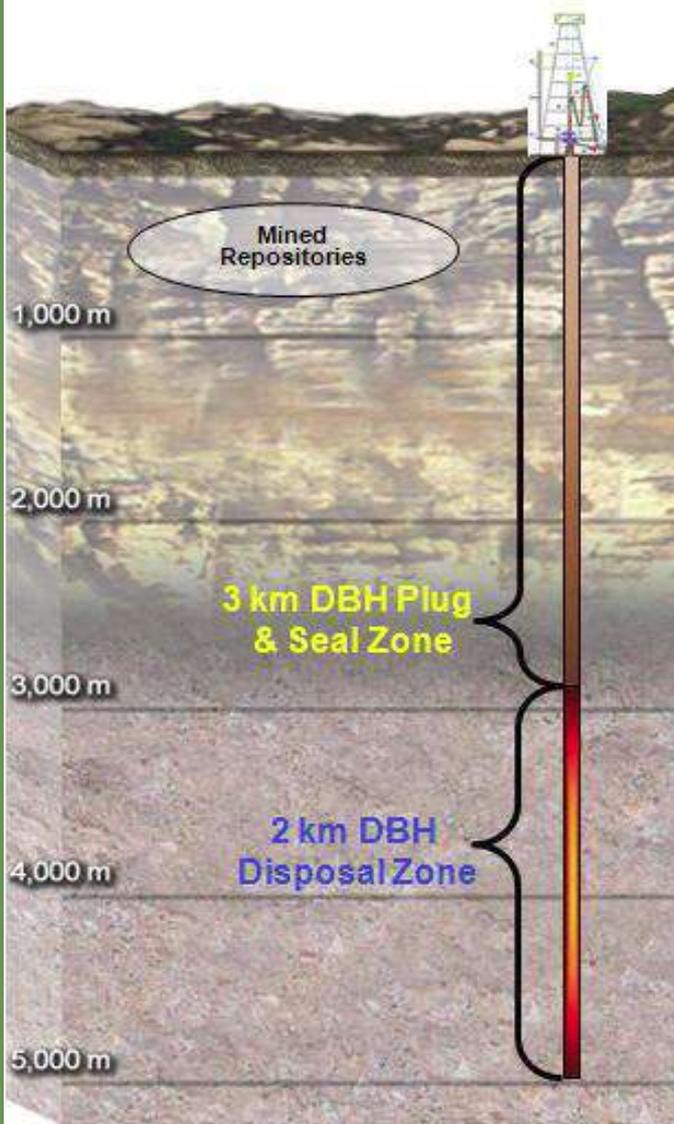


# USDOE Deep Borehole Proposal River & Plateau Committee

*February 9, 2016*

**Dirk Dunning, P.E.**

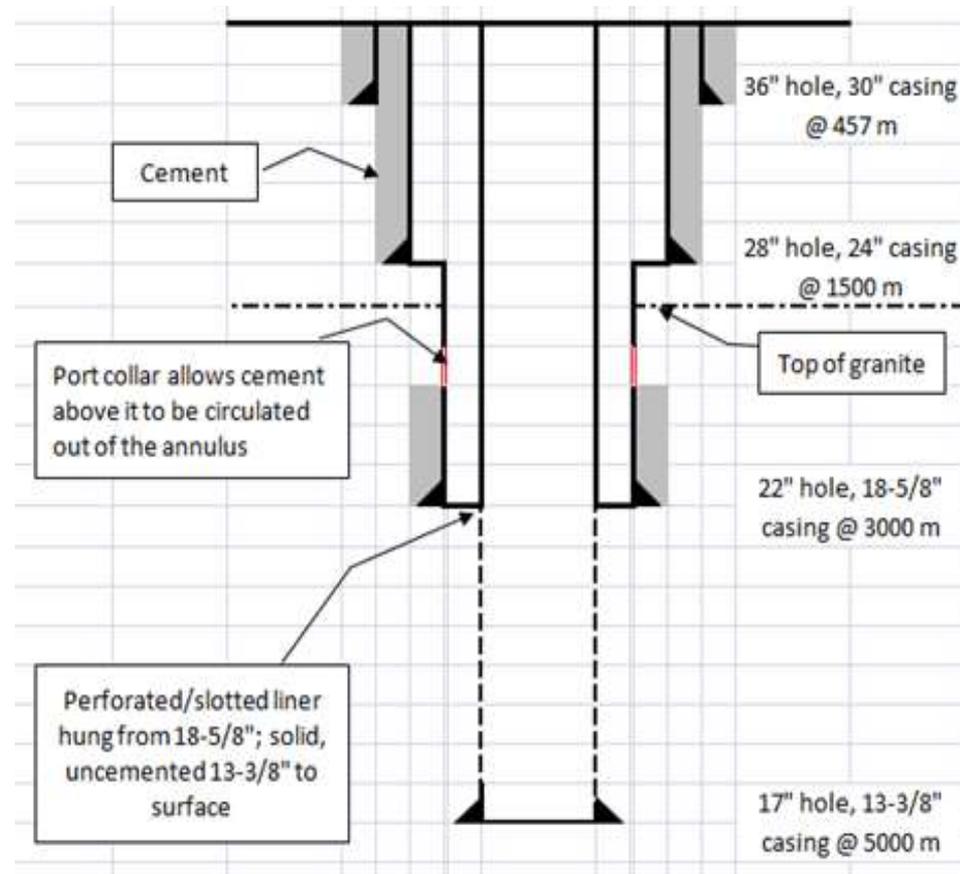
# Basic idea



- Drill one or more boreholes into crystalline basement rock to about 5,000 m depth
- Emplace waste canisters in the lower 2,000 meters of the borehole
- Seal the upper borehole
  - compacted bentonite clay, cement plugs, and cemented backfill
- Deep borehole disposal of high-level radioactive waste has been considered since the 1950s and periodically studied since the 1970s
- One of several possible disposal options
- Develop the science and engineering tools to support implementation

# Borehole Reference Design

- Borehole liner for unrestricted emplacement of waste canisters
- Liner casing for the emplacement of waste canisters and for potential retrieval
- Perforated liner would remain in the disposal zone.
- Liner will be removed in the seal zone and most of the intermediate casing



# Possible wastes considered

Some DOE-managed small waste forms are potential candidates for deep borehole disposal (SNL 2014)

- ❖ Specialized waste types
  - Cesium and strontium capsules. 1,936 cesium and strontium capsules stored at the Hanford Site
- ❖ Small dimension DOE spent nuclear fuel
  - Some DOE-managed SNF currently stored in pools at INL and SRS
- ❖ Some high-level radioactive wastes
  - Untreated calcined HLW currently stored at INL
  - Salt wastes from electrometallurgical treatment of sodium-bonded fuels



Model of Bin Set #6



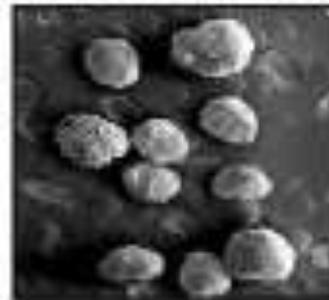
Top view of CSSF #6 bins

<http://energy.gov/sites/prod/files/em/IDAHOwtihSTIRvw.pdf> page 3

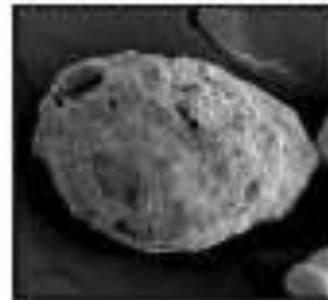
***Idaho National Lab calcined waste &/or hot isostatic pressed waste***



Calcine Bed Material 40x



Calcine Bed Material 150x

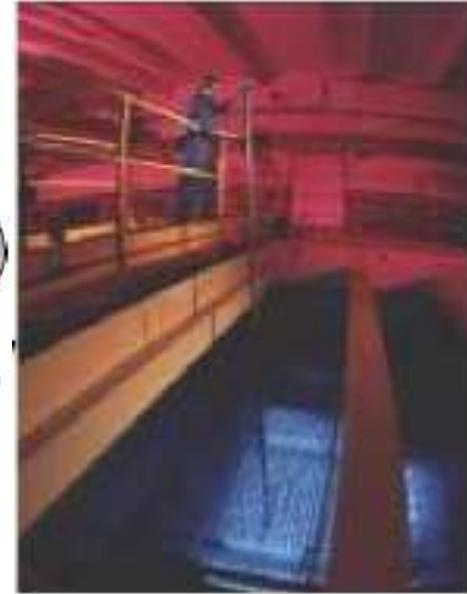
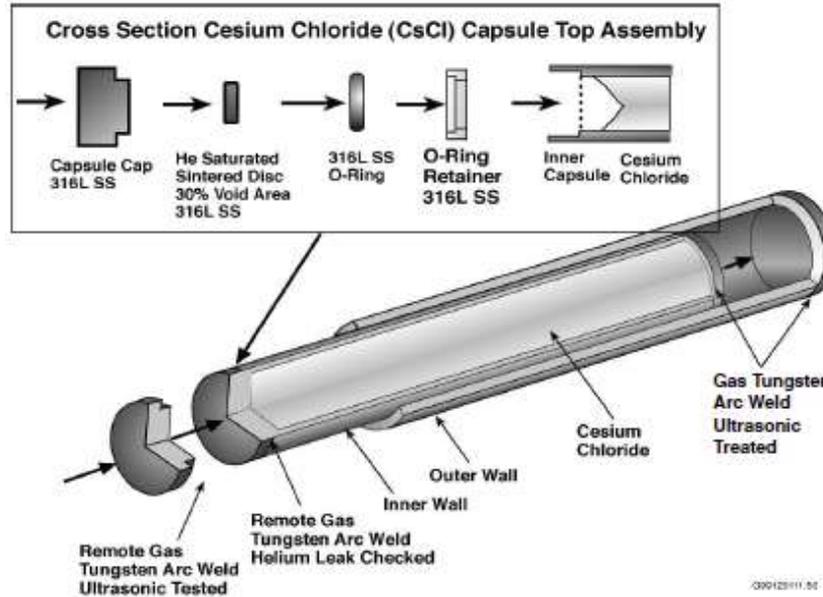


