Addressing technical challenges of Deep Borehole Disposal

Presented to:

International Waste Manaagement Symposium

Presented By:

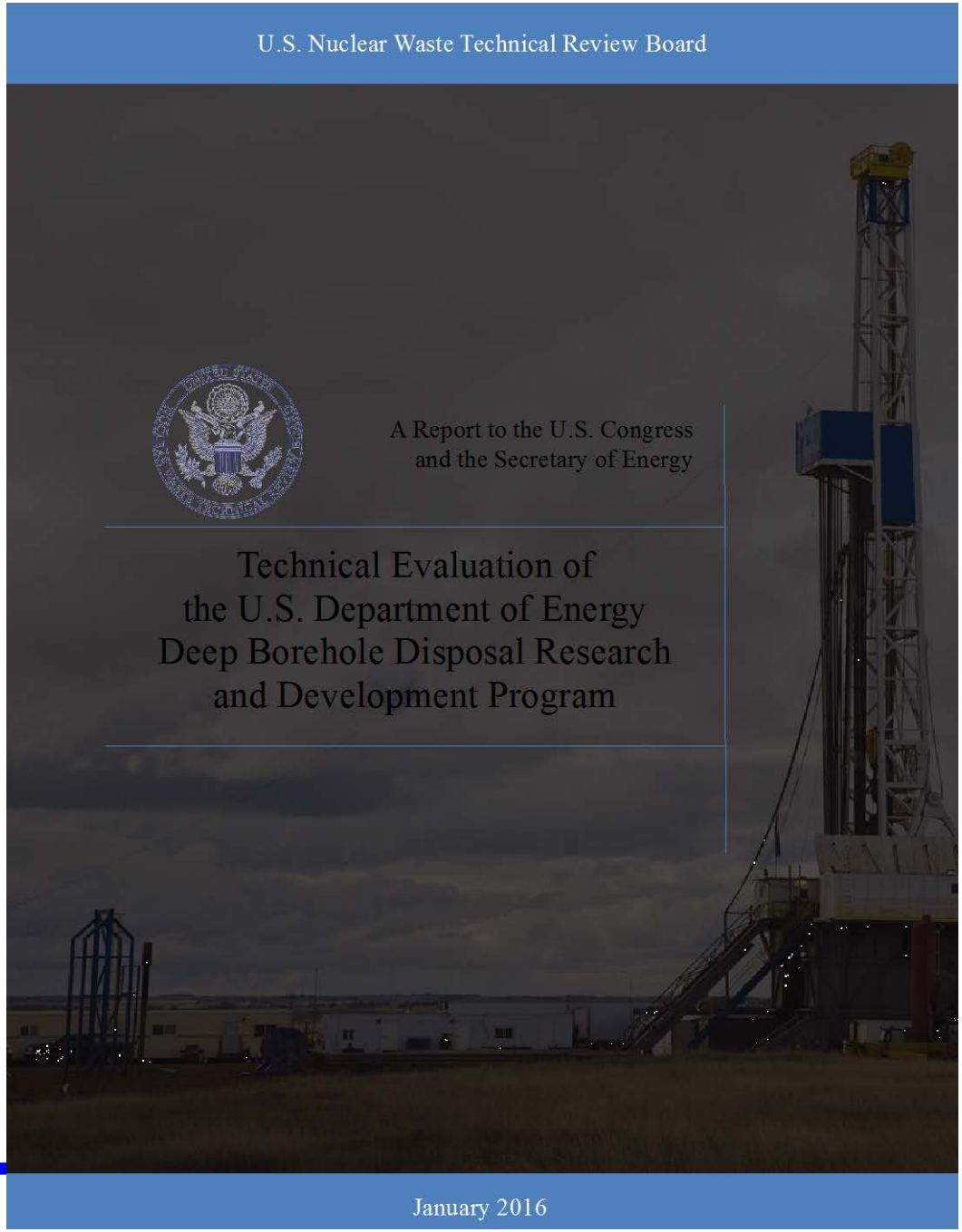
Mary Lou Zoback, Consulting Professor, Dept. of Geophysics, Stanford Univ. & Board Member

