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Deep Borehole Field Test (DBFT) FY15 Site Evaluation Overview

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U.S. Nuclear Waste Technical Review Board Briefing

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Presentation Outline

- **Deep Borehole Field Test (DBFT) Project**
  - Site Evaluation Overview/Background
- **Deep Borehole Disposal (DBD) Concept**
  - Geologic conditions
    - *Hydrogeologic information at depth*
    - *Geochemical information at depth*
- **Site Evaluation Process**
  - Status
  - Process
- **DBFT Technical Site Guidelines**
- **Evaluation Examples Using Regional Geology GIS Database**

Site Evaluation Participants, Laboratories, FY15 Milestone

- **DOE**
  - NE-53 (NV): Tim Gunter, Lam Xuan
  - DOE-ID Procurement: Gordon Mc Clellan, Bradley Heath
- **SNL – DBFT Site Evaluation Technical Lead – Dave Sassani**
  - Bob MacKinnon, Geoff Freeze, Kris Kuhlman, Ernie Hardin, Bill Arnold, Pat Brady, Jack Tillman, Mark Rigali
- **LANL – Geoscience**
  - Frank Perry, Rick Kelley
- **LBNL – Geoscience**
  - Jim Houseworth, Pat Dobson
- **ORNL – GIS surface siting characteristics (OR-SAGE)**
  - Randy Belles
- **Site Evaluation**
  - ***06/04/15: - Site Selection Evaluation for Deep Borehole Field Test***
    - ***Plan/approach to evaluation of technical information***

DBD Concept: Unfavorable Geologic Conditions

- **Geologic conditions that are undesirable for the deep borehole disposal concept and waste isolation:**
  - Natural, interconnected high permeability zone (e.g., fault zone) from the waste disposal interval to the surface or shallow aquifer
  - At depths of greater than 3 km (i.e., disposal interval):
    - *Young meteoric groundwater*
    - *Low-salinity, oxidizing groundwater*
    - *Economically exploitable natural resources*
    - *Significant upward gradient in fluid potential (over-pressured conditions)*
  - High geothermal heat flow
- **Absent these unfavorable features**
  - Potential scenarios for radionuclide release to the biosphere include
    - *thermally driven groundwater flow (from waste heat), or simply diffusive flux, through the borehole seals and/or along the disturbed rock zone annulus*
- **Additionally, high differential horizontal stresses are undesirable for borehole completion and disposal operations**

DBD Concept: Preferred Geologic Conditions

- **Geohydrological Considerations**
  - No large-scale connected pathways from depth to aquifer systems
    - *No through going fracture/fault/shear zones that provide fast paths*
    - *No structural features that provide potential connective pathways*
  - Low permeability of crystalline basement at depth
    - Urach 3: (Stober and Bucher, 2000; 2004)
      - *~10^{-19} m^2 (intact rock); ~10^{-14} to 10^{-17} m^2 (bulk: parallel to or across shears)*
      - *Decreasing with Depth*
  - Evidence of ancient, isolated nature of groundwater
    - *Salinity gradient increasing downward to brine at depth (Parks et al., 2009)*
      - Limited recharge/connectivity with surface waters/aquifers
      - Provides density resistance to upward flow
    - *Major element and isotopic indication of compositional equilibration with rock*
      - Crystalline basement reacting with water (Stober and Bucher, 2004)
      - Ancient/isolated groundwater
        - *Ages – isotopes, paleoseawater (Stober and Bucher, 2000)*
        - *Radiogenic isotopes from atmosphere lacking: ^{81}Kr, ^{129}I, ^{36}Cl*
        - *Radiogenic isotopes/ratios from rock: ^{81}Kr, ^{87}Sr/^{86}Sr; ^{238}U/^{234}U*
        - *Noble gases (^{4}He, Ne) & stable isotopes (^{2}H, ^{18}O) compositions from deep water: (e.g., Gascoyne and Kamineni, 1993)*

DBD Concept: Preferred Geologic Conditions (Continued)

- **Geochemical Considerations**
  - Reduced, or reducing, conditions in the geosphere (rock and water system)
    - *Crystalline basement mineralogical (and material) controls*
      - Magnetite-hematite buffer low oxygen potential
        - *Oxides equilibria => T-low fO_2 paths (e.g., Sassani and Pasteris, 1988; Sassani, 1992)*
      - Biotite common Fe^{+2} phase (Bucher and Stober, 2000)
      - Lacking reductants, deep groundwater can be reduced if isolated
        - *Rock-reacted fluid compositions – water sink (Stober and Bucher, 2004)*
        - *More rock dominated at depth (Gascoyne and Kamineni, 1993)*
      - Steels in borehole will provide reducing capacity (H_2 source)
  - Stratification of salinity – increasing to brine deep in crystalline basement
    - *Canadian Shield salinity increases with depth to ~350 g/L TDS; (Gascoyne and Kamineni, 1993; Parks et al., 2009)*
      - More Ca-rich brines with further reaction with deeper rock
    - *Urach 3, Germany, ~70- g/L TDS NaCl brine (Stober and Bucher, 1999; 2004)*
  - Subset of waste forms and radionuclides are redox sensitive
    - *Lower degradation rates*
    - *Lower solubility-limited concentrations*
    - *Increased sorption coefficients*
  - Higher salinity
    - *Density gradient opposes upward flow*
    - *Reduces/eliminates colloidal transport*

