Hot Sedimentary Aquifer Heat in Scotland – the Guardbridge (Fife) Project

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The GHURUS (Geothermal Heat Undergraduate Research Unit @ St Andrews)

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FIFE GEOTHERMAL

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Geothermal energy projects awarded quarter million

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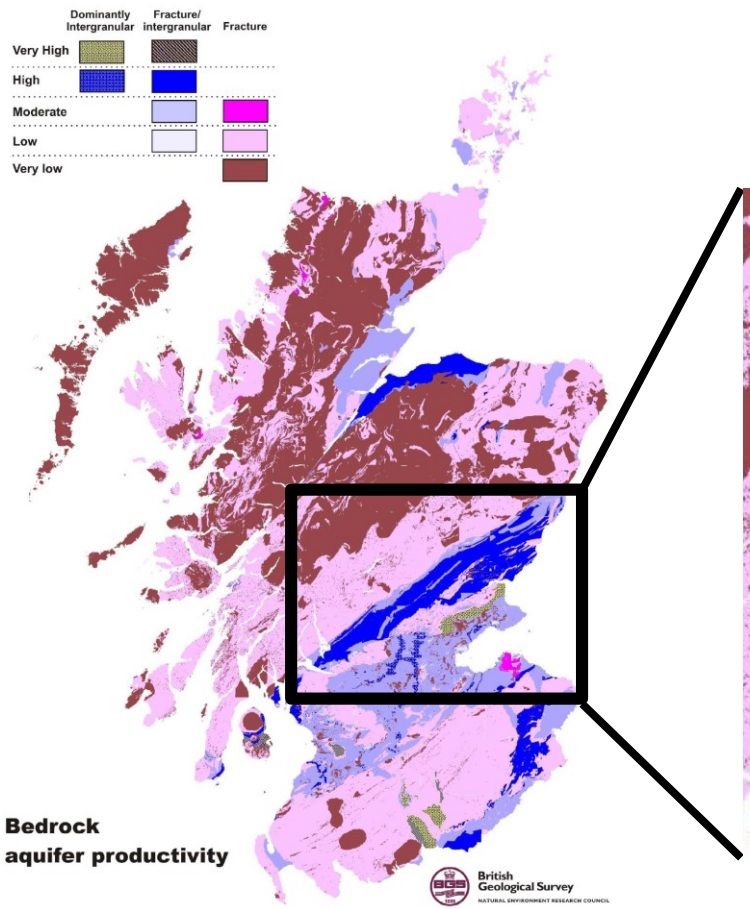
Scotland Agriculture Environment Housing Rural Development

Downloads

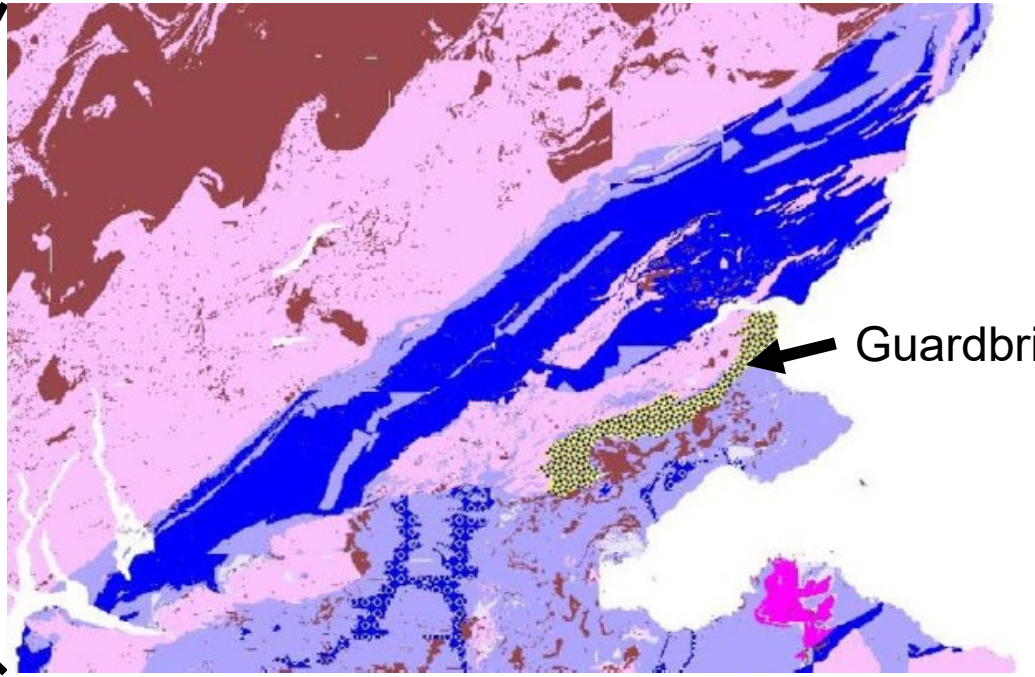
Aberdeen Exhibition & Conference Centre among five schemes planning to harness Scotland's significant energy potential.

- **Aberdeen Exhibition and Conference Centre**: to conduct a feasibility study for the installation of a deep geothermal single well system to provide heat to the new Centre and associated buildings
- **Guardbridge, Fife:** to explore the geothermal potential under a brownfield site to provide heat to on-site industries and the local community
- **Polkemmet, West Lothian:** to establish the feasibility of geothermal heat from mineworkings, which will heat proposed new social housing in the area
- **Hartwood, North Lanarkshire:** to develop a fully operational minewater geothermal district heating system which could act as an exemplar of how to transform farm economics and transfer benefits to local communities
- **Hill of Banchory, Aberdeenshire:** to explore the viability of adding geothermal energy from hot dry and hot wet rocks to the existing renewable heat network that is already serving the local communities

Potential geothermal heat in central Scotland – why Guardbridge?

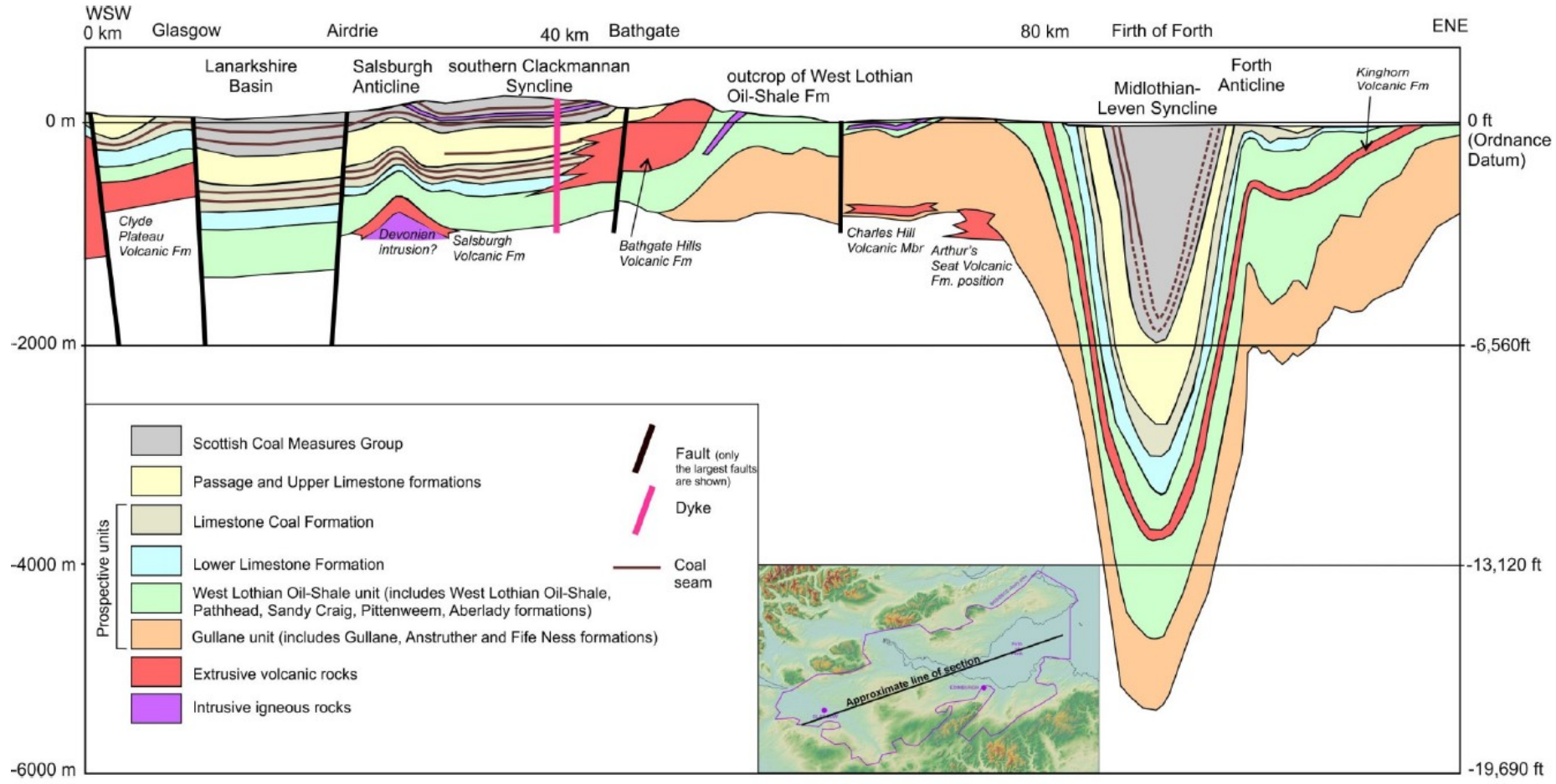


Bedrock productivity map
MacDonald et al. (2004)