8 March, 2017 Phoenix, AZ

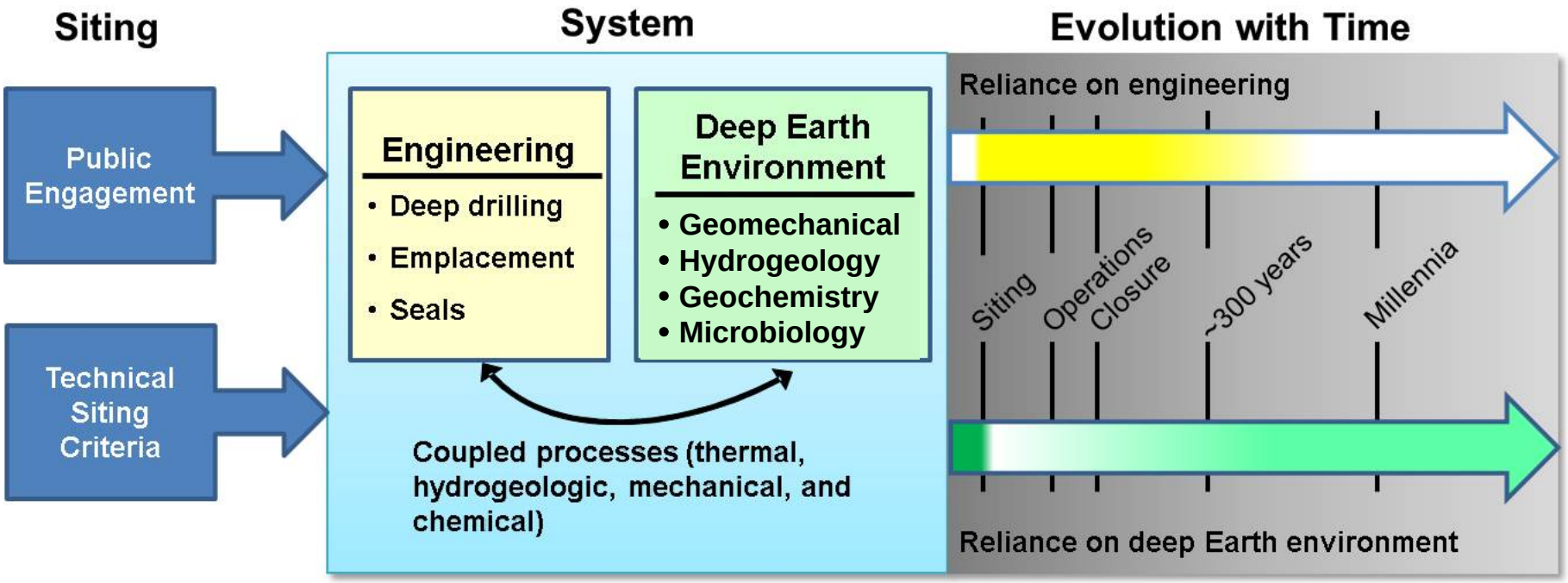
About the Board

- Created by 1987 Nuclear Waste Policy Act
- 11 Board members appointed by the President -- technical and scientific experts nominated by National Academy of Sciences
- Board members serve on a part-time basis for 4-year terms.
- The Board evaluates the technical and scientific validity of DOE activities, including
  - Transportation, packaging, and storage of spent nuclear fuel and high-level radioactive wastes
  - Site characterization, design, and development of facilities for disposing of such wastes.
- Required by law to report findings, conclusions, and recommendations at least twice each year to Congress and the Secretary of Energy.

- 20-21 October, 2015 International Workshop Washington, DC
- About half of the invited speakers had no previous knowledge of deep borehole disposal of radioactive waste
- Final report, all presentations, webcast, and full transcript available at: **www.nwtrb.gov/meetings**



Board's view: DBD System



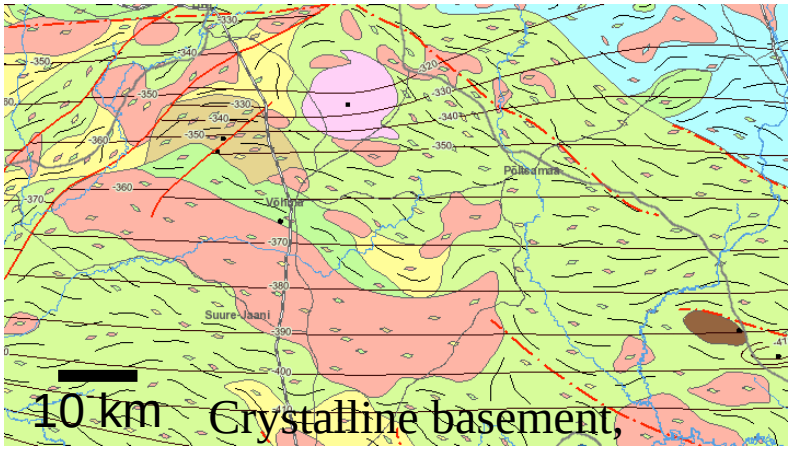
- Two subsystems: 1) Engineering 2) Deep Earth Environment
- Subsystems interact continuously over a range of temporal and spatial scales, and involve a range of coupled processes

