The Sherwood Sandstone Group as a potential geothermal aquifer across Northern Ireland

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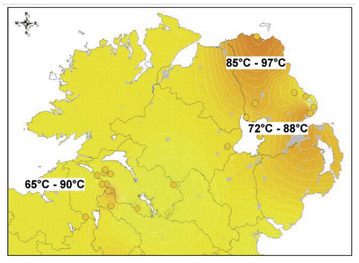
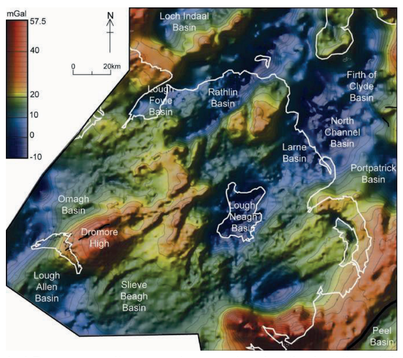
Introduction

Downing and Gray (1986) estimated the Identified Geothermal Resource in the Sherwood Sandstone Group across Northern Ireland, at temperatures greater than 20°C, as about 523 Mtce (million tonnes of coal equivalent), a figure that would be equivalent to 2.5 billion barrels of oil, or approximately half the size of the largest UK offshore oil field. Only a small percentage of this resource could be extracted but, nonetheless, this is significant in terms of Northern Ireland's energy needs. This conservative estimate was based on very limited data and subsequent downhole measurements should allow more accurate estimates to be made. This project aims to refine some of the information on reservoir distribution and quality.



Modelled temperatures for Northern Ireland at 2.5 km from Kelly et al. (2005). Based upon data from CSA Ltd (2005). The temperatures at 2500m are relevant to the exploitation of deep geothermal aquifers in Northern Ireland and these show a range from 65°C to 90°C for the Rathlin, Larne and Lough Neagh basins, all of which would be suitable for direct heating applications.



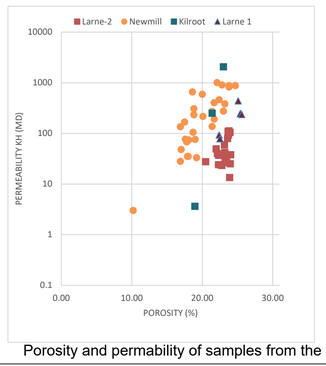
Shaded Bouger gravity anomaly map showing the location of the sedimentary basins (generally blue) across Northern Ireland. The Lough Neagh, Larne, Rathlin and Lough Foyle basins are largely buried under Palaeogene basalts.

