North American Power Group, Ltd.

Two Elk Energy Park Carbon Site Characterization Study

DOE NETL Meeting February 3-4, 2010

February 3, 2010

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NAPG Background and Commitments

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- North American Power Group, Ltd. is a privately held small business formed in 1992. NAPG develops, manages and operates renewable and fossil electric power generation. With its western heritage and as a full member of the Western Electricity Coordinating Council, NAPG recognizes the importance of developing, advancing and integrating all forms of energy and transmission infrastructure, including CO_2 for beneficial use or sequestration, to meet our commitments to:
  - use the earth's resources responsibly
  - use best practices and technologies to reduce our impact on air, land and water
  - demonstrate that we can and will protect the value of the environment and social resources
  - demonstrate that our host communities will share in our success

Two Elk Energy Park

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- NAPG is developing the Two Elk Energy Park in the Powder River Basin. The Energy Park is a planned series of renewable and other electric power generation, carbon capture, sequestration and related facilities.
- The initial Energy Park development is located within an 880-acre site immediately adjacent to the top three largest mines in the United States, together supplying over 20 percent of U.S. coal production.

Two Elk Project Location

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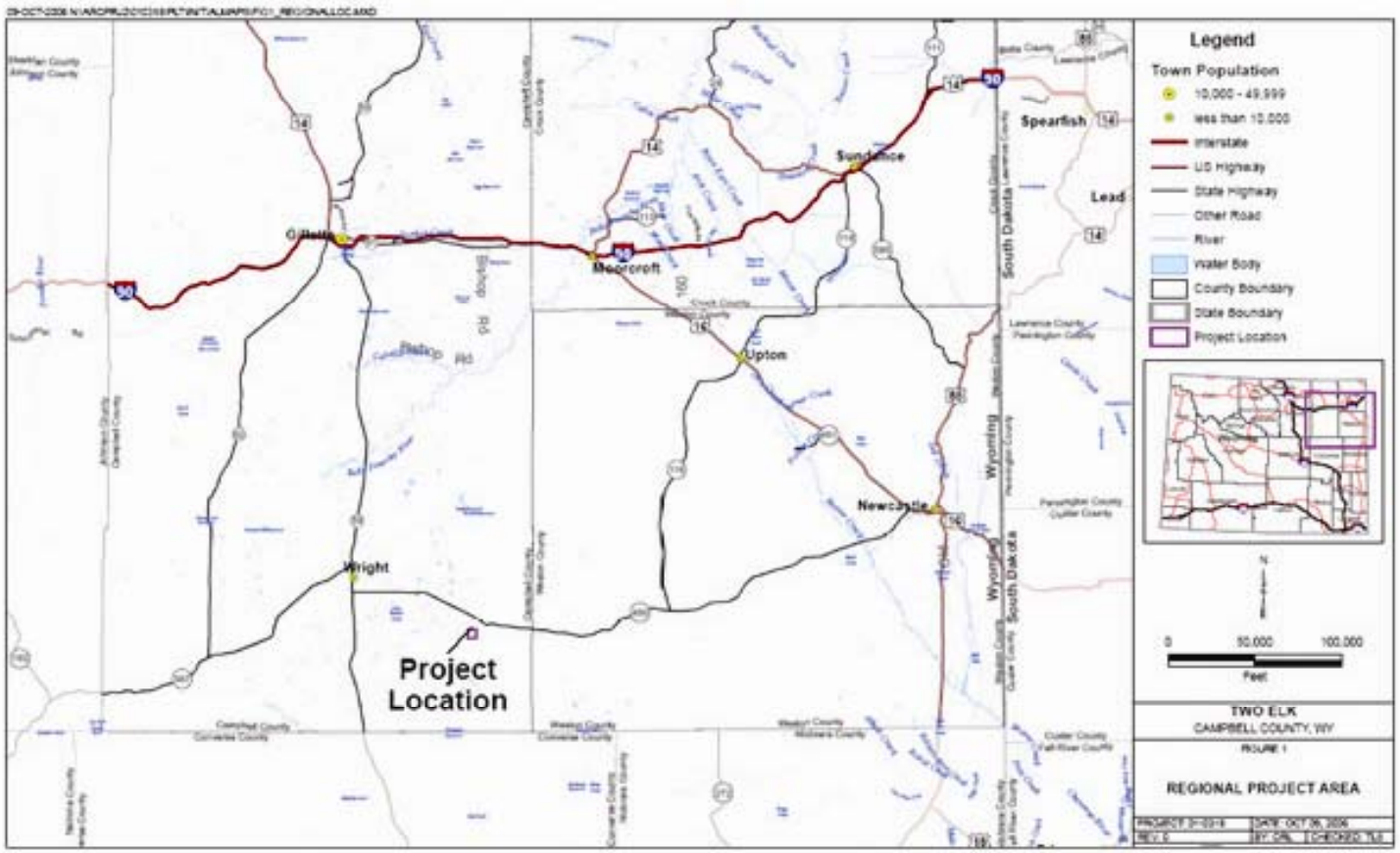

Unique Site Features

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- The initial Energy Park site is a mine-mouth location next to the first, second and third largest coal mines in the United States
- Wyoming is a leader in carbon sequestration and storage legislation
- Over 300 oil reservoirs suitable for immediate enhanced oil recovery have been identified by DOE in the Carbon Sequestration Atlas as lying within a 90-mile radius. All recovered CO_2 will immediately be put to beneficial use in Enhanced Oil Recovery
- The Energy Park is directly on top of saline aquifers and lies nearby coal seams and other geologic formations similarly identified in the Carbon Atlas as having “high potential” for CO_2 sequestration. Site Characterization will determine which formations could be used for sequestration and the methodologies to do so
- The Powder River Basin and Energy Park Site are ringed by existing CO_2 point sources

Two Elk in Relation to Local Mines

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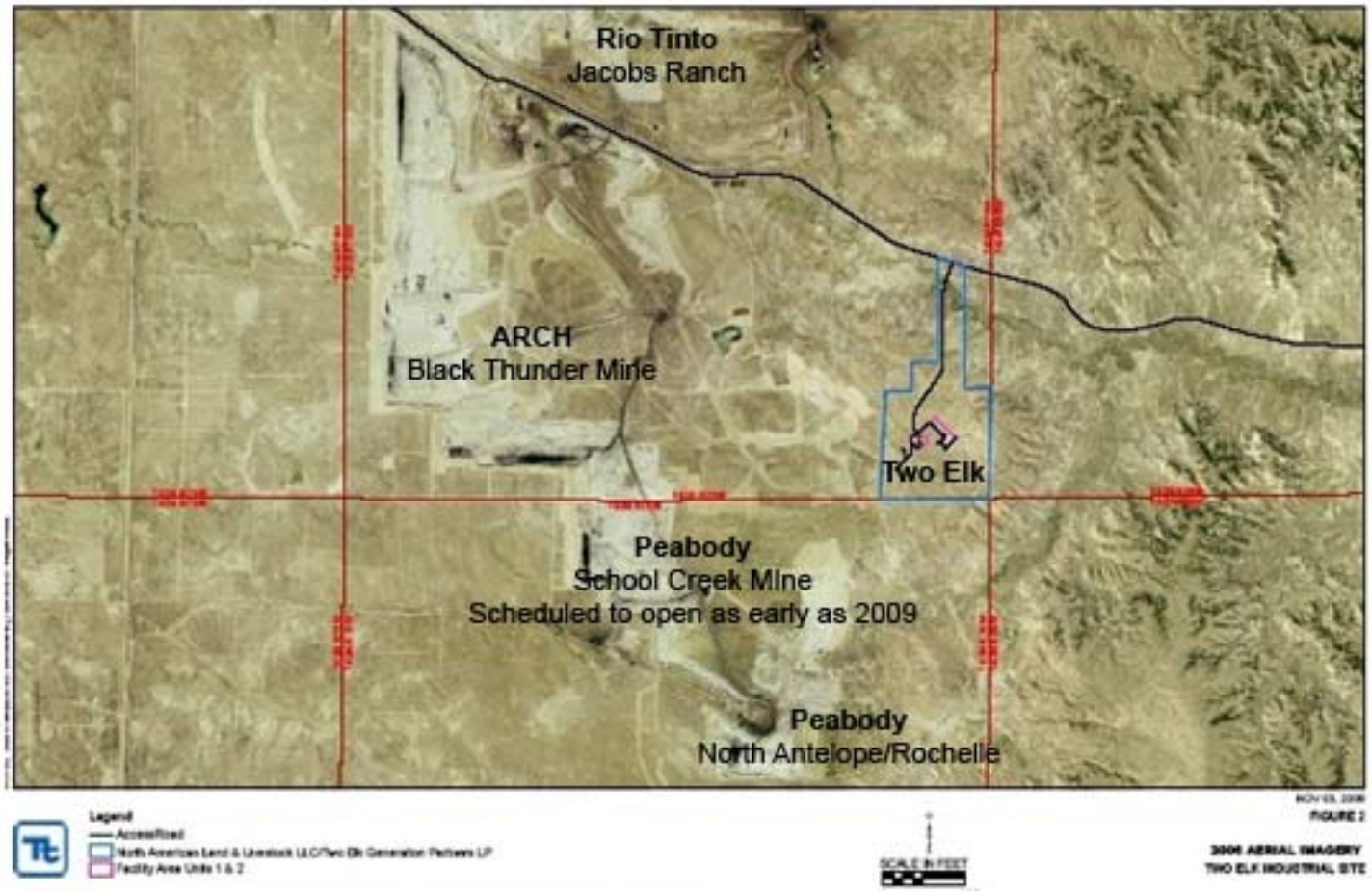