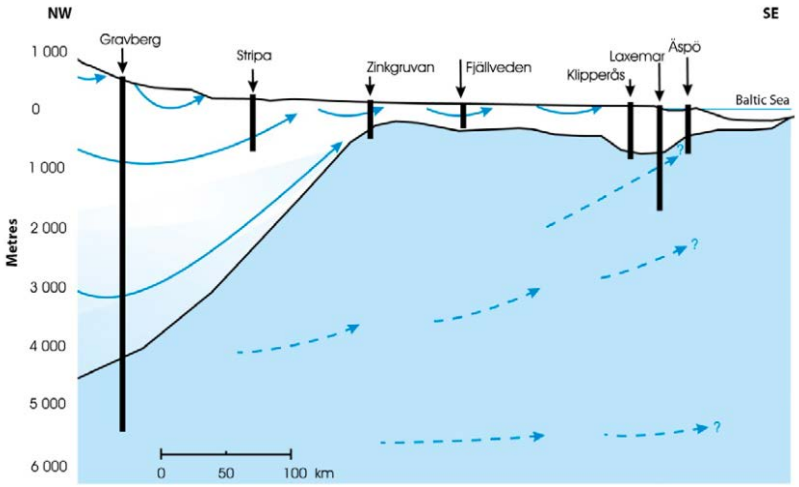
Some key scientific and technical issues

- Subsurface inhomogeneity
- Breakouts, drilling-induced fractures, natural fractures: implications for seals/damage zone
- Basement permeability, potential for induced seismicity
- Corrosion, hydrogen gas generation, microbial activity: implications for seals and possible migration
- Assessing **coupled** **geomechanical-geohydrologic-geochemical-geomicrobiological** processes and feedbacks
- Seal design, implementation, testing
- Emplacement risks – why wireline?

Subsurface Inhomogeneity/Site characterization

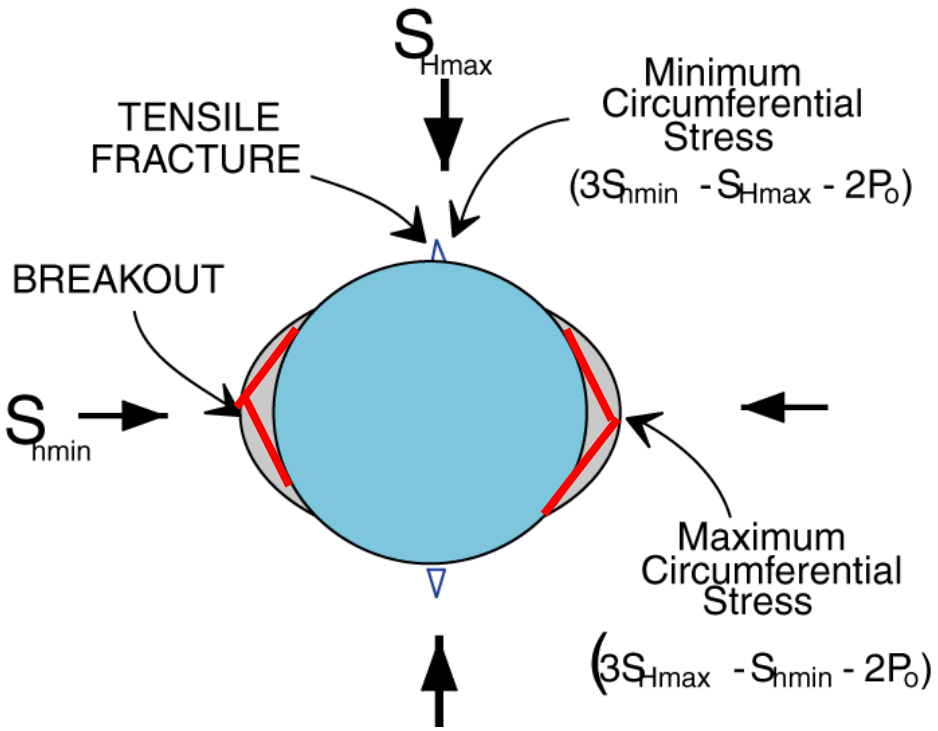
- Implicit assumptions:
  - less characterization needed because conditions likely more homogeneous at depth?
  - potentially advantageous conditions are found everywhere?
- No surface geophysical site characterization planned
- Even if test site works, how to identify another?

