GEOTHERMAL ENERGY UTILIZATION
ASSOCIATED WITH OIL & GAS DEVELOPMENT
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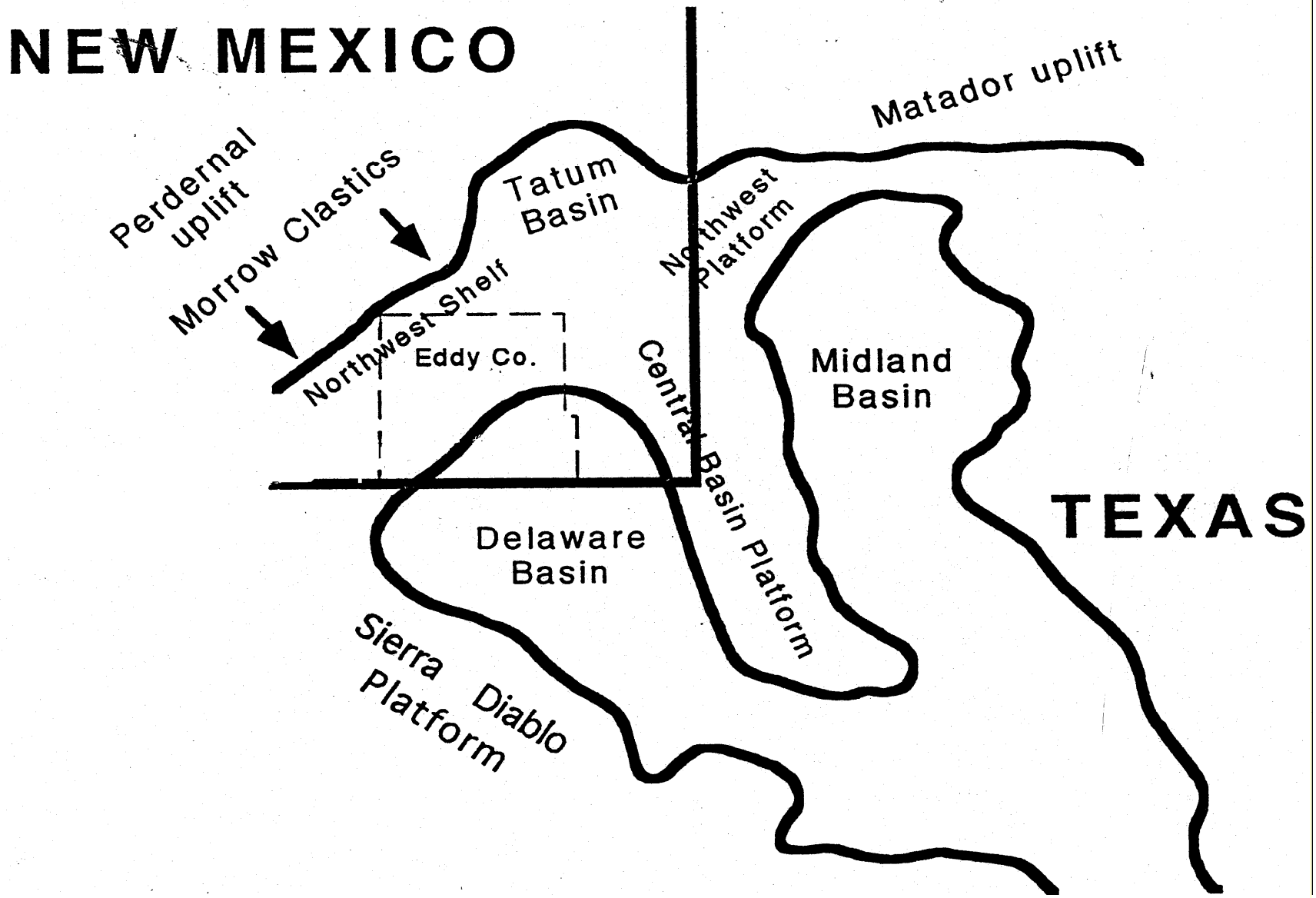
Southern Methodist University
Dallas, Texas

El Capitan Mountain

The Capitan Aquifer - Ellenburger Production Wells – Geothermal Engine Source?

Prentice Creel, PE

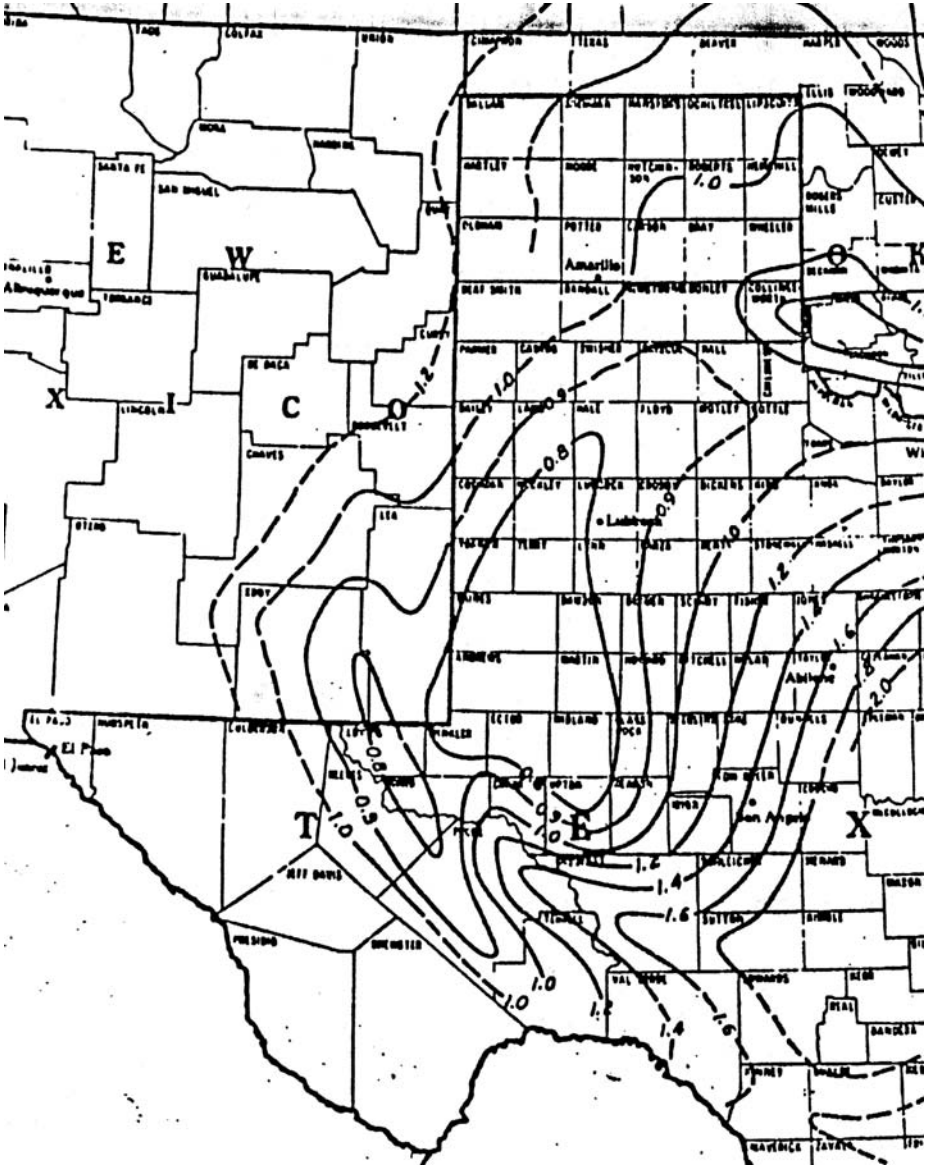

NEW MEXICO
Matador uplift
Perdernal uplift
Morrow Clastics
Tatum Basin
Northwest Platform
Northwest Shelf
Eddy Co.
Central Basin Platform
Midland Basin
TEXAS
Delaware Basin
Sierra Diablo Platform

