Geothermal Resources in the Raton Basin, South-Central Colorado: Recent and Contemporary Seismicity; Current Plans for Power Production

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Colorado Geological Survey

Colorado School of Mines

for the Conference on

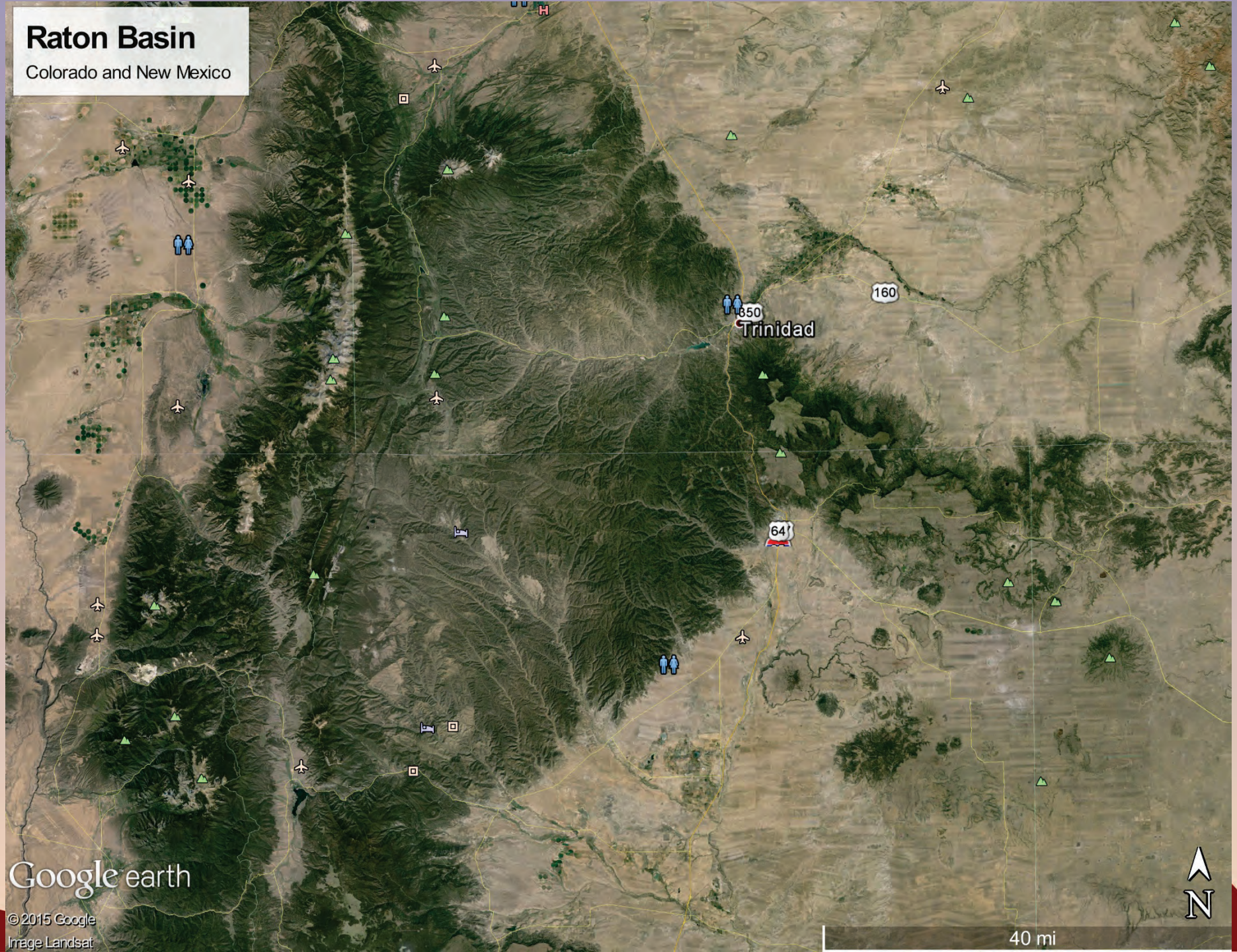
Power Plays: Geothermal Energy in Oil and Gas Fields

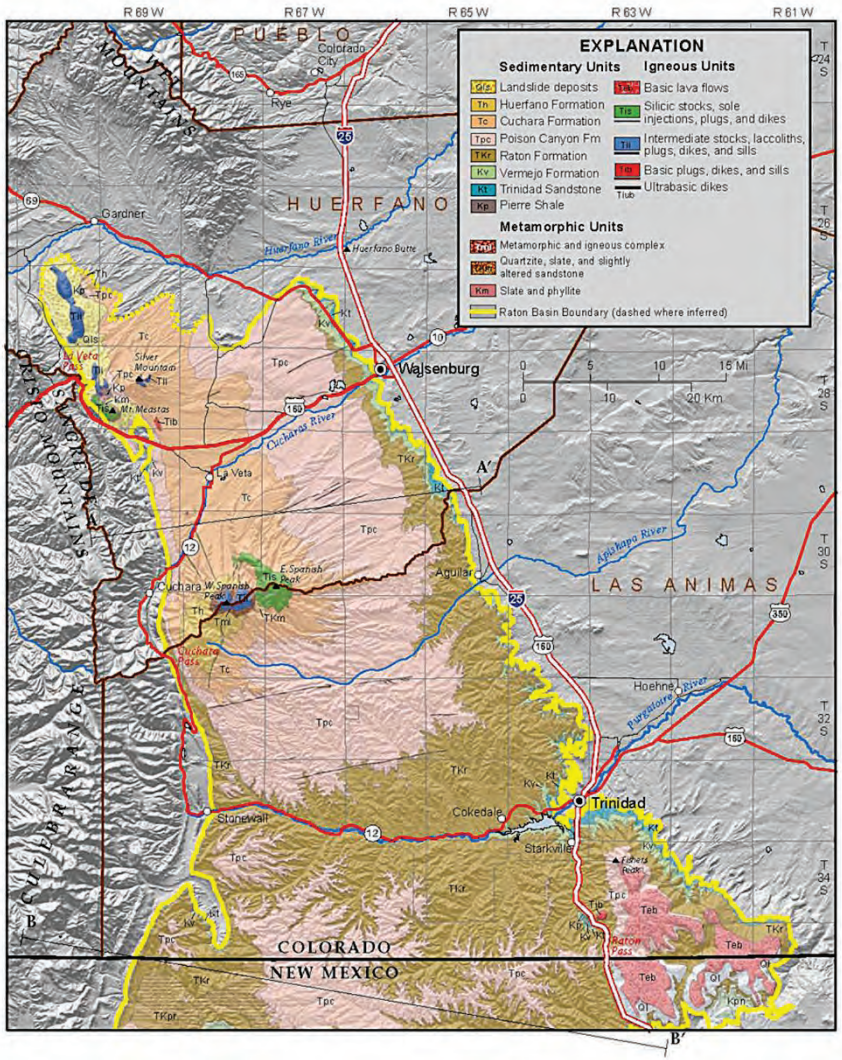
Southern Methodist University, Dallas, TX