Existing CO_2 Utilization Locations

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Top CO_2 Reservoirs Around Two Elk

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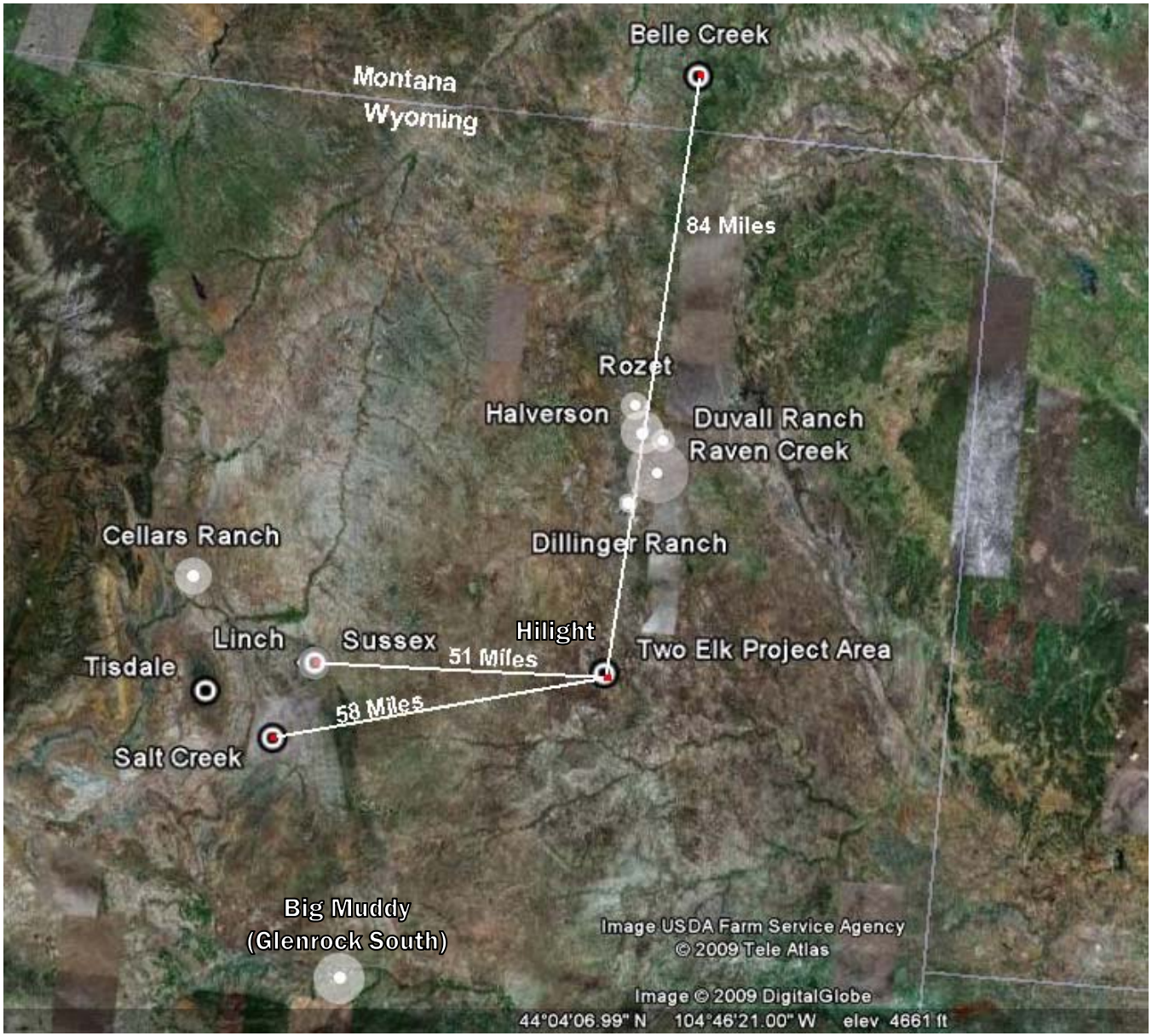

Existing Regional CO_2 Point Sources

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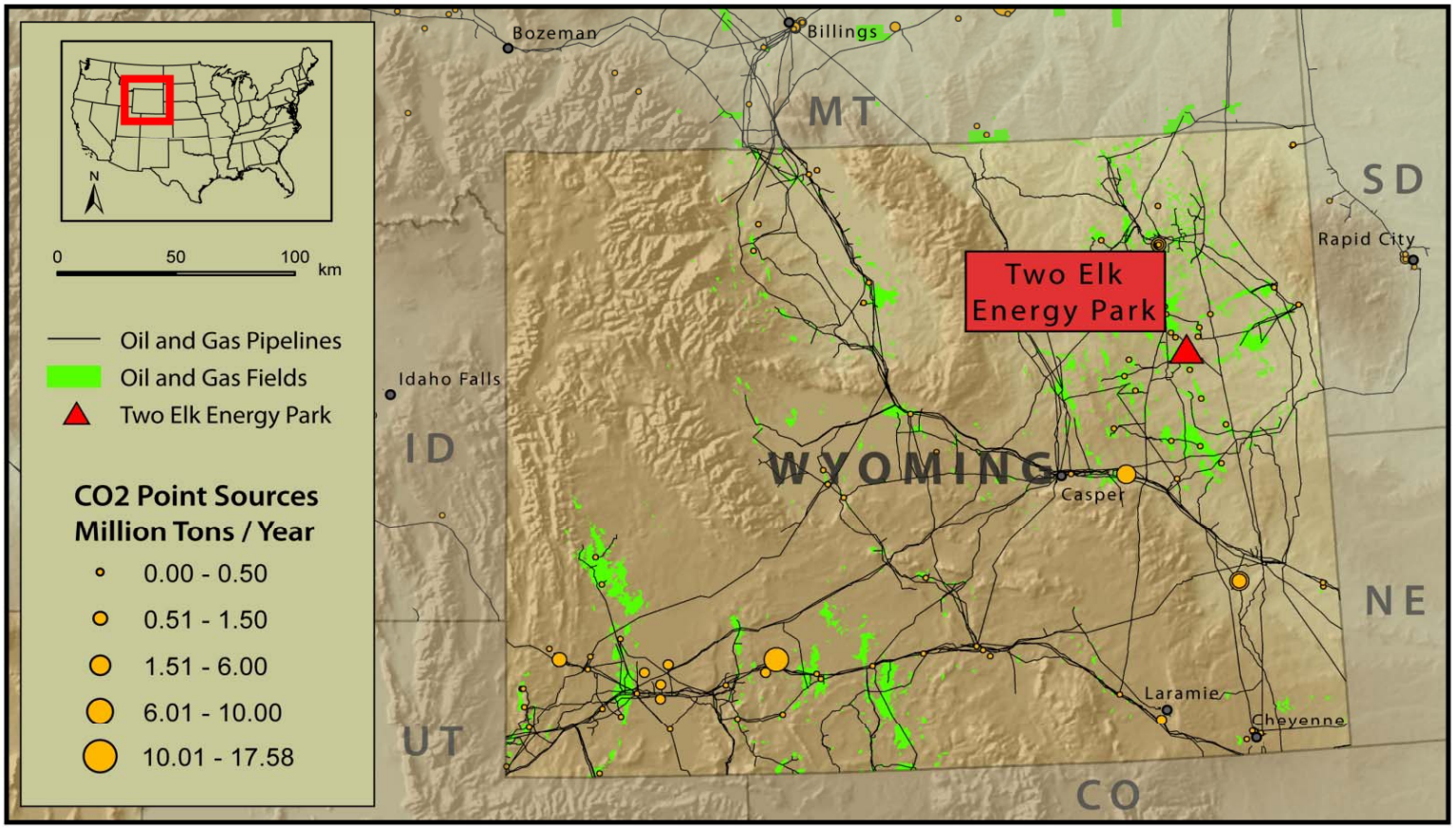

