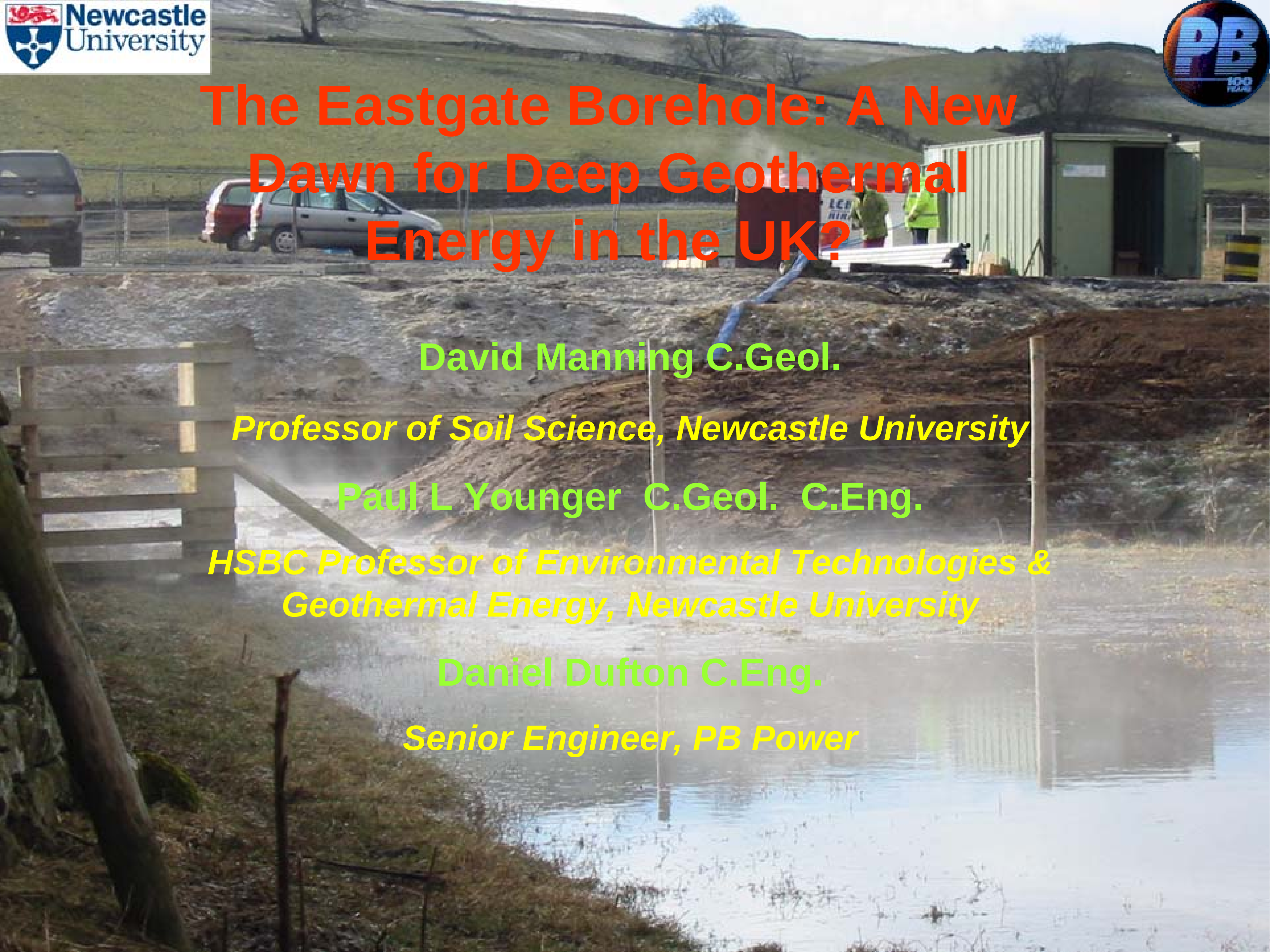

The Eastgate Borehole: A New Dawn for Deep Geothermal Energy in the UK?

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- **Wear Valley District Council**
- **LaFarge plc**

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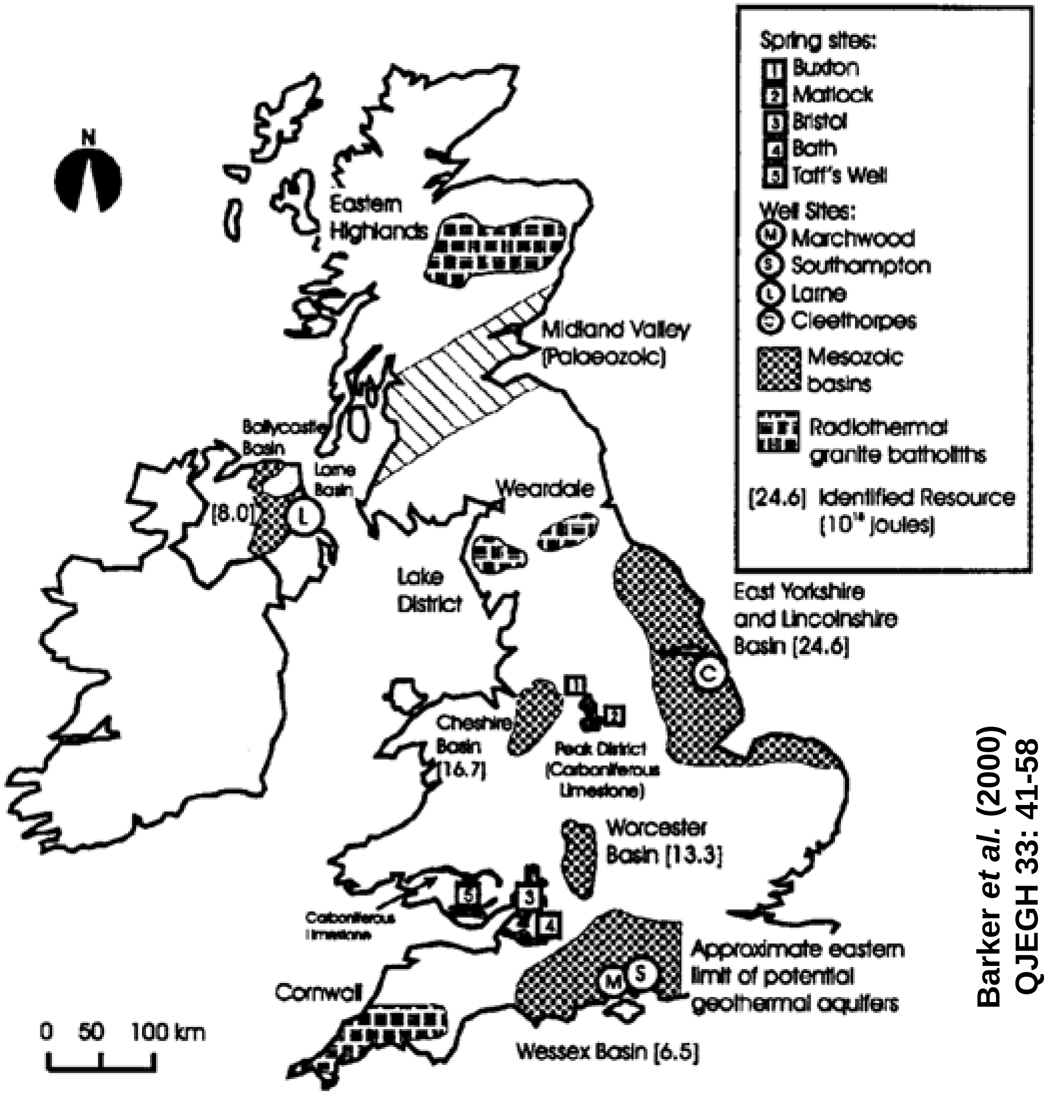
UK Deep Geothermal Prospects



Barker *et al.* (2000)
QJEGH 33: 41-58

Deep Geothermal Energy in the UK

- The story so far …

    - 1970s Oil Crisis panic response ….

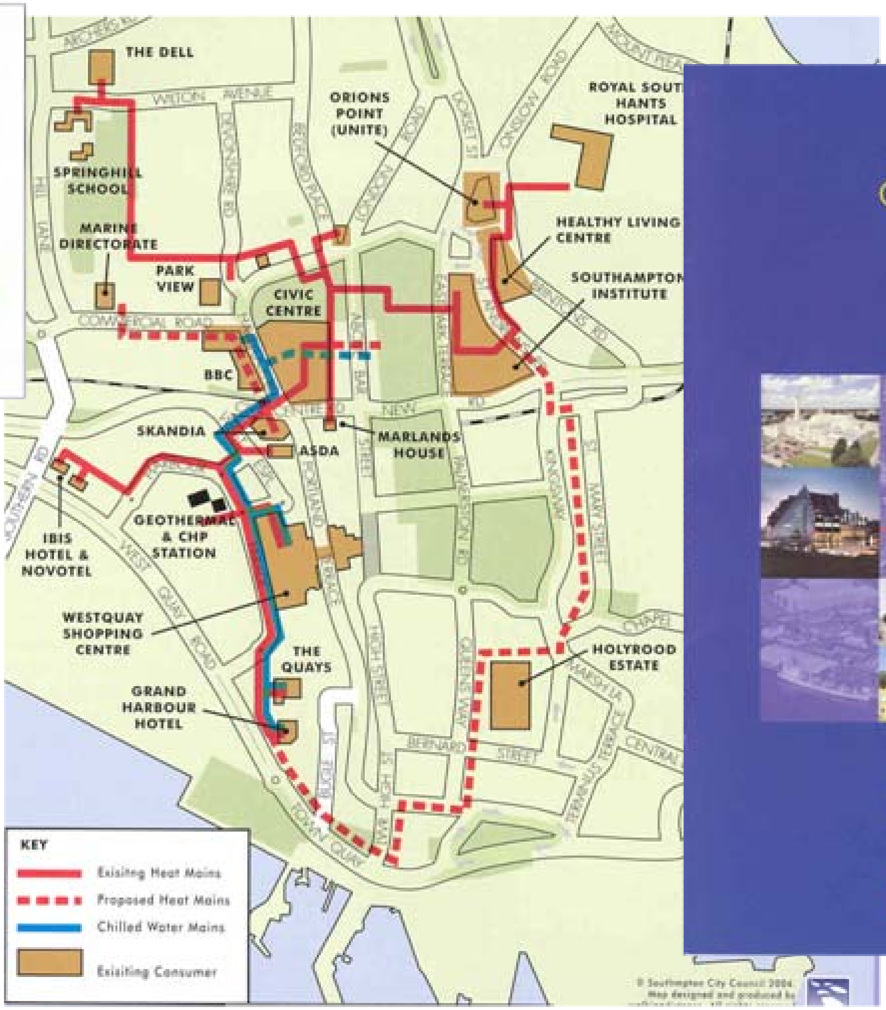
        - Hot Dry Rock (HDR) – Cornish experiments