Calcine Bed Material 500x



<http://energy.gov/sites/prod/files/em/IDAHOwtihSTIRvw.pdf> page 2

<http://nsnfp.inel.gov/program/strategymtg/2010-mar/DOE%20ID%20HLW%201.pdf> page 27



*Idaho National Laboratory  
Site, Sodium bonded fuel*

*Hanford Site Cesium Chloride and Strontium Fluoride capsules*

# Proposed attributes

- ❖ Lots of possible sites (crystalline basement rocks are common)
- ❖ Can use existing drilling technology
  - > may permit construction at acceptable cost
- ❖ Disposal flexibility (option for disposal of smaller waste forms)
- ❖ Potential for earlier disposal (of some wastes)

# Proposed attributes

- ❖ Possibly reduced costs (for some wastes)
- ❖ Potential for robust isolation (presumed conditions)
  - low permeability and long residence time of high-salinity groundwater
    - > limited interaction with shallow fresh water
  - geochemically reducing conditions at depth
    - > limit solubility & enhance sorption
    - > but not for all radionuclides
  - dense salty groundwater underlying fresh groundwater
    - > would oppose heat induced groundwater convection

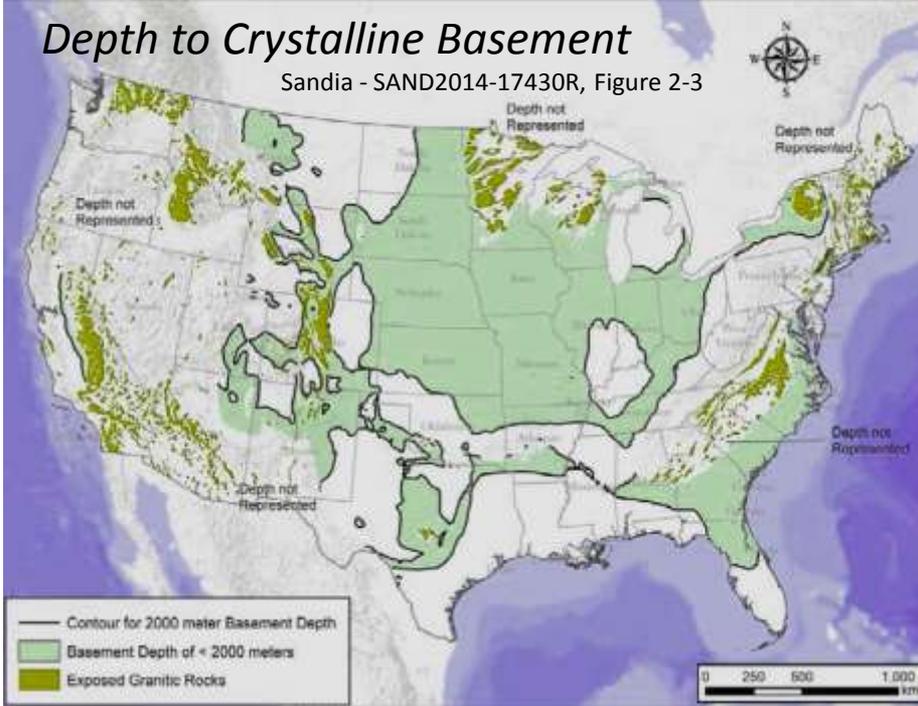
# Site selection criteria

## Desirable features present:

- ❖ Crystalline rock within 2,000 meters of the surface
- ❖ Absence of commercial mineral resources and hazards
  - Oil, natural gas, commercial minerals
- ❖ Absence of volcanoes or recent faults
- ❖ Low seismic risk potential (< 0.16 g in 50 years)
- ❖ Low heat flow and moderate temperatures (~ less than boiling)

