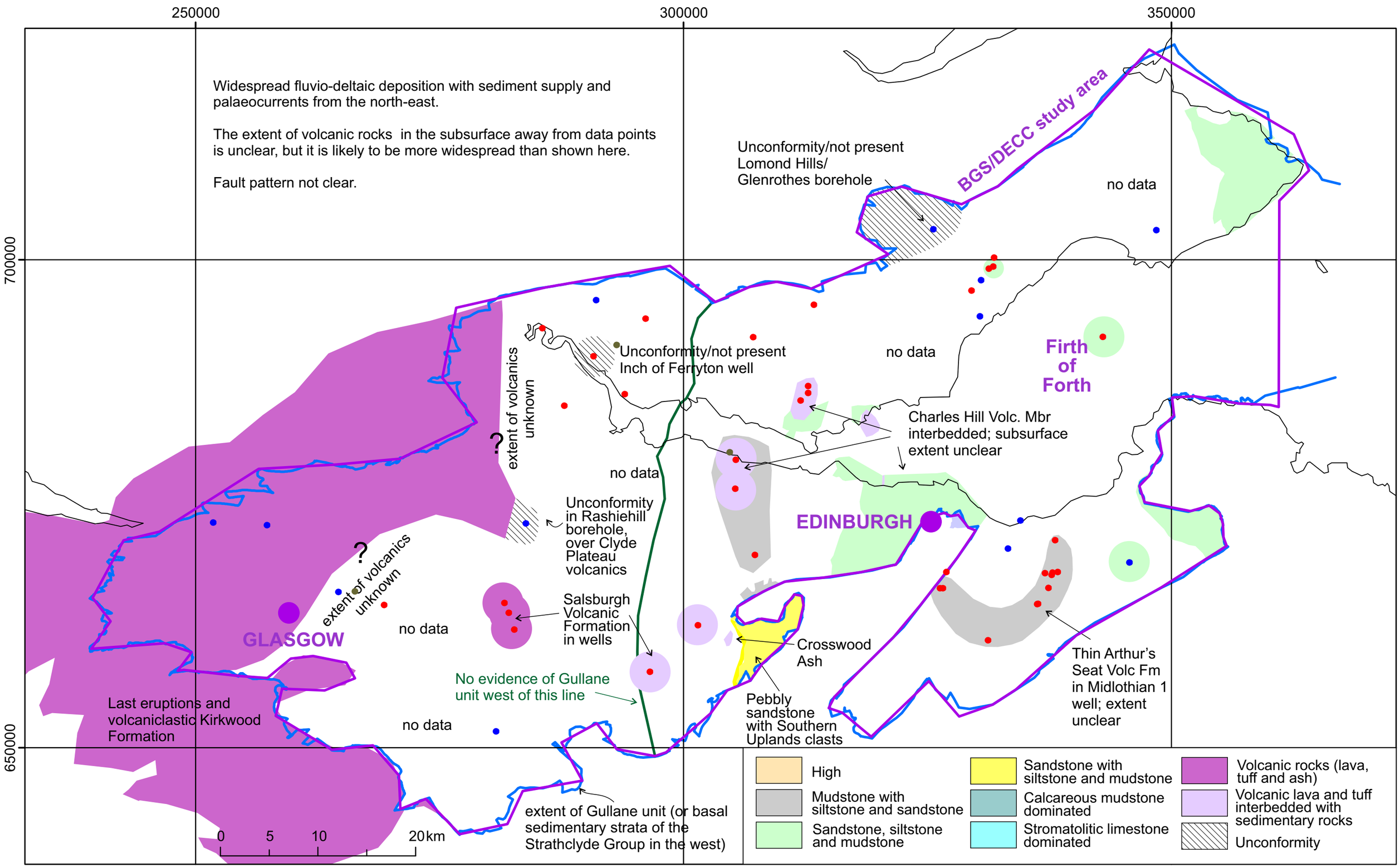

Figure 27 Gullane unit times (c. 336 Ma, TC palynomorph zone)
a) summary of evidence from well/borehole and outcrop data, note that wells/boreholes proving the Gullane unit or an unconformity are surrounded by shading, other wells/boreholes do not prove the Gullane unit.