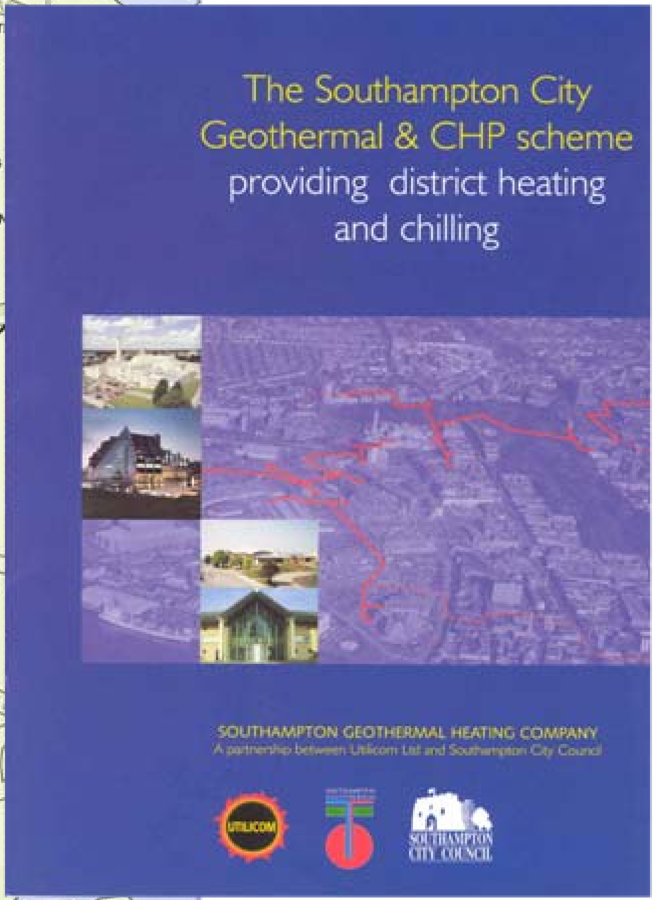
        - Low-enthalpy resources: “geothermal aquifers” in Mesozoic basins

Reasons to be cheerful about geothermal energy in the UK

- The Southampton Geothermal Heating Company
- The changing world climates (i.e. real ones and political ones …)
- Technological innovations: heat pumps and borehole heat exchangers
- The Weardale perspective: our ancient hydrothermal systems are not extinct!

The Southampton Geothermal Heating Company






SOUTHAMPTON
GEOTHERMAL HEATING
COMPANY LIMITED

Lessons from Southampton

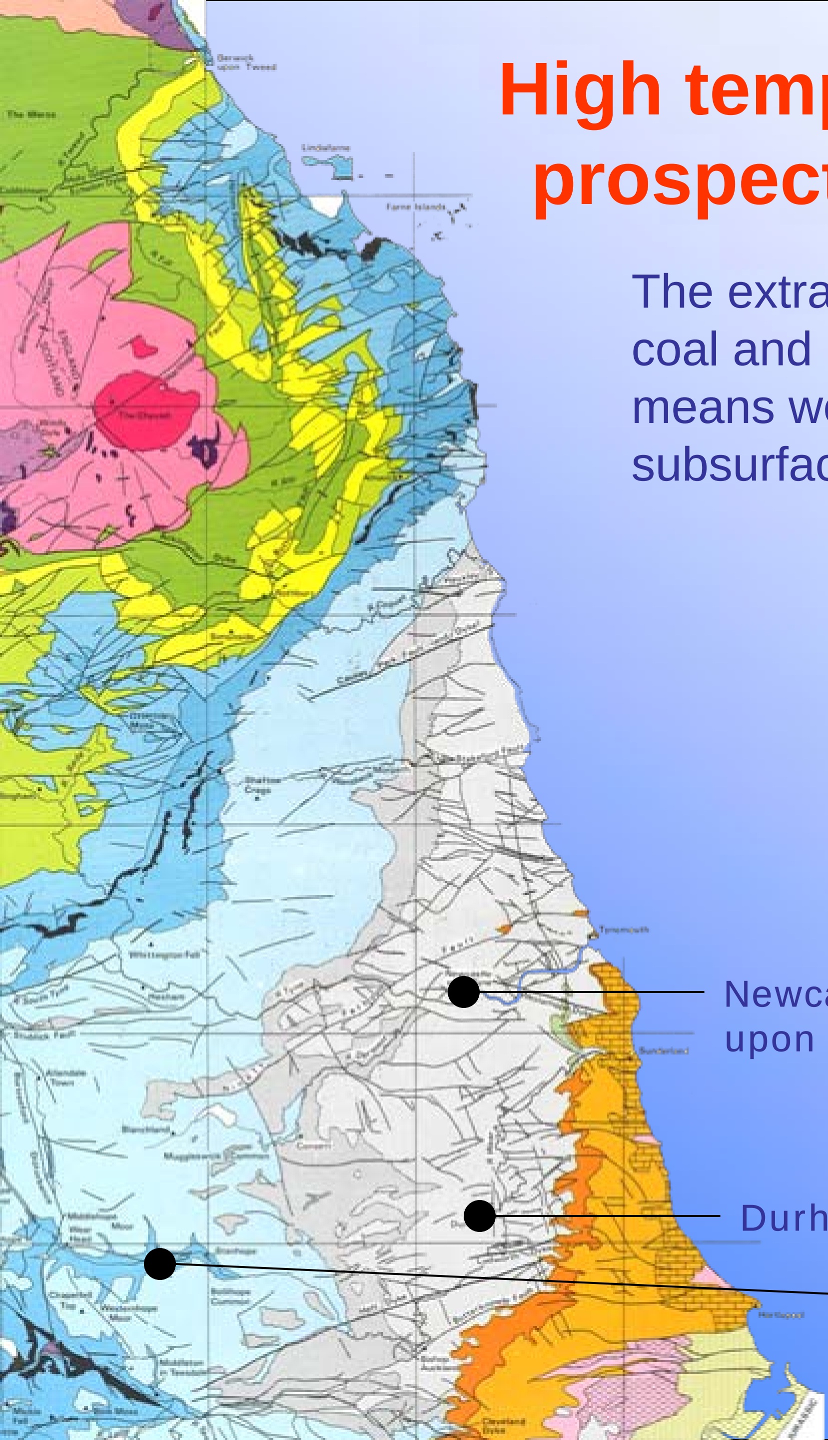
- Even modest geothermal resources have the potential to provide significant district heating, with major savings in carbon emissions (e.g. 10Kt/yr in Southampton case)
- Geothermal energy captures the imagination of the public and consumers, and thus provides the vanguard for other new and renewable sources of combined heat and power generation (CHP) (e.g. further 20 MW in Southampton)
- Geothermal space heating works for retrofits, and is cheaper than alternatives (~ £250K / yr cheaper than fossil fuel sourced energy in Southampton at present)

The Eastgate Geothermal Exploration Project

2003-2006

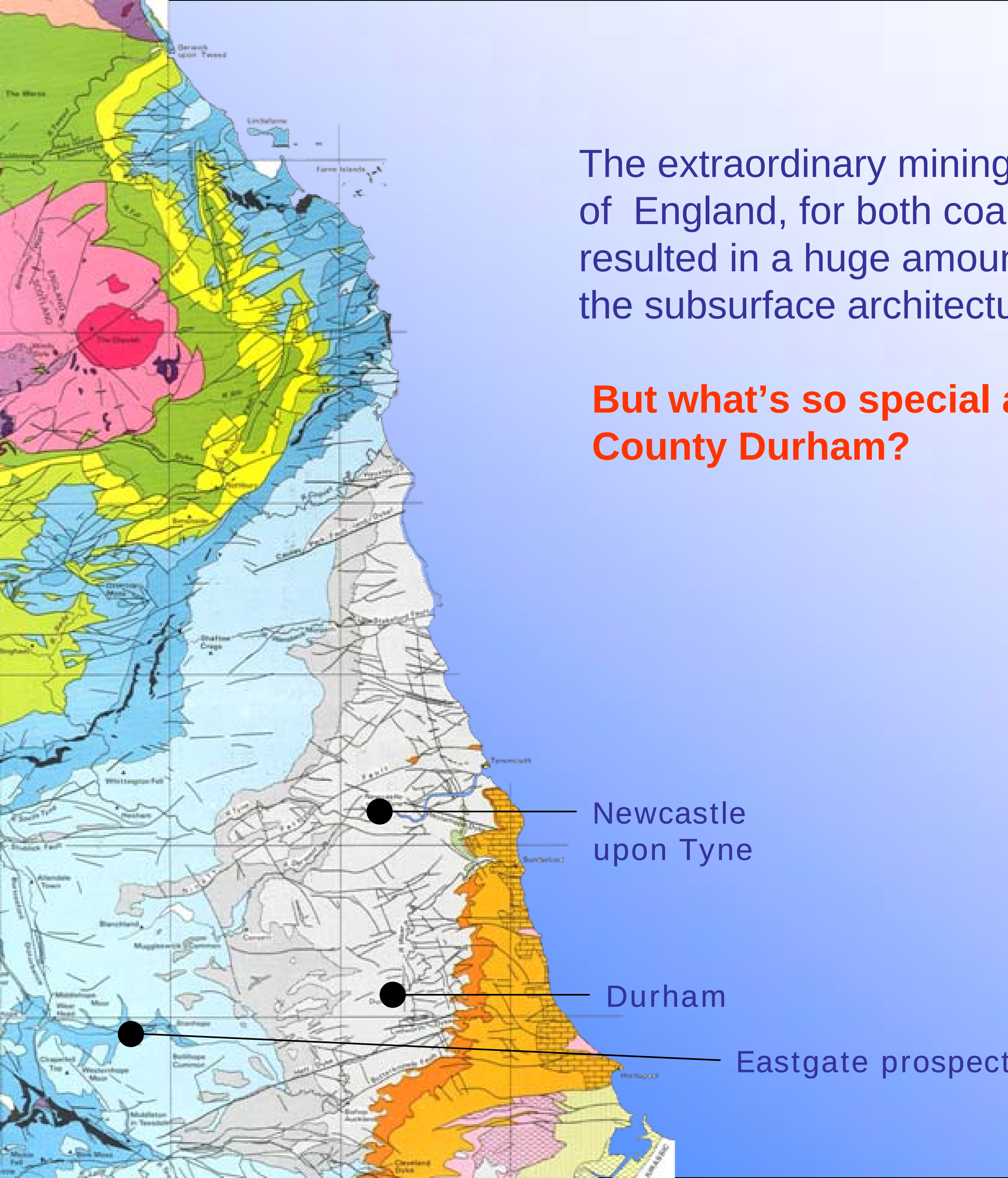
High temperature geothermal prospects in the North East