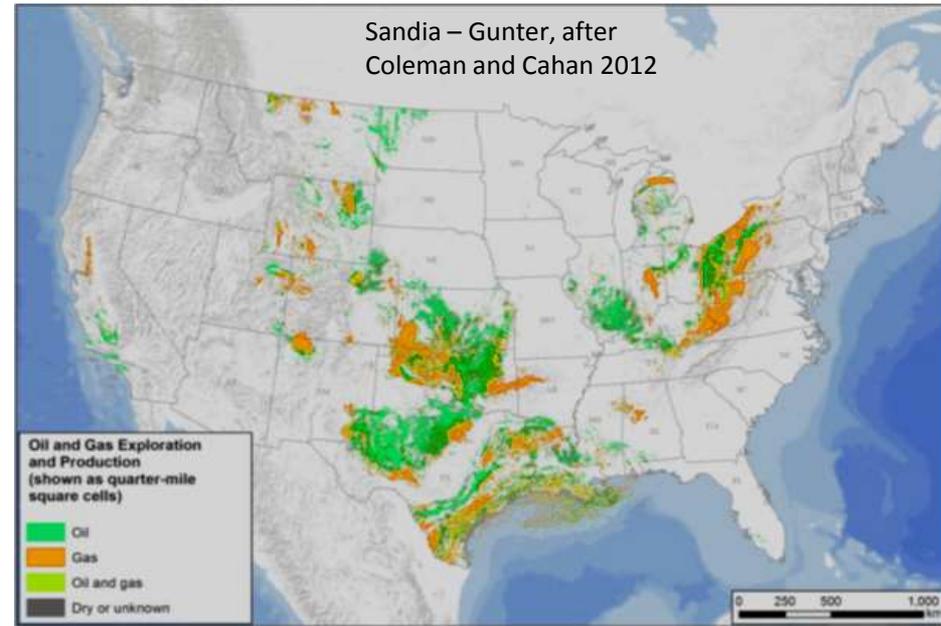
# Depth to Crystalline Basement

Sandia - SAND2014-17430R, Figure 2-3

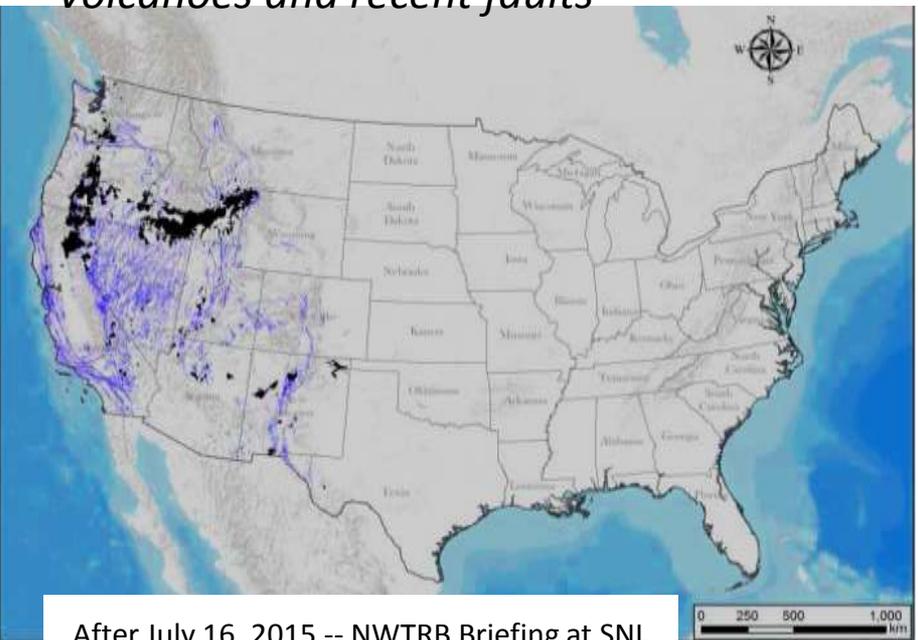


# Oil and Gas

Sandia – Gunter, after Coleman and Cahan 2012

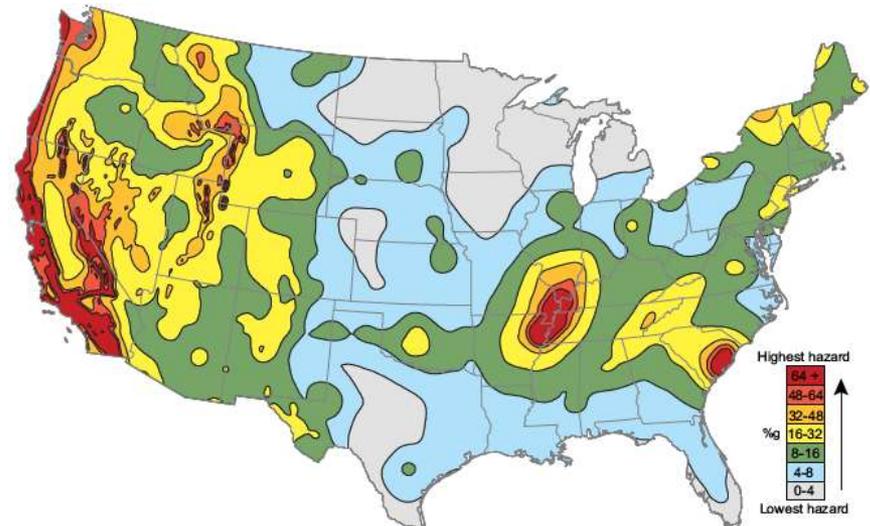


# Volcanoes and recent faults



After July 16, 2015 -- NWTRB Briefing at SNL

# Seismic force map



USGS

# Site deselection guidelines

## Undesirable features present:

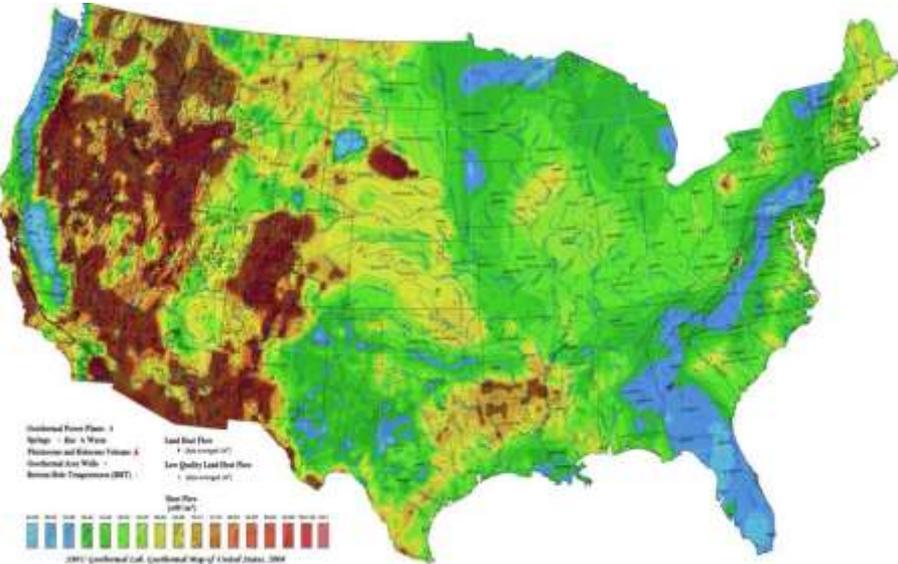
- ❖ Absence of crystalline rock within 2,000 meters of the surface
- ❖ Volcanoes or recent faults
- ❖ Over-pressuring (e.g. natural gas or high formation pressures)
- ❖ High permeability hydraulic connections to the subsurface
  - Presence of young surface water at depth (indicating movement)
  - Low-salinity, oxidizing groundwater (indication of surface water)
- ❖ Upward hydraulic gradients

# Site deselection guidelines

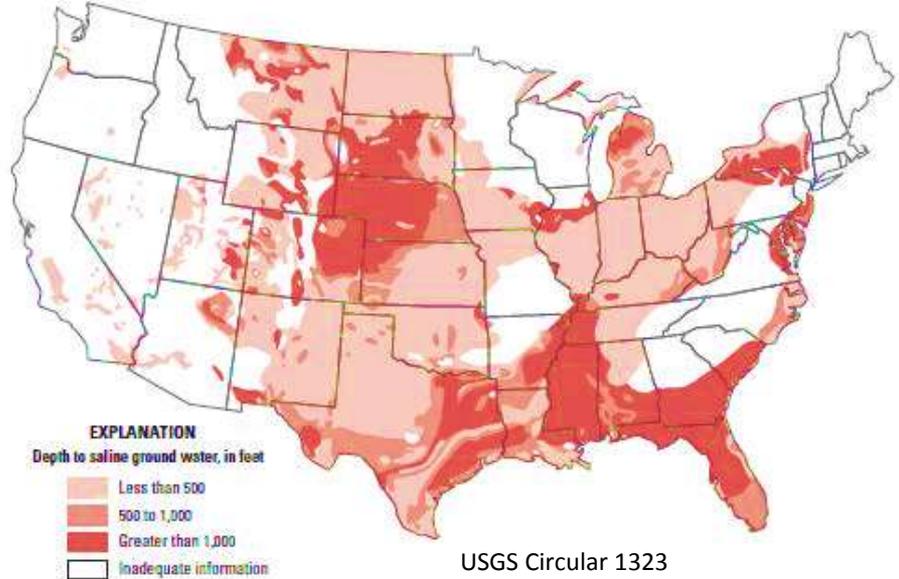
## Undesirable features present:

- ❖ High geothermal heat flow (driving movement)
- ❖ High permeability hydraulic connections to the subsurface
- ❖ Presence of economic natural resources (gas, oil or minerals)
- ❖ Significant nearby populations

## Heat Flow



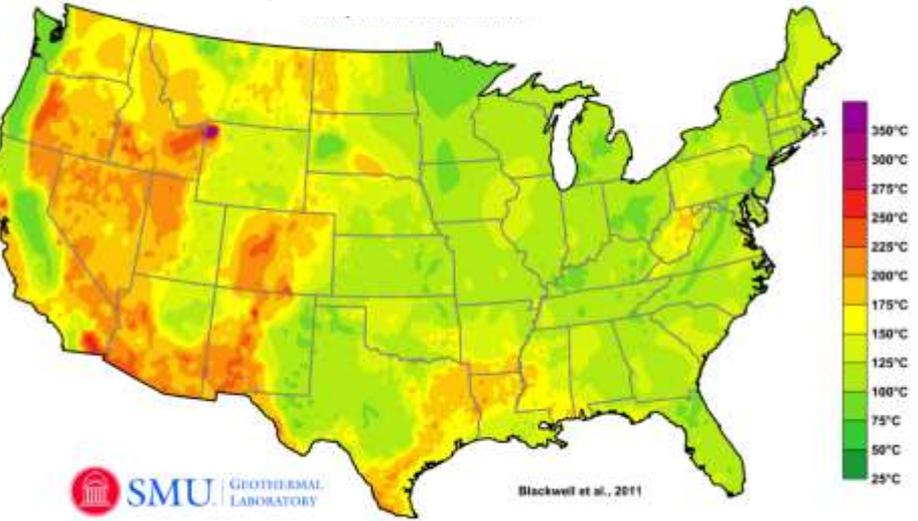
## Depth to highly salty water



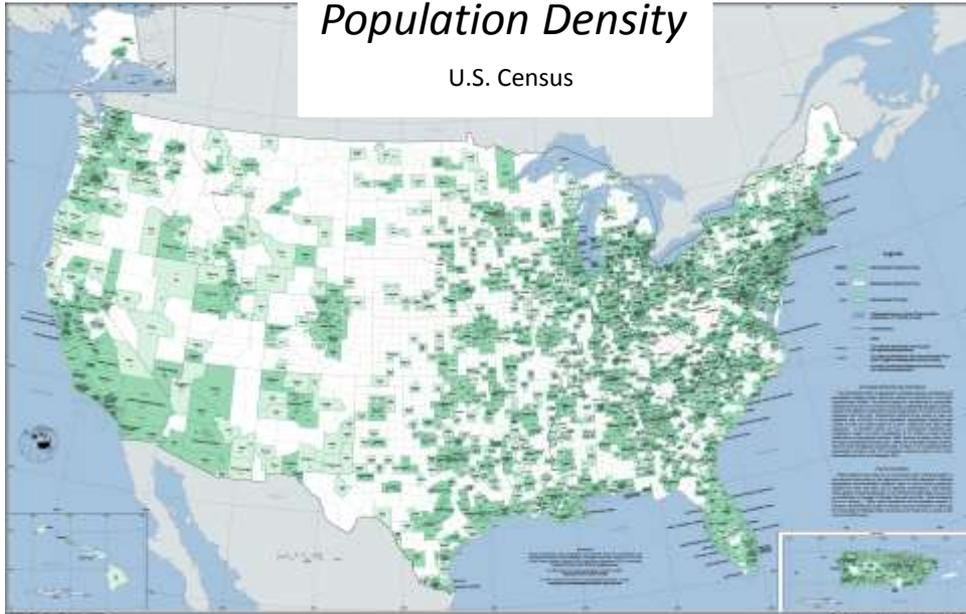
USGS Circular 1323

Impact of enhanced geothermal systems on US energy supply in the twenty-first century  
 15 April 2007, DOI: 10.1098/rsta.2006.1964

