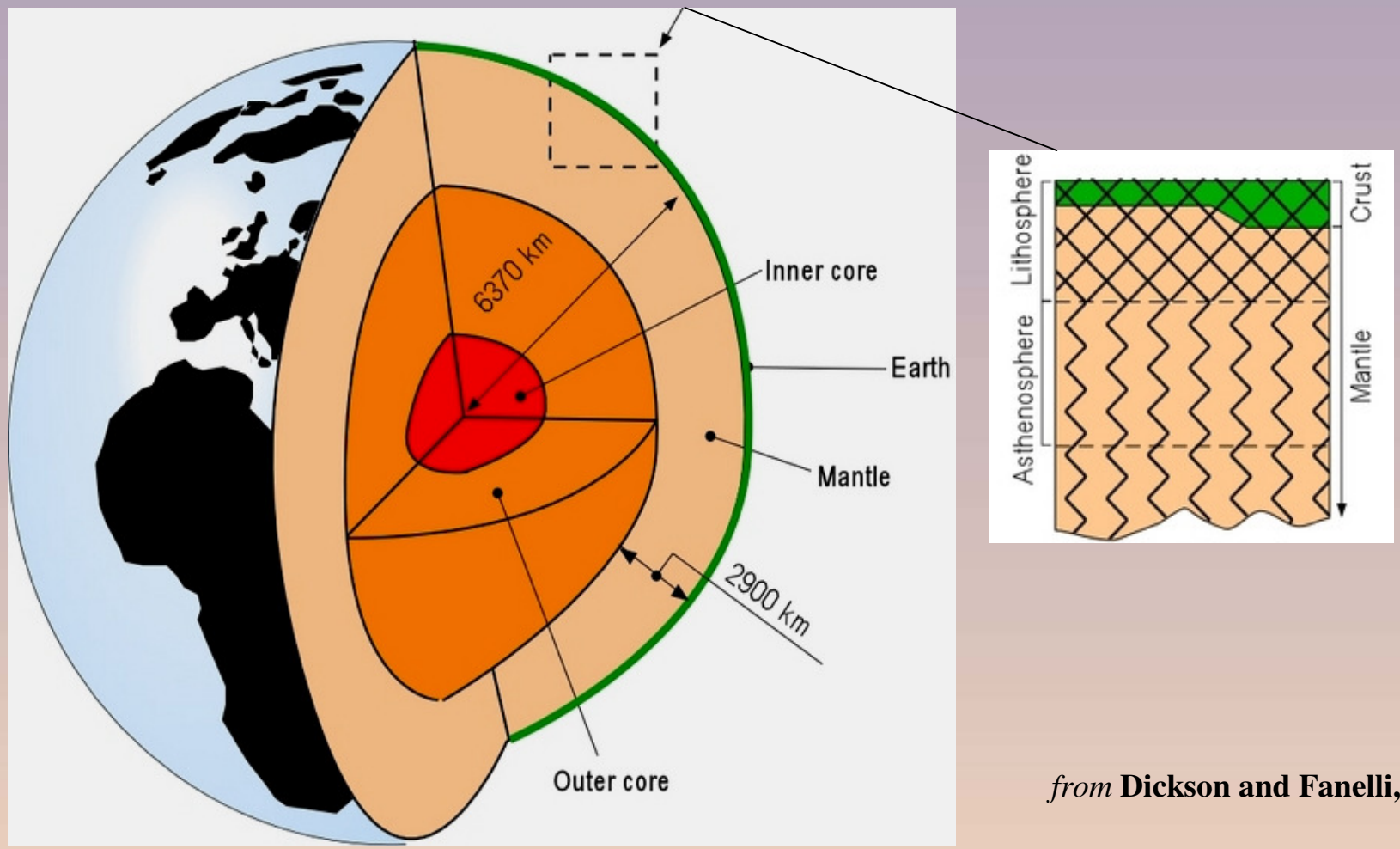
Assessing Colorado's Geothermal Potential to Generate Electricity

COLORADO GEOLOGICAL SURVEY

Presentation Outline:

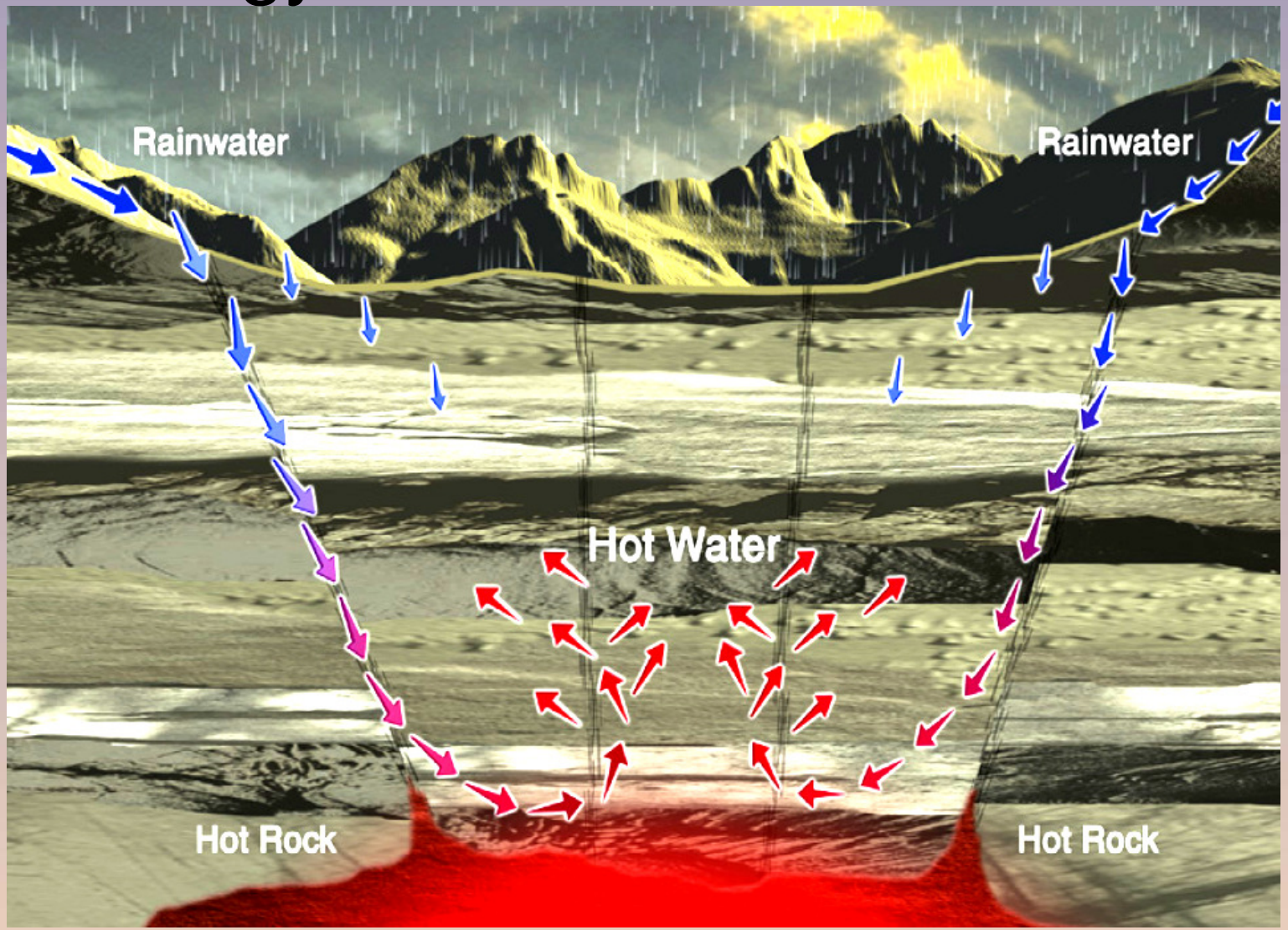
- Background and Geology
- Current Uses in Colorado
- Indicators of Geothermal Potential
- New Data, Mapping, and Studies

