Geologic Structure & Seismic Analysis

Progress Report

Kentucky Geological Survey
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Trenton–Black River Research Consortium

October 5, 2005

Pittsburgh, PA

Structure & Seismic Analysis Objectives

- Structure and isopach maps
  - Top and Base of Devonian Shale
  - Ordovician - Kope Fm
  - Utica Shale - Trenton Fm
  - Black River Ls - Knox Unconformity
  - Basal Ss - Precambrian Basement

Structure & Seismic Analysis Objectives, cont.

- Map major structural features
  - Major fault trend maps (i.e., seismically resolvable)
  - Isolate faults of suitable age, orientation, and location to be relevant for HTD creation within the Trenton-Black River section

Structure & Seismic Analysis Objectives, cont.

- Structural evaluation of region
  - Potential hydrothermal dolomite development fairways
  - Source of heated fluids
  - Fluid migration routes

Outline of Tasks

- Data Acquisition *Done!*
  - Seismic, well logs, and stratigraphic well tops
- Load Seismic data *Done!*
  - Digital SEGY files into Kingdom Suite
  - Raster images into PetraSeis
- Load Well Data *Done!*
  - Digital LAS files into Kingdom Suite & Petra
  - Raster images into Petra
- Load Preliminary Well Tops *Done!*

Outline of Tasks, con't.

- Use sonic logs for synthetic seismogram creation and creation of velocity models *Done!*
- Use velocity model to transform well top depths in feet subsea to depths in time *Done!*
- Correlate log tops to reflecting seismic horizons *Done!*
- Interpret stratigraphy and structure from seismic *Done!*
- QC data and correct "misties" *Almost done…*

Outline of Tasks, con't.

- Create regional fault trend maps — *In progress…*
- Create 3D surfaces from well based stratigraphic tops — *In progress…*
- Create 3D (X(m), Y(m), Z(sec)) surfaces from seismic horizons — *In progress…*
- Merge products with those of the other members of TBRRC — *Beginning soon.*

KGS

Time-to-Depth Calculations

- Procedure
  - Create 3D grids of seismic horizons
  - Create fault lines/polygons affecting each layer
  - Use well tops as control points
  - Warp time grid to fit control points
    - Surface will be discontinuous across faults, with offset determined by seismic and/or regional trends
  - Generate surface to horizon velocity grids based on above grid curvature
  - Calculate depth in feet of horizon surface