Major Structural Features of the Northern Rocky Mountain Region

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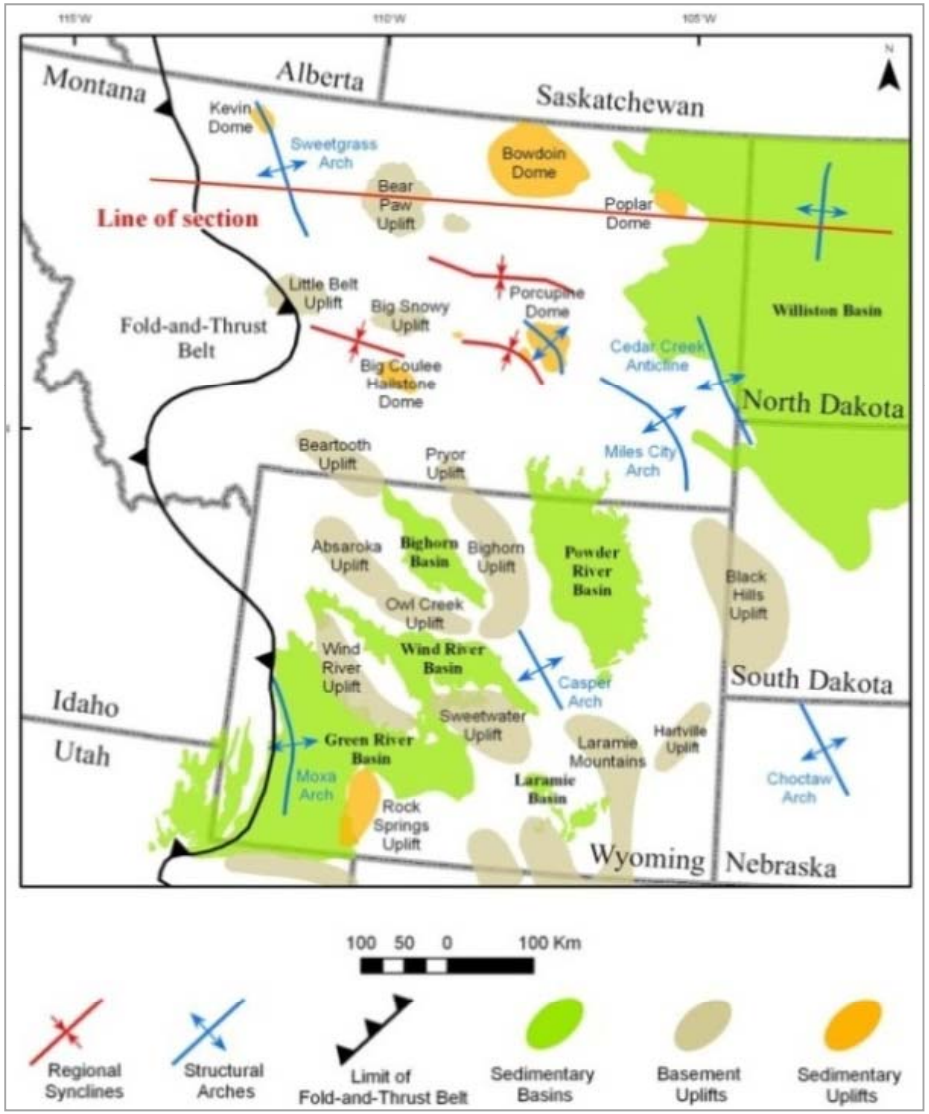
The Powder River Basin is a Laramide aged structural basin located in northeastern Wyoming. The basin is bounded by the Black Hills Uplift to the east, the Bighorn Mountains to the west , the Laramie Mountains and Hartville Uplift to the south, and the Miles City Arch to the north.



Isopach map of the thickness of sedimentary rocks

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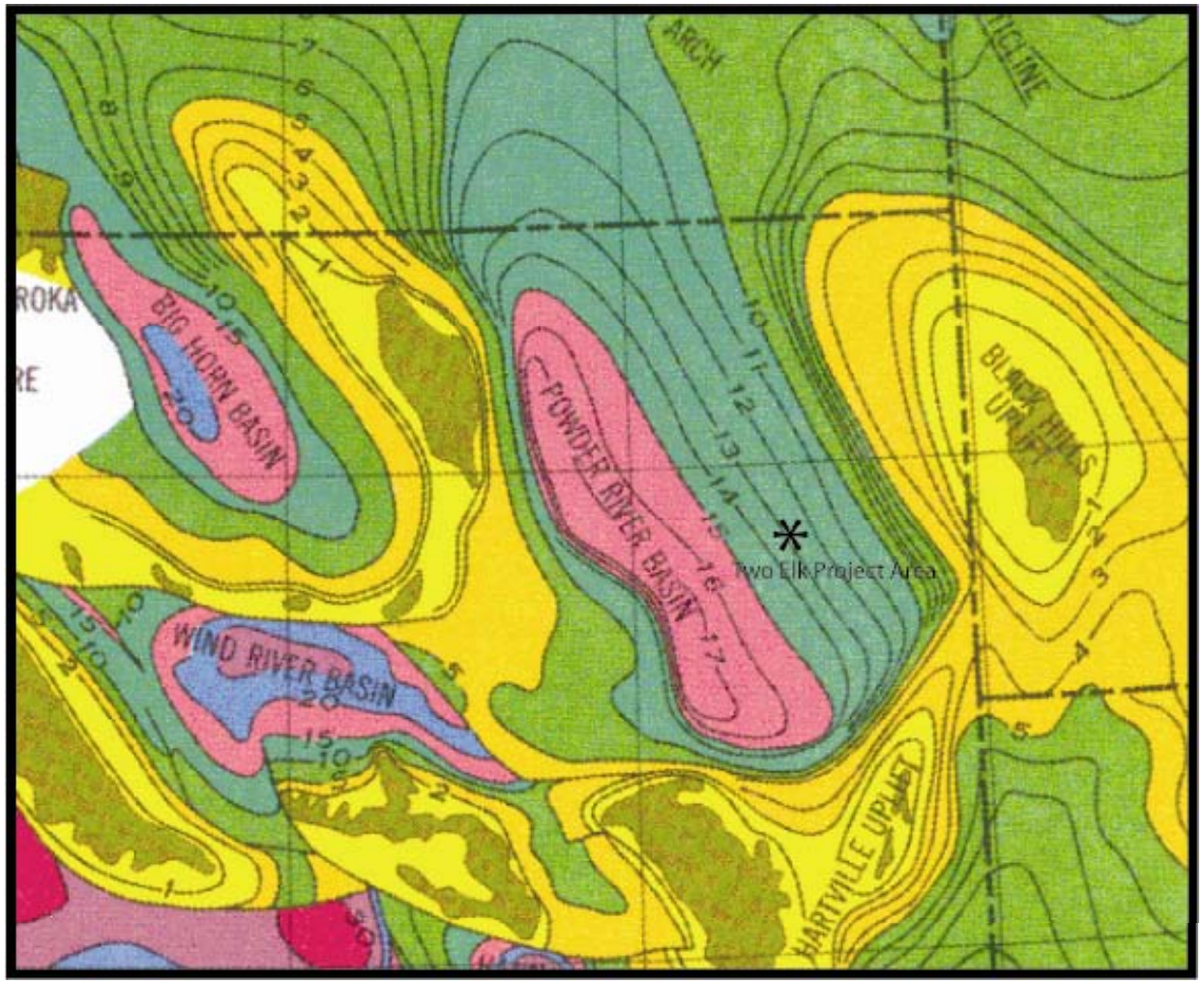
A thick package of sedimentary strata are present in the basin