Geology of Geothermal Resources

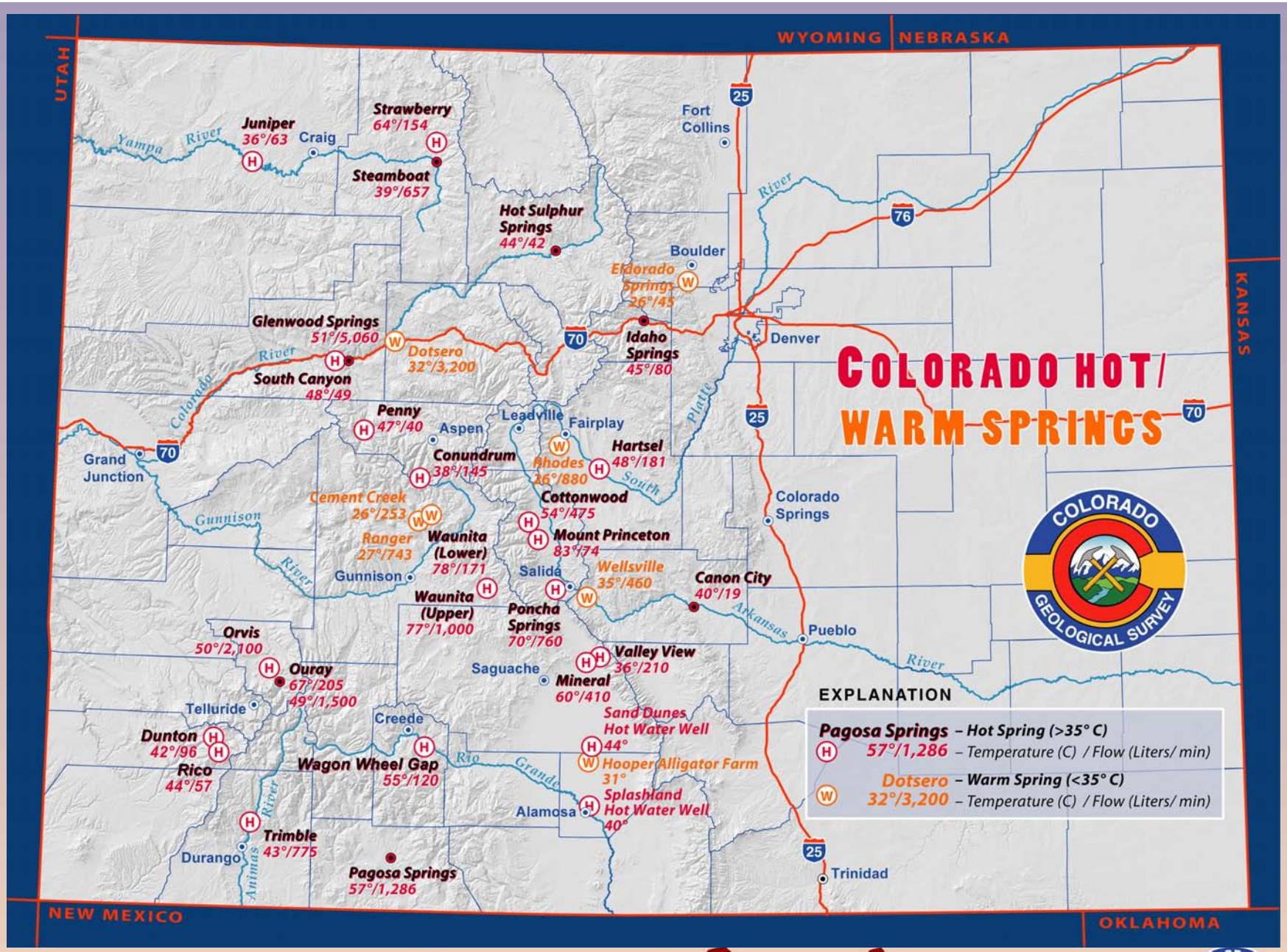


from **Dickson and Fanelli, 2004**

Geology of Geothermal Resources



Courtesy Geothermal Education Association



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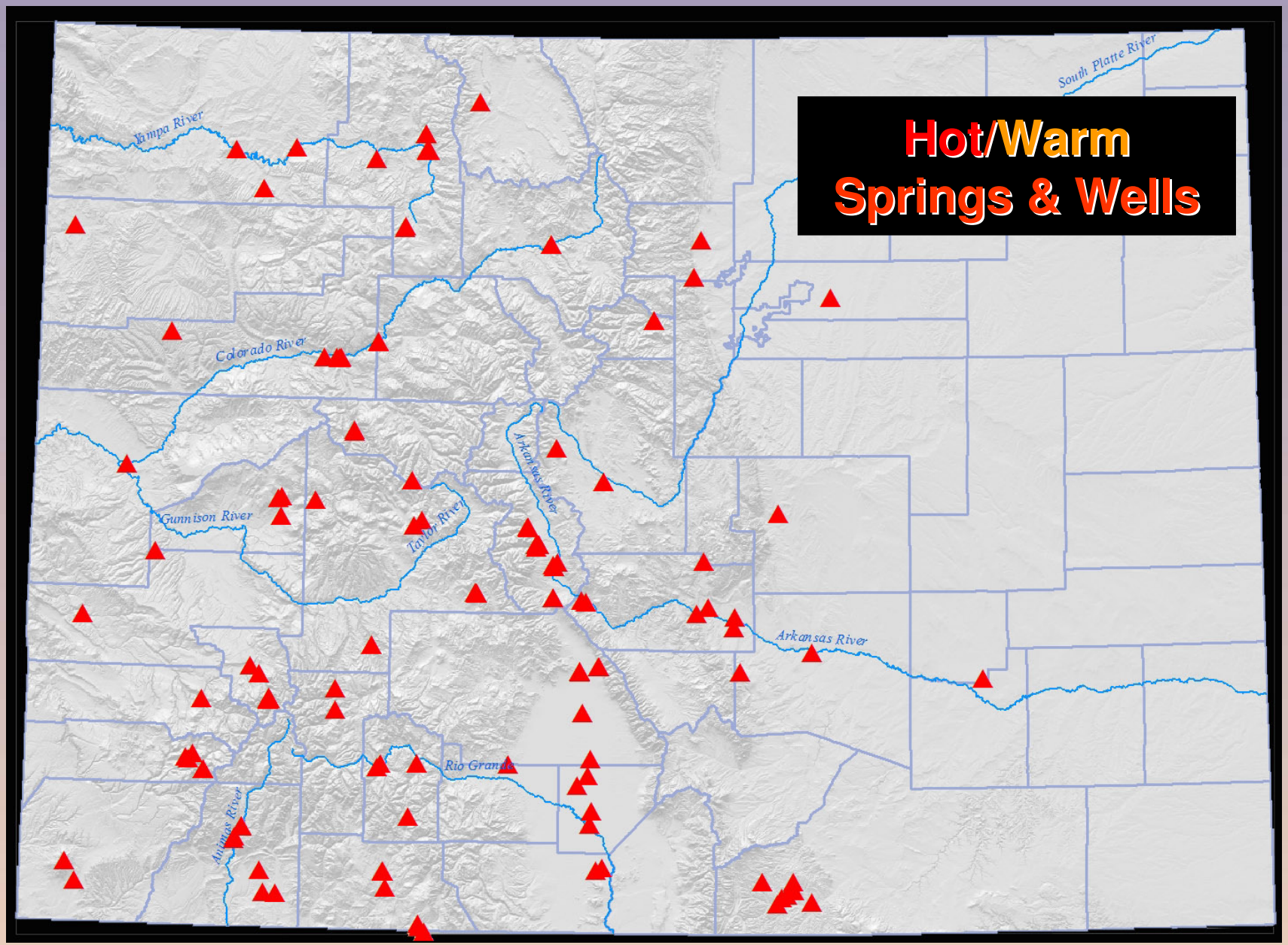

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Cottonwood Hot Springs, Buena Vista

Yampah Hot Spring, Glenwood Springs

Wuanita Hot Spring, Gunnison Valley

Rico Hot Spring

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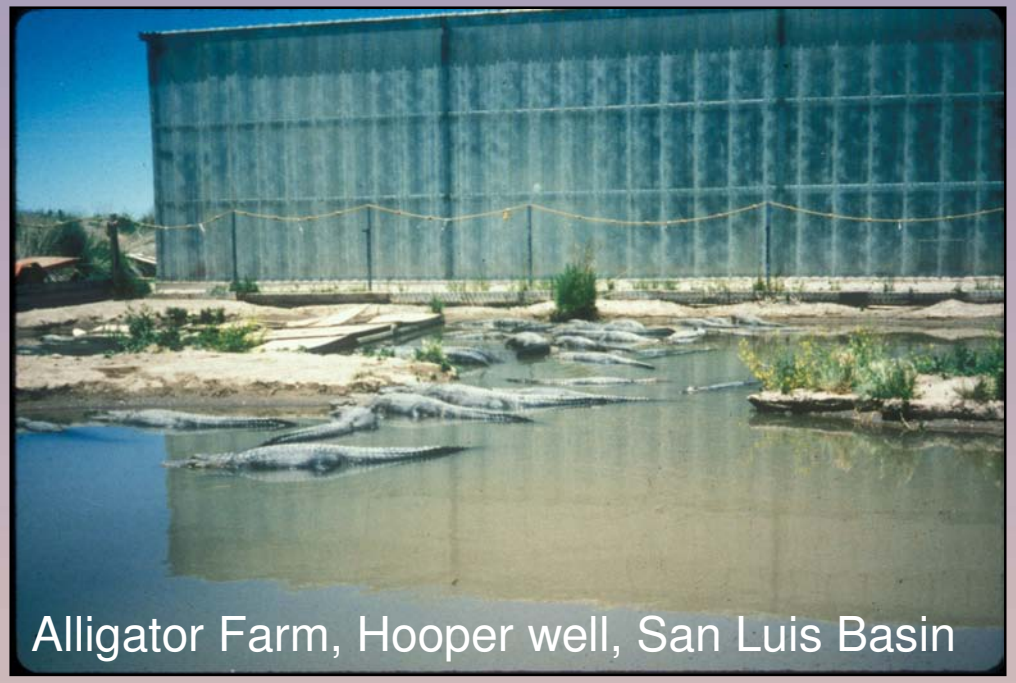

Alligator Farm, Hooper well, San Luis Basin

- Spas & Pools - 18 sites
- Space Heating - 15 sites
- Aquaculture - 4 sites
- District Heating - 1 site
- Greenhouses - 1 site

...What's Missing???

Electrical Power Generation!

Binary Geothermal Plant Heber, CA

Criteria for geothermal power potential:

- Quaternary volcanism
- Quaternary faulting
- High heat flow

- **5 Quaternary volcanoes**
- **>90 Quaternary faults**
- **2nd largest heat flow anomaly in US >100 mW/m^2**

Colorado is also outstanding in these criteria!