## Temperature at 5,500 meters



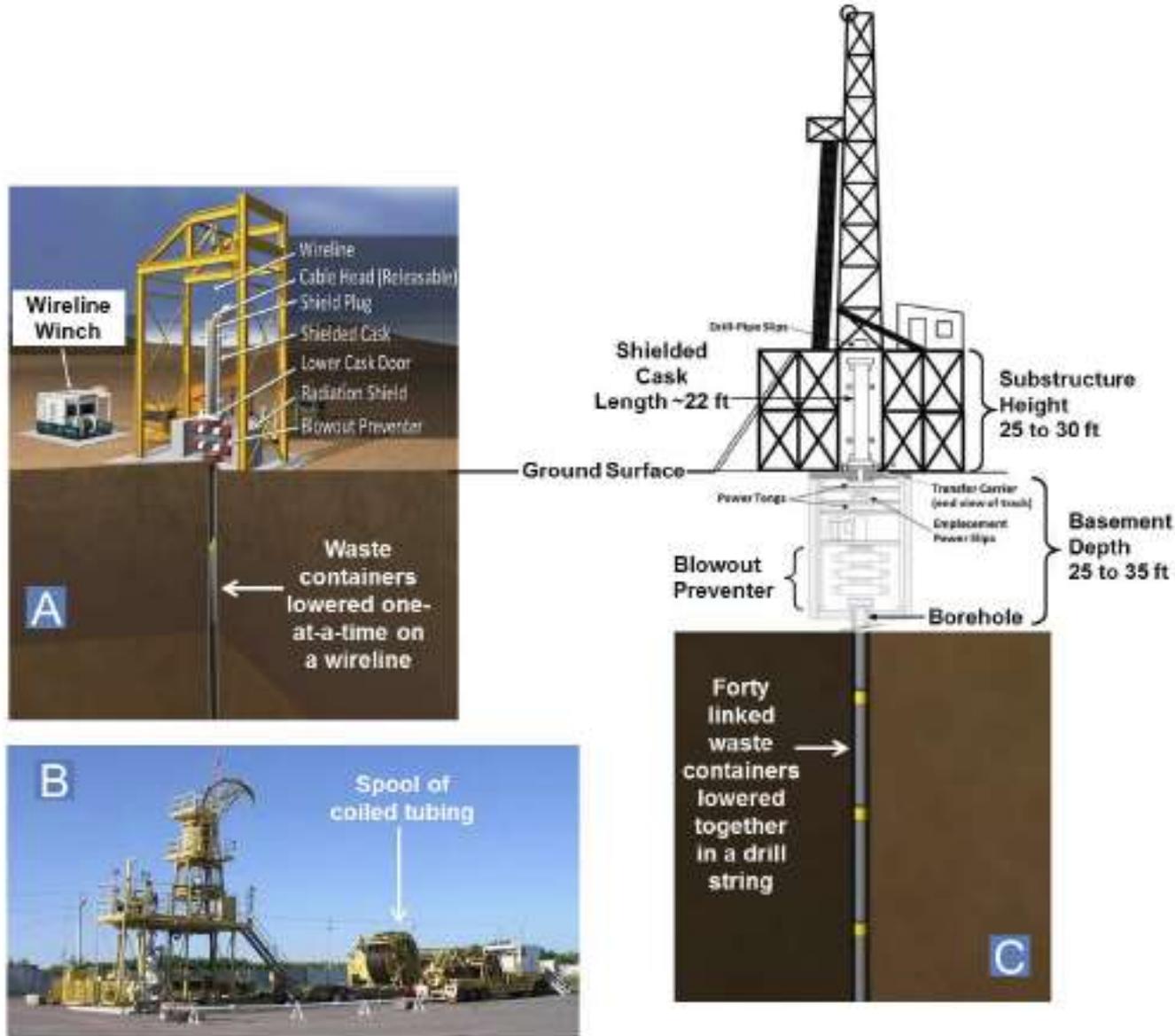
## Population Density





# Methods

- DOE Proposed two means of putting waste into the borehole:
  - Drill string emplacement  
Connecting all of the packages together and lowering them as a single 600,000 pound package
  - Wireline emplacement  
Lowering each waste container one at a time
- Experts suggested a third means
  - Coiled tube  
Lowering each waste container one at a time

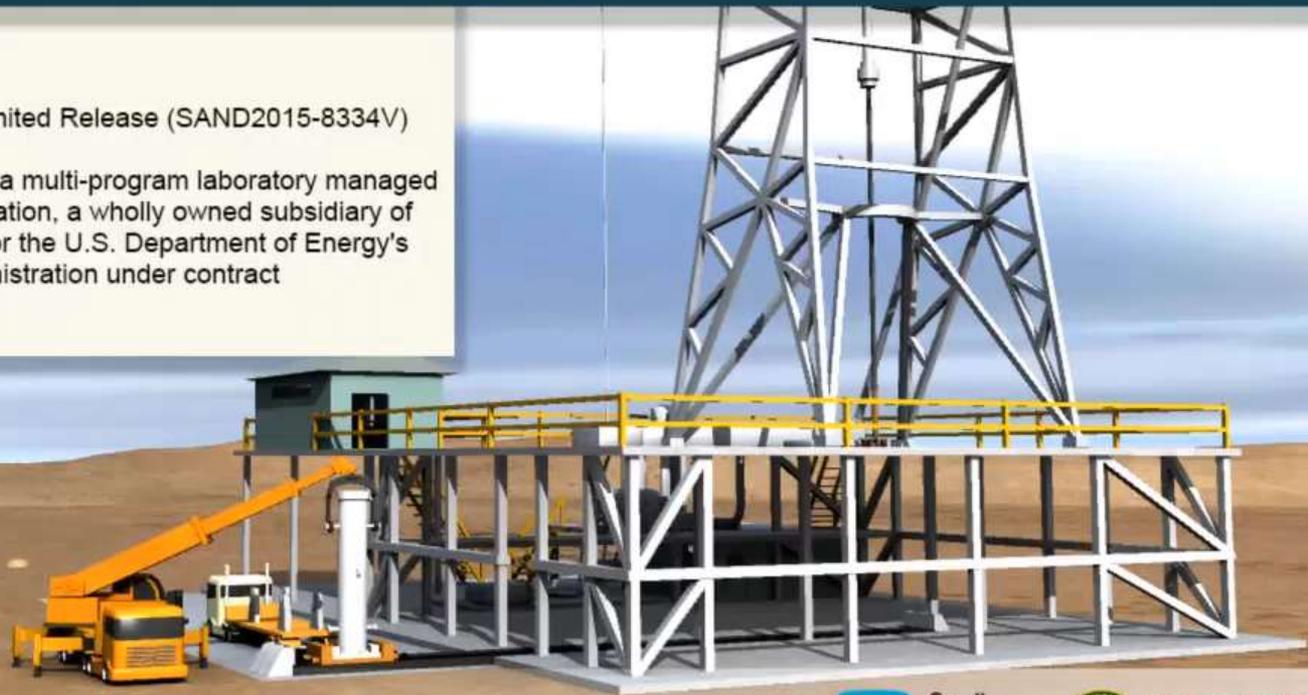


**Figure 2. Comparison of deep borehole emplacement modes: (A) wireline, (B) coiled tubing, and (C) drill-string**

# Deep Borehole Field Test Engineering Design Selection Study Drill-String Emplacement Operations

Sandia National Laboratories  
Albuquerque, NM  
Approved for Unclassified, Unlimited Release (SAND2015-8334V)

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Laboratories



U.S. DEPARTMENT OF  
**ENERGY**



OREGON  
DEPARTMENT OF  
ENERGY



# NWTRB

U.S. Nuclear Waste Technical Review Board

**October 20-21, 2015**

**Board Deep Borehole Workshop  
Washington, DC**

- International Panel of experts
- Two days of presentations and discussions with the Board
- Wide array of expertise
- Lots of hands on experience drilling deep wells.
- ❖ Identified a very large array of severe problems, issues, challenges and concerns with every aspect of the proposal
- ❖ Identified several technologies DOE/Sandia had not considered

# Key Observations

- Seven Panels
  - ❖ Panel 1 – Experience in Deep Drilling in Crystalline Rocks
  - ❖ Panel 2 – Emplacement
  - ❖ Panel 3 – Seals
  - ❖ Panel 4 – Hydrogeology
  - ❖ Panel 5 – Geochemistry
  - ❖ Panel 6 – Barriers
  - ❖ Panel 7 – Efficacy
- Long litany of issues that make potential success of deep boreholes extremely challenging

# Panel 1 – Deep Drilling Experience



[Кольская сверхглубокая скважина](#), [Andre Belozeroff](#),

# Panel 2 – Emplacement



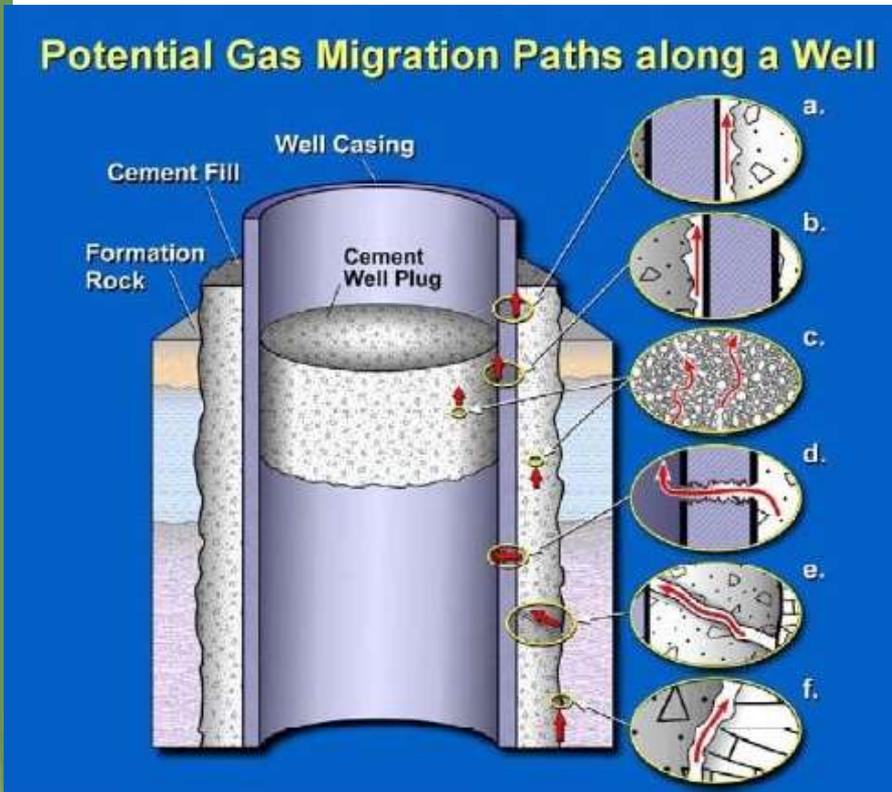
TRG Rig 131 oilfield blowout in Oklahoma.