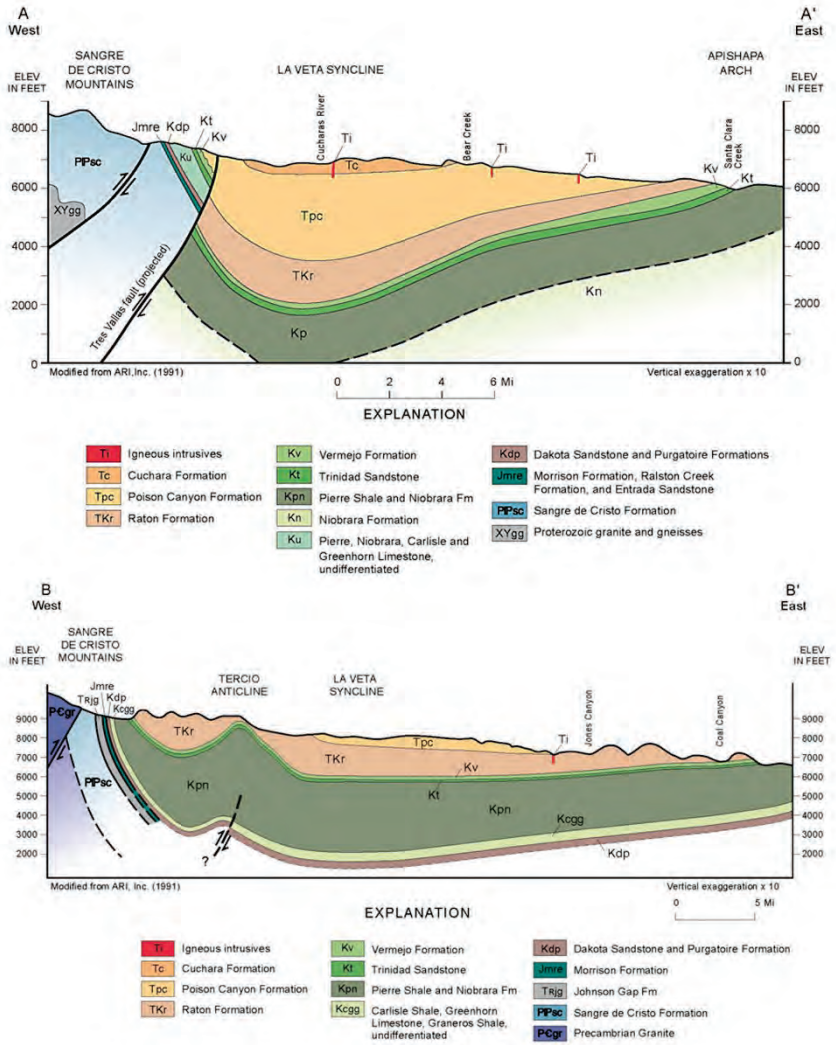
May 19-20, 2015

Still crazy after all these years…

- Best poster award, 2009 GRC: “A preliminary analysis of Geothermal Resources in the Central Raton Basin, Colorado;
  - Aerially largest geothermal anomaly in Colorado;
  - Anomaly originally primarily defined from bottom-hole temperatures from coalbed methane production wells;
  - Now seismic support that anomaly is not shallow water flow.
- Historical and current seismicity.
- Demand for clean energy in region;
  - Rejections for funding from DOE and NSF
  - Now trying alternative, non-governmental funding sources.


Raton Basin
Colorado and New Mexico
Trinidad
160
350
64
Google earth
© 2015 Google
Image Landsat
N
40 mi


R 69 W
R 67 W
R 65 W
R 63 W
R 61 W
PUEBLO
Colorado City
Rye
HUERFANO
Gardner
Huerfano River
Huerfano Butte
Walsenburg
Cuchara River
La Veta
Silver Mountain
Mt. Mestas
Cuchara Pass
W. Spanish Peak
E. Spanish Peak
Aguilar
Apishapa River
LAS ANIMAS
Hoehne
Purgatoire River
Trinidad
Cokedale
Starkville
Stonewall
Fisher's Peak
Raton Pass
COLORADO
NEW MEXICO
SANGRE DE CRISTO MOUNTAINS
CULEBRA RANGE
A
A'
B
B'
EXPLANATION
Sedimentary Units
Qls Landslide deposits
Th Huerfano Formation
Tc Cuchara Formation
Tpc Poison Canyon Fm
TKr Raton Formation
Kv Vermejo Formation
Kt Trinidad Sandstone
Kp Pierre Shale
Igneous Units
Tib Basic lava flows
Tis Silicic stocks, sole injections, plugs, and dikes
Ti Intermediate stocks, laccoliths, plugs, dikes, and sills
Tib Basic plugs, dikes, and sills
Tiub Ultrabasic dikes
Metamorphic Units
Xmgn Metamorphic and igneous complex
Qtzs Quartzite, slate, and slightly altered sandstone
Sm Slate and phyllite
Raton Basin Boundary (dashed where inferred)
0 5 10 15 Mi
0 10 20 Km


A
West
A'
East
SANGRE DE CRISTO MOUNTAINS
LA VETA SYNCLINE
APISHAPA ARCH
ELEV IN FEET
8000
6000
4000
2000
0
Jmre
Kdp
Kt
Kv
Ku
Ti
Tc
Tpc
TKr
Kn
Kp
PIPsc
XYgg
Cucharas River
Bear Creek
Santa Clara Creek
Tres Vallas fault (projected)
Modified from ARI,Inc. (1991)
Vertical exaggeration x 10
0 2 4 6 Mi
EXPLANATION
Ti Igneous intrusives
Tc Cuchara Formation
Tpc Poison Canyon Formation
TKr Raton Formation
Kv Vermejo Formation
Kt Trinidad Sandstone
Kpn Pierre Shale and Niobrara Fm
Kn Niobrara Formation
Ku Pierre, Niobrara, Carlisle and Greenhorn Limestone, undifferentiated
Kdp Dakota Sandstone and Purgatoire Formations
Jmre Morrison Formation, Ralston Creek Formation, and Entrada Sandstone
PIPsc Sangre de Cristo Formation
XYgg Proterozoic granite and gneisses
B
West
B'
East
SANGRE DE CRISTO MOUNTAINS
TERCIO ANTICLINE
LA VETA SYNCLINE
ELEV IN FEET
9000
8000
7000
6000
5000
4000
3000
2000
Jmre
TRjg
Kdp
Kcgg
PCgr
TKr
Tpc
Kv
Kt
Kpn
PIPsc
Ti
Jones Canyon
Coal Canyon
Modified from ARI, Inc. (1991)
Vertical exaggeration x 10
0 5 Mi
EXPLANATION
Ti Igneous intrusives
Tc Cuchara Formation
Tpc Poison Canyon Formation
TKr Raton Formation
Kv Vermejo Formation
Kt Trinidad Sandstone
Kpn Pierre Shale and Niobrara Fm
Kcgg Carlisle Shale, Greenhorn Limestone, Graneros Shale, undifferentiated
Kdp Dakota Sandstone and Purgatoire Formation
Jmre Morrison Formation
TRjg Johnson Gap Fm
PIPsc Sangre de Cristo Formation
PCgr Precambrian Granite