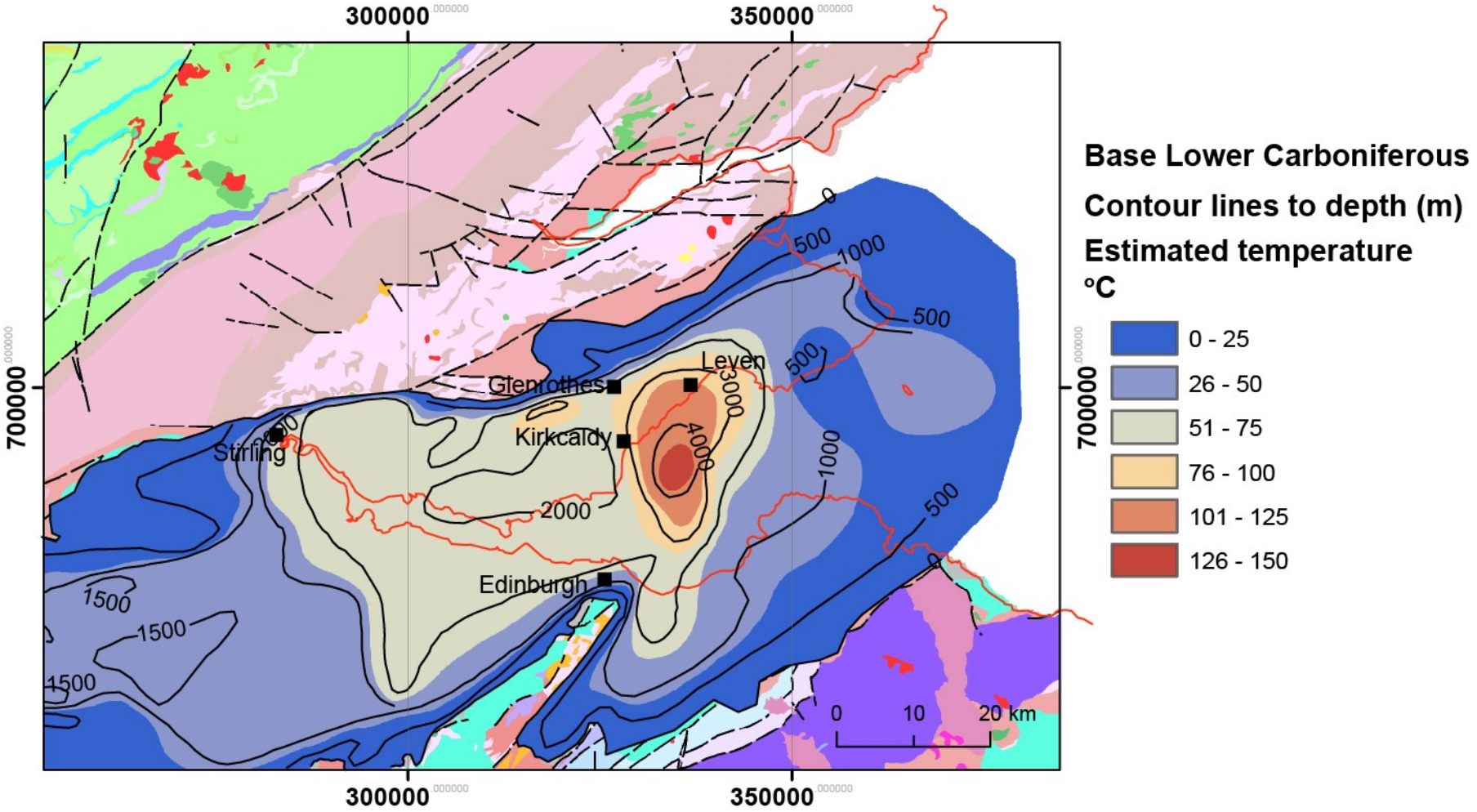
Very productive intergranular aquifers around Guardbridge

Regional significance of geothermal exploration at Guardbridge – sedimentary rocks are folded and reach depths of 4 - 5 km



From Monaghan (2014)

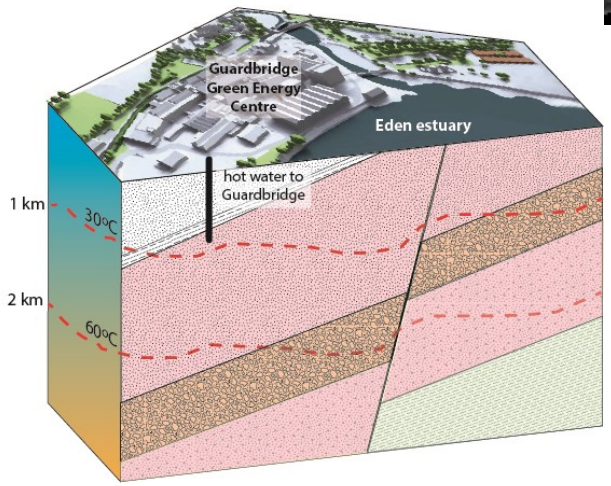
Hot saline aquifer targets are available in Fife near large towns

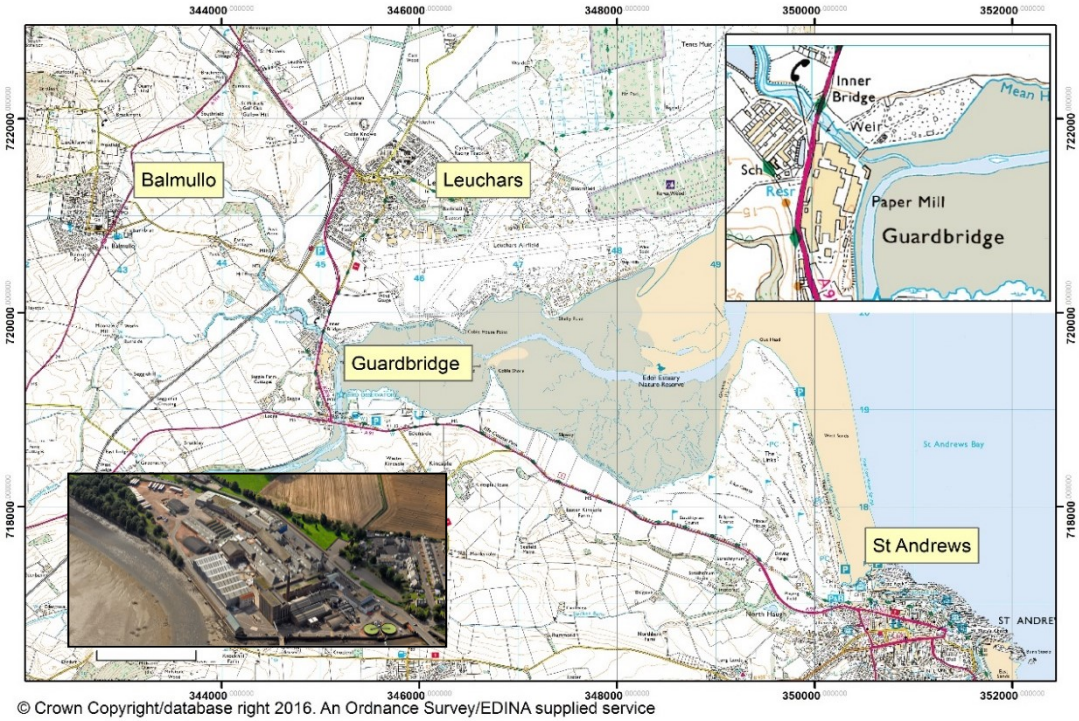


Based on Browne et al.(1985)