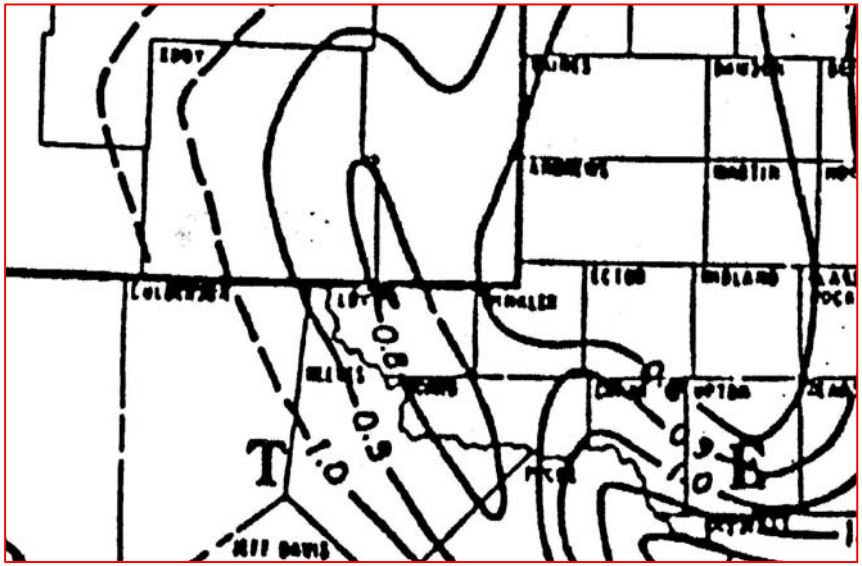
Looking for a massive water source

- Possibility of continuation without pressure depletion
- Fairly low in solids and corrosion aspects
- Hydraulically capable of penetrating heat source and perpetuating a continued flow

Fracture Directions

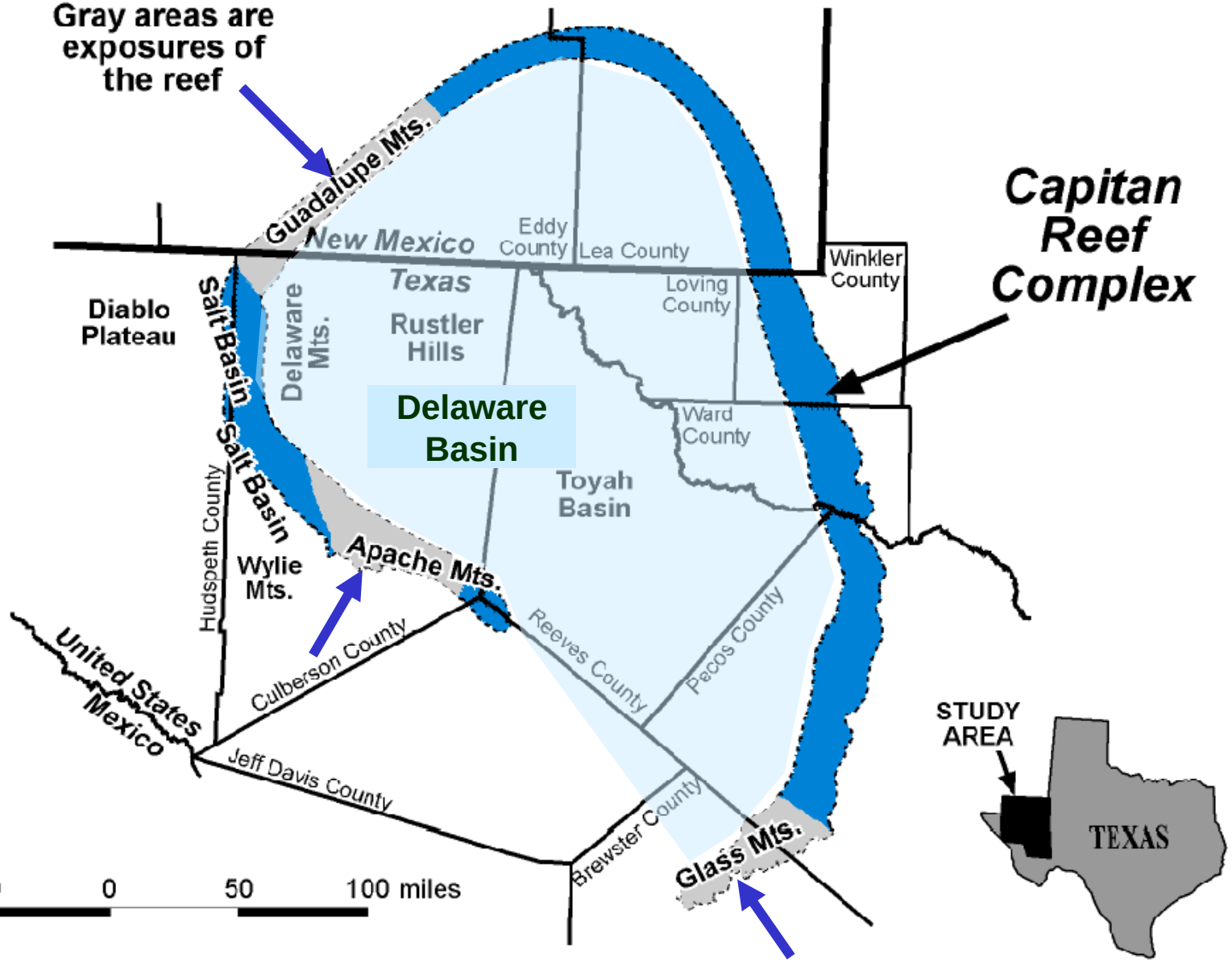
Temperature Gradients





Capitan Reef

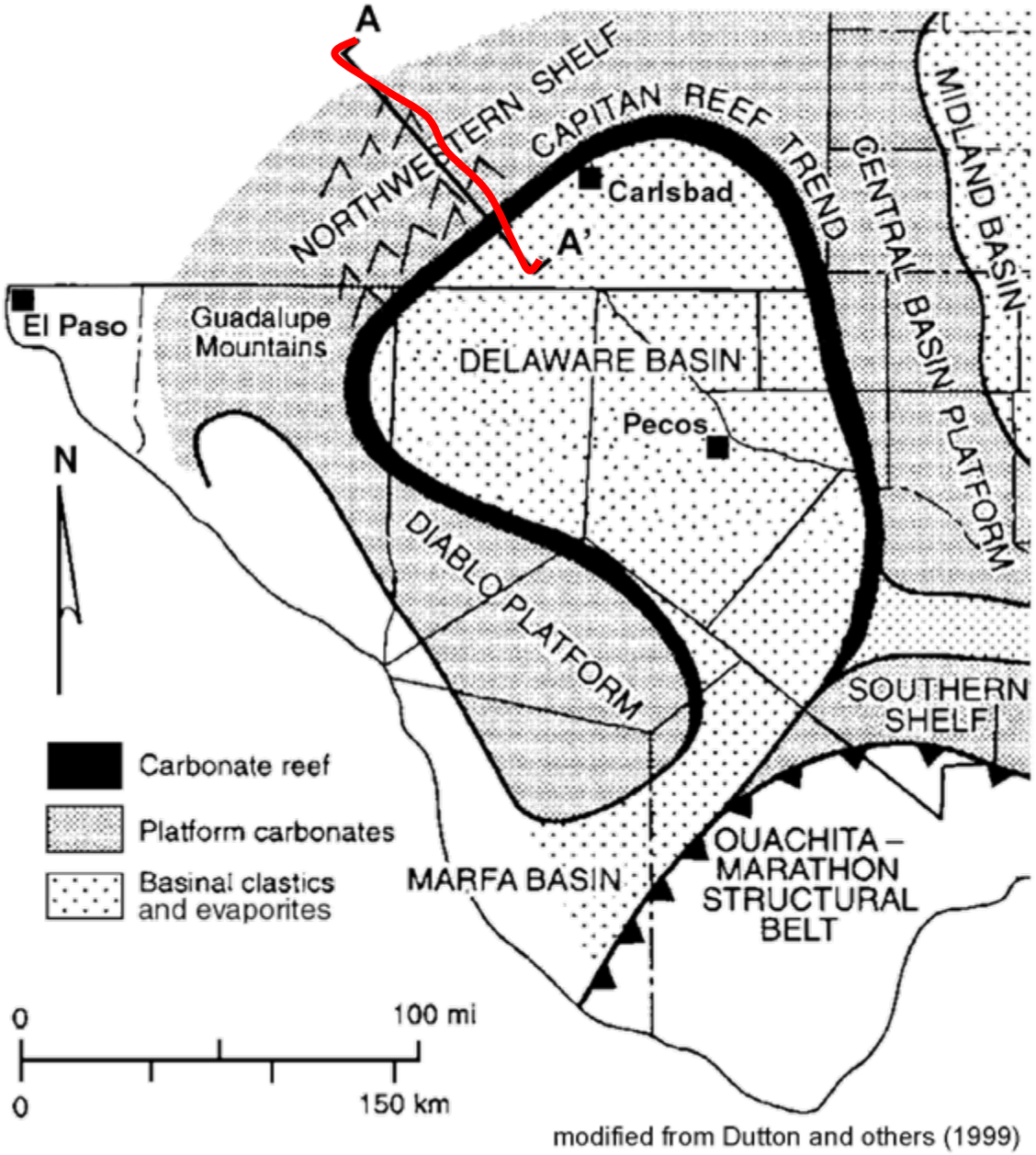
- **Located in west Texas and southeast New Mexico**
- **Occurs in the Capitan Reef Complex**
  - Ancient reef which formed around the margins of the Delaware Basin in the Permian Period (~250 million years ago)
    - algae, sponges, and tiny colonial animals called bryozoans
  - Excellent exposure of the reef in Guadalupe Mountains National Park