Surface Outcrops of Major Aquifer Units

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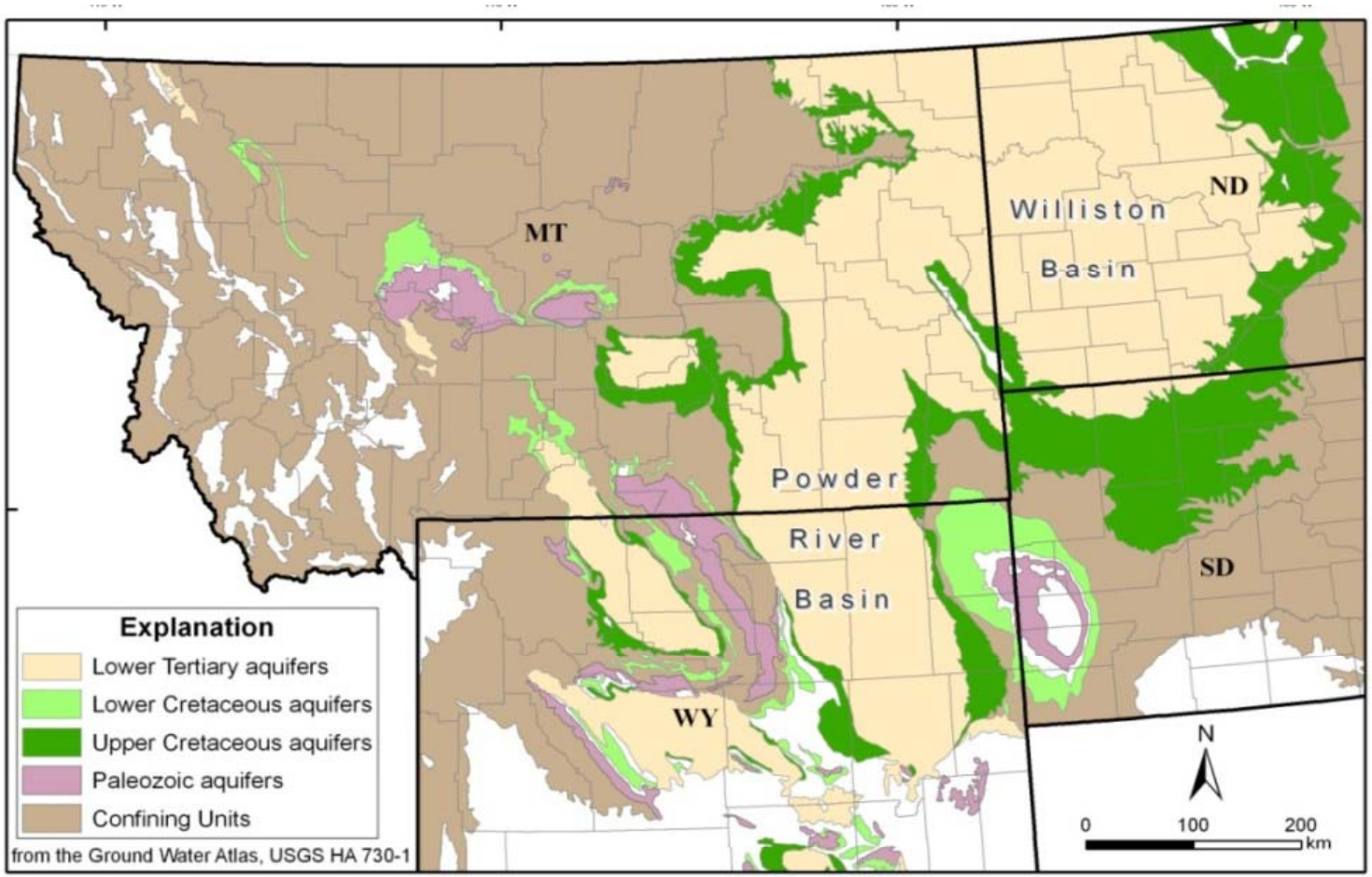
These same units outcrop in the surrounding mountain ranges.



Hydrostratigraphic Units Northern Great Plains Aquifer System

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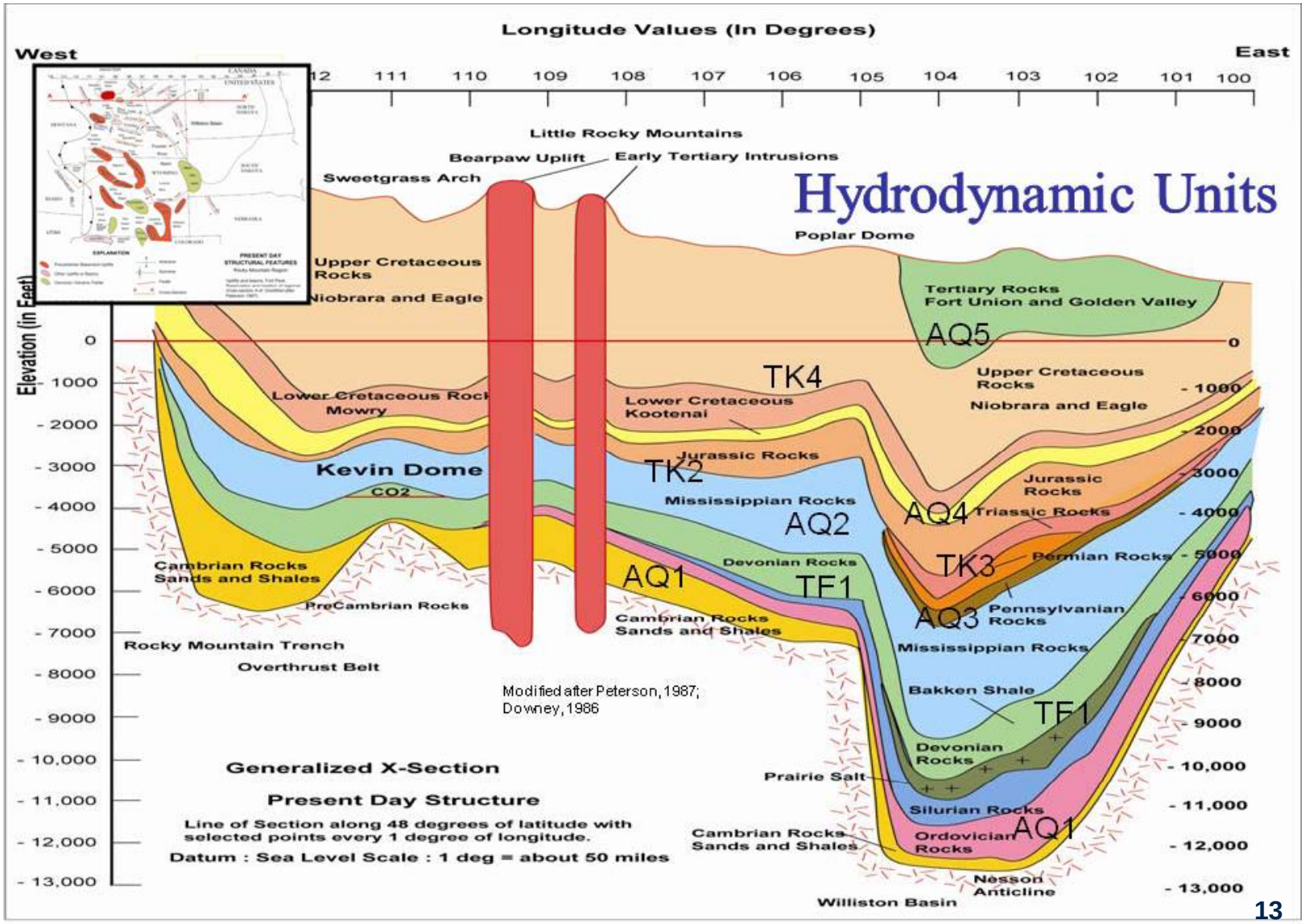
Regional Reservoir (AQ) and Tight Rock Formations (TF) exist.