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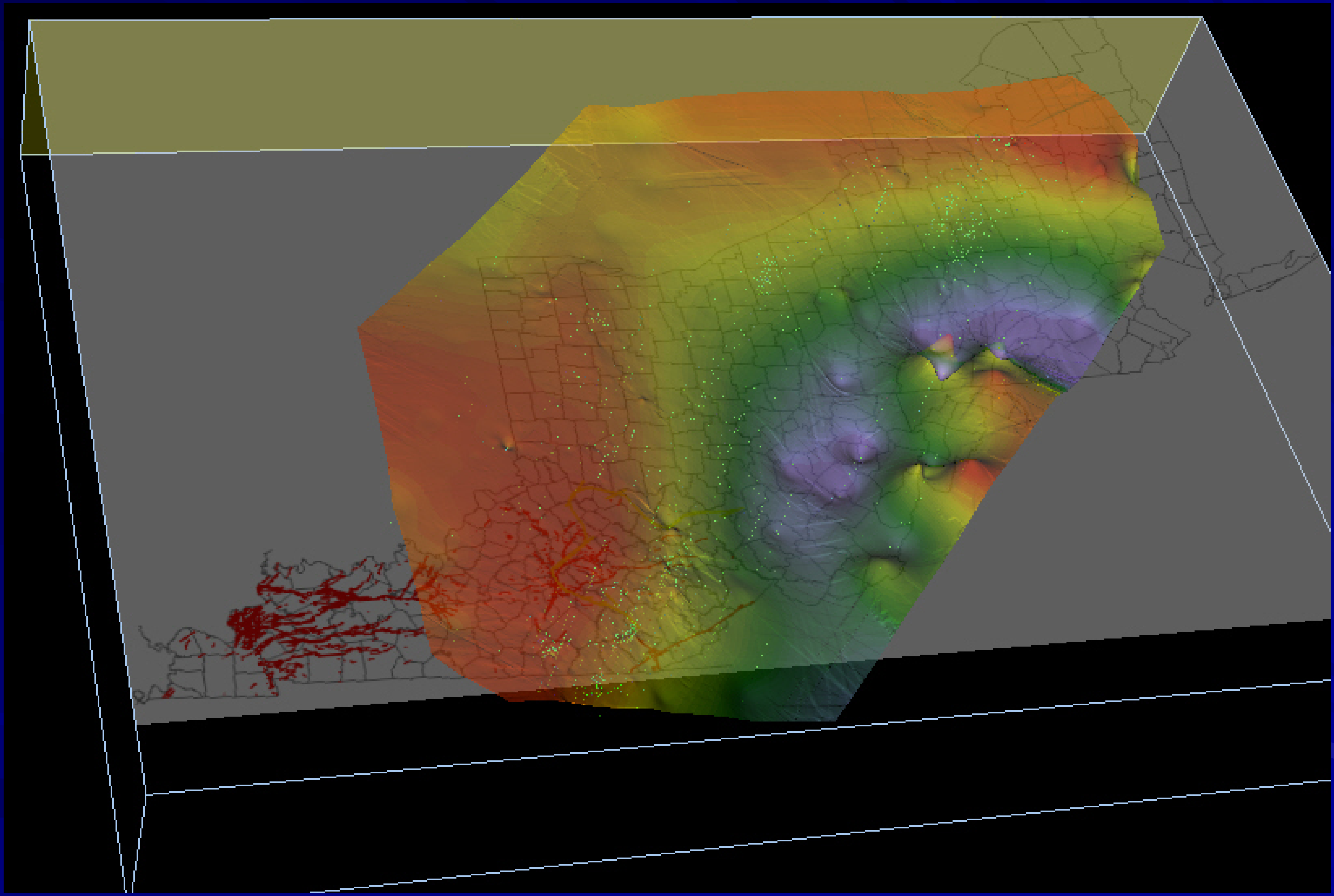
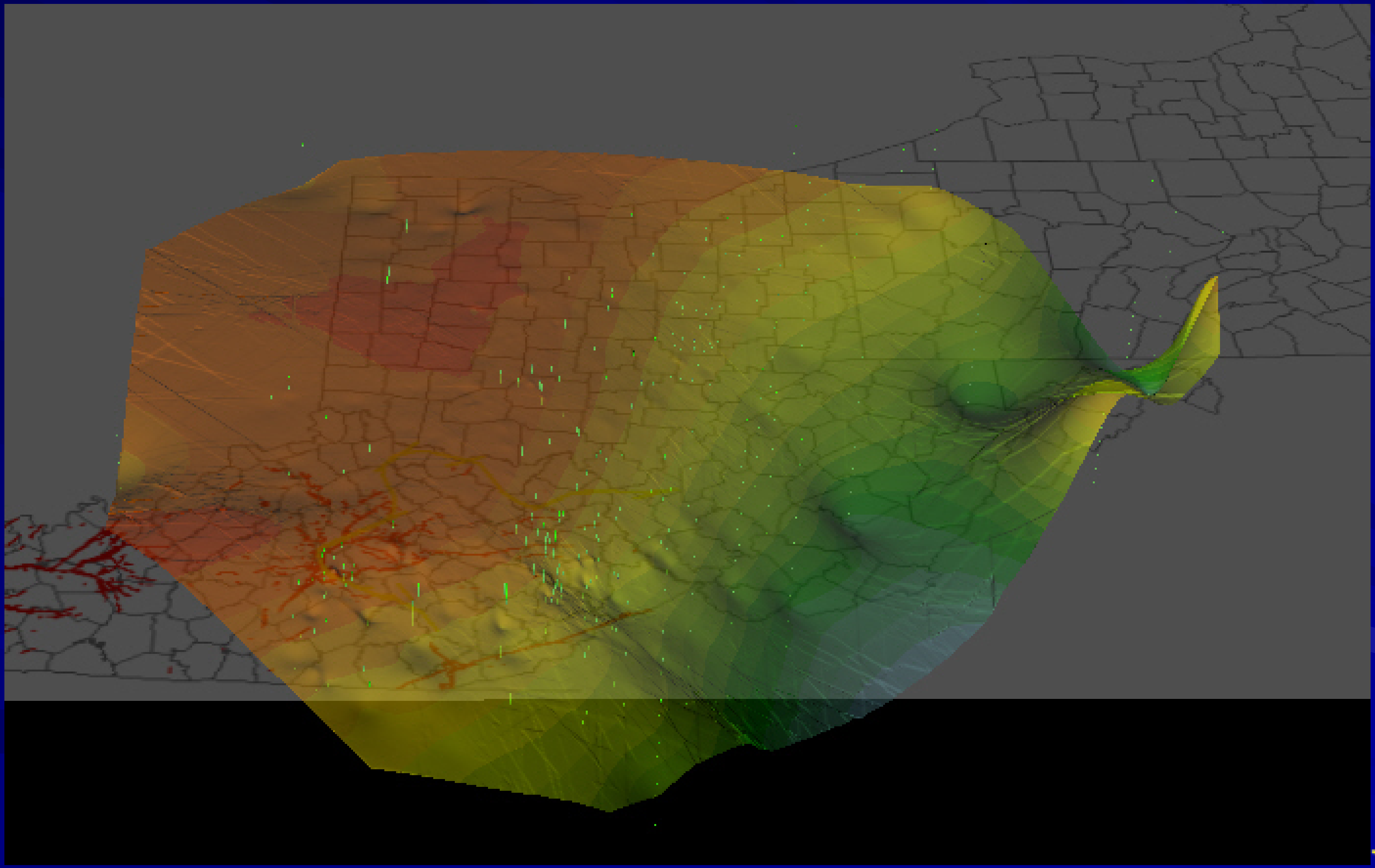
3D Structure Grid Examples