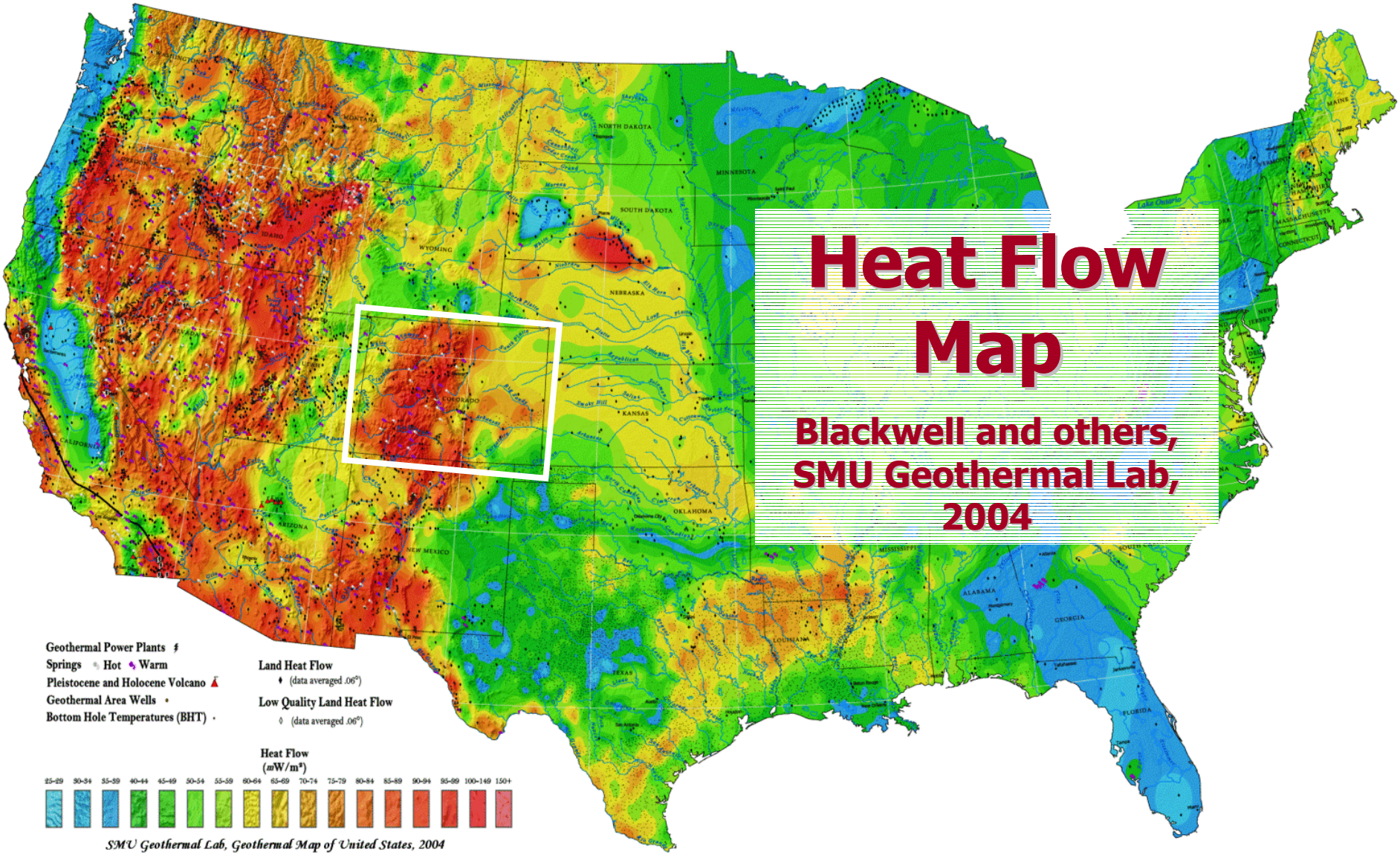
Heat Flow

Causes of high heat flow:

1) Thinner crustal rock
2) Igneous pluton at depth
3) Resident heat
4) Upwelling of deep, heated groundwater
5) Concentration of radioactive elements

Heat Flow Map

Blackwell and others, SMU Geothermal Lab, 2004



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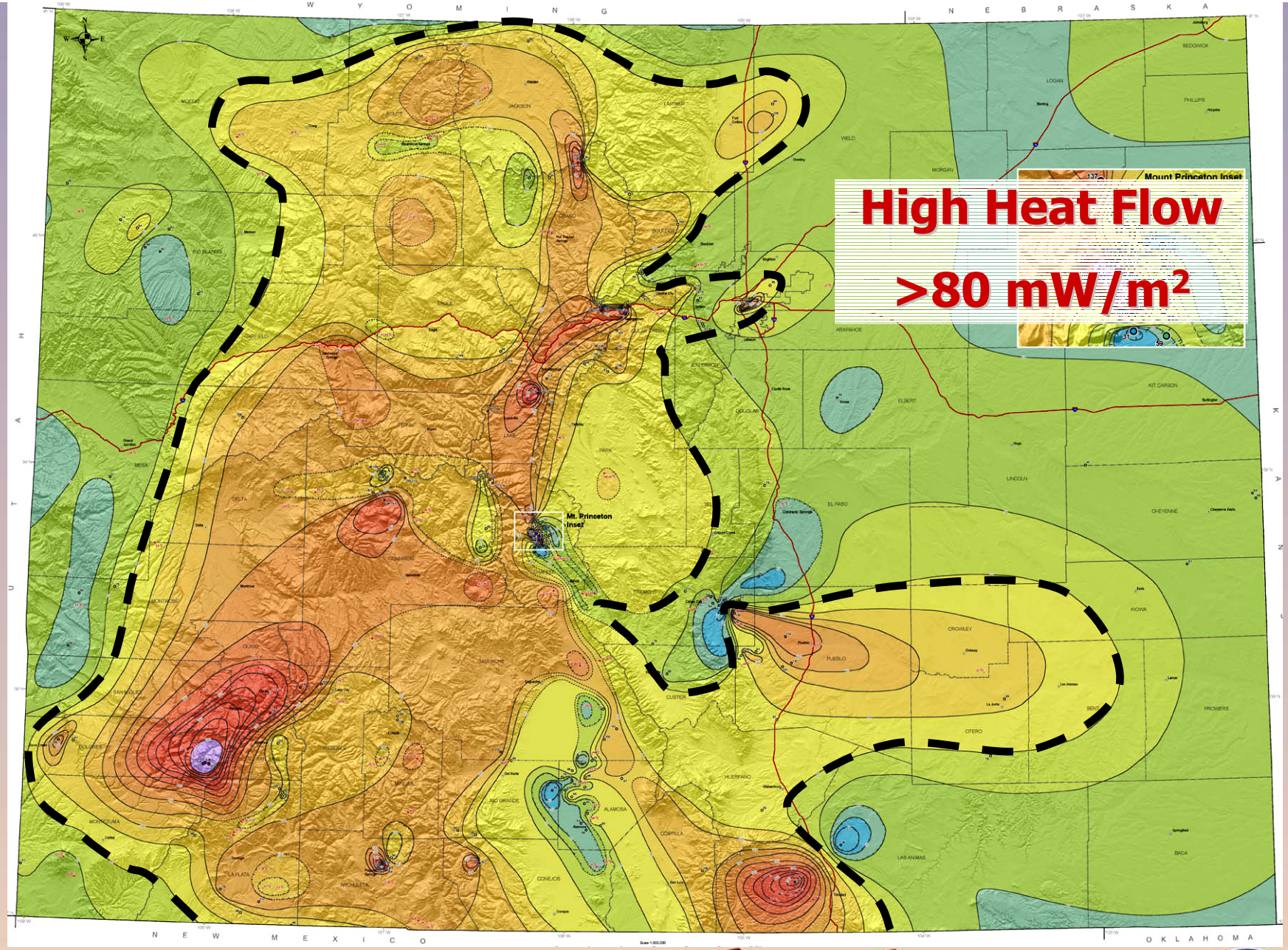