Guardbridge Geothermal Demonstrator Project - hot sedimentary aquifer

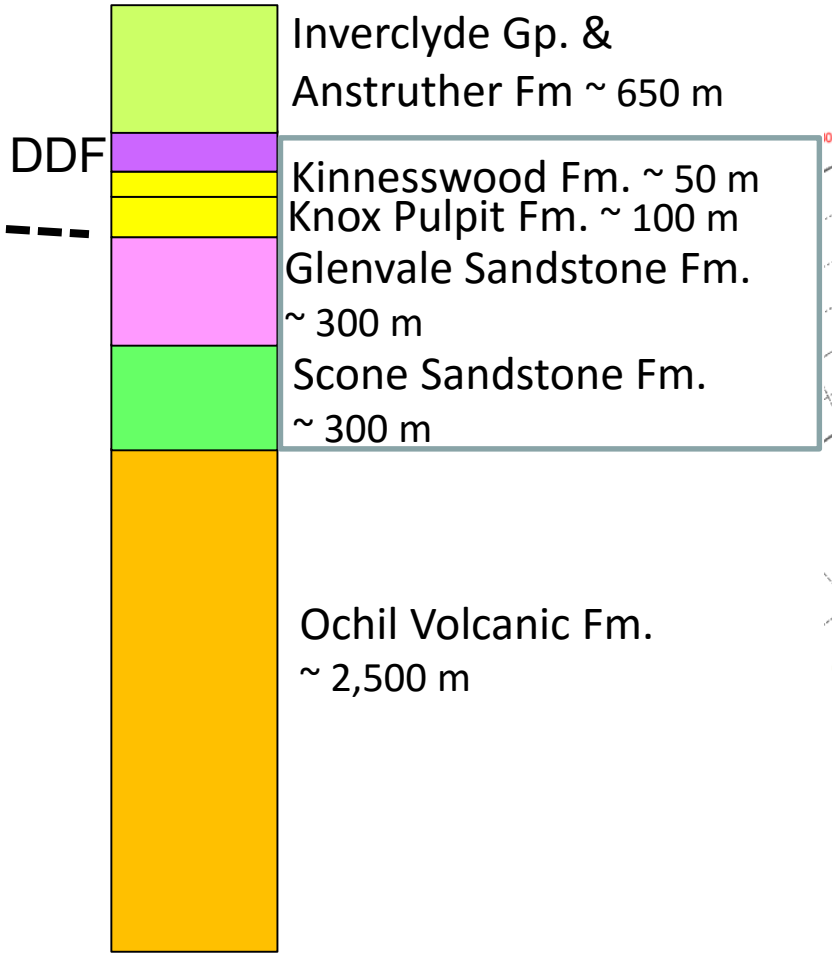
Is a geothermal well supplying heat to a district heating network economically feasible?

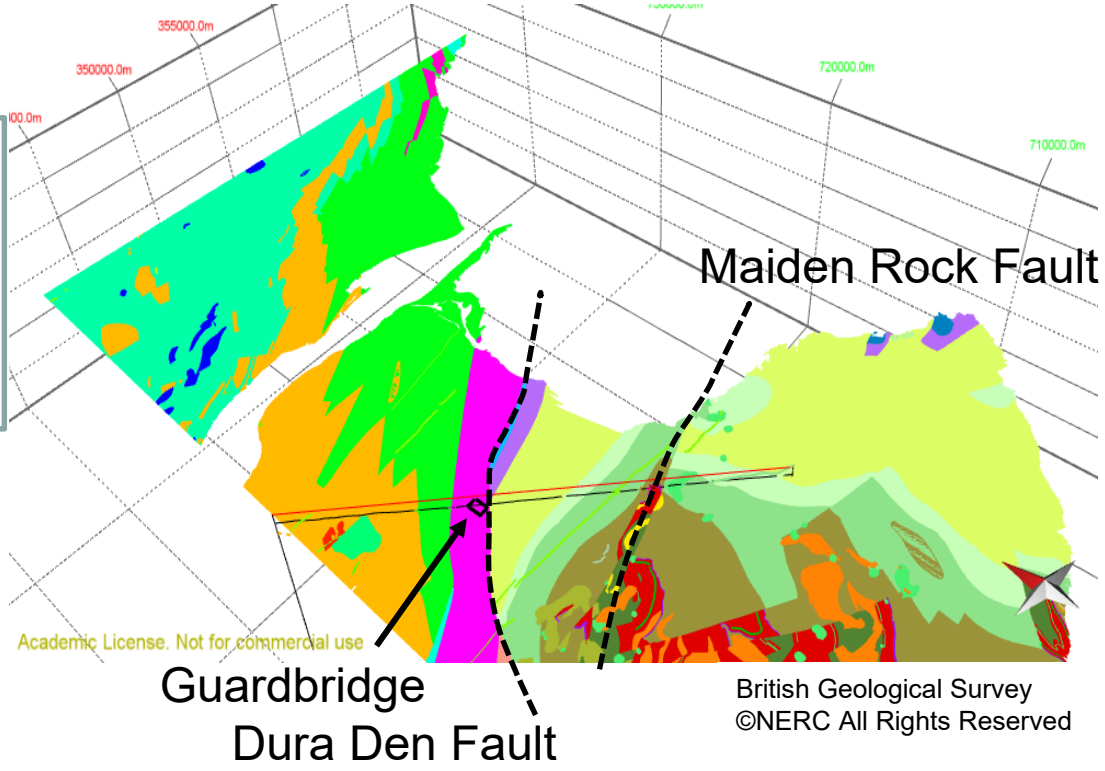




Guardbridge Low Carbon Energy Centre is site of 6.5 MW biomass plant (£25M funding). Heat to the University of St Andrews' buildings.

Guardbridge geothermal feasibility project - the rocks!