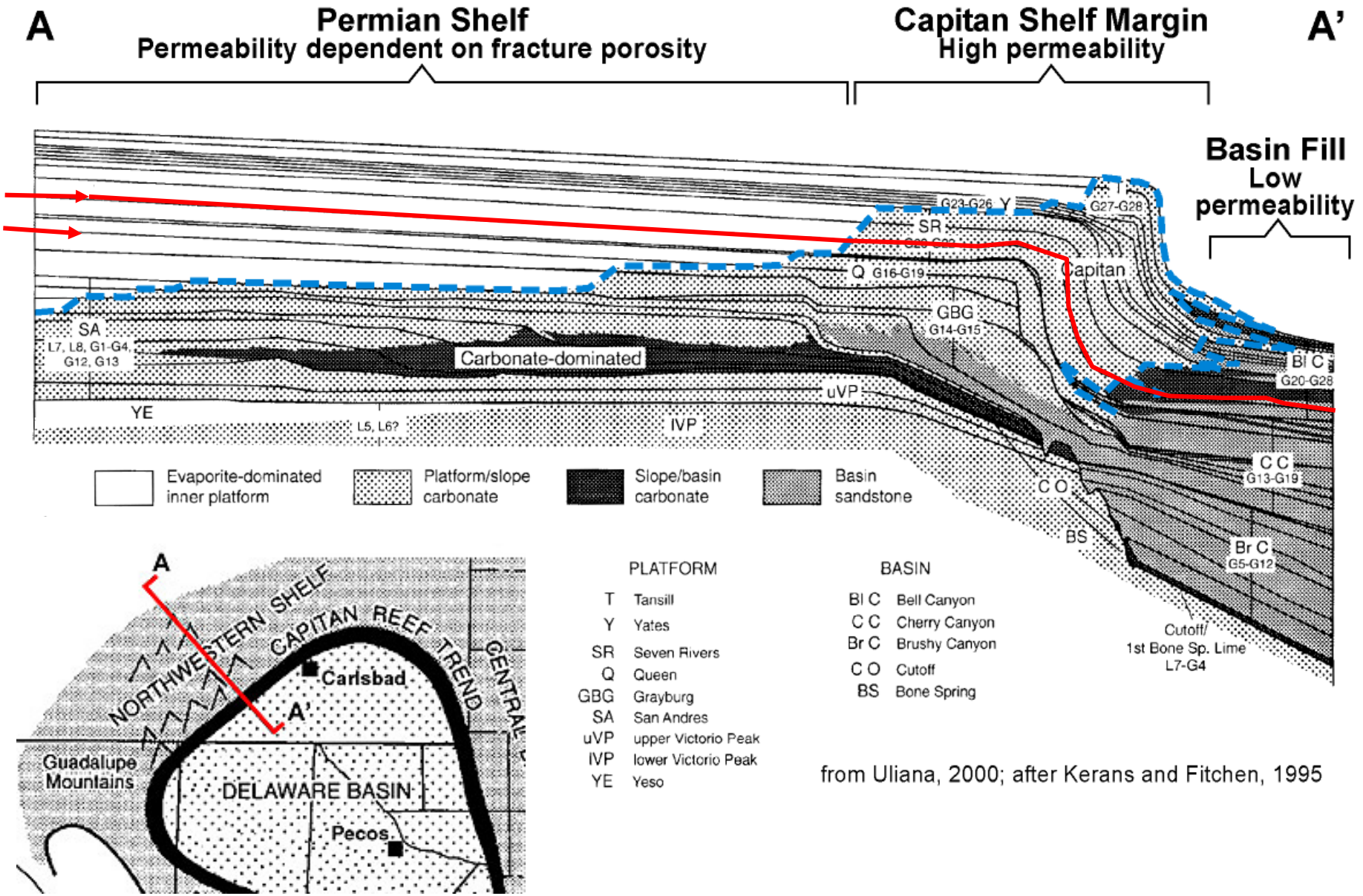
Location of the Capitan Reef Complex in western Texas and New Mexico

Geologic History of the Reef

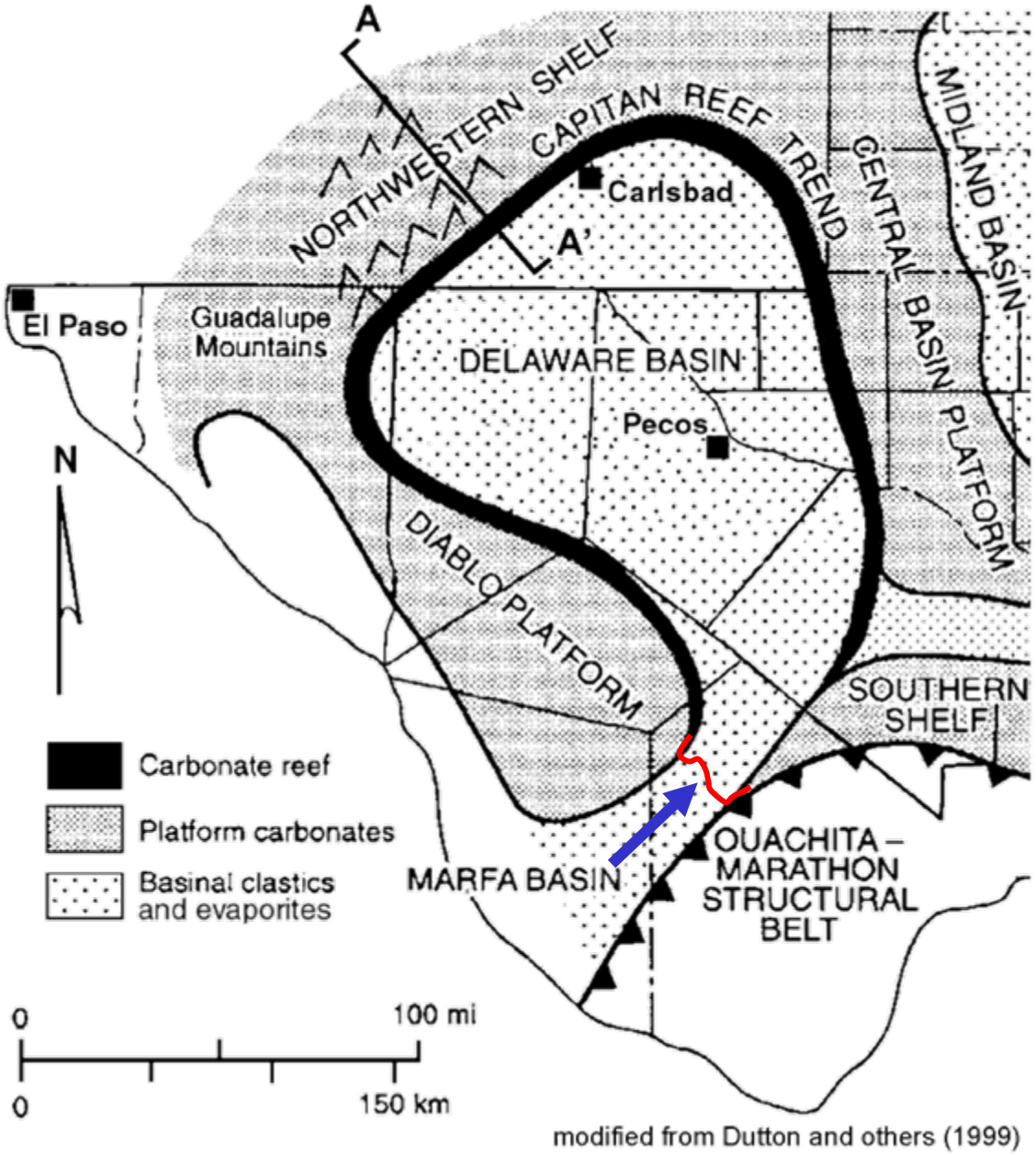
- **In Permian Period (280 to 225 m.y.a.) New Mexico and Texas were on the coast of a large super-continent**
- **A shallow inland sea, called the Delaware Basin formed off of the main coast**



modified from Dutton and others (1999)



from Uliana, 2000; after Kerans and Fitchen, 1995



modified from Dutton and others (1999)

