SAND2014-15278PE

Used Fuel Disposition Campaign

Deep Borehole Disposal Work Package

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Sandia National Laboratories

UFD Working Group Meeting UNLV 2014
June 4, 2014

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Objectives

- **Provide summary of work on deep borehole disposal project since June, 2013 and for first part of FY14**
- **Enhance coordination and collaboration with other participants in the UFD program, in particular regarding the deep borehole demonstration project beginning in FY15**
- **Obtain input and suggestions from other UFD participants on potential future work in the deep borehole disposal demonstration project**

Deep Borehole Disposal Participants

- **DOE Lead**
  - Lam Xuan
- **SNL**
  - Bill Arnold, Patrick Brady, Robert MacKinnon, Jack Tillman
- **LLNL**
  - Mark Sutton
- **University of Sheffield**
  - Fergus Gibb and Karl Travis

Outline

- Introduction
- Demonstration Project Site Evaluation
- Deep Borehole Disposal of Alternative Waste Forms
- Borehole Seals Research
- Review of RD&D Goals for Overlap with Enhanced Geothermal Energy Research
- FY15 Planning: Initiation of Deep Borehole Demonstration Project

Introduction: Milestones

- **M2FT-14SN0817022 – Deep Borehole Disposal Research: Demonstration Site Selection Guidelines, Borehole Seals Design, and RD&D Needs**
  - **Level 2 Milestone Report**
  - **Delivered 10/25/2013 as Report # FCRD-USED-2013-000409 (SAND2013-9490P)**
- **M3FT-14SN0817021 – Geological Data Evaluation, Alternative Waste Forms, and Seals for Deep Borehole Disposal Demonstration**
  - **Level 3 Milestone Report**
  - **Due 09/05/2014**

Introduction: FY14 Workscope

- **Evaluation of sub-regional geological information for the deep borehole disposal demonstration project site selection at several representative sites**
- **Development of reference disposal designs for alternative waste forms (e.g., Cs-137 and Sr-90 capsules)**
- **Borehole seals research and planning**
- **Review of deep borehole RD&D goals and needs for overlap with enhanced geothermal energy research being conducted by DOE**

Demonstration Site Evaluation

- Several potential representative sub-regional areas were considered for research on demonstration site evaluation
- Three representative areas were chosen, based on preliminary regional site selection analyses from FY14 and programmatic considerations:
  - Area in northeastern South Dakota
  - Texas panhandle area, including Pantex Plant Site
  - Savannah River Site area in South Carolina
- Evaluations based on existing geological, hydrogeological, and geophysical data

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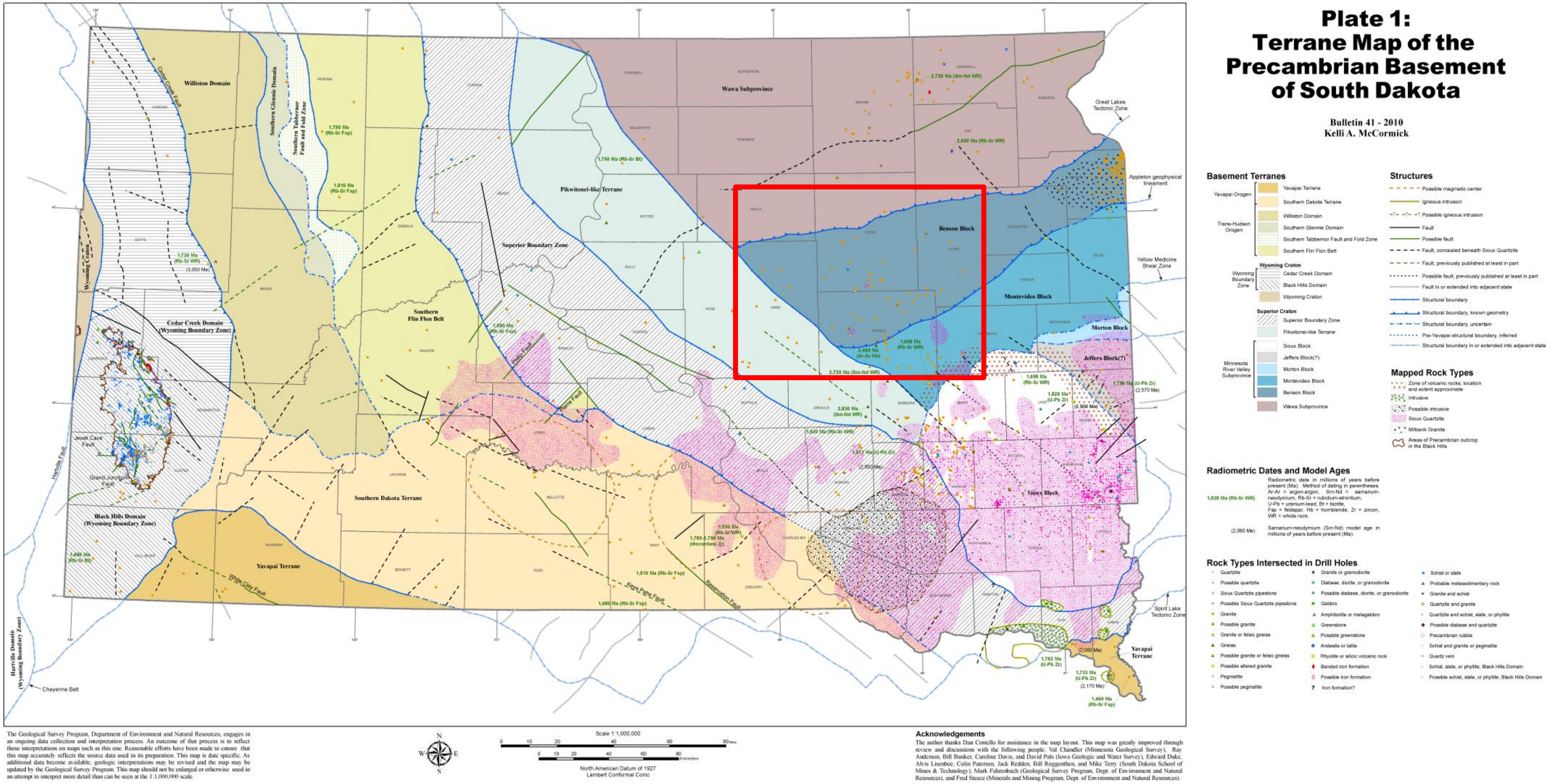
Demonstration Site Evaluation Example: South Dakota



from McCormick (2010)

