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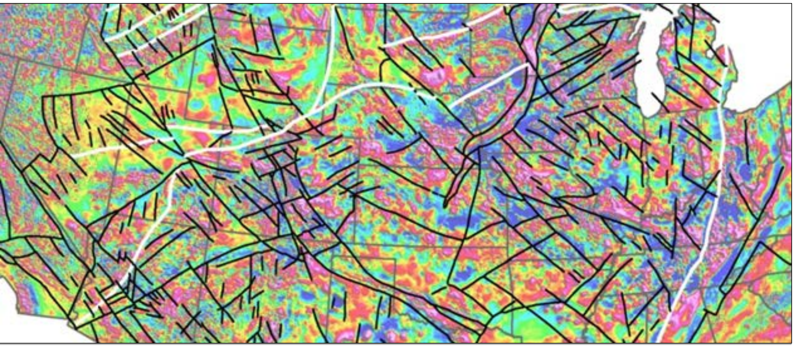

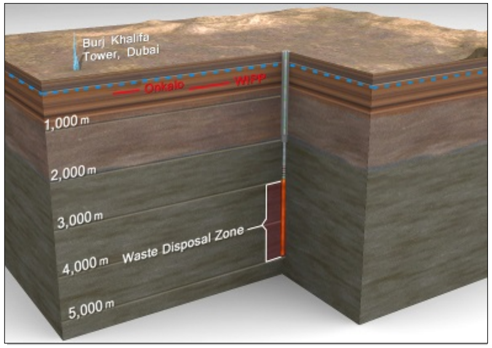

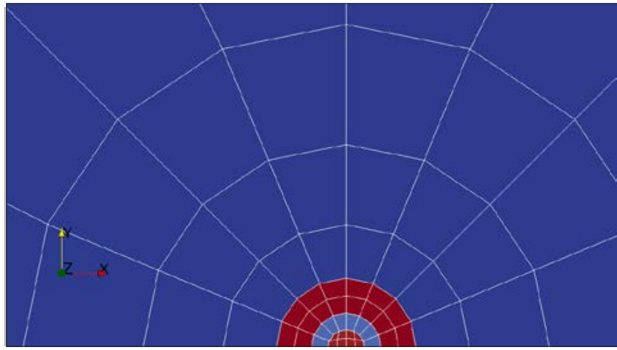

Evaluating Geologic Site Guidelines for a Deep Borehole Field Test

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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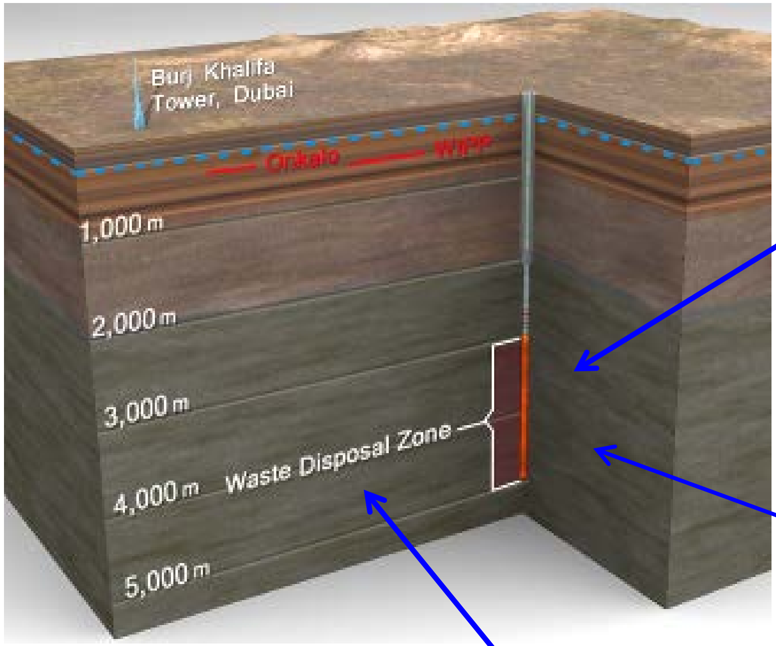
Presentation Overview

- Deep Borehole Field Test (DBFT) Background
  - The Deep Borehole Disposal (DBD) Concept
    - Feasibility is being evaluated
  - DBFT Objectives – Science and Data to Evaluate DBD Concept
- Geoscience Guidelines for DBFT Site
  - Considered Characteristics
  - Preferred Characteristics and Uncertainties
- Status of US DOE Program
- Previously Considered Site Geology Example
- Summary and Conclusions

Deep Borehole Disposal Concept –
Safety and Feasibility Considerations

Long-Term Waste Isolation (hydrogeochemical characteristics)



Waste emplacement is deep in crystalline basement

- At least 1,000 m of crystalline rock (seal zone) overlying the waste disposal zone
- Crystalline basement within 2,000 m of the surface is common in many stable continental regions

Crystalline basement can have very low permeability

- limits flow and transport

Deep groundwater in the crystalline basement:

- Can have very long residence times – isolated from shallow groundwater
- Can be highly saline and geochemically reducing – enhances the sorption and limits solubility of many radionuclides
- Can have density stratification (saline groundwater underlying fresh groundwater) – opposes thermally-induced upward groundwater convection

Deep Borehole Field Test Objectives

- The RD&D objectives for deep borehole disposal are being met with a borehole field test that is conducted to a depth of 5 km in a suitable location (without emplacement of radioactive wastes)
- The DBFT includes the following major activities:
  - Obtain a suitable test site
  - Design, drill and construct the Characterization Borehole (8.5” diameter) to requirements
  - Collect data in the Characterization Borehole to characterize crystalline basement conditions and evaluate expected hydrogeochemical conditions
- Accommodate a subsequent Field Test Borehole (17” diameter)
  - Design, drill and construct the Field Test borehole to requirements
  - Design and develop surface handling and emplacement equipment systems and operational methods for safe canister/waste package handling and emplacement

