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Geologic Disposal Options in the USA

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Introduction

- **The USA has many geologic settings suitable for deep geologic disposal of nuclear waste**
- **There is substantial confidence that compliance with regulatory standards can be demonstrated**
- **Rock types include salt, shale, and granite (and other massive, competent rock types)**
- **Media-specific, internationally recognized disposal concepts**

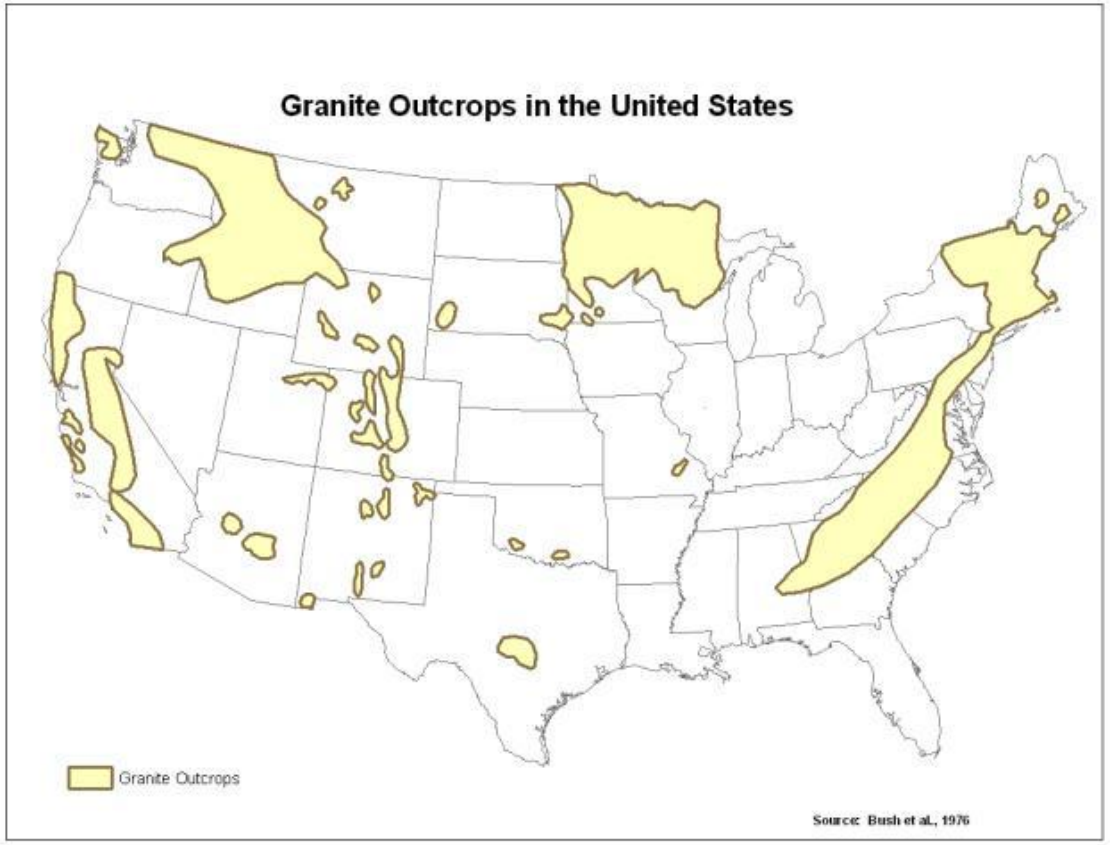
Siting and Geologic Considerations

- **Depth –** The disposal horizon is determined by site-specific conditions
- **Unit Thickness –** Maximal thickness is desired to ensure radionuclide migration does not exceed regulatory criteria or boundaries
- **Uniformity and Structure –** The potential repository interval and surrounding rock should be reasonably homogeneous both vertically and horizontally
- **Seismicity –** Seismically quiescent regions favor repository design, operations, and long term performance

Desirable Attributes of the Geologic Setting

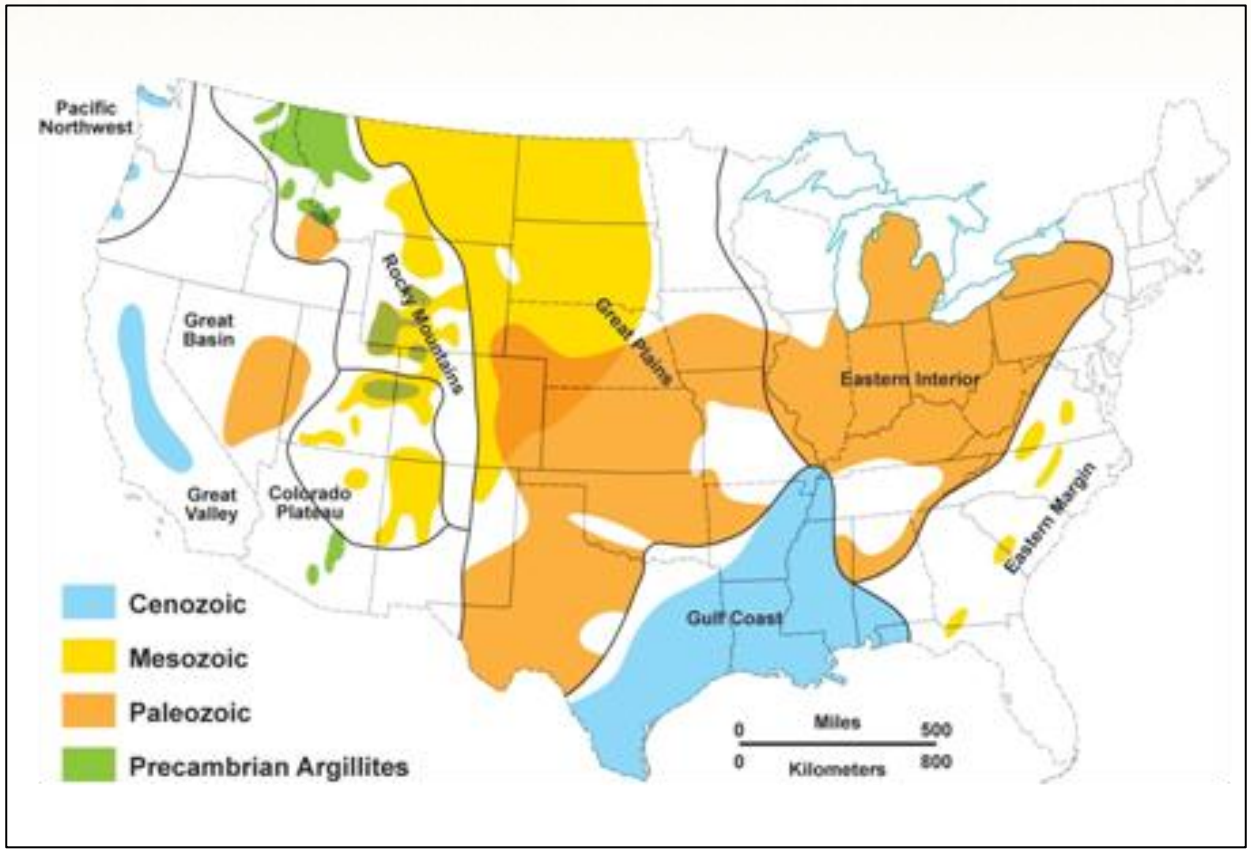
- **Hydrogeology – Low hydraulic conductivity**
  - Approx. 10^{-12} m/sec or less
- **Self-Sealing, Plastic Deformation Characteristics**
  - Reestablish diffusion-dominated transport conditions
- **Hydrogeochemistry – Reducing Chemical Conditions**
  - Limit corrosion of engineered barriers & waste forms
  - Reduce solubility for most radionuclides
  - Improve sorption

