SAND2017-9392C

Basin-Scale Density-Dependent Groundwater Flow Near a Salt Repository

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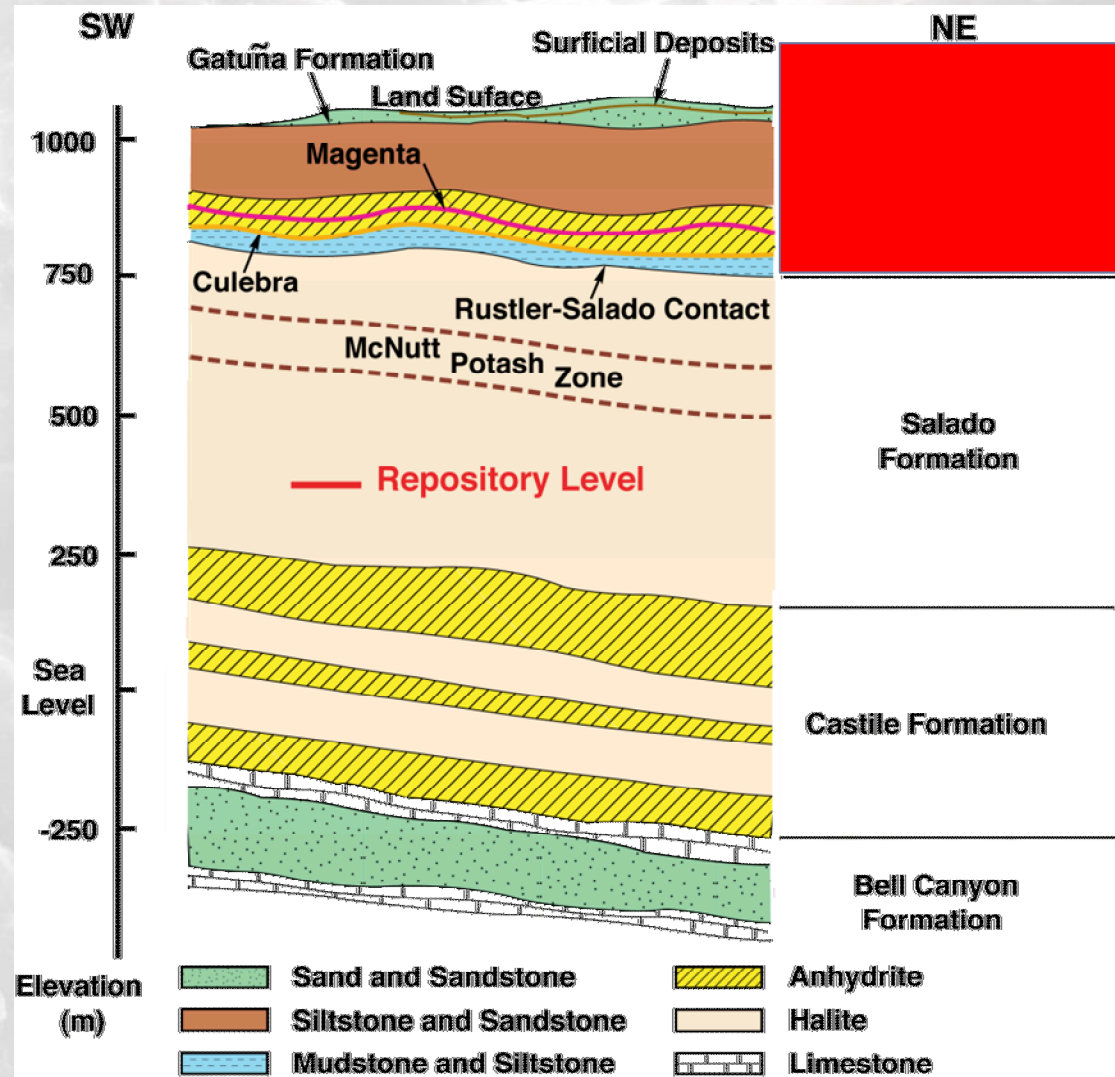
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Sandia National Laboratories