Composite Geologic Map of the Raton Basin In Colorado

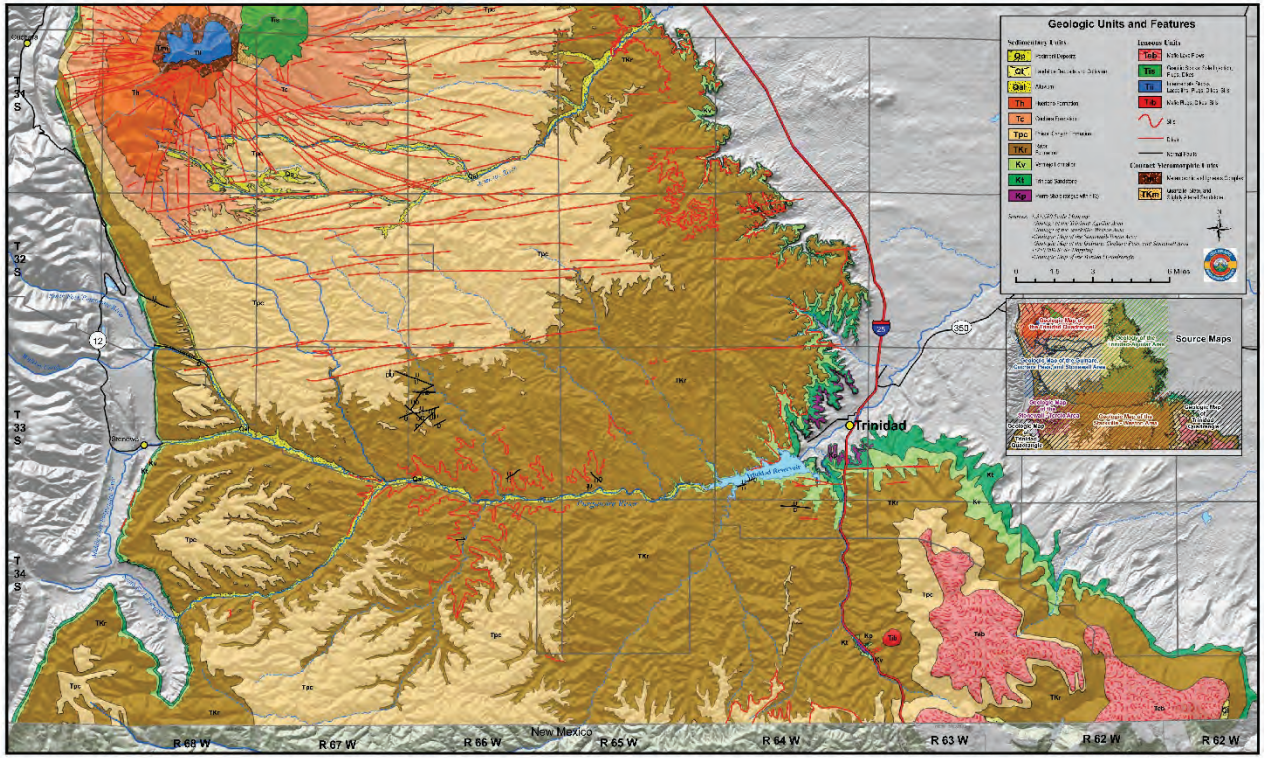
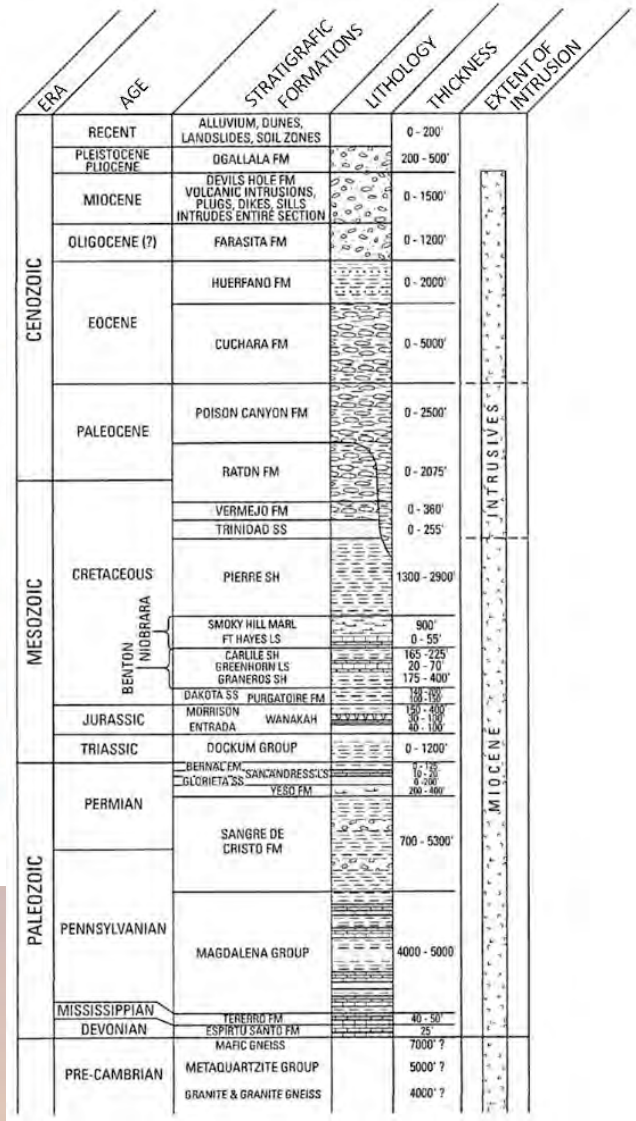
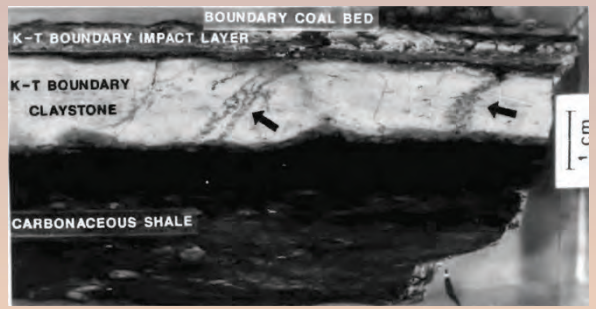
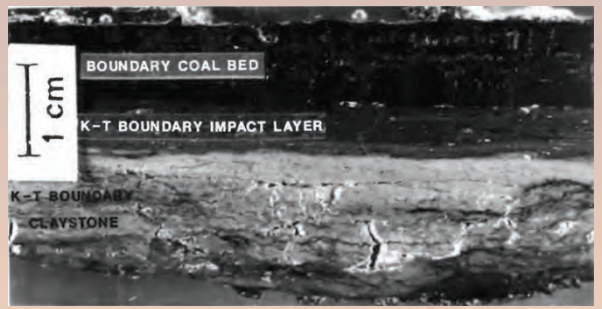