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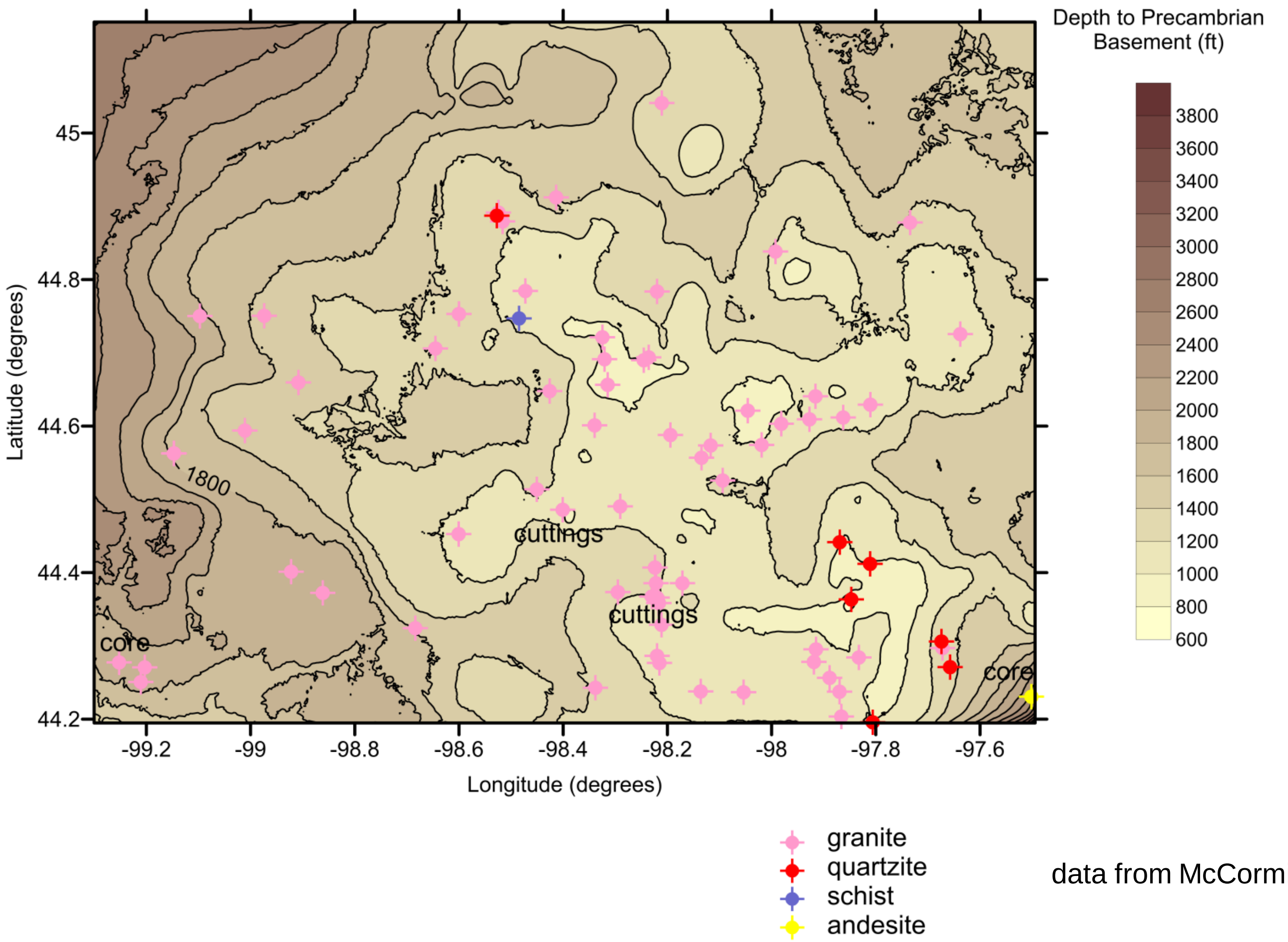

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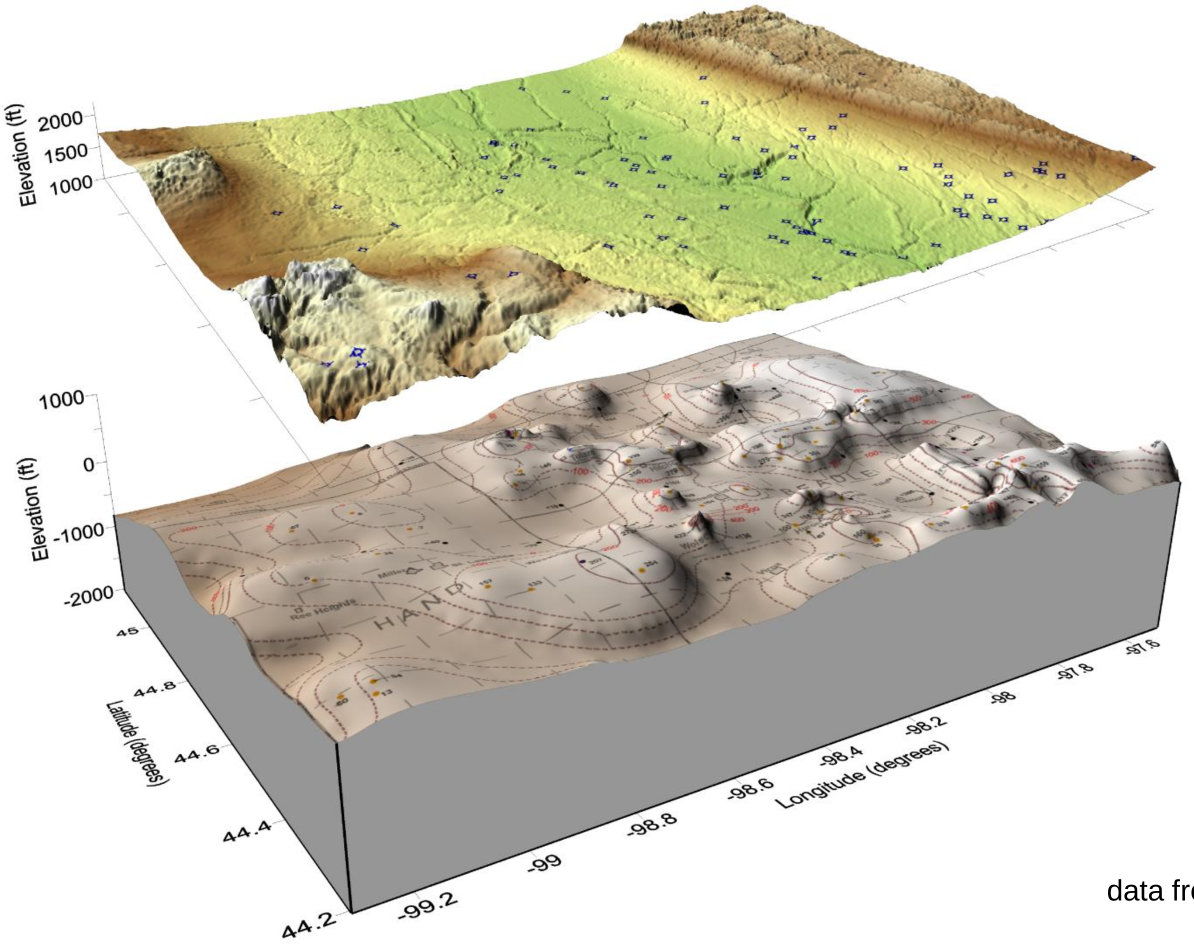