Middelburg, The Netherlands

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US/GERMAN WORKSHOP

Salt Repository Research, Design, & Operation
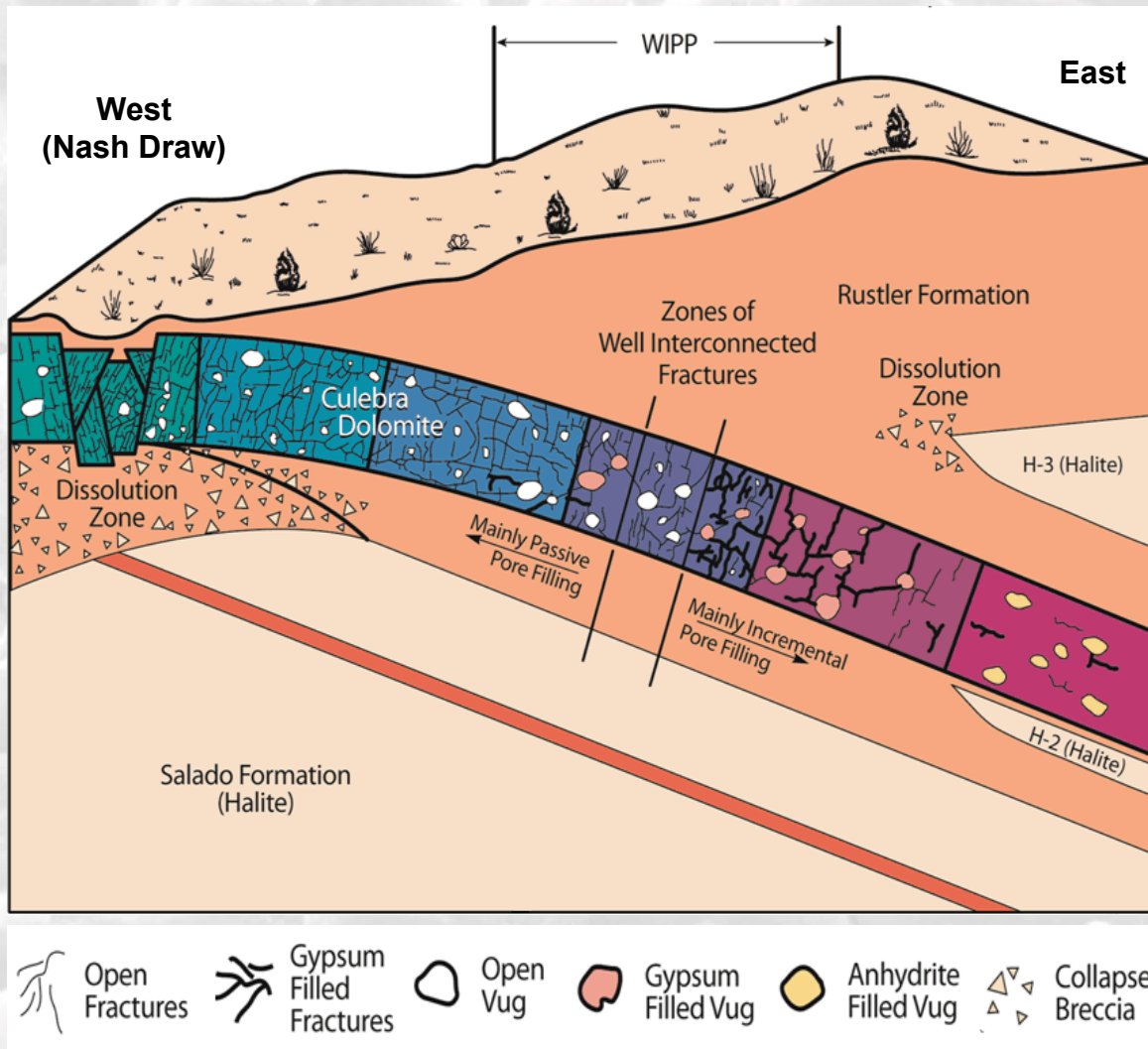
WIPP Hydrogeology