Generalized cross-section, present day structure.

Stratigraphic Units in the Powder River Basin

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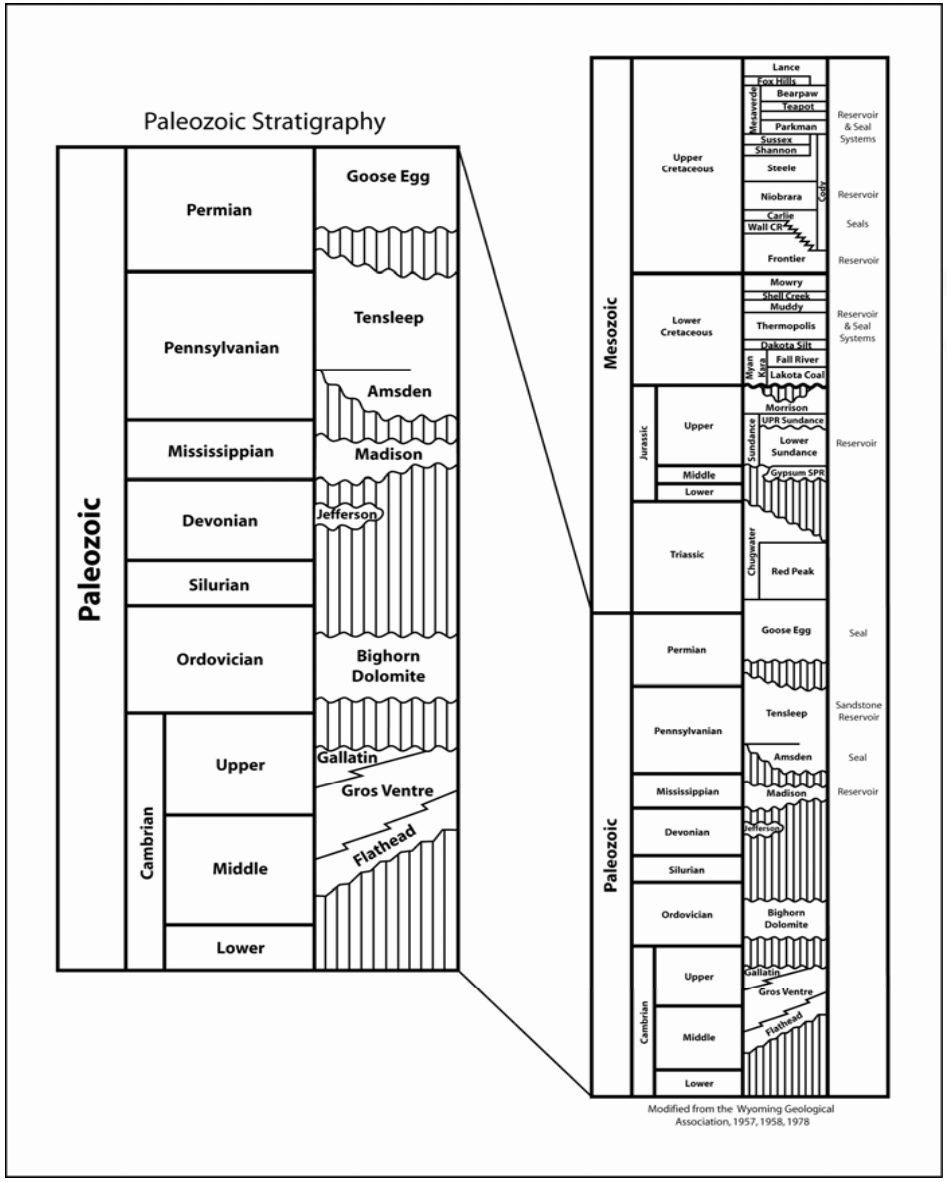

Structure Contour Map of the Precambrian Surface NE Wyoming

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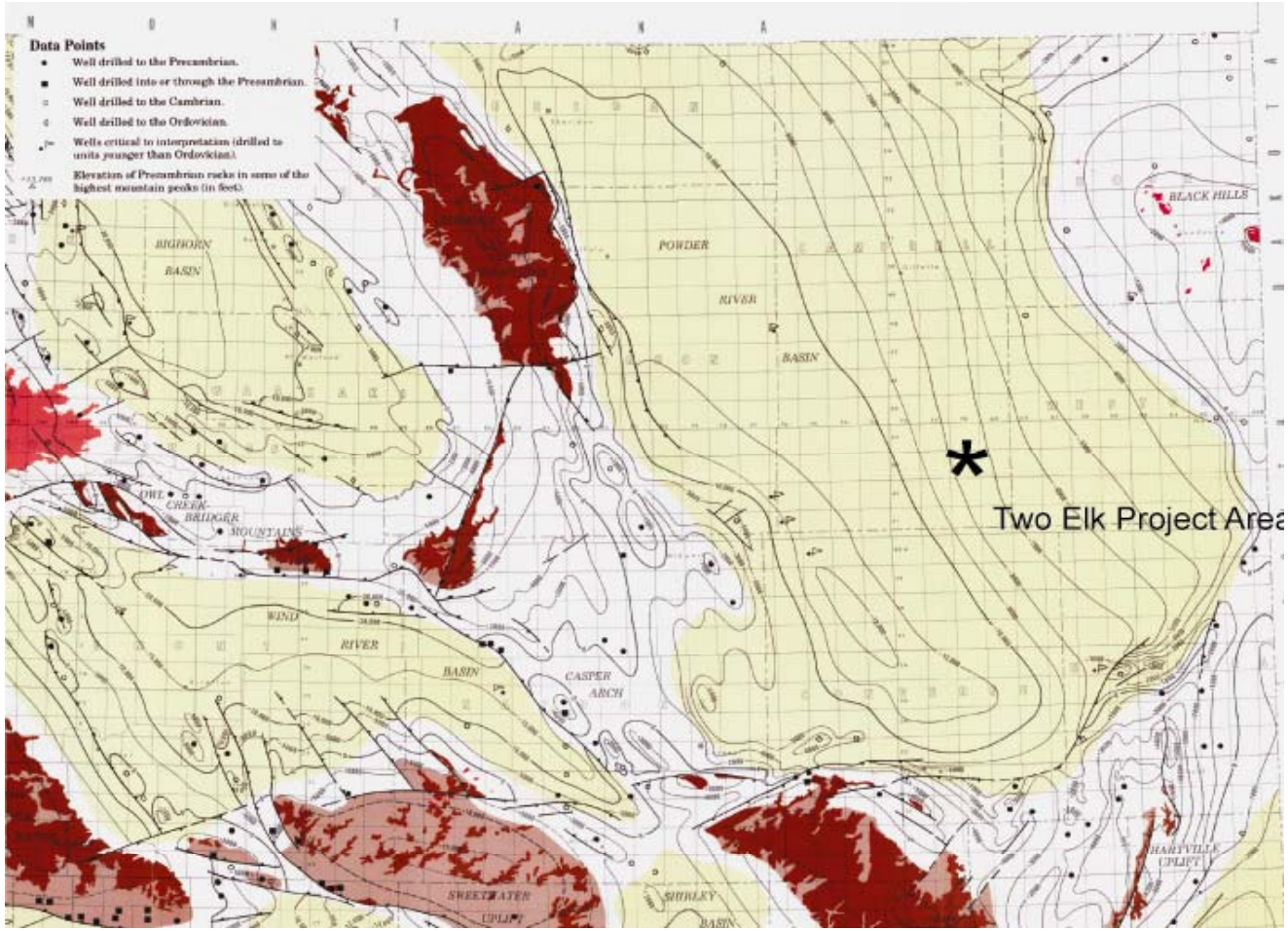
The Two Elk project area lies on the more gently dipping eastern flank of the Powder River Basin.