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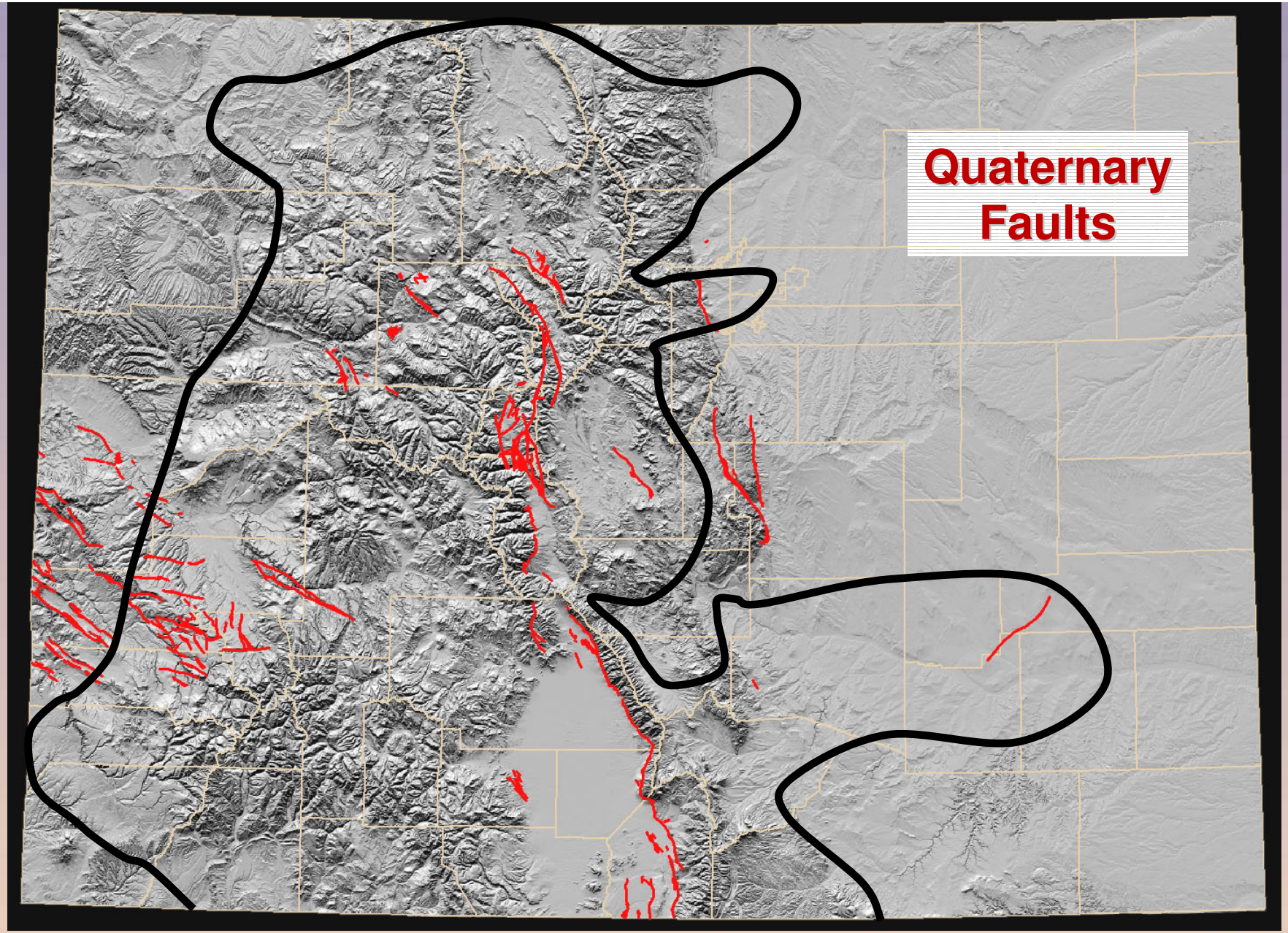
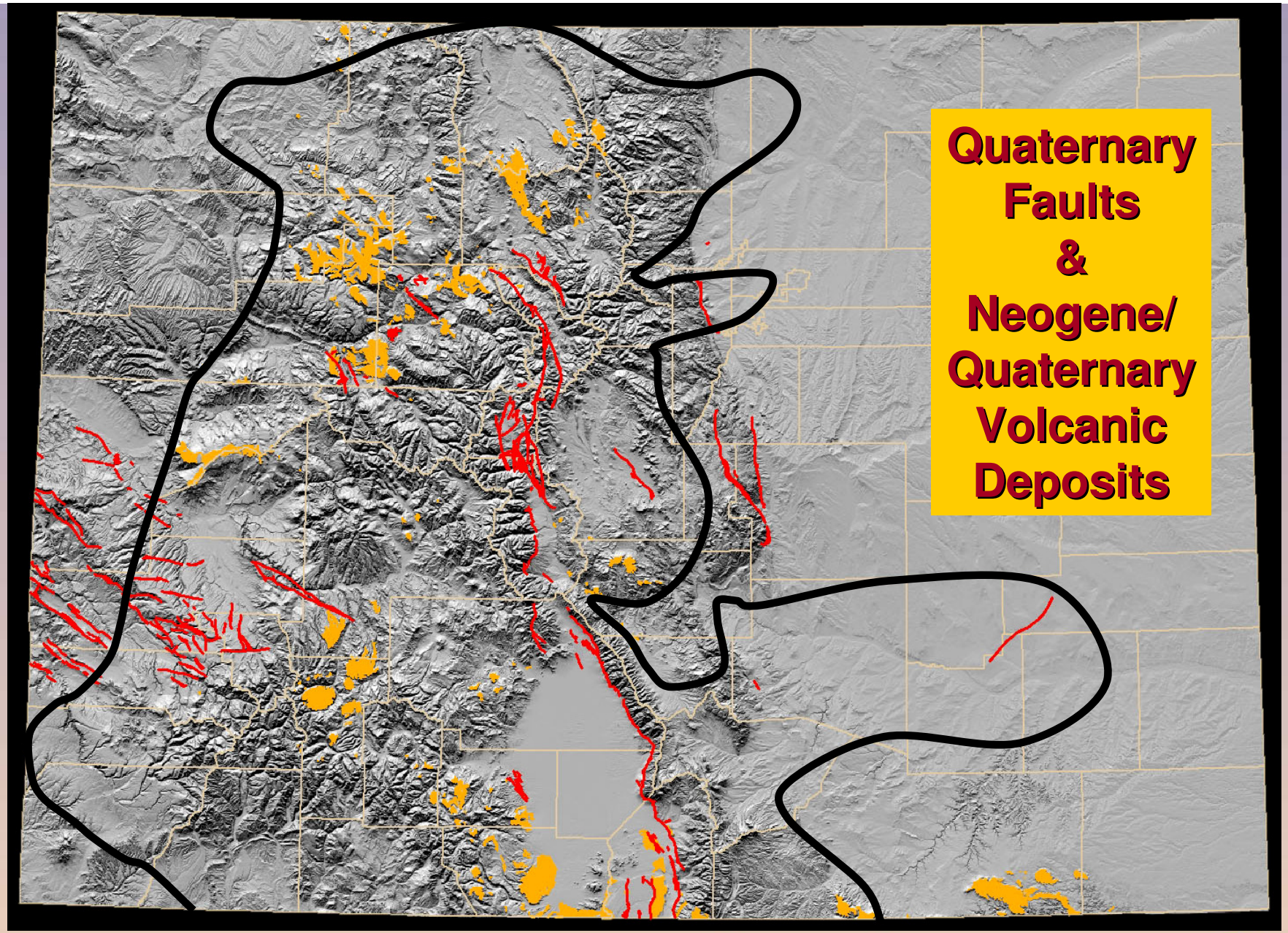