Granite Outcrops in the United States



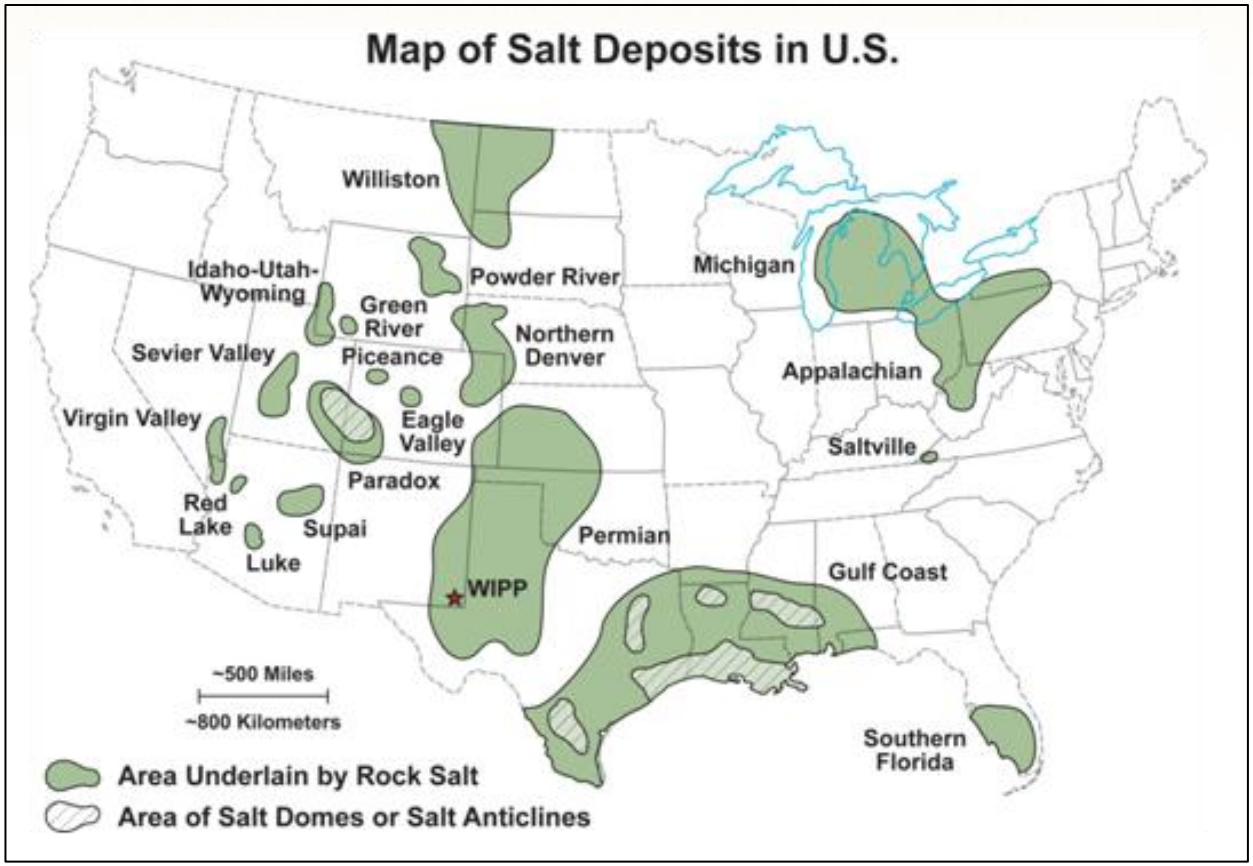
- Includes a range of competent, crystalline rock types
- The USA had an R&D and siting program for crystalline rock, until the 1980s
- Fractured/unfractured
- Saturated/unsaturated
- International progress (e.g., Swedish KBS-3)

Shale Provinces in the United States



- **Includes a range of plastic to indurated clay-rich lithologies**
- **The USA had active shale repository programs in the 1970s and 1980s**
  - Thermomechanical laboratory and field tests
- **International progress (e.g., French program at Bure locality)**

Salt Deposits in the United States



- **The USA has supported significant salt repository investigations**
  - Project Salt Vault
  - Avery Island
  - WIPP (limited thermal testing)
- **International interest is high (e.g., Germany)**

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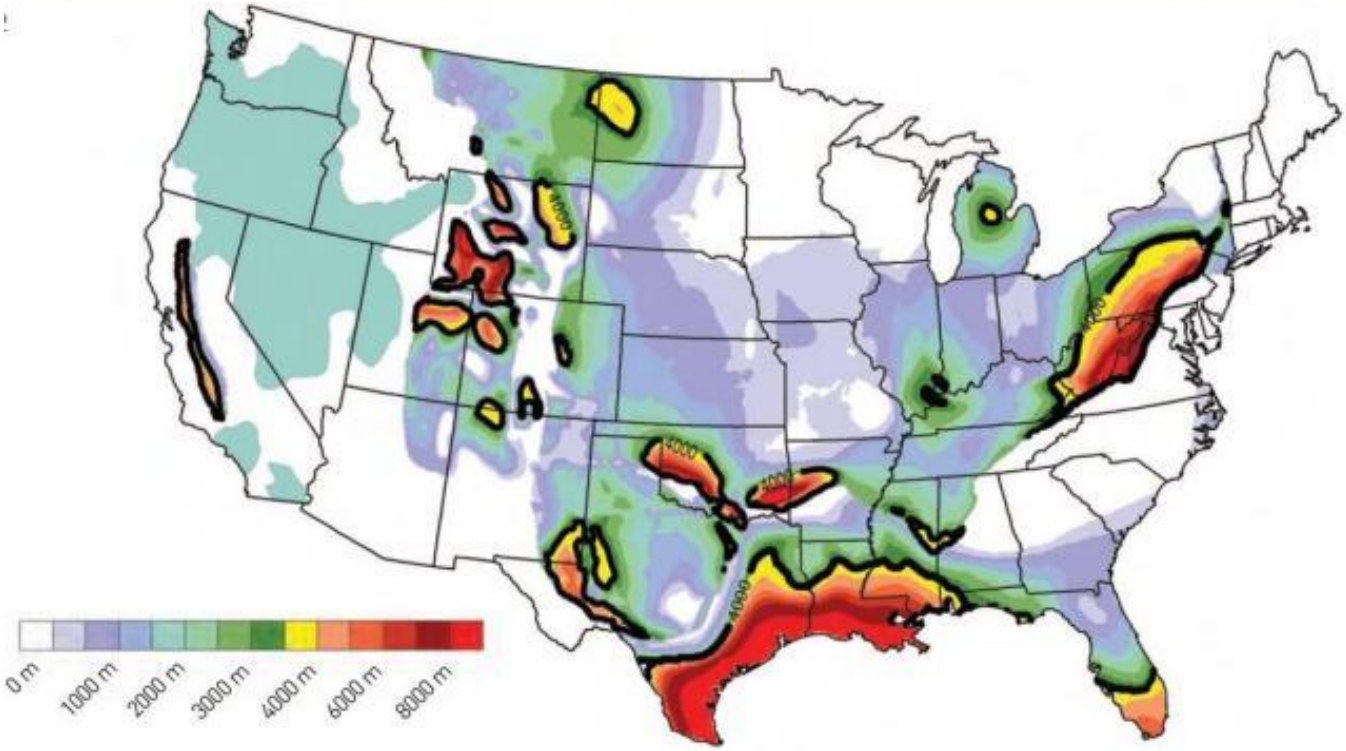
Depth to Basement Rock in the United States



- Very deep holes (3 to 5 km)
- Crystalline basement rock
- Less research than mined repositories

Concepts of Disposal

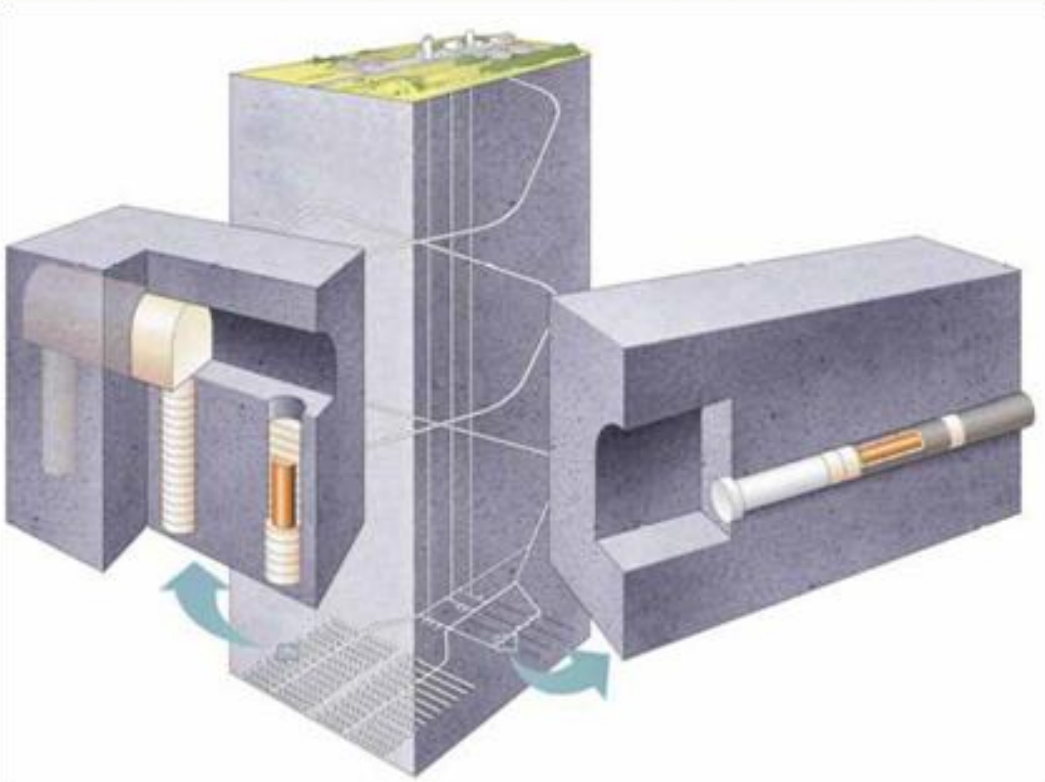
- **A repository disposal concept requires:**

  Waste Stream + Geologic Setting + Concept of Operations

- **Concepts for geologic disposal have been developed in several countries**
- **The following slides give a general overview**
  - Granite/crystalline rock
  - Clay/shale
  - Salt repository
  - Deep borehole disposal concept