Photographer: Charles Keevert

[http://www.energyindustryphotos.com/oilfield\\_blowout\\_photos\\_and\\_rig.htm](http://www.energyindustryphotos.com/oilfield_blowout_photos_and_rig.htm)

<http://www.drillingformulas.com/wp-content/uploads/2013/04/LeNorman-Ruth-87-2H-Fracking-Accident-4.jpg>

# Panel 3 – Seals



Alberta Energy

SAND2011-6749, October 2011, "Reference Design and Operations for Deep Borehole Disposal of High-Level Radioactive Waste", Arnold et.al, Figure 9

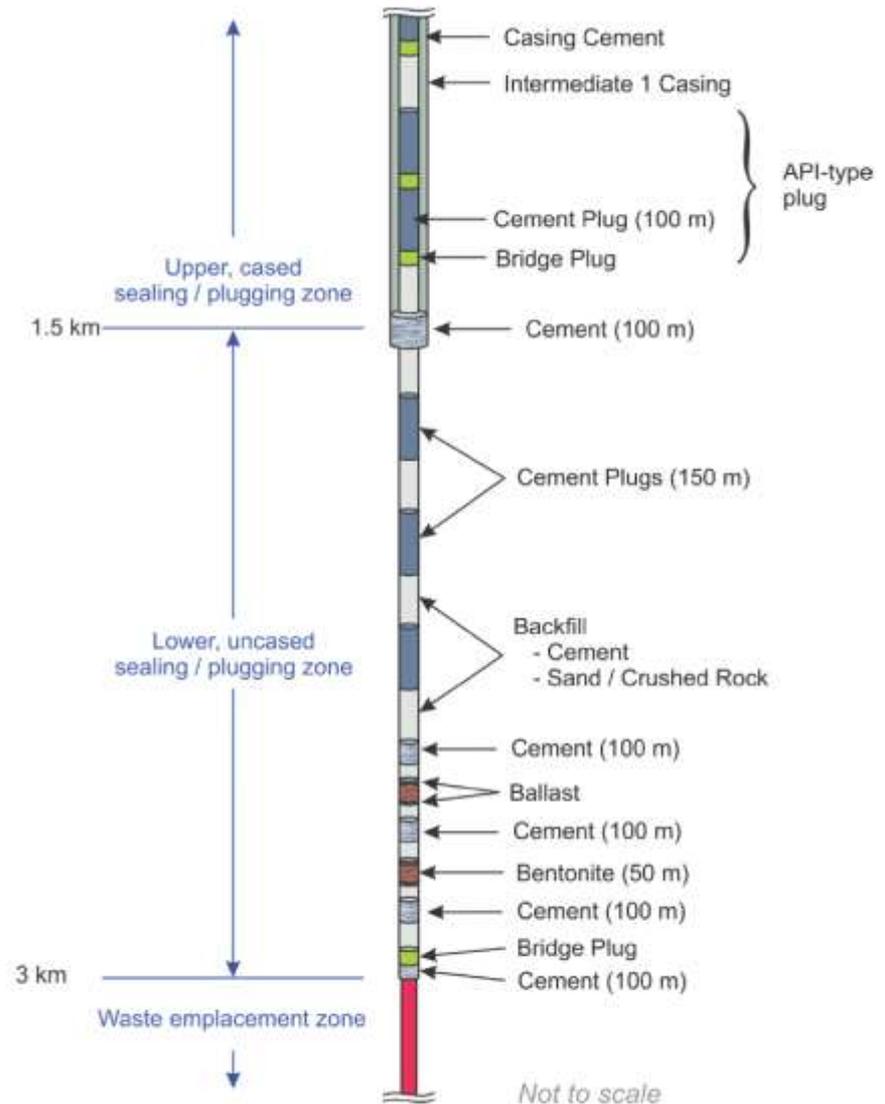


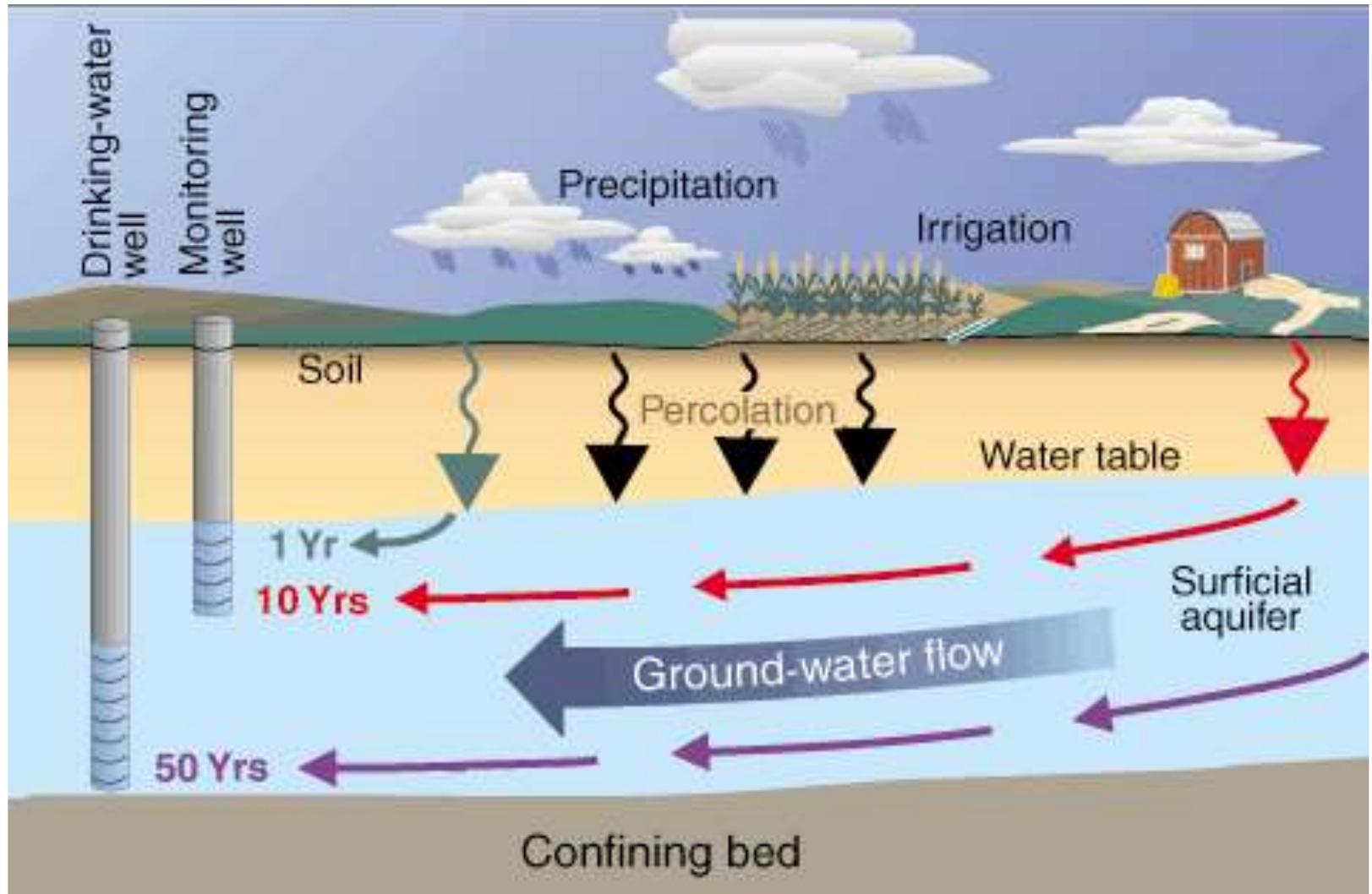
Figure 9. Borehole Sealing, Plugging, and Backfilling Reference Design Schematic.