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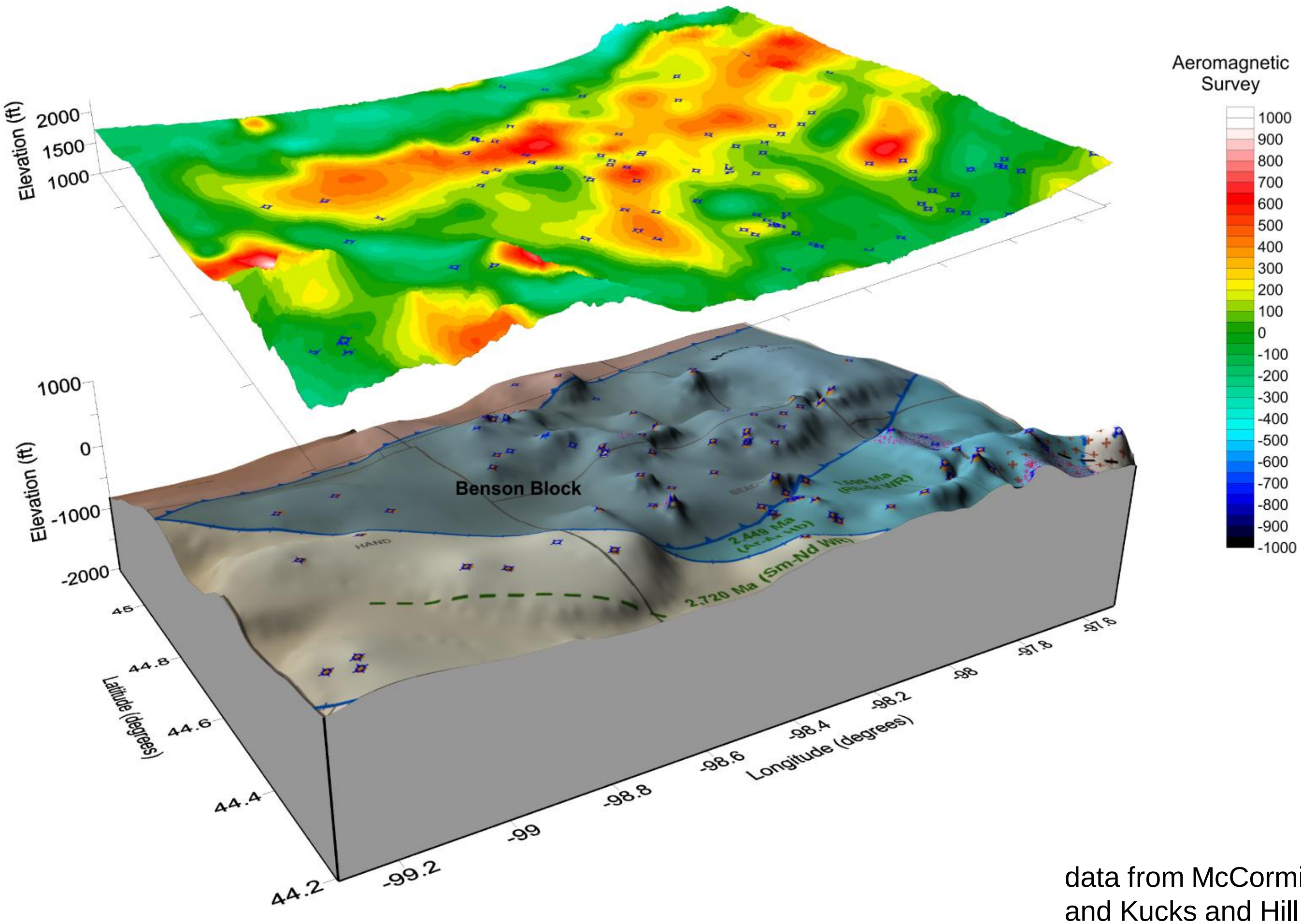

data from McCormick (2010) and Kucks and Hill (2002)

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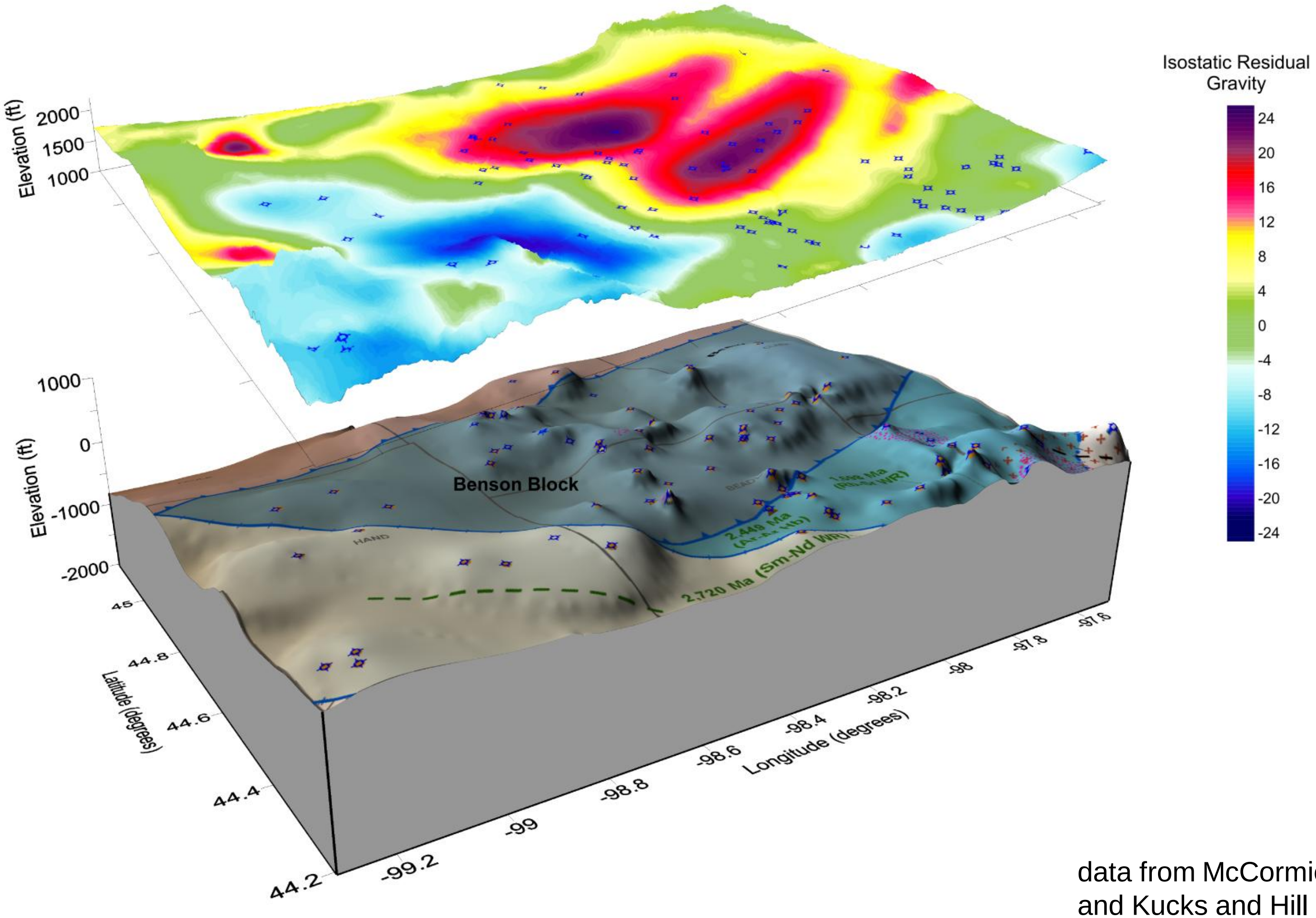

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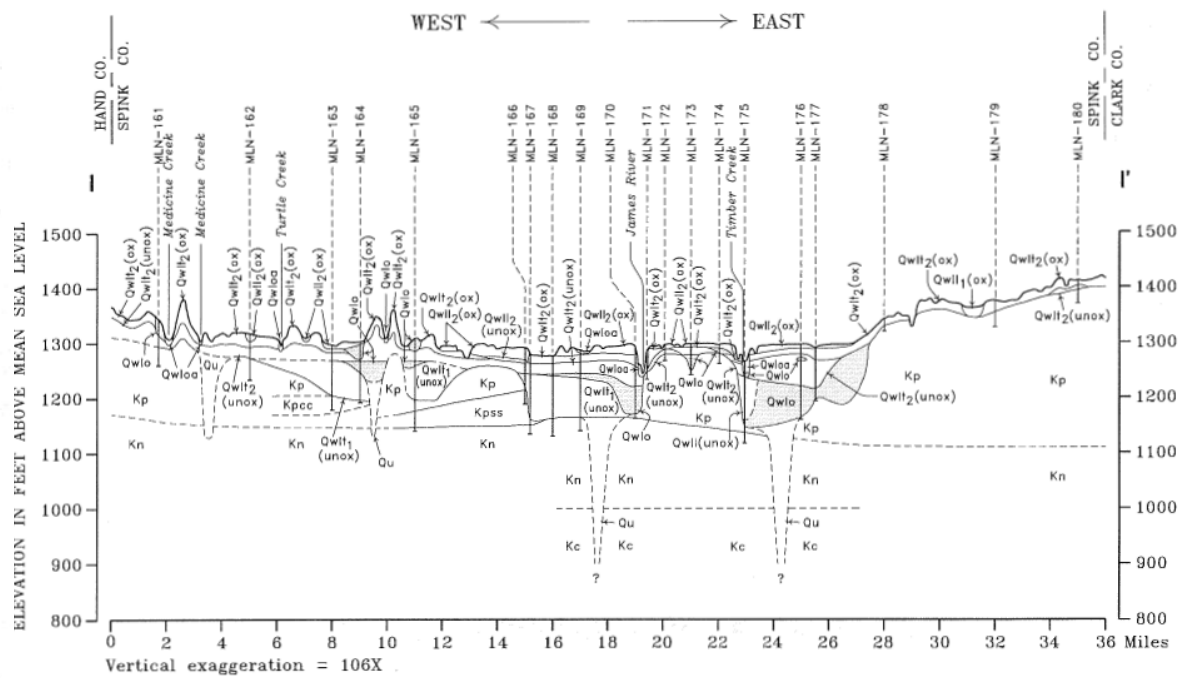
Demonstration Site Evaluation Example: South Dakota