Deep Borehole Field Test Objectives

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Evaluate site

Design and construct characterization borehole then field test borehole

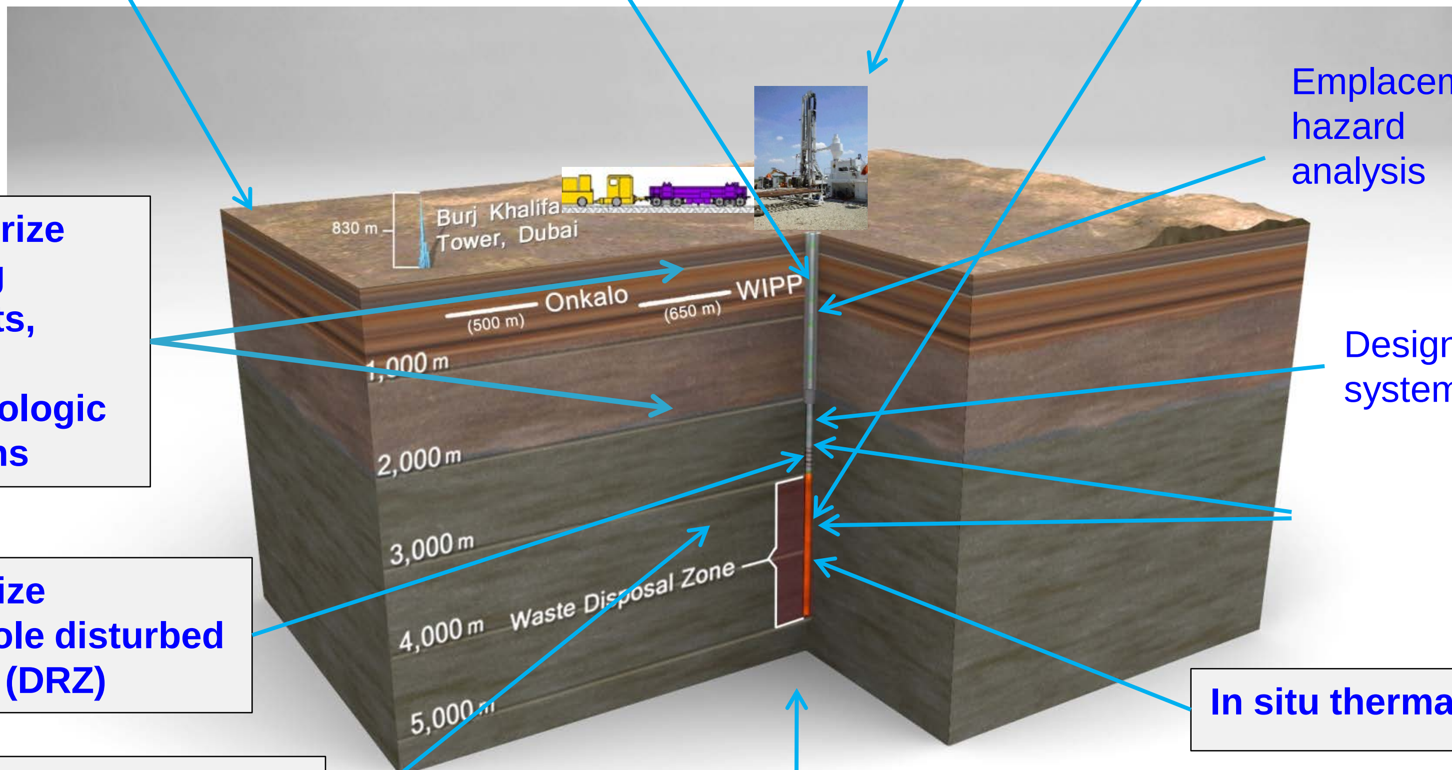
Develop and test systems for handling, emplacing, and retrieving WPs

Design and test WPs

Emplacement hazard analysis

Design seal system

Characterize overlying sediments, fluids, and hydrologic conditions



Characterize the borehole disturbed rock zone (DRZ)