DBFT FY15 Site Evaluation Status

- July 9, 2015: Final RFP released by DOE
  - "RFP Deep Borehole Field Test: Site and Characterization Borehole Investigations“
    - *Solicitation Number: DE-SOL-0008071*
  - Proposals due September 9, 2015
- Leading Up
  - Oct 24, 2014: DOE issued Deep Borehole RFI:
    - *“Request for Information (RFI) - Deep Borehole Field Test”*
      - Solicitation Number: DE-SOL-0007705
        - *Responses received Dec 8, 2014*
  - Jan 7, 2015: Site Guidelines Workshop:
    - *Reviewed and updated Technical Site Guidelines*
    - *Decision to use Request for Proposal (RFP) process*
      - DOE to procure site and site management/operations team
  - April 7, 2015: DOE released Draft RFP—requesting feedback
    - *"Deep Borehole Field Test: Site and Characterization Borehole Investigations"*
      - Solicitation Number: DE-SOL-0008071
        - *Feedback received May 5, 2015*
  - June 22, 2015: DOE Pre-solicitation notice
      - Solicitation Number: DE-SOL-0008071

Site Evaluation Process – RFP Criteria

- **Three Technical Criteria:**
  - Criterion 1. Availability and Geologic Conditions of Proposed DBFT Site
    - *Site Technical site guidelines*
  - Criterion 2. Organization and Qualifications
    - *Site management team experience, expertise, knowledge, and capabilities*
  - Criterion 3. Proposed Approach
    - *Methodology for successful accomplishment*
- **Three Additional Criteria**
  - Nontechnical criteria for DOE procurement

DBFT Technical Site Guidelines

- **The site area should be sufficient to accommodate:**
  - two drilling operations with boreholes nominally separated by at least 200 m;
  - surface facilities
    - to support the drilling operations;
    - for sample management and on-site data collection;
    - for evaluation of handling operations for surrogate (mock-up) waste containers; and
    - for site operation needs
  - Sites with ample open area surrounding the drilling site would be preferred.
  - The site area should be outside of wetlands areas and should be outside of 100-year flood zones, with ample access for heavy equipment needs.
- **Depth to crystalline basement –**
  - Less than 2 km (1.2 miles) depth to crystalline basement

DBFT Technical Site Guidelines (Continued)

- **Lack of conditions associated with fresh ground water flow at depth –**
  - Geologic information and bases should include conditions/features (and the technical bases for those identified) that provide evidence of the absence of recharge at depth. This could include (but is not limited to)
    - Lack of significant topographic relief that would drive deep recharge,
    - Evidence of ancient groundwater at depth, and/or
    - Data suggesting high-salinity groundwater at depth
- **Geothermal heat flux –**
  - Geologic information and bases should include evidence of the geothermal gradient and/or geothermal heat flux at the proposed site
    - A heat flux of less than 75 mW/m^2 is preferred

DBFT Technical Site Guidelines (Continued)

- **Low seismic/tectonic activity –**
  - Less than 2% probability within 50 years of peak ground acceleration greater than 0.16 g (generally indicative of area of tectonic stability)
  - Distance to Quaternary age volcanism or faulting greater than 10 km
  - Geologic information and bases should provide evidence of the aspects listed above, as well as any evidence that is available on
    - Existence, and orientation, of any foliation in the crystalline basement rocks
    - The horizontal stress state at depth in the crystalline basement rocks
      - Lack of steeply dipping foliation or layering is preferred
      - Low differential horizontal stress is preferred
- **Crystalline basement structural simplicity –**
  - Lack of known major regional structures, major crystalline basement shear zones, or major tectonic features
  - Geologic information and bases should include identification of major regional structures, basement shear zones, or other tectonic features within 50 km of the proposed site

