Estimate of Geothermal Energy Resource in Major U.S. Sedimentary Basins*

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Abstract

Recently, there has been renewed interest in recovering the geothermal energy stored in sedimentary basins for electricity production. Because most sedimentary basins have been explored for oil and gas, well logs, temperatures at depth, and reservoir properties are known. This reduces exploration risk and allows development of geologic exploration models for each basin as well as a relative assessment of geologic risk elements for each play. This study estimates the magnitude of recoverable geothermal energy from fifteen major known sedimentary basins in the United States and ranks these basins relative to their potential. The total available thermal resource for each basin was estimated using the volumetric heat-in-place method originally proposed by Muffler (1978) (USGS), and a recovery factor was used to estimate the size of the recoverable thermal resource.

Total sedimentary thickness maps, stratigraphic columns, cross sections, and temperature gradient information was gathered for each basin from published articles, USGS reports, and state geological survey reports. When published data was insufficient, thermal gradients and reservoir properties were derived from oil and gas well logs obtained on oil and gas commission websites. Basin stratigraphy, structural history, and groundwater circulation patterns were studied in order to develop a model that estimates resource size, temperature distribution and a probable recovery factor. The resource estimate will be used to develop an alternative sedimentary basin supply curve.

Reference

Muffler, L.P.J., and R. Cataldi, 1978, Methods for regional assessment of geothermal resources: Geothermics, v. 7, p. 53-89.

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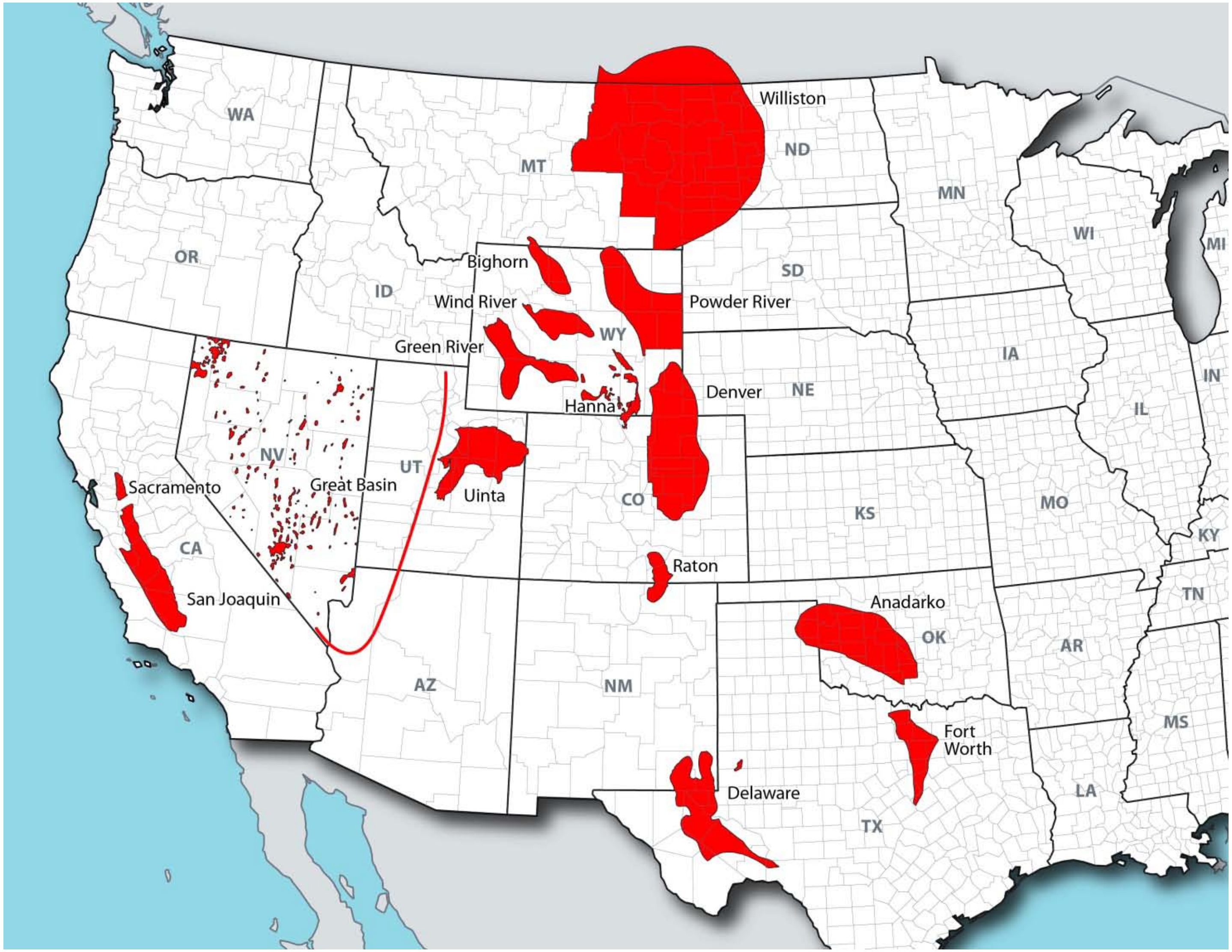
WHAT IS SEDIMENTARY BASIN GEOTHERMAL?