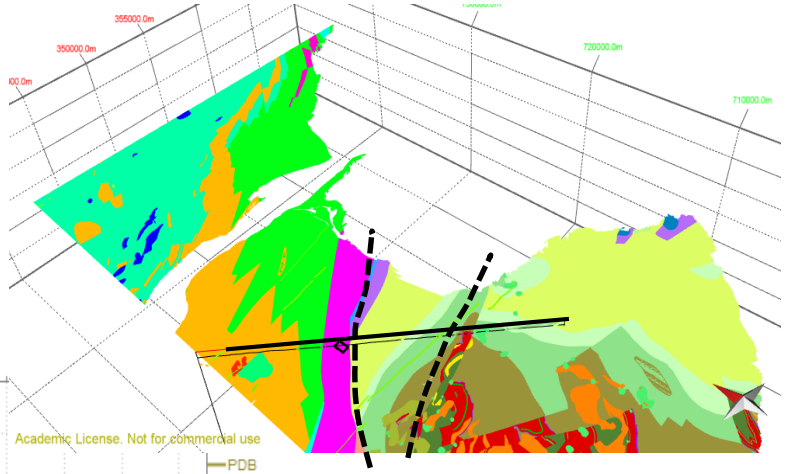


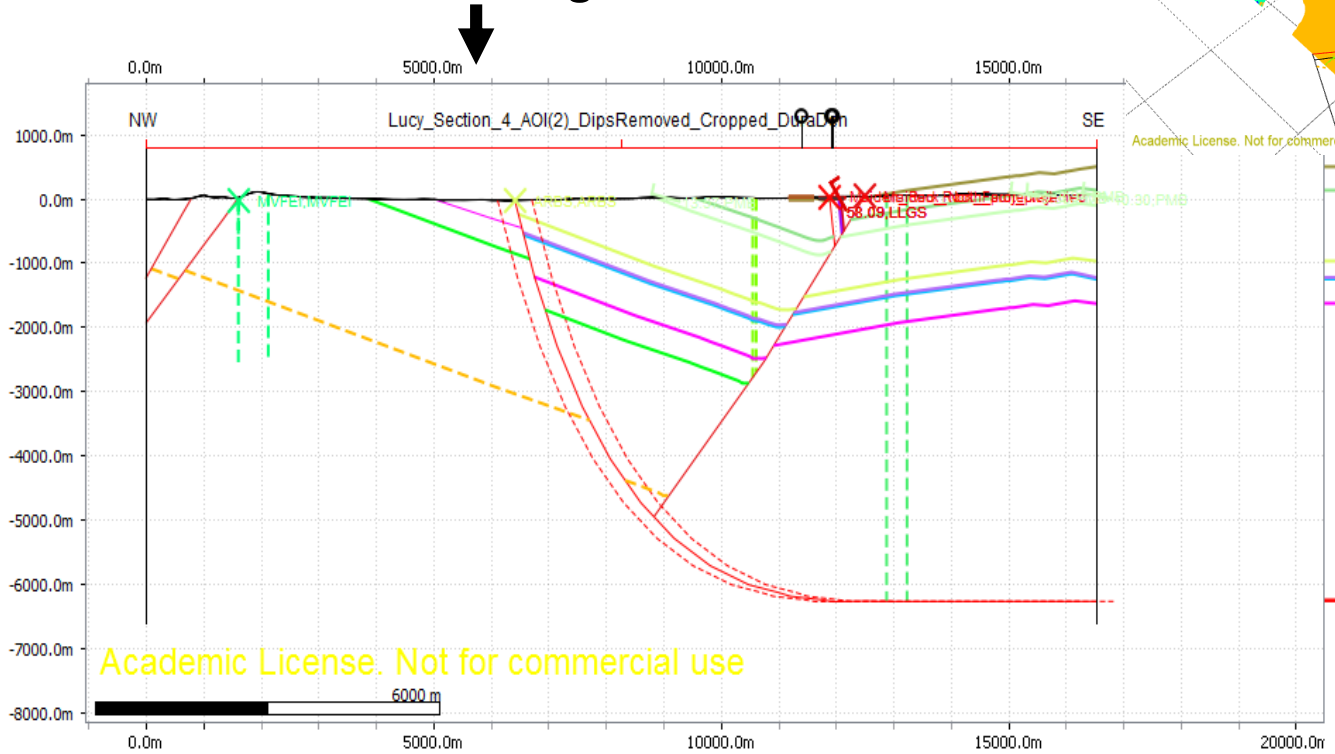
Lucy McKay (U St A) & Rachael Ellen (BGS)

Photo by Sarah Alexander (U St A)

Local – regional geological model

Results relevant to Midland Valley of Scotland



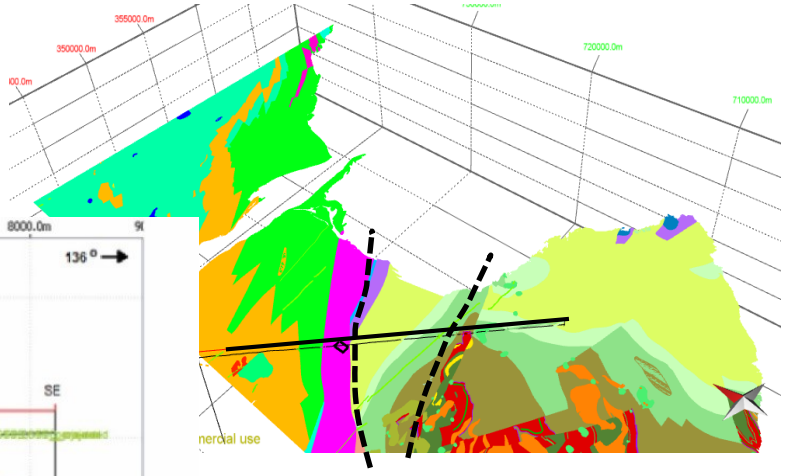


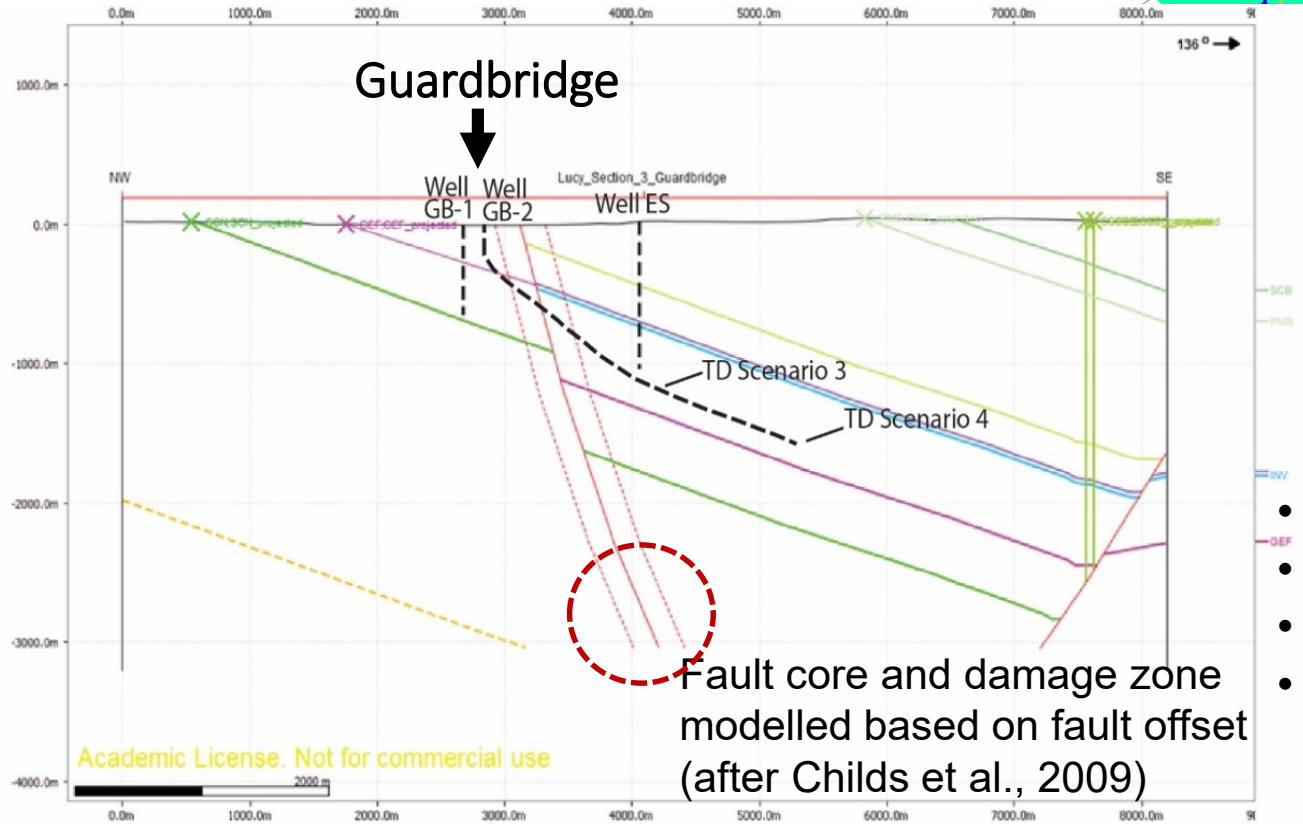
- All available boreholes
- Some new BH coding
- Nothing deeper than 270 m
- Incorporation of existing BGS cross-sections
- McCoss (1987) for fault geometry

Lucy McKay (U St A; now Glasgow) & Rachael Ellen (BGS)