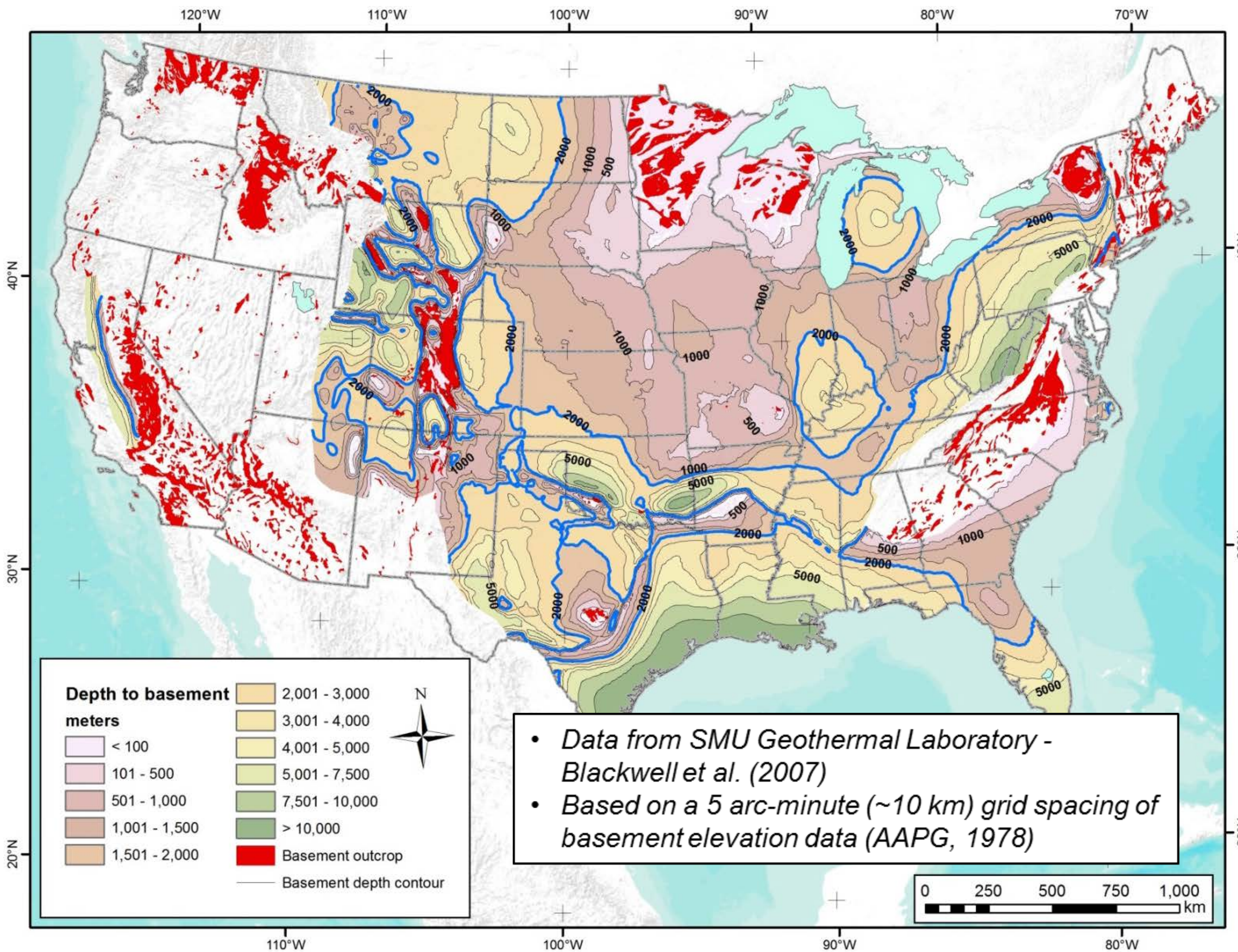
DBFT Technical Site Guidelines (Continued)

- **Low potential for interference with testing from other surface and subsurface usage –**
  - Information and bases provided for the proposed site should identify any *previous or current* uses of the surface and/or subsurface that could interfere with the test investigations. Such activities include but are not limited to
    - Wastewater disposal by deep well injection,
    - CO_2 injection,
    - Oil and gas production,
    - Mining,
    - Underground drinking water extraction, and
    - Strategic petroleum reserve sites
  - Absence of potential resources in the crystalline basement and sedimentary overburden is preferable
  - The information and bases provided for the proposed site should identify existing drinking water aquifers and any previous or current uses of the surface and/or subsurface (such as listed above) within 30 km of the proposed site as far back as available records indicate

DBFT Technical Site Guidelines (Continued)

- **Lack of *existing/previous* surface or subsurface anthropogenic radioactive or chemical contamination –**
  - Information and bases provided for the proposed site should identify any *previous or current* anthropogenic radioactive or chemical contamination within 10 km of the proposed site

Examples Using the Regional Geology GIS Database: 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)*