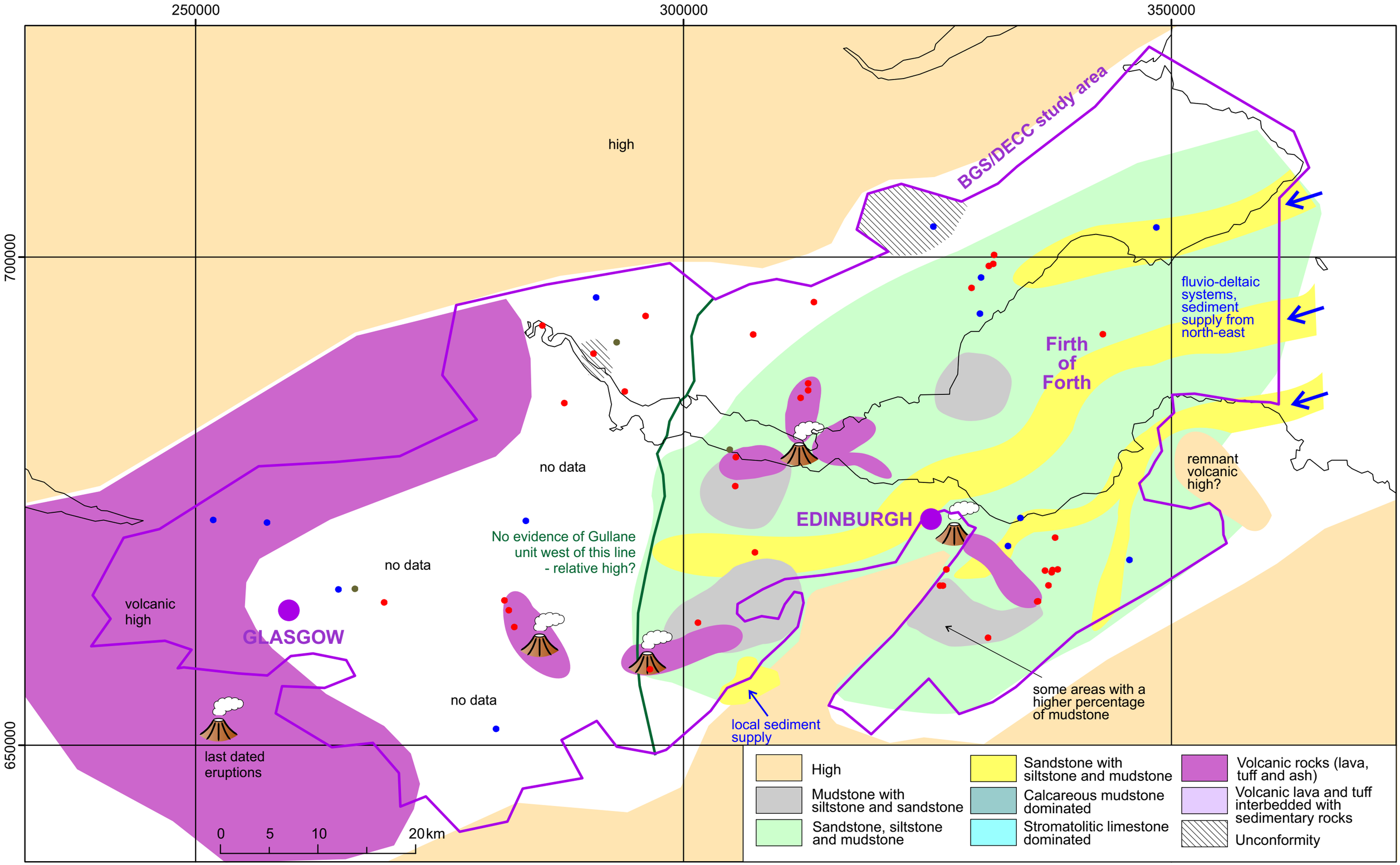

Figure 27 Gullane unit times (c. 336 Ma, TC palynomorph zone)
b) summary palaeogeography. Evidence is patchy and the reconstruction is tentative.