1. The Larne Basin

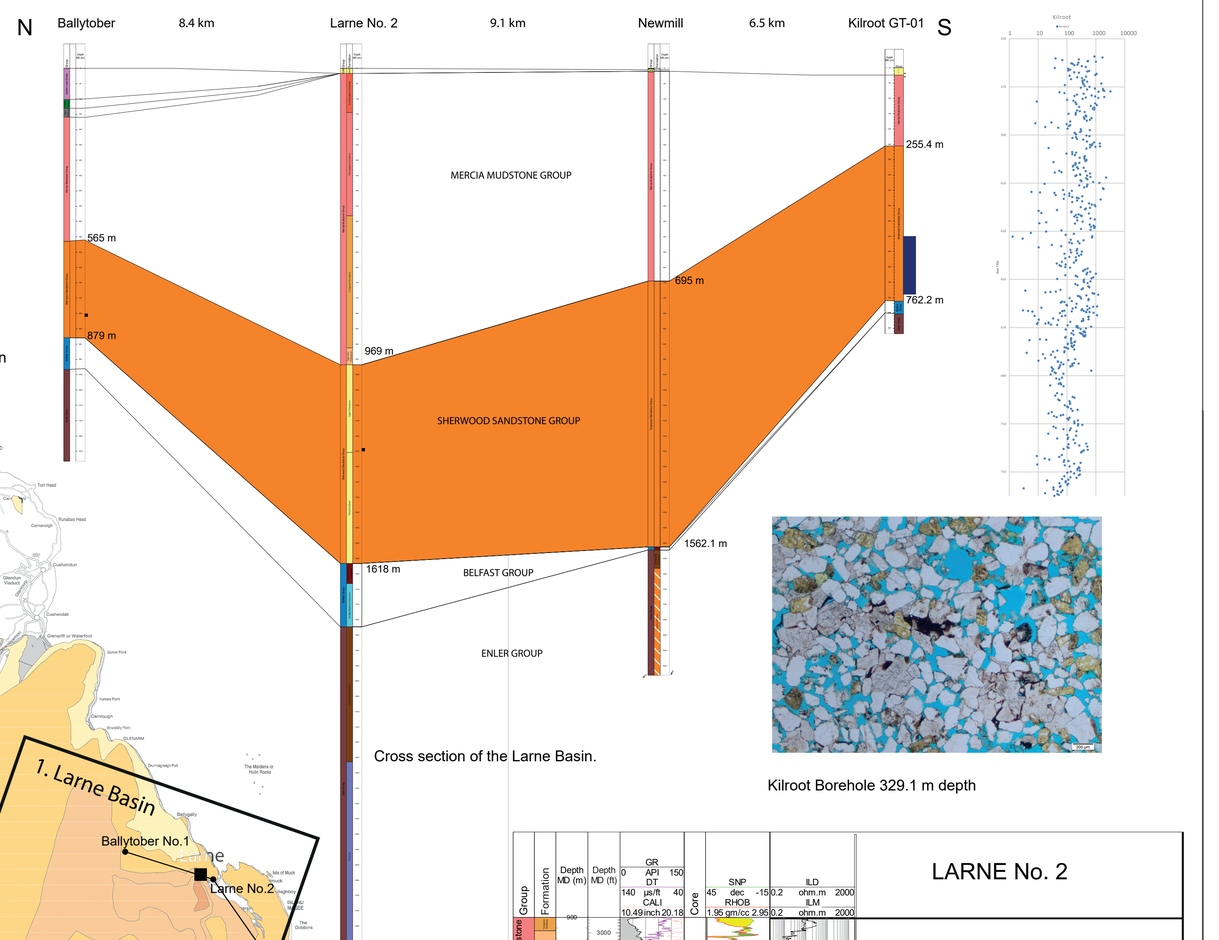
The Larne Basin holds potential for both shallow and deep geothermal reservoirs. It has been the site of previous geothermal exploration, with the drilling of the Larne No. 2 Borehole in 1981 (Downing et al. 1982). The depths to the top Sherwood Sandstone Group were shallower than expected and temperatures were therefore low at 37 and 54 C for the top and base Sherwood Sandstone Group respectively. Gravity data suggests that the Sherwood Sandstone may deepen towards the SW, reaching higher temperatures. The recorded permeabilities in the Larne No. 2 borehole were somewhat low and not necessarily representative of the basin as a whole, however the upper part is more porous and permeable as shown by samples from the nearby Larne No.1 salt exploration borehole.

In Larne No. 2, two successful tests were conducted in the Sherwood Sandstone Group (between 4420 and 4452 ft. (1347.2 and 1356.9 m) and between 4580 and 4632 ft. (1395.9 and 1411.8 m). They indicate low transmissivity values that agree with the low permeability measurements made in this borehole. It suggests that the topmost interval is the most open aquifer in the Sherwood Sandstone Group and contributes around 7 Dm to a total transmissivity of 8 Dm for the whole group.

An additional geothermal borehole (Kilroot GT-01) was drilled in 2009 to obtain a continuous core through the Sherwood Sandstone Group. Although drilled at shallower depths the borehole was sunk to recover core from the entire Sherwood Sandstone Group. Recent work on the reservoir quality of this core is ongoing. The upper part of the group has porosities up to 23% and 2057 mD permeability. There is a decrease in permeability towards the base of the group, but not to the extent seen in the Larne No. 2 borehole.