The extraordinary mining history of mining (both coal and Pb-(F-Zn)) in the north-east of England, means we know a huge amount about the subsurface architecture of the region



The extraordinary mining history of the north-east of England, for both coal and Pb-(F-Zn), has resulted in a huge amount being known about the subsurface architecture of the region

But what’s so special about Tyneside and County Durham?

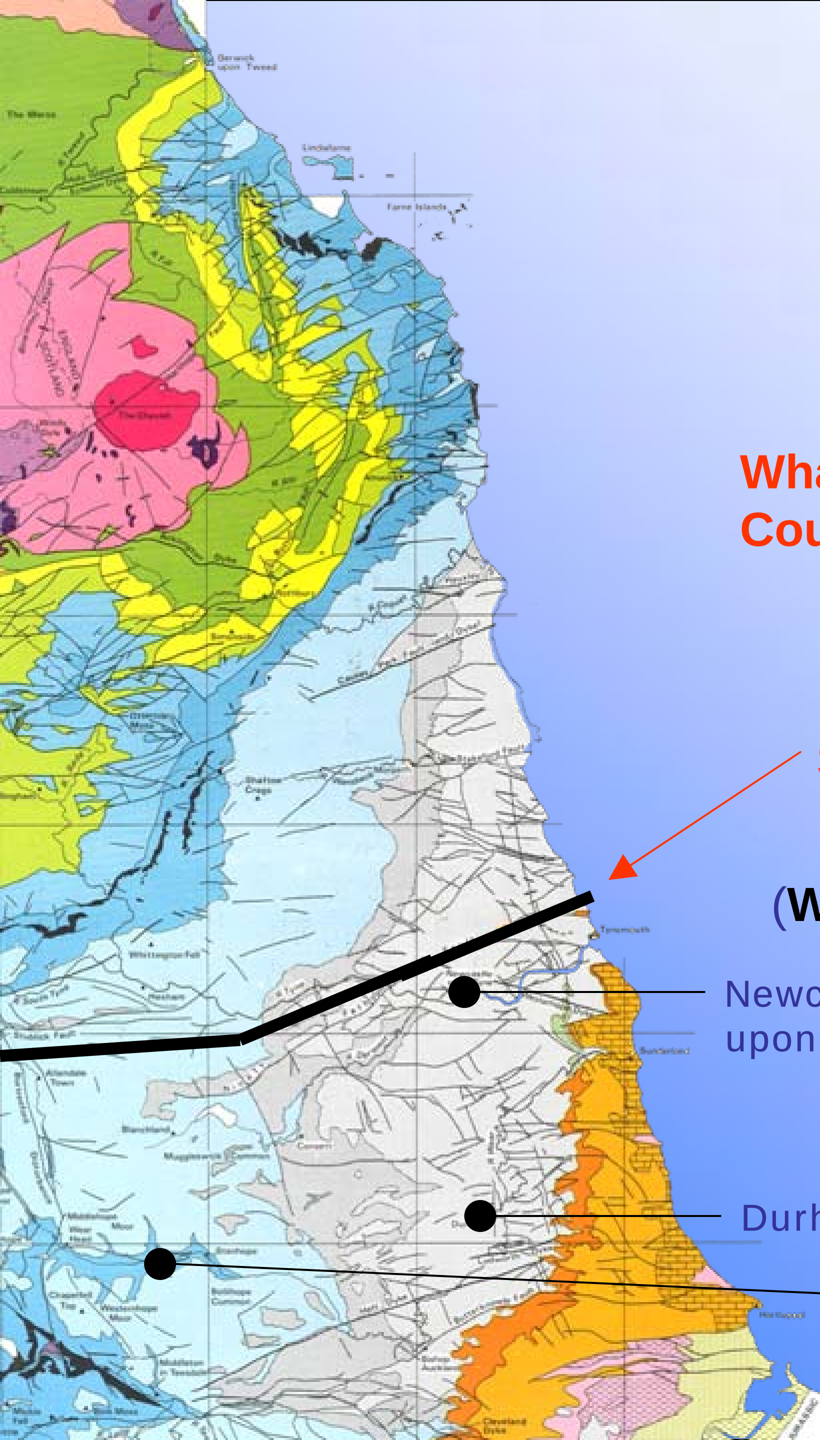


What's so special about Tyneside and County Durham?

North of fault: deep trough filled with > 4.5km of sedimentary rocks.

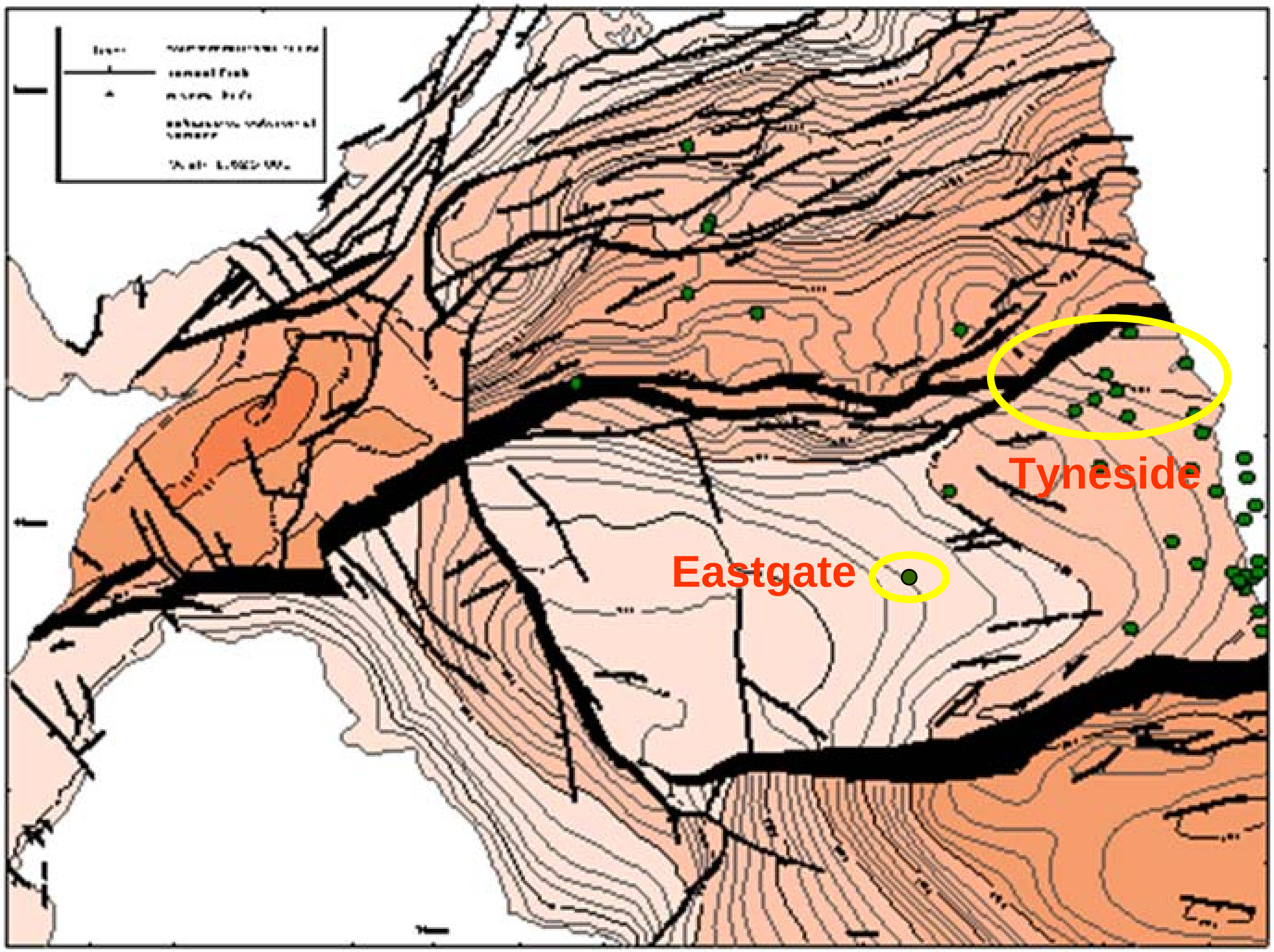
STUBLICK – 90 Fm FAULT SYSTEM

South of fault: deep basement rocks (**Weardale Granite**) closest to the surface.