In situ thermal test

Characterize crystalline basement, fluids, and hydrologic conditions

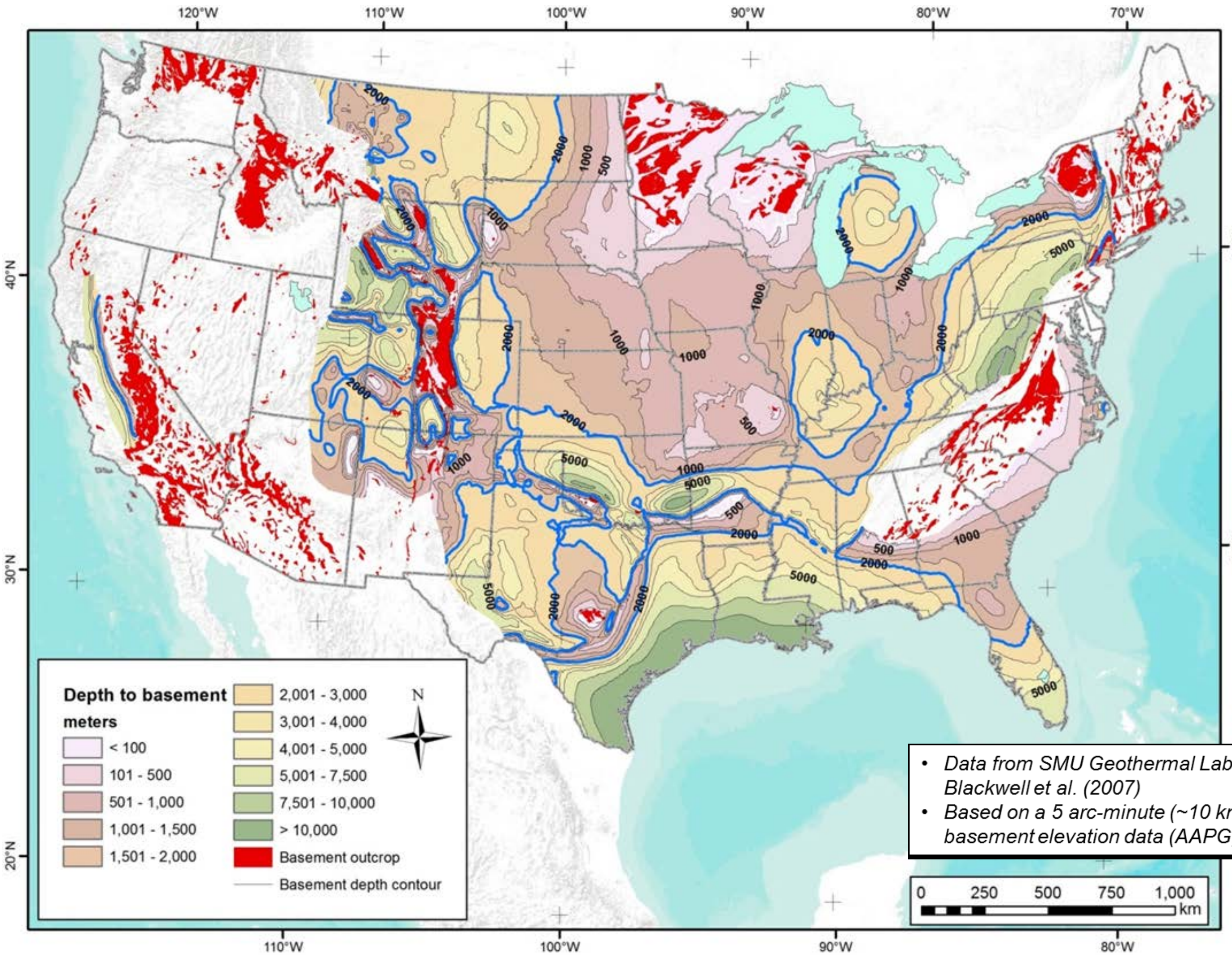
Assess post-closure safety
Synthesize field test activities, test results, and analyses into a comprehensive evaluation of concept feasibility

No radioactive waste will be used in conjunction with the DBFT activities (DOE RFP 2016).

Geoscience Guidelines Considerations

- Crystalline Basement
  - Depth
  - Rock Fabric & Stress State
  - Regional Structure(s)
  - Hydrology
- Heat Flow
- Recent Seismicity/Volcanism
- Resources
- Anthropogenic Contamination

Depth to Basement – National Scale



- *Data from SMU Geothermal Laboratory - Blackwell et al. (2007)*
- *Based on a 5 arc-minute (~10 km) grid spacing of basement elevation data (AAPG, 1978)*

Distribution of crystalline basement at a depth of less than 2 km (tan shading) and granitic outcrop (red) in the contiguous US (from Figure 3-2 in Perry et al., 2015)

Geologic Aspects of DBFT Siting

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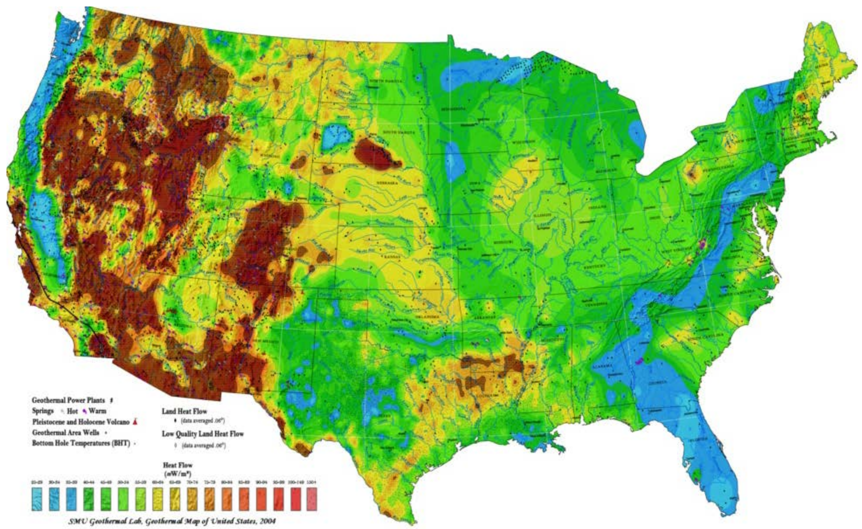
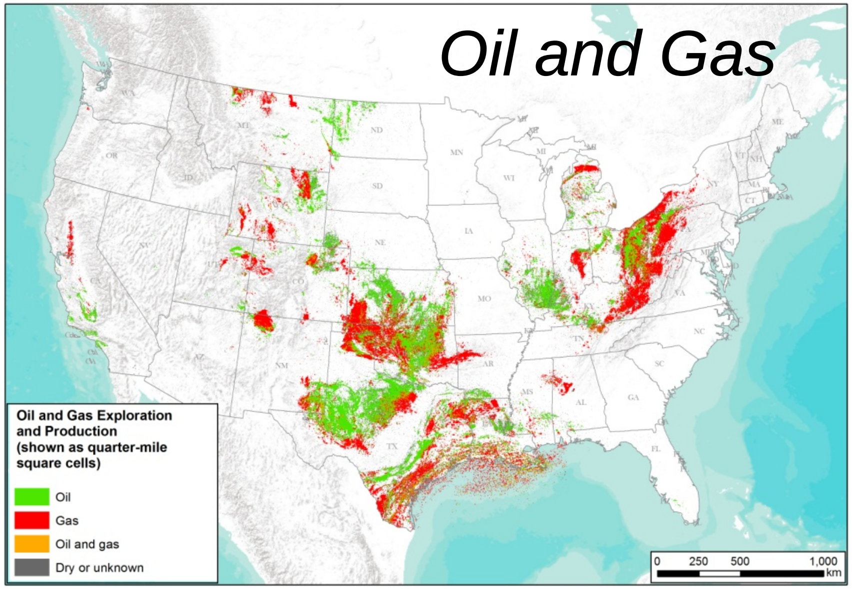
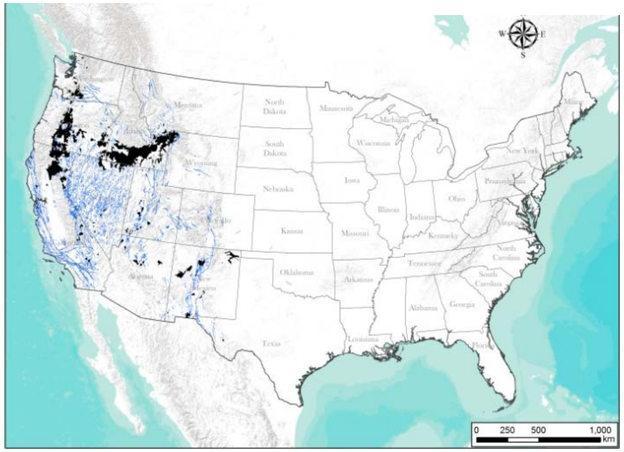
Heat Flow