Porosity and permability of samples from the Larne Basin



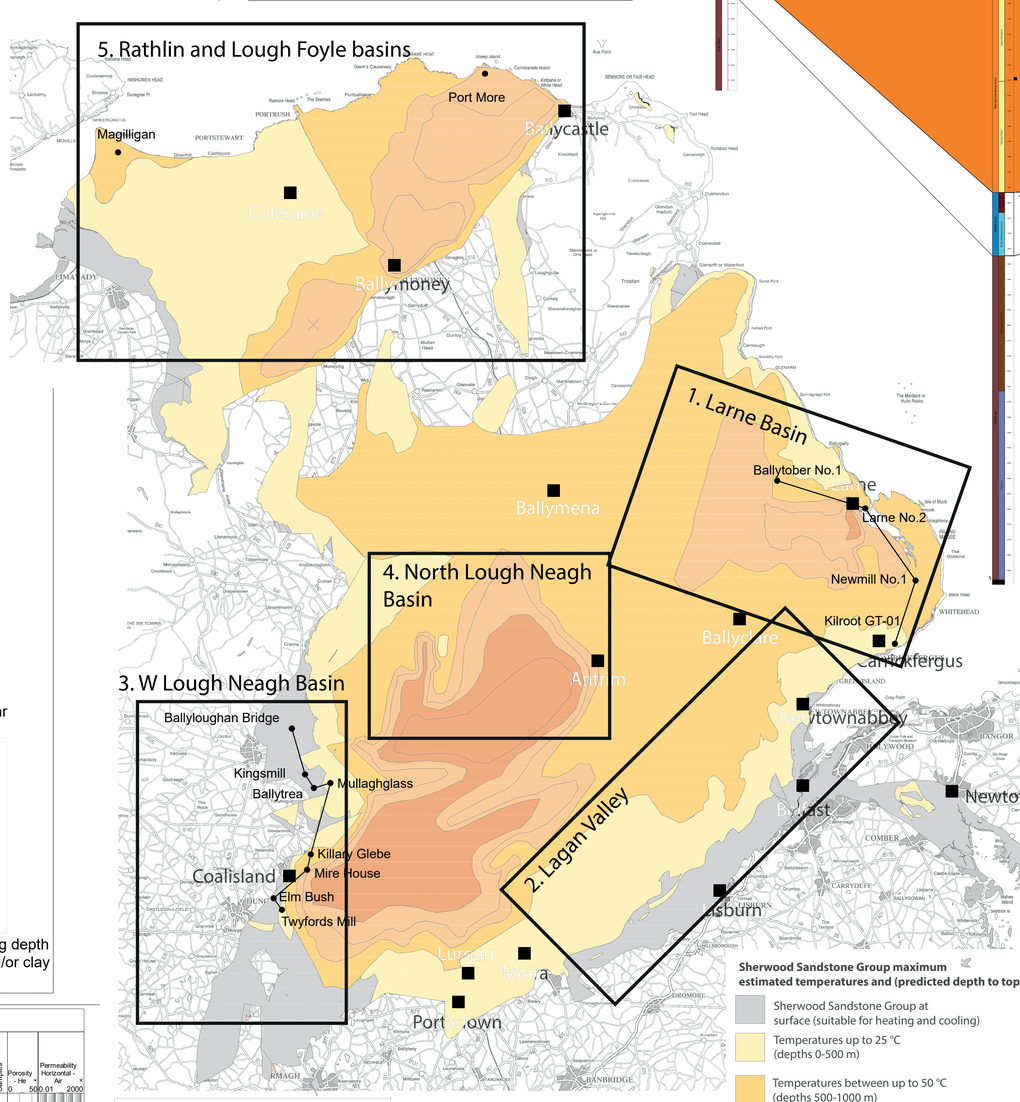
Cross section of the Larne Basin.

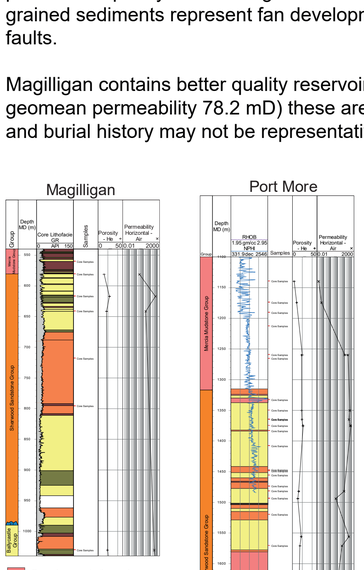
Kilroot Borehole 329.1 m depth

5. Rathlin and Lough Foyle basins

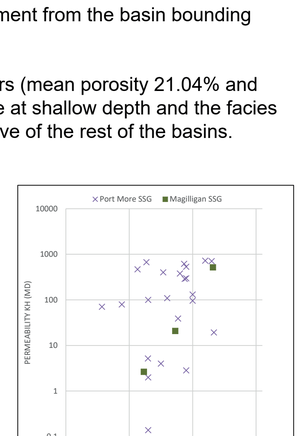
Limited data exists for the Rathlin and Lough Foyle basins. Although two deep wells were drilled, only selected pieces of core remain and the logs are poor and incomplete. Characterisation of the reservoir quality has been focussed on poroperm of remaining core samples and petrography. In Port More the average porosity is 16.73% with the geometric mean permeability 49.1 mD. The porosity is locally reduced by sulphate cement and by the presence of poorly sorted conglomerates and breccias. These coarser grained sediments represent fan development from the basin bounding faults.