Era	Period		Rock Units		Description	Thickness in Feet	Cretaceous Cyclothem
Cenozoic	Quaternary	Holocene / Pleistocene	See Table 2		See text pages 34 to 38	0 - 400	
	Tertiary		None		None	0	
Mesozoic	Cretaceous	Upper	Pierre Shale	undifferentiated	Gray to dark-gray, noncalcareous claystone; with concretions and bentonite layers.	0 - 240	Bearpaw
				DeGrey Member	Gray claystone; with numerous bentonite layers.	(0 - ?)	
				Crow Creek Member	Light-gray; calcareous sand, chalk, and calcareous shale.	(0 - 35)	
				Gregory Member	Gray, noncalcareous claystone.	(0 - 110)	Claggett
				Sharon Springs Member	Black, highly organic noncalcareous, bentonitic claystone.	(0 - 60)	
			Niobrara Formation		Dark-gray; calcarenite, chalk, and calcareous shale; pyritic, burrowed, containing some bentonite.	0 - 130	Niobrara
			Carlile Shale	unnamed member	Gray shale.	190 - 240	Greenhorn
				Codell Sandstone Member	Fine- to coarse-grained sandstone; cross-bedding; abundant sharks teeth and phosphatic nodules.		
				Blue Hill Shale Member	Dark-gray, pyritic, concretionary mudstone.		
				Fairport Chalky Member	Grayish-brown, chalky, organic-rich shale.		
			Greenhorn Limestone		Grayish-brown calcareous claystone; with thin shelly, argillaceous limestone layers.	20 - 75	
			Graneros Shale		Dark-gray, noncalcareous, pyritic, poorly fossiliferous claystone; with abundant thin sand layers near base.	250- 360	
			Dakota Formation		White to light-gray, fine-grained, quartz sandstone; with some claystone layers.	100 - 200	
		Lower	Skull Creek Shale		Dark-gray to black claystone.	0 - 50	Kiowa-Skull Creek
			Inyan Kara Group		Undifferentiated sandstone and claystone.	0 - ?	
	Jurassic				?	0 - ?	
	Triassic				?	0 - ?	
Paleozoic					?	0 - ?	
Precambrian			Precambrian		Variable igneous and metamorphic rocks.	?	

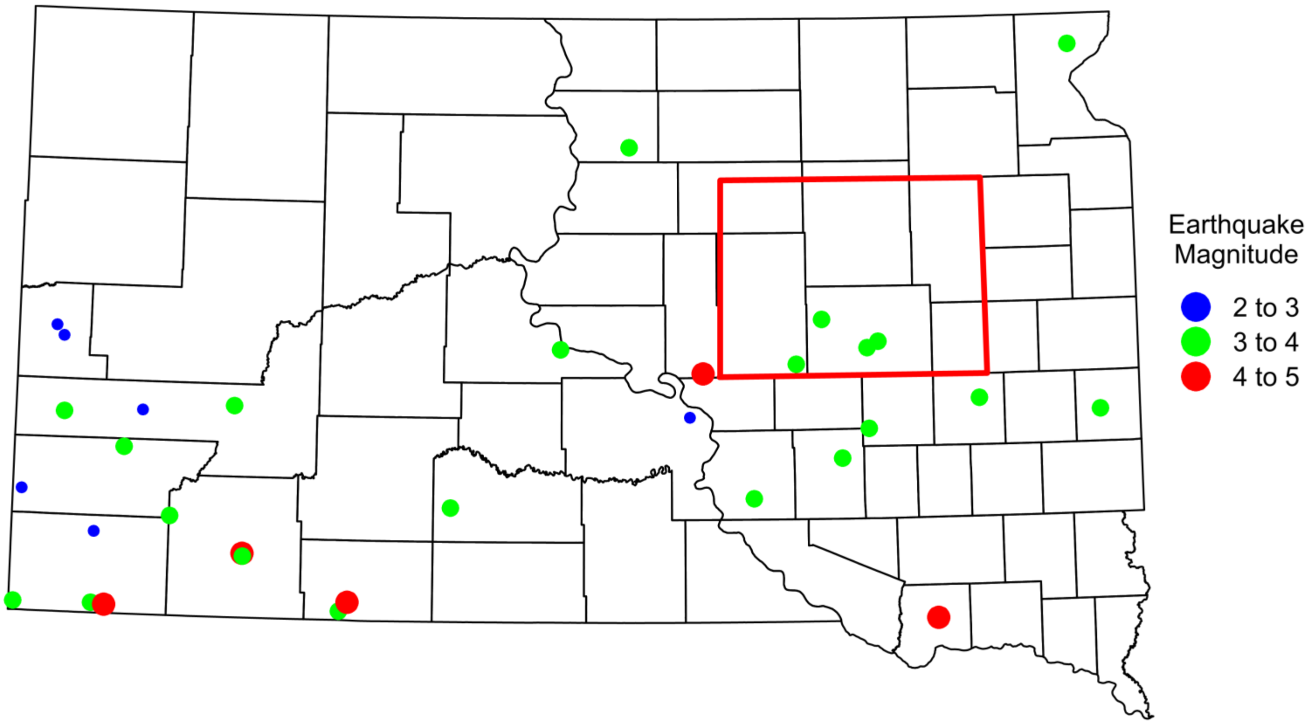
══ Period of erosion or nondeposition (unconformity)

TABLE 1. Generalized stratigraphic column of geologic units in Spink County, South Dakota



from Tomhave (1997)