Local – regional geological model

Results relevant to Midland Valley of Scotland

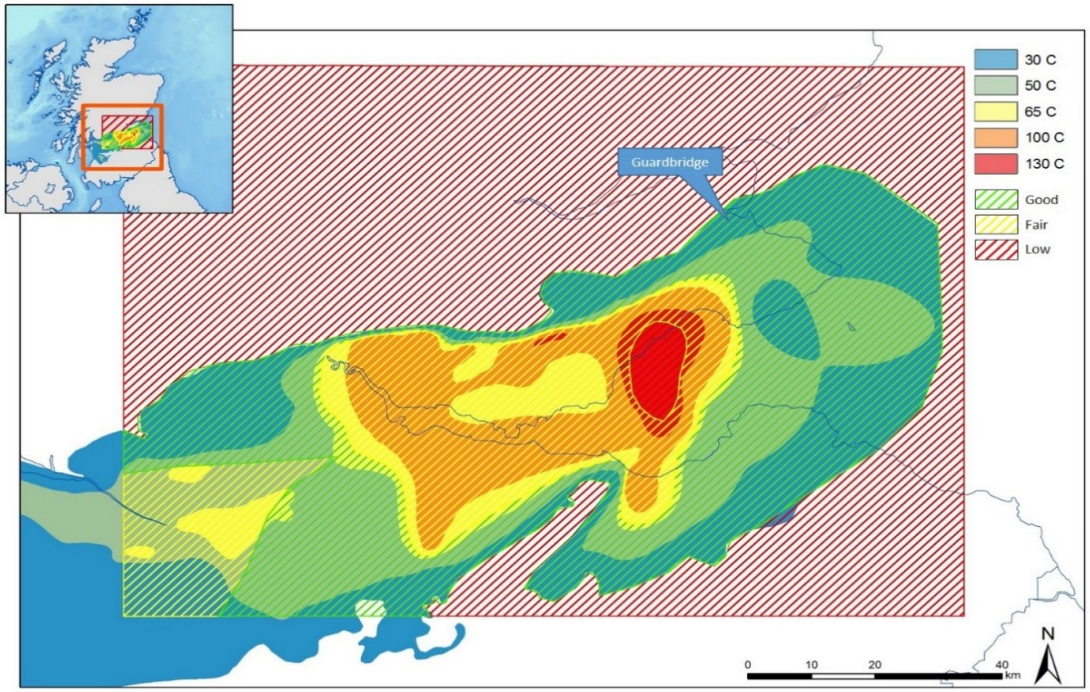




- 3 wells investigated
- GB-1 on site (Scone Ss.)
- ES-1 off site (Knox Pulpit)
- GB-2 deviated well (Knox Pulpit)

Lucy McKay (U St A; now Glasgow) & Rachael Ellen (BGS)

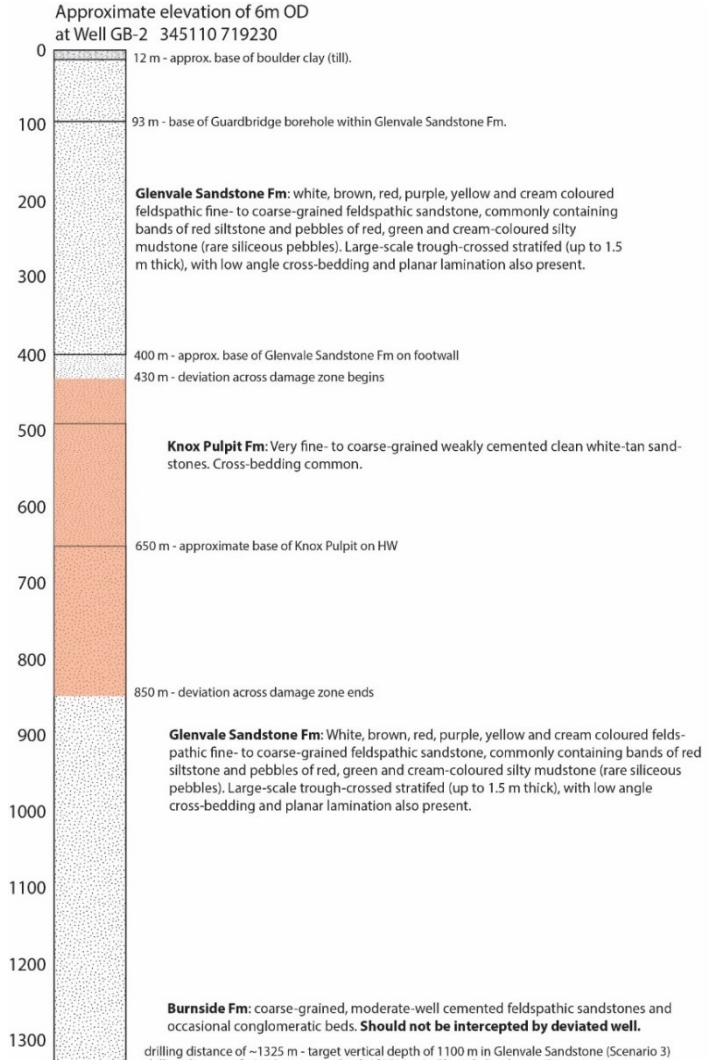
Target aquifer properties: estimating porosity, permeability, and temperature



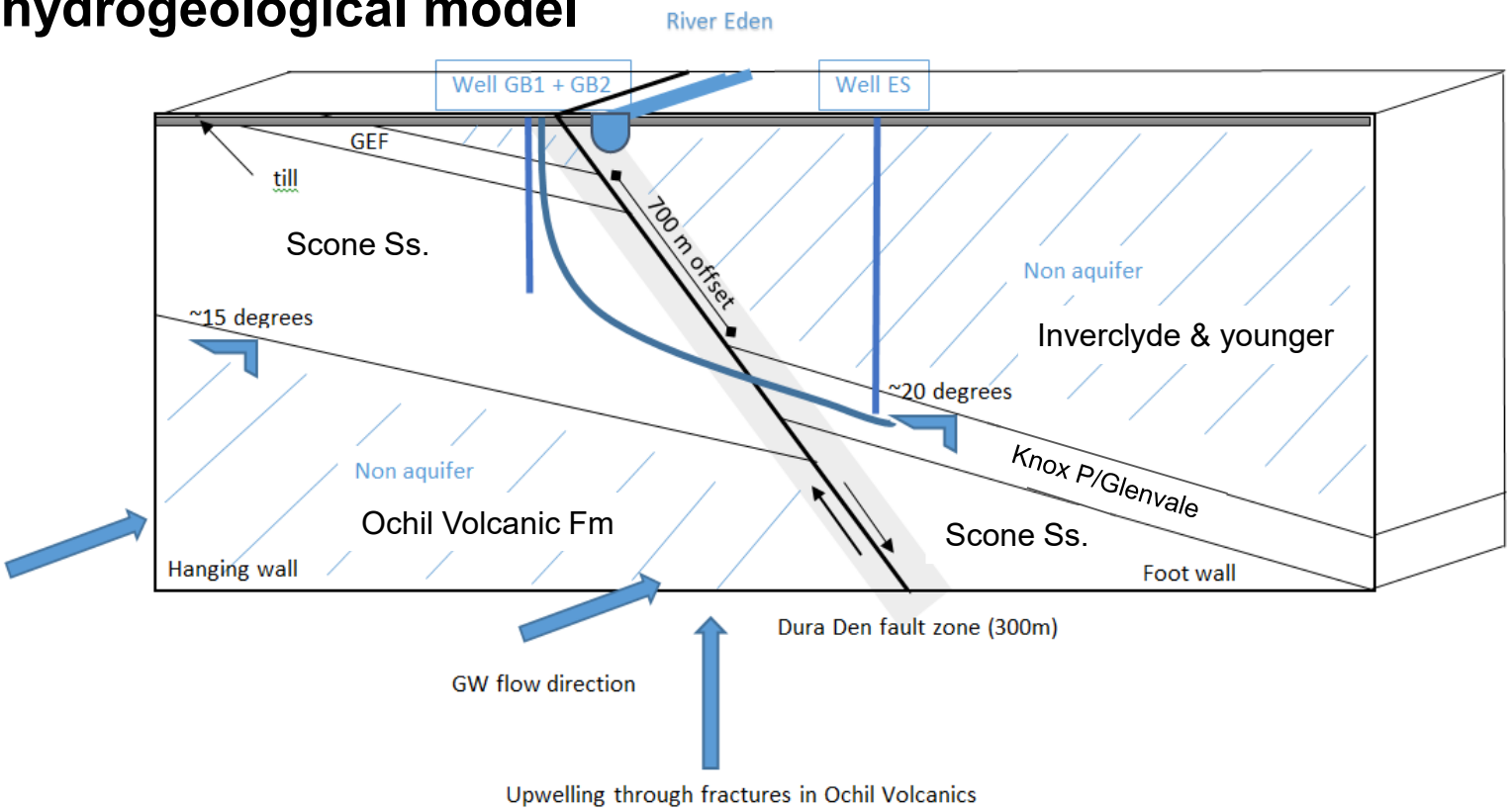
Combined map of estimated aquifer quality and predicted temperature.

Town Rock Energy with University of St Andrews.

Wireline log data, new poroperm measurements, field work.