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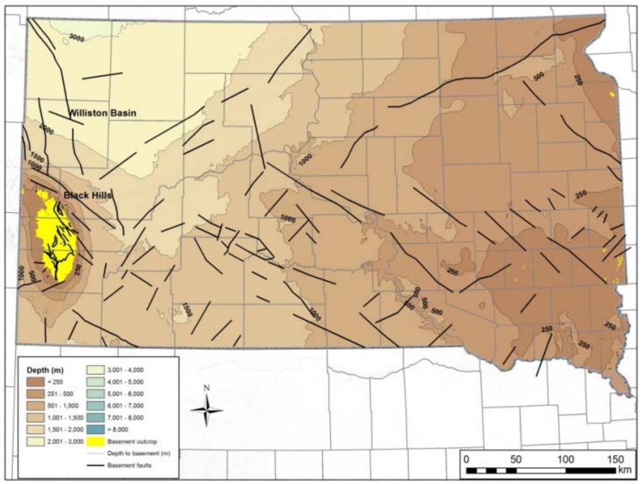
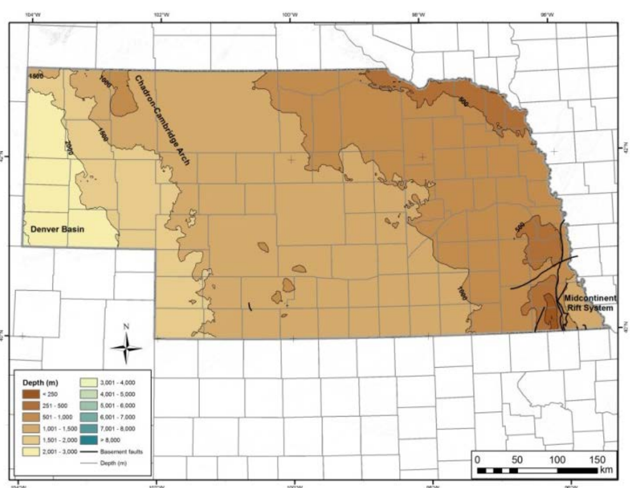
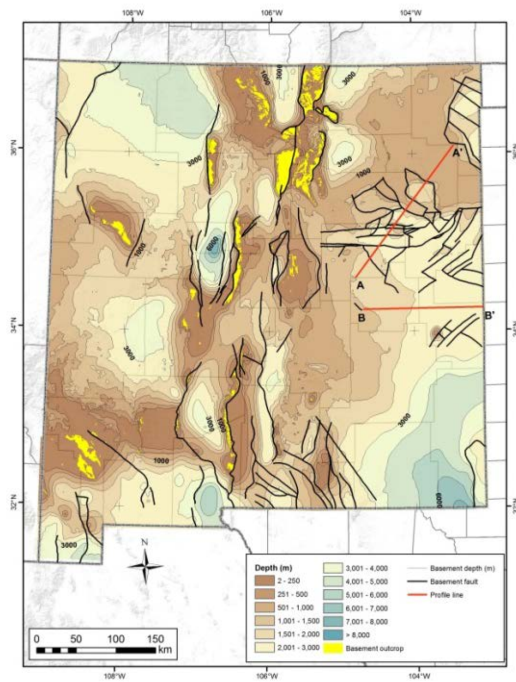
Examples Using the Regional Geology GIS Database (Continued)

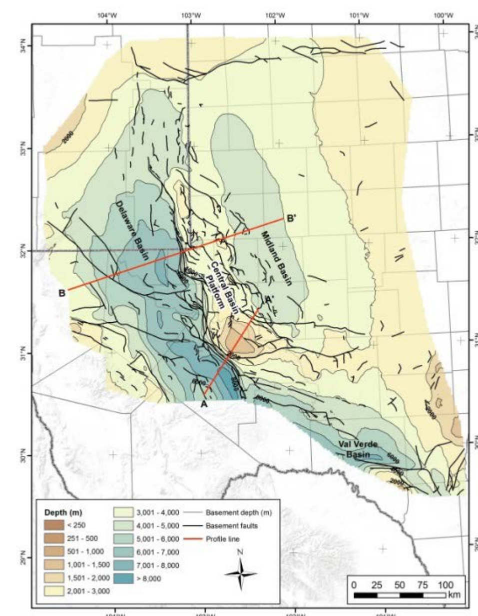
Depth to Basement Maps







Control on basement depth depends primarily on the density and locations of borehole data



Data: McCormick et al. (2010) U. Nebraska, School of Natural Resources; Broadhead et al. (2009); Ruppel et al. (2005)