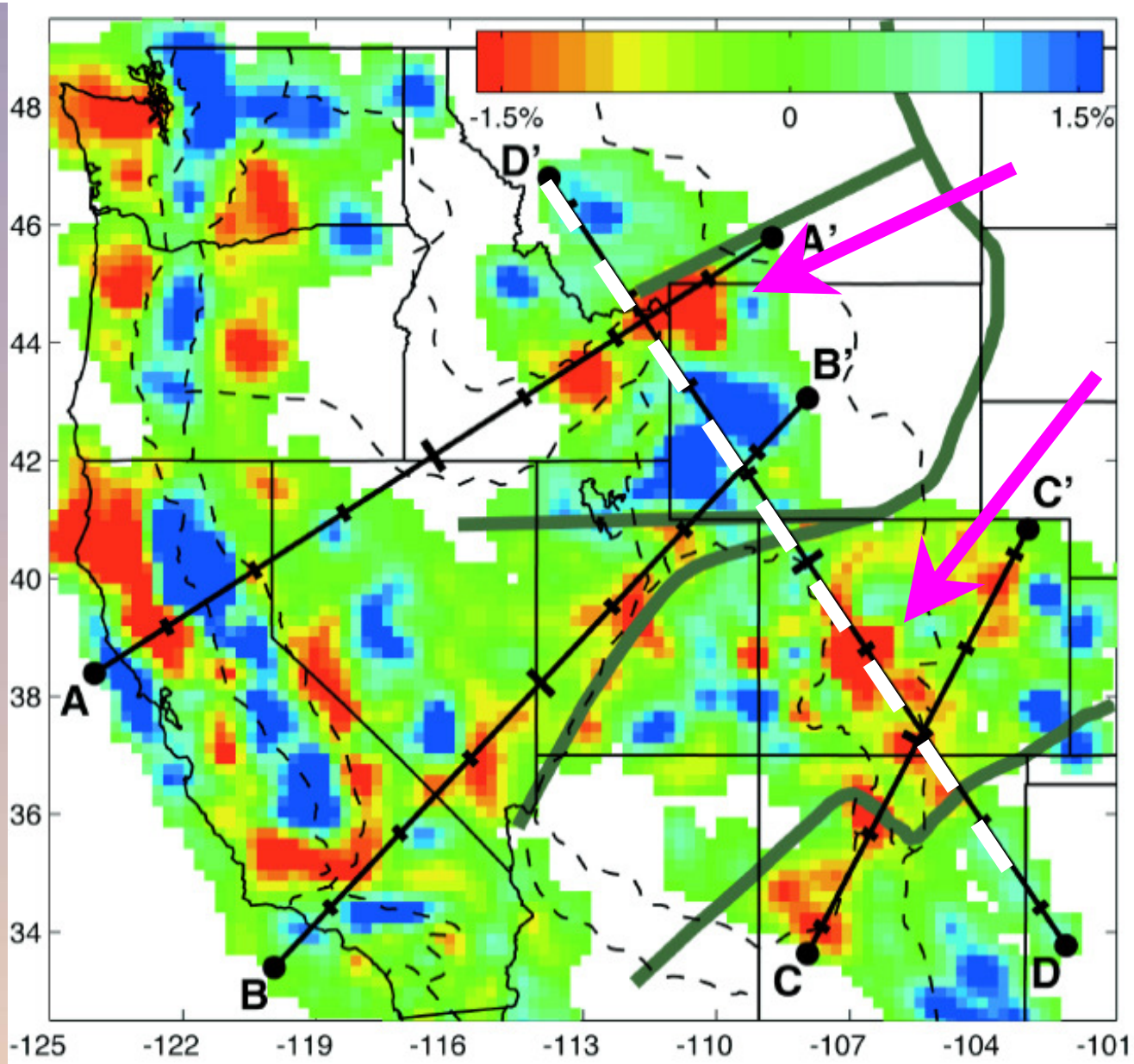
Machette, 2003, USGS OFR 03-417


Quaternary
Faults
&
Neogene/
Quaternary
Volcanic
Deposits

Tomographic P-wave velocity variations

Map at 100 Km Depth

Yellow/red = Low Velocity Material

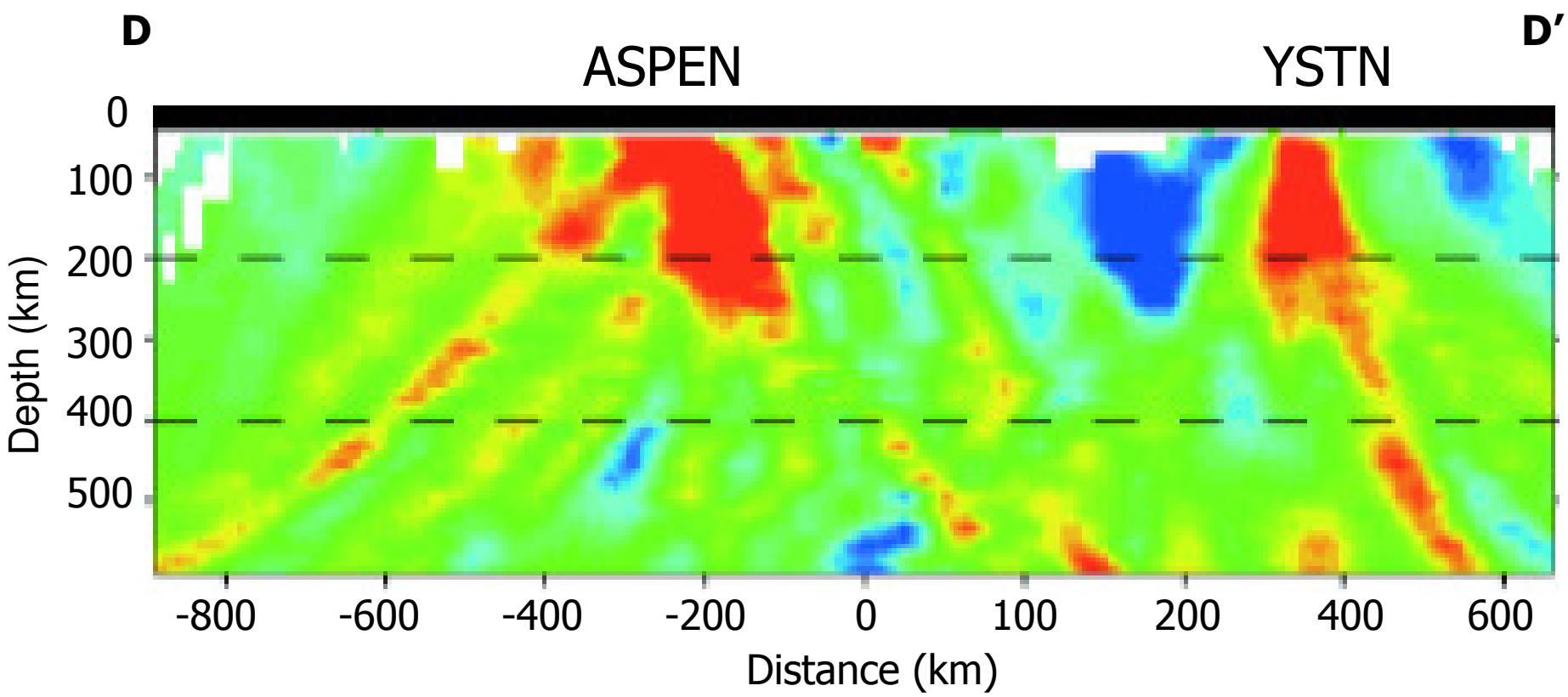


from Dueker, Yuan, & Zurek, 2001

Tomographic P-wave velocity variations