Plate 1

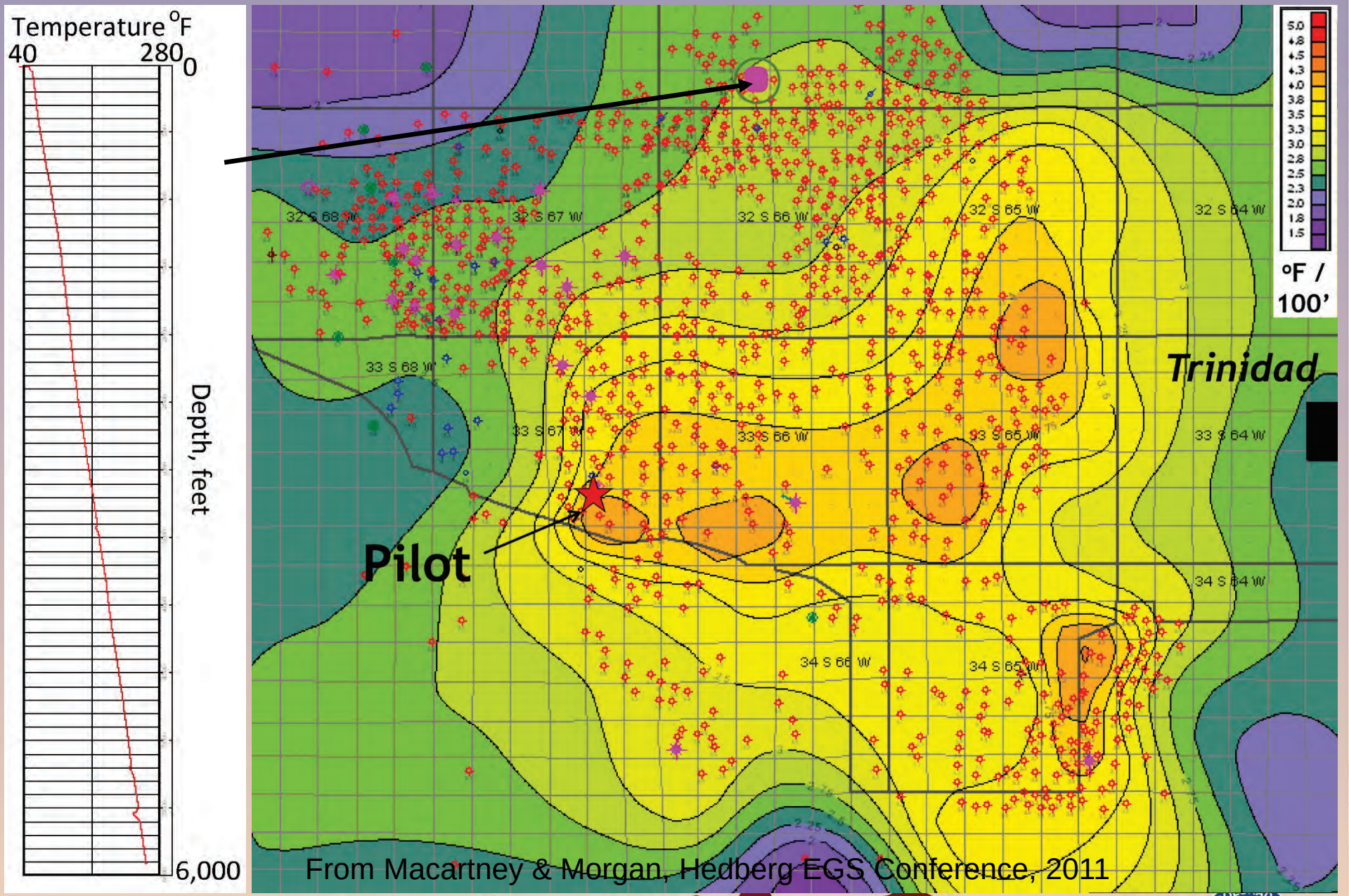


K-T Boundary

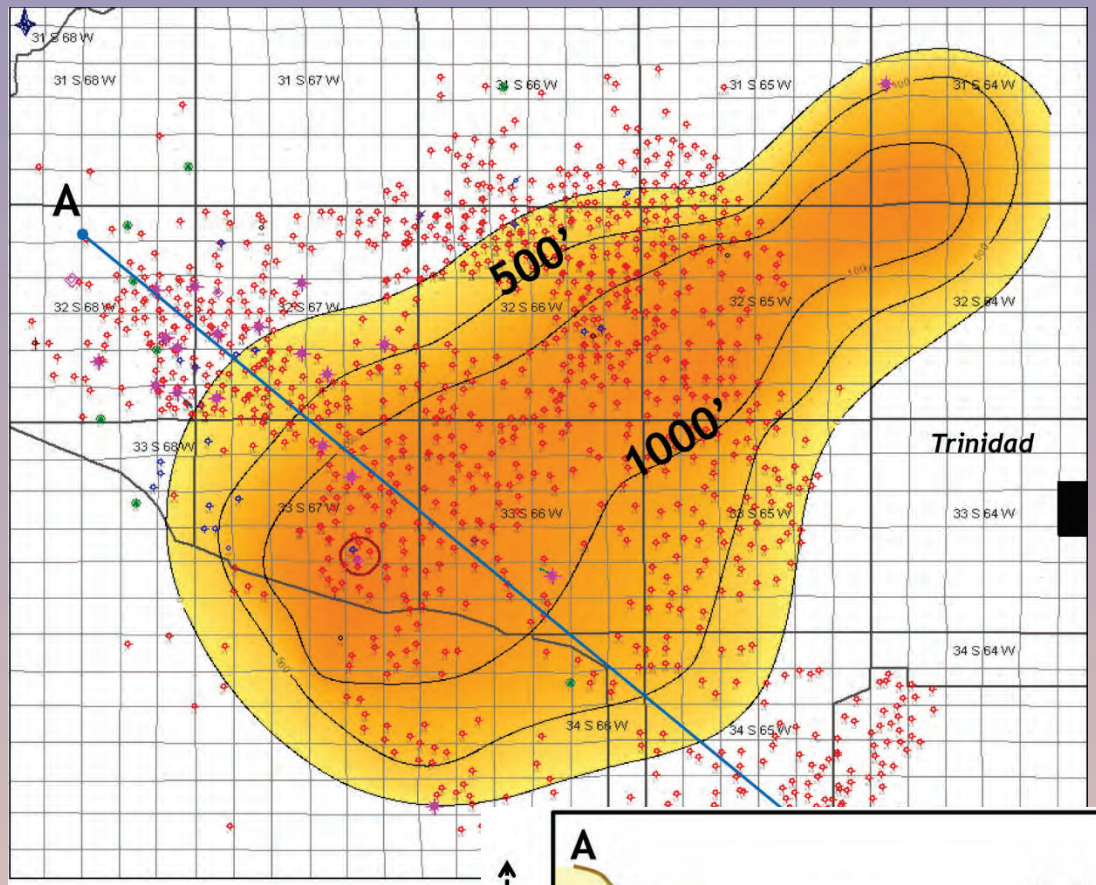




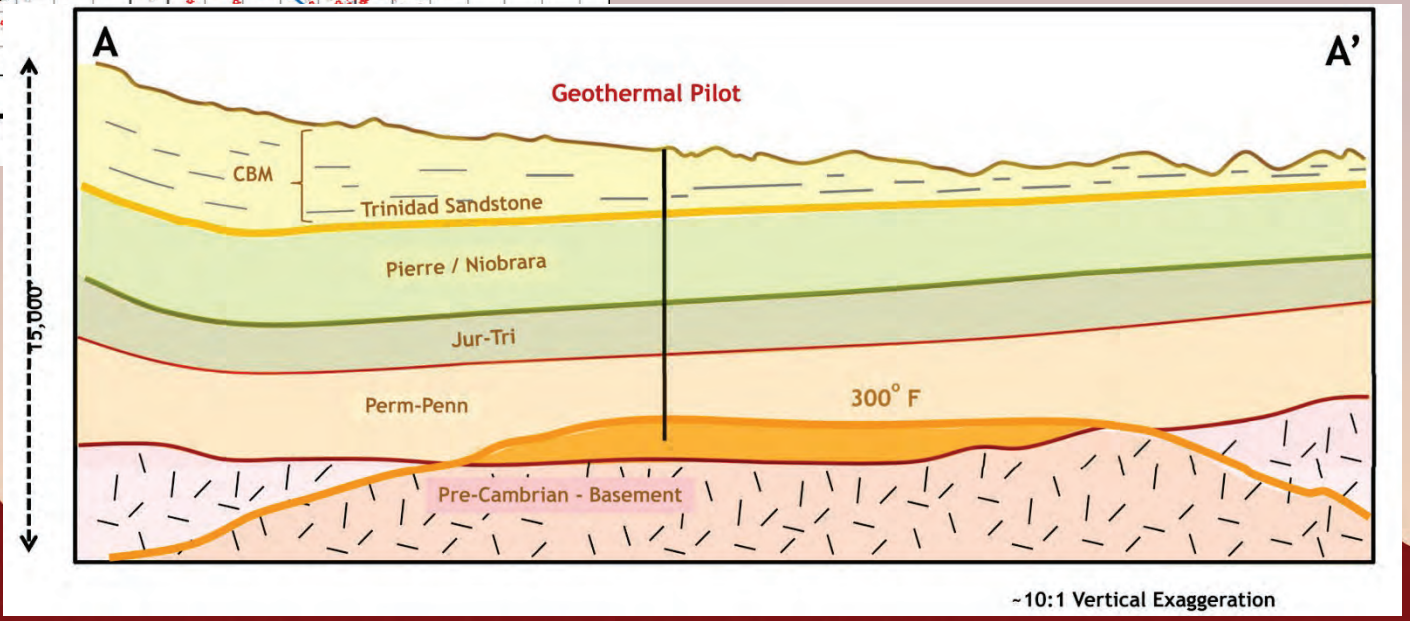
From G. A. Izett, USGS Open File Report 87-606