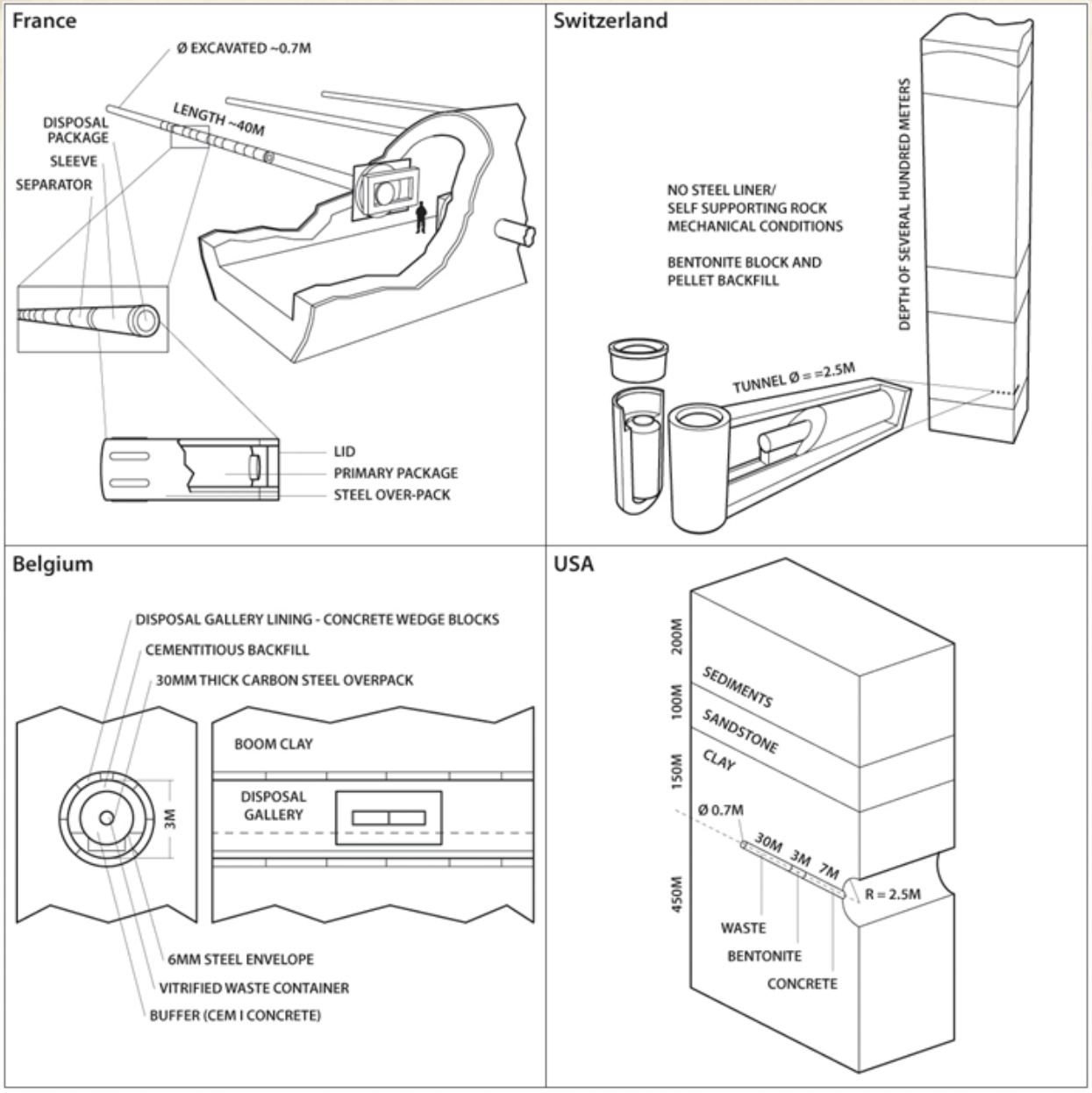
Representative Disposal Concept for Mined Granite Repository

- **Sweden, Finland, Spain, Switzerland**
- **Spent fuel or HLW**
- **Reducing, undersea, crystalline host rock**
- **Vertical & horizontal emplacement modes**
- **Well studied concept:**
  - Cast iron insert
  - Copper or steel canister
  - Compacted clay buffer
  - Drift backfill
  - Plugs and seals

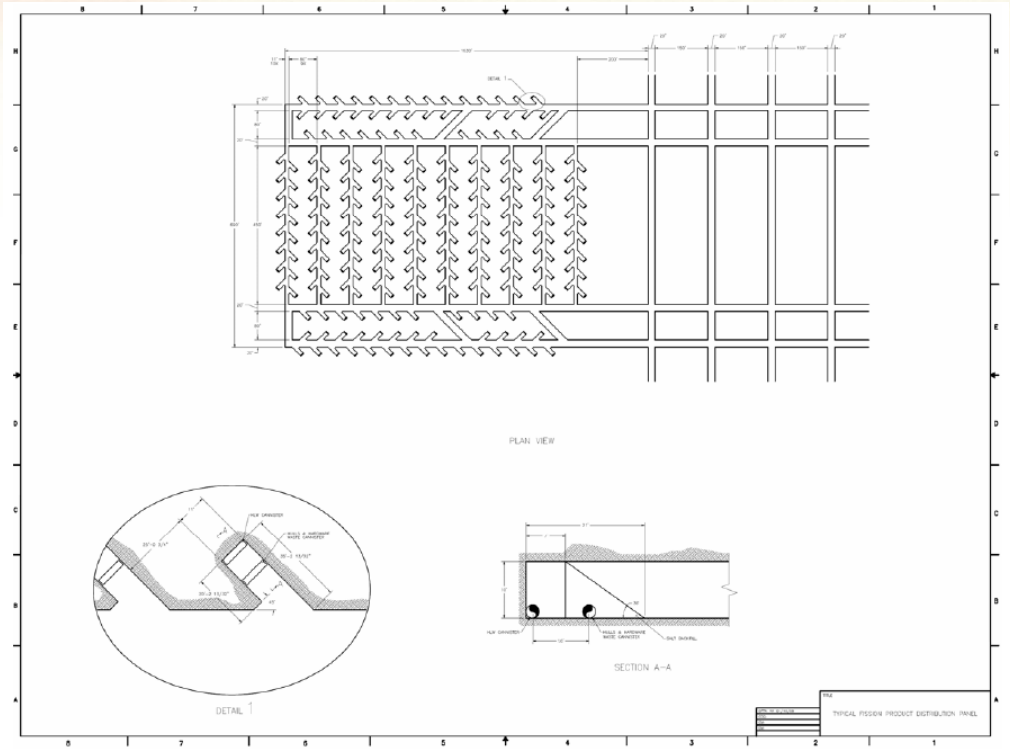


Clay/Shale Disposal Concepts

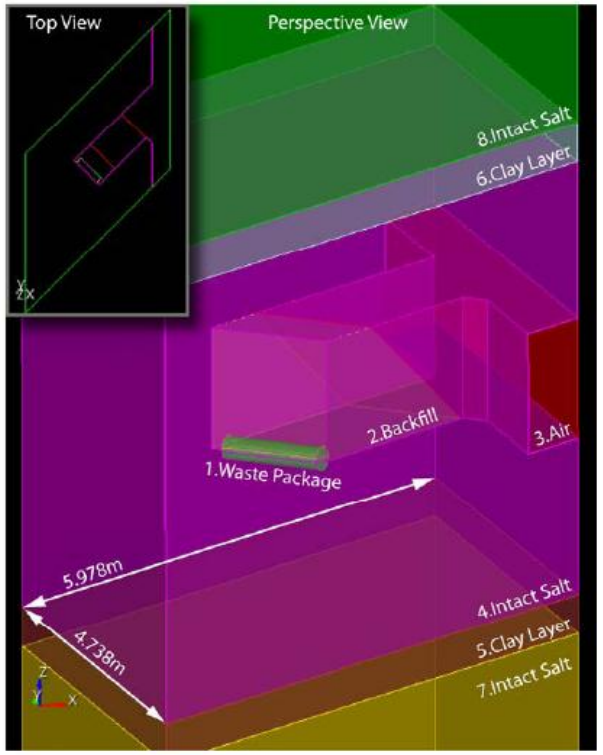
- Borehole & in-drift emplace-ment modes
- Reducing host rock
- Steel canister
- Plugs and seals