# Panel 4 – Hydrogeology

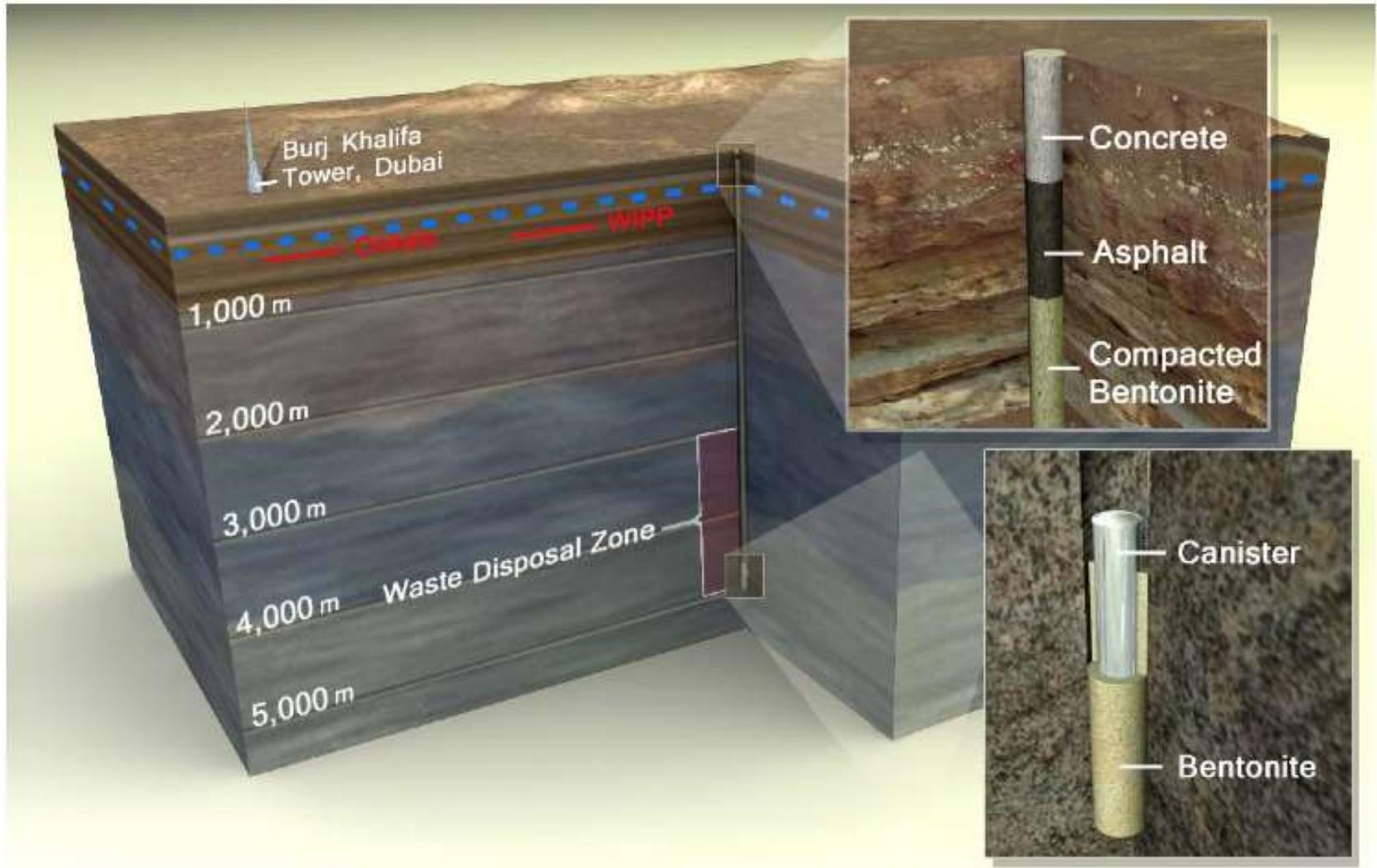


[http://www.dentonrc.com/incoming/20130728-drc\\_gas\\_leak.jpg.ece/BINARY/w460x307/DRC\\_Gas\\_Leak.jpg](http://www.dentonrc.com/incoming/20130728-drc_gas_leak.jpg.ece/BINARY/w460x307/DRC_Gas_Leak.jpg)

# Panel 5 – Geochemistry



# Panel 6 – Barriers



SAND2011-6749, October 2011, "Reference Design and Operations for Deep Borehole Disposal of High-Level Radioactive Waste", Arnold et.al. Figure 2.1

# Panel 7 – Efficacy

**Uncertainties & Unknowns**

**Risks and (in)Experience**



# Board recommendations

- *Independent expert review*
- *Comprehensive risk analysis*
- *Assess heterogeneity of subsurface geology and transferability of data and results of analysis*
- *Pre-drilling geophysical subsurface characterization*
- *Robust waste forms, waste packages, and seals*
- *Develop an operational safety strategy*
- *Engage regulators to define retrievability requirements*
- *Transparent pathway from the Deep Borehole Field Test to siting*
- *Chief scientist in charge of the Deep Borehole Field Test program*

# Field Test Site

- DOE issued a Request for Proposal for a field test borehole in April 2015
  - One characterization well,
  - One field test borehole, and
  - Emplacement of surrogates for actual waste test packages.
- No solicitation for public comment on
  - Site selection criteria – or –
  - Actual test site selection
- No radioactive or hazardous waste will ever be disposed at the test site.
- DOE received five proposals

# Field Test Site

- Jan 5, 2016 - DOE selected a Battelle Memorial Institute-led team
  - *Battelle Memorial Institute, Columbus, OH*
  - *University of North Dakota Energy & Environmental Research Center, Grand Forks, ND*
  - *Schlumberger, Houston, TX*
  - *Solexperts, Monchaltorf, Switzerland*
- Test borehole of over 16,000 feet into a crystalline basement rock
- \$35 million, 5 year contract
- 20 acres of a state-owned land outside of Balta
- About 15 miles south of Rugby in Pierce County, North Dakota
- Precise location withheld pending negotiations over lease and State approval

# State Response

- January 15, 2016 – State of North Dakota Land Board
  - > Wants a hearing on any application
  - > On the board's Jan. 29, 2016 agenda
- *“It is not certain whether there will be an application on the table, or whether team members, including the Energy and Environmental Research Center at Grand Forks, will simply provide information.”*
- *“The board heard some preliminary information in September and made it clear that anything about this project must be brought to them”*
  - board administrator Lance Gaebe
- North Dakota State Land Board members:
  - Jack Dalrymple: Governor
  - Alvin A. Jaeger: Secretary of State
  - Kirsten Baesler: Superintendent of Public Instruction
  - Kelly Schmidt: State Treasurer
  - Wayne Stenehjem: Attorney General

# Land Board meeting, Jan 29, 2016

## **Jack Dalrymple, Governor and Chair of the State Board of University and School Lands:**

- *"It seems to me that normally you would test where you are thinking you might someday actually do something"*
- *"We need to hold up until we figure out what the proper steps are if we want to keep working on this."*

## **Wayne Stenehjem, N.D. Attorney General:**

- *"It is unlikely that there would be broad public support for utilizing North Dakota for the purpose of storage of spent nuclear waste."*
- *"It might be nice to know what the composition of the bedrock is, but if the goal is to utilize North Dakota as a place for storing spent nuclear waste, that's something that I think not very many people would be excited about."*
- *"I think there's a long ways to go."*
- *"We're not unused to having the federal government come in and push things down our throat."*

<http://www.inforum.com/news/3935017-officials-raise-deep-concern-proposed-drilling-project-near-rugby-could-lead-nuclear>

<http://www.thepiercecountytribune.com/page/content.detail/id/511502/Rocky-Roads-for-Borehole.html?nav=5003>



# Land Board meeting

## **Mike Nowatzki / Forum News Service quoting Harju:**

- John Harju, vice president for strategic partnerships at the EERC, stressed that the five-year project will involve no nuclear waste, noting that the type of disposal being studied isn't allowed under current law. But he said it will produce valuable core samples and information about the state's geology, potential new mineral wealth and geothermal possibilities. The Department of Energy has committed \$35 million to the project. *"This is an extremely rare opportunity to learn a great deal about the deep subsurface under our state,"* he said.

## **Lauren Donovan, Bismarck Tribune quoting Harju:**

- The chance to go that deep, into the oldest rock on the planet, *"May never present itself again,"* Harju said.

<http://www.inforum.com/news/3935017-officials-raise-deep-concern-proposed-drilling-project-near-rugby-could-lead-nuclear>

<http://www.thepiercecountytribune.com/page/content.detail/id/511502/Rocky-Roads-for-Borehole.html?nav=5003>



# Land Board meeting

## **Mike Nowatzki / Forum News Service quoting Stenehjem:**

- If the study finds the site suitable for nuclear waste disposal, *“then we’ll go through that turmoil.”* He questioned whether it’s an alternative to the stalled Yucca Mountain Nuclear Waste Repository in Nevada, which has faced intense public and political opposition.
- He questioned whether it’s an alternative to the stalled Yucca Mountain Nuclear Waste Repository in Nevada, which has faced intense public and political opposition. *“This isn’t something that I’m all that thrilled to see,”* he said. *“We’re contributing plenty to the energy needs of this nation, and I don’t know if I even want to start with this.”*

<http://www.inforum.com/news/3935017-officials-raise-deep-concern-proposed-drilling-project-near-rugby-could-lead-nuclear>

## **Jim Olson, KX News quoting Stenehjem:**

- Stenehjem says the Land Board has not taken any action on the lease request - and even if the EERC finds a landowner willing to allow the drilling, there would have to be a permit issued by the State Industrial Commission.
- He's encouraging the EERC to work with local governments in Rugby and Pierce County to explain the plan before the idea moves along any further.

<http://www.kxnet.com/story/31095378/rugby-project-could-bring-nuclear-waste-to-nd>

# Land Board meeting

## **Dave Migler, Pierce County Commissioner:**

- *"I had three (citizen calls) this morning, absolutely against it."*
- *"I don't know why they're coming here but nuclear waste is a scary deal, I mean there's none in North Dakota now. But that's the big issue right there is nuclear waste."*

## **Mike Nowatzki / Forum News Service quoting Migler:**

- Pierce County Commissioner David Migler, who lives 12 miles from the proposed site, said news of the proposal *"really threw us for a loop"* and has generated a lot of calls to local officials. Harju said the EERC learned it had been selected the same day Moniz released his statement. *"It is a deep concern for us,"* Migler said, adding, *"I don't see any benefit to the county."*

## **Mike Nowatzki / Forum News Service quoting Dalrymple:**

- *"I think the whole state Legislature is ultimately the place you're going to wind up,"* he told Harju.