Geothermal Energy from Sedimentary Rock

- Using ‘hot” geothermal fluids (>100^{o}C) produced from sedimentary basins to generate electricity
- Advantages:
  - Reservoirs are porous, permeable, and well characterized
  - Known/proven temperature gradients from oil and gas well records
  - Drilling and reservoir fracturing techniques proven in sedimentary environment
- Disadvantages:
  - Great depths required to encounter high temperatures
  - Emerging industry

SEDIMENTARY BASINS CONSIDERED IN STUDY



- Anadarko
- Bighorn
- Denver
- Ft. Worth
- Green River
- Great Basin
- Hannah
- Delaware/Pm
- Powder River
- Raton
- Sacramento
- San Joaquin
- Uinta
- Williston
- Wind River

GOALS AND METHODOLOGY

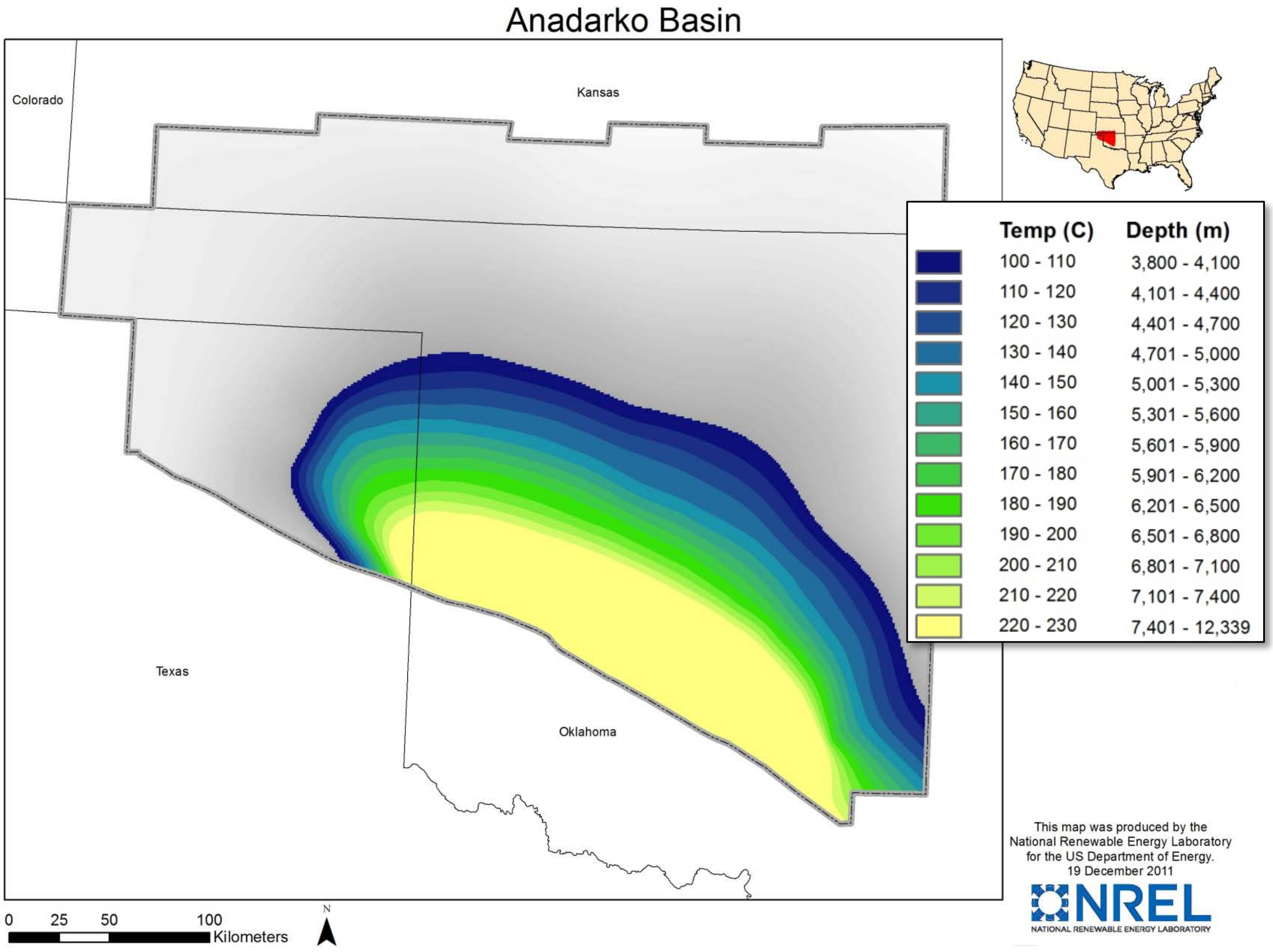
Provide an initial estimate of Sedimentary Basin geothermal resources in the US:

1. Preliminary review of major sedimentary basins in US
2. Delineate and map areal extent and depth contours of each basin in GIS
3. Estimate temperature profile for each basin (assume single temperature gradient for each basin)
4. Calculate basin volume as a function of temperature
5. Convert volumes to heat in place and electricity generation potential

APPROACH

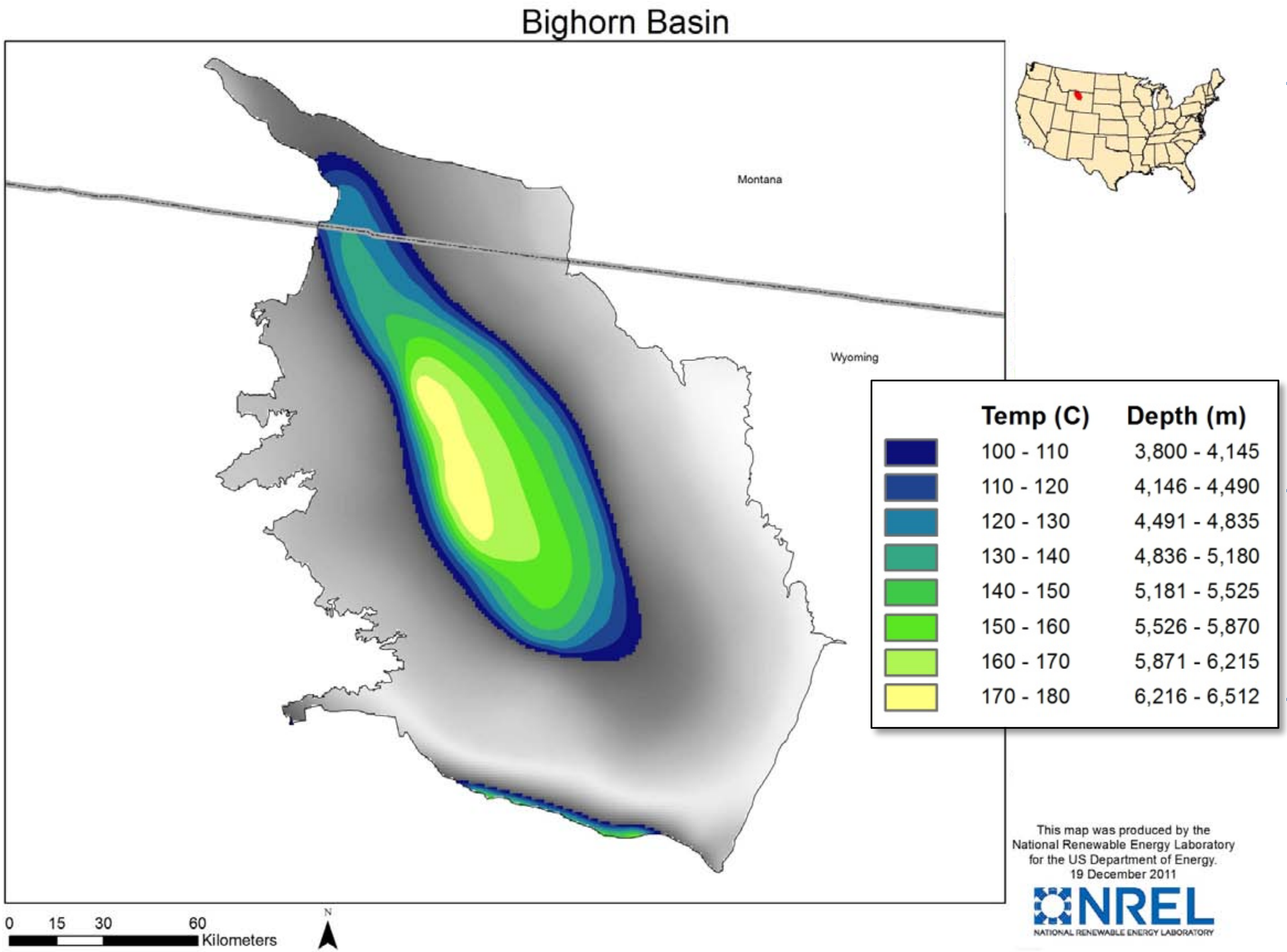
1. Literature search for all known deep sedimentary basins.
2. Gathered published information on:
   - Basin lithology – stratigraphic column
   - Structural cross-sections (USGS & AAPG)
   - Depth to basement maps (AAPG, USGS, other publications)
   - Temperature logs, thermal profiles & BHTs from the basin's deepest wells (State Geological Surveys and Oil & Gas Commissions)
   - Production rates and reservoir properties
   - Hydrologic potentiometric maps (USGS – Water Resources)
   - Hottest documented downhole temperature in each basin (State GS & AAPG)
   - Previous geothermal assessments (State GS & DOE)
3. Applied Kehle temperature correction to downhole temperatures.
4. Estimated thermal resource in-place using reservoir volume, assuming constant rock density and heat capacity.
5. Developed qualitative thermal recovery factor for each basin.