Demonstration Site Evaluation Example: South Dakota



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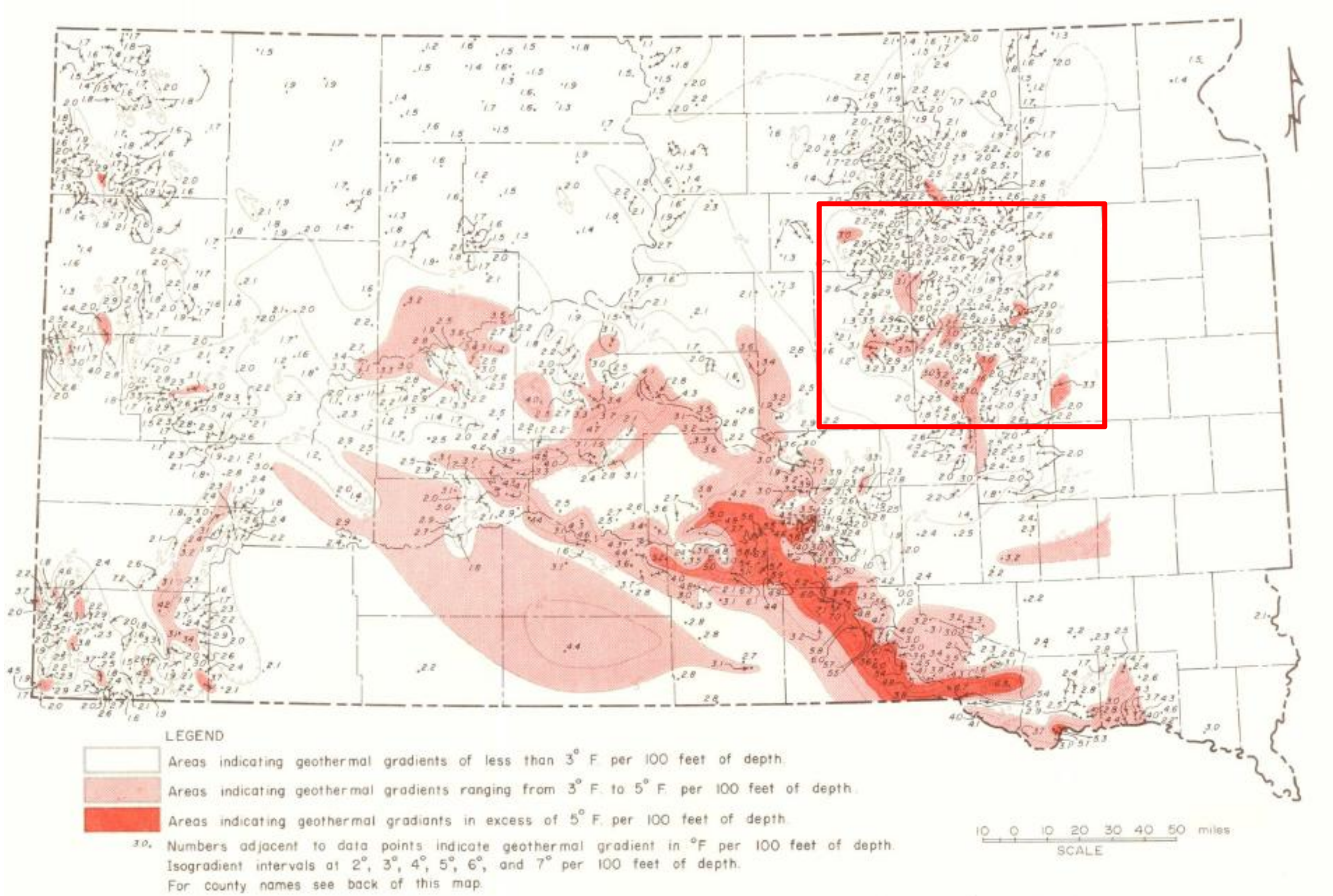


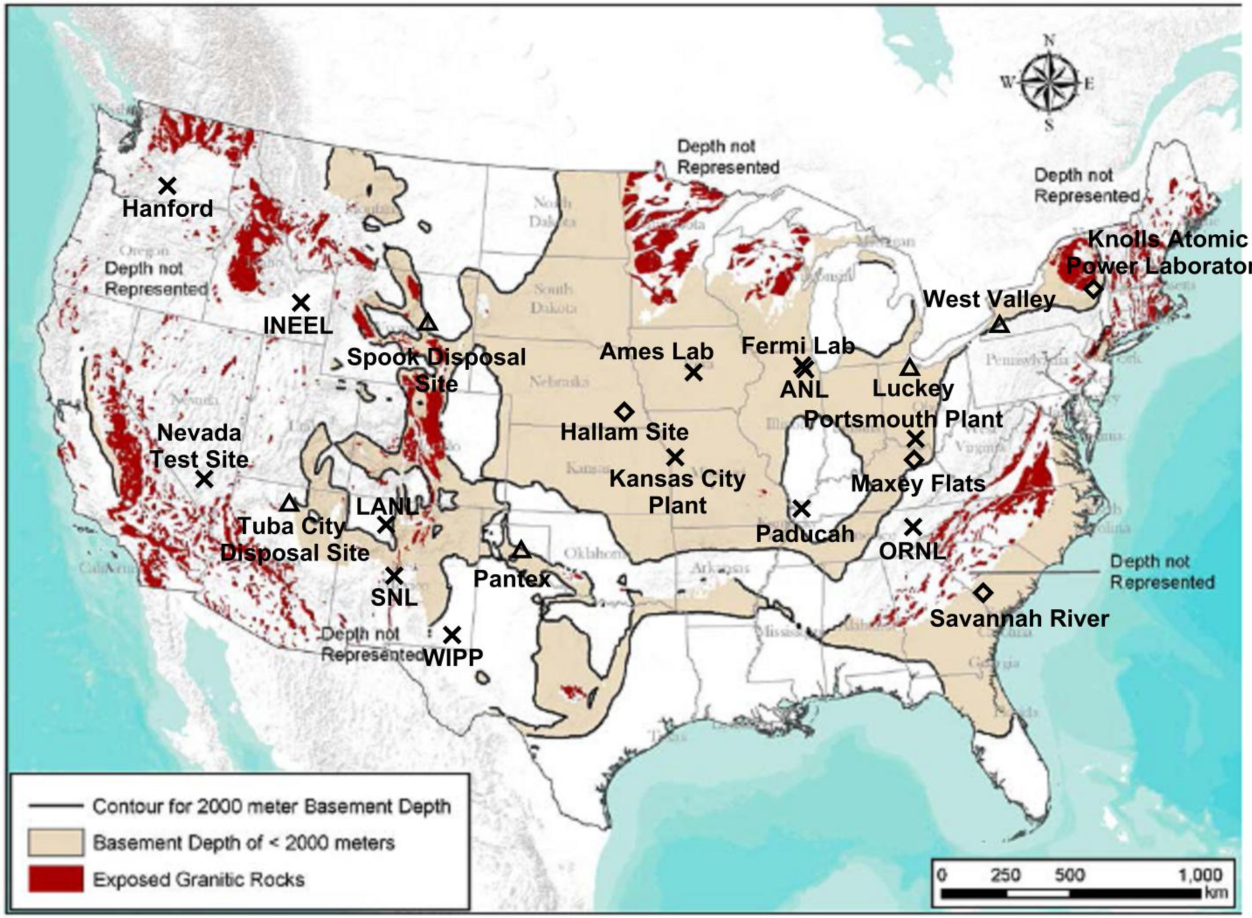
from Schoon and McGregor (1974)

Demonstration Site Evaluation: Preliminary DOE Site Screening

DOE Site Screening Criteria

- **<u>Depth to crystalline basement</u> – less than 2 km to basement effectively required**
- **<u>Strategic petroleum reserve site</u> – these sites were effectively eliminated**
- **<u>Distance to urban area</u> – sites within 10 km of an urban area were effectively eliminated**
- **<u>Site area greater than 1 km^2</u> – sites with ample area for drilling operations preferred**
- **<u>Distance to large topographic relief</u> – distance of greater than 100 km to topographic slope of greater than 1º preferred to avoid deep groundwater circulation**
- **<u>Geothermal heat flux</u> – less than 75 mW/m^2 preferred**
- **<u>Seismic hazard</u> – less than 2% probability within 50 years of peak ground acceleration greater than 0.16 g preferred. Also generally indicative of tectonic stability**
- **<u>Distance to Quaternary age volcanism</u> – greater than 10 km distance preferred**
- **<u>Distance to Quaternary age faulting</u> – greater than 10 km distance preferred**
- **<u>Crystalline basement structural complexity</u> – lack of major shear zones or major tectonic features preferred**
- **<u>Density of petroleum drilling</u> – low density of deep drilling preferred**
- **<u>Existing deep subsurface radioactive contamination</u> – lack of existing radioactive contamination preferred**

Demonstration Site Evaluation: Preliminary DOE Site Screening



Demonstration Site Evaluation: Preliminary DOE Site Screening

High Ranking DOE Sites

DOE Site Name	State	Ranking Class	Notes
Maxey Flats Disposal Site	Kentucky	Primary	Some uncertainty in depth to crystalline basement
Hallam Nuclear Power Facility	Nebraska	Primary	Crystalline basement may be structurally complex.
Savannah River Site	South Carolina	Primary	Crystalline basement rocks at this site are geologically younger than the Precambrian age rocks at most other sites. Hydrogeological isolation of these rocks is less well established.
Knolls Atomic Power Laboratory	New York	Primary	Relatively near urban area
Luckey Site	Ohio	Secondary	Relatively small site area
Spook UMTRA Site	Wyoming	Secondary	Significant uncertainty exists concerning the depth to crystalline basement. Additional information might eliminate this site on that basis.
Pantex Plant	Texas	Secondary	Significant uncertainty exists concerning the depth to crystalline basement. Additional information might eliminate this site on that basis.
Tuba City UMTRA Site	Arizona	Secondary	Significant uncertainty exists concerning the depth to crystalline basement. Additional information might eliminate this site on that basis.
West Valley Demonstration Project	New York	Secondary	Significant uncertainty exists concerning the depth to crystalline basement. Additional information might eliminate this site on that basis.