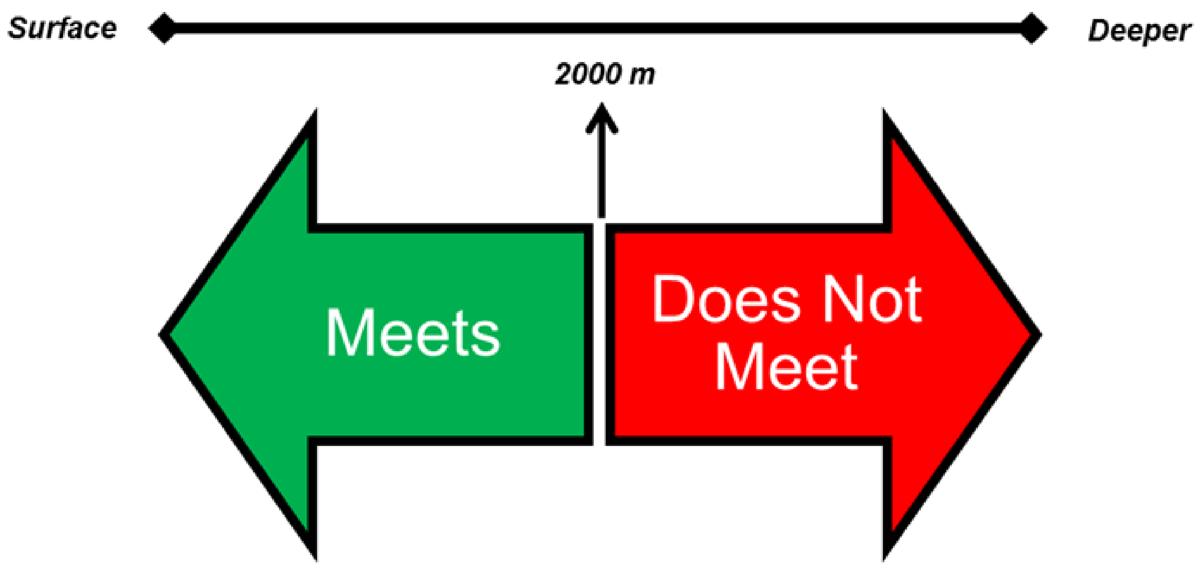


Volcanoes and recent faults

Depth to Basement Guideline

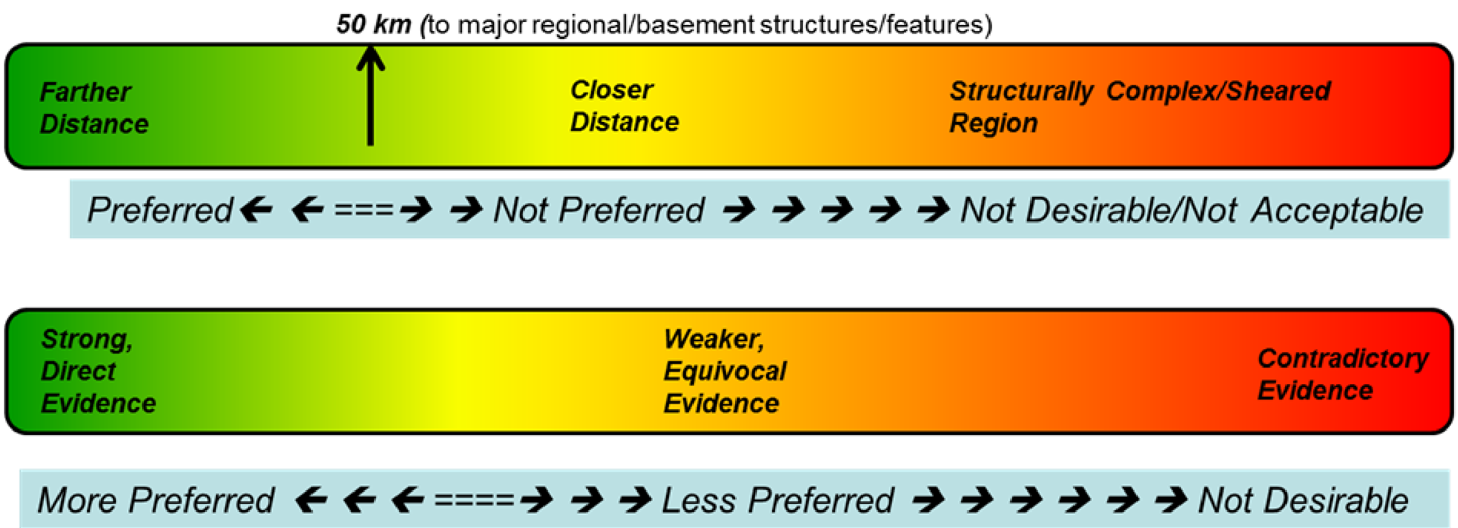
- Guideline is based on reference design
- Uncertainty in data is considered
  - Local boreholes with basement contact – highly certain
  - Regional data sets constrained by points within 50 km
  - National scale data set
    - Basement surface gradients

Depth to Basement--The depth to the crystalline basement is 2 km (1.2 miles) or less (note that all depths shallower than 2 km are considered equivalent, although the uncertainty of the data is considered).



Major Regional Structures Guideline

Major Regional Structures, Basement Shear Zones and Other Tectonic Features-- Geologic information and bases identifying any major regional structures, basement shear zones, or other tectonic features within 50 km of the proposed site. The absence within this distance of known major regional structures, major crystalline basement shear zones, or major tectonic features is preferred.