Local hydrogeological model



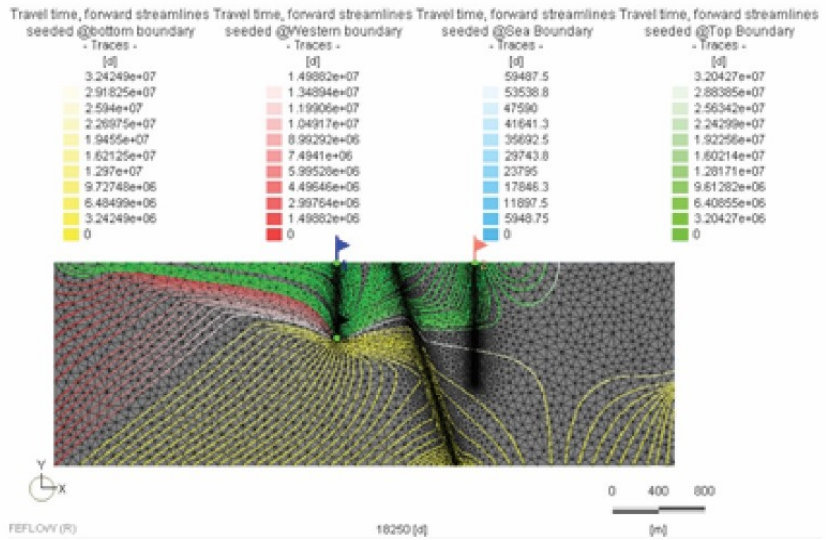
Conceptual hydrogeological model based on geological modelling:

Build numerical model to test hydraulic conductivities (permeabilities) required for economic flow rates using finite element mass and heat transport model called FEFLOW.

MIKE Powered by DHI

Sarah Alexander (U St A; now Birmingham) & Corinna Abesser (BGS)

A.



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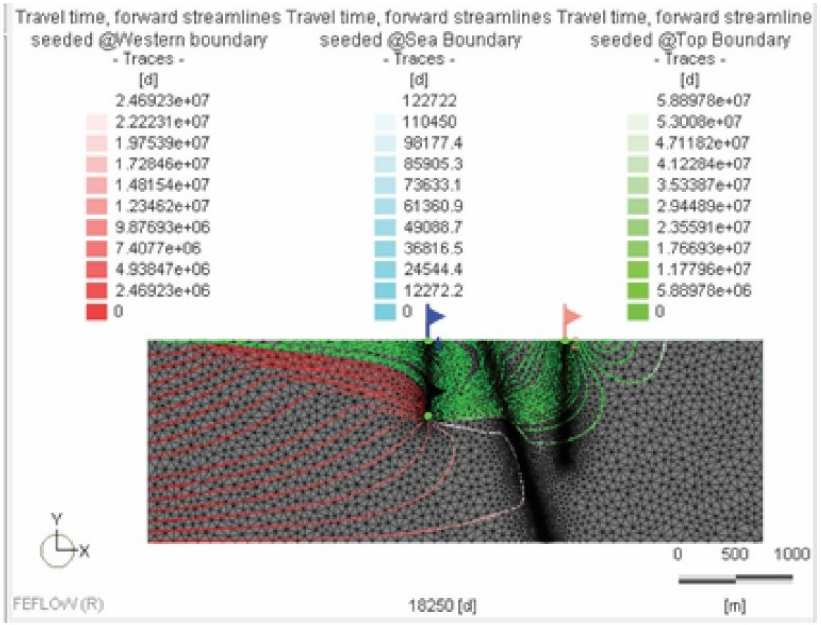
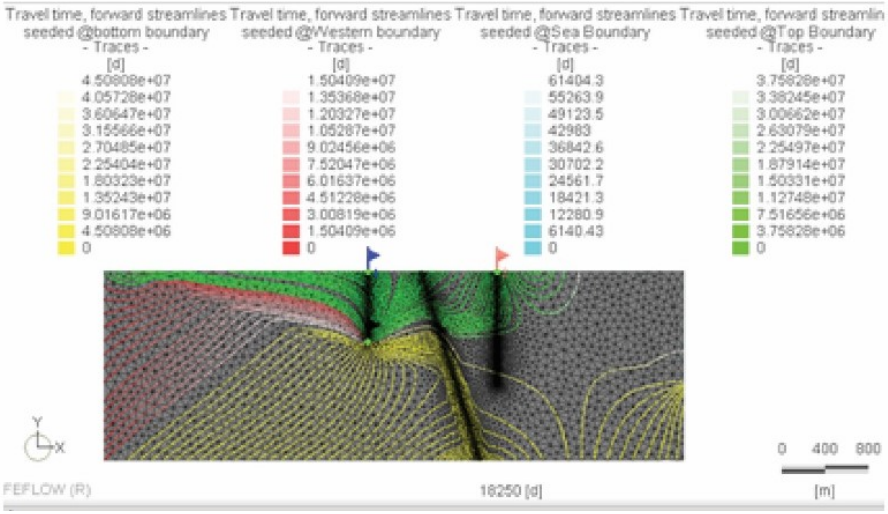


Increasing width of fault and hydraulic conductivity produces faster pathways:

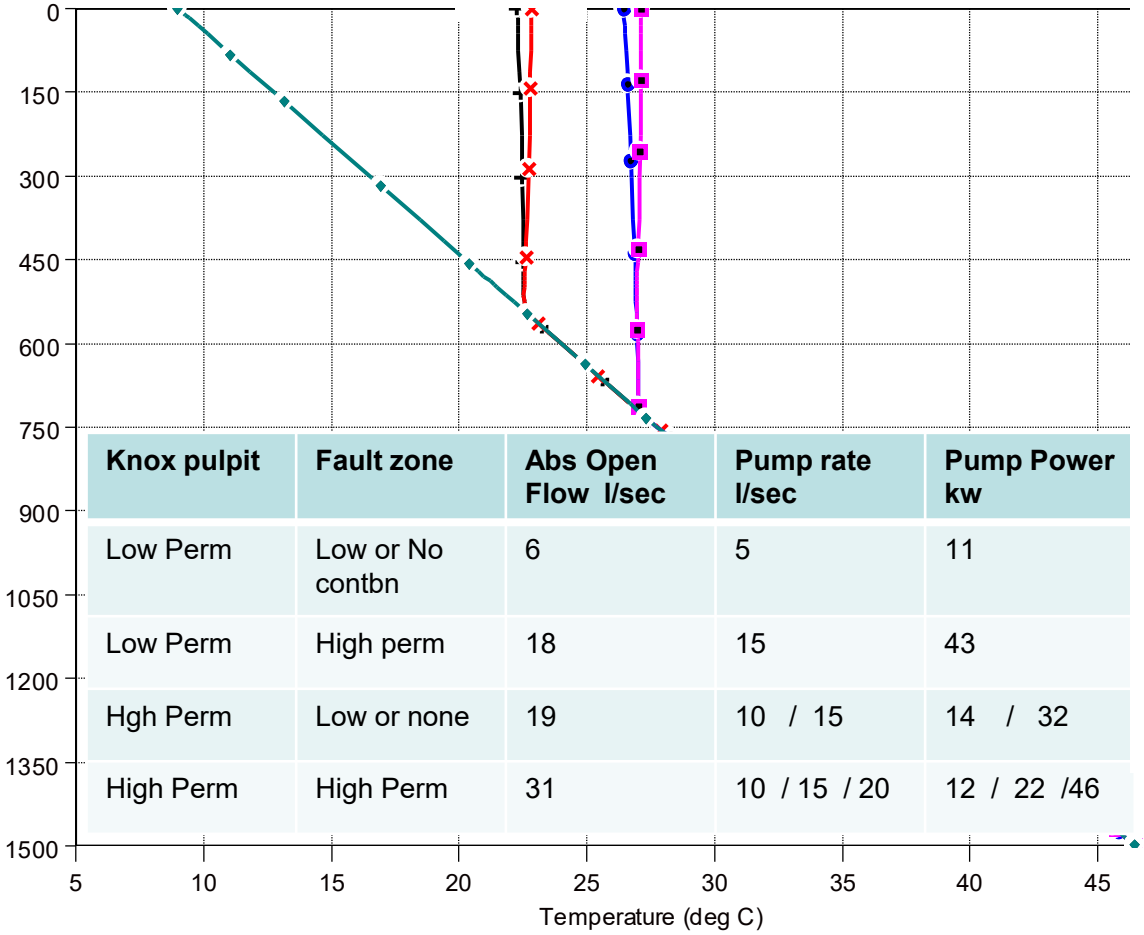
Summary: A sustainable and economic aquifer (15 l/s) requires fracture permeability in rocks and fault zone.

C.