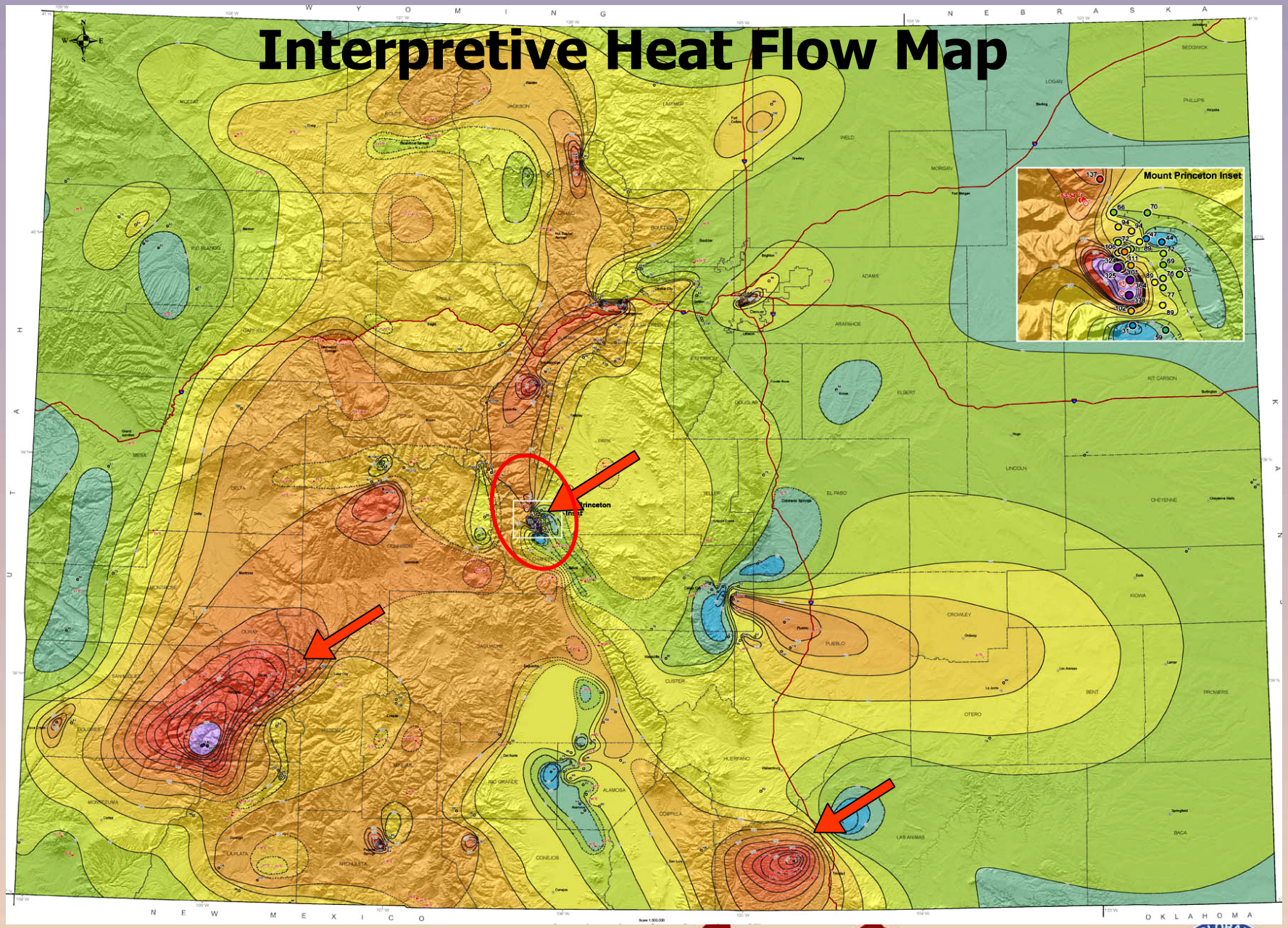
Cross-Section View

South **North**



from Dueker, Yuan, & Zurek, 2001

Interpretive Heat Flow Map



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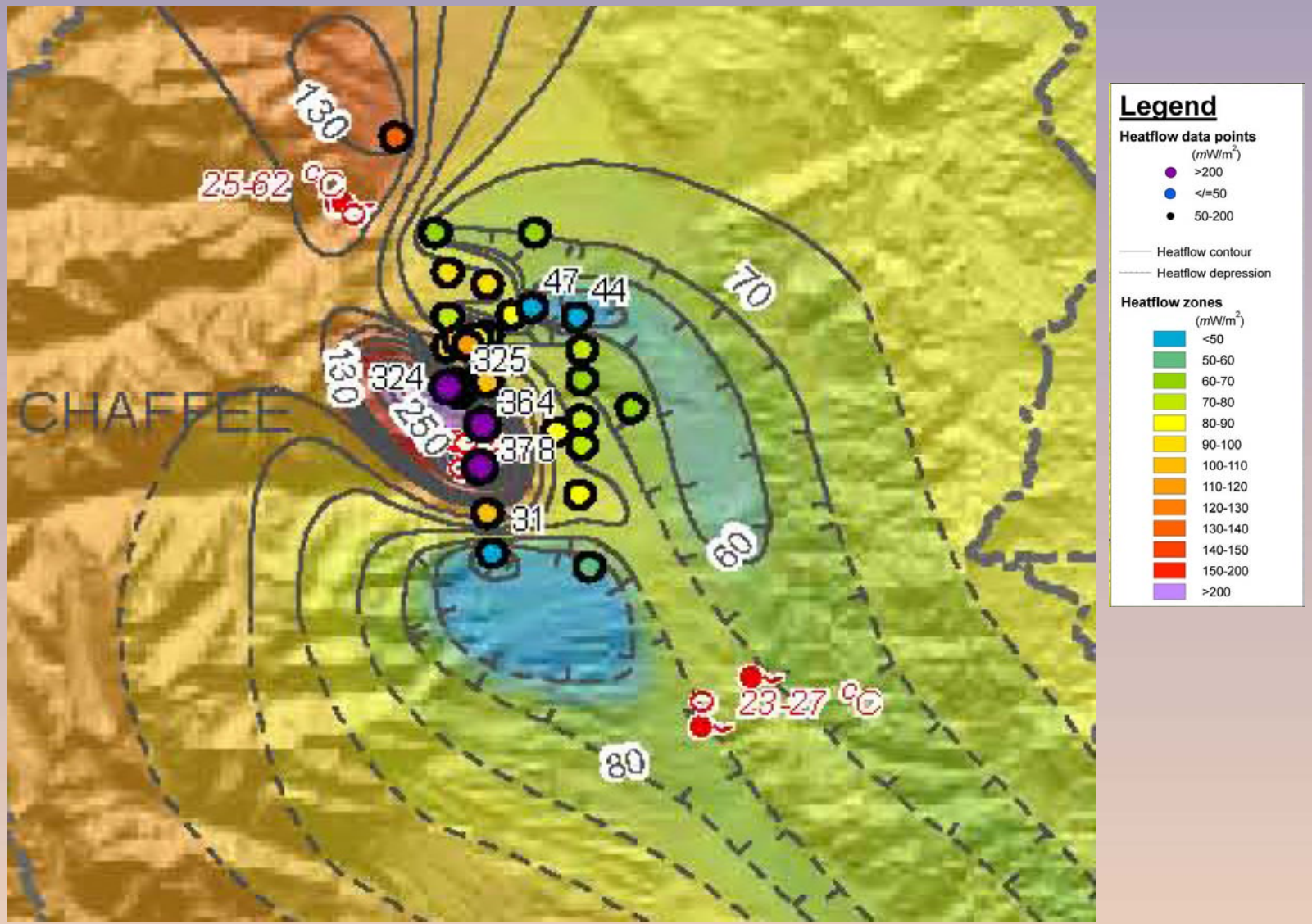
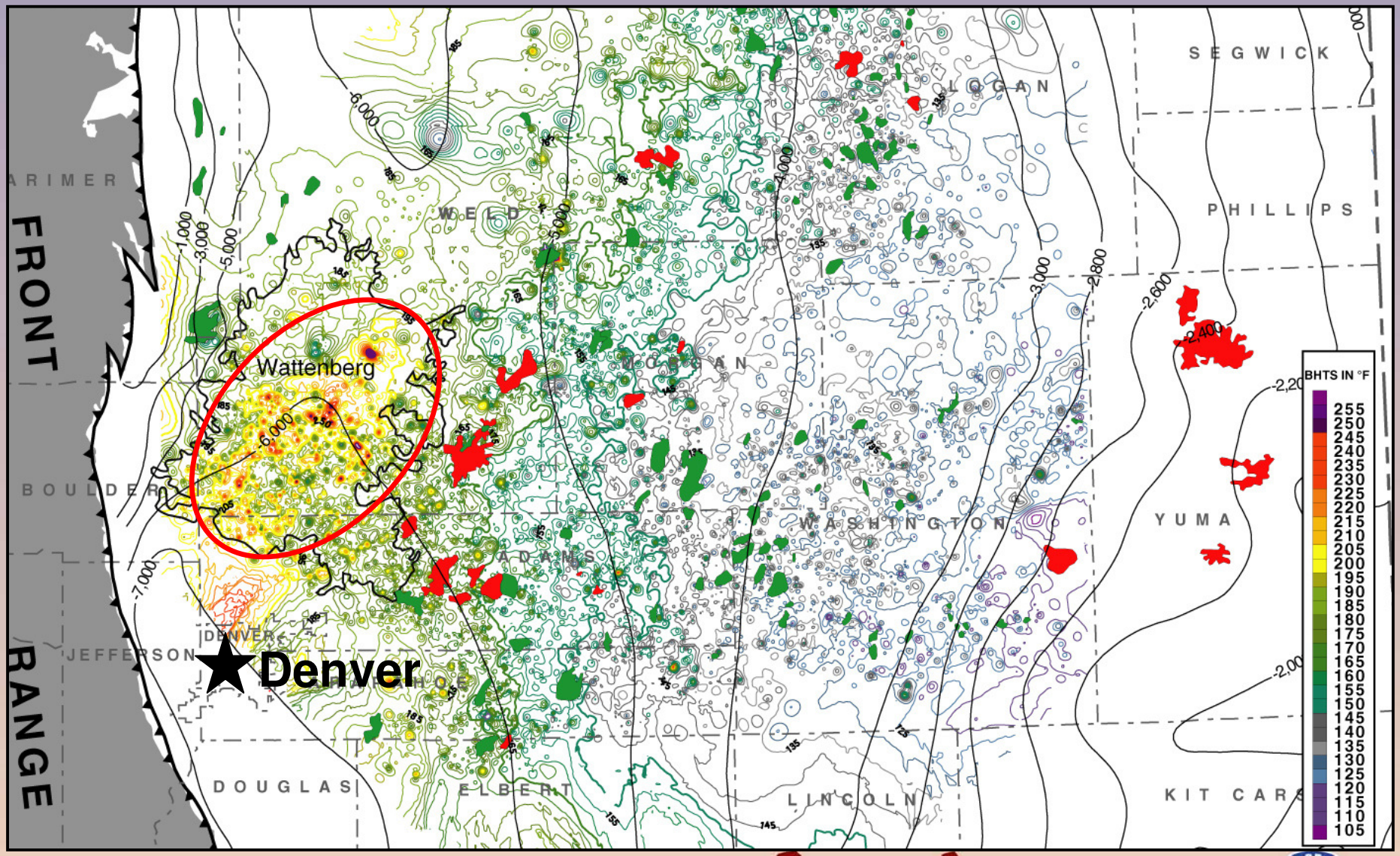
Heat Flow Map – Mt. Princeton