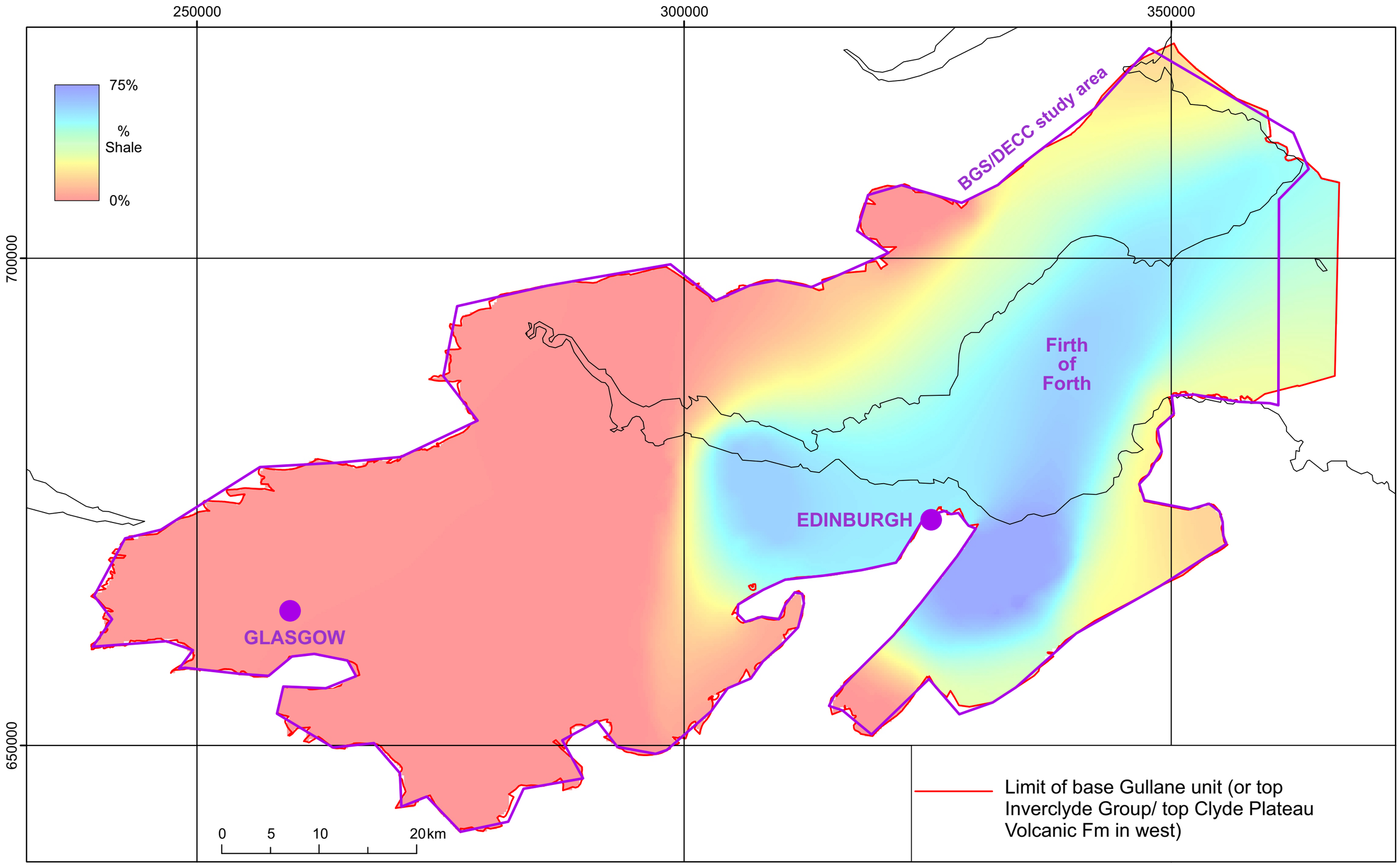

Figure 28 Percentage shale map for the Gullane unit, note that the western part of the area has zero percent shale where the Gullane unit is not proven.