Coal Fields of the Powder River Basin

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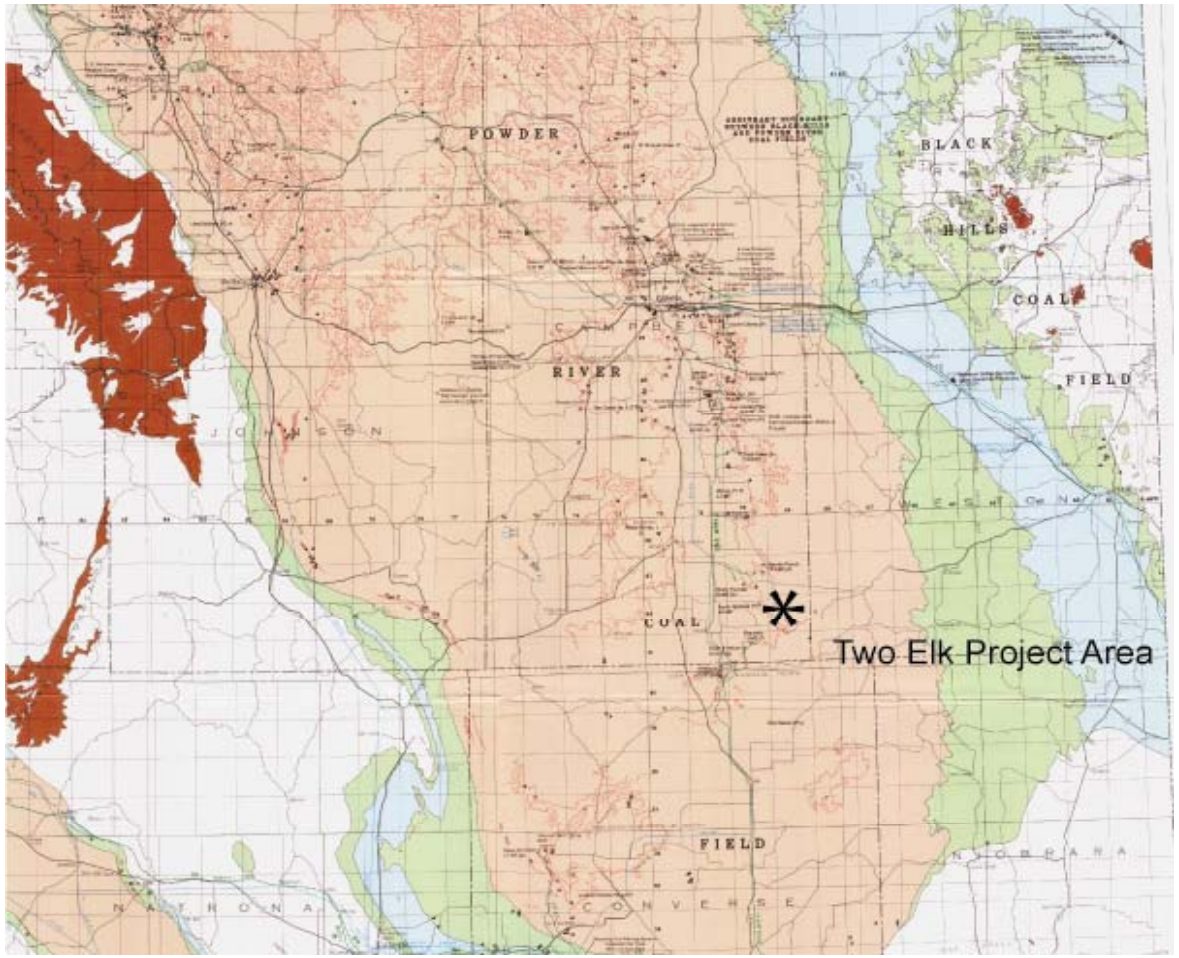
The Powder River Basin is a major coal bed methane producing area, ECBM may be a viable consideration for sequestration as may sequestration into deeper unminable coal seams in the basin.



Oil and Gas Field of the Powder River Basin

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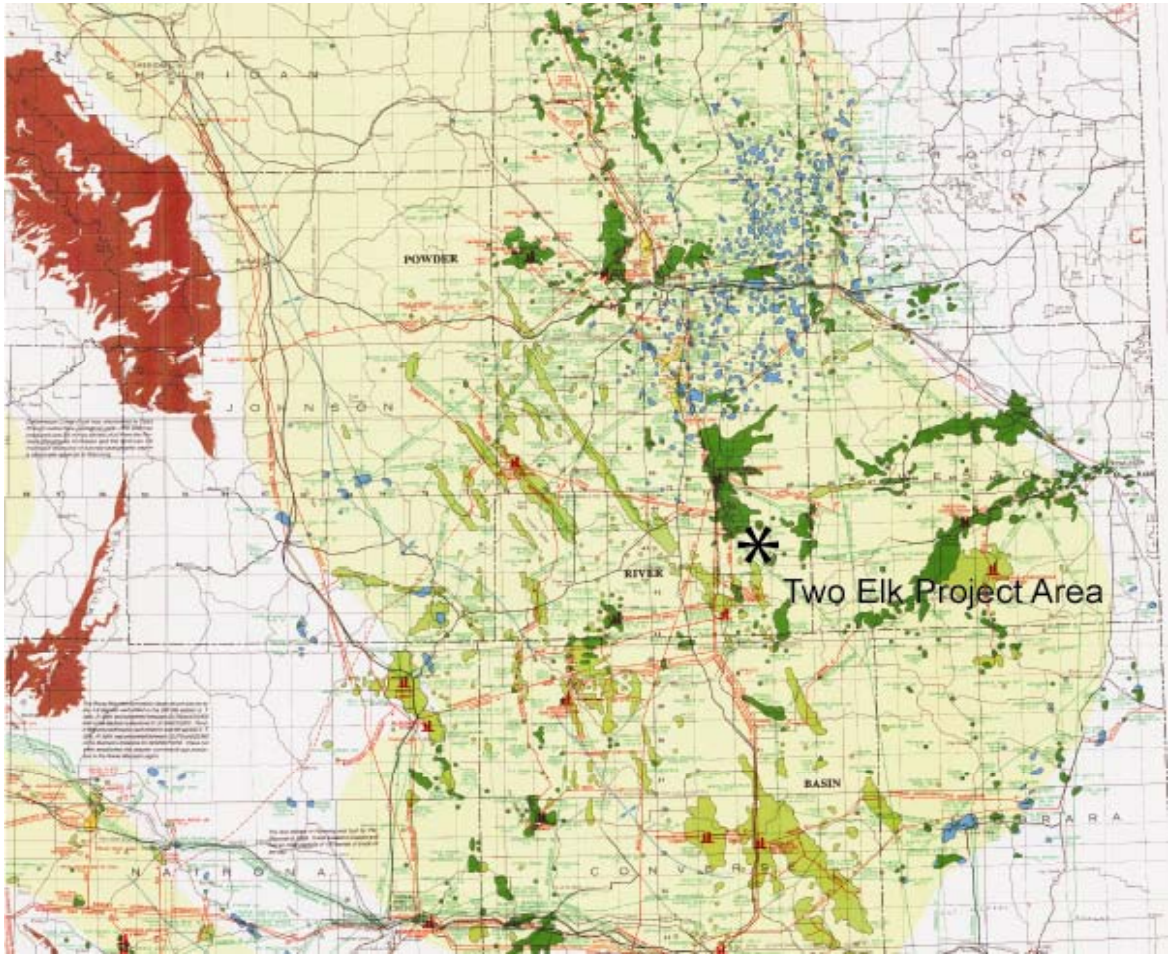
The Powder River Basin is a prolific oil and gas basin. Many of these oil fields are at a mature stage and are prime candidates for EOR using CO2. Two fields on the west flank of the basin are currently being flooded using CO2 and several other projects are under consideration.