Sarah Alexander (U St A) &
Corinna Abesser (BGS)

Drilling strategy and options – oil and gas methodologies

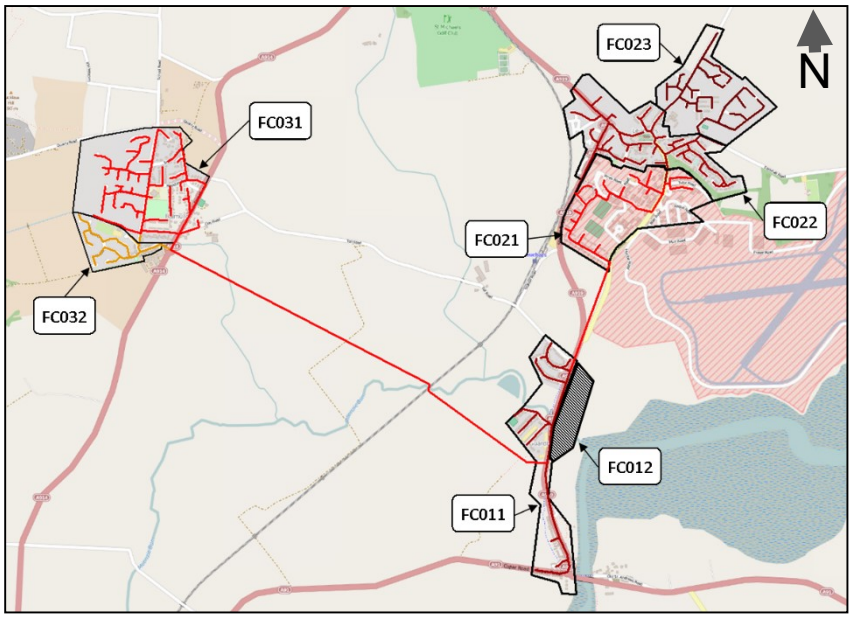


Knox pulpit	Fault zone	Abs Open Flow l/sec	Pump rate l/sec	Pump Power kw
Low Perm	Low or No contbn	6	5	11
Low Perm	High perm	18	15	43
Hgh Perm	Low or none	19	10 / 15	14 / 32
High Perm	High Perm	31	10 / 15 / 20	12 / 22 /46

Summary:

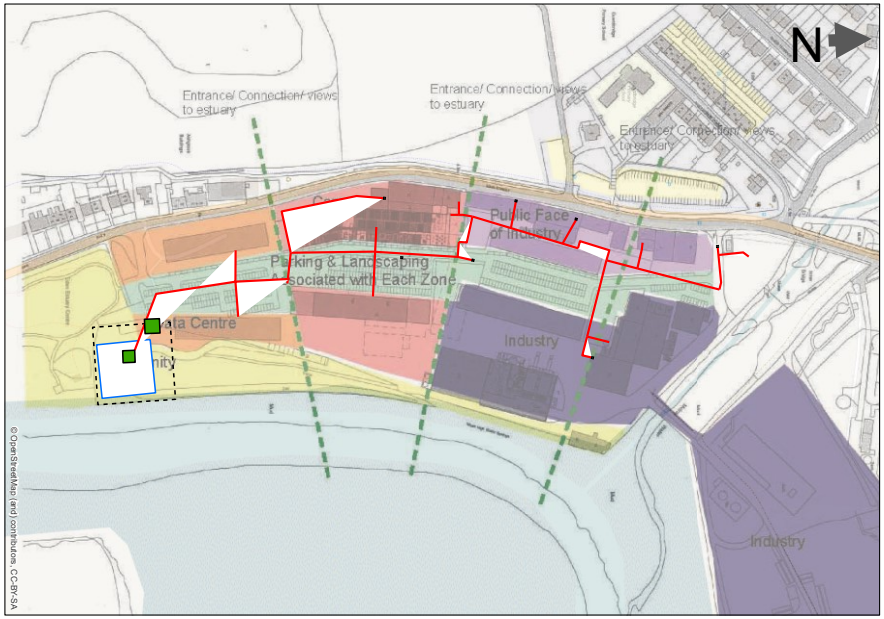
- Deviated well with submersible pump
- 1000 – 1200 metres well depth (TVD)
- 2 scenarios for flow rates – 5l/s & 15l/s
- 11 kw ESP or 22-43 kw pump required
- Output temperature of 23 – 27°C
  - 139 kW to **418 kW** of heat output
- Heat pump delivering **75°C** (COP = 4)
- Drilling costs - £750k - £1.1m (P90-P10)
- Well completion and flow tests - £150k

Where is the heat demand?



Potential district heat network for Guardbridge site, Guardbridge village, Leuchars and Balmullo.

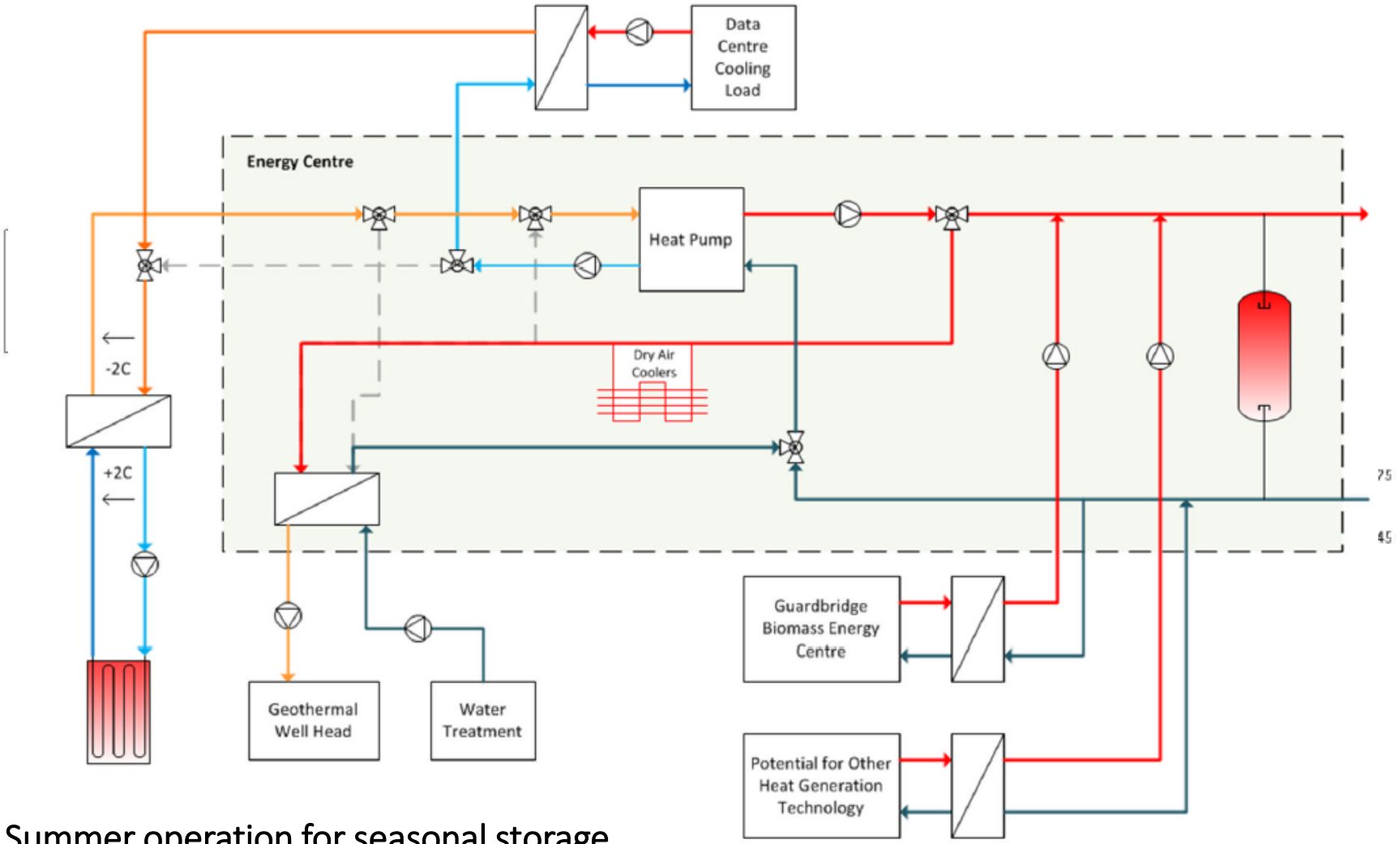
Guardbridge site deemed economically feasible for the one well option.



DHN network design (red lines) for the proposed development at the Guardbridge Low Carbon Energy Centre.