Temperature °F
40
280
0
6,000
Depth, feet
°F / 100'
Trinidad
Pilot
From Macartney & Morgan, Hedberg EGS Conference, 2011

Raton Basin Geothermal Anomaly



From Macartney & Morgan, Hedberg EGS Conference, 2011

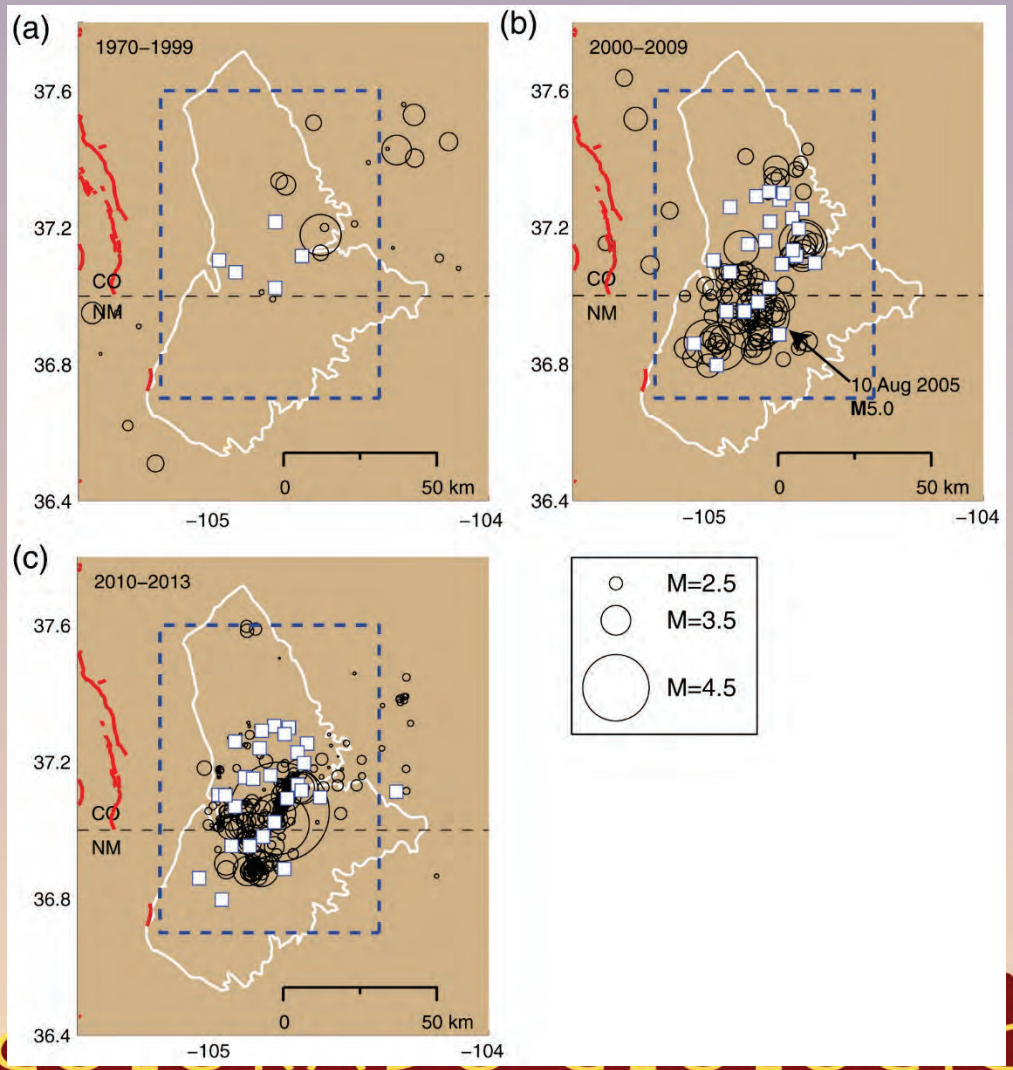


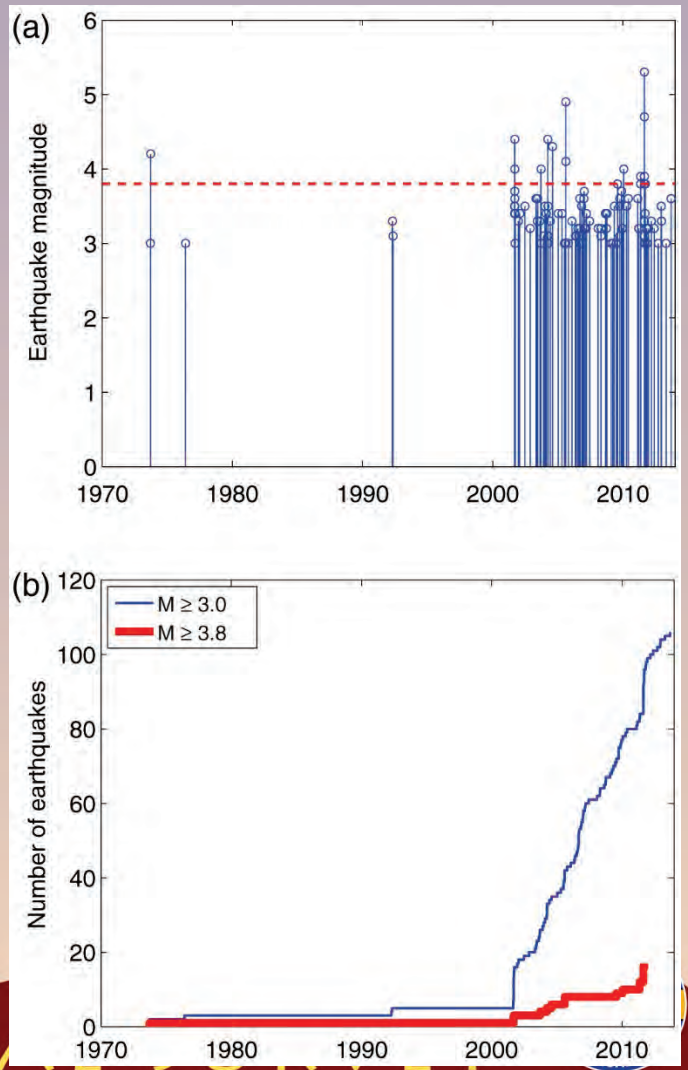
COLORA

Bulletin of the Seismological Society of America, Vol. 104, No. 5, pp. –, October 2014, doi: 10.1785/0120140009