Salt Repository Disposal Concept



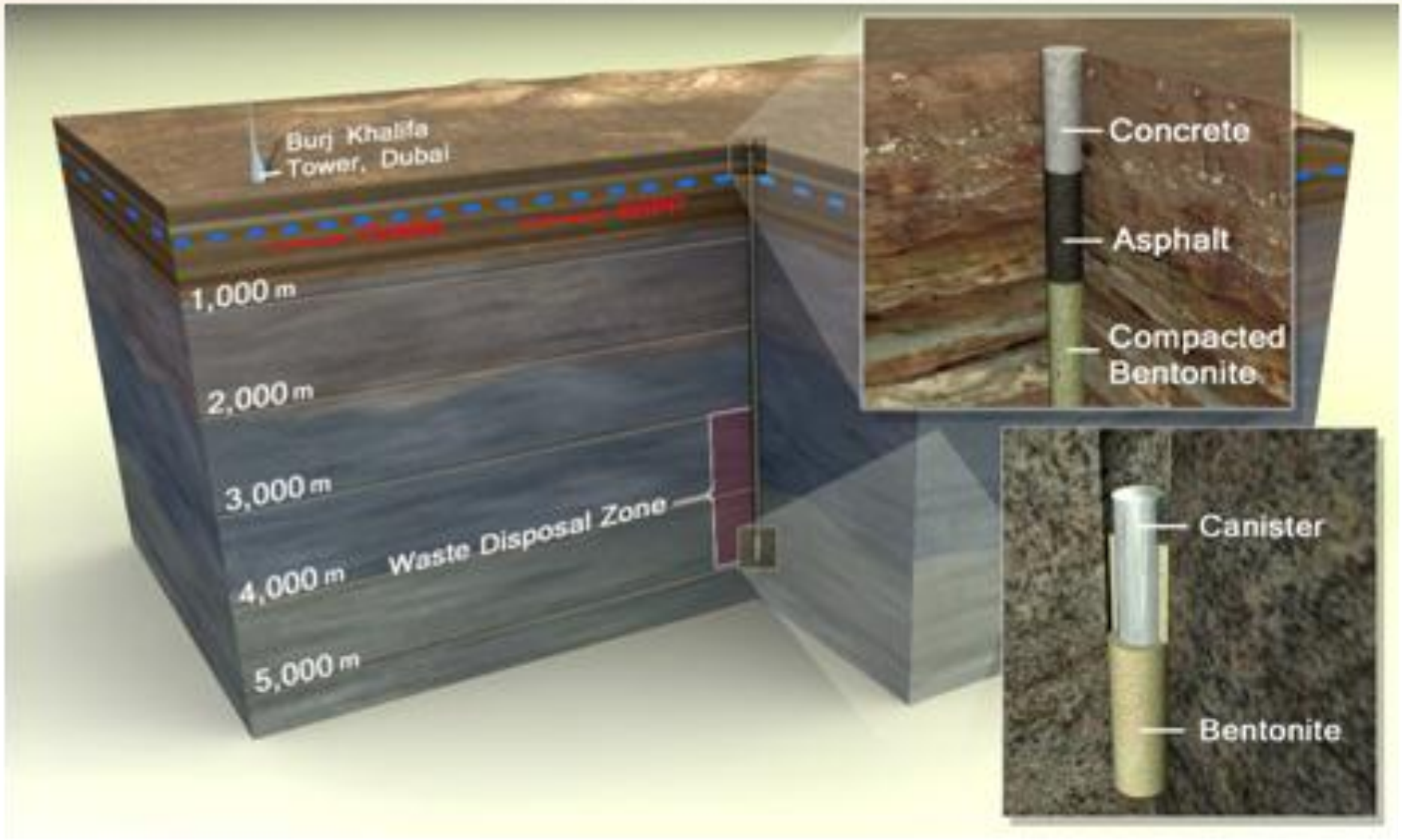
(Washington Savannah River Co. et al. 2008)



(Clayton & Gable 2009, AFCI-WAST-PMO-MI-DV-2009-000002)

- **Based on WIPP experience**
- **Cover waste canisters with crushed salt (subject to heating, re-consolidation)**

Deep Borehole Disposal Concept



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Comparison of Disposal Concepts

Property	Salt	Shale	Granite	Deep boreholes
Thermal conductivity	High	Low	Medium	Medium
Permeability	Practically impermeable	Very low to low	Very low (unfractured) to permeable (fractured)	Very low
Strength	Medium	Low to medium	High	High
Deformation behavior	Visco-plastic (creep)	Plastic to brittle	Brittle	Brittle
Stability of cavities	Self-supporting on decade scale	Artificial reinforcement required	High (unfractured) to low (highly fractured)	Medium at great depth
In situ stress	Isotropic	Anisotropic	Anisotropic	Anisotropic
Dissolution behavior	High	Very low	Very low	Very low
Sorption behavior	Very low	Very high	Medium to high	Medium to high
Chemical	Reducing	Reducing	Reducing	Reducing
Heat resistance	High	Low	High	High
Mining experience	High	Low	High	Low
Available geology*	Wide	Wide	Medium	Wide
Geologic stability	High	High	High	High
Engineered barriers	Minimal	Minimal	Needed	Minimal

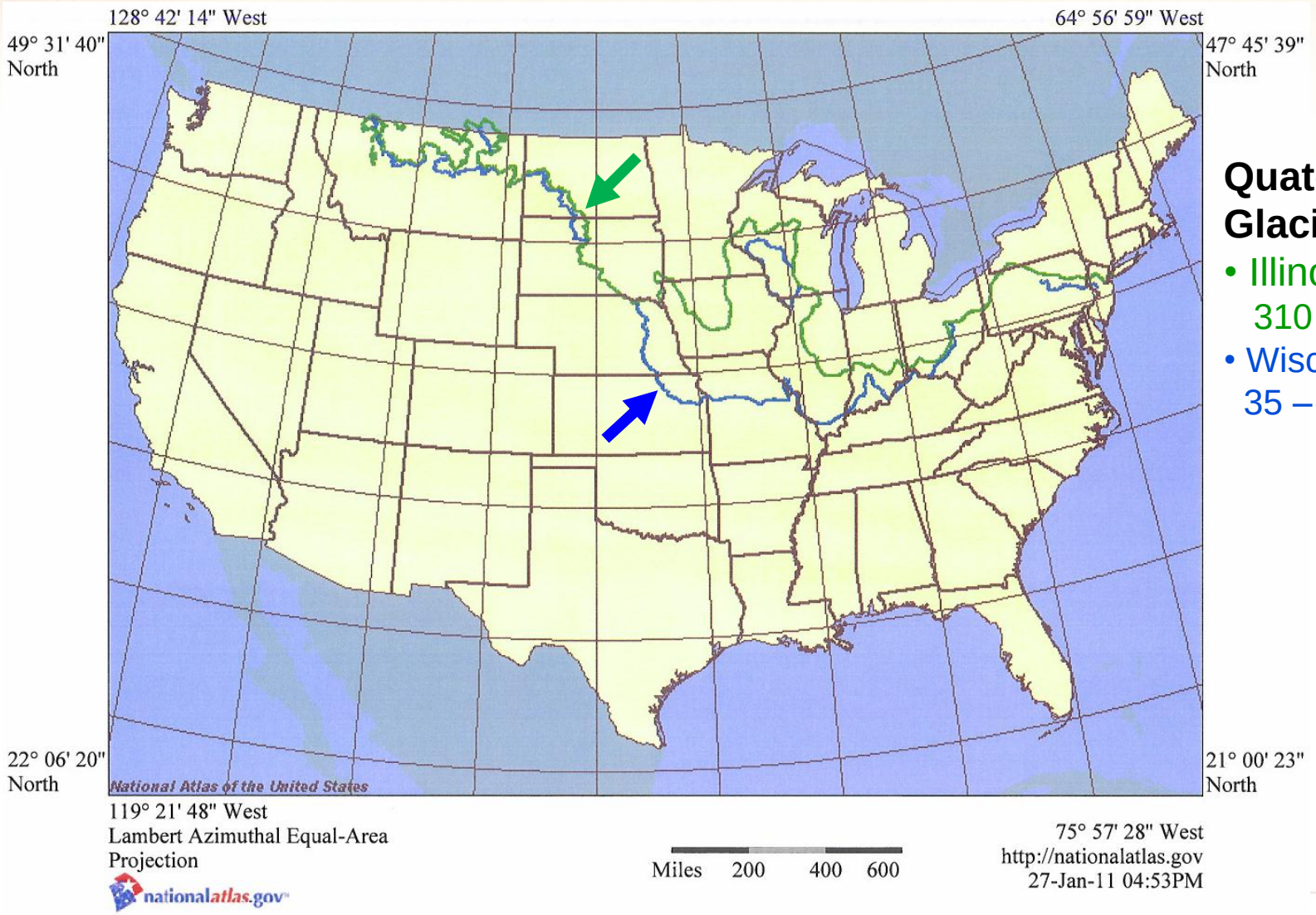
Favorable property Average Unfavorable property

*** See accompanying figures.**

Technical Factors in Site Suitability

- **We anticipate that the U.S. will develop new radioactive waste management policy.**
  - Many of the policy issues debated in the 1970s and early 1980s will be revisited.
- **Evaluating the suitability of a particular disposal concept (to eventually include siting) will require a regulatory framework.**
- **The U.S. has multiple, technically promising geologic disposal options (example technical screening data)**

Example Technical Screening Data: Generalized Glacial Limits



Quaternary Glacial Cycles:

- Illinoian
  310 – 128 kyr BP
- Wisconsin
  35 – 11 kyr BP

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Example Technical Screening Data: + Volcanoes (<10 kyr)

Quaternary Glacial Cycles

Volcanoes:

