"Deep" groundwater discussion session

- What current research regarding deep ground water flow is underway?
- What are the alternatives for accurately characterizing deep round water flow?
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- **Research is limited – but increasing**
- **Development of suitable test methods - limitations**
- **Primarily in Western Europe**
- **Main focus on sedimentary basins and deep igneous terrains**

Current Research

SELLAFIELD TEST SITE (NW ENGLAND)

- Coastal basin filled w/ Permo-Triassic sedimentary rocks underlain by Ordivician meta-volcanic rocks
- 20 deep boreholes – up to 6300 ft deep
- Permeabilities measured in field and on cores & fracture geometries measured at outcrops
- Discrete fracture network model established
- Several numerical models were run(2D & 3D)

- 3 GW "Regimes"
  - Freshwater regime – recharged by present day precip – topographically driven
  - Mixed freshwater /saline water regime – multiple sources of water – topographically driven & at depth driven by density differences
  - Basin derived brines regime driven by basin scale processes
- All regimes dominated by meteoric recharge –but with varying ages
- Regimes will be affected by climate change

From Hebig, et. al., 2012

Current Research

GEOTHERMAL RESEARCH IN NORTH GERMAN PLAIN

- Tertiary & Quaternary glacial sediments overlying Paleozoic & Mesozoic sedimentary formations – up to 10 Km thick
- Thick sandstones w/ high effective porosity & K, found down to 9700 feet
- Samples from 4000 to 10,500 ft depth – results suggest same origin for all samples – strong meteoric component with some seawater (Naumann ,2000)
- High salinity at depth due to dissolution of salt formation
- Magri, et. al., 2005 modeled very slow but deep reaching thermally induced convective flow which causes transport of brine to the surface from depth

From Hurter & Schellschmidt 2003 ; Seibt & Kellner, 2003

Current Research

IGNEOUS AND METAMORPHIC ROCKS

- Rybach (1997) – groundwater may flow and even circulate at great depths
- Stober & Bucher (2007) reported hydraulic conductivities up to 10^{-6} m/s at depth of 1 km
- Hercynian basement of Western Europe – K at depths of 4800 ft to 16,000 ft – 10^{-10} to 10^{-11} m/s and gw circulation at 5 km
- Stober & Bucher (2005) – pump test on 13,000 ft borehole – concluded that water saturated fracture pore space of brittle upper crust is highly connected

What are the alternatives for accurately characterizing deep round water flow?

- Single borehole tests
  - Hydraulic tests –gw velocity
  - Tracer tests
  - Hydrochemical / isotopic characterizations
  - Borehole geophysics - tomography
- Constraints
  - High T and density hinders pumping tests
  - Long periods needed to reach steady state
  - Drilling fluids affect chemistry of water

What are the alternatives for accurately characterizing deep round water flow?

- **Isotopic analysis**
  - **Stable water isotopes ^{18}O, D**
  - **^{14}C , ^{13}C**
- **Models**
  - **Numerical flow and transport models**
  - **Fracture network models**
- **Need to evolve conceptual models**