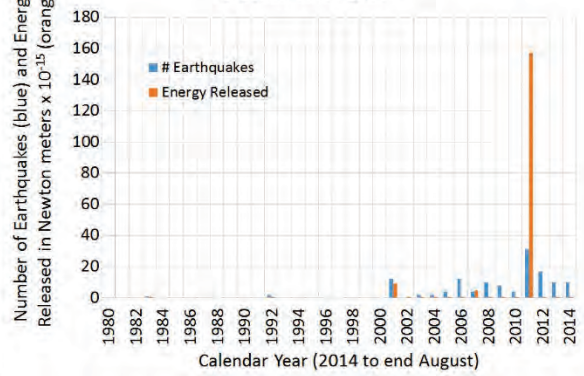
The 2001–Present Induced Earthquake Sequence in the Raton Basin of Northern New Mexico and Southern Colorado

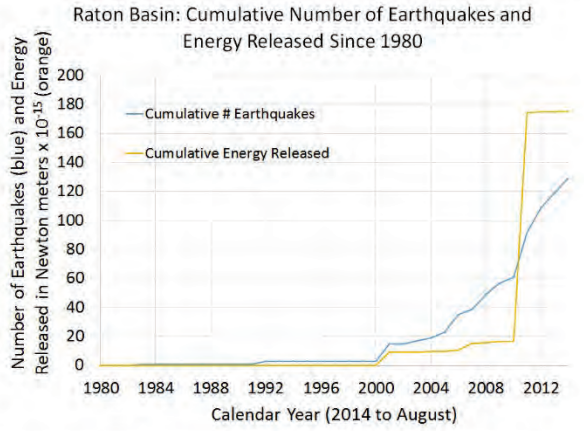
by Justin L. Rubinstein, William L. Ellsworth, Arthur McGarr, and Harley M. Benz



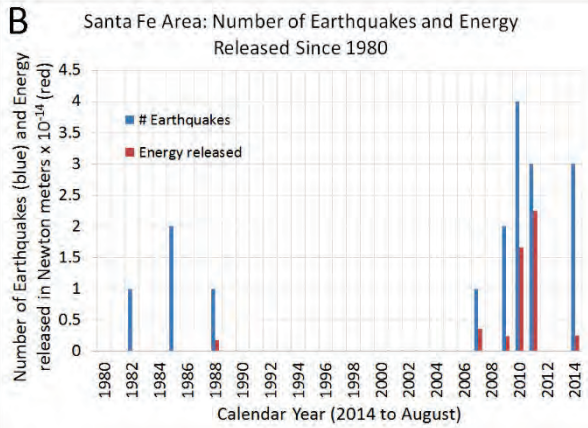


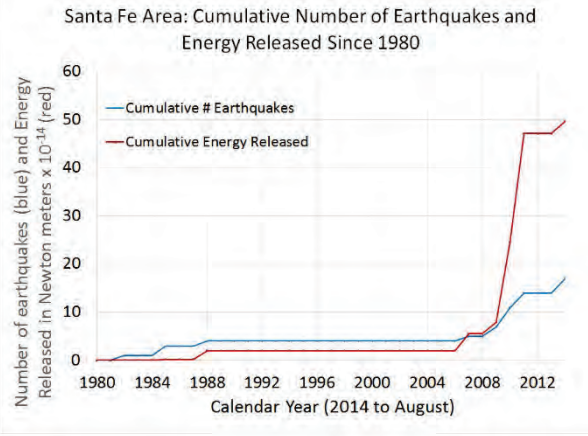
A


Raton Basin: Number of Earthquakes and Energy Released Since 1980
Number of Earthquakes (blue) and Energy Released in Newton meters x 10-15 (orange)
Earthquakes
Energy Released
Calendar Year (2014 to end August)

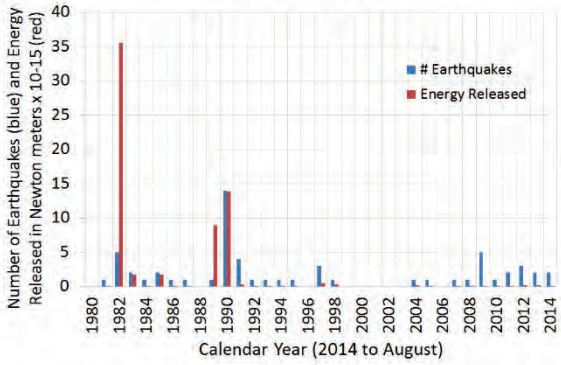

Raton Basin: Cumulative Number of Earthquakes and Energy Released Since 1980
Number of Earthquakes (blue) and Energy Released in Newton meters x 10-15 (orange)
Cumulative # Earthquakes
Cumulative Energy Released
Calendar Year (2014 to August)