SEDIMENTARY BASIN MAPS



- Developed maps of basins showing regions with temperature >100°C (212°F)
- Single temperature gradient assumed
- Color shading indicates depth to given temperature interval

SEDIMENTARY BASIN MAPS



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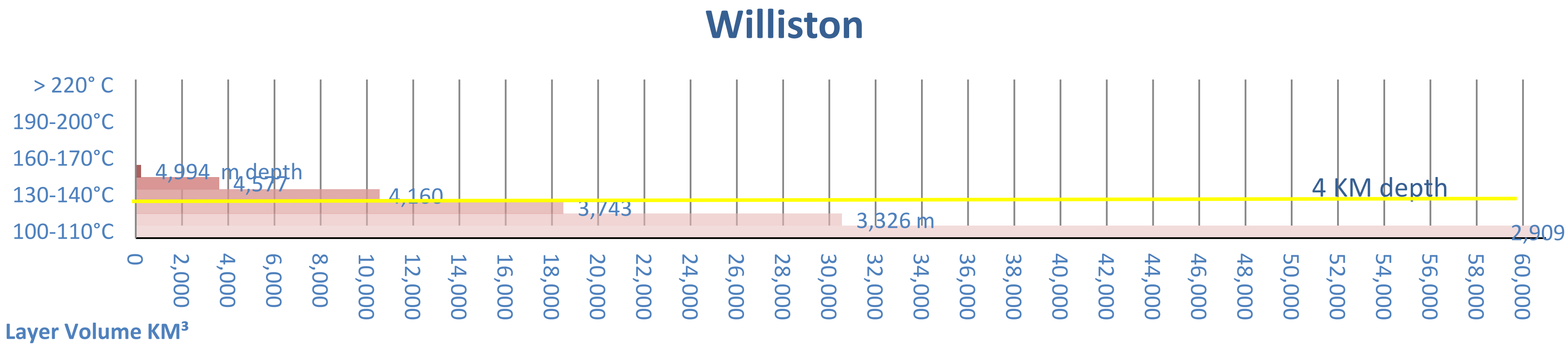
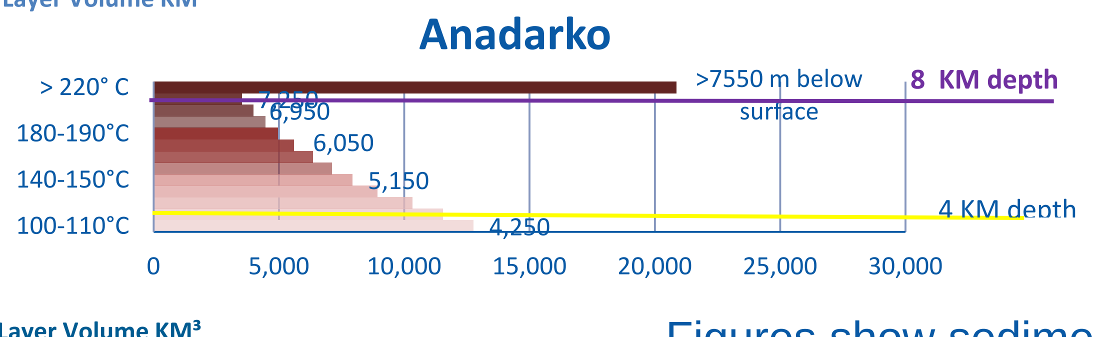
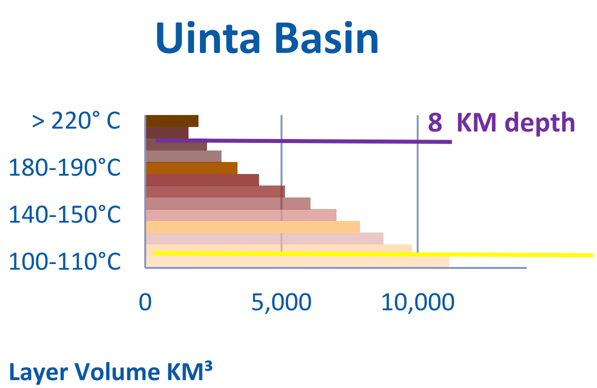
SEDIMENTARY BASIN VOLUME VS. TEMPERATURE