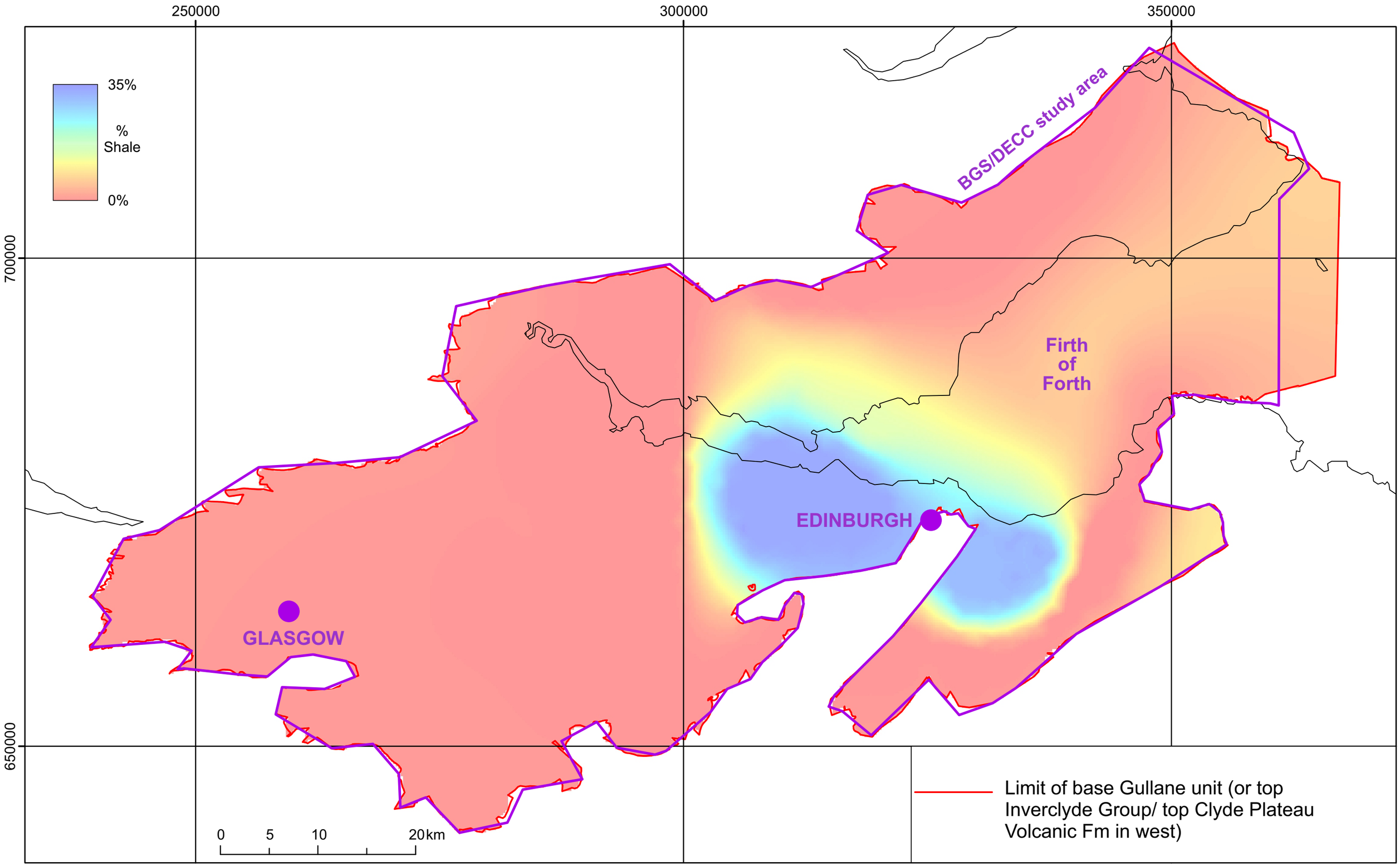

Figure 29 Percentage shale map for shale intervals greater than 50 ft (15 m) within the Gullane unit, note that the western part of the area has zero percent shale where the Gullane unit is not proven.