- Simpler structure is preferred, though not essential
- Specific structures closer than 50 km would be evaluated on a case-by-case basis

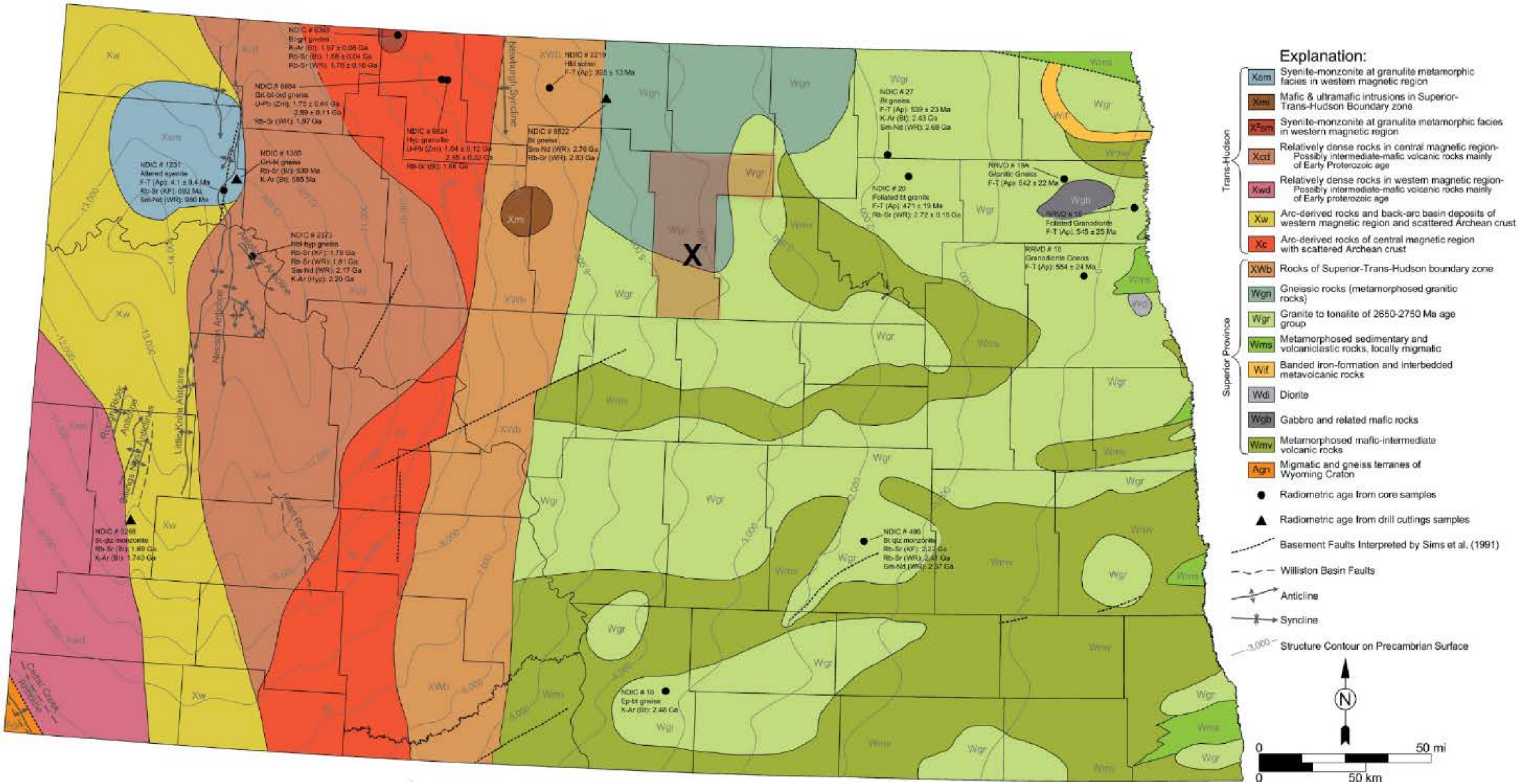
Deep Borehole Field Test

Acquisition of Site and Services

- Initial Request for Proposal (RFP)/Award
  - Did not establish a suitable test site
- US DOE RFP (Solicitation Number DE-SOL-0010181)
  - Pre-solicitation notice posted on August 5, 2016
  - Final RFP posted on FedBizOps on August 22, 2016
  - Proposals due October 21, 2016
  - Contract award anticipated in early 2017

Example Site: Pierce County, ND

Location and Crystalline Basement Map



Map of crystalline basement terrains in North Dakota, with example site location shown by the black X—lies above the 2700 ma rocks of the Superior Craton (after Nesheim, 2012).