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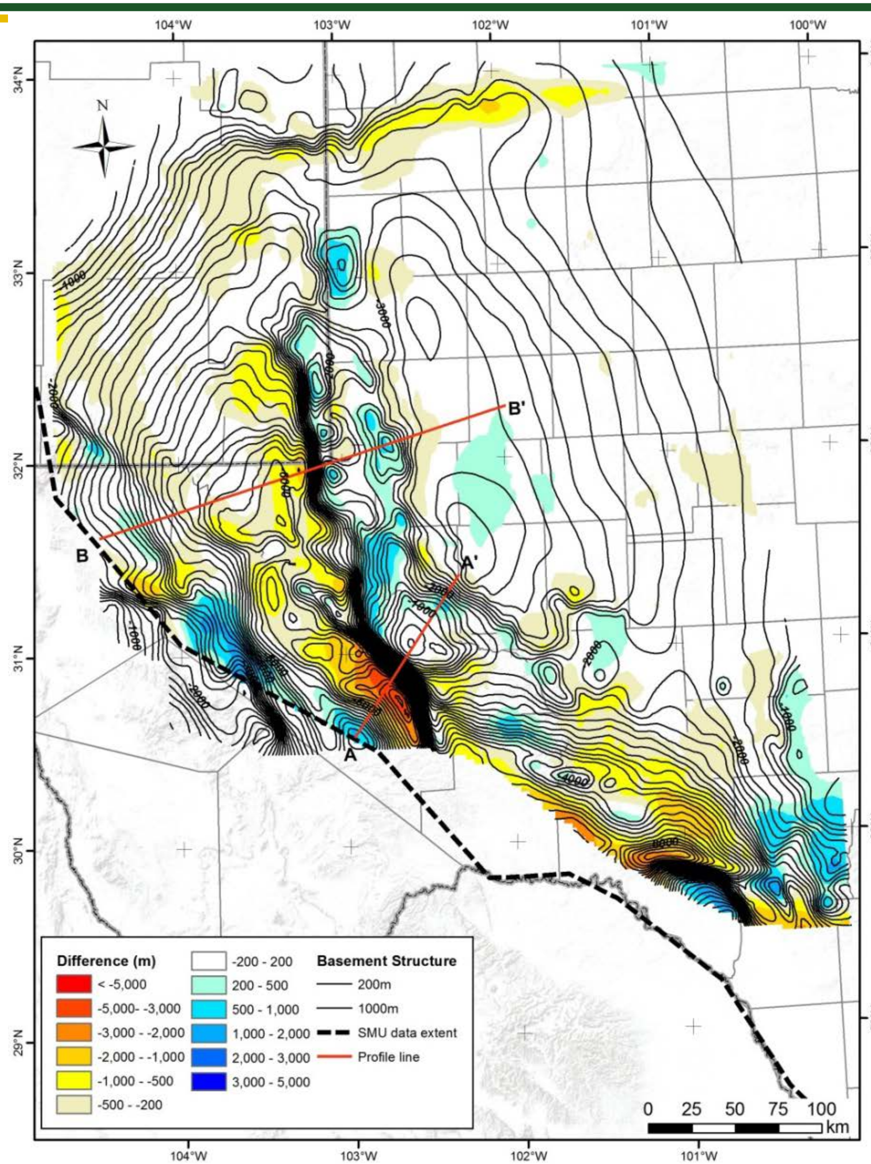
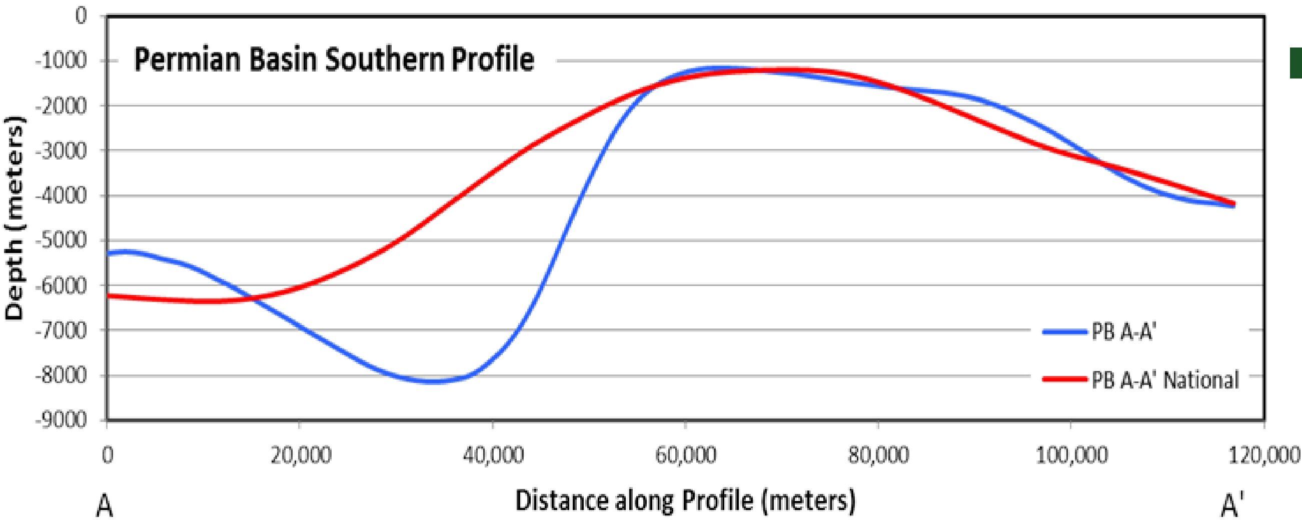
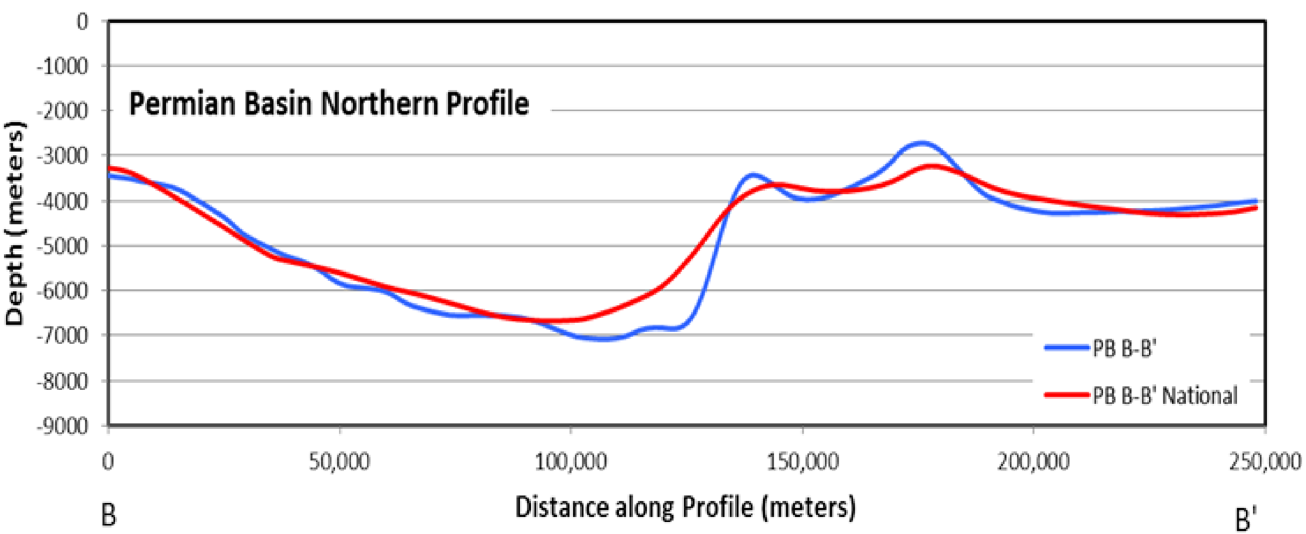
Examples Using the Regional Geology GIS Database (Continued)