Demonstration Site Evaluation: Preliminary DOE Site Screening

Representative Disqualified DOE Sites

DOE Site Name	State	Notes
Argonne National Laboratory - East	Illinois	Relatively near urban area
Portsmouth Gaseous Diffusion Plant	Ohio	Relatively near urban area
Fermi National Accelerator Laboratory	Illinois	Relatively near urban area
Nevada Test Site	Nevada	Crystalline basement may be too deep and structurally complex, potential for high heat flow
Kansas City Plant	Missouri	Relatively near urban area
Waste Isolation Pilot Plant	New Mexico	Crystalline basement too deep
Ames Laboratory	Iowa	Relatively near urban area
Oak Ridge Reservation (Y-12, ORR, K-25, ORNL)	Tennessee	Crystalline basement too deep
Hanford Site	Washington	Crystalline basement too deep
Idaho National Engineering and Environmental Laboratory	Idaho	Crystalline basement too deep, potential for high heat flow
Los Alamos National Laboratory	New Mexico	Crystalline basement too deep, potential for high heat flow
Paducah Gaseous Diffusion Plant	Kentucky	Crystalline basement too deep, relatively near urban area
Sandia National Laboratories – New Mexico	New Mexico	Not a DOE site, Crystalline basement too deep and may be structurally complex

Alternative Waste Forms

- **A number of DOE owned alternative radioactive waste forms are under consideration for potential disposal in deep boreholes**
- **Preliminary evaluations of deep borehole disposal for Cs-137 and Sr-90 capsules from Hanford, and calcine waste from Idaho are being conducted**
- **Deep borehole disposal of some of these waste forms potentially may be more easily and quickly accomplished than used nuclear fuel because of smaller-diameter borehole requirements, shorter half lives, lower radionuclide inventories, and regulatory considerations**

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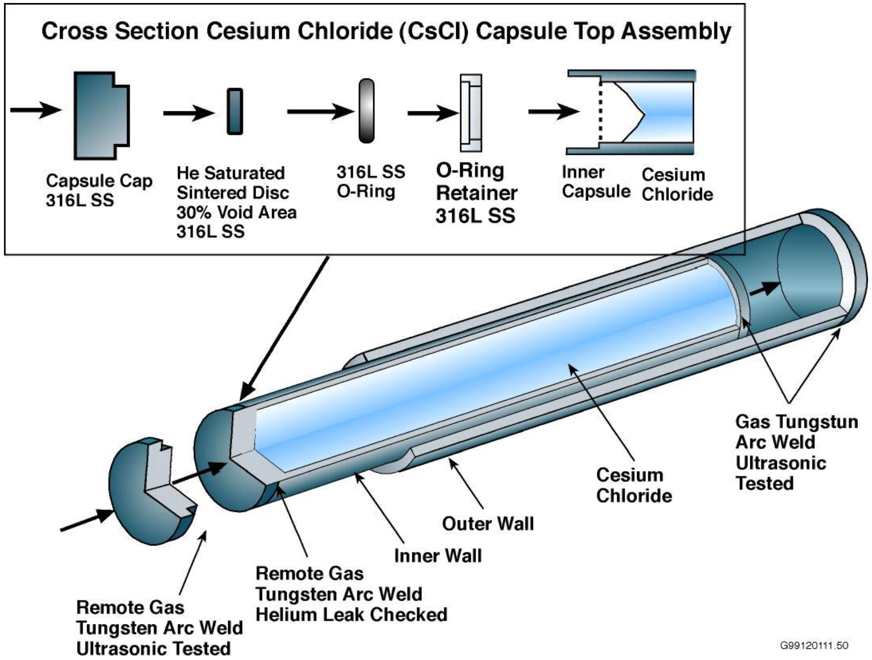
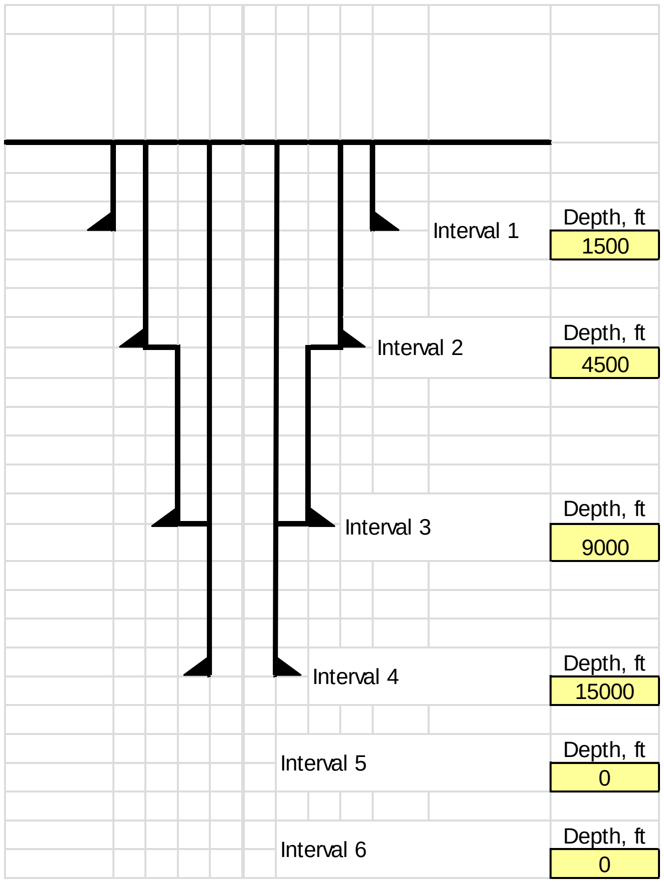
Alternative Waste Forms– Cs-137 and Sr-90 Capsules

- Cs-137 and Sr-90 capsules are high-activity, small-volume waste forms, with high thermal output
- Capsules are about 21 inches in length and 2.6 inches in diameter
- About 2000 capsules had total activity of about 67 million curies in 2002
- Entire inventory can be disposed in a single deep borehole



Alternative Waste Forms – Cs-137 and Sr-90 Capsules



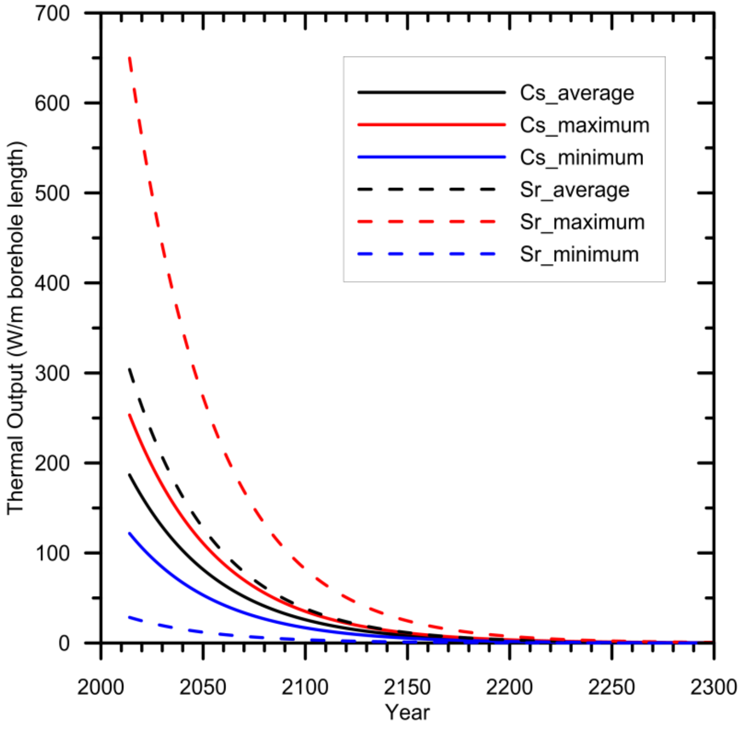
Interval	Hole dia., inches	Casing dia., in.	Csg. Wt., lb/ft	Csg or liner C=1, L=0	ROP ft/hr	Bit Life hours	Logging yes=1, no=0	Dir. Drllg yes=1, no=0
Interval 1	26	20	107	1	30	80	1	0
Interval 2	17.5	13.38	72	1	20	60	1	1
Interval 3	12.25	9.63	47	0	8	50	1	1
Interval 4	8.5	7	23	1	8	40	1	1
Interval 5								
Interval 6								