Bottom Hole Temps – Denver Basin



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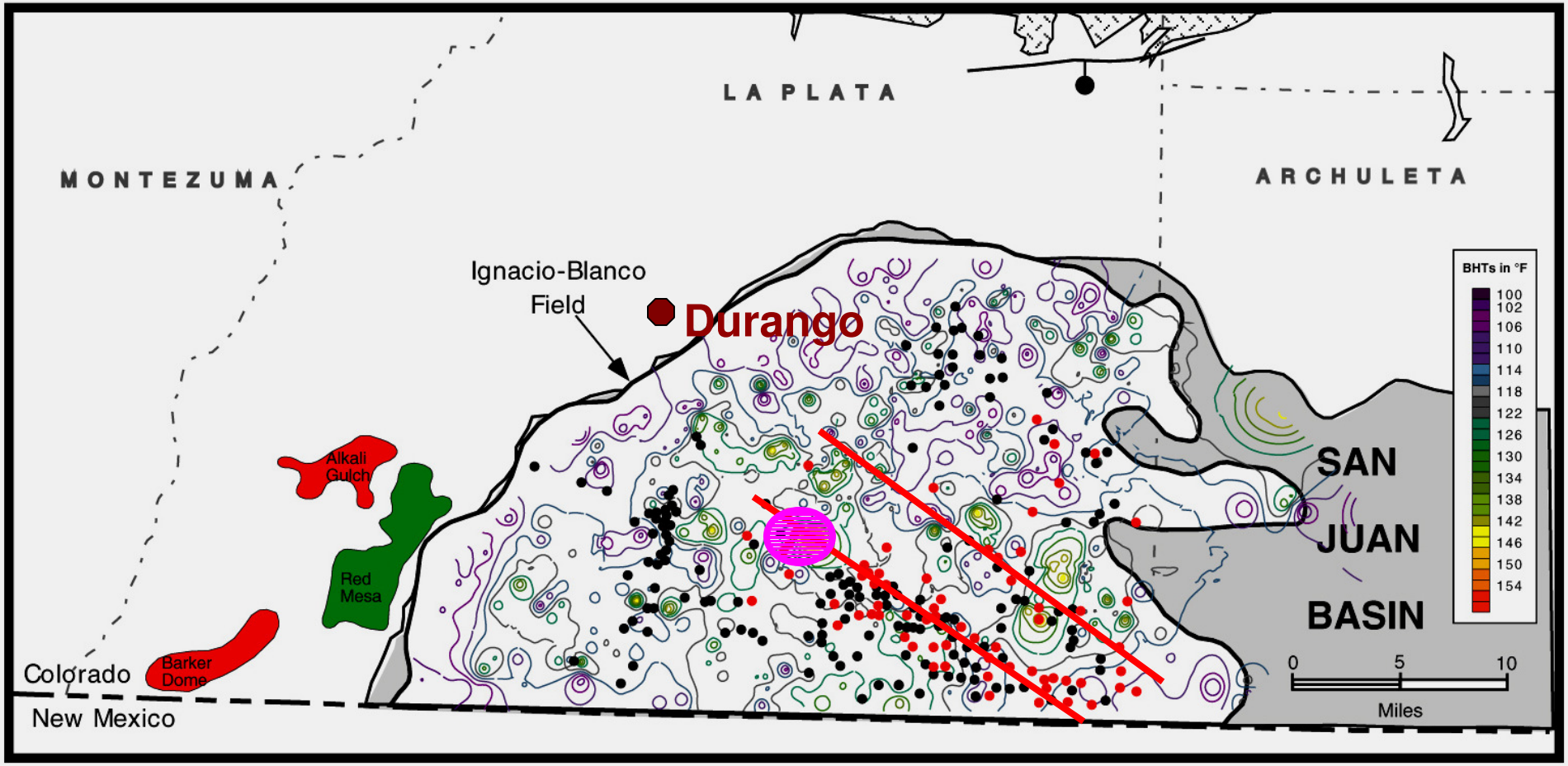
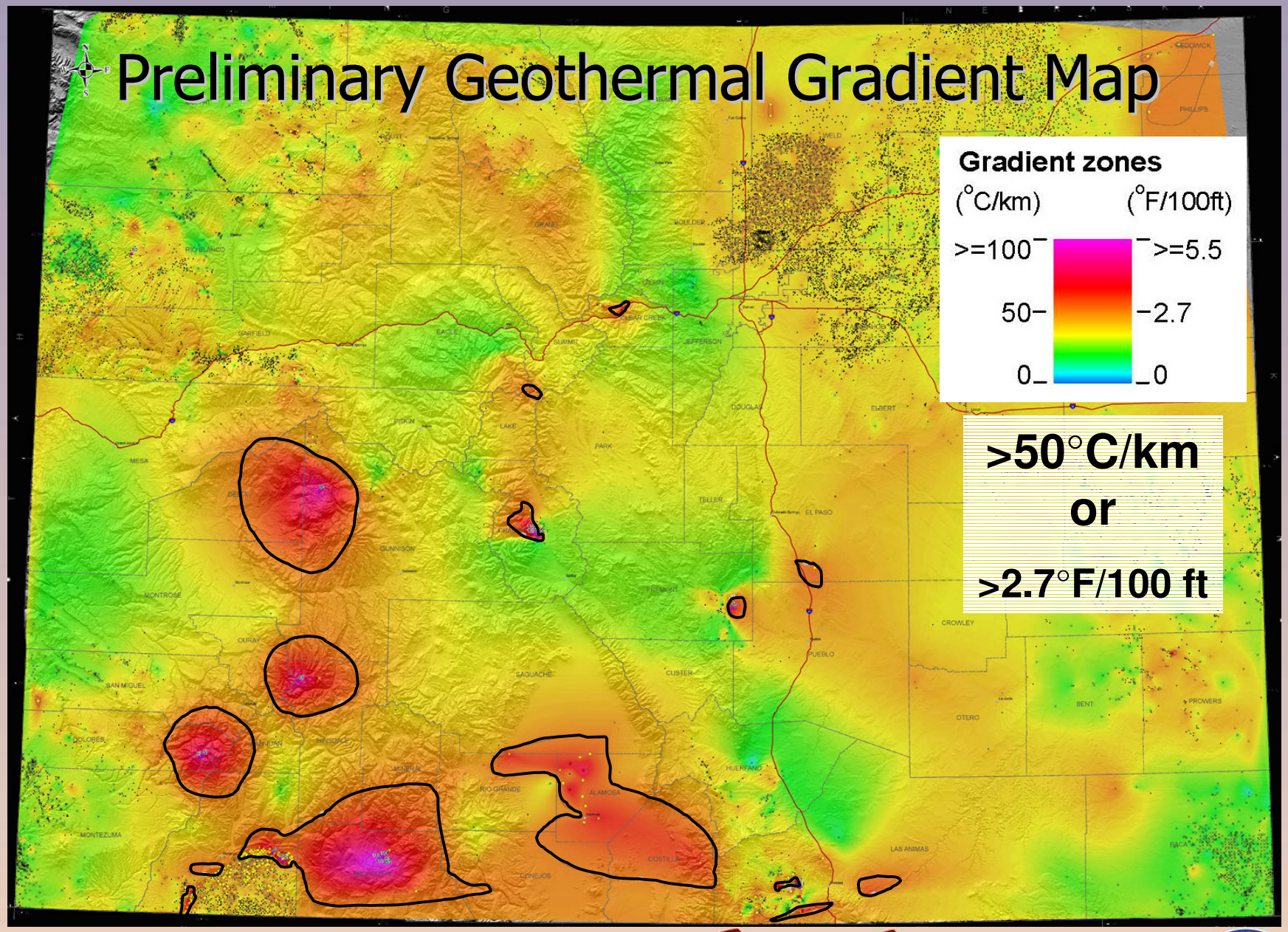
Bottom Hole Temps – San Juan Basin



Preliminary Geothermal Gradient Map



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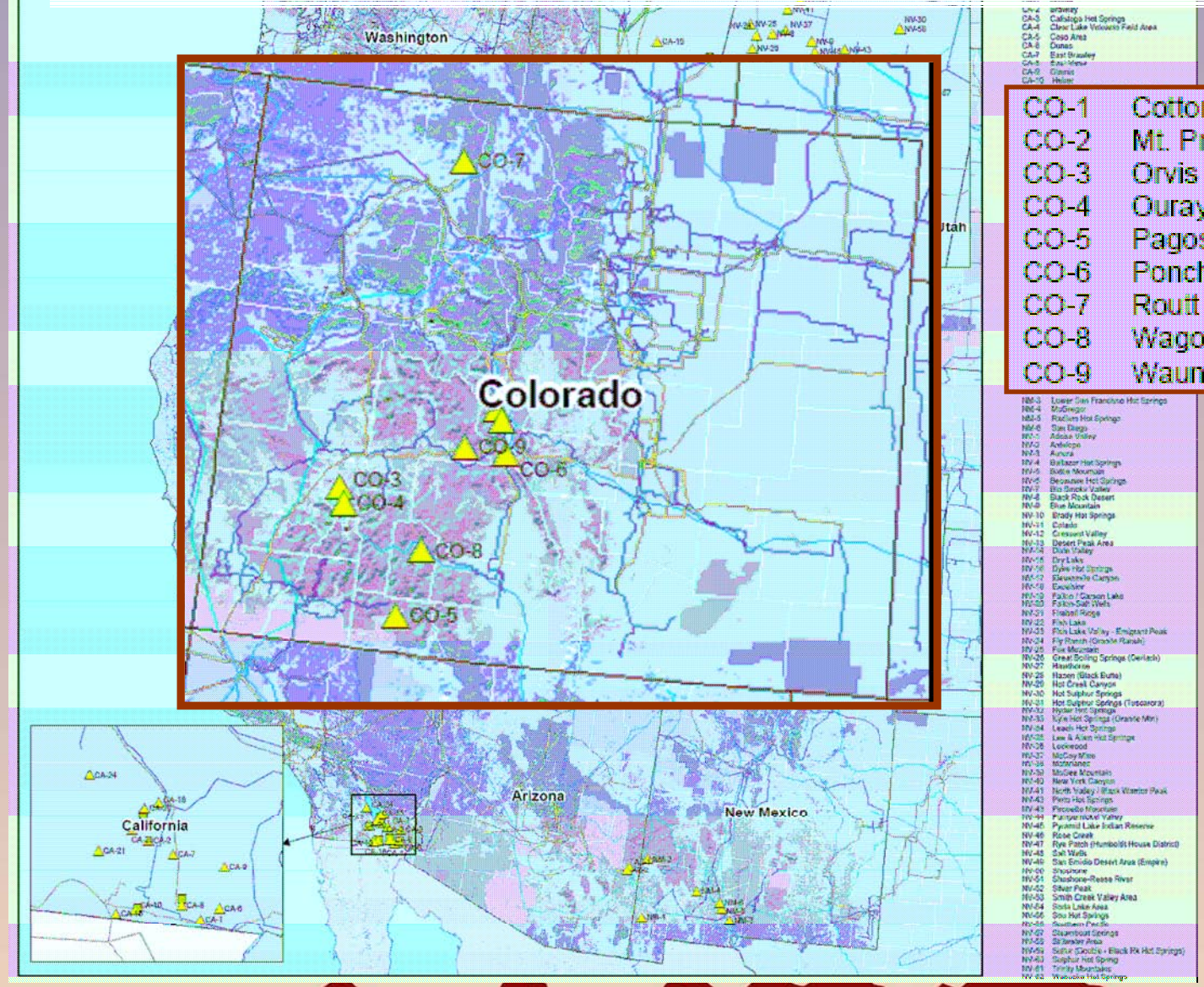
Geothermal Power Potential Western U.S.