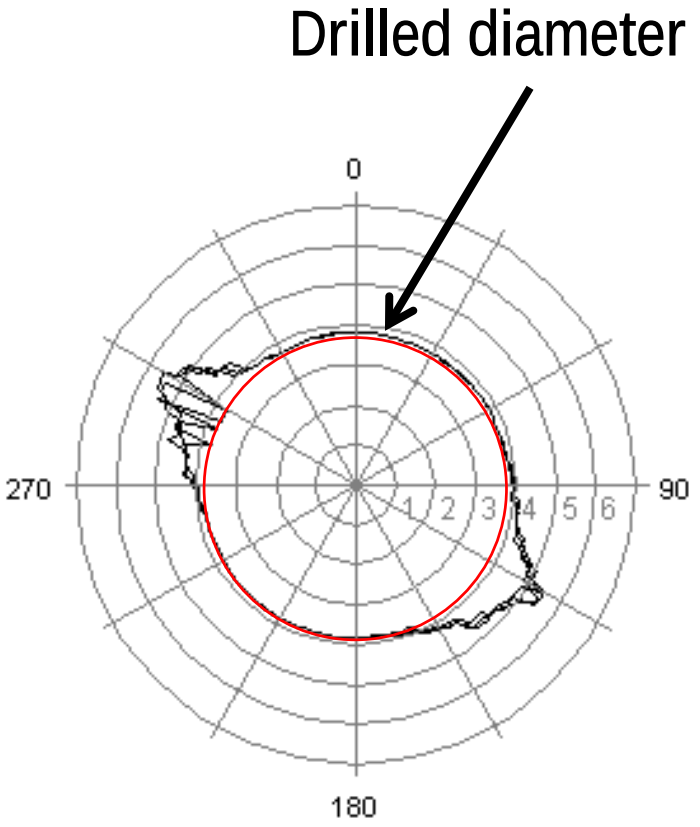




Groundwater flow and salinity across Sweden based on deep boreholes, blue shows high salinity. Juhlin et al. (1998), Marsic et al. (2012)