Example Site: Pierce County, ND

Overburden Stratigraphy: Williston Basin

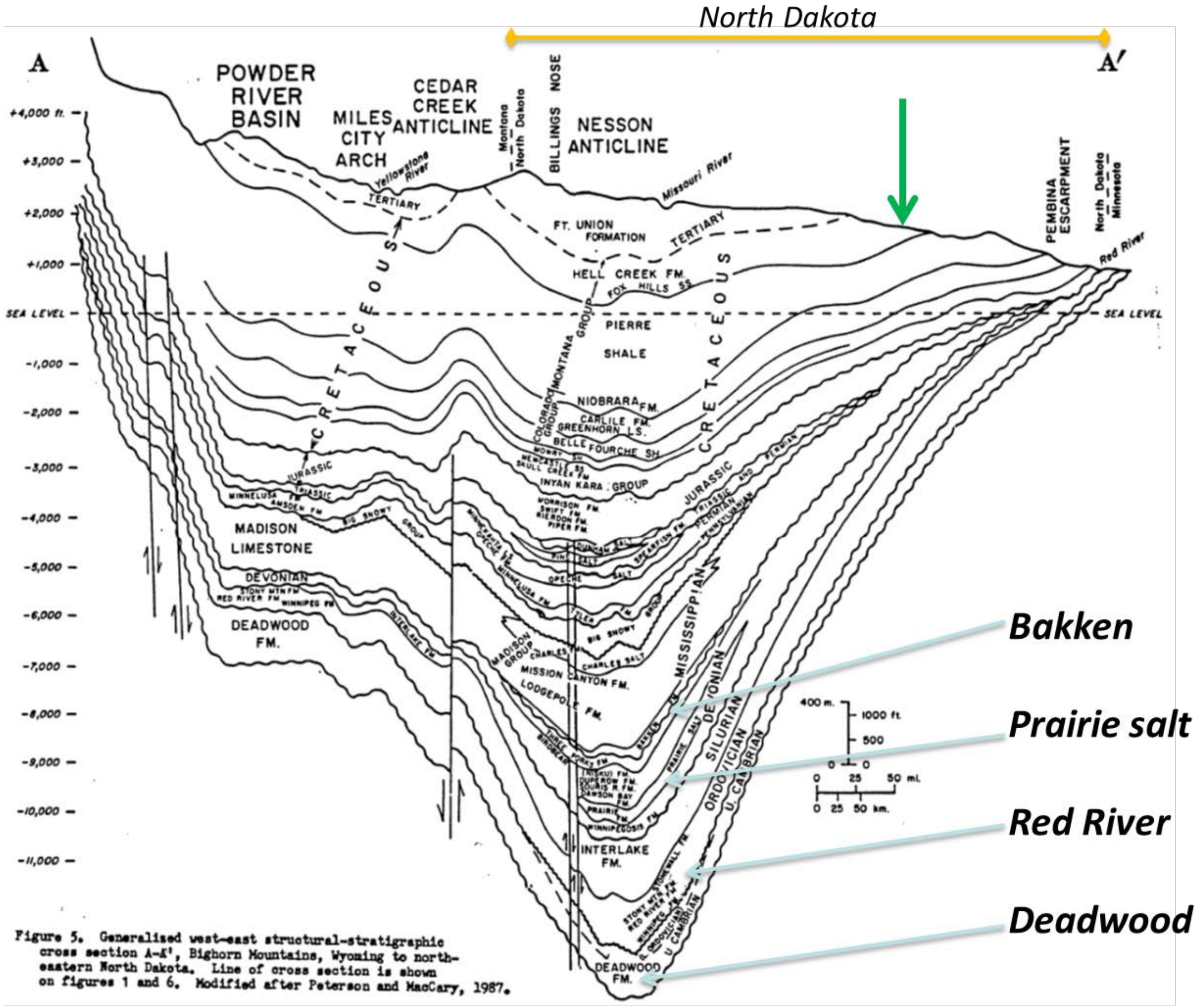
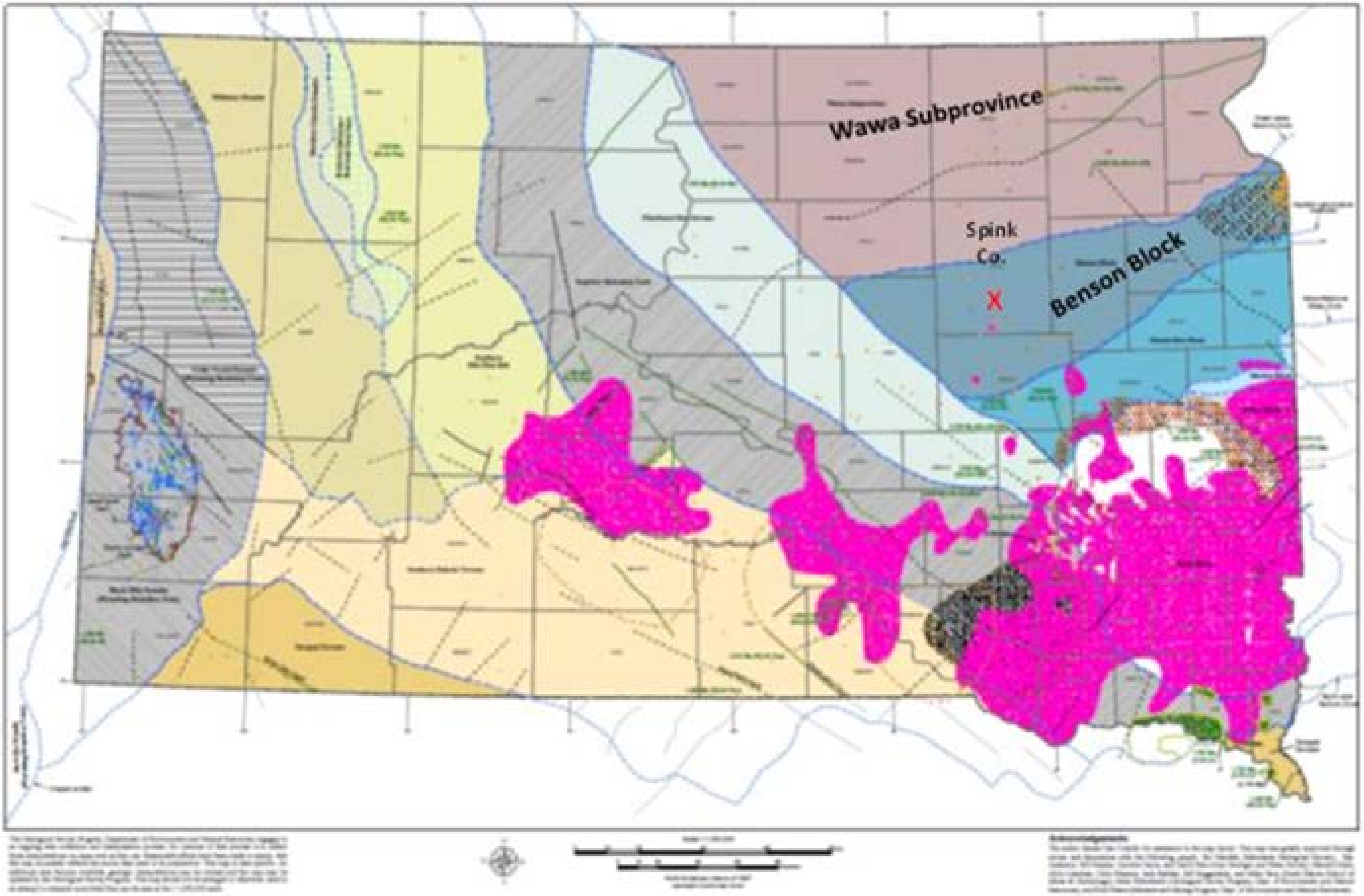