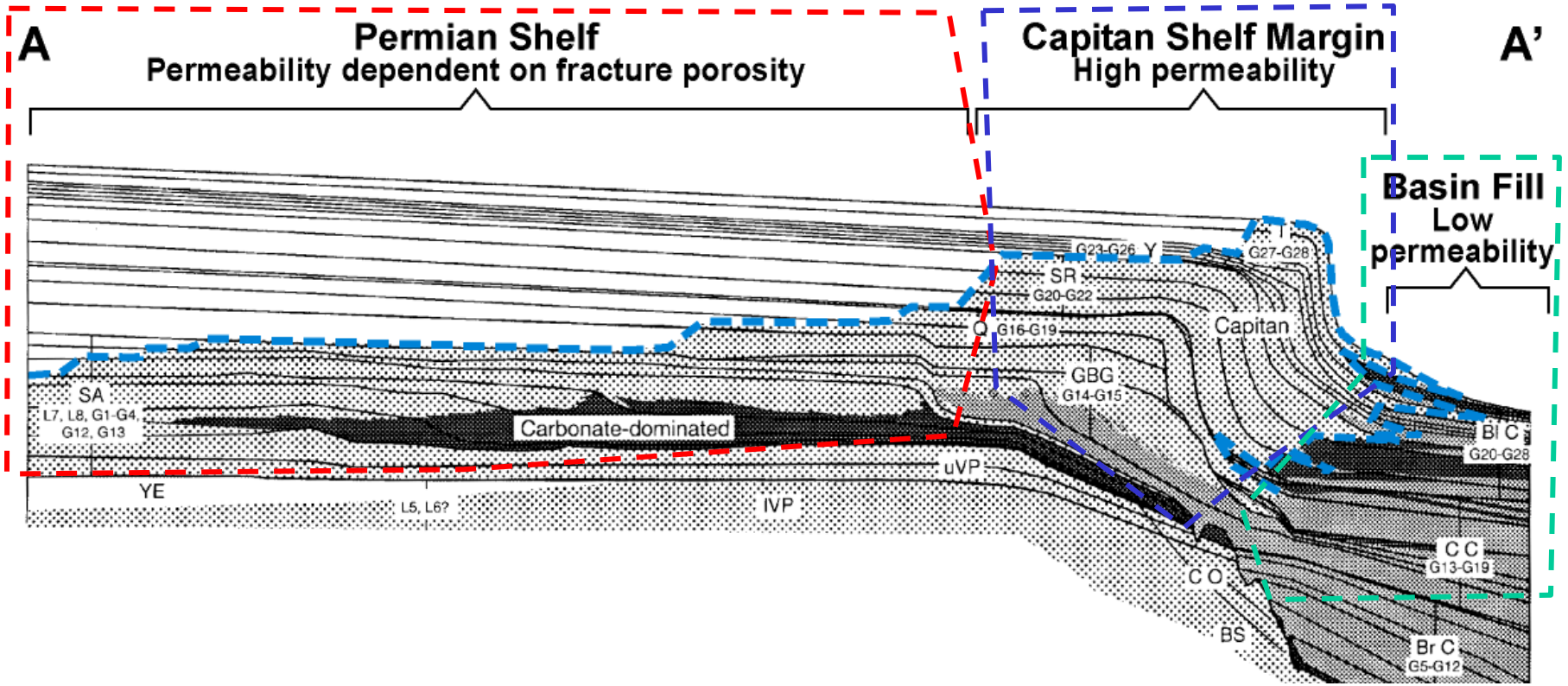
Hydrogeology of the Capitan

- **The geologic strata associated with the Capitan aquifer can be divided into three hydrostratigraphic groups:**
  - The Permian Shelf
  - The Capitan Shelf Margin (which is the actual reef trend itself)
  - The Basin Fill in the interior of the basin
- **The locations - outlined on the cross section**

The Permian Shelf facies consist of lower permeability carbonate sediments and evaporites (gypsum and rock salt). Permeability is dependant upon fracture porosity, and well yields and water quality are highly variable.

The Capitan Shelf Margin facies consist of the reef itself, which has a relatively high porosity and permeability. The permeabilities in the shelf margin are the highest in the strata associated with the Permian Basin.

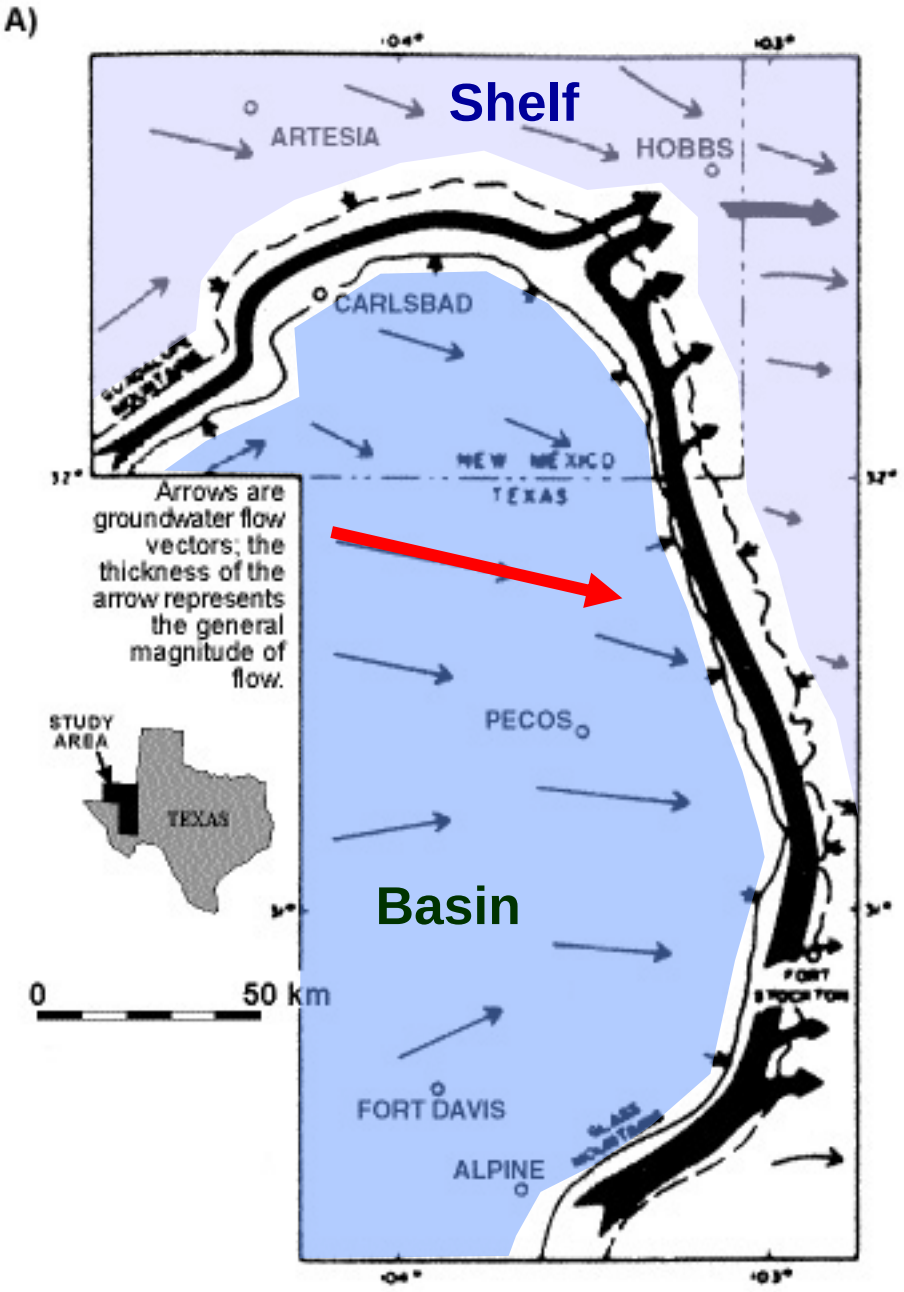
The Basin Fill facies consist of lower permeability siliciclastic sediments (like fine sand and mud). Permeability is generally very low, and water quality is not all that good.