Geomechanics: Spontaneous borehole deformation

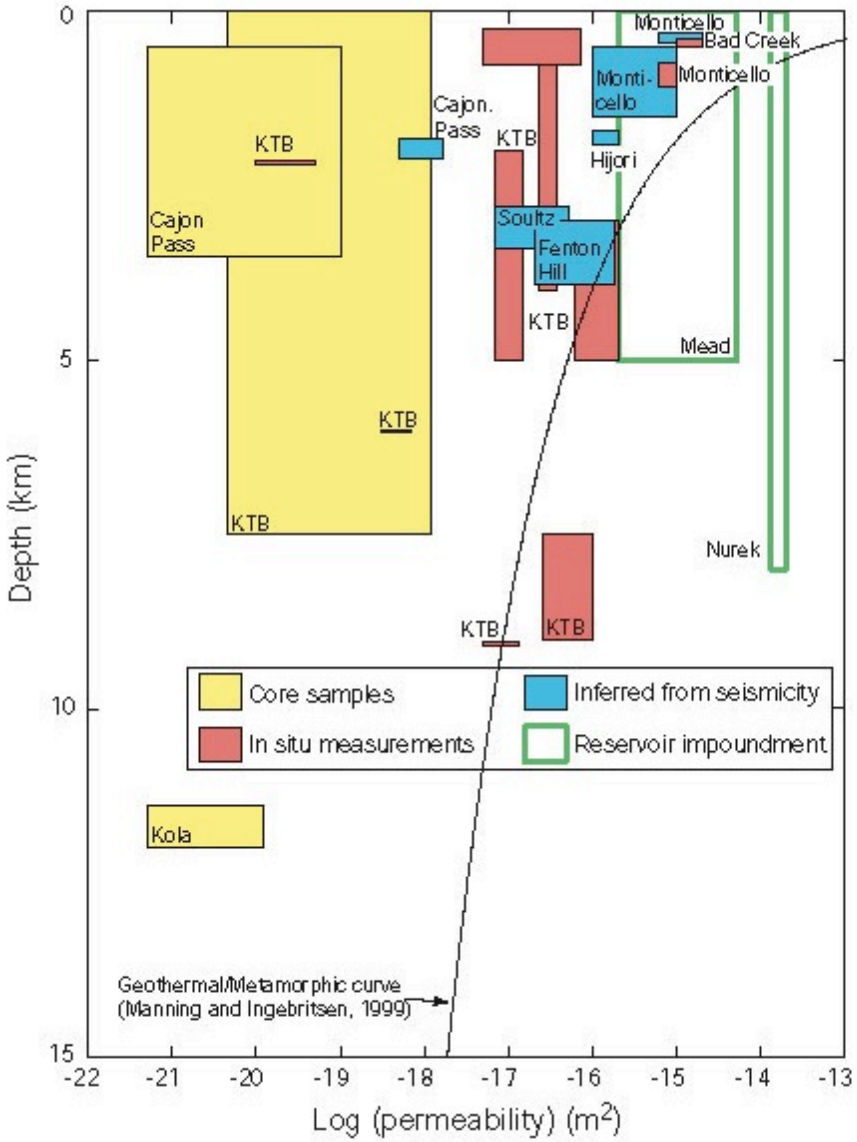




M. D. Zoback (2007)

Elastic stress concentration produces borehole deformation

Challenge understanding regional permeability



Townend and Zoback (2000)

- Small perturbations of pore pressure capable of triggering seismicity, even in “stable areas”

- In Oklahoma, pore pressure increases of < 1 Mpa (<145 psi) trigger earthquakes 10 kms away in basement within weeks, implying basement fault permeabilities: ~10^{-12} -10^{-13} m^2

Keranen et al (2014)

Weingarten and Zoback (2016)

Report Principal Findings

- Even if disposal of some radioactive waste in deep boreholes is determined to be feasible, **need for mined, geologic repository not eliminated**
- Establishing a regulatory framework, identifying an acceptable site, and characterizing a deep borehole at depths down to 5 km (3.1 mi) are challenging and time consuming activities—suggesting **time required for completing a deep borehole disposal facility might be comparable to that of a mined, geologic repository.**
- DOE's Deep Borehole Field Test will provide only **limited information on which to base an evaluation of the feasibility of the deep borehole disposal concept** and the selection of an actual deep borehole disposal site.

Recommendations

- **SCIENCE AND ENGINEERING**
  - Heterogeneity and complexities of subsurface geology complicate transferability of data and results of analysis
  - Pre-drilling geophysical subsurface characterization essential
  - Consider robust waste forms, waste packages, and seals
  - Carry out comprehensive risk analysis
- "Available evidence indicates that …high stress levels, potentially active faults, and highly permeable fractures and faults persist to at 5+ kilometers depth. These features represent potential pathways for migration of gases and brines." *Mark Zoback, Stanford*
- "In geochemistry when we look to the subsurface, same thing. Wherever we go we find surprises." *Kirk Nordstrom, USGS*
- "Seal/liner/rock disturbed zone is a likely pathway for radionuclide migration… conceptually this is thought to be within engineering capability to manage, but this remains to be demonstrated." *Neil Hyatt, Sheffield*

Recommendations

- **REGULATORY**
  - Develop an operational safety strategy
    - Must integrate conventional borehole operations and remote handling of highly radioactive materials
    - Emphasize engineering controls over administrative controls
  - Engage regulators to define requirements, including retrievability

- "If you're going to treat this as a demonstration of a nuclear disposal system, you really need to try and ensure that you have demonstrated all of the key elements of a nuclear disposal system." *Doug Minnema U.S. Defense Nuclear Facilities Safety Board*

Recommendations

- **MANAGEMENT**
  - Independent expert review (drilling and downhole operations)
  - Chief scientist to lead Deep Borehole Field Test program
    - Integrate science and engineering objectives and assure the drilling and scientific sampling and testing program are fully coordinated and collecting key data to develop safety case for deep borehole disposal
  - Transparent pathway from the Deep Borehole Field Test to siting needed
    - Missed opportunity to obtain experience on consent-based siting

"Integrated approach is needed for the whole lifetime of the project, for the drilling, for the completion, and the emplacement phase. ….project leaders need to own entire process…you can subcontract services, but you cannot subcontract responsibilities." *Claus Chur, Chief Drilling engineer, German KTB Scientific Deep Drillling Project*

Panelists' words of wisdom

- "Expect surprises", "Plan for contingencies", 'Plan for the unforseen"
- "Little things can turn into big things very quickly"
- 'Don't want a drilling engineer handling nuclear materials, don't want a nuclear engineer drilling'
- "Measure everything. Don't necessarily know beforehand what will be useful, so there's some betting that's involved."
- "Do not "assume away" things that could affect applicability or transferability of the results or conclusions of the test"