- ***Permian Basin Difference Map***
  - Subtracted state-scale map from national map (on a cell by cell basis)
    - Depth(national) – Depth(state)
    - Colors show larger differences
  - Largest differences in depth correlate with areas of high basement elevation relief (i.e., closely spaced contour lines)
  - Depth profiles (A-A’) and (B-B’)
    - Show basement depth differences
    - Elucidate differences between national and basin-/state-scale maps



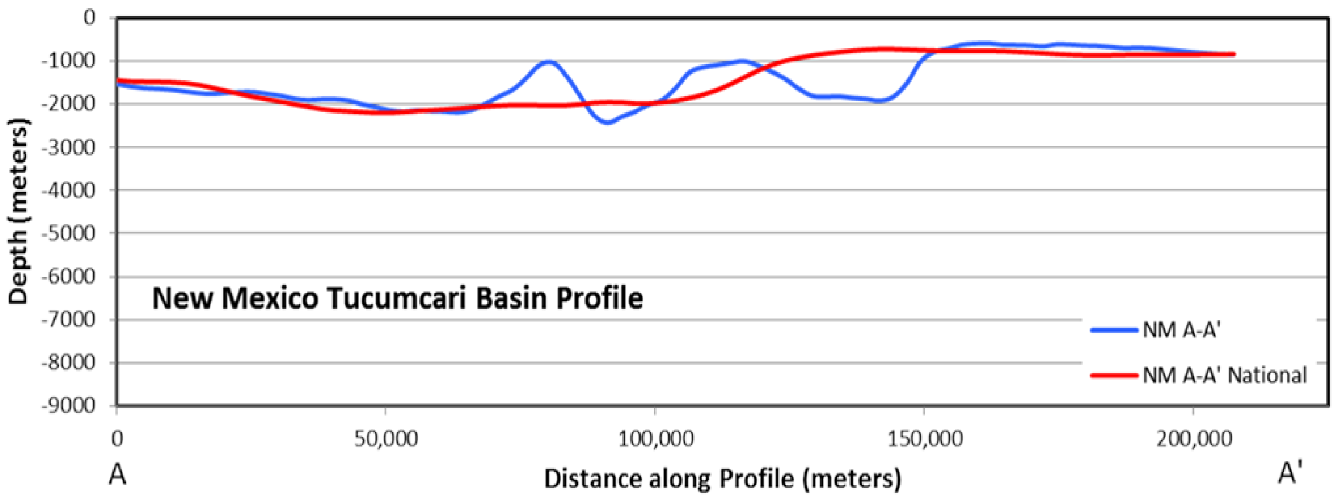
Examples Using the Regional Geology GIS Database (Continued)