Daily Rental Rate for Rig
$60,000

Total Well Cost
$17,384,903

Alternative Waste Forms – Cs-137 and Sr-90 Capsules

- **Initial thermal output of capsules is relatively high**
- **Thermal output declines rapidly because of short half lives (30.2 years for Cs-137 and 28.8 years for Sr-90)**
- **Cumulative heat released is small relative to used nuclear fuel**
- **Cs capsules also contain significant quantities of Cs-135 (half life 2.3 million years) which might impact long-term risk**



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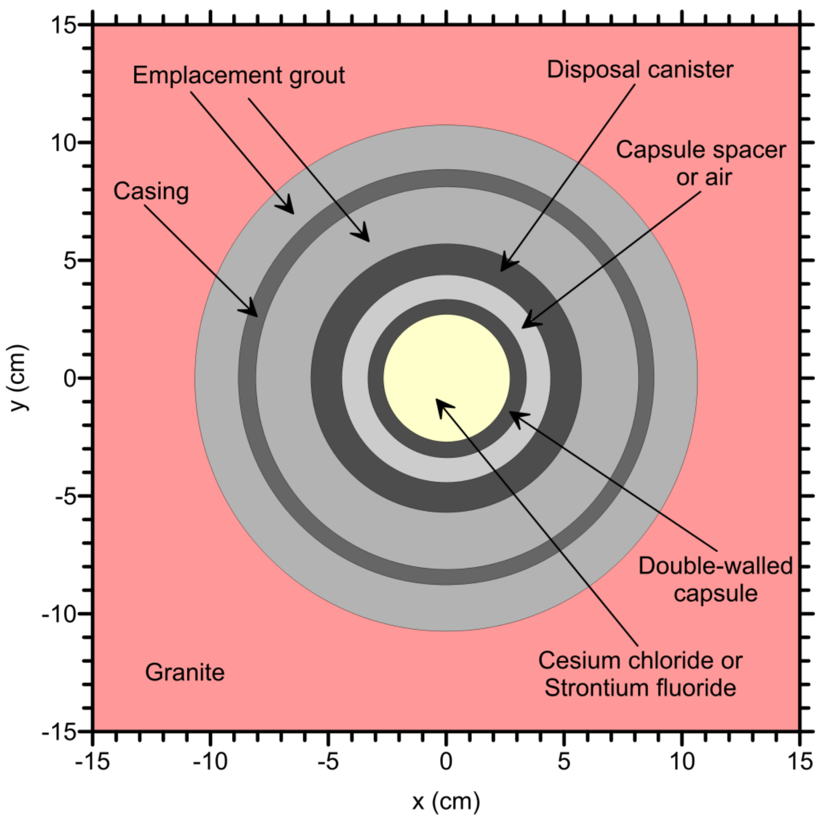