Mine water investigations over the years have revealed the presence of highly mineralised waters at relatively shallow depth (< 1200m) with chemistries explicable only in terms of equilibration with country rock at much higher temperatures (and pressures)

Mine waters with chemistries indicative of highest temperatures

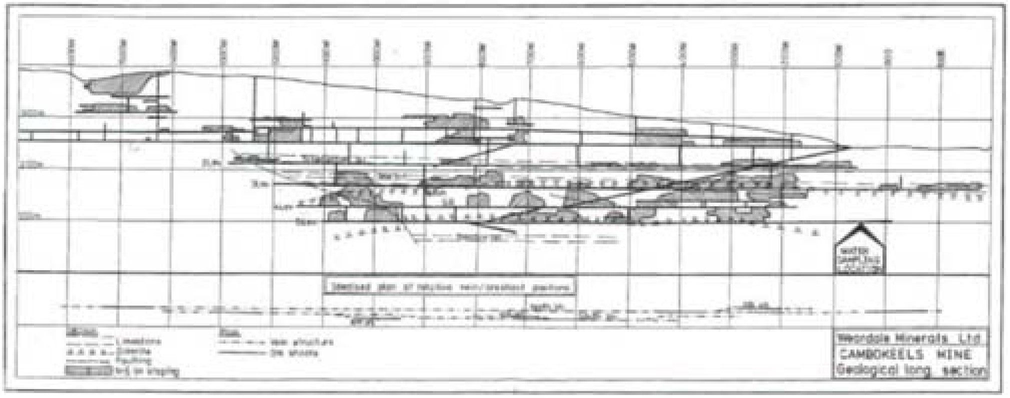


Orla Fitzpatrick MSc project 2003
British Geological Survey base map

Cue the redevelopment project

- **Closure of the Blue Circle Cement Works (Eastgate, Weardale) has prompted the development of plans for regeneration of the large industrial site as the UK’s first ‘model renewable energy village’**
- **We suggested that there was a credible geothermal prospect beneath the site**
- **Exploration funding (£460K) was granted …**

The target: Slitt Vein (Cambokeels Mine)



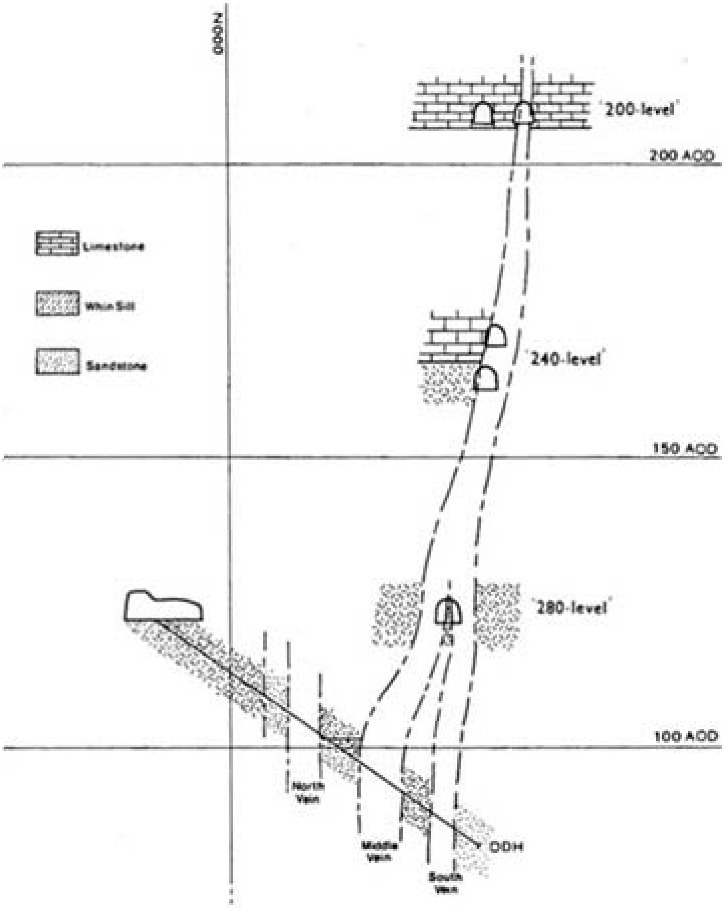


Fig.3.iii
CROSS SECTION of VEIN and MAIN LEVELS at 800.W. Cambokeels Mine

Slitt Vein, Cambokeels Mine

•- Presence of a persistent feeder of tepid (16°C), highly mineralised water (38,000 mg/l TDS) in eastern forehead of workings (only ~ 50m below River Wear) during last period of working of mine (noted by Dunham)

•- Thorough geochemical analysis of this water in late 1980s provided basis for geothermometric modelling (see Manning & Strutt, 1990, *Min. Mag*., 54, 629 - 636)

-- Finding: This water equilibrated at about 160°C, presumably somewhere at depth in / near Slitt Vein structure

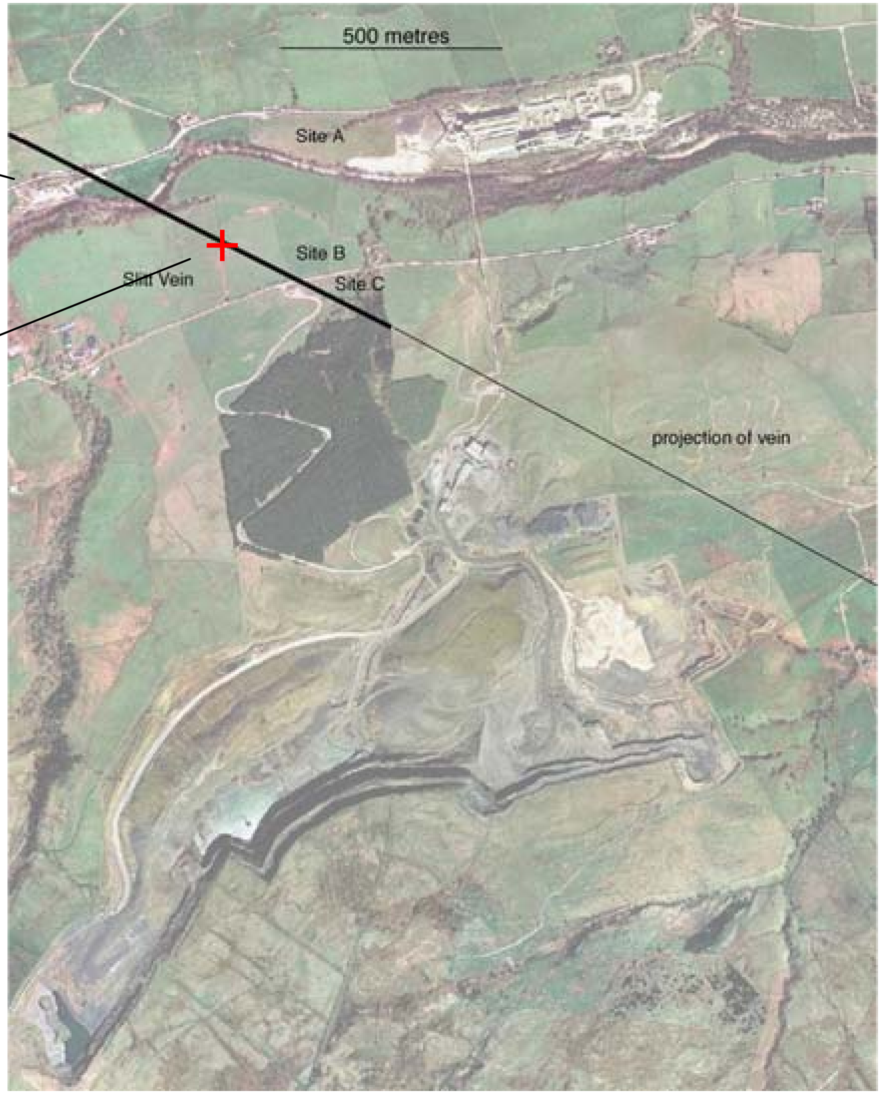
-- Recent analysis shows that this water still forms a component of present-day mine water outflow from flooded Cambokeels workings

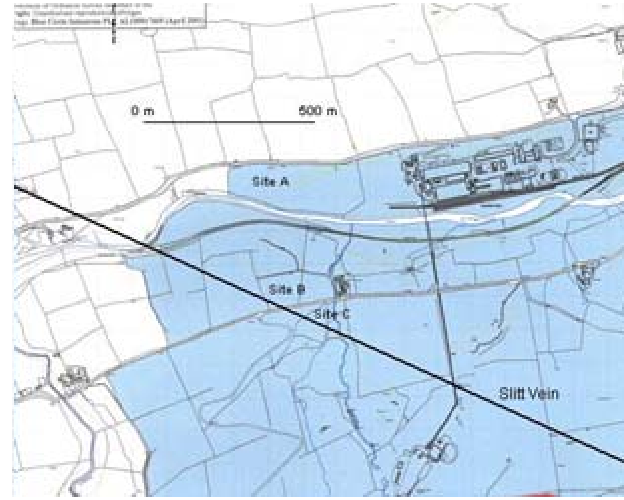
-- The Slitt Vein passes right beneath Lafarge-owned land to SE of river near Cambokeels – thought to be unmined in this area