▲ Since 1900

▲ A.D. 0-1900

▲Holocene & undated

▲Holocene & uncertain

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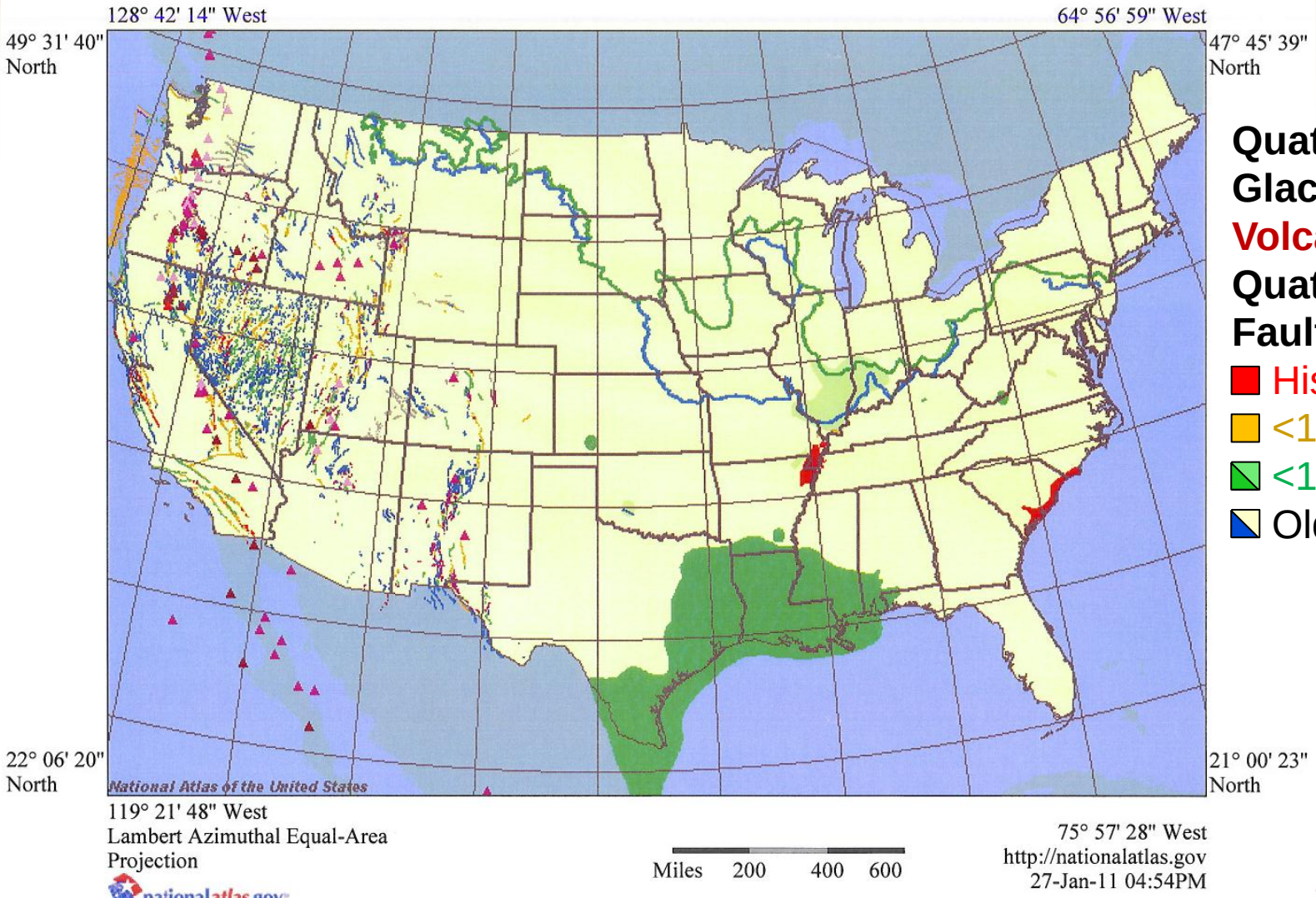
Example Technical Screening Data: + Quaternary Faults/Fault Zones



Quaternary Glacial Cycles

Volcanoes: ▲

Quaternary Faults/Zones

- Historic
- <15 kyr
- <130 kyr
- Older

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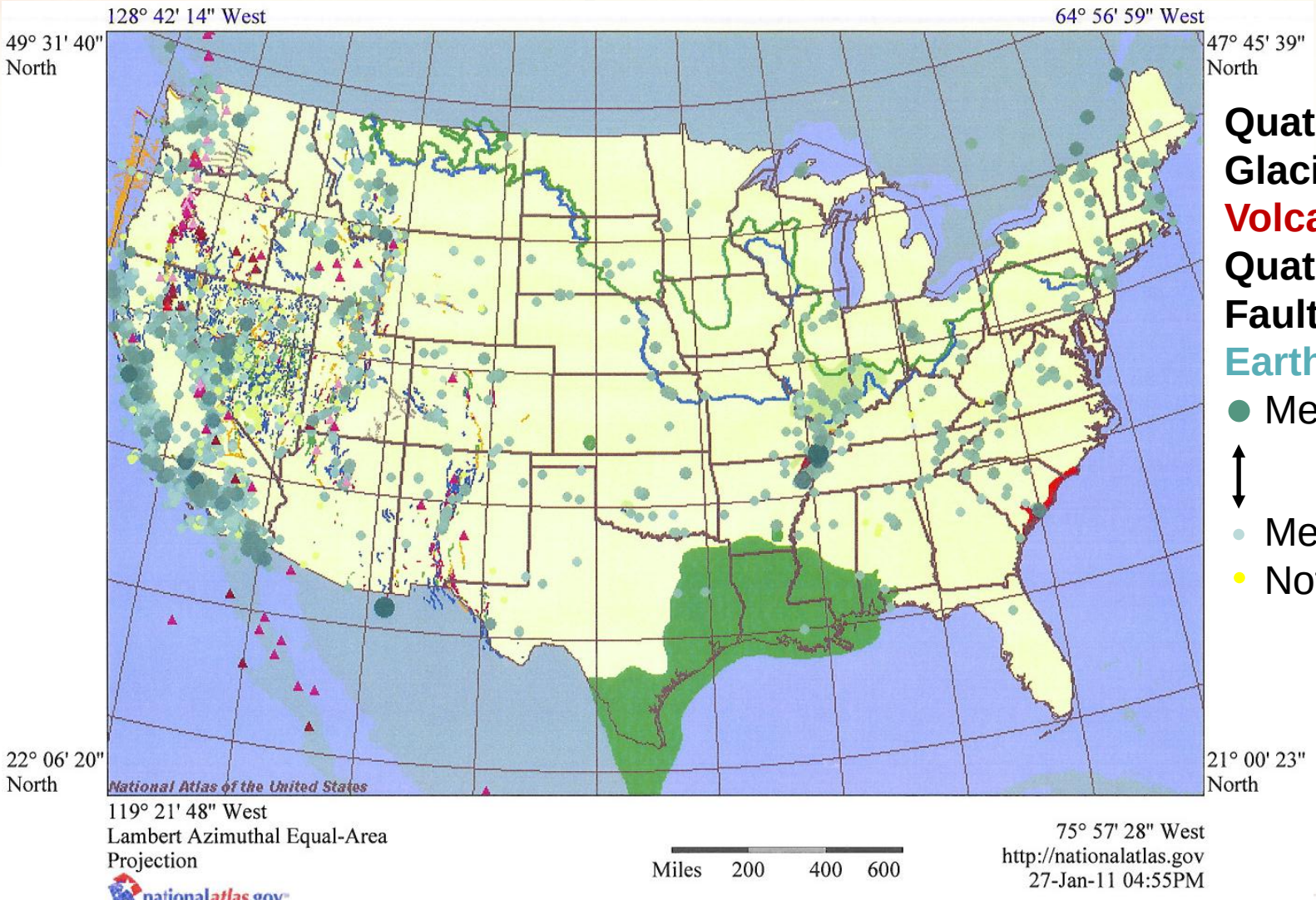
Example Technical Screening Data: + Earthquakes 1568-2009