- Repository in Salado bedded salt formation
  - >500-m thick salt unit
- Hydrogeology of formations above salt
  - Rustler Formation
    - Culebra dolomite
    - Magenta dolomite
    - Anhydrite
    - Mudstone/Halite
  - Dewey Lake Red Beds
    - Silt/sand stones + clay
  - Dockum Group
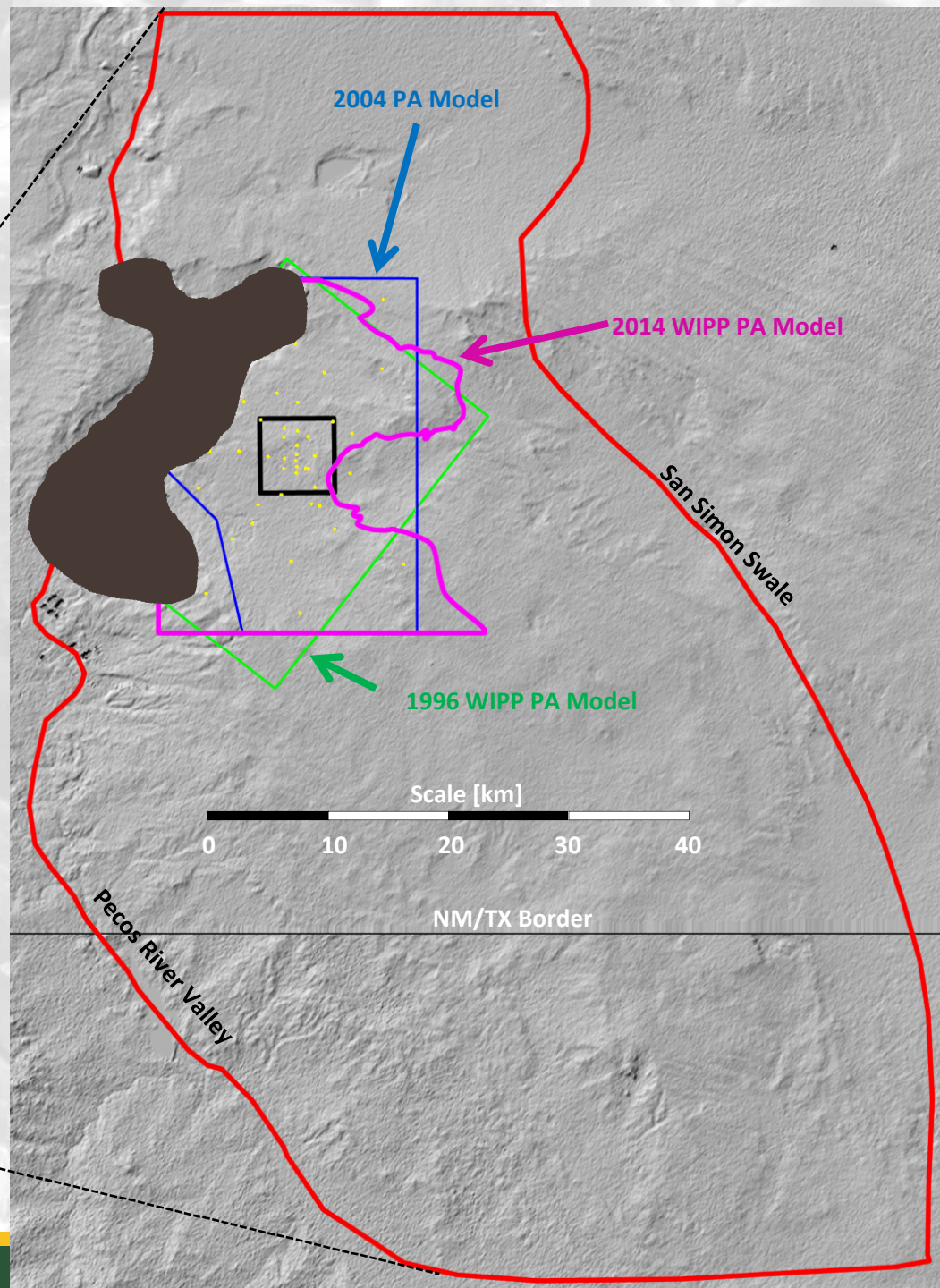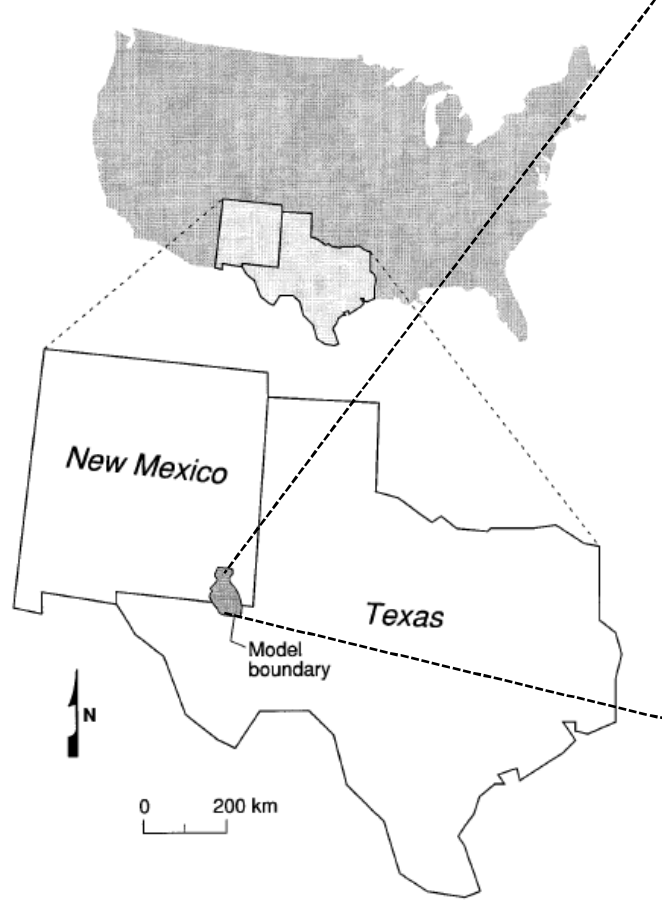   - Silt/sand stones + clay
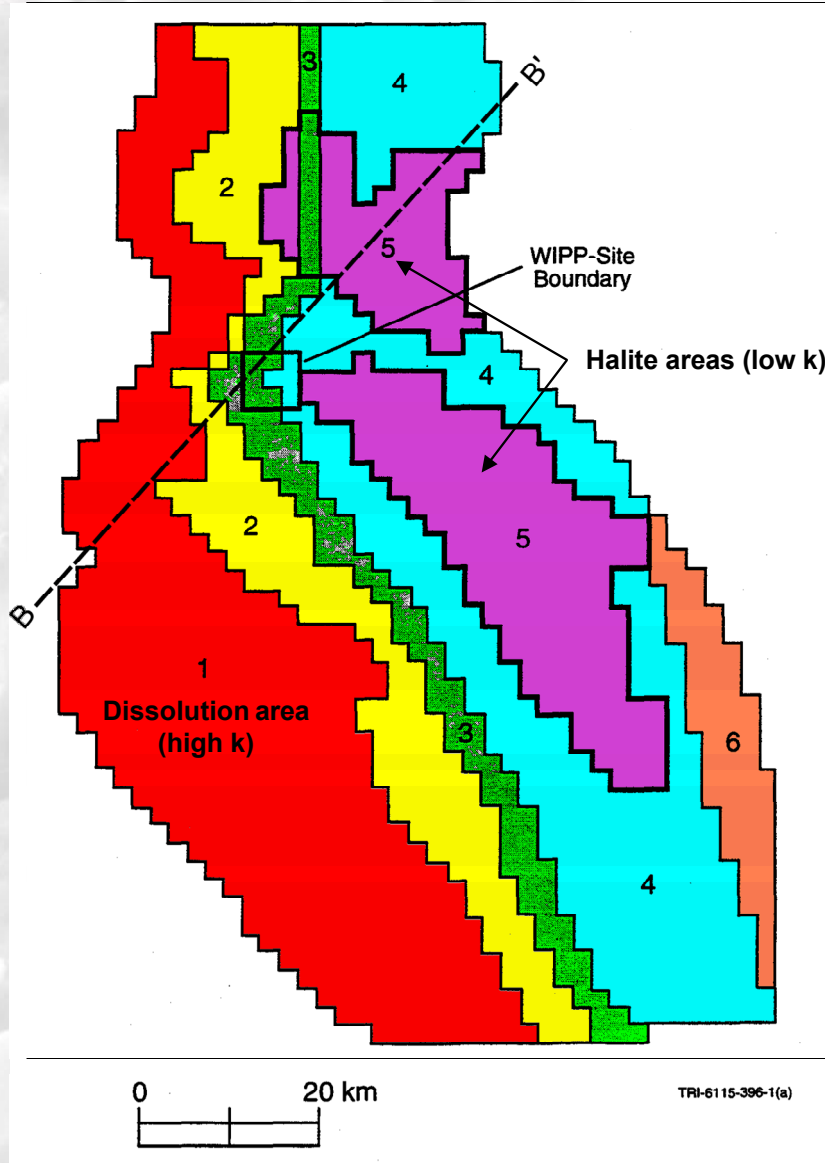
Rustler Conceptual Model