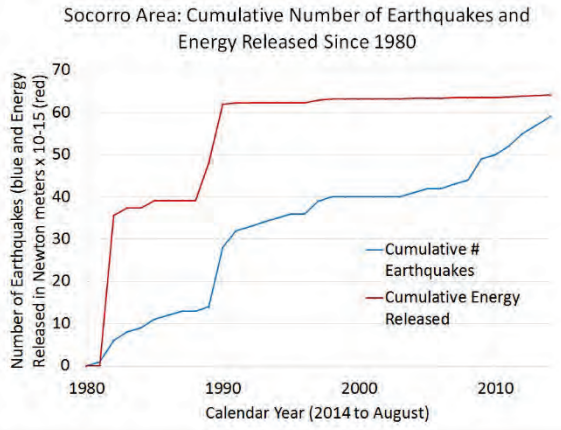
B

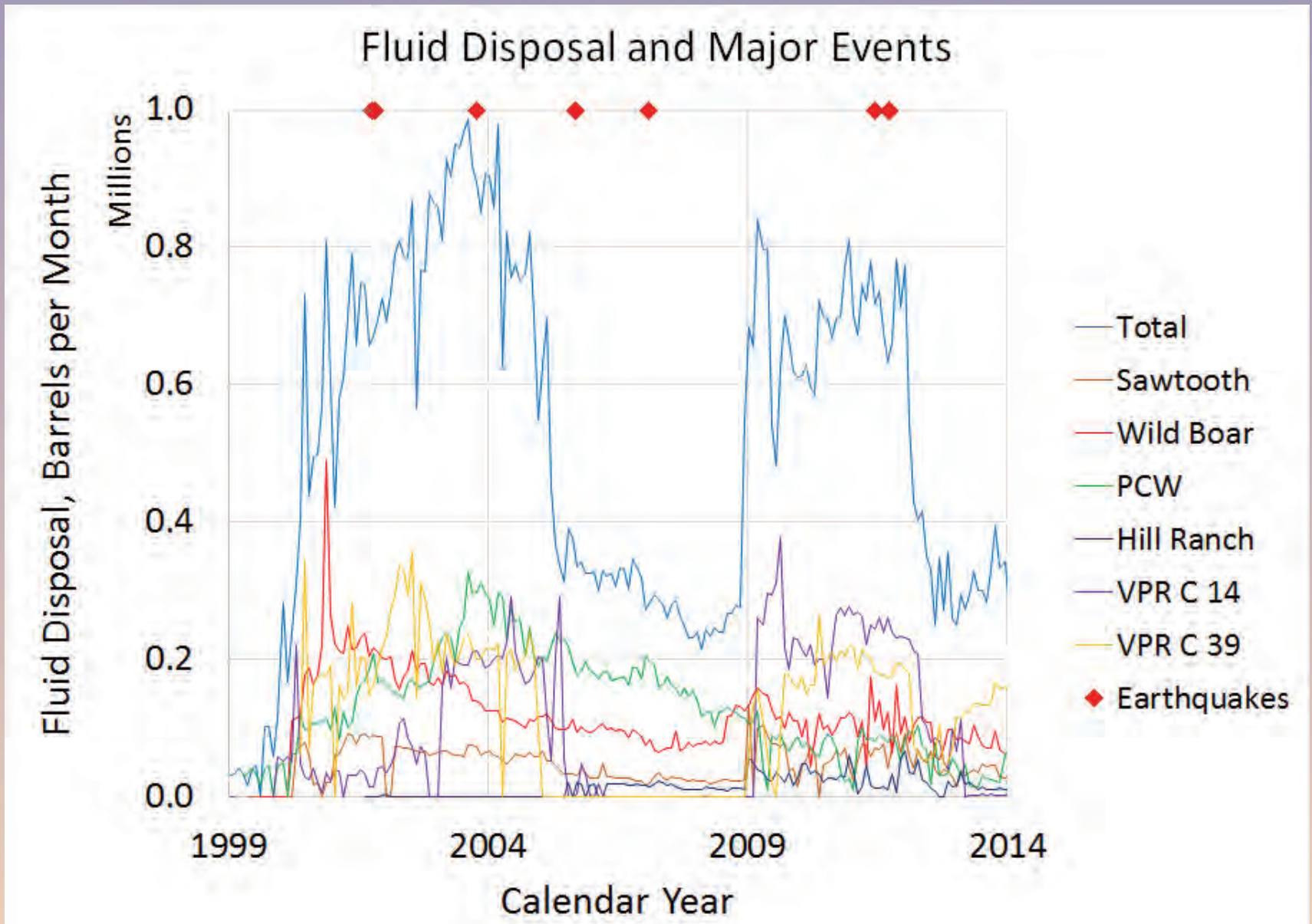

Santa Fe Area: Number of Earthquakes and Energy Released Since 1980
Number of Earthquakes (blue) and Energy released in Newton meters x 10-14 (red)
Earthquakes
Energy released
Calendar Year (2014 to August)


Santa Fe Area: Cumulative Number of Earthquakes and Energy Released Since 1980
Number of earthquakes (blue) and Energy Released in Newton meters x 10-14 (red)
Cumulative # Earthquakes
Cumulative Energy Released
Calendar Year (2014 to August)

C

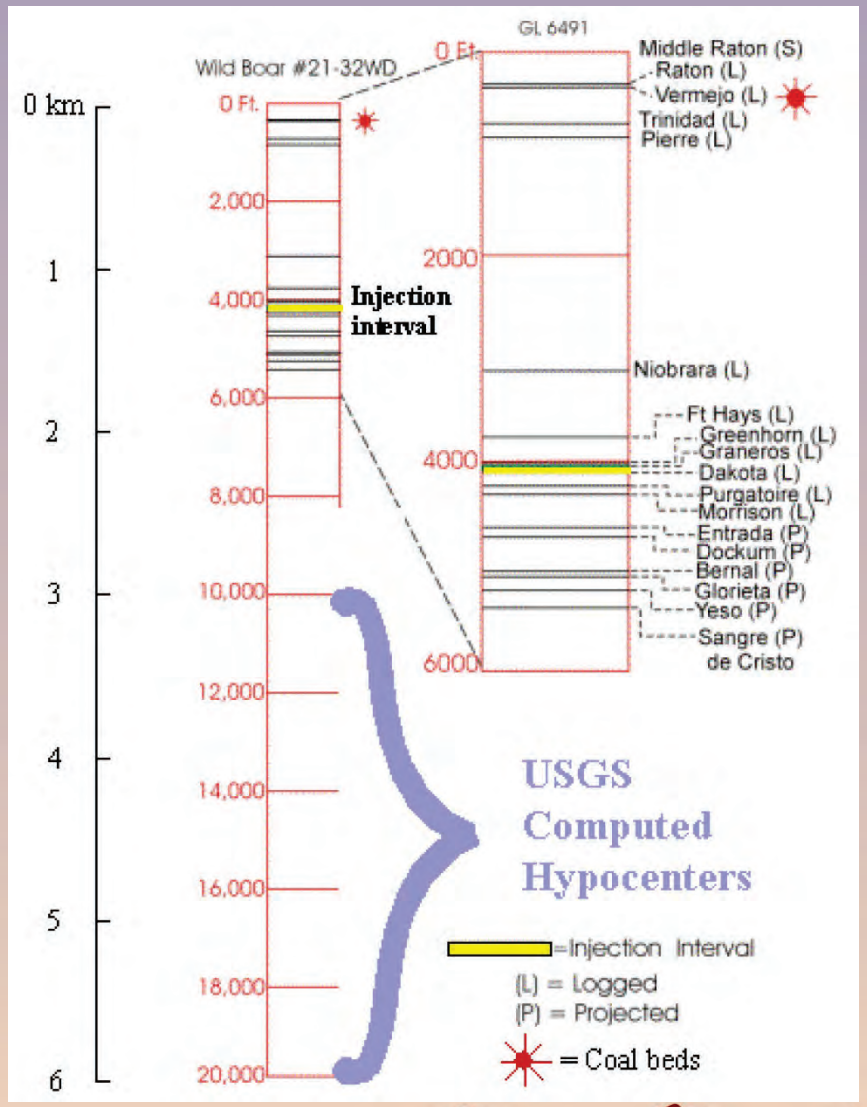

Socorro Area: Number of Earthquakes and Energy Released Since 1980
Number of Earthquakes (blue) and Energy Released in Newton meters x 10-15 (red)
Earthquakes
Energy Released
Calendar Year (2014 to August)

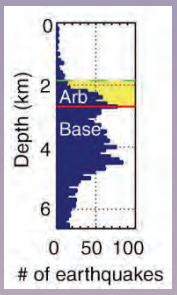

Socorro Area: Cumulative Number of Earthquakes and Energy Released Since 1980
Number of Earthquakes (blue and Energy Released in Newton meters x 10-15 (red)
Cumulative # Earthquakes
Cumulative Energy Released
Calendar Year (2014 to August)


Fluid Disposal and Major Events
Fluid Disposal, Barrels per Month
Millions
1.0
0.8
0.6
0.4
0.2
0.0
1999
2004
2009
2014
Calendar Year
Total
Sawtooth
Wild Boar
PCW
Hill Ranch
VPR C 14
VPR C 39
Earthquakes