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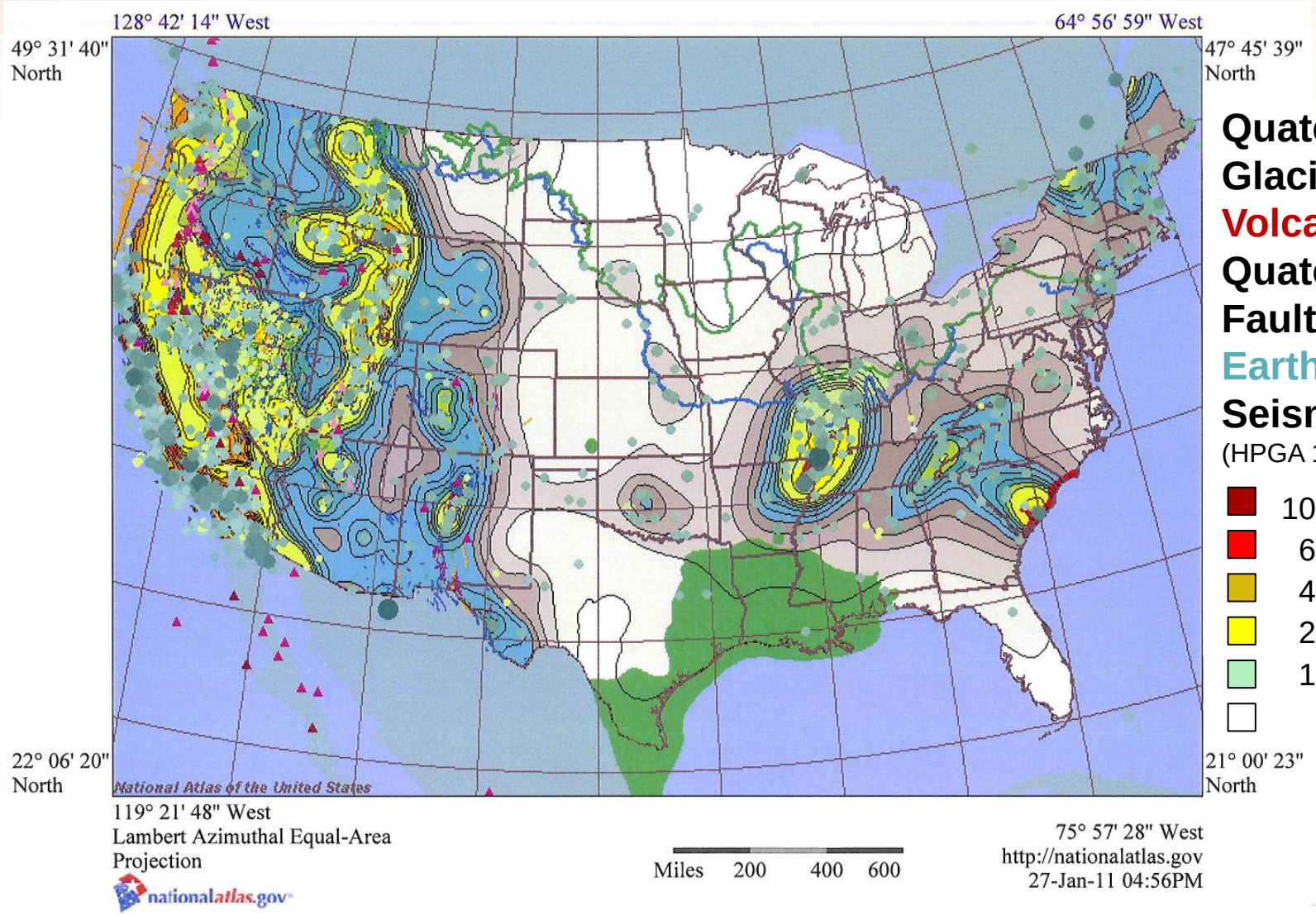
Example Technical Screening Data: + Seismic Hazard



Quaternary Glacial Cycles:

Volcanoes: ▲

Quaternary Faults/Zones

Earthquakes: ●

Seismic Hazard

(HPGA 10% Prob./50 yr)

- 100% of g
- 60%
- 40%
- 20%
- 10%
- 0%

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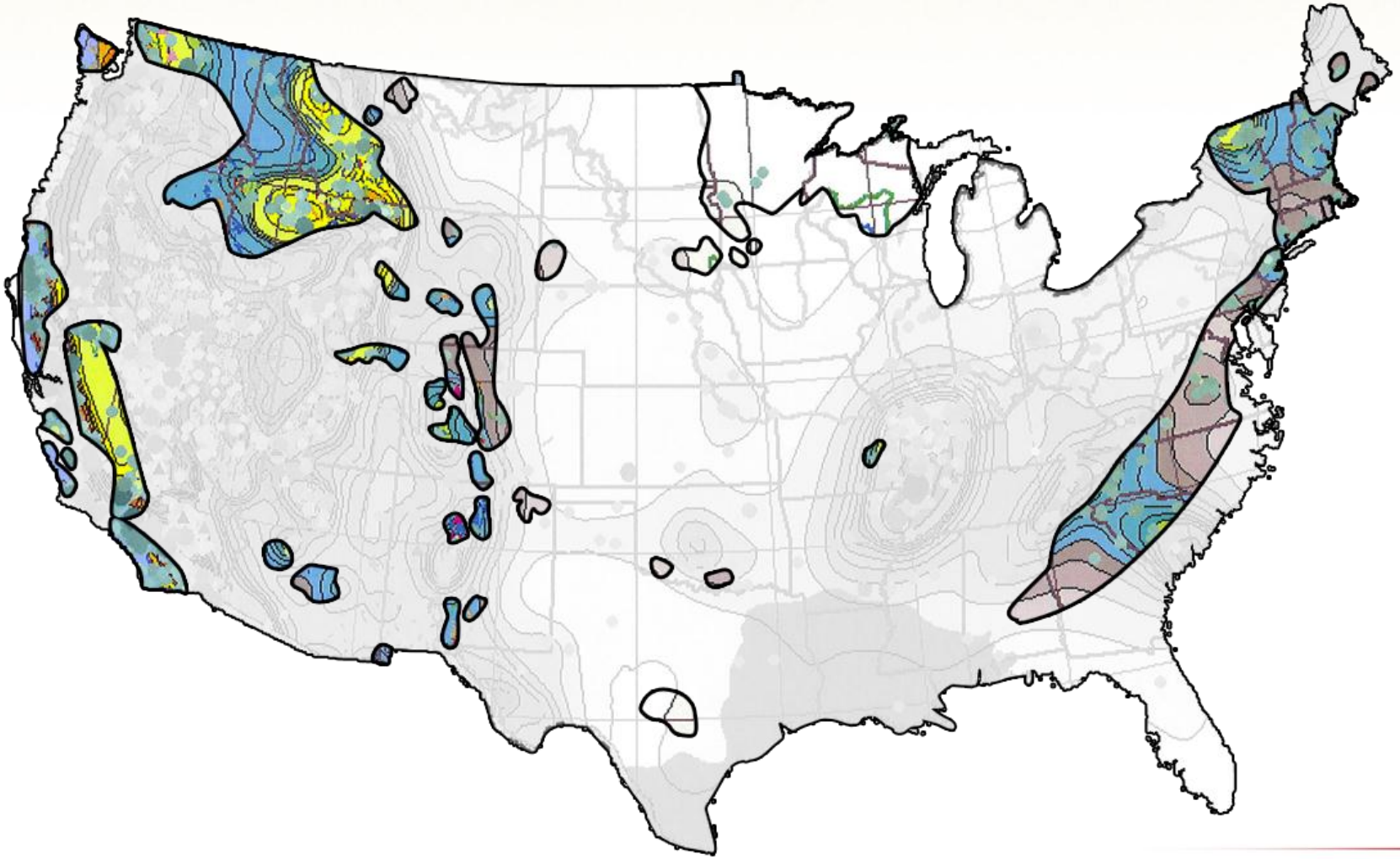
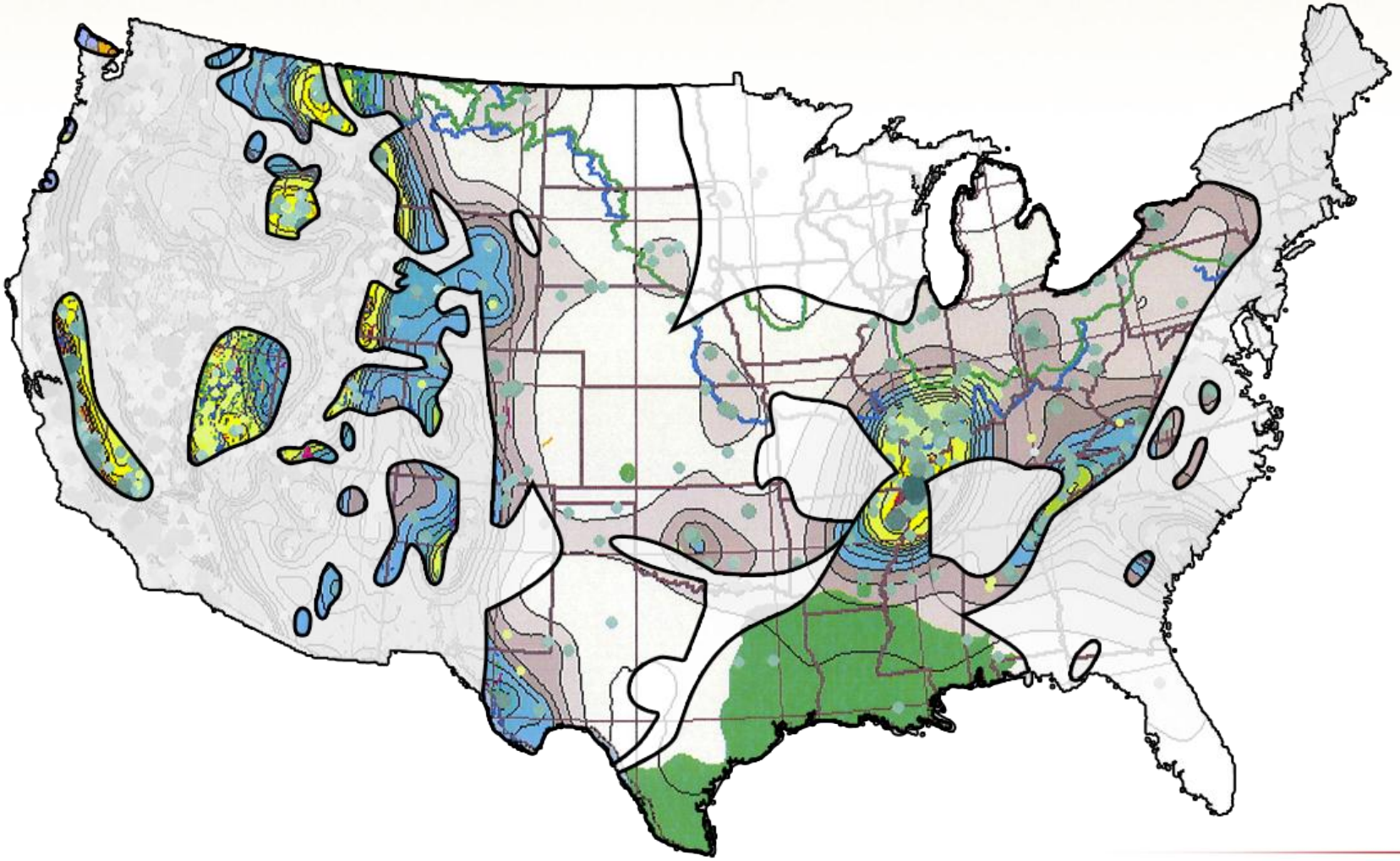
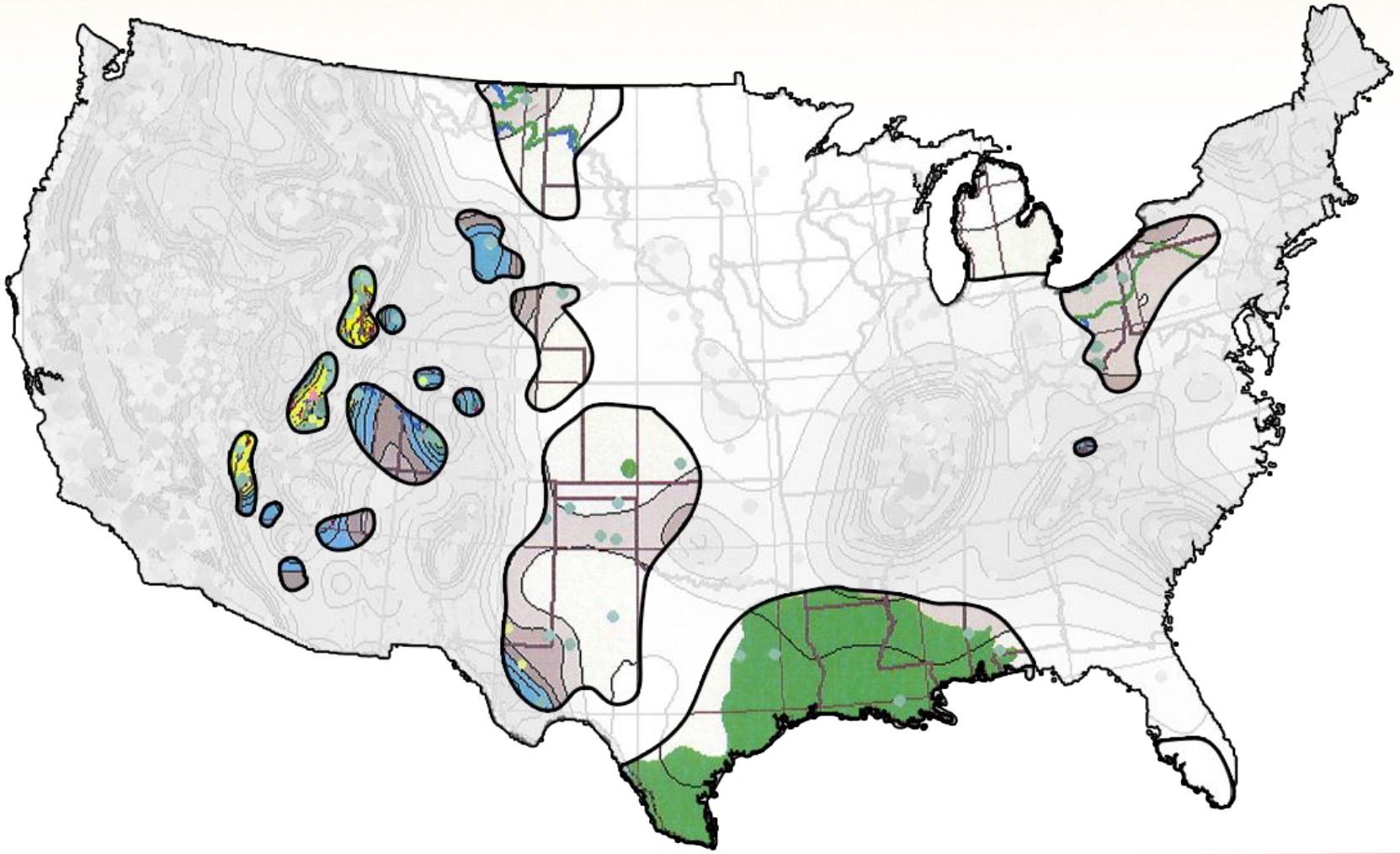
Example Technical Screening Data: Base Map + Surficial Granite Overlay