- **West of WIPP**
  - Shallow units
  - High permeability
  - Relatively fresh water
- **East of WIPP**
  - Deeper units
  - Low permeability
  - Saturated brine
- **Regional groundwater**
  - Flow used in WIPP PA
  - Long-term geological stability of salt

Corbet (2000) Model Domain

2004 PA Model

2014 WIPP PA Model

1996 WIPP PA Model

San Simon Swale

Pecos River Valley

NM/TX Border

Scale [km]

0   10   20   30   40

New Mexico

Texas

Model boundary

N

0   200 km

4

Corbet (2000) WIPP Model

- **Most of Delaware Basin**
- **Transient Simulation**
  - Climate variation (dry vs. wet)
  - 14,000 y → present → 10,000 y
- **Model Implementation**
  - "water table" moving boundary model
  - ~8700 km² region (78 km × 112 km)
  - Coarse mesh (2 km square cells)
  - 12 model layers (10 geo layers)
  - 1,500 cells/layer
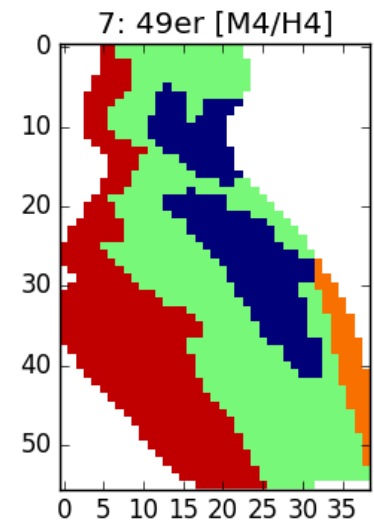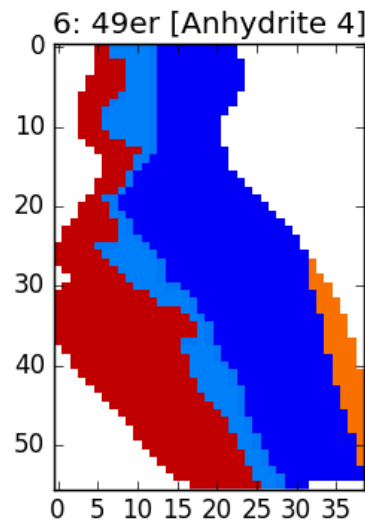 - ~18,000 elements total

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(figure labels within image)

WIPP-Site Boundary

Halite areas (low k)