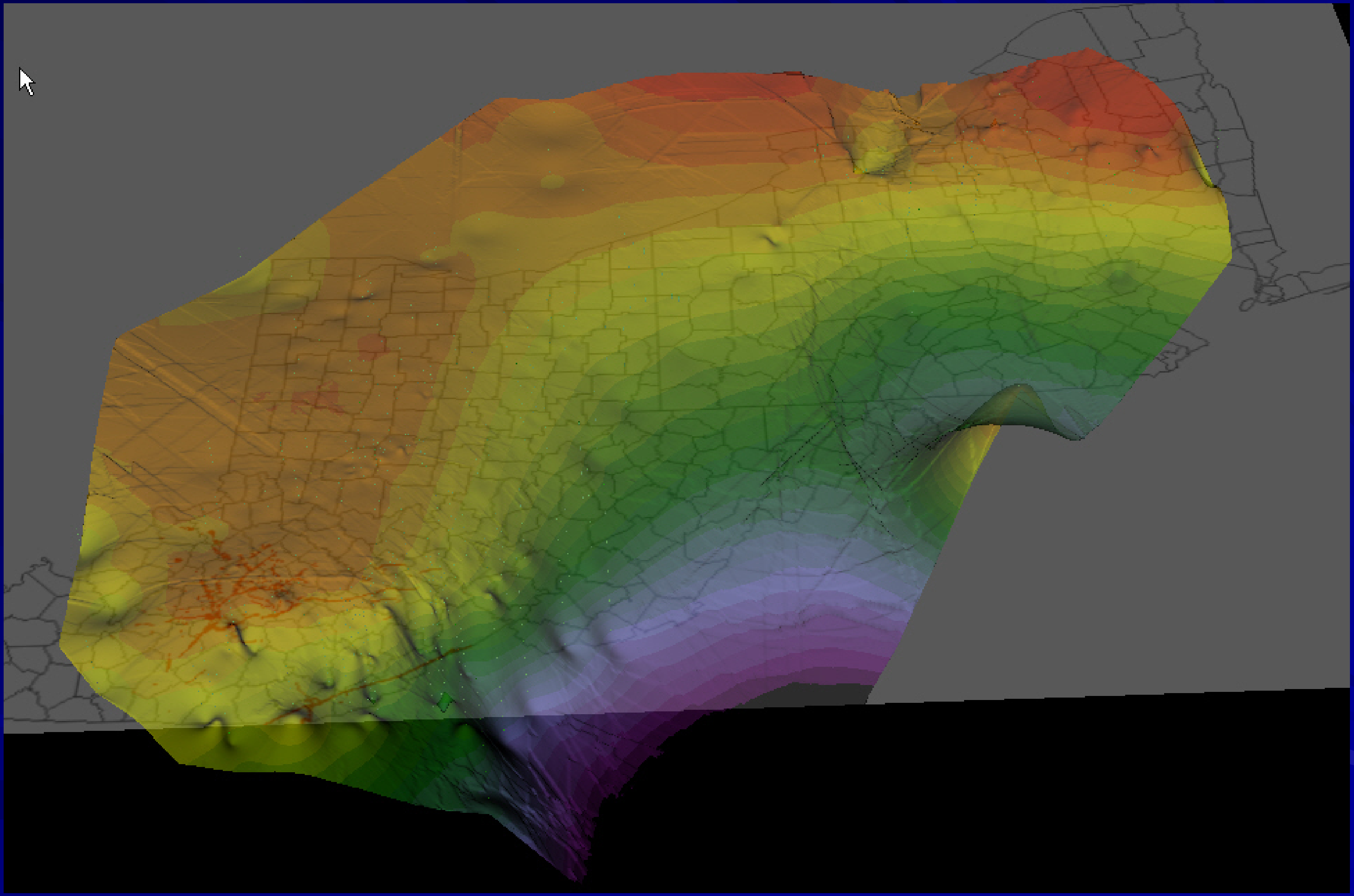
Top of Trenton from well data, 10X V.E.