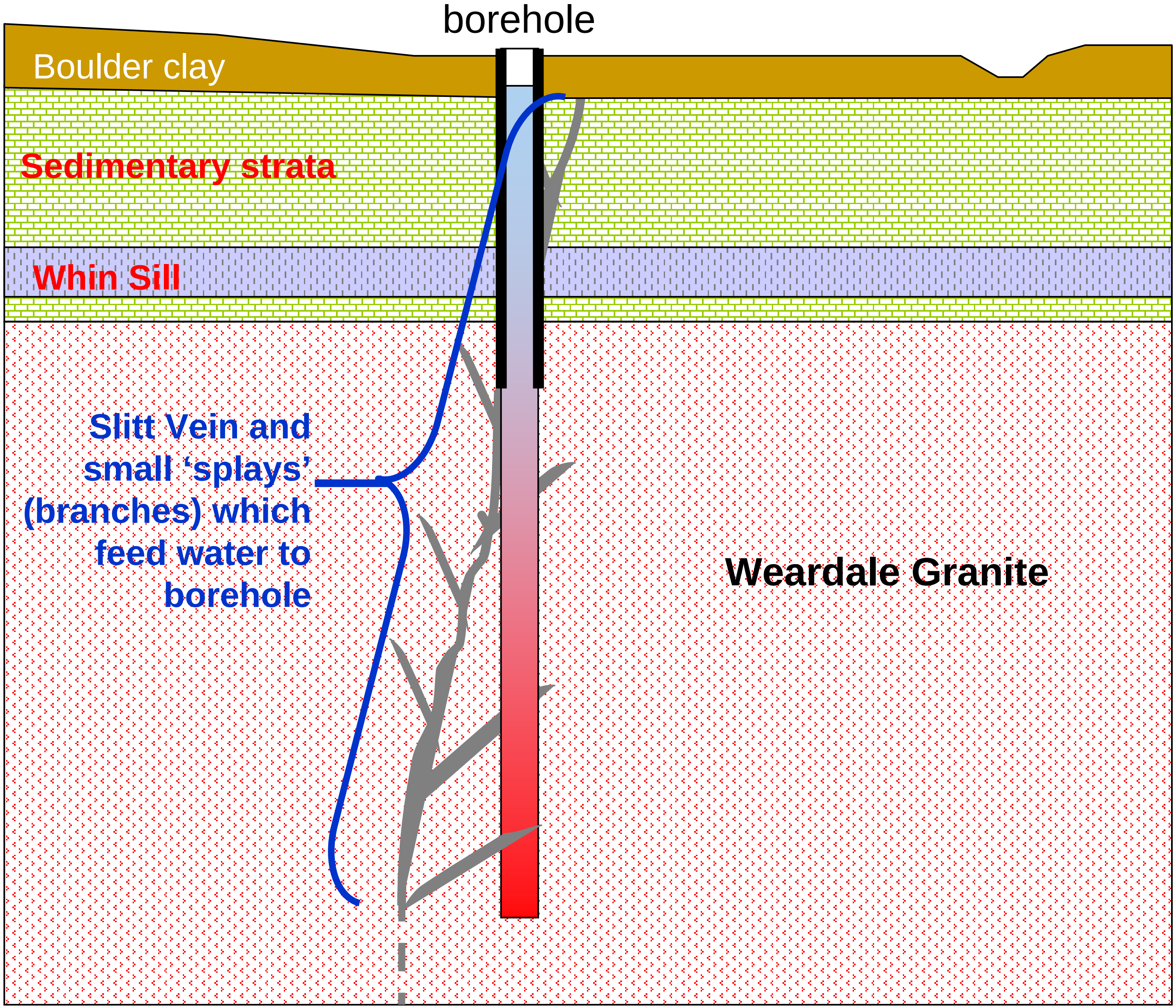
Slitt Vein at Eastgate

Cambokeels mine

Eventual borehole location







Borehole concept

Prospecting programme

-1. Desk study of area to west of cement works, to make the case for funding deep drilling works – completed May 2004

-(funding for further phases approved late June 2004)

-2. Shallow site investigations to pin down position of Slitt Vein in locations with reasonable access:

- - trial pitting
- - inclined boreholes (completed 5-7-2004)

-3. Deep drilling programme: (NB: only 2nd borehole ever to enter Weardale Granite!)

-- Specification: drill (hammer / tri-cone roller) to 1000m, finishing at 8.5" diameter, to allow geophysical logging at depth

-- case-off through Carboniferous and > 50m into Weardale granite; uncased below to maximise contact with granite

-(Drilling 26-8-2004 → 4-12-2004)

-4. Geophysical logging (6 – 7 Dec ‘04)

-5. Pump tests (completed March 2006)

-6. Interpretation of data, development of further proposals - still ongoing

Shallow, inclined boreholes

- Expertly drilled by Drilcorp Ltd, of Seaham

- total of 5 boreholes up to 60m in length drilled at angles of dip between 45^{o} and 60^{o}

<u>Proved:</u>

- Scar Limestone here contains extensive mud-filled caves

- Slitt Vein is ~ 8 m wide at this point, predominantly quartz and fluorspar; lies further to the N than would be judged from outcrops by quarry roads to SE

Deep exploration borehole

- Specialist open-hole drilling by FORACO S.A. (France)

- Centred on Slitt Vein initially (sited from inclined bh data)

- 17.5" diam to Whin Sill; 12.5" into granite; 8.5" after casing (toe 403m)

- 995m vertical hole completed 4-12-2004 (geophysical logging by Reeves)

- serious attrition rate for drill-bits due to strength of granite and salinity of groundwaters

FORACO

Deep exploration borehole

Findings:

- Groundwater
- Geothermal resource
- Pump tests

Deep exploration borehole: water strikes and casing

- Unusually high rates of groundwater ingress to borehole from Carboniferous sequence (at times > former water make of Cambokeels Mine (1.6 Ml/d)) made hammer drilling inefficient; switch to tri-cone roller

- Casing grouted-in to eliminate shallow-sourced groundwaters:

    - First cased off at 92.7m to cut off water makes above Whin Sill; two major feeders later hit within Whin Sill (very unusual); brought water make back to previous levels (> 60 m^3/hr)

    Second casing at 403m depth (130m into granite); eliminated all shallow feeders

- Major open fissure hit at 411m in granite

    - bit dropped suddenly 0.5m; pressure gauge jumped to 23 bar at 411m, then max (> 30 bar) at 411.5m

    - water strike on the order of 50 – 60 m^3/hr (amazing in granite!)

- Other water-bearing fractures hit in 700s – 800s

Deep exploration borehole: water quality

- Conductivity of groundwater began to show signs of elevated salinity very close to surface; major increases in conductivity coincided with successive water strikes

- Chemical composition (e.g. sample air-lifted from 674m):

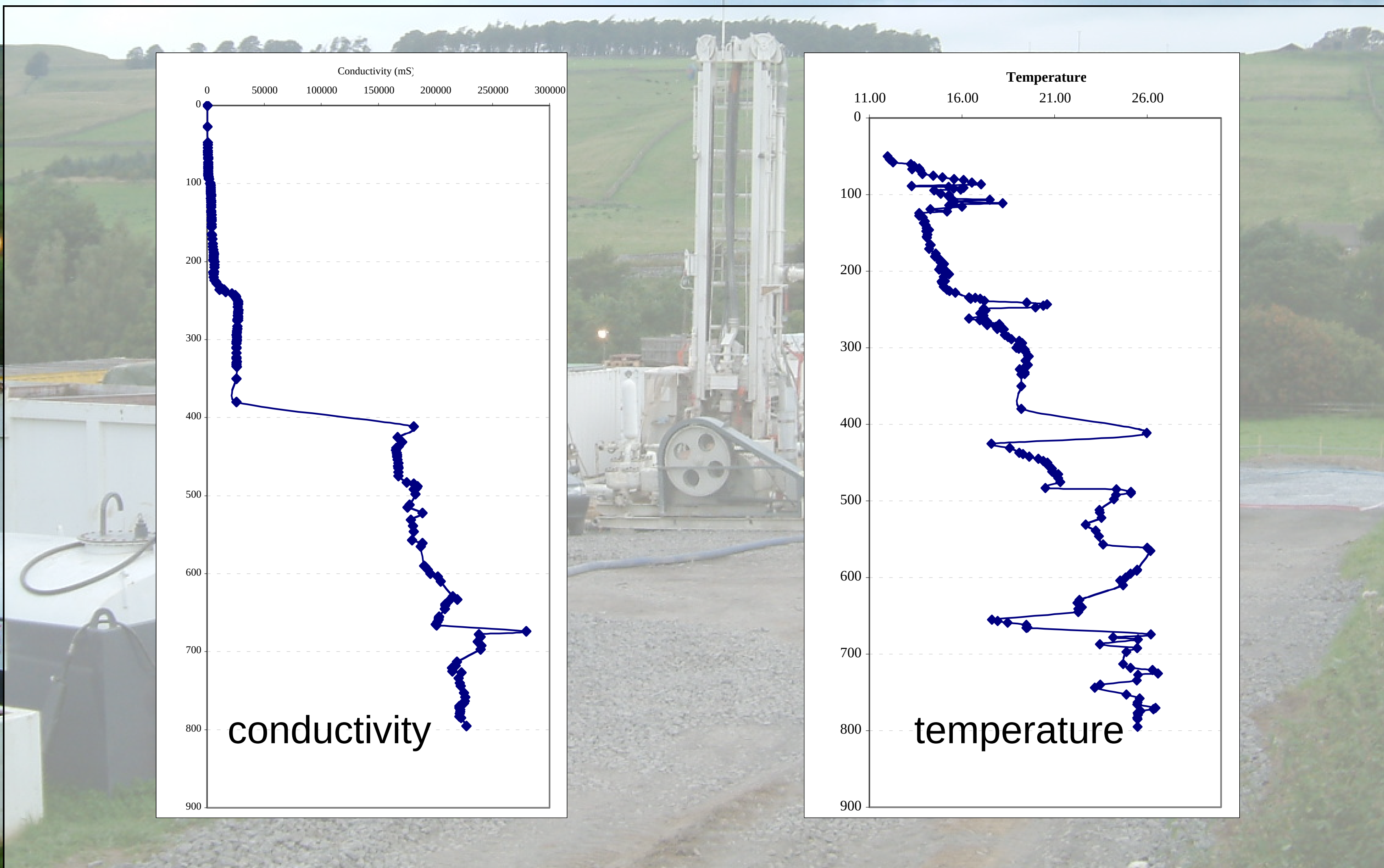
Cations: **Ca: 5250** Mg: 73 **Na: 9790** K: 656 Li: 93 Sr: 350 Ba 13

Anions: **Cl: 28560** SO_4: 48 HCO_3: 54 (ALL ABOVE IN mg/l)