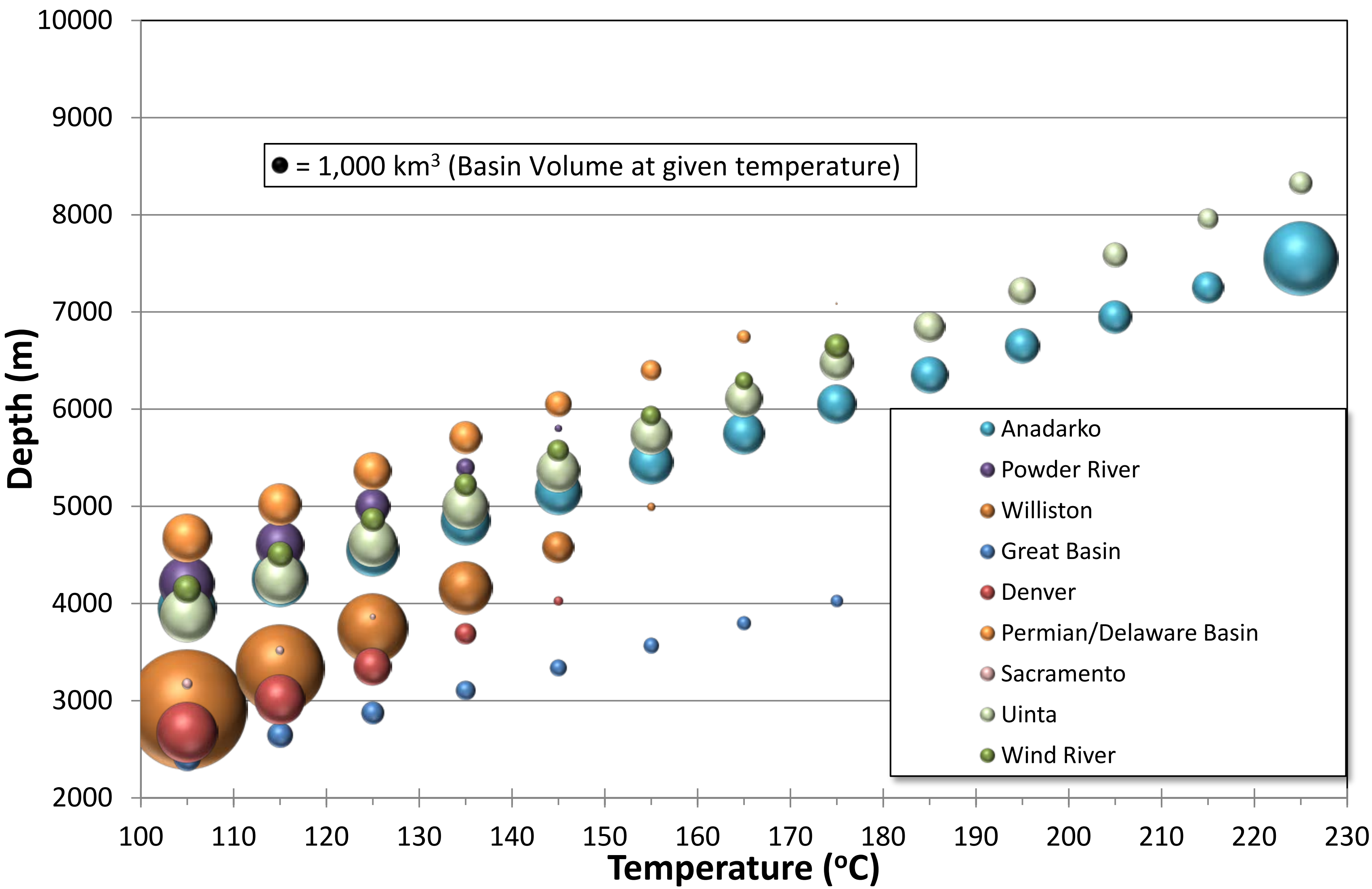




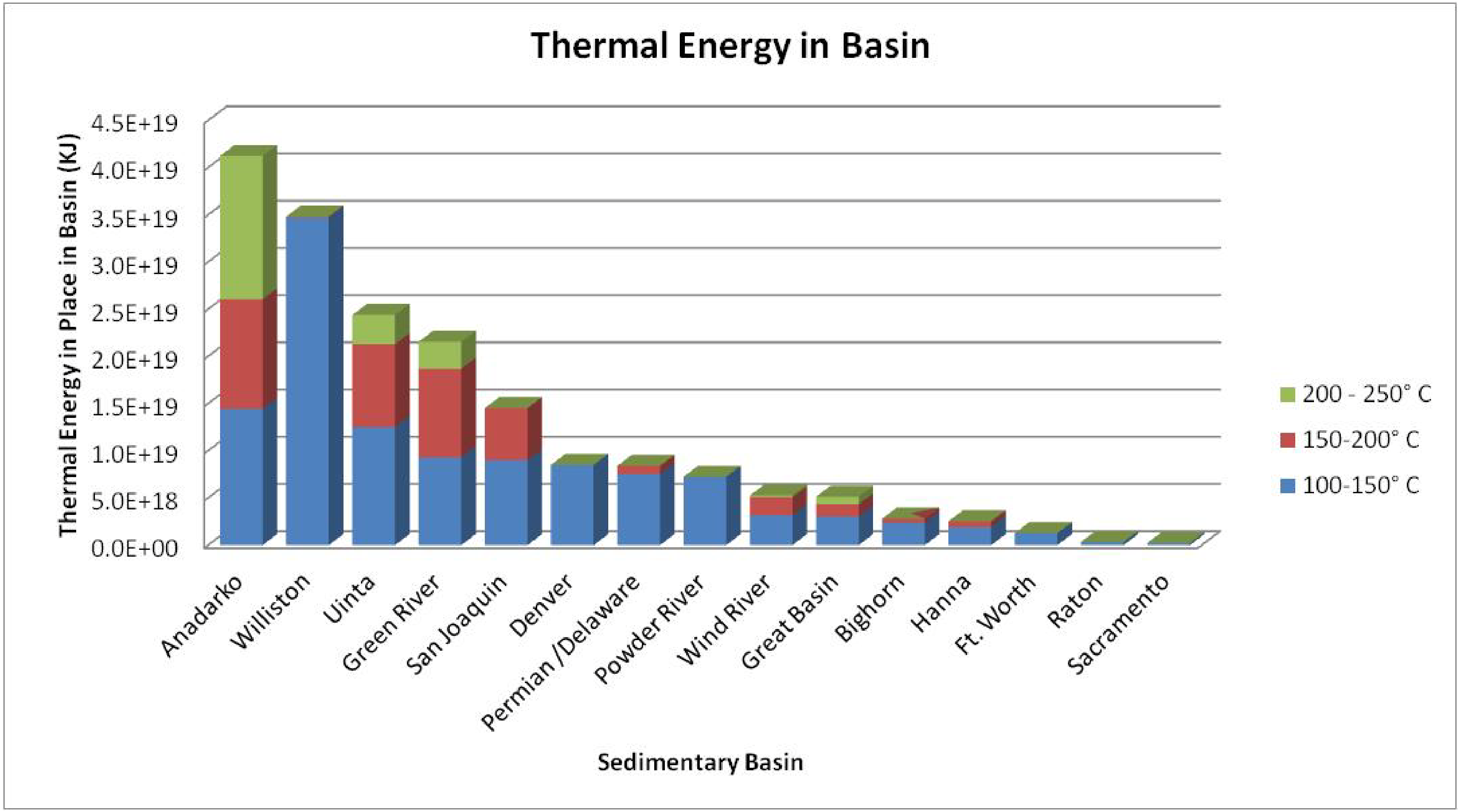


- Figures show sedimentary basin volumes vs. temp
  - Roughly match basin profiles
  - Figures have identical scale so that comparisons of relative volume of basins can be made
- Great variability among basins
  - Thermal energy in place function of temperature and volume
  - Williston is large, but relatively cool vs. Anadarko, which is smaller but at significantly higher temperatures

SEDIMENTARY BASIN VOLUME VS. TEMPERATURE AND DEPTH



THERMAL ENERGY IN-PLACE (KJ) BY BASIN



- Thermal Energy in place includes thermal energy in both rock and pore fluids
- Majority of thermal energy in sedimentary basins is at relatively low temperatures (100-150^{o}C)

RESERVOIR PRODUCTIVITY

Converting thermal energy in place estimate to electricity generation potential requires knowing thermal recovery factor (amount of thermal energy that can be produced) for reservoir, but…