Magilligan contains better quality reservoirs (mean porosity 21.04% and geomean permeability 78.2 mD) these are at shallow depth and the facies and burial history may not be representative of the rest of the basins.

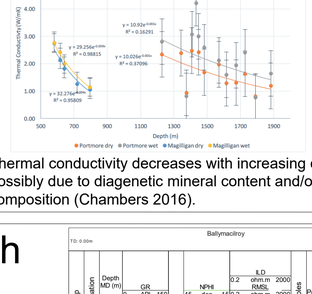




Facies through the Sherwood Sandstone Group in the Magilligan and Port More boreholes. The locations of thin section samples and poroperm datapoints is shown.



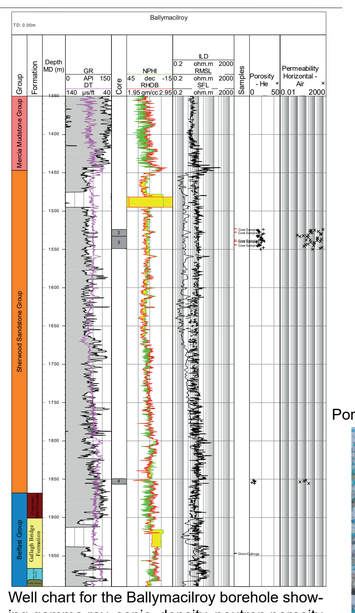
Porosity plotted against permeability for the Sherwood Sandstone in the Port More and Magilligan boreholes. The distribution of datapoints in Port More away from a linear trend represents the interplay of intergranular cement and variable sorting and silt content.



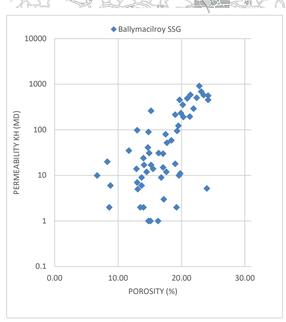
Thermal conductivity decreases with increasing depth possibly due to diagenetic mineral content and/or clay composition (Chambers 2016).

4. North Lough Neagh Basin

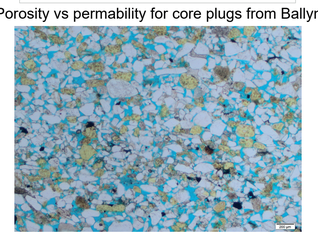
The northern part of the Lough Neagh Basin contains the deepest buried Sherwood Sandstone Group as interpreted from boreholes and gravity data and the reservoir quality has been shown to be good. Combined with the prospect for underlying older sandstones at even hotter temperatures this part of Northern Ireland in the vicinity of Antrim offers the best prospect for deep geothermal reservoirs.
In Ballymacilroy one drill stem test was conducted on the Sherwood Sandstone Group (across the interval 1534–1549 m depth) (Burgess 1979). The results of the Sherwood Sandstone Group test are assumed to be representative of the upper 215 m thick aquifer by correlation with the petrophysical logs and the 72 mD estimate of bulk field permeability, suggesting transmissivity of about 15 Dm for this interval and temperatures of 62 C. Below this the permeability of the Sherwood Sandstone Group decreases significantly but an intermediate interval could contribute a transmissivity of several Darcy-metres to a geothermal production well.



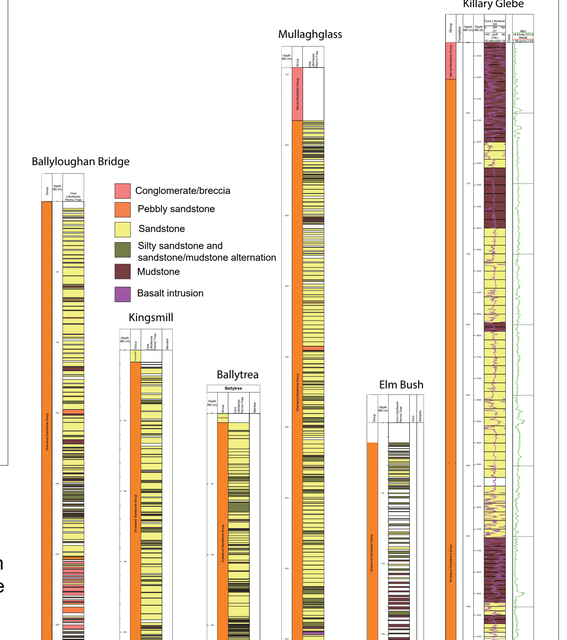
Well chart for the Ballymacilroy borehole showing gamma ray, sonic, density, neutron porosity and resistivity. The separation between density and neutron porosity is an indication of good quality reservoirs if shaded yellow and more silty or cemented reservoirs if shaded green.