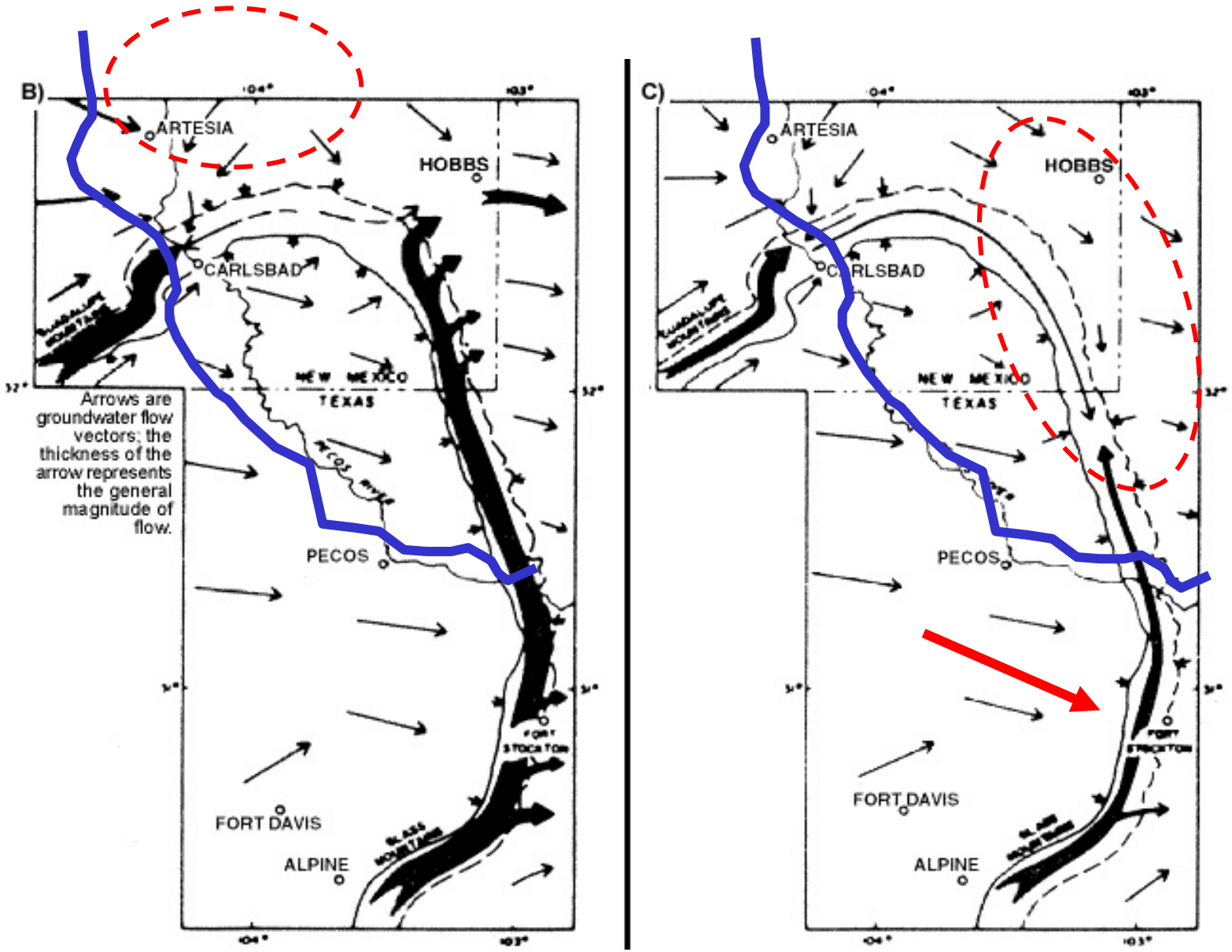
Groundwater Flow Patterns

- **Groundwater flow in the shelf facies and basin fill is generally towards the east**
- **The high permeability of the Capitan aquifer results in concentrated flow along the trend of the reef, generally towards the north and northeast**

- When the aquifer first formed, the regional flow was to the east and southeast (small arrows)
- Flow was concentrated along the trend of the reef, and the primary discharge point was somewhere around the town of Hobbs, NM (large arrows)
- Exited the Permian rocks and entered the Cretaceous San Andres limestone
- Continued on towards the Gulf Coast
  - **Where does this resource go?**
  - **Can it be re-routed via wellbores**



Concentrated flow along the trend of the reef, generally towards the north and northeast



Water Quality

- **Water in the Capitan is generally poor quality**
  - Average TDS of 17 samples was 3,059 mg/L; average chloride concentration was 881 mg/L
- **Water is potable in a few areas**
  - Mostly near Carlsbad and in some spots in the Glass Mts.
- **Not enough historical data to identify trends**
- **Bad – but not that Bad**

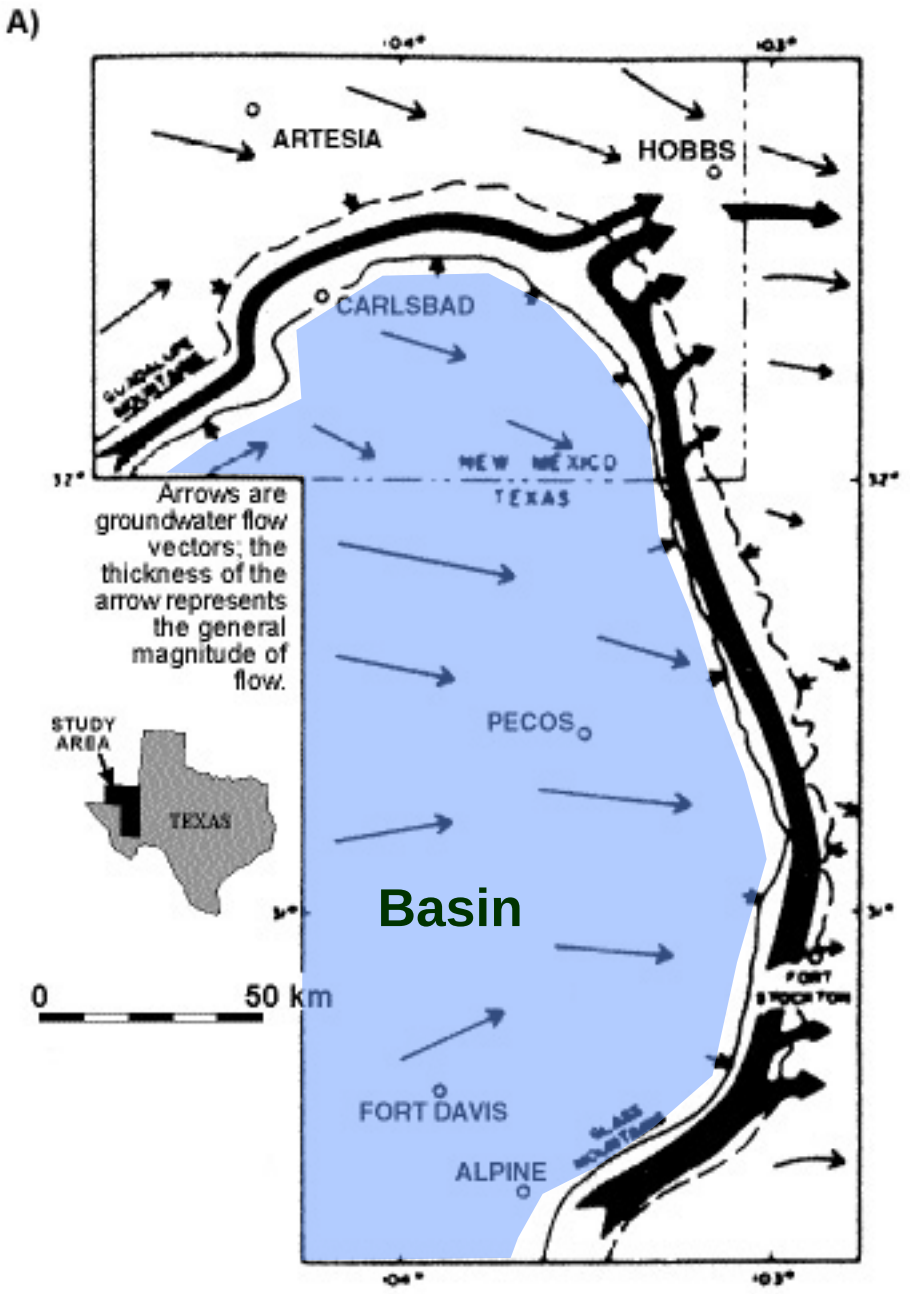
Capitan Reef

- **Regionally, groundwater flow is to the east; in the Capitan it was towards the north**
  - Incision of the Pecos River and development of oil/water interrupted the flow system
- **Water quality is generally poor**
  - Good enough for agriculture in most places
  - Potable water exists near Carlsbad