Sedimentary Column of Study Area

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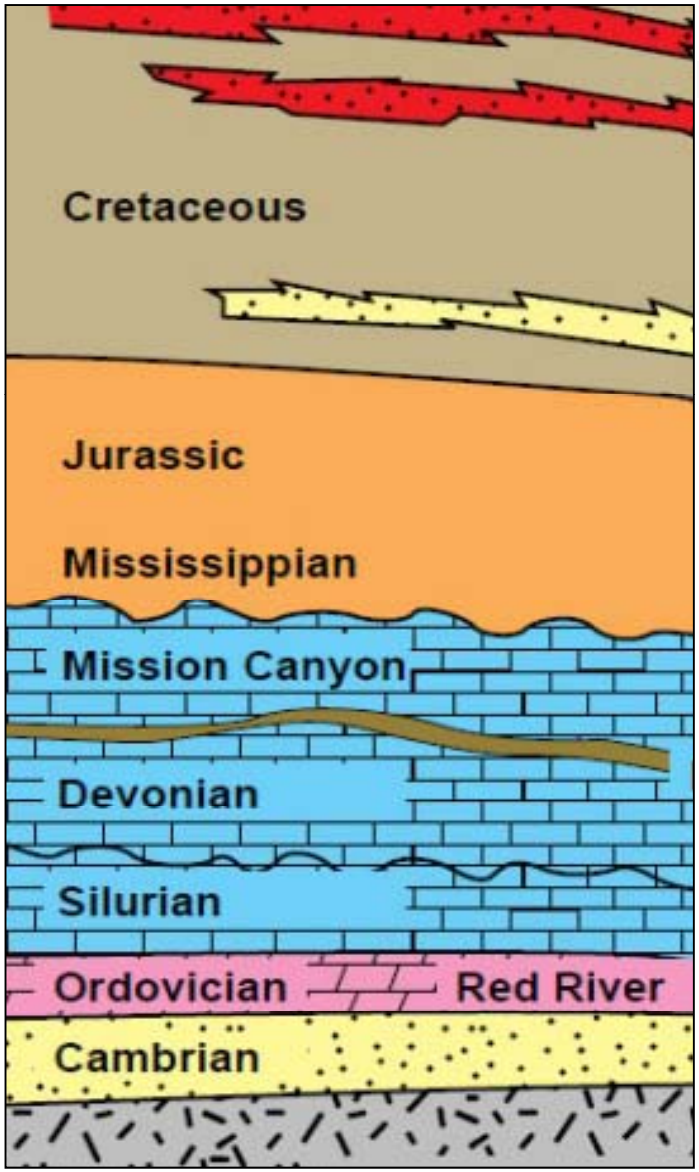
Most of the oil and gas reservoirs of the Powder River Basin are in Mesozoic Units with the exception of the Permian Minnelusa Formation. The deeper Paleozoic strata, potential saline aquifers, are dominated by limestone and dolostone.



Numerous wells have been drilled in the basin for oil and gas, however very few of these wells penetrate the Paleozoic carbonate rocks that lie below the oil and gas producing formations.

Saline Aquifer Sequestration

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- **Numerous wells have been drilled in the basin for oil and gas, however very few of these wells penetrate the Paleozoic carbonate rocks that lie below the oil and gas producing formations.**

- **The major questions for saline aquifer sequestration in the region are 1) what is the reservoir quality of these deeper units, and 2) what is the quality of the water in these saline aquifers**.

Water Quality Upper Paleozoic Aquifers

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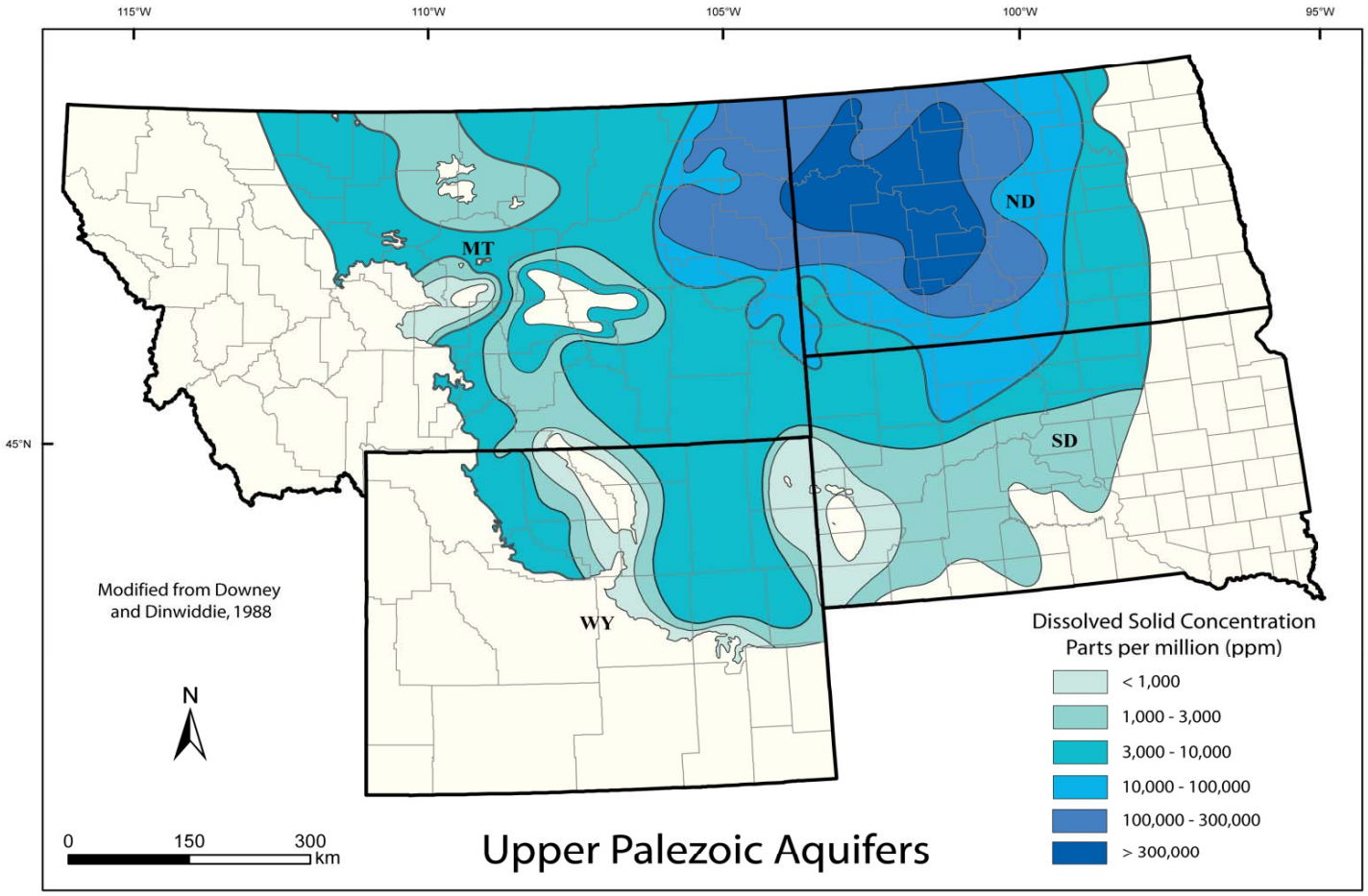