Porosity vs permability for core plugs from Ballymacilroy.

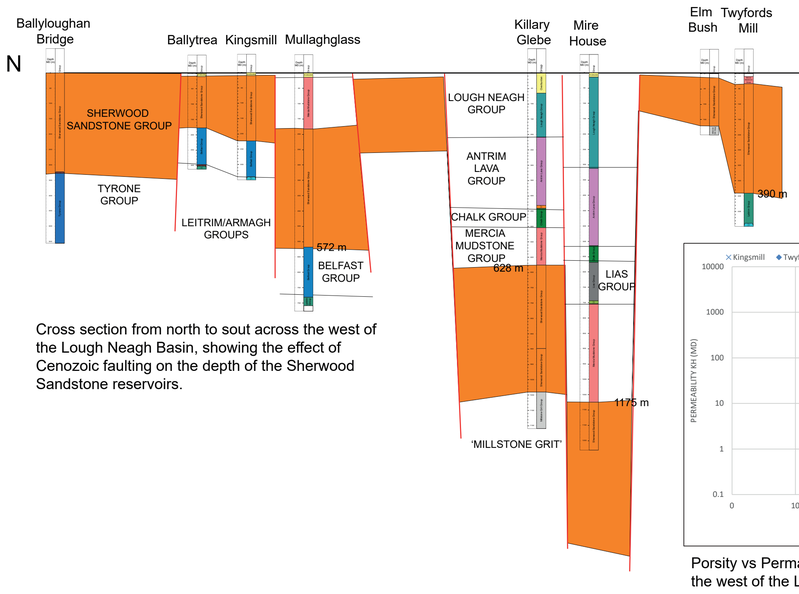


Thin section from Ballymacilroy 1538.5 m depth showing low levels of diagenetic cements and open, connected pores.

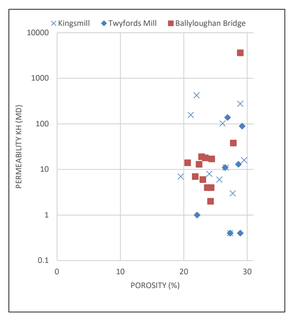


3. West Lough Neagh Basin

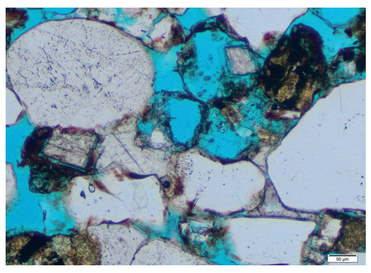
The area representing the western parts of the Lough Neagh Basin are underlain by Sherwood Sandstone of variable depth and thickness. Temperature data for boreholes in this area is sparse and limited study on the reservoir quality suggests that sandstones in this part of the basin have lower reservoir quality (average porosity of 24-27.5% and geomean permeabilities of 11.9 to 23.5 mD). The reasons for this are not well understood and requires more work. The distribution of facies within the Sherwood Sandstone Group is more variable than other basins in Northern Ireland and the grain size, silt content and grain composition all have an effect on the reservoir quality. In the north of the basin the lower part of the Sherwood Sandstone contains numerous breccia and conglomerate beds and in the south of the area mudstones are present in the lower part of the group and affect reservoir quality.