Example Technical Screening Data: Base Map + Shale Overlay



Example Technical Screening Data: Base Map + Salt Overlay



Site Screening Methodology

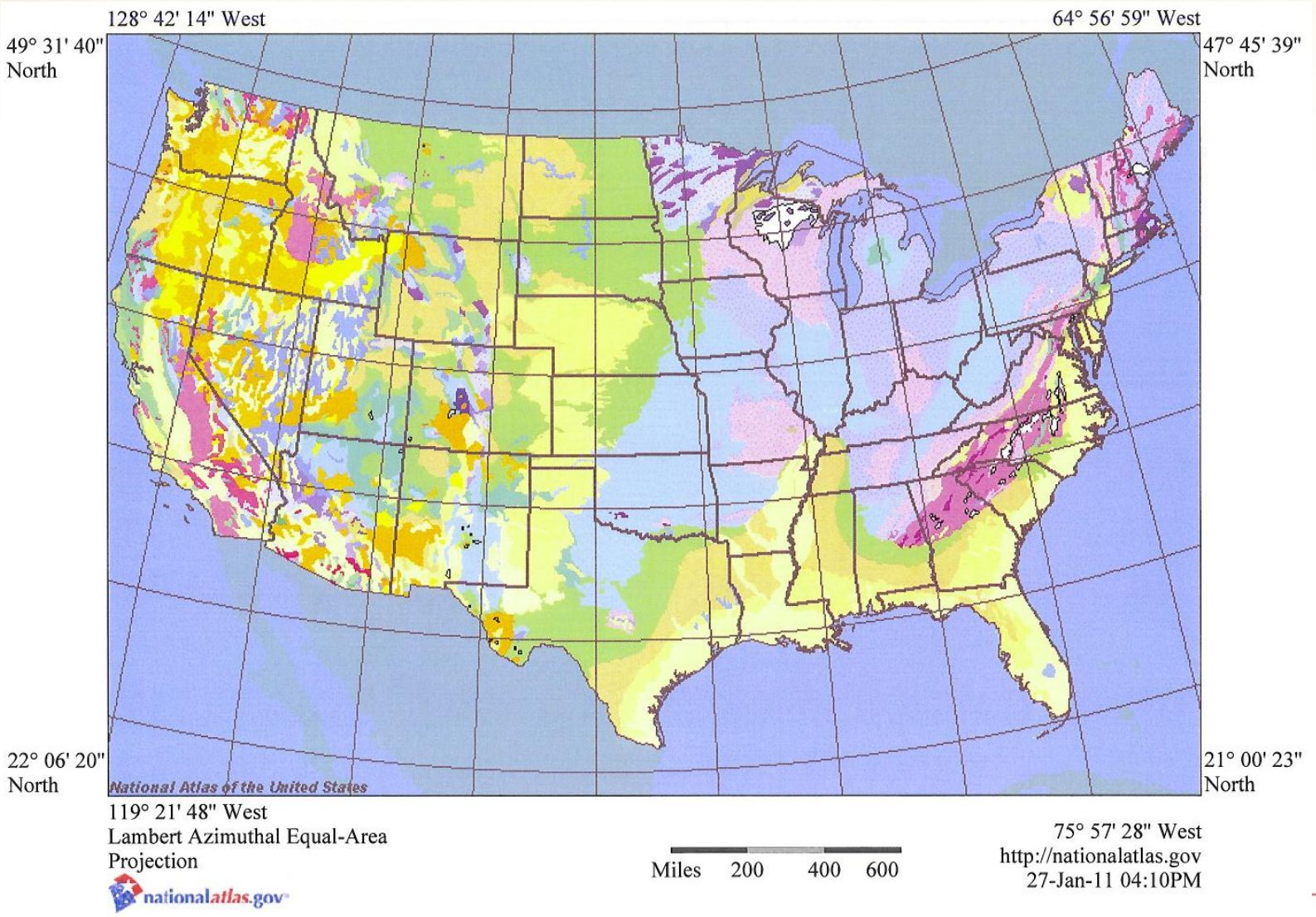
- **Interpretation of Geographic Overlays**
  - Scale of repository sites vs. siting data
  - Source data type and accuracy
  - Data relevance (e.g., for different disposal concepts)
  - Data surrogacy can be inexact
- **Repository Siting Experience**
  - U.S. first and second repository programs (prior to 1988)
  - Sweden, France, and other countries
  - Phasing, decision process, and consultation are very important factors