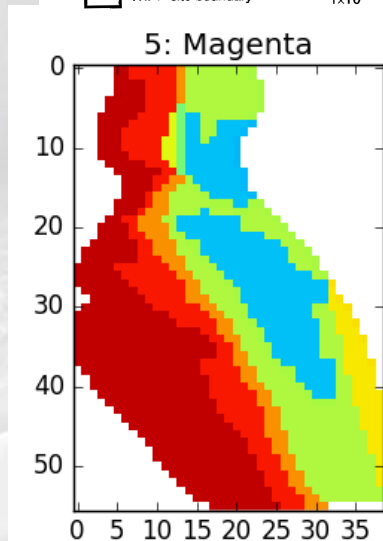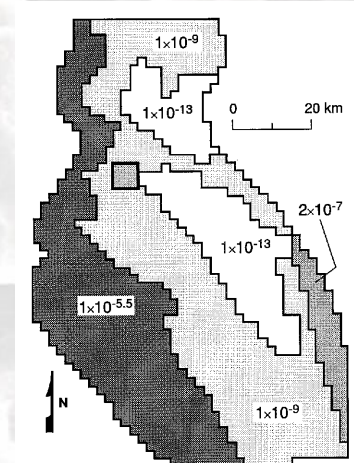Dissolution area (high k)
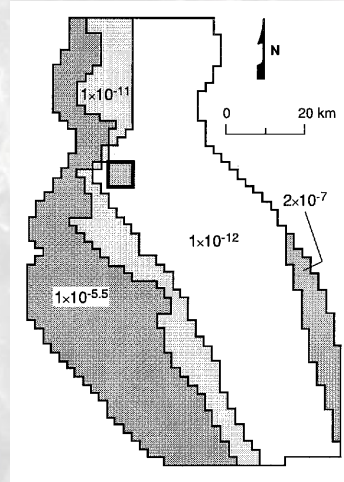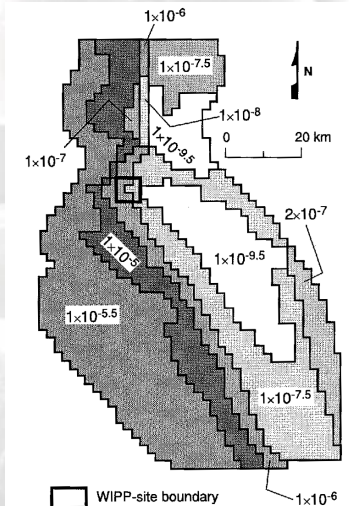
0   20 km

TRI-6115-396-1(a)