Other: pH = 6.5, Cond = 66.8 mS/cm

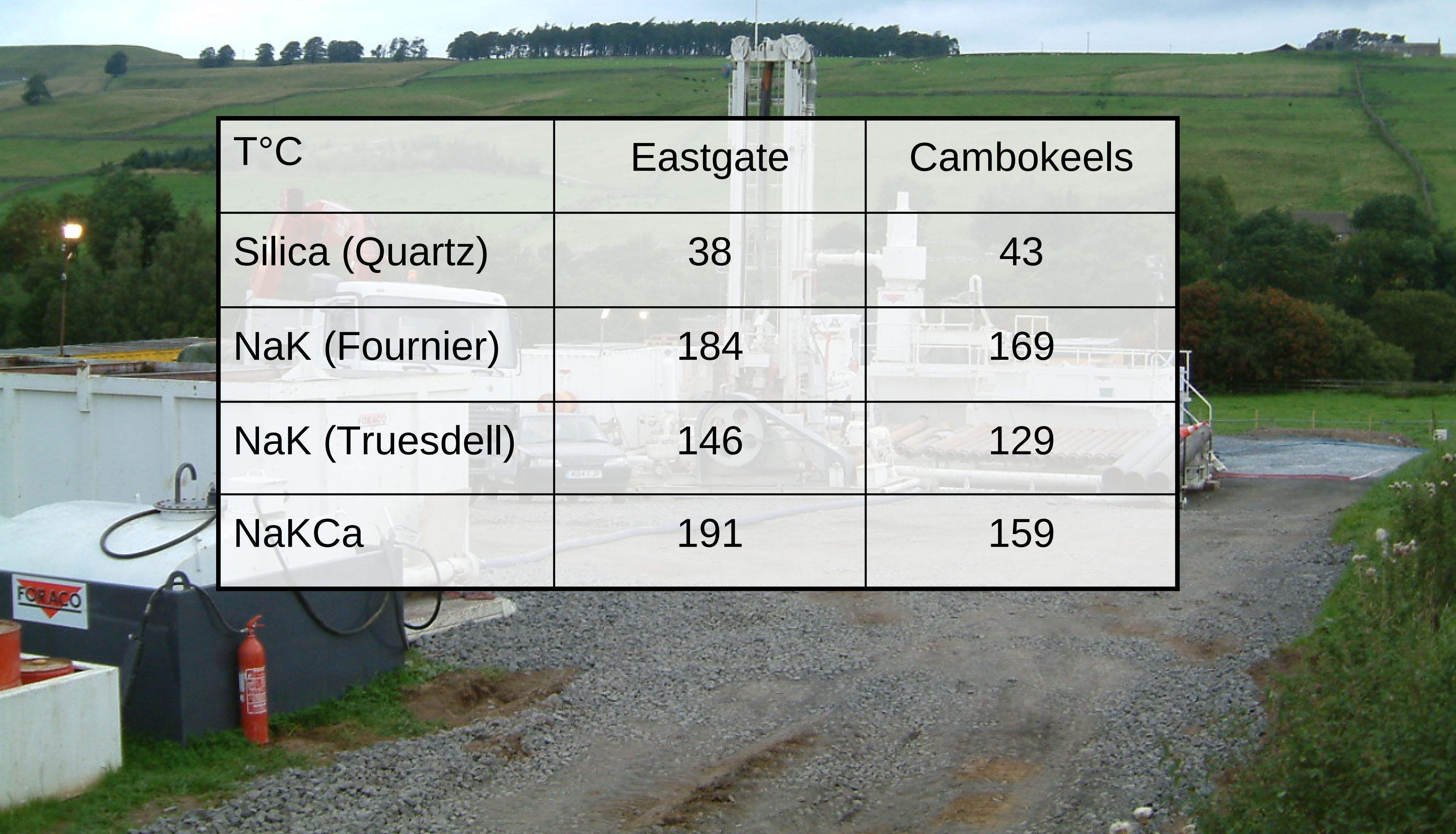
- Clearly a deep-seated water, *not polluted mine water* (Slitt Vein mine drainage is SO_4-dominated, with Cond ≤ 1 mS/cm)

Changes in conductivity and temperature of groundwater air-lifted from borehole



Geothermometric evaluation of water composition

T°C	Eastgate	Cambokeels
Silica (Quartz)	38	43
NaK (Fournier)	184	169
NaK (Truesdell)	146	129
NaKCa	191	159



Comparison with Southampton CHP

	Eastgate	Southampton
Temperature (°C)	46	76
Depth	I km	2 km
Yield (m^3/day)	1600	1700
Salinity (mg/l)	44500	124500
Power	?	2MW

Deep exploration borehole: Geothermal Findings - I

- Very encouraging rise in groundwater temperature with increasing depth
- True geothermal gradient signal was unclear during drilling due to:

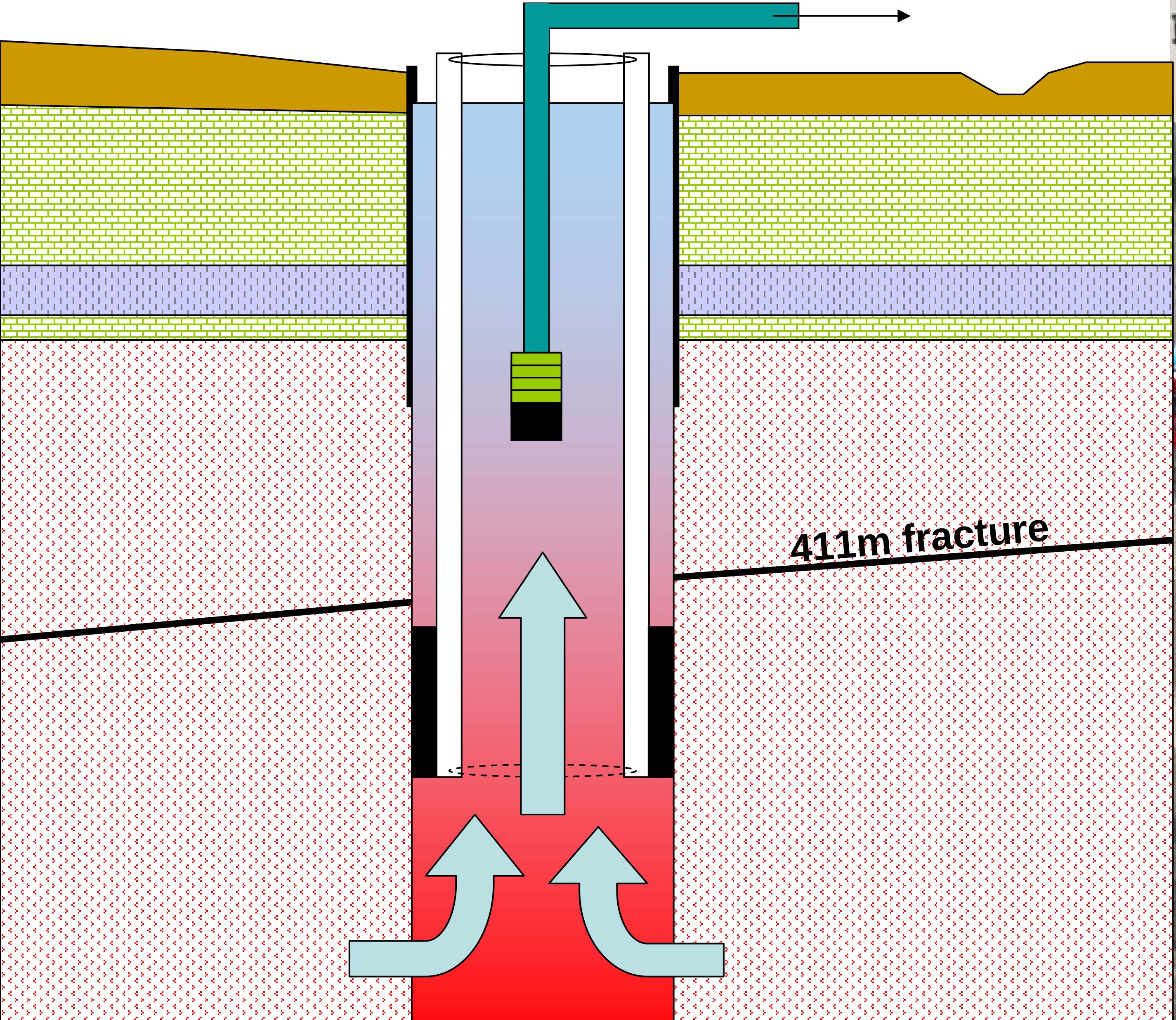
  (i) recirculation of excess water make within the borehole, and

  (ii) mixing of waters from different depths
- Geophysical logging of settled water column three days after end of drilling gave best indication of actual gradient
- Bottom hole temperature (1000m) > 46°C
  - cf. temp expected if geothermal gradient were only average: 30 – 35°C max.

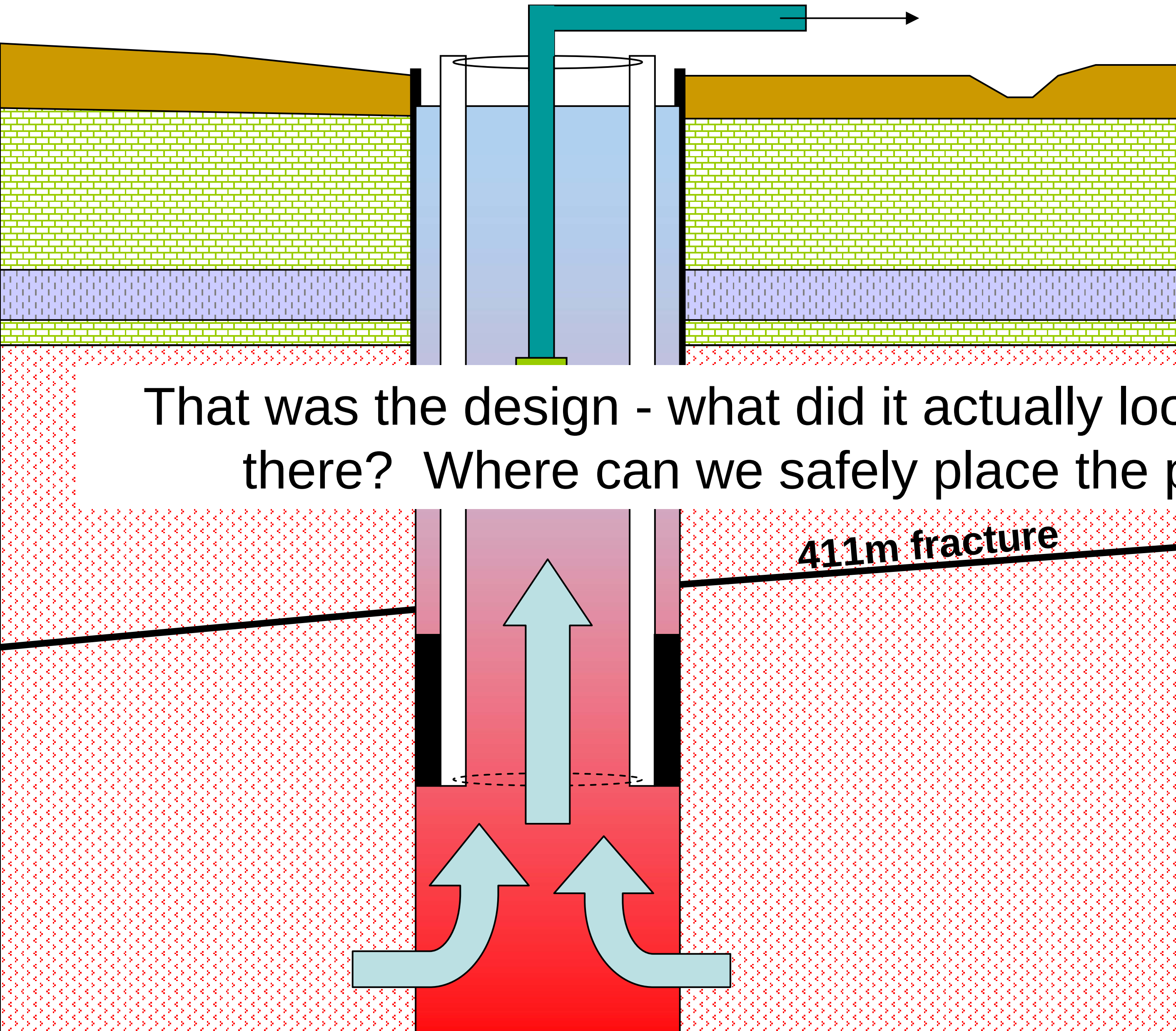
Deep exploration borehole: Geothermal Findings - II