Figure 5. Generalized west-east structural-stratigraphic cross section A-A', Bighorn Mountains, Wyoming to northeastern North Dakota. Line of cross section is shown on figures 1 and 6. Modified after Peterson and MacCary, 1987.

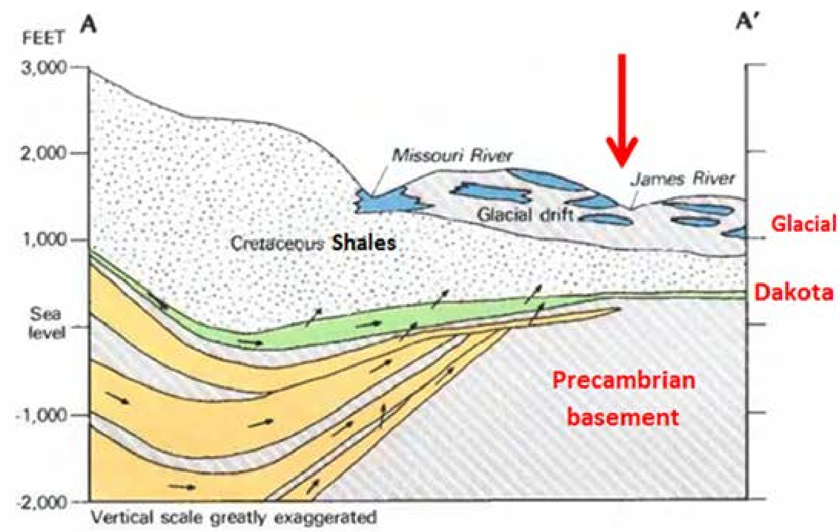
Geologic cross section (note large vertical exaggeration) of the Williston Basin overlying crystalline basement rocks in North Dakota (after Figure 5 in Peterson, 1988).

