RESEARCH NEEDS FOR DEEP BOREHOLES

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Attendees at the Deep Borehole Science Needs Workshop, Albuquerque, New Mexico November 12, 2014. Participants from left to right: Paul Johnson/LANL, Pat Brady/Sandia, Bill Arnold/Sandia, Kris Kuhlman/Sandia, Hari Viswanathan/LANL, Andrew Manning/USGS, John Cochran/Sandia, Dave Sassani/Sandia, Ernie Hardin/Sandia, Teklu Hadgu/Sandia, Frank Perry/LANL, Tom Daley/LBNL, Florie Caporuscio/LANL, Jim Houseworth/LBNL, Bob MacKinnon/Sandia, Dave Sevougian/Sandia, Dan King/DOE, Geoff Freeze/Sandia, Mark Freshley/PNNL, Tim Gunter/DOE, Lance Roberts/SD School of Mines, Mark Everett/Texas A&M, Jason Heath/Sandia, Mary Lou Zoback/NWTRB, Jack Tilman/Sandia, Paul Reimus/LANL. Not shown: Peter Davies/Sandia, Marianne Walck/Sandia, Erik Webb/Sandia, Fergus Gibb/Sheffield, Karl Travis/Sheffield, Frank Hansen/Sandia, Susan Altman/Sandia.

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Collected **Red** Issues

- **(3) Surface-based geophysics for e.g. salinity/fracture determination (Seismic/EM/Gravity/Aeromagnetic)**
- **(1) Dating the water using isotopic tracers; Identification of the fluid source, profiling**
- **(1) How to get GOOD samples (consistent data from multiple methods).**
- **(2) How to get GOOD data (e.g. pressures) at great depth in relatively impermeable formations?**
- **(2) Are we causing/will we cause over-pressured conditions?**
- **(3) Quality of sampling methodologies; how much will drilling perturb situation? "Tag" the drilling fluids? Use small well results to inform big well analyses.**
- **(4) Characterization of fractures, how they might change, which ones are conductive.**
- **(5) Long-term monitoring (using new materials? – e.g. self-monitoring fibers); seals that communicate their performance. New techniques – e.g. that sense seals wall rock bonding, fracture densities.**
- **(6) Geomechanical predictors of borehole stability = in situ stress measurements**
- **(UK) - Formation and behavior (fluid mechanics) of disturbed rock zone**

Collected **Green** Issues

(4) Vertical dipole pump test/tracer tests

- **(2) How will it all change once temperature changes, corrosion occurs, etc.?**
- **(3) Redox disequilibria/reducing conditions**
- **(5) Evolving seals mineralogy over T, P, time.**
- **(5) Gas generation/movement past seals.**

Elements of Science Needs

- 1 - Groundwater in the deep crystalline basement at disposal zone depths is very old and has been isolated from the surface for very long times.
- 2 - Ambient fluid potential does not have a significant upward gradient between the disposal zone and the shallow subsurface (i.e., overpressured conditions are not present).
- 3 - Deep groundwater has high salinity, well known chemical composition, and is chemically reducing.
- 4 - Bulk permeability of host rock and the borehole DRZ are acceptably low.
- 5 - Borehole seals, plugs, and grout have sufficient integrity and durability to meet safety requirements.
- 6 – Basic parameter values chemical, thermal, hydrology
- 7 – Equipment and approaches for monitoring post-closure data

Element 1
Groundwater in the deep crystalline basement at disposal zone depths is very old and has been isolated from the surface for very long times.

- **Dating the water using isotopic tracers** and best tools – history/provenance; which isotopes, which tracers? What mixtures?
- **Identification of the fluid source, profiling**
- Fluid inclusions vs. fracture fluids
- Mineral equilibria in fractures
- Disequilibria between rocks and waters; can we reproduce water compositions theoretically?
- Multiple source water mixing(?)
- **How to get GOOD samples (consistent data from multiple methods).**

Element 2

Ambient fluid potential does not have a significant upward gradient between the disposal zone and the shallow subsurface (i.e., overpressured conditions are not present).

- **How to get GOOD data (e.g. pressures) at great depth in relatively impermeable formations?**
- What scales (time, distance) are the measurements interrogating?
- **How will it all change once temperature changes, corrosion occurs, etc.?**
- Determine fracture pressure; how close to ambient pressure?
- How to use flow survey to integrate pressure? What tools?
- Salinity profile links to pressure.
- Long-term monitoring of microseismicity to infer shear state and evolution.
- How to model time-dependent rock mechanics and hydrology.
- **Are we causing/will we cause over-pressured conditions?**

Element 3
Deep groundwater has high salinity, well known chemical composition, and is chemically reducing.

- **Quality of sampling methodologies; how much will drilling perturb situation? "Tag" the drilling fluids? Use small well results to inform big well analyses.**
- Sorption coefficients and solubilities in high TDS brines at T > 100C, especially anions. Pitzer coefficients available?
- Reactive transport modeling approaches
- Fracture mineralogy and whole rock mineralogy; isotopic analysis of fracture mineralogy
- Multi-method distinguishing of scale-dependent permeabilities
- Tailored backfills
- **Redox disequilibria/reducing conditions**
- Microbial activity? Colloids?
- Use high value characterization targets to choose drilling fluids (if we can)
- What will corrosion do to geochemical behavior?
- **Surface-based geophysics for e.g. salinity/fracture determination (Seismic/EM/Gravity/Aeromagnetic)**

Element 4
Bulk permeability of host rock and the borehole DRZ are acceptably low.

- **Characterization of fractures, how they might change, which ones are conductive.**
- Borehole televiewer to provide 3D fracture imaging.
- Packer bleedoff measurements
- **Vertical dipole pump test/tracer tests**
- Time-phased sampling of groundwater to track DRZ reactivity.
- Cross-well and surface-borehole hydrogeologic/geophysical analysis
- 4d seismic, passive imaging tracked through time
- Reaction-transport analysis of long pump time geochemical results.
- Standard borehole fractured rock permeability testing

Element 5
Borehole seals, plugs, and grout have sufficient integrity and durability to meet safety requirements.

- **Long-term monitoring (using new materials? – e.g. self-monitoring fibers); seals that communicate their performance. New techniques – e.g. that sense seals wall rock bonding, fracture densities.**
- Include Karl/Fergus' comments
- Keep track of international URL's (Canadian)
- Alternative sealing materials – e.g. tailored epoxies
- **Evolving seals mineralogy over T, P, time.**
- **Gas generation/movement past seals.**
- How to demonstrate better seals performance
- Seals sensitivity to heat/pressure from waste.
- Seals cross-interaction
- Better waste forms; resistant to corrosion, etc.

UK Science Needs

- 1 - Sealing the borehole above the waste
  - Rock welding
- 2 - Sealing and support matrices
  - High density support (HDSM)
  - Class G cement formulation
- 3 - Fluid mechanics and package deployment
- 4 - Thermal modeling
- 5 - Thermal hydrologic modeling
- **6 - Formation and behavior (fluid mechanics) of disturbed rock zone**
- Larger diameter borehole/canisters

Grab Bag

- What is the “standard” optimal site characterization protocol for dozens of boreholes?

Element 6. Basic parameter values chemical, thermal, hydrology
Equipment and approaches for monitoring post-closure data

- **Geomechanical predictors of borehole stability = in situ stress measurements,**
- Thermodynamic gaps = e.g. Green rust, RN sulfides.
- High T, P, high salinity, sensors
- Data collection while drilling

Decision Points

1. Do you want to drill at a given site based on surface characterization?
2. Do you want to go beyond initial borehole characterization?
3. What about perturbations from waste emplacement?