Motivation

- Benchmark against existing solution (Corbet, 2000)
- Comparison with original model
  - Old mesh, model parameters & boundary conditions
- Include new processes, features & data
  - Include density-driven flow (e.g., Davies, 1989)
  - Include chemistry & mineral dissolution
  - Investigate flow & chemistry boundary conditions
  - Test and update hydrogeological conceptual model
  - Incoporate current data: ^{81}Kr GW age data, water level data
- Comparison and Development of Models
  - PFLOTRAN (SNL)
    - Add density dependent flow
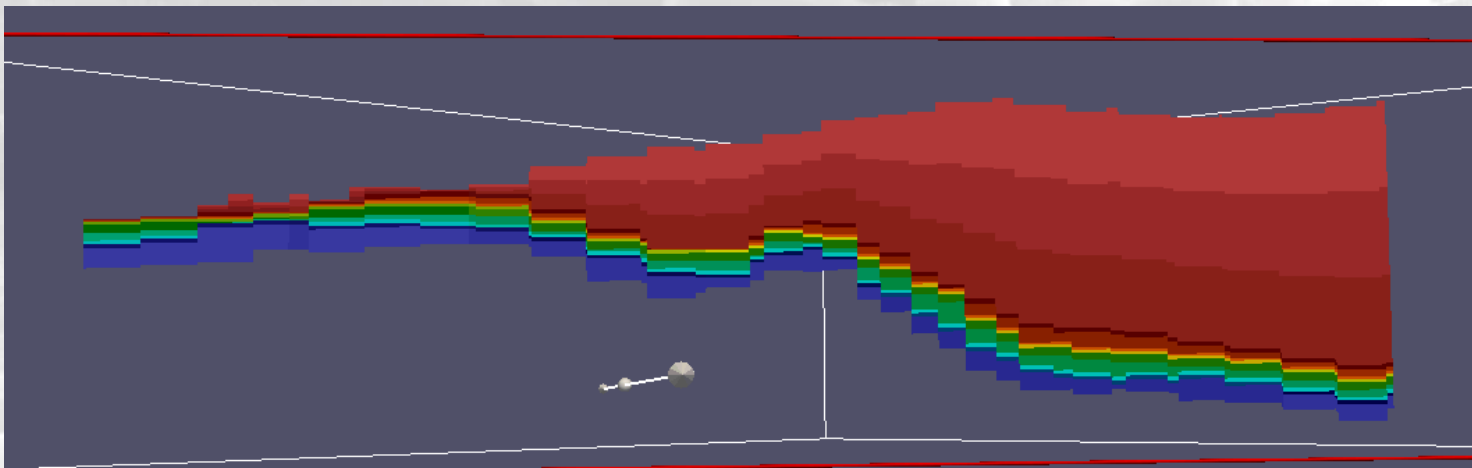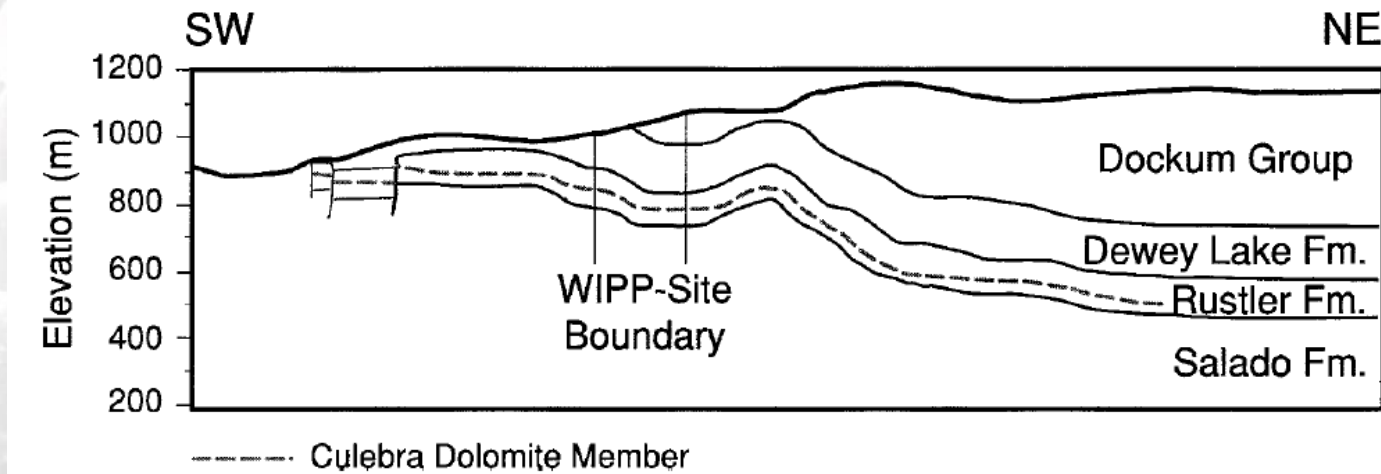 - d^3f (GRS)

SNL PFLOTRAN version

Corbet (2000): Hydraulic conductivity [m/s]

PFLOTRAN: Permeability [m²]