## **John Harju, vice president for strategic partnerships at the EERC**

- *"Plan B? We don't have one. If the project is not able to proceed, the DOE will have to evaluate alternatives."*

<http://www.kxnet.com/story/31095378/rugby-project-could-bring-nuclear-waste-to-nd>  
<http://www.thepiercecountytribune.com/page/content.detail/id/511502/Rocky-Roads-for-Borehole.html?nav=5003>



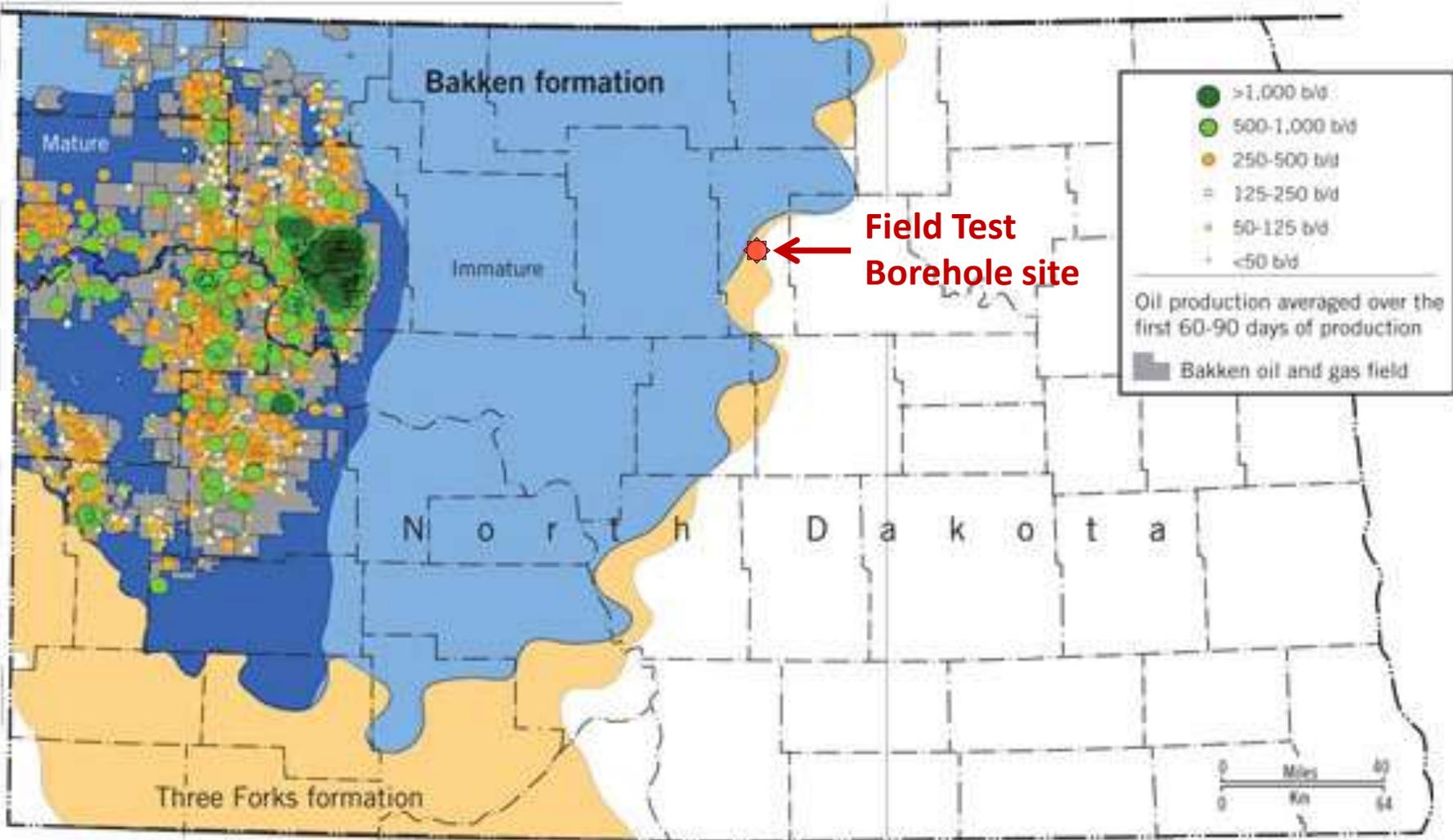
# USDOE Consent Based Siting

- Views the voluntary nature of the teams submitting proposals as a test of the Blue Ribbon Commission on America's Nuclear Future "consent based siting" process.
- Refuses to release details about the precise location selected
- Refuses to release any details at all about the other four teams or sites claiming legal procurement limitations.
  - *"Unfortunately, the Federal Acquisition Regulation (FAR) 15.506.(e) prevents the Department from providing information on the unsuccessful applicants to the Borehole Funding Opportunity Announcement."* – Alison Kennedy, DOE/HQ
  - *"Additionally, this also prevents the Department from releasing the evaluation of the winning proposal."* – Alison Kennedy, DOE/HQ
  - *"The drilling site itself is located on 20 acres of Department of North Dakota Trust land in Pierce County, North Dakota. It is about thirty miles south of Rugby on the west side of Highway 3. We cannot provide exact coordinates at this time, as Battelle is still working to finalize the land lease."* – Alison Kennedy, DOE/HQ

# Field Test Schedule

	FY15	FY16	FY17	FY18	FY19	
<b>Characterization Test Borehole Contract</b>		* 2/5/16				
Start Drilling		* 9/1/16				
Complete Borehole			* 2/27/17			
<b>Field Test Borehole Contract</b>			* 1/13/17			
Start Drilling			* 7/7/17			
Complete Borehole				* 1/7/18		
<b>Emplacement</b>						
Start Emplacement				* 1/17/18		
Complete Emplacement					* 1/17/19	
Evaluate Results					* 9/30/19	

# DISTRIBUTION OF NORTH DAKOTA BAKKEN WELLS



Source: Reference E

# North Dakota Geology

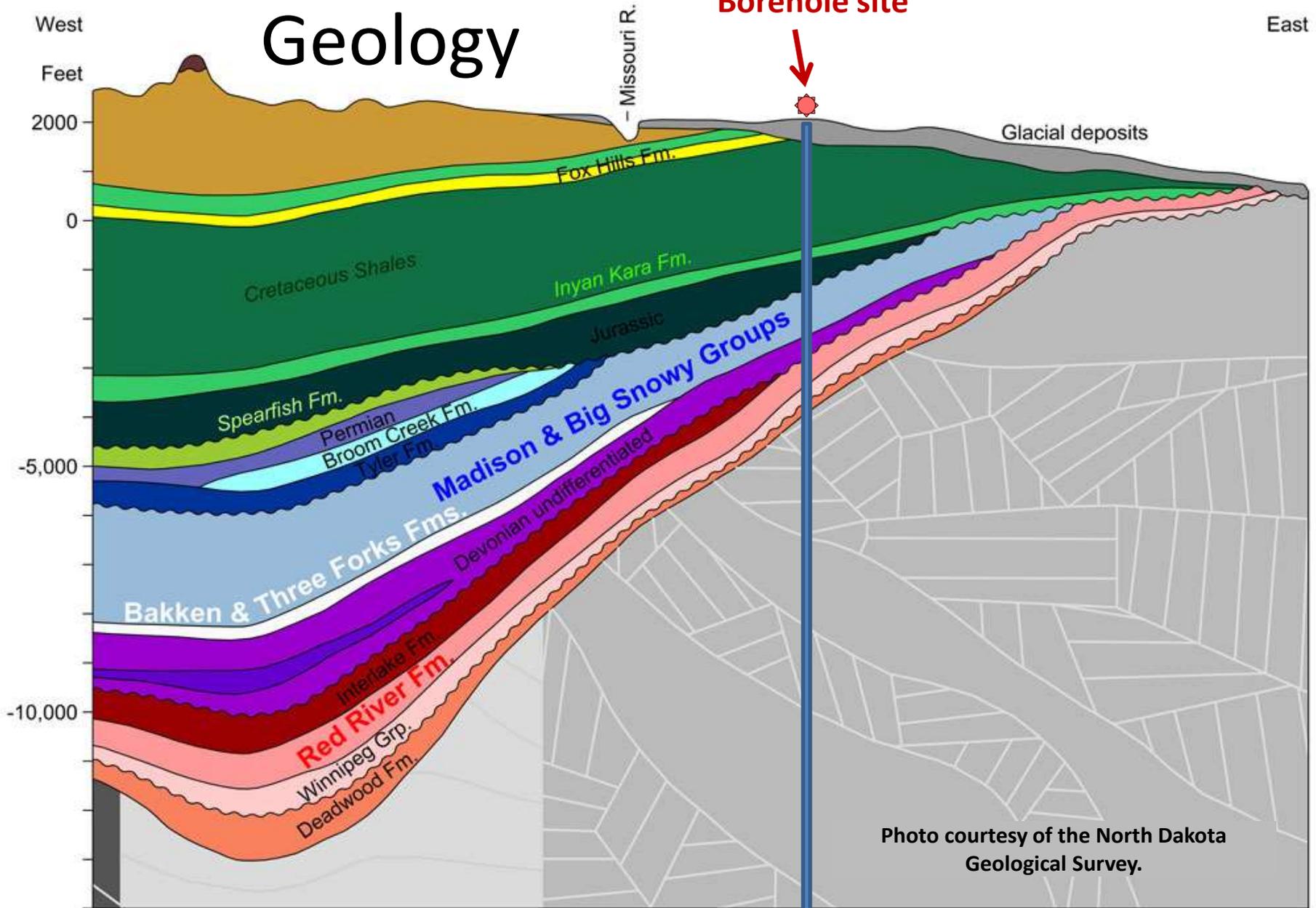


Photo courtesy of the North Dakota Geological Survey.