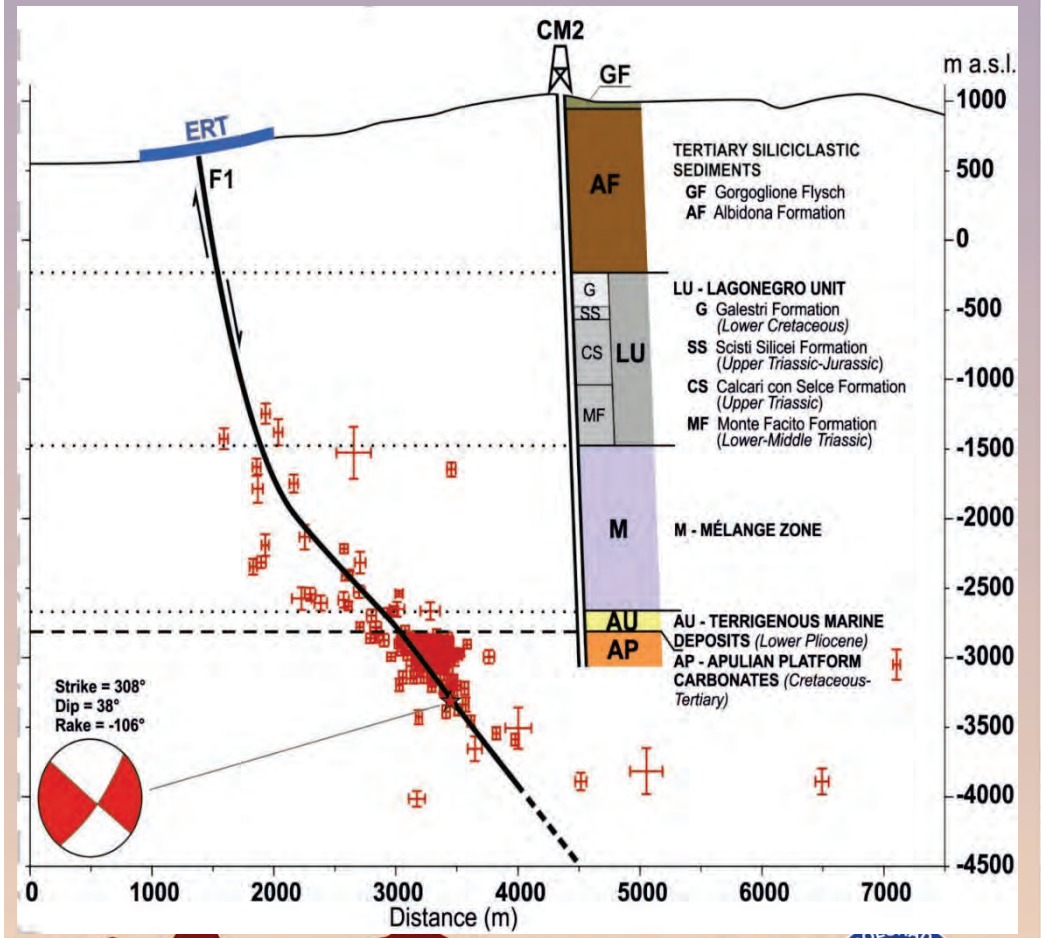
Depth of Seismicity and Depth of Injection

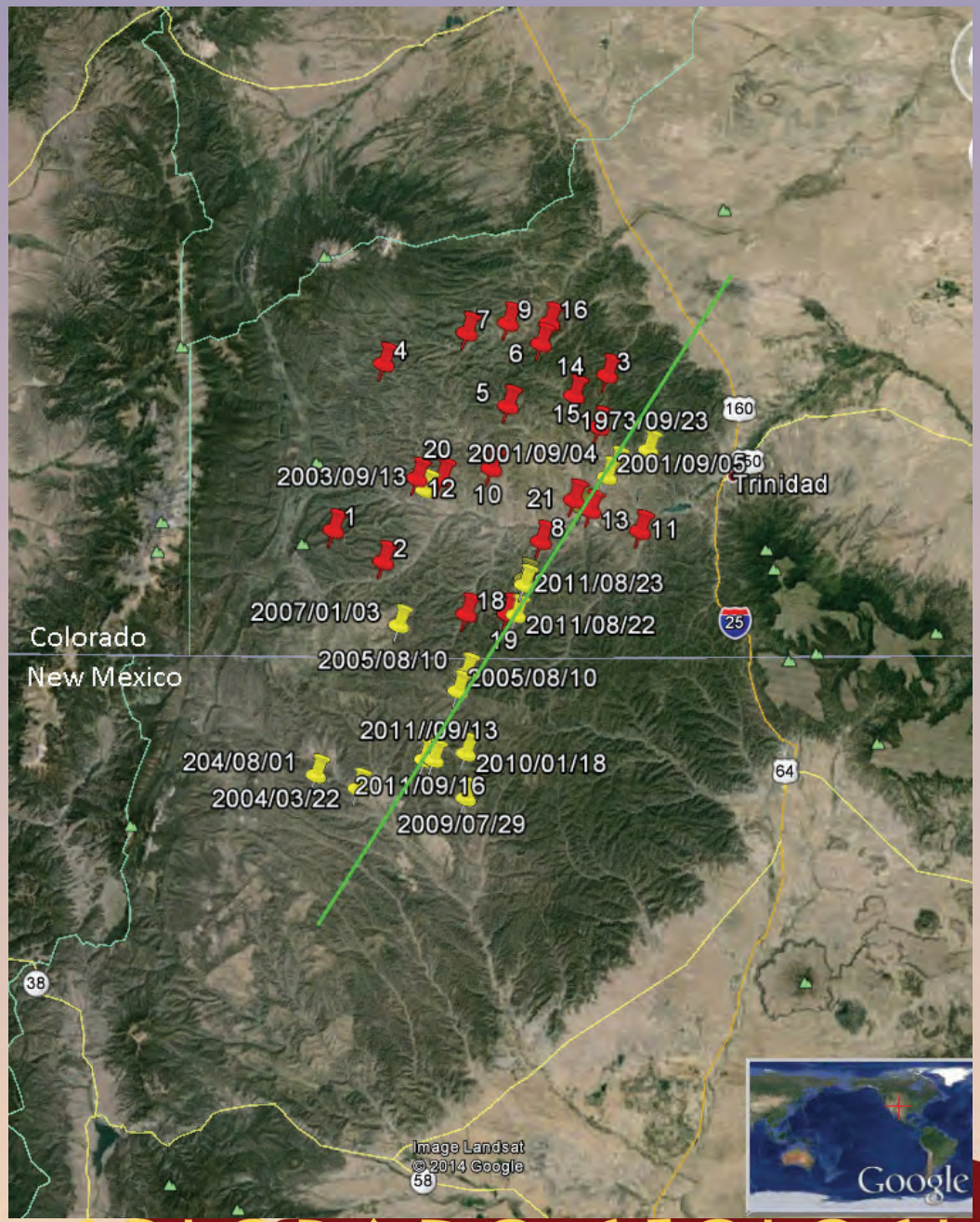
The Raton Depth-Gap





Oklahoma et al. Depth-Overlap





Locations of Major Earthquakes and Disposal Wells in Colorado

Red pins – Disposal wells
Yellow pins – Epicenters >2.7
Green line – Inferred fault trend

Development?

- Raton Basin geothermal anomaly has previously been proposed as a site for sedimentary basin EGS development:
  - Proposals to DOE rejected x2.
- Proposed as a site for sedimentary basin geothermal laboratory:
  - Proposal to NSF rejected.
- Current efforts are underway to seek private funding:
  - Crowdsourcing (Kickstarter);
  - Large company foundations (Google, Apple, etc.);
  - Environmental group foundations;
  - Participant company foundations.

Proposed Development

- Drill strat/test hole to basement (~9,000 feet);
  - Target Mississippian limestone, likely to be karst, just above basement, T > 300°F (150°C).
- Flow test target formation and other potentially permeable zones > 300°F (150°C);
  - If necessary, stimulate well to connect with permeability.
- If flow tests are successful, drill disposal well and flow-test system to tests sustainability
- Invite commercial developer to build power plant.

THANK YOU

- Acknowledgements and Disclaimer:
  - Although not specifically funded, this work has benefitted from various grants from the Colorado Governor's Energy Office (now the Colorado Energy Office) the National Geothermal Database System project, and support from the Colorado Geological Survey. However, the views and ideas in this presentation are those of the authors and do not reflect the official positions of any of these funding organizations, the Colorado School of Mines, or the Colorado Geological Survey.

- For Further Information
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      - Geothermal
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