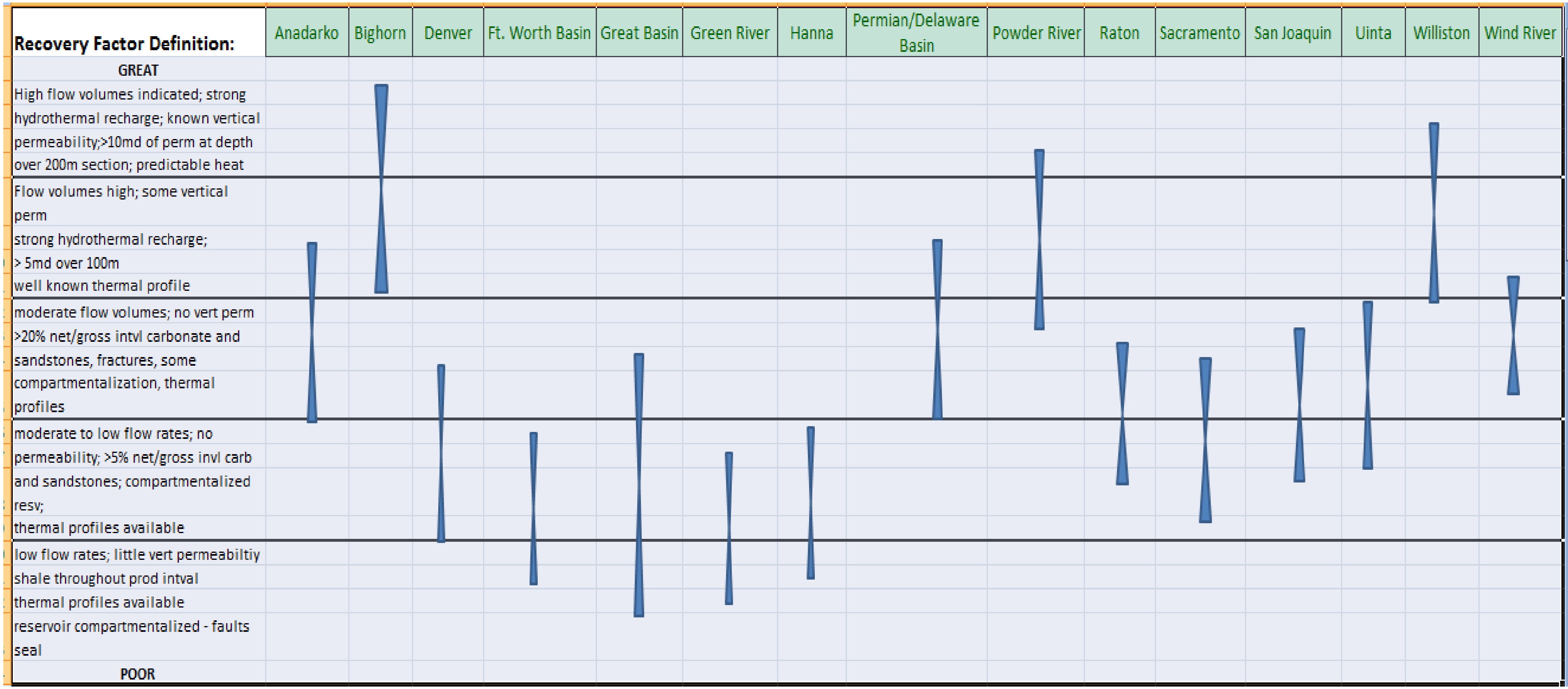
- Recovery factors for geothermal rarely published
- Little previous work/data on recovering geothermal fluids (brine) from sedimentary basins
- Reservoir stimulation or fracturing techniques could significantly increase the amount of fluid that can be recovered from a reservoir compared to its “natural” reservoir productivity

Instead, assessed reservoir productivity by creating a matrix that correlated reservoir productivity to measurable geologic conditions

RESERVOIR PRODUCTIVITY

Qualitative Reservoir Productivity			
GOOD			
Flow Volume	**Hydrothermal Recharge**	**Vertical Permeability**	**Horizontal Permeability**
High flow volumes proven	Strong hydrothermal recharge	High vertical permeability	>10md permeability over 200m interval
High flow volumes indicated	Strong hydrothermal recharge	Some vertical permeability	> 5md permeability over 100m interval
Moderate flow volumes	Fractures, some compartmentalization	Little vertical permeability	>20% net/gross interval carbonate and sandstones
Moderate to low flow volume	Reservoir compartmentalized	Little vertical permeability	>5% net/gross interval carbonate and sandstones
Low flow volume	Reservoir compart-mentalized w/ sealing faults	No vertical permeability	Shale throughout producing interval
POOR			

RESERVOIR PRODUCTIVITY BY BASIN



- Reservoir productivity for each basin qualitatively estimated based on literature review of basin properties
- Each basin has geologic properties that indicate a range of reservoir productivity over expected depths
- Known variation throughout each basin generally indicated large range in expected reservoir productivity

RESULTS AND CONCLUSIONS

Sedimentary Basin Geothermal

- 15 Sedimentary basins were studied to estimate the magnitude of this resource
  - Created maps of basin temperature profiles
  - Estimated thermal energy in place for each basin
  - This is a 'first look' – basin properties were averaged across large areas and more detailed studies are needed to refine estimates
- Overall resource potential is large
  - Thermal energy in place in sedimentary basins is substantial
  - Majority of thermal energy is at relatively low temperatures (100-150^{o}C), but high temperature regions have been identified
- Electricity generation potential depends on thermal recovery factor
  - Currently, little data exists on this for sedimentary basins
  - Qualitatively assessed reservoir productivity for each basin
  - Reservoir productivity varies significantly across basins. Also expected to have sizable variation within a given basin.
  - Thermal recovery factor should be correlated with reservoir productivity, but reservoir stimulation/fracturing techniques could significantly increase amount of geothermal fluid that could be recovered – more study needed.

THANK YOU!

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