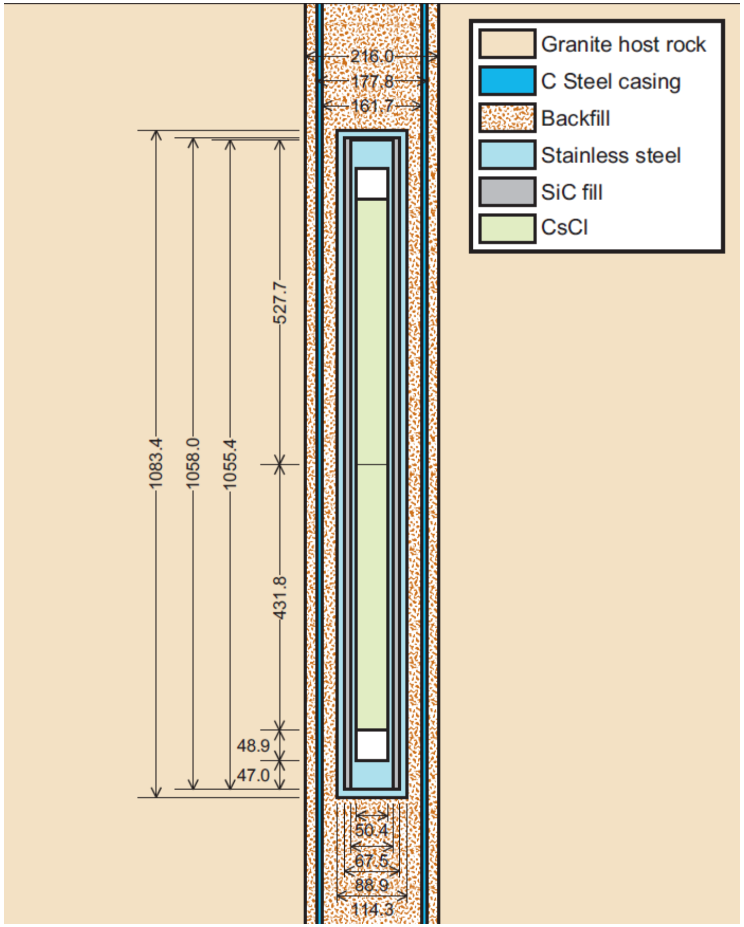

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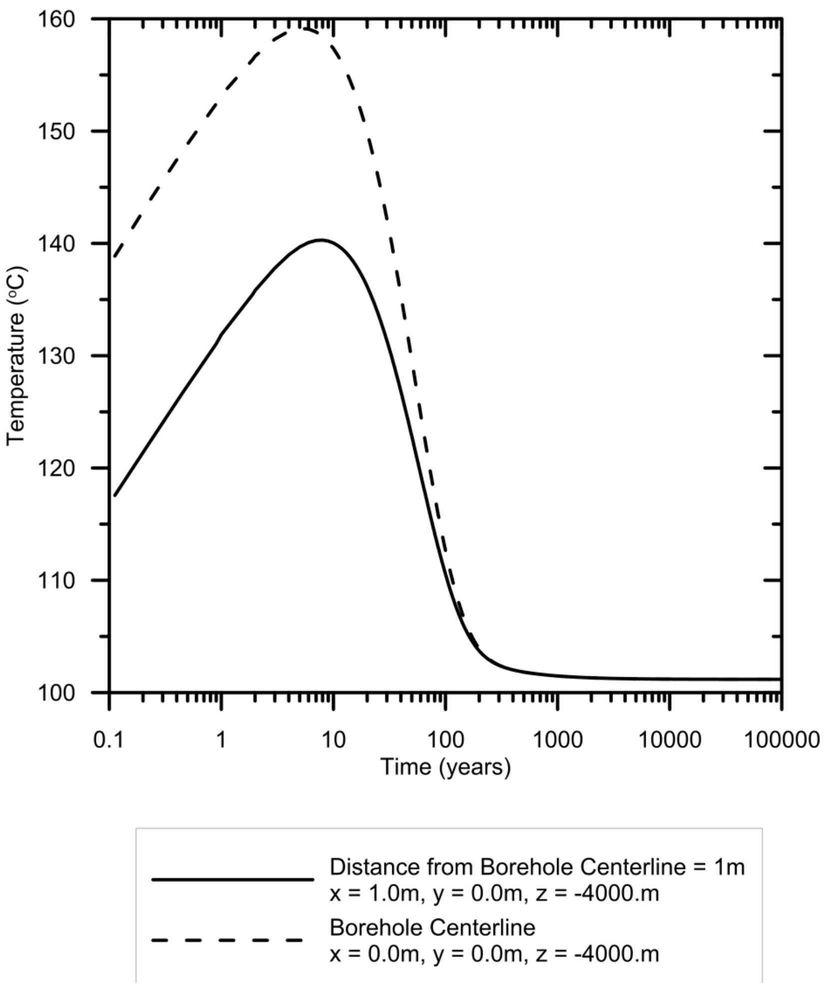
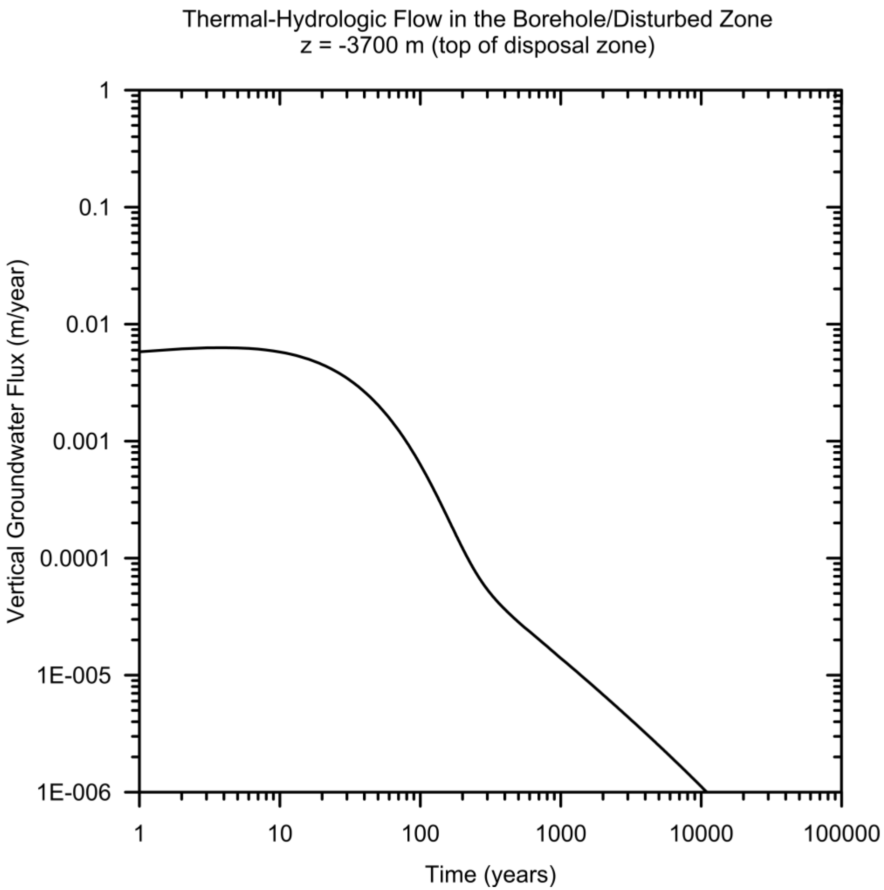
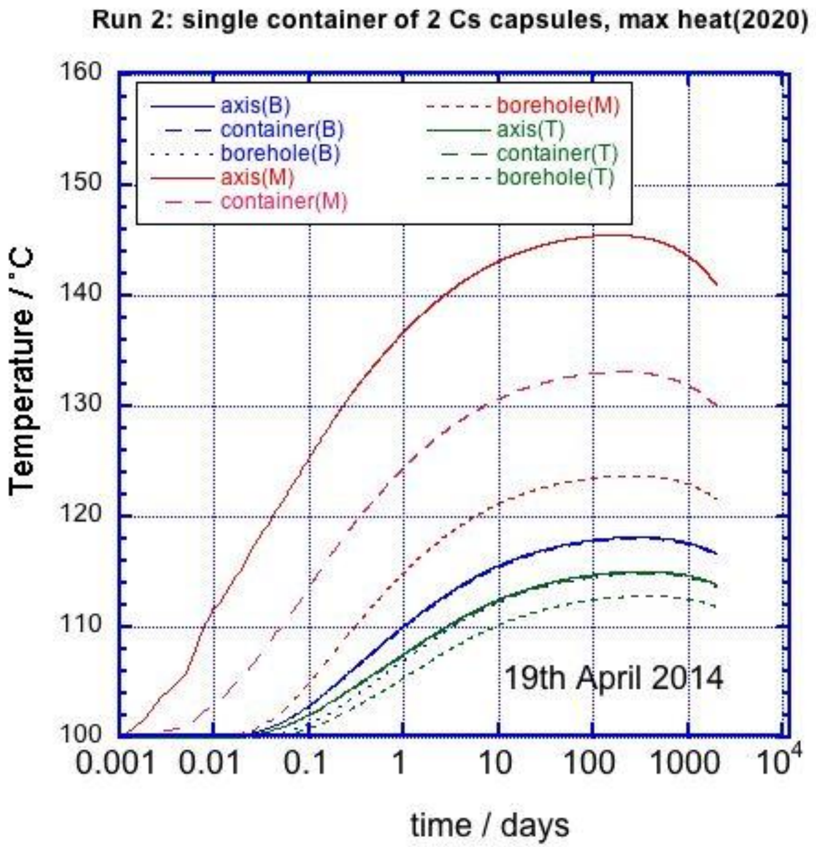




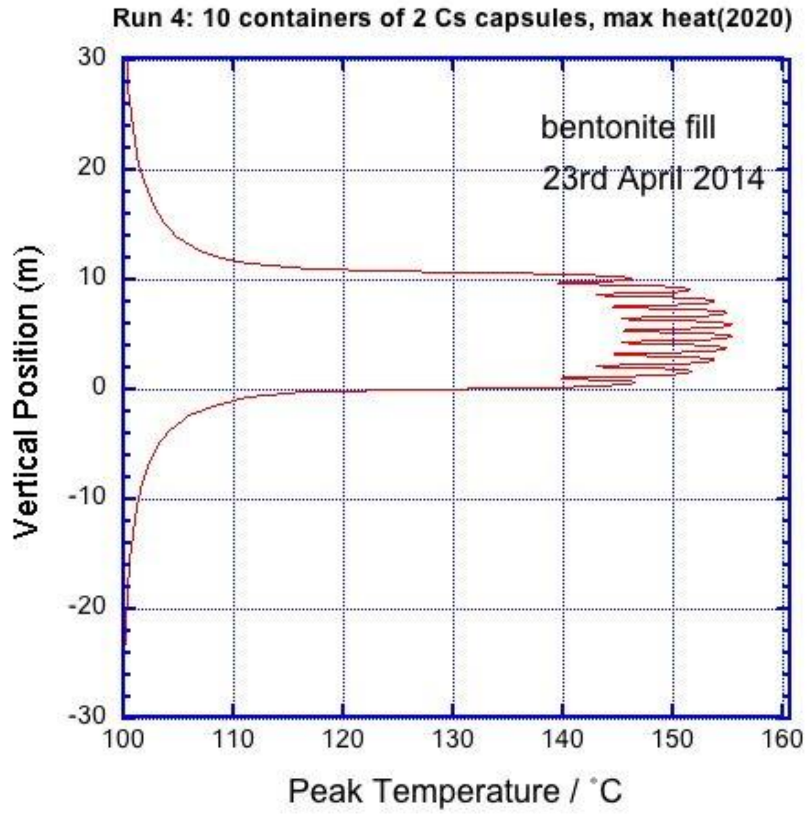
Alternative Waste Forms– Cs-137 and Sr-90 Capsules

- **High resolution 3-D simulations of thermal conduction performed at the University of Sheffield**
- **Results provide more accurate near-term temperature predictions in the engineered system of the deep borehole disposal system**



from Karl Travis and Fergus Gibb

Alternative Waste Forms– Cs-137 and Sr-90 Capsules



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