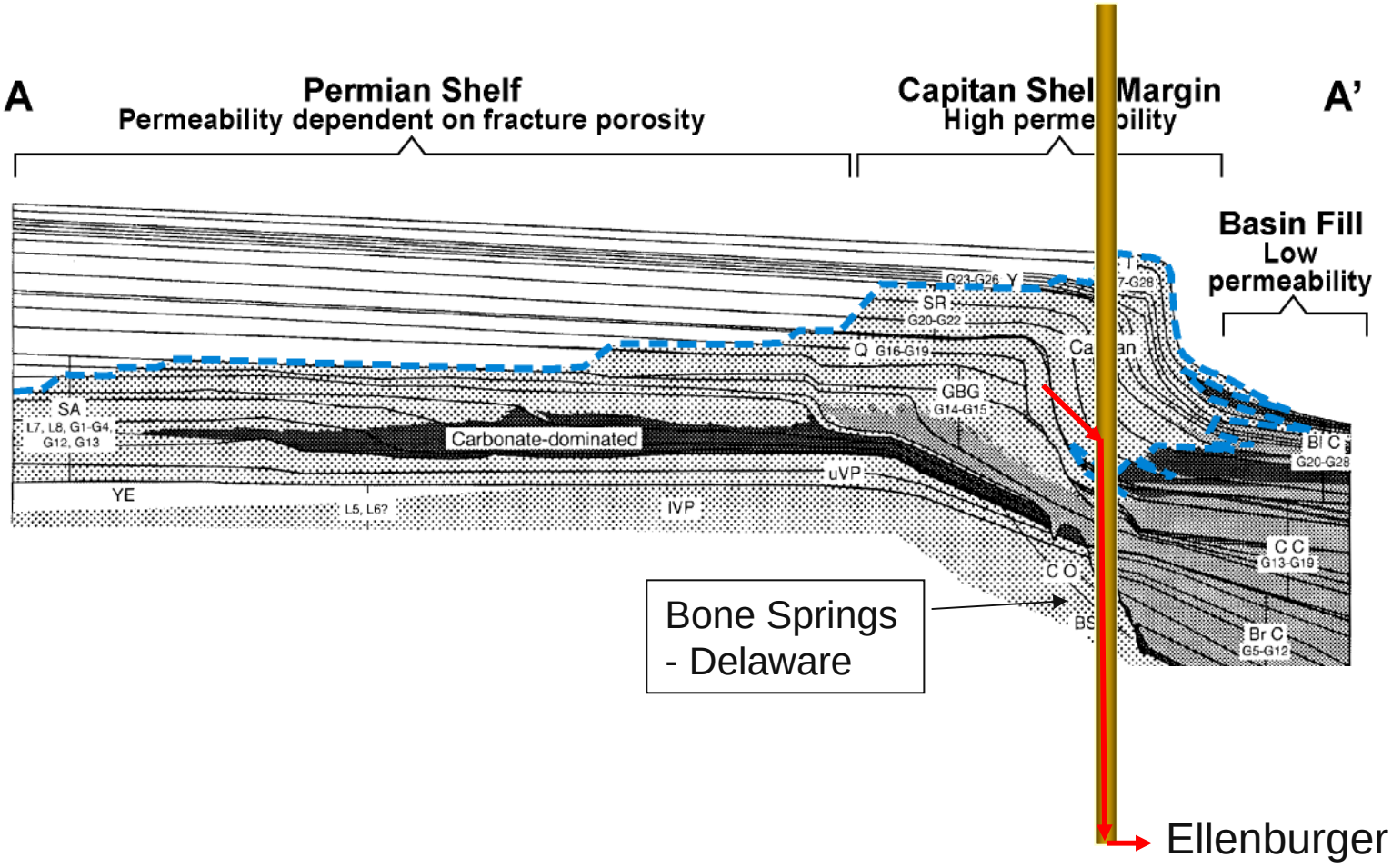
How to Build a Geothermal Engine

- **Find a dynamic water that is a replenish able Resource**
- **Find a temperature Conduction Source**
- **Develop these two separate Resources into a Geothermal Engine**
  - Fracture capabilities and engineering
  - Regulatory acceptance
  - Environmental acceptance

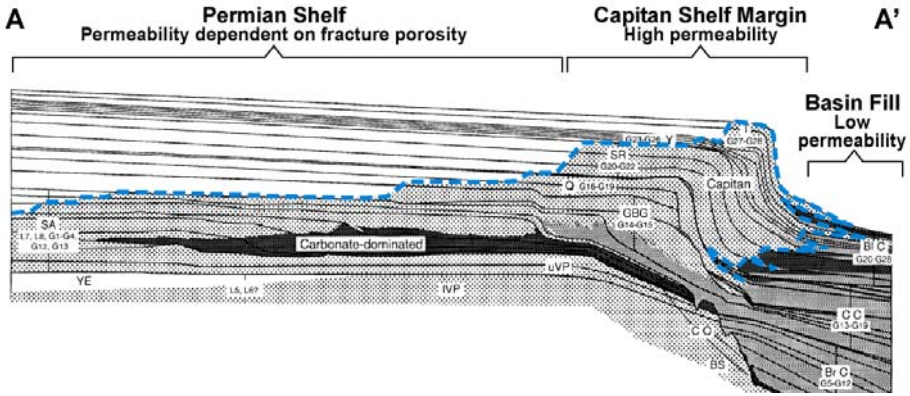
Where does the interconnection take place – Capitan Reef down to the Ellenburger or other Heat Sources