Concluding Remarks

- **The U.S. has multiple, technically promising geologic disposal options.**
- **Technical site screening and suitability evaluations depend on the disposal concept.**
- **New radioactive waste management policy will determine how and when siting and suitability evaluations are performed.**
- **Suitability evaluations for a particular disposal concept (to include siting) will require a legal/ regulatory framework.**

BACKUP SLIDES

Surface Geology



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Waste Handling/Storage Demonstration in Granite at the Nevada Test Site (NNSS)

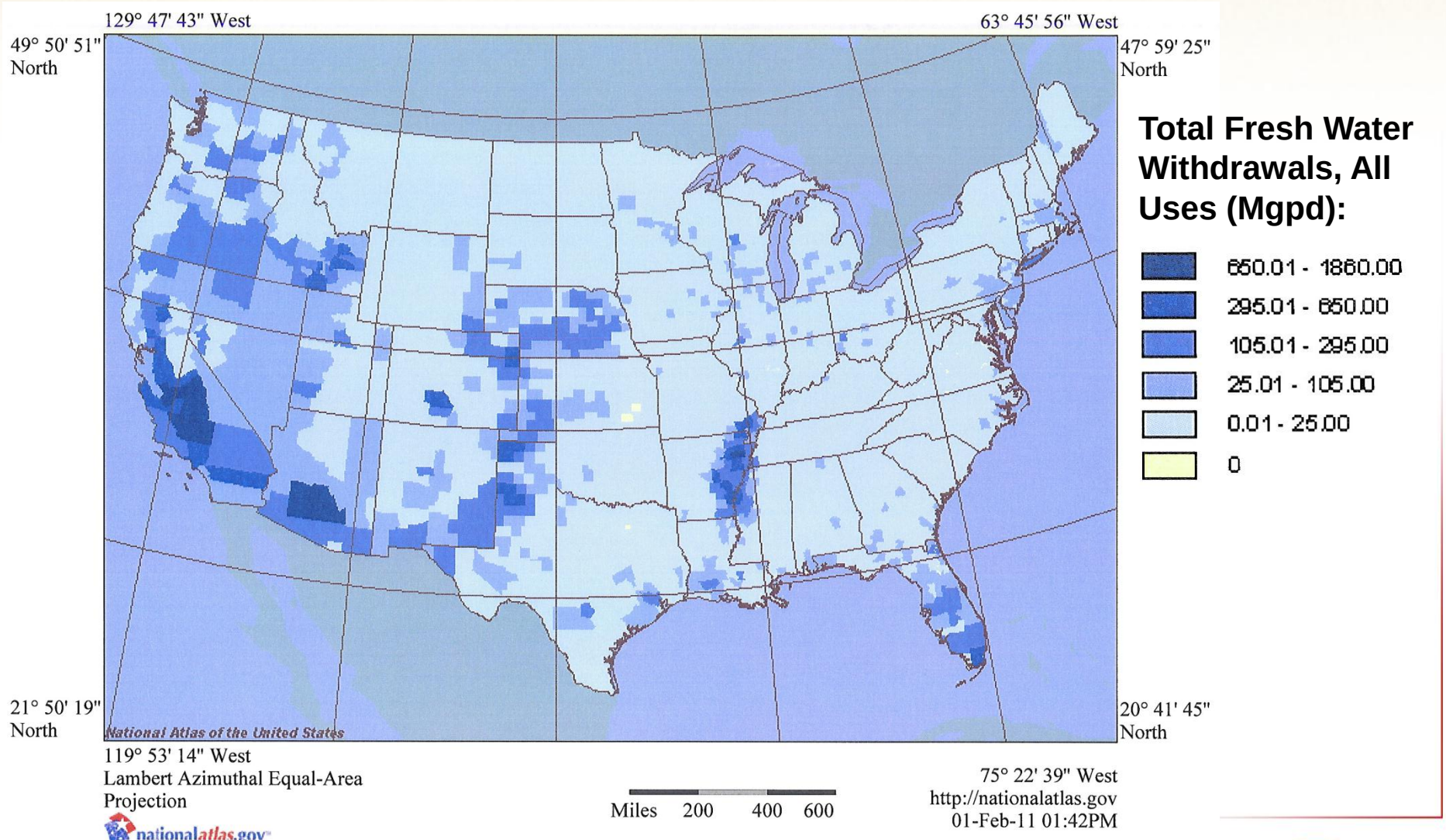
Spent Fuel Test – Climax (1978-1986)

Waste Canister Drift

Disposal Configuration for Transuranic Waste at the WIPP

Simulating HLW at WIPP

Example Technical Screening Data: Fresh Groundwater Withdrawal (2005)



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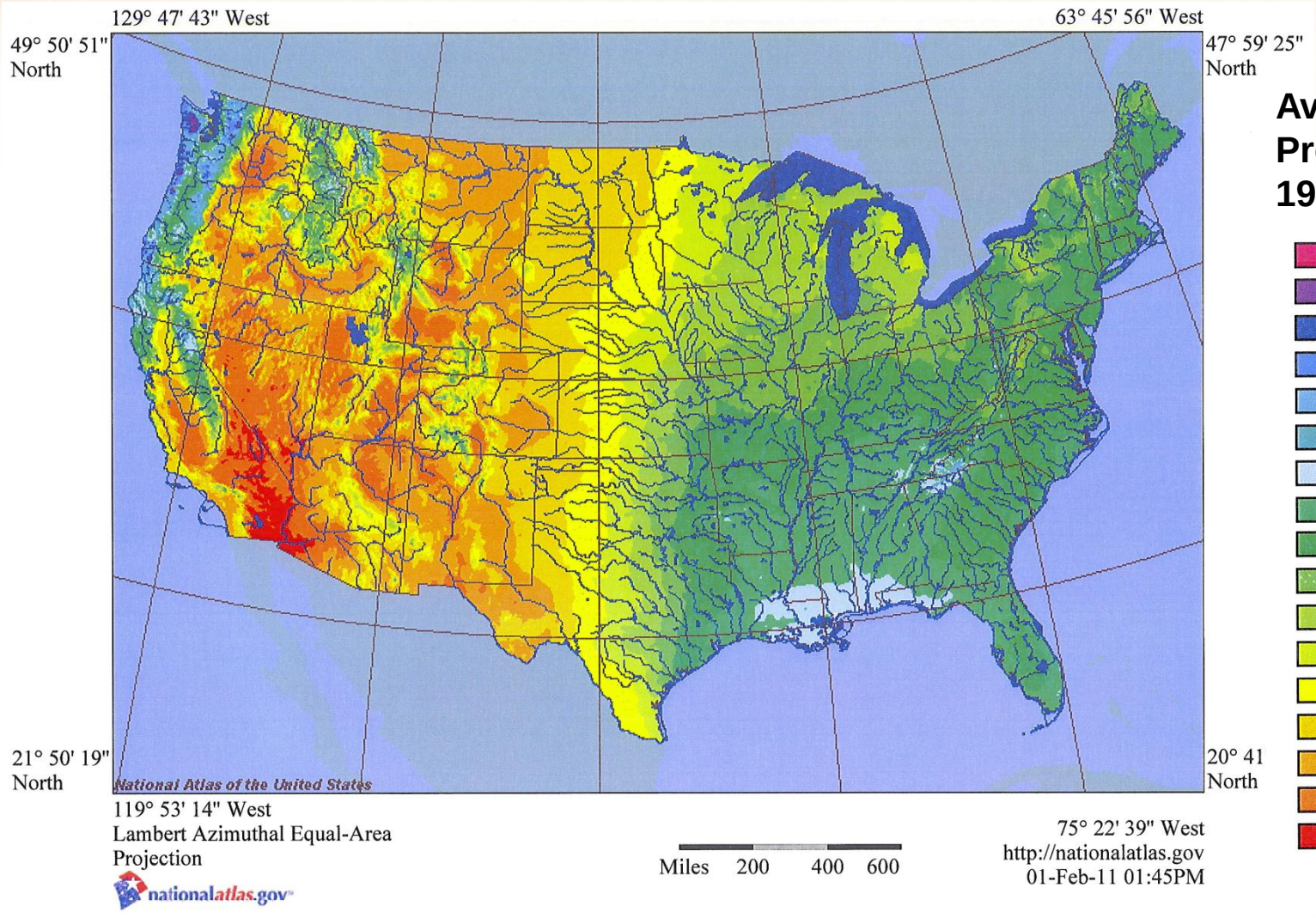
Example Technical Screening Data: Average Annual Precip., Streams & Waterbodies



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References

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Bush et al. 1976.

Hansen, F.D. et al. 2010. *Shale Disposal of U.S. High-Level Radioactive Waste*. Sandia National Laboratories, Albuquerque, NM. SAND2010-2843.

U.S. Geological Survey, http://www.nationalatlas.gov

Salt map?