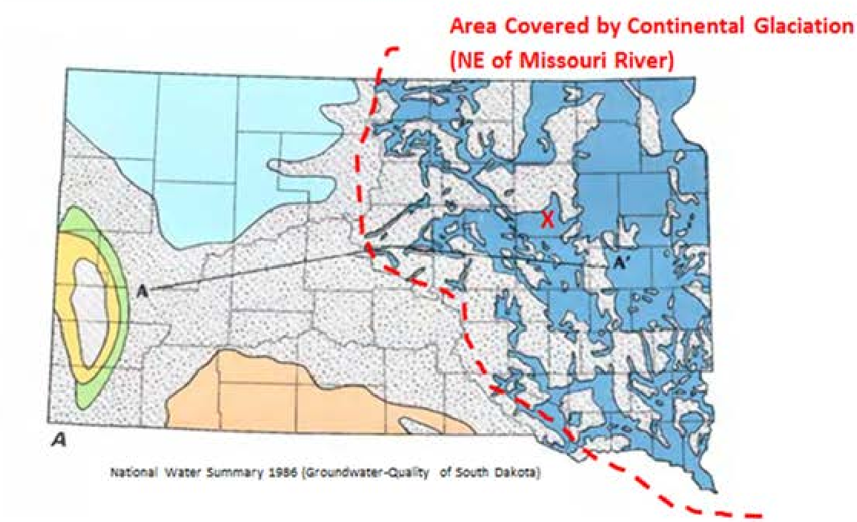
Example Site: Spink County, SD
Location and Crystalline Basement Map

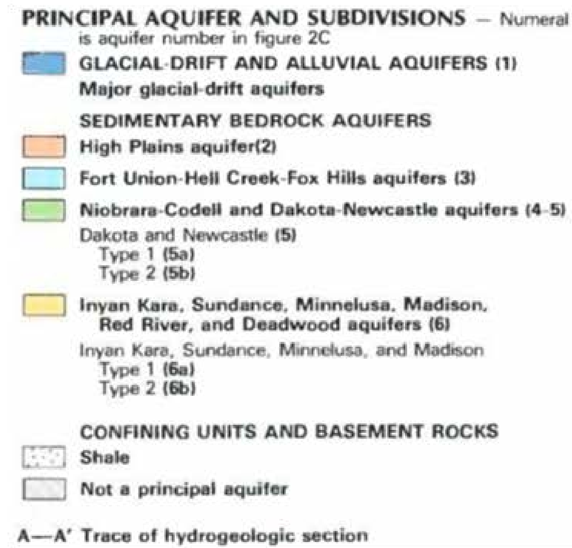


Terrane Map of the Precambrian Basement of South Dakota (after McCormick, 2010, Plate 1)

Example Site: Spink County, SD
Overburden Stratigraphy: Dakota Sandstone







Generalized hydrologic cross-section (Top) across SD along A – A' shown (Bottom) in map view (figure after Figure 2 from Koch et al., 1986).

Summary and Conclusions

- Many Sites within U.S. with Functional Geology
  - Multifaceted Objectives of DBFT Provide Opportunities for Success
- Choosing Site will be based on Uncertain Geologic Information
  - Generally regions lacking exploration
  - Based on the Weight of the Sum of the Evidence
- Each Site will have its own Geologic Challenges
  - Nature of Scientific Exploration
  - Will Provide Substantial Direct Data and Understanding
- Current US DOE Approach has more Explicit/Earlier Community Outreach/Involvement

Backup Materials

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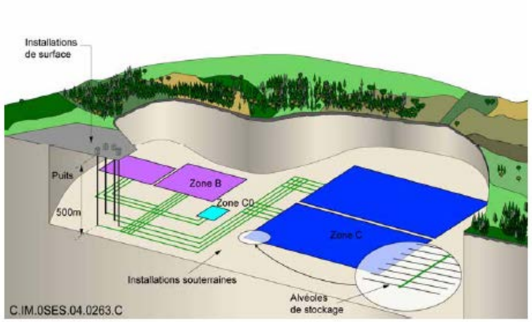
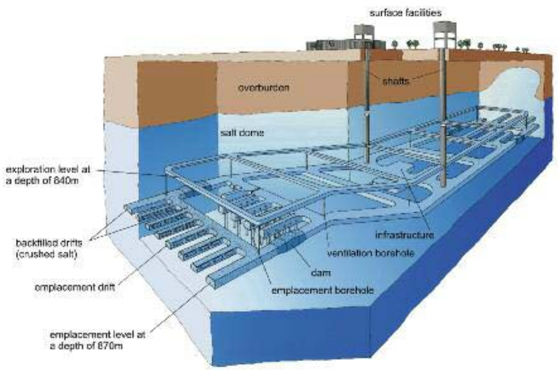
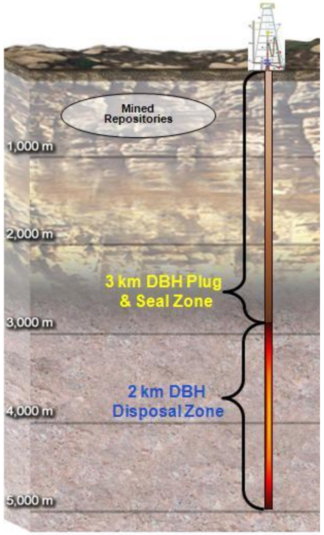
Deep Geologic Disposal Remains an Essential Element of Nuclear Waste Management

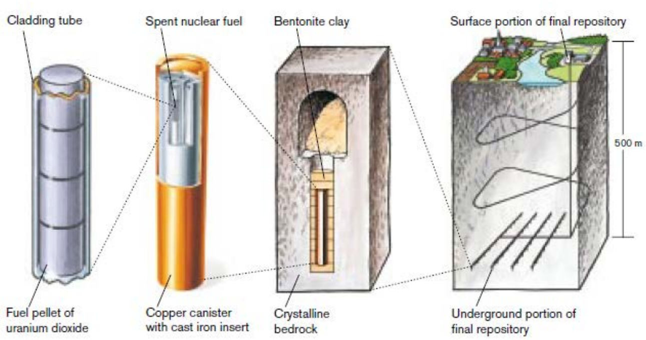
"The conclusion that disposal is needed and that deep geologic disposal is the scientifically preferred approach has been reached by every expert panel that has looked at the issue and by every other country that is pursuing a nuclear waste management program."

Blue Ribbon Commission on America's Nuclear Future, 2012









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