3D Structure Grid Examples

Base of Knox Supergroup from well data, 10X V.E.



3D Structure Grid Examples



Top of Precambrian Basement from well data, 10X V.E.

Source of Fluids

Fluid inclusion data from TBR dolomites in Central Kentucky and Western New York indicate that the dolomitizing fluids were at elevated temperatures relative to the affected country rocks.

Where were these fluids from, and how did they get there?

Source of Fluids

Since there has been no evidence to imply regional lateral migration of high Mg fluids, we can assume that they came from deeper in the section.

These are most probably from within the upper section of the Precambrian metamorphics (weathered zone?).

Source of Fluids

The presence of sphalerite, barite, and pyrite mineralization within a hydrothermal dolomite zone (Harris, et al., 2004) also implies a source with higher metal content (like Precambrian metamorphics).

Source of Heat

Stratigraphic data suggest that the Trenton was faulted and dolomitized by the Late Ordovician.

At the end of the Ordovician, the depth to the Precambrian in New York was roughly 1250m, and 1600m in Kentucky.

Even if we assume a high surface temp of 28°C and a high geothermal gradient of 30°C/km, expected temps within the upper portion of the Precambrian would be 76°C for KY and 65°C for NY.

Source of Heat

However, homogenization temps from fluid inclusions indicate temps of 105 and 140°C for KY and NY, respectively. Correcting these values for pressure raises these values even further (110-122*C for KY).