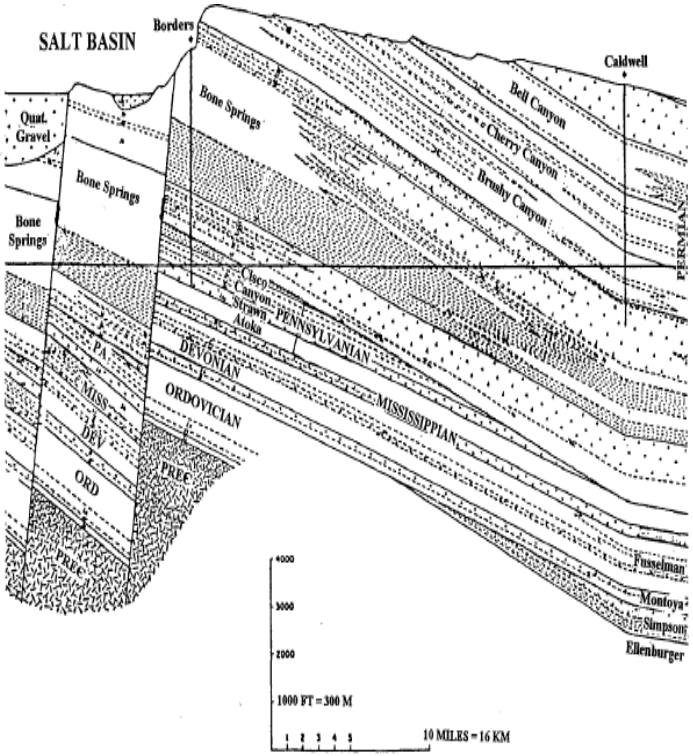


Connecting the Formations



Connecting the Capitan Aquifer to the Ellenburger Formation

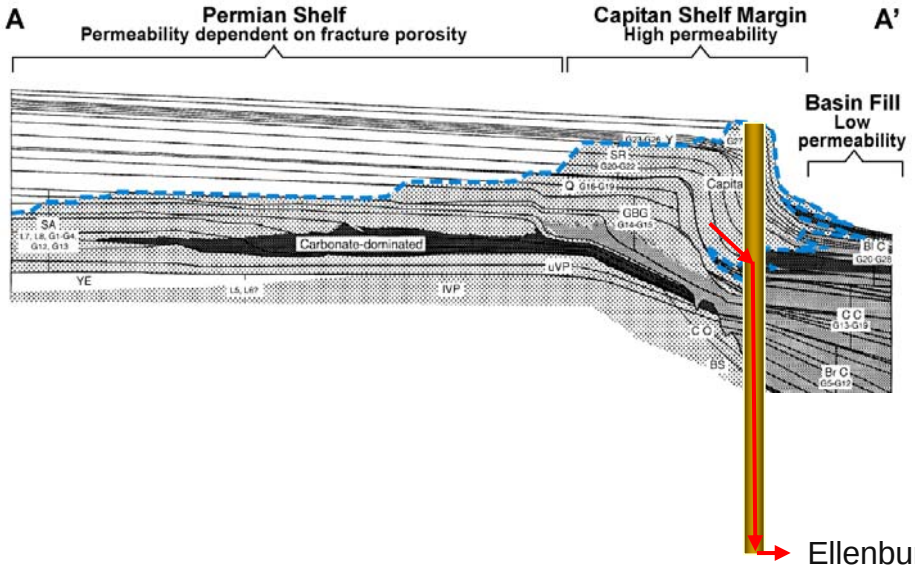


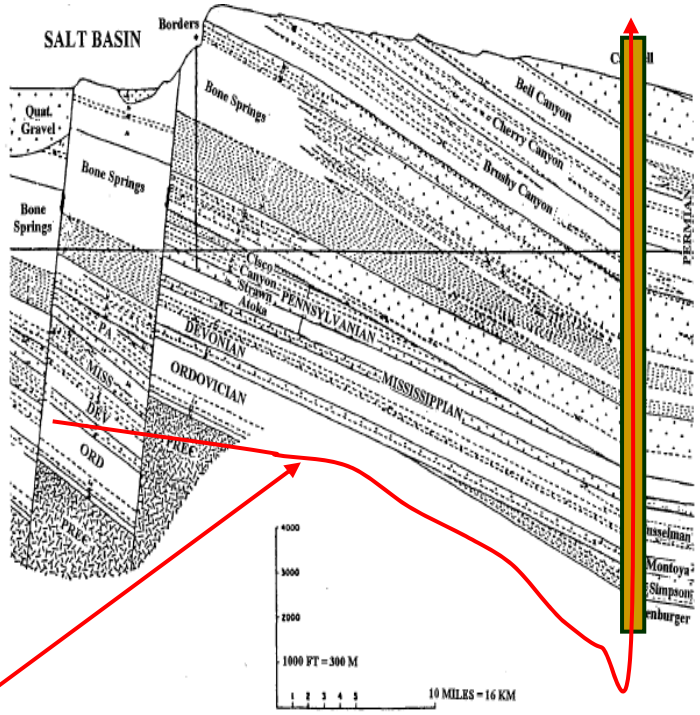


Geological and Reservoir understanding needed to connect these two sources – Water to Heat

Conversion to Heat Sources from Hydrocarbon Production – Feasible?

Multi-well developments from existing Gas Producers





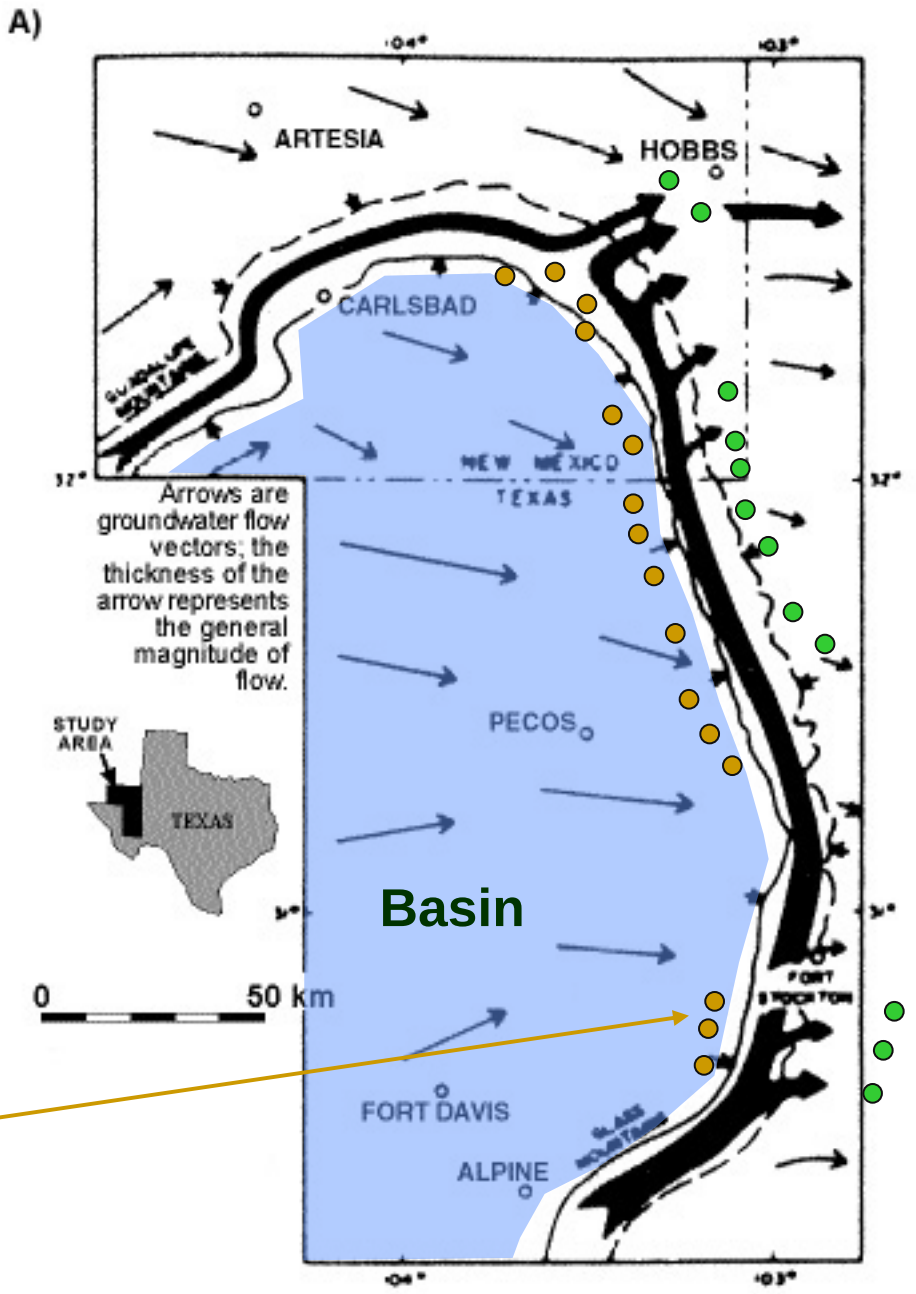
Fractured Inter-well System is natural and can be developed extensively by hydraulic stimulation technology

Temp > 250 F

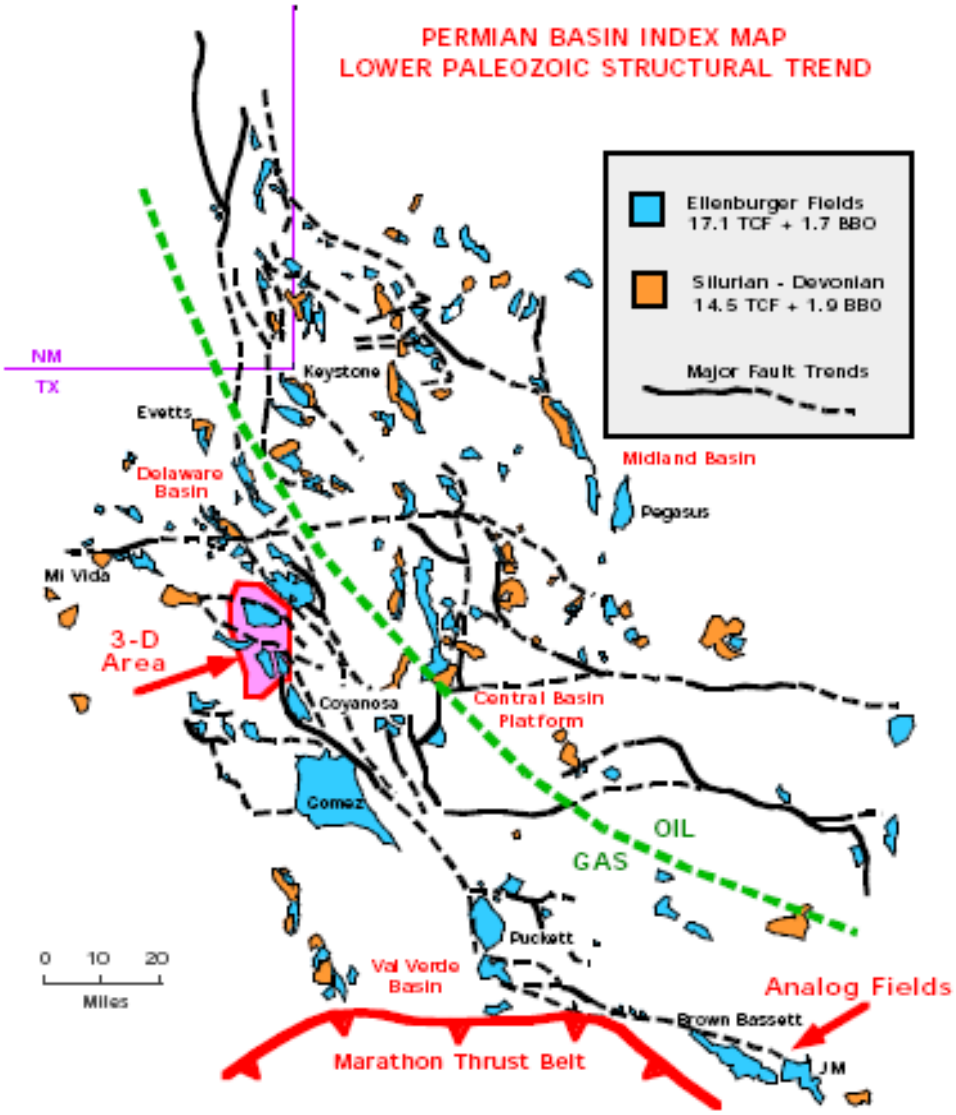
Capitan Reef water production and losses