SNL PFLOTRAN version

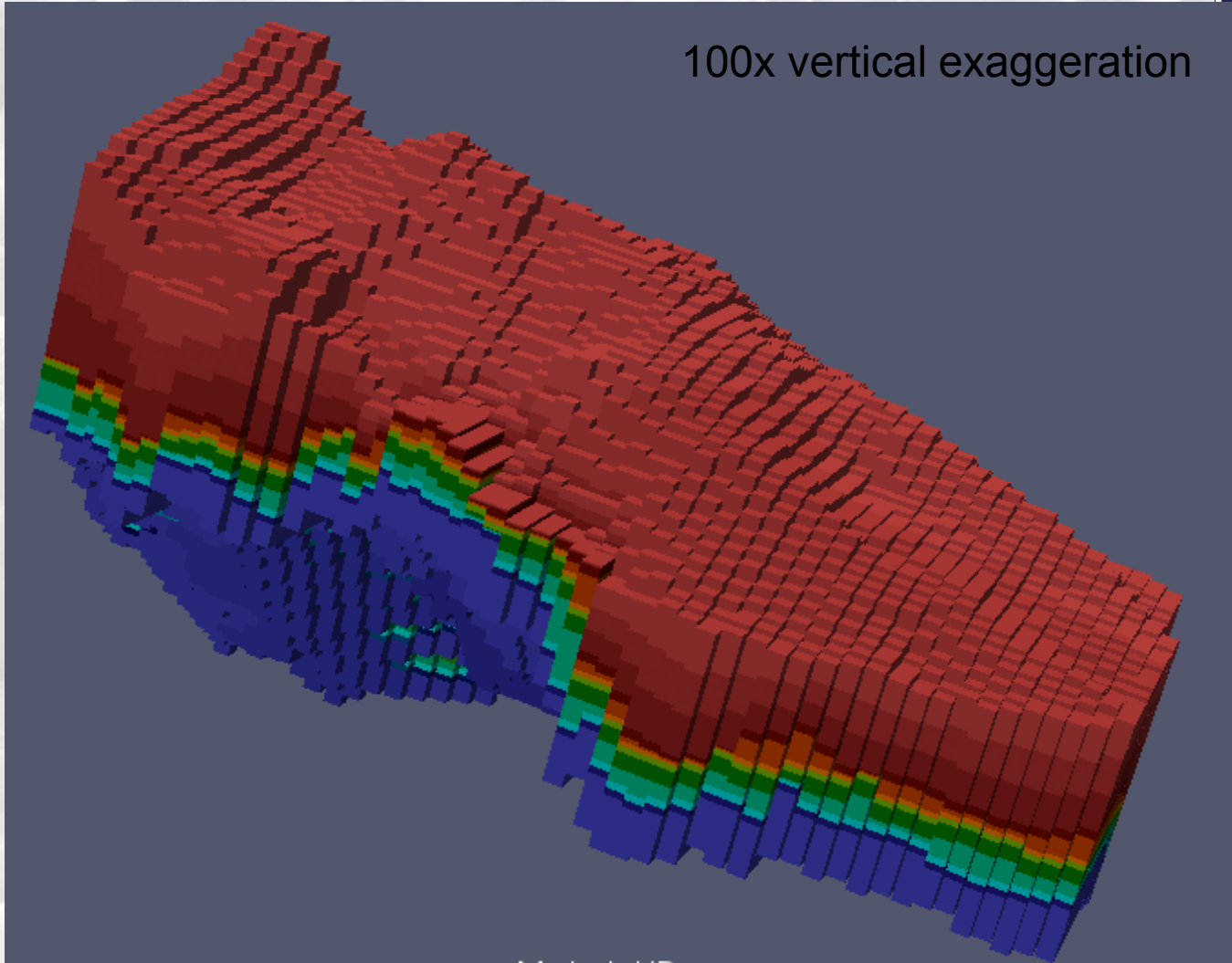
~25x vertical exaggeration

SNL PFLOTRAN version

100x vertical exaggeration

Original Mesh: 13-layer hexahedral (cuboid) elements (18,000 elements)

Issues Encountered

- Old Mesh is very coarse
  - **PFLOTRAN and d³f have difficulty with mesh**
  - Mesh violates conventions regarding
    - Regularity (Δz varies too much in space)
    - **Connectivity (must build mesh "by hand")**
    - Aspect ratio (2 km × 2 km × 1s-100s m)
  - **Anke (GRS): re-mesh using modern tools (LARGE)**
  - **Kris (SNL): struggle with old mesh (COARSE)**
  - **Too coarse for efficient variably saturated flow**
- **Moving water table ≠ Richards equation**
  - **Unsaturated flow parameters are guessed**
  - **Recharge applied at water table vs. applied at land surface**

Schedule

Year 1

- SECOFL3D data provided by SNL
- GRS begins building d³f model
- SNL begins building PFLOTRAN model
- SNL consults

Year 2

- GRS builds d³f model equivalent to Corbet (2000)
- SNL builds PFLOTRAN equivalent to Corbet (2000)
- GRS 'includes' density-driven flow

+Year

- SNL includes density-driven flow to PFLOTRAN
- Including new features / data
    - Update boundary conditions
    - Update hydrological implementation and conceptual model
    - Include geochemical tracers