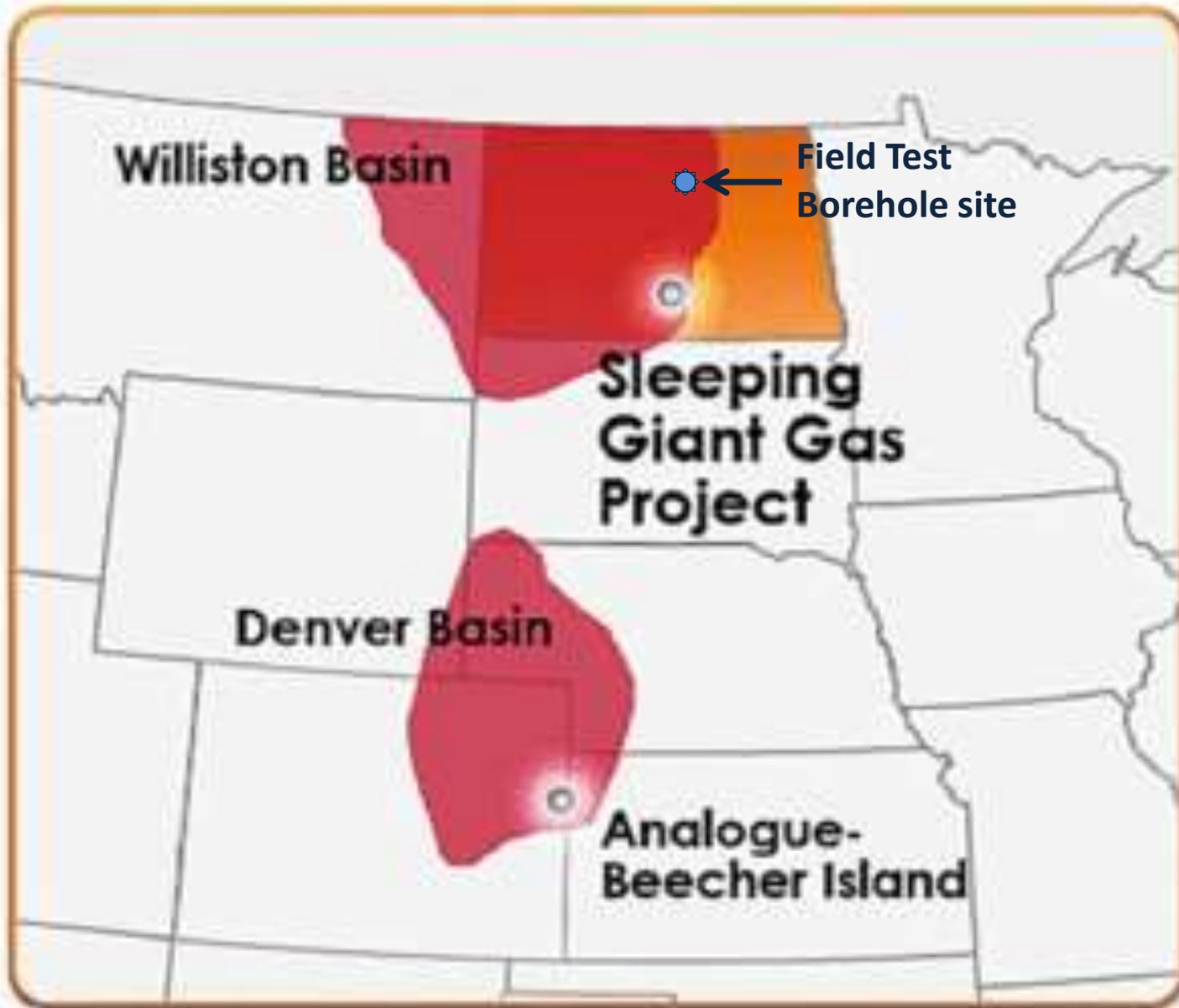
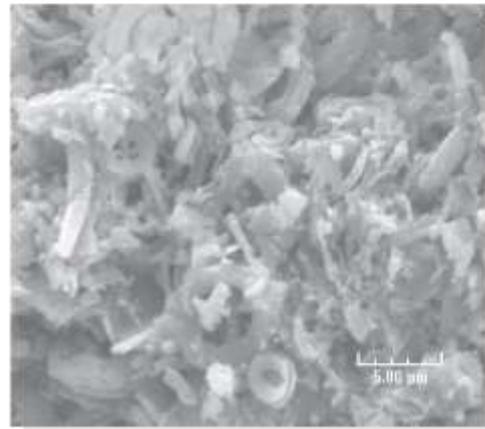
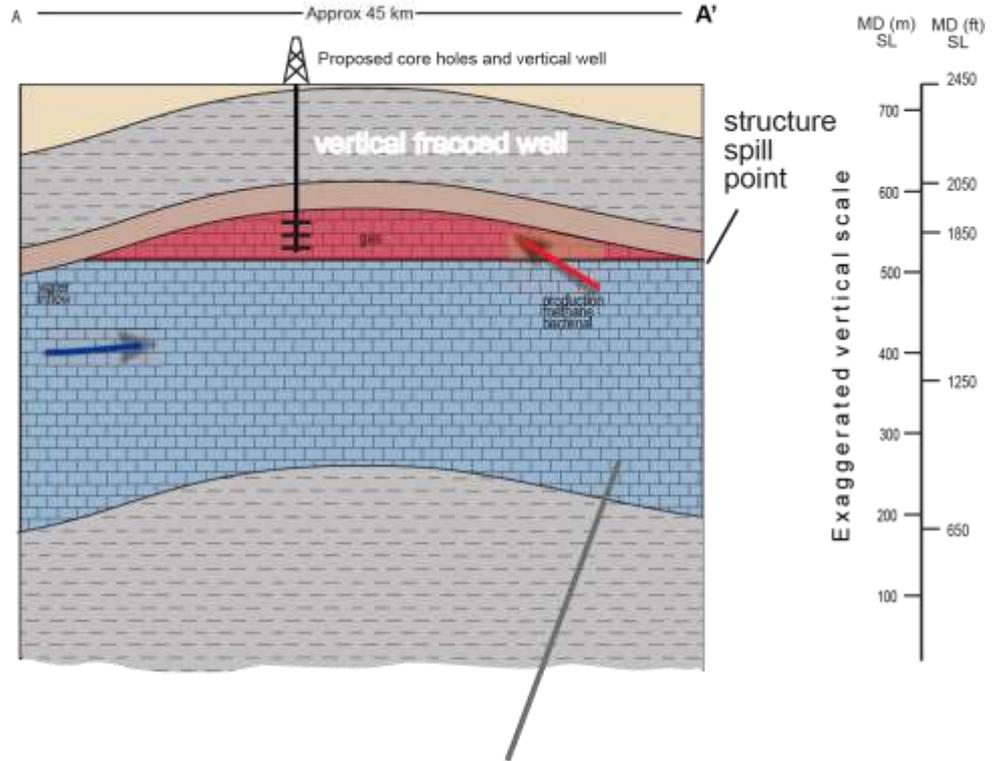
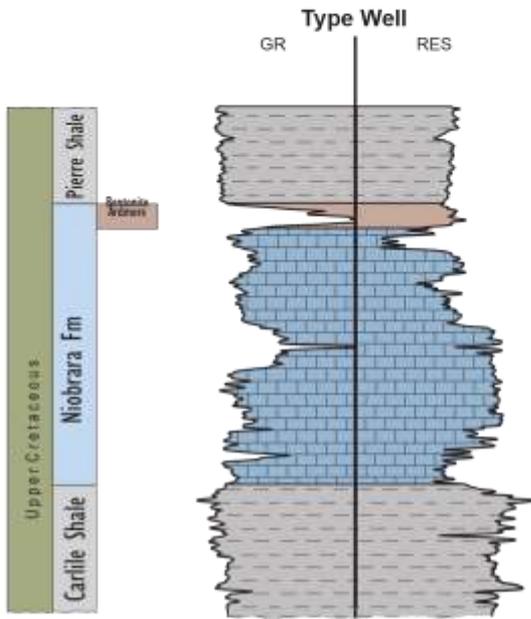


Image: Courtesy of Strata-x

# SLEEPING GIANT SHALLOW NIOBRARA GAS PLAY



SEM Image showing abundant porosity

Image: Courtesy of Strata-x <http://www.strata-x.com/images/sleeping-giant-01.png>



OREGON  
DEPARTMENT OF  
ENERGY

# Summary - Potential advantages

- Alternate path for small diameter waste forms
- Earlier disposal than a large deep repository
- Cost advantages depending on waste pretreatment required

# Summary - Potential Disadvantages

- No protection to the environment from the hole
- Claimed passive safety appears unlikely
- No full site characterization or safety assessment
- Calculated doses mean little

# Summary - Risks

- Sudden failures possible
  - with loss of control and little ability to recover
- Single point failures during operation
  - e.g. package drop, well collapse, ...
- Costs will push toward single barrier -> increasing risks
- Large suite of unknowns

# Summary - Expected uncertainties

- Operational risks likely to dominate
- Post-closure risks may pop up as we better understand conditions and scenarios
  - Geotechnical
  - Microbial
  - Hydrogeologic
- High temperatures may impact waste forms and needs consideration
- Lack of international experience: No benchmark available

# Questions



# Credits

Coleman, J.L., Jr., and Cahan, S.M., 2012, *Preliminary catalog of the sedimentary basins of the United States: U.S. Geological Survey Open-File Report 2012–1111*, 27 p. (plus 4 figures and 1 table available as separate files), <http://pubs.usgs.gov/of/2012/1111/>

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Nuclear Waste Technical Review Board, January 2016, *A Report to the U.S. Congress and the Secretary of Energy, Technical Evaluation of the U.S. Department of Energy Deep Borehole Disposal, Research and Development Program*, <http://www.nwtrb.gov/reports/DBD.pdf>

# Credits

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