8.5 ppg load will flow to surface

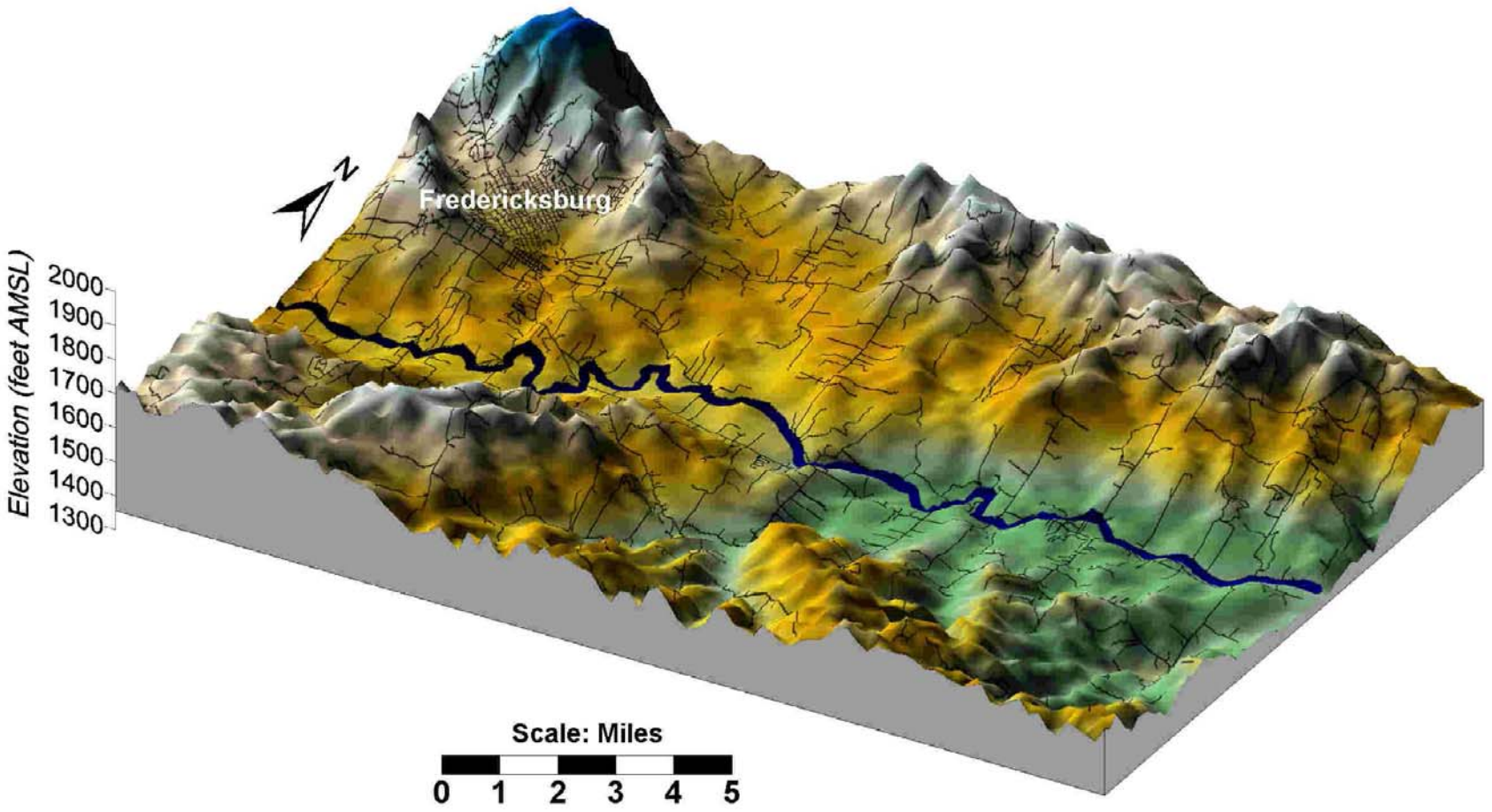
10.0 ppg load will have a loss into the Reef on a vacuum



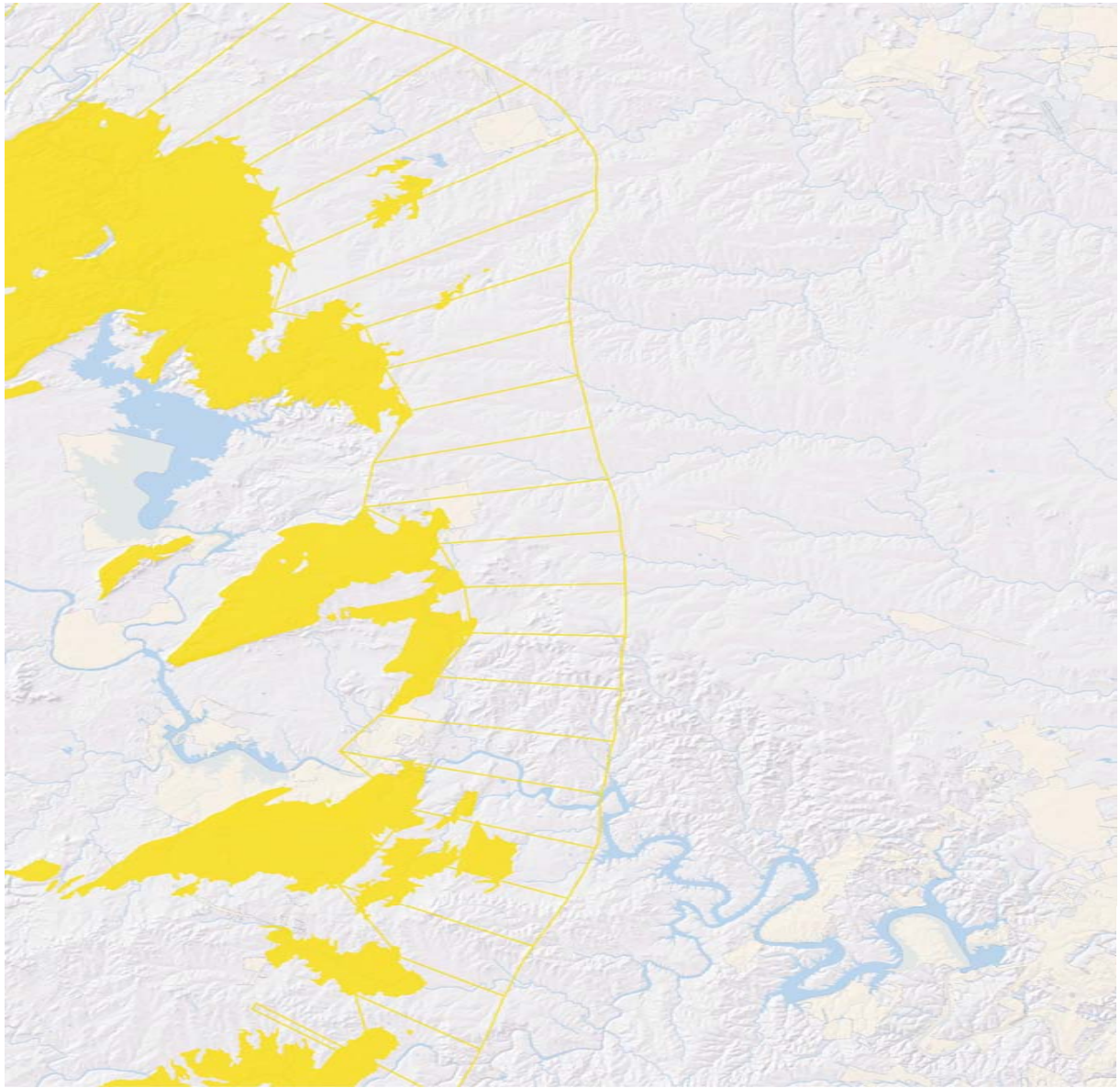
Permian Basin Index map showing 3-D study area and analog fields.



Groundwater Availability Model for the Ellenburger Aquifer in Southeast Gillespie County, Texas



ELLENBURGER AQUIFER
Central Texas GCD



Production Enhancement - Biggest CO_2 Frac