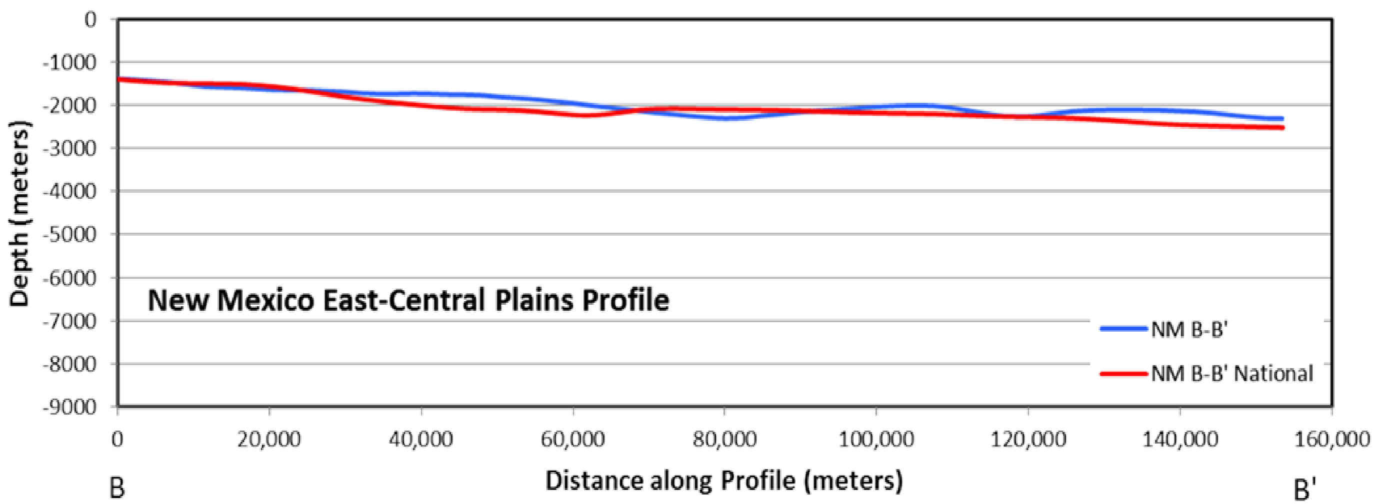




- Permian Basin Depth Profiles
  - National profile is smoothed relative to profile of basin-scale data
  - Consistent with a larger 5 arc-minute grid spacing of the national map and the level of detail that it was intended to convey

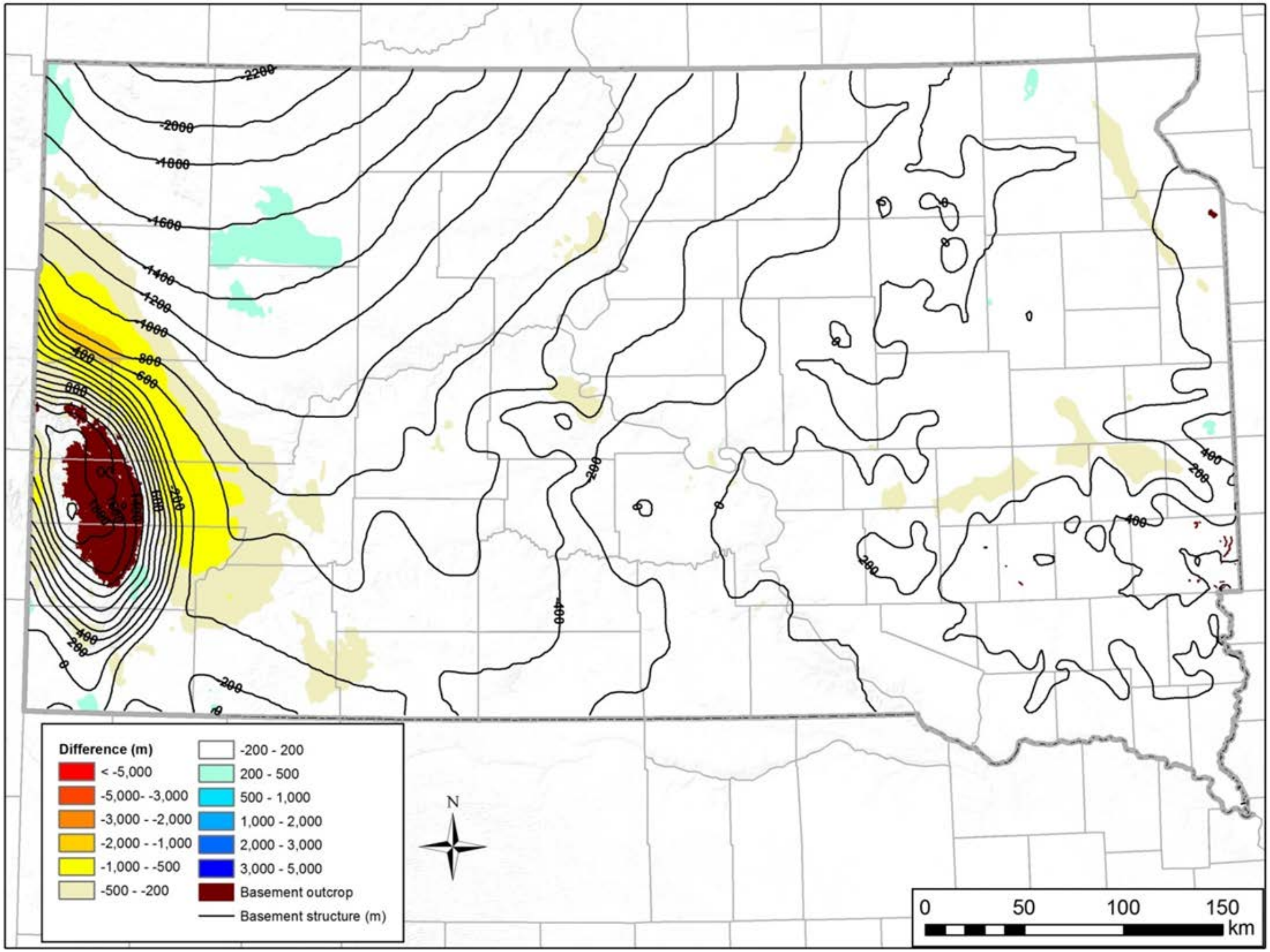
Examples Using the Regional Geology GIS Database (Continued)