Water Quality Lower Paleozoic Aquifers

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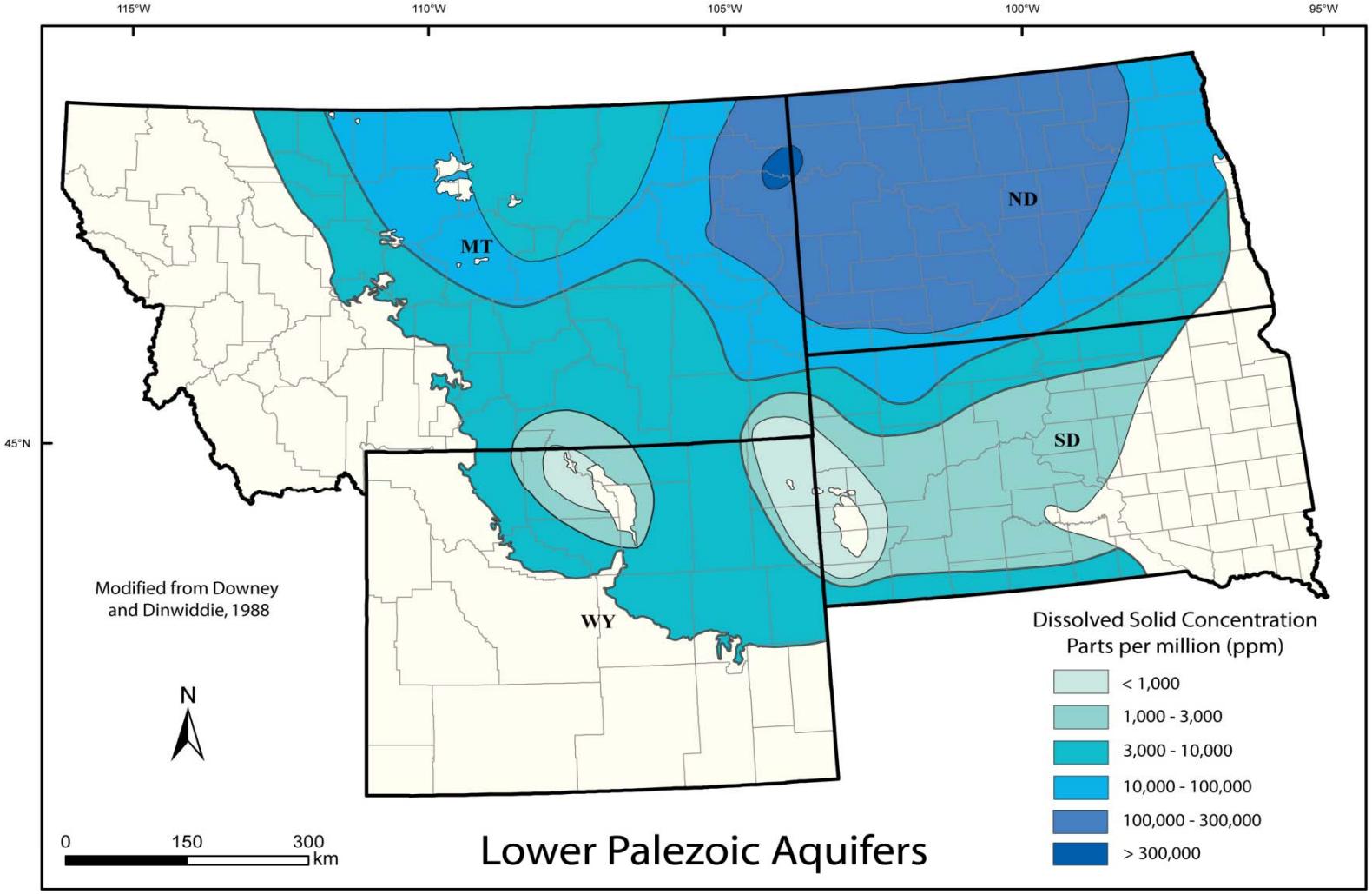

Water Quality Lower Cretaceous Aquifers

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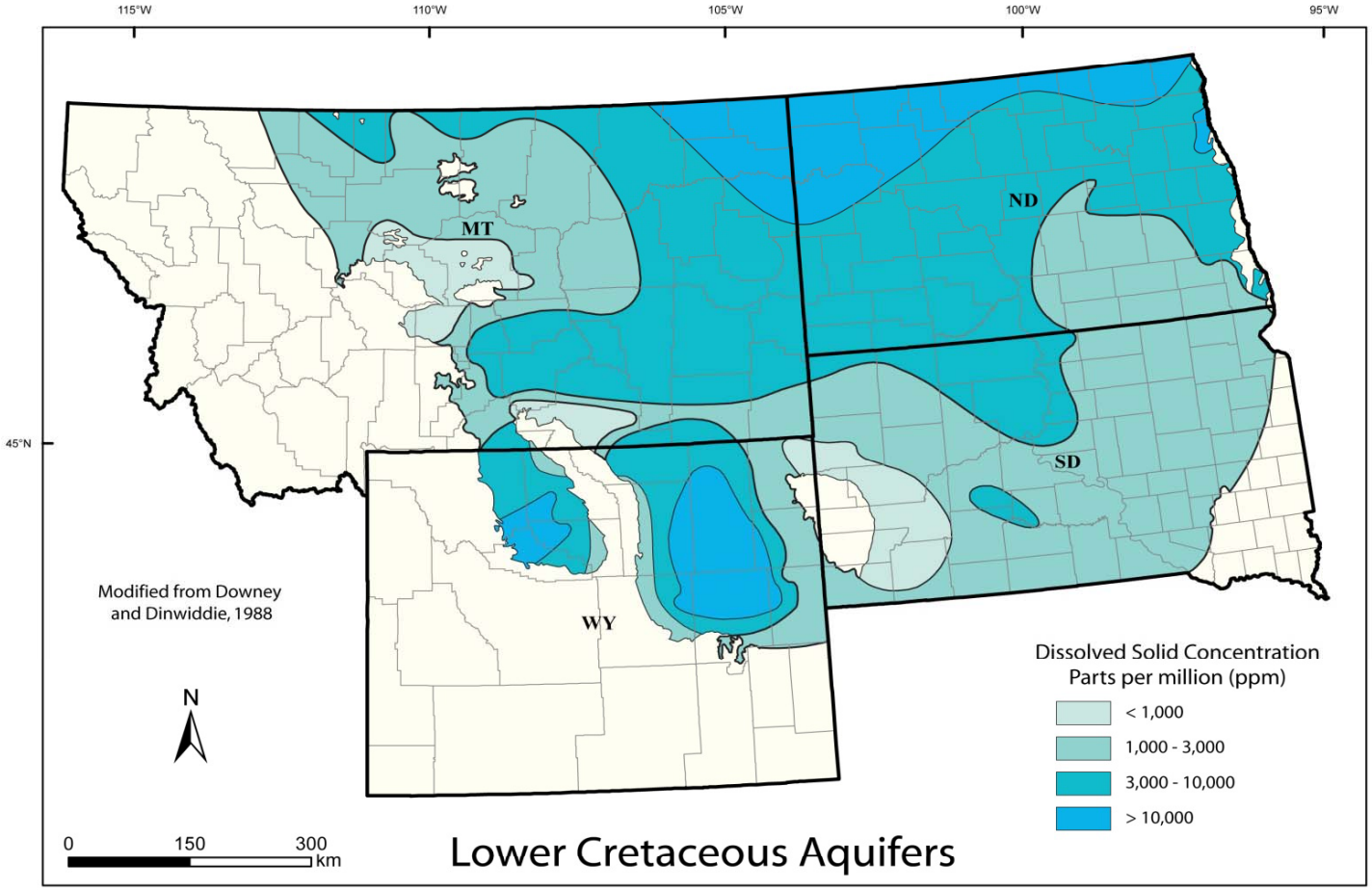

Regional Ground Water Flow, Paleozoic Aquifers

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