Heat pump and DHN CAPEX - £530k
Total CAPEX ~ £2.2M

Energy centre design – integrated sources and combined heating/cooling



Summer operation for seasonal storage

Carbon emissions reductions?

Carbon emissions reductions from district heating compared to individual gas boilers

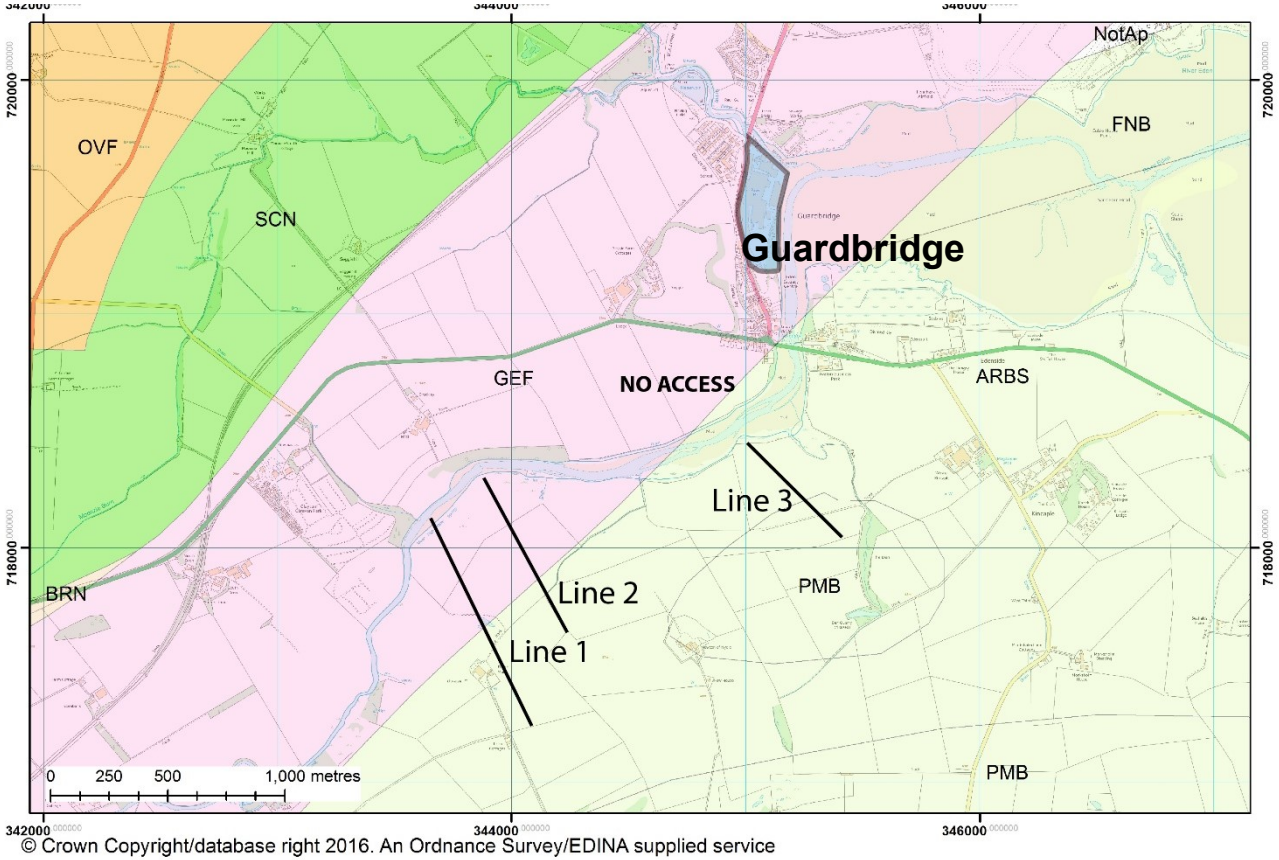
20 Year Lifecycle Carbon Emissions Reduction		
Total CO_2 emission district heating	4,677	Tonnes
Total CO_2 emission baseline (gas boilers)	28,574	Tonnes
Saved CO_2 emission district heating compared to baseline	23,987	Tonnes

- 84% reduction in emissions based on combined geothermal heat pumps and biomass plant

LCITP Phase 2: Development Stage

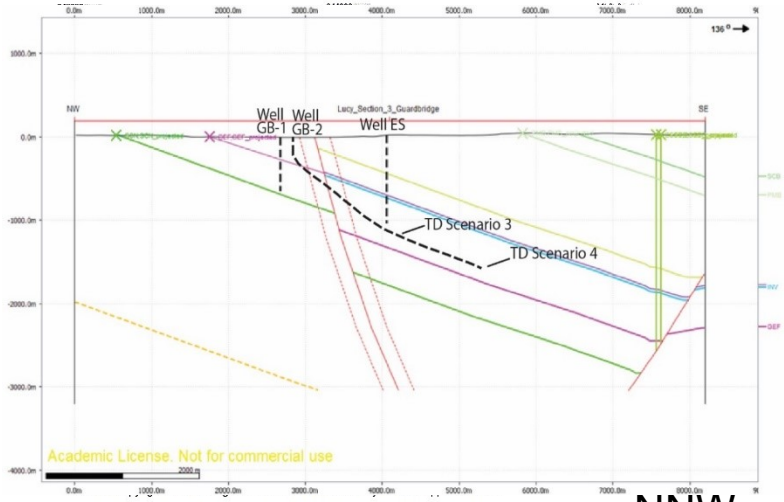
How do we start to reduce the risks associated with drilling?

1. Geophysical survey of the geothermal resource (moderately deep reflection seismic)
2. Review/revise well design and drilling CAPEX
3. Proceed to production or test borehole based on survey outcome

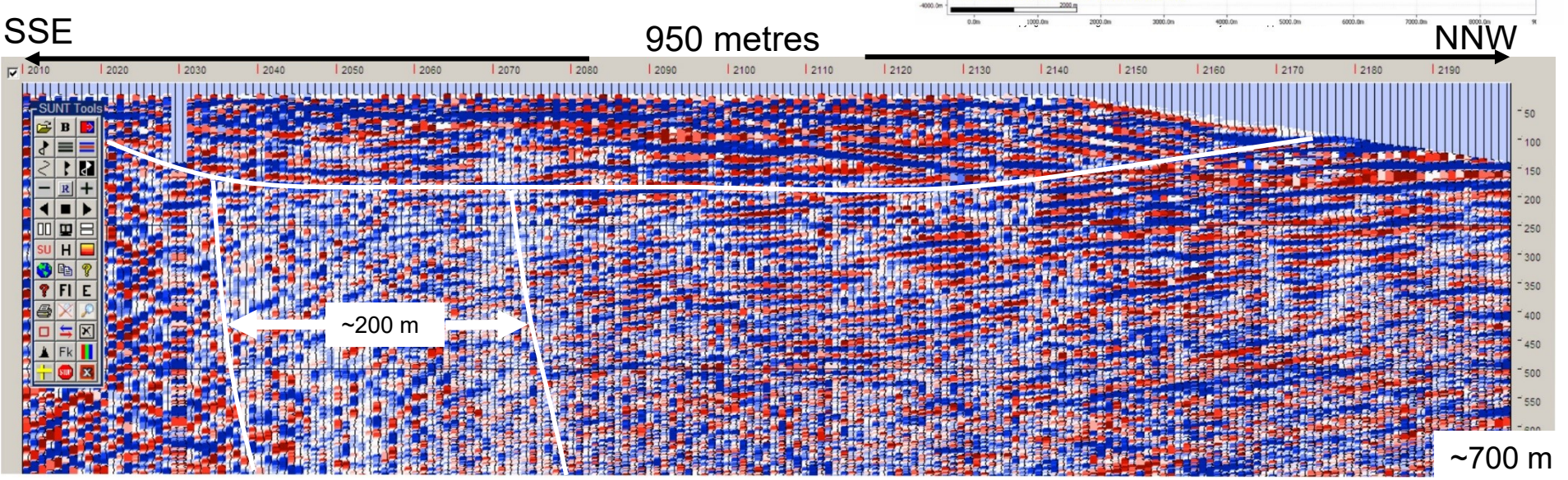


LCITP Phase 2: Development Stage
How do we start to reduce the risks associated with drilling?

TERRA DAT
geophysical innovation



Line 2 – crude stacking, preliminary processing



University of St Andrews
TOWN ROCK ENERGY
RAMBOLL
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL
resource efficient solutions

Thanks to:

Ed Stephens

Richard Bates

Lucy McKay

Sarah Alexander