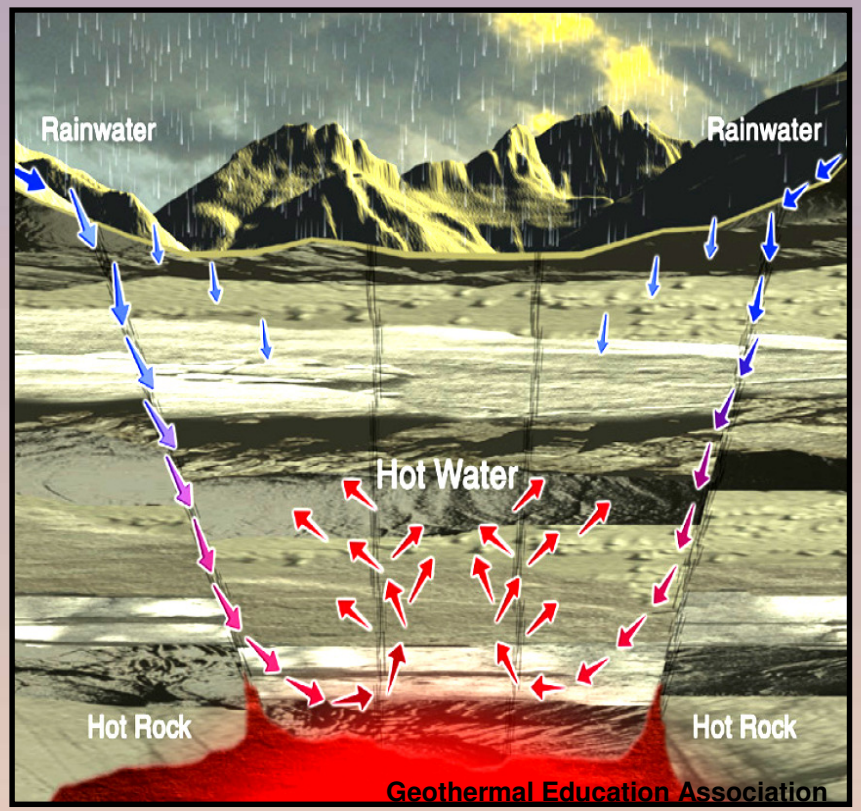
CO-1	Cottonwood Hot Springs
CO-2	Mt. Princeton Hot Springs
CO-3	Orvis Hot Springs
CO-4	Ouray
CO-5	Pagosa Springs
CO-6	Poncha Hot Springs
CO-7	Routt Hot Springs
CO-8	Wagon Wheel Gap
CO-9	Waunita Hot Springs

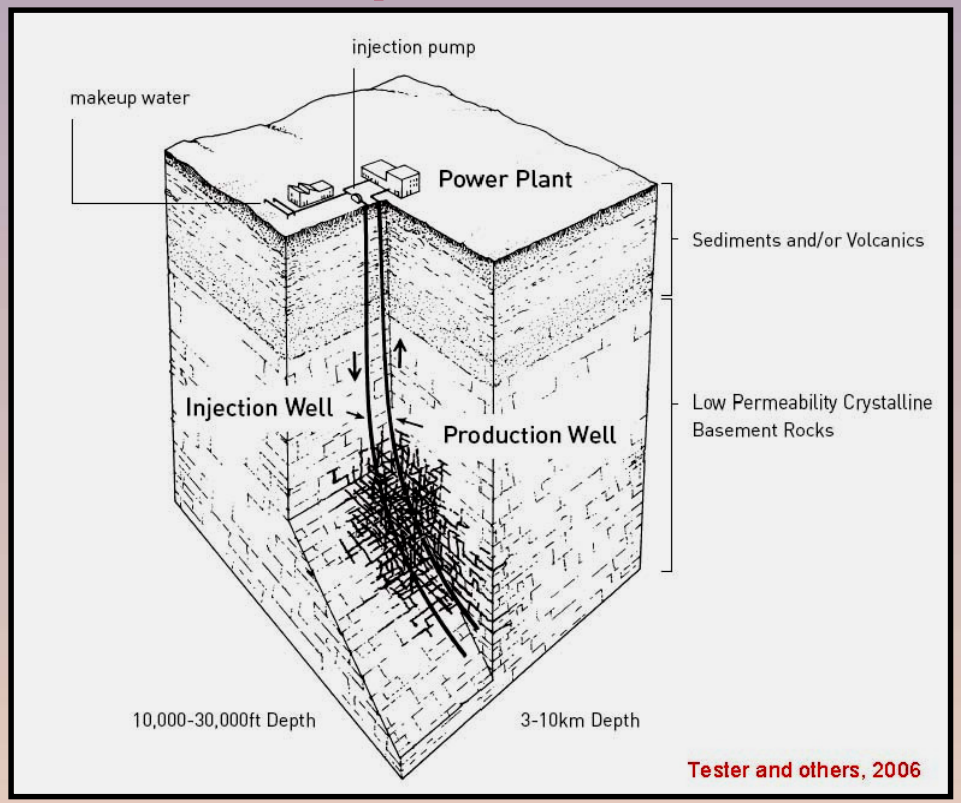
Laney and Brizzee, 2005, INL

http://www.geo-energy.org/information/resources.asp

Hydrothermal Systems

Enhanced Geothermal Systems





<10,000 ft (<3 km)

10,000-30,000 ft (3-10 km)

MIT Study - Enhanced Geothermal Systems

For EGS, Colorado has the one of the best high temp resources in the US.

Figure 1.5 Temperatures at a depth of 10 km.

from **Tester and others, 2006**

MIT Study - Enhanced Geothermal Systems

Table 2.2. High-grade EGS areas (>200°C at depths of about 4 km)

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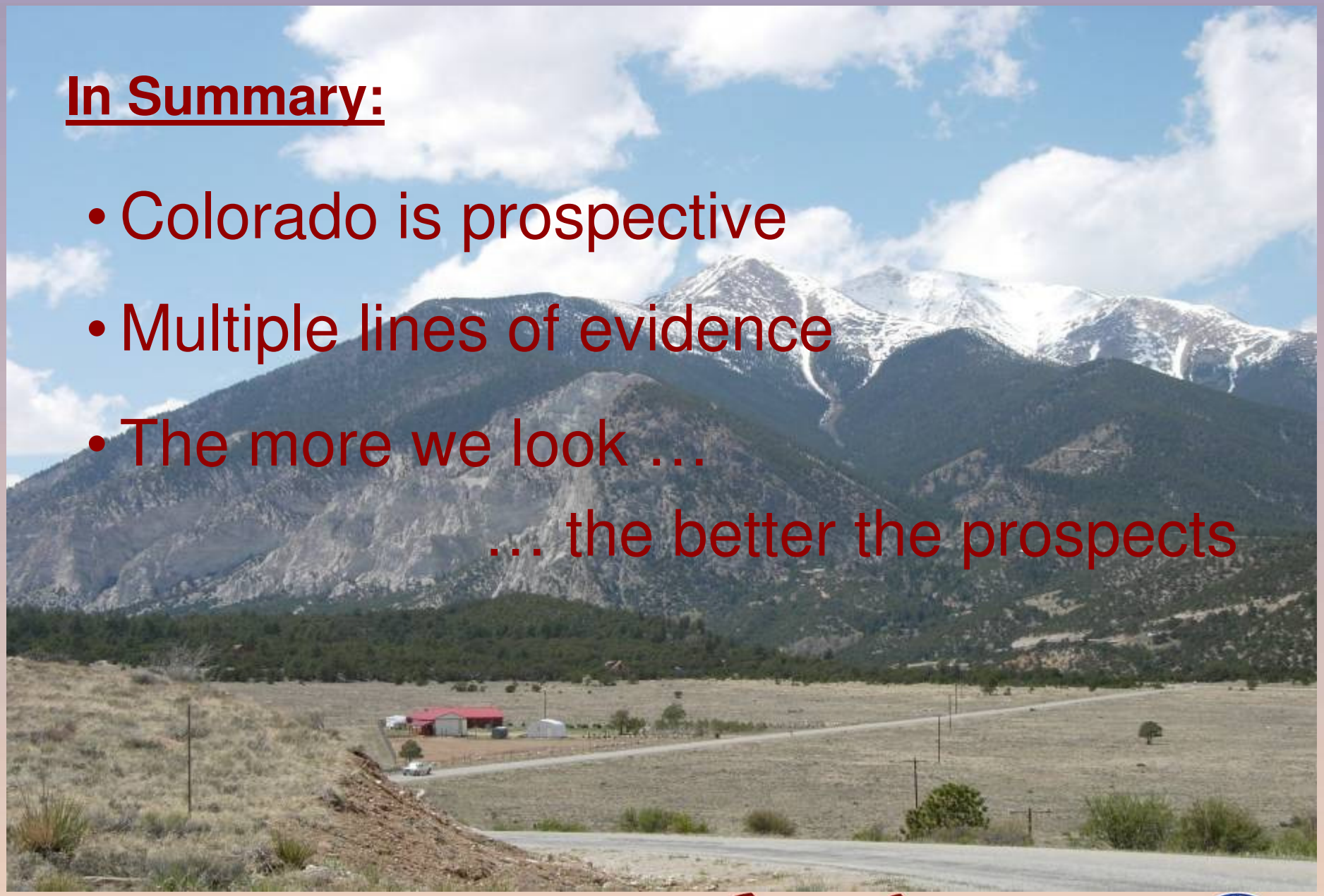
Region	Characteristics
Great Basin	30% of the 500 km x 500 km area is at temperatures > 200°C. Highly variable geologic and thermal conditions with some drilling confirming deep conditions. Large-scale fluid flow both laterally and horizontally so extensive fracturing at depth in many areas. The stress regime is extensional. Rocks are highly variable with depths of 4-10 km, mostly sedimentary with some granite and other basement rock types.
Southern Rocky Mountains	25% of the 100 km x 300 km area is at temperatures > 200°C. Geology is variable. Area includes the northern Rio Grande Rift and the Valles Caldera. Can have sediments over basement, generally thermal conditions in basement are unknown. Both high crustal radioactivity and high mantle heat flow contribute to surface heat flow. Probably highest basement EGS potential on a large scale.
	drilling in the existing geothermal systems and limited background data available from hydrocarbon exploration.
Clear Lake Volcanic Field	50% of the 30 x 30 km area is at temperatures > 200°C (steam reservoir is 5 km x 10 km). Low-permeability Franciscan sediments, may find granite at deeper depths. Possible access problems. Significant deep drilling with temperatures of 200°C at 2 km over a large area.

2-24

from **Tester and others, 2006**



In Summary:

- Colorado is prospective
- Multiple lines of evidence
- The more we look …

… the better the prospects

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