- If this borehole (or another nearby) were sunk to a typical "production" depth of about 1800m, the bottom-hole temperature would be expected to be around 78^{o}C
- Following heat-exchange with fresh water, this would be sufficient to heat even conventional radiators and supply hot water tanks for a large number of buildings (as in Southampton)
- The volumes of water found in the Eastgate borehole exceed those found at Southampton, and the rest water level in the borehole is only 14m below ground (compared with 150m at Southampton), implying inexpensive pumping lift costs.
- By any standards, therefore, the Eastgate prospecting programme has been a great success, revealing the presence of a geothermal resource at least as promising as the best ever previously identified in the UK.

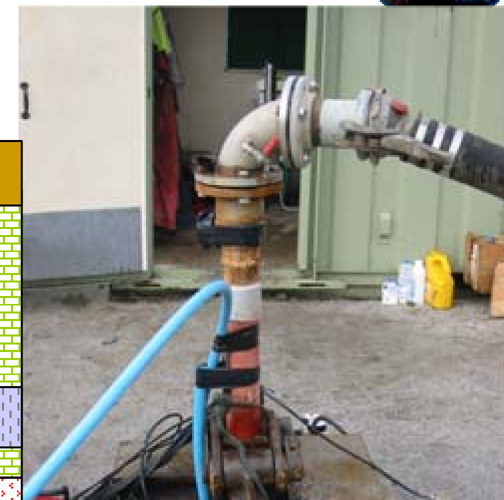
Pump tests: with and without a packer to isolate the 411 m fissure

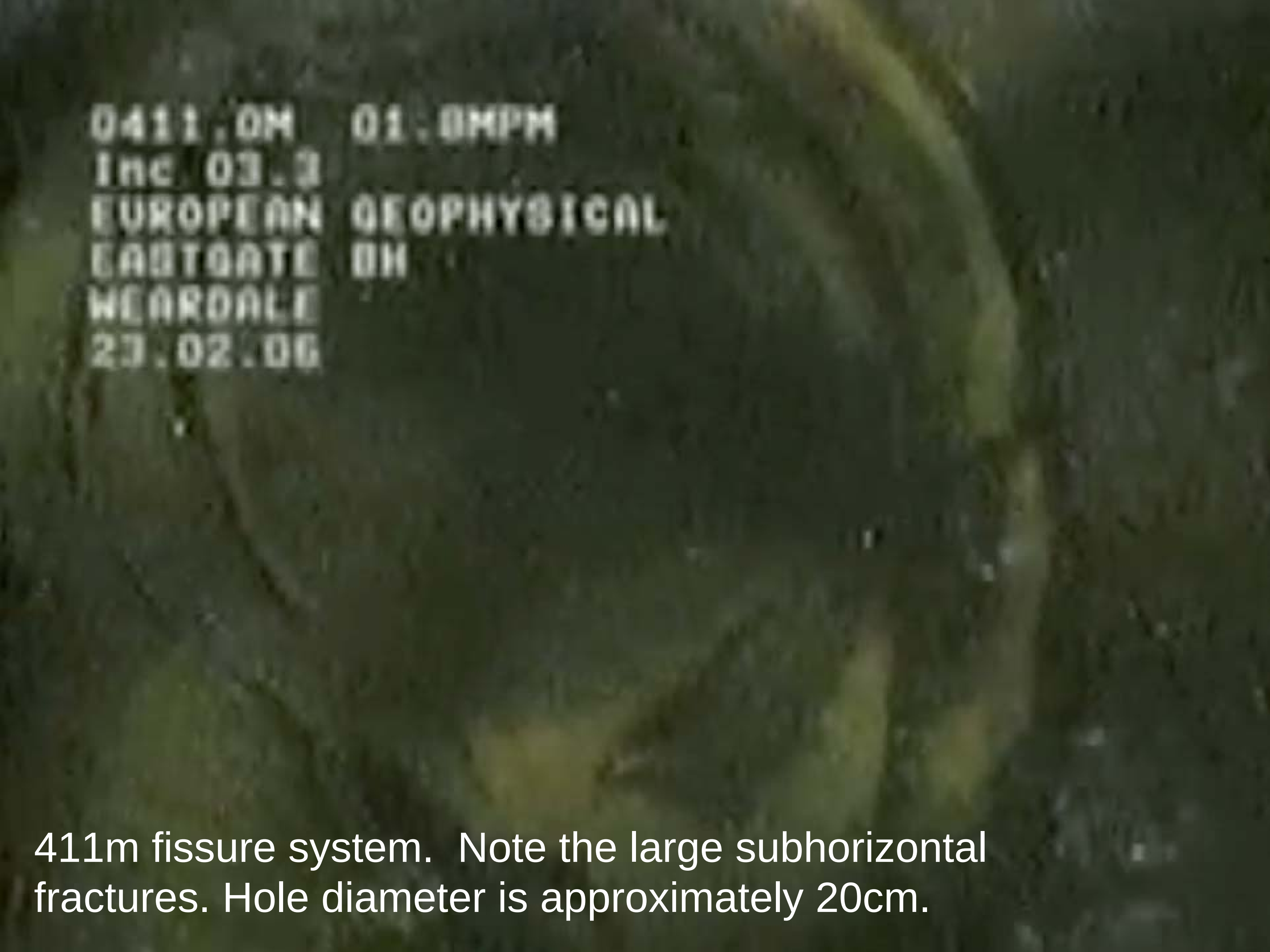


Pump tests: with and without a packer to isolate the 411 m fissure



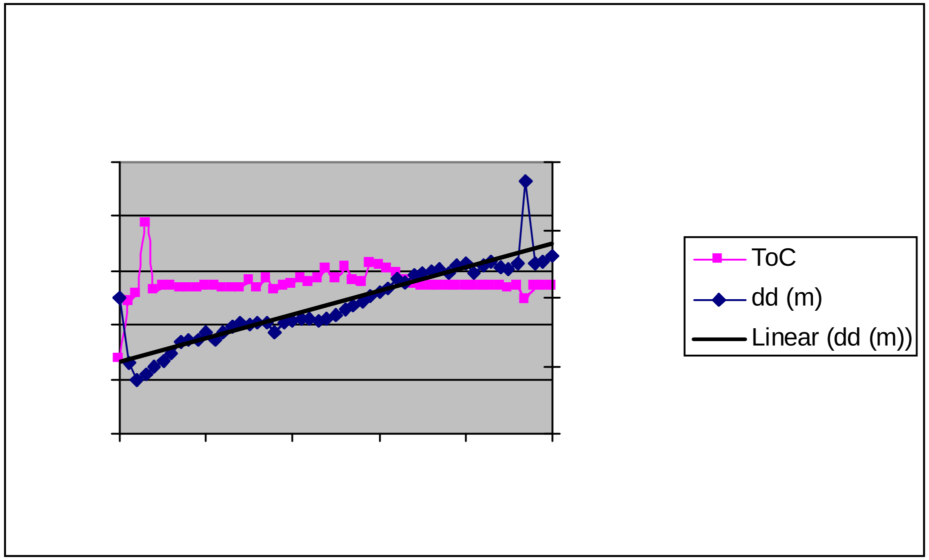
That was the design - what did it actually look like down there? Where can we safely place the packer?



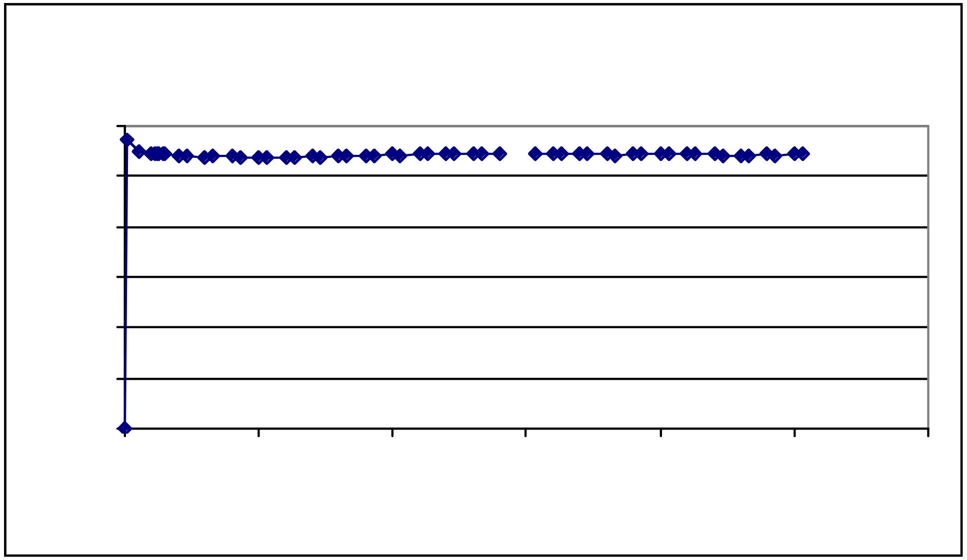


411m fissure system. Note the large subhorizontal fractures. Hole diameter is approximately 20cm.