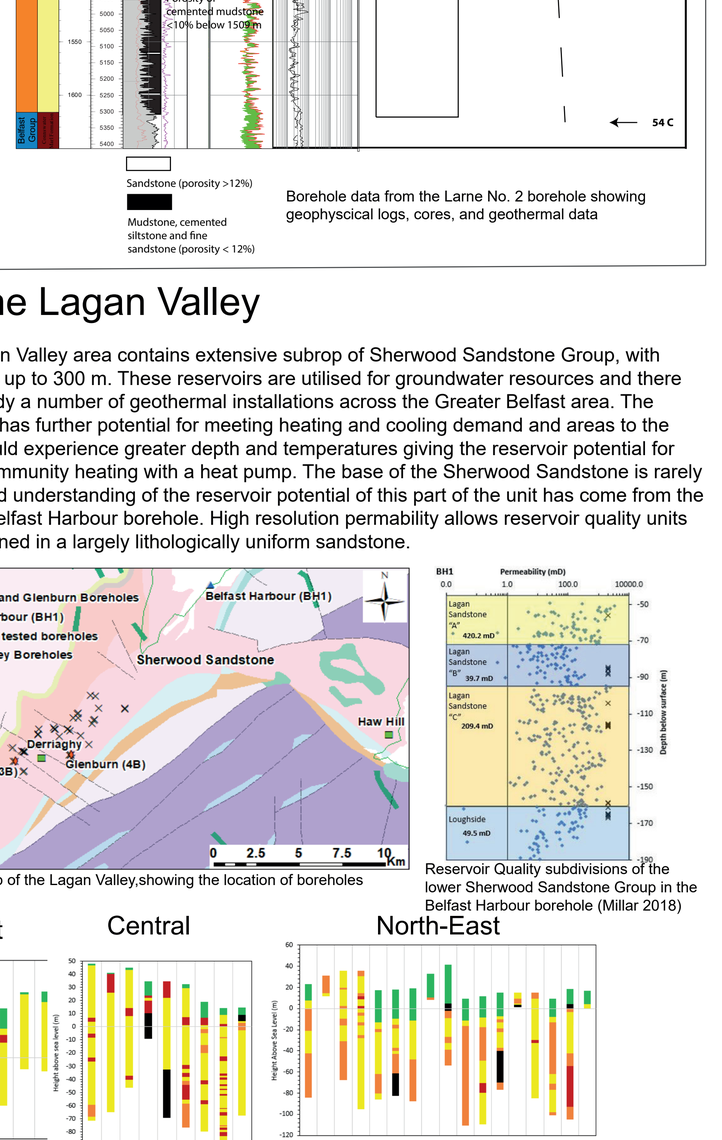
Cross section from north to sout across the west of the Lough Neagh Basin, showing the effect of Cenozoic faulting on the depth of the Sherwood Sandstone reservoirs.



Porsity vs Permability measurements from boreholes in the west of the Lough Neagh Basin (Lovelock 1972).



Thin section photomicrograph from Ballyloughan Bridge 180.04 m depth. The sample shows one possible explanation for high porosity but low permeability. Many of the feldspar grains are dissolved leaving isolated secondary pores surrounded by illite clay shells.



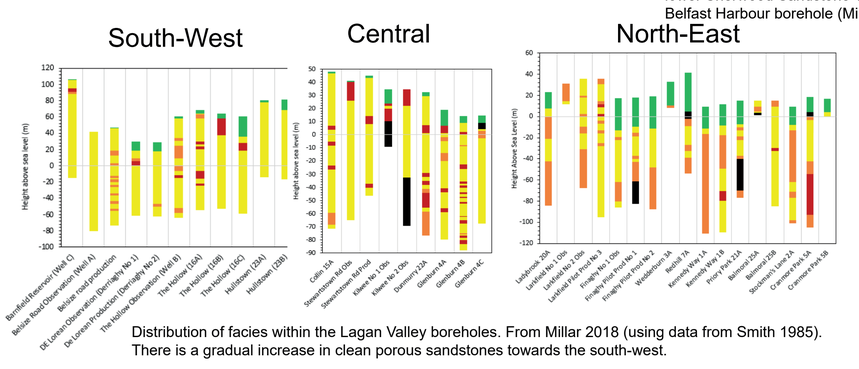
Borehole data from the Larne No. 2 borehole showing geophyscical logs, cores, and geothermal data

2. The Lagan Valley

The Lagan Valley area contains extensive subrop of Sherwood Sandstone Group, with thickness up to 300 m. These reservoirs are utilised for groundwater resources and there are already a number of geothermal installations across the Greater Belfast area. The reservoir has further potential for meeting heating and cooling demand and areas to the north would experience greater depth and temperatures giving the reservoir potential for use in community heating with a heat pump. The base of the Sherwood Sandstone is rarely drilled and understanding of the reservoir potential of this part of the unit has come from the nearby Belfast Harbour borehole. High resolution permability allows reservoir quality units to be defined in a largely lithologically uniform sandstone.

Geology map of the Lagan Valley,showing the location of boreholes

Reservoir Quality subdivisions of the lower Sherwood Sandstone Group in the Belfast Harbour borehole (Millar 2018)



Distribution of facies within the Lagan Valley boreholes. From Millar 2018 (using data from Smith 1985). There is a gradual increase in clean porous sandstones towards the south-west.