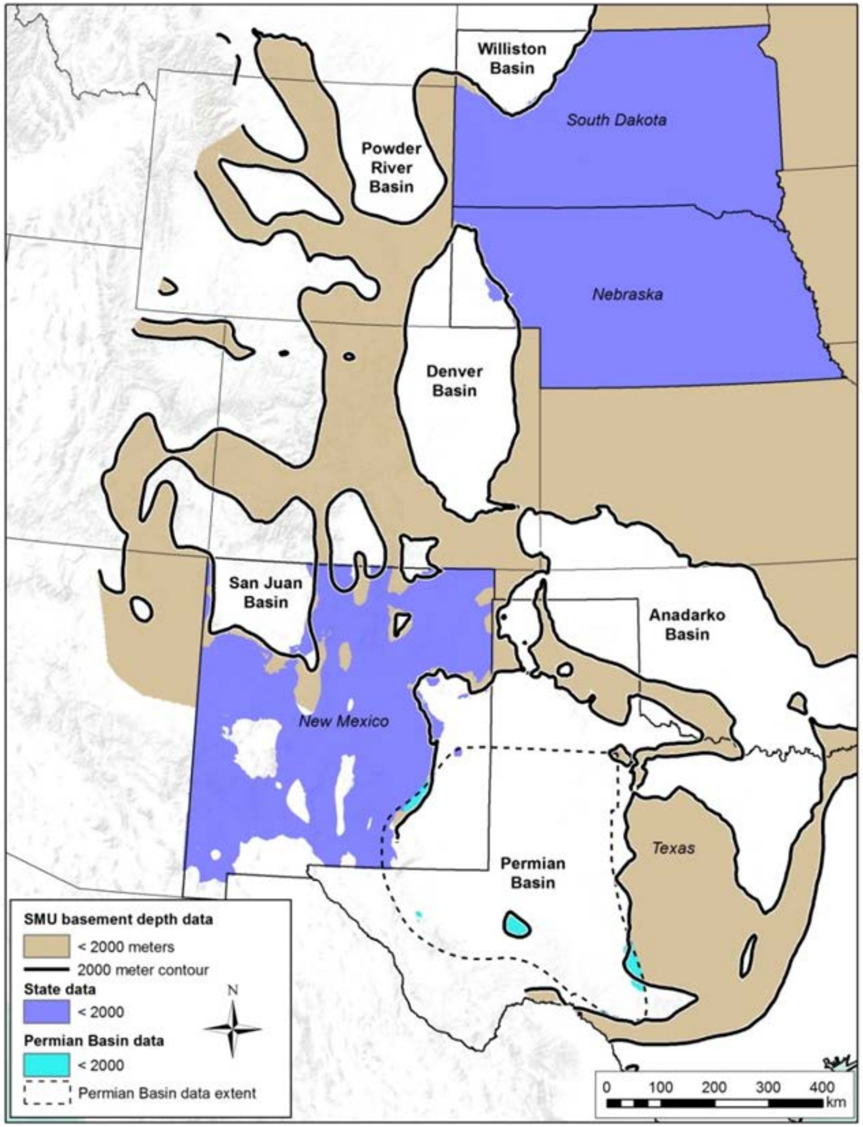


- New Mexico Depth Profiles
  - Moderate relief areas
    - National map does not capture full detail of depth variations (> 1km difference)
  - Minimal relief areas
    - agreement is very good (~± 200 m), comparable to majority of areas in states such as Nebraska and South Dakota

Examples Using the Regional Geology GIS Database (South Dakota Difference Map)



Examples Using the Regional Geology GIS Database (Continued)



- Comparison of 2 km Depth Contour
  - Agreement in the location is good for areas evaluated
  - Maps at different scales also agree well on the overall extent of areas with basement at < 2 km depth
    - *Particularly in areas with little basement relief*
  - Areas with a large amount of basement relief show the least agreement
    - *These are areas that would be avoided because of basement structural complexity*
  - Access to actual borehole data will be important in some areas

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