Results of pump tests were remarkable



37 m^3/hour



22 m^3/hour

- High water yields are evidently achievable, at 27 - 30°C
- Water comes from fractures in vicinity of packer; not tapping waters >450m
- Aquifer 'stratified' hydrogeologically

Pumping trial results were remarkable for a basement granite:

	Phase 1 - entire open hole (403-995m)	Phase 2 - packer in place (432-995m)
Pumping rate	880 m^3/d	518 m^3/d
Drawdown after 0.5 hour:	- 0.48m	+ 27.37m
Drawdown after 12 hours:	- 0.16m	+ 27.27m
Drawdown after 24 hours:	+ 0.25m	+ 27.17m
Transmissivity	4000 darcy-metres	26 darcy-metres
Permeability	170 darcies	0.05 darcies

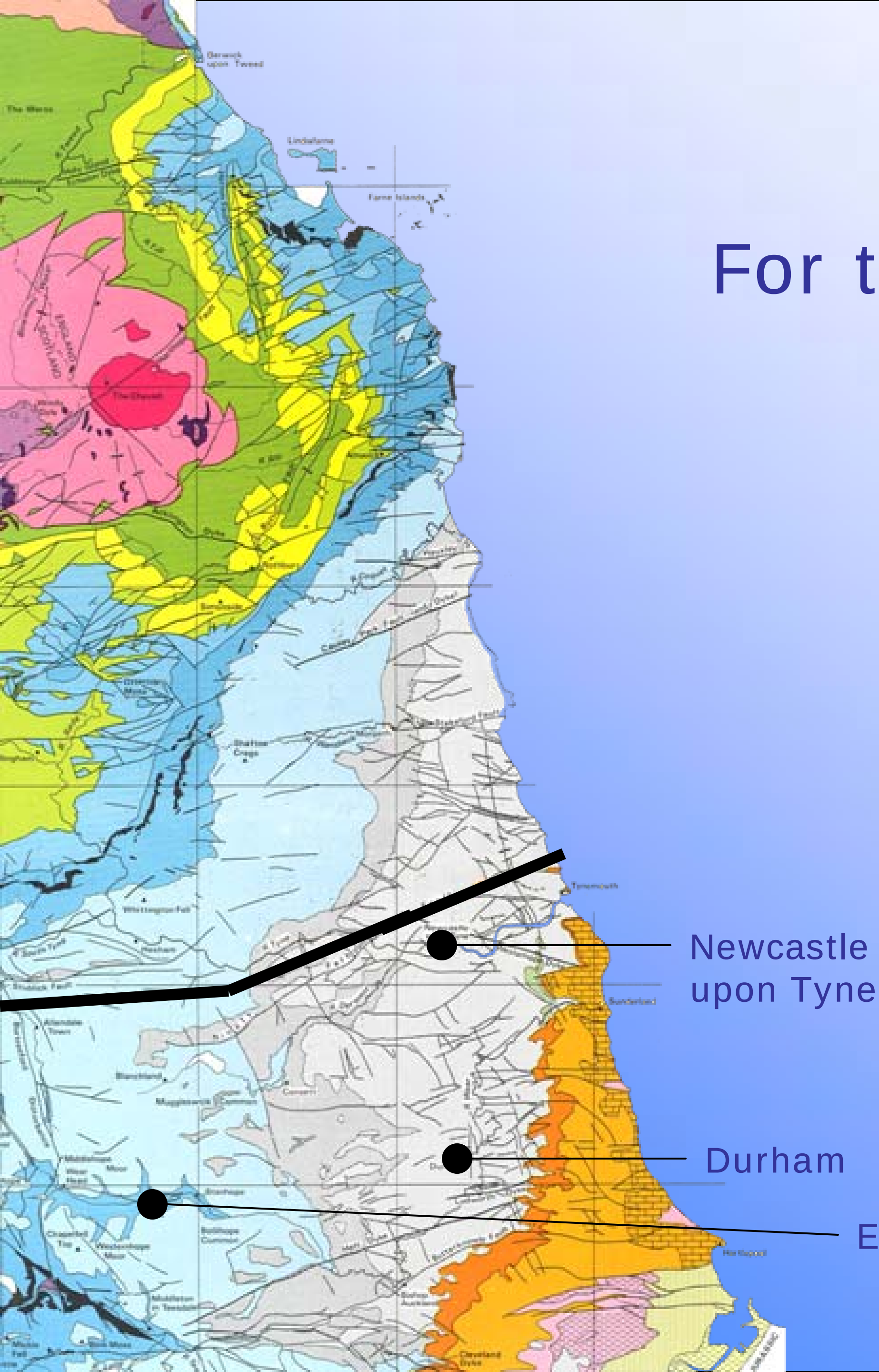
Water level rises in Phases 1 and 2 - thermal expansion effects.

What could be done with this resource?

- Exploitation in Southampton-style CHP mode, involving capture of heat from warm water (with or without boosting using heat pumps) for heating of any new / refurbished buildings at Eastgate re-development site (spa / swimming pool / leisure centre, new school, housing, commercial premises, railway station, visitor centre etc)
- ? electricity generation for local use / selling to grid (deeper drilling / binary plant)
- All subject to planning/developer’s requirements

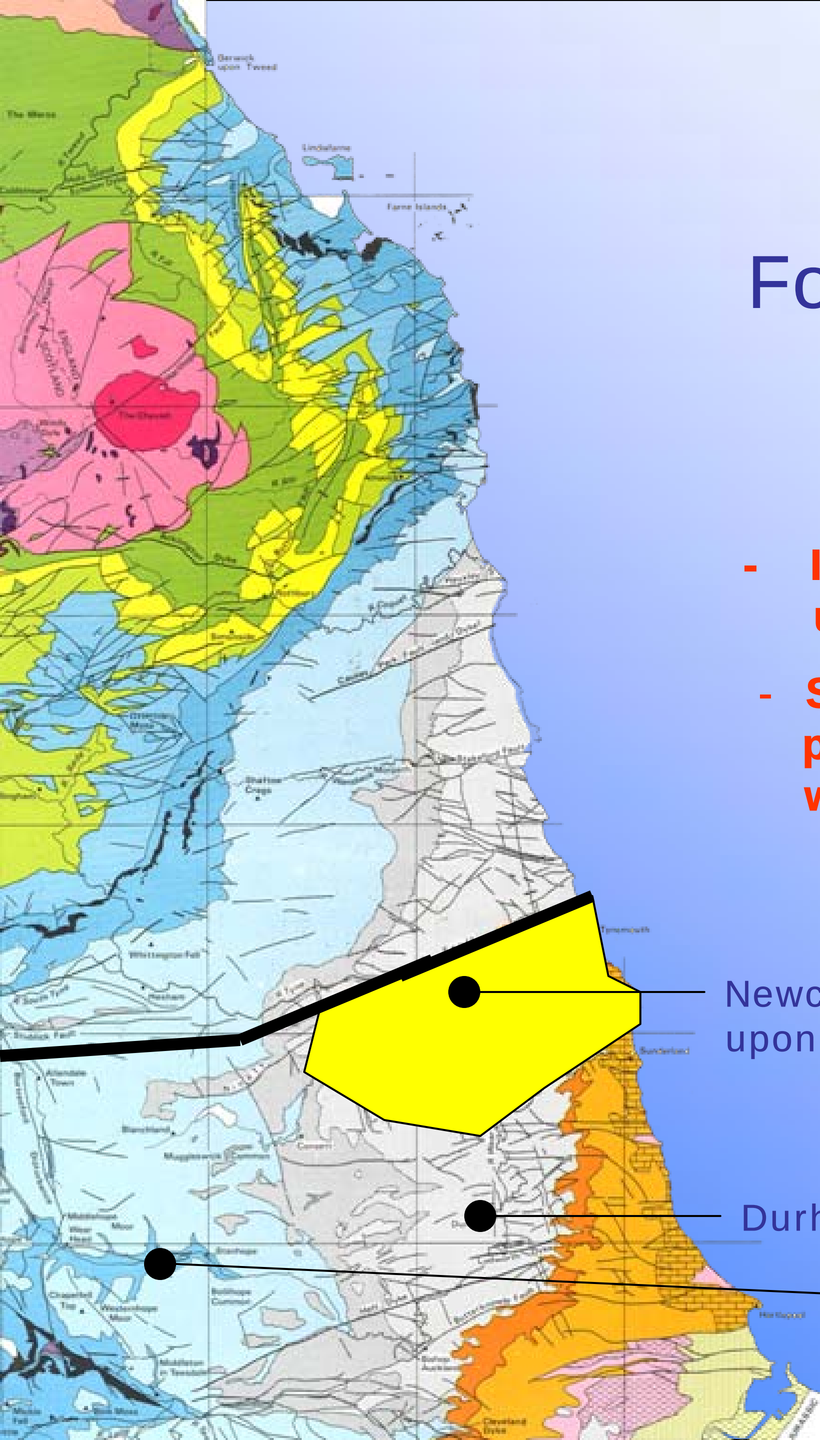

There’s warmth in them thar hills….

For the future elsewhere in the North East?



For the future elsewhere in the North East?

- **Is there a major prospect beneath urban Tyneside?**
- **Should we be undertaking geochemical prospecting (i.e. looking for saline waters) to S of 90 Fathom Fault?**



References

More information can be found out about the Eastgate project from the following publications:

Manning, D. A. C., Younger, P. L., Smith, F. W., Jones, J. M., Dufton, D. J. and Diskin, S. 2007 A deep geothermal well at Eastgate, Weardale, UK: a novel exploration concept for low-enthalpy resources. *Journal of the Geological Society of London*, 164, 371-382.

Manning, D. A. C. and Strutt, D. W. 1990 Metallogenetic significance of a North Pennine springwater.   *Mineralogical Magazine*, 54, 629-636.

Head, I. M., Manning, D. A.C. and Younger, P.L. 2009 Deep Heat. *Planet Earth*, Spring 2009, 28-29. www.planetearth.nerc.ac.uk