Where does this extra 75+*C (uncorrected) for NY and 35-45*C for KY dolomite come from?

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Possible additional heat sources

- Deep seated fault fluids

  Igneous/metamorphic rocks have near 0% porosity. Sufficient fluid volume within fault aperture unlikely.

- Volcanics/pluton emplacement

  No evidence of igneous intrusions west of Blue Ridge, especially one from Tennessee all the way to Ontario.

- Latent mantle heat from Keweenaw rifting

  Very unlikely after 660Ma of cooling and plate migration.

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Possible additional heat sources

- Coseismic frictional heating?

Earthquake motions along wrench faults raise heat locally, pore fluid heats and expands and rises up newly formed fault conduit.

Repeated episodes are needed for the required fluid volume, but this scenario works well with the "fault-valve" model from Sibson, and agrees with observed core data.

More work is needed to evaluate this scenario…

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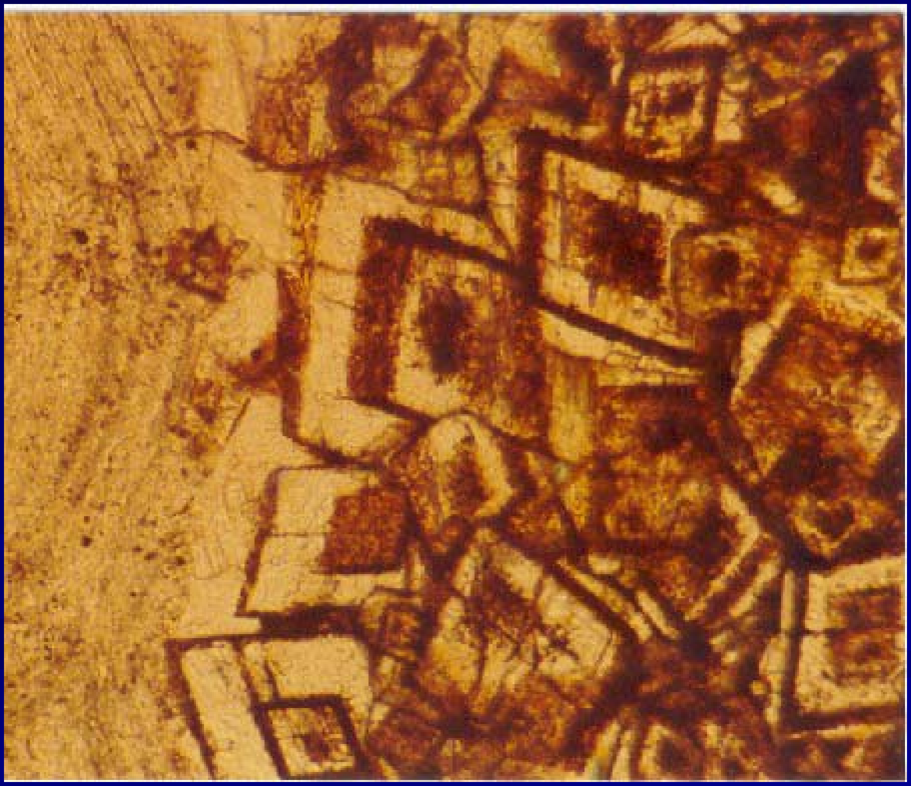
Hydrothermal dolomite zoning

Multiple episodes of fluid migration are indicated by the zoning observed in the KY HT dolomites below. This situation could have been created by the coseismic fault valve model.



Transmitted light

Cathodoluminescence

Possible additional heat sources

- Middle Devonian "thermal event"

Data suggesting Late Ordovician HTD emplacement are somewhat circumstantial.

It is possible that the faulting occurred during the Taconic, but that the dolomitizing fluids migrated to the TBR during the Acadian.

Added overburden and a possible temp anomaly (Rb/Sr data within illites) could create the heat needed.

Conclusion

- Work is ongoing to refine the timing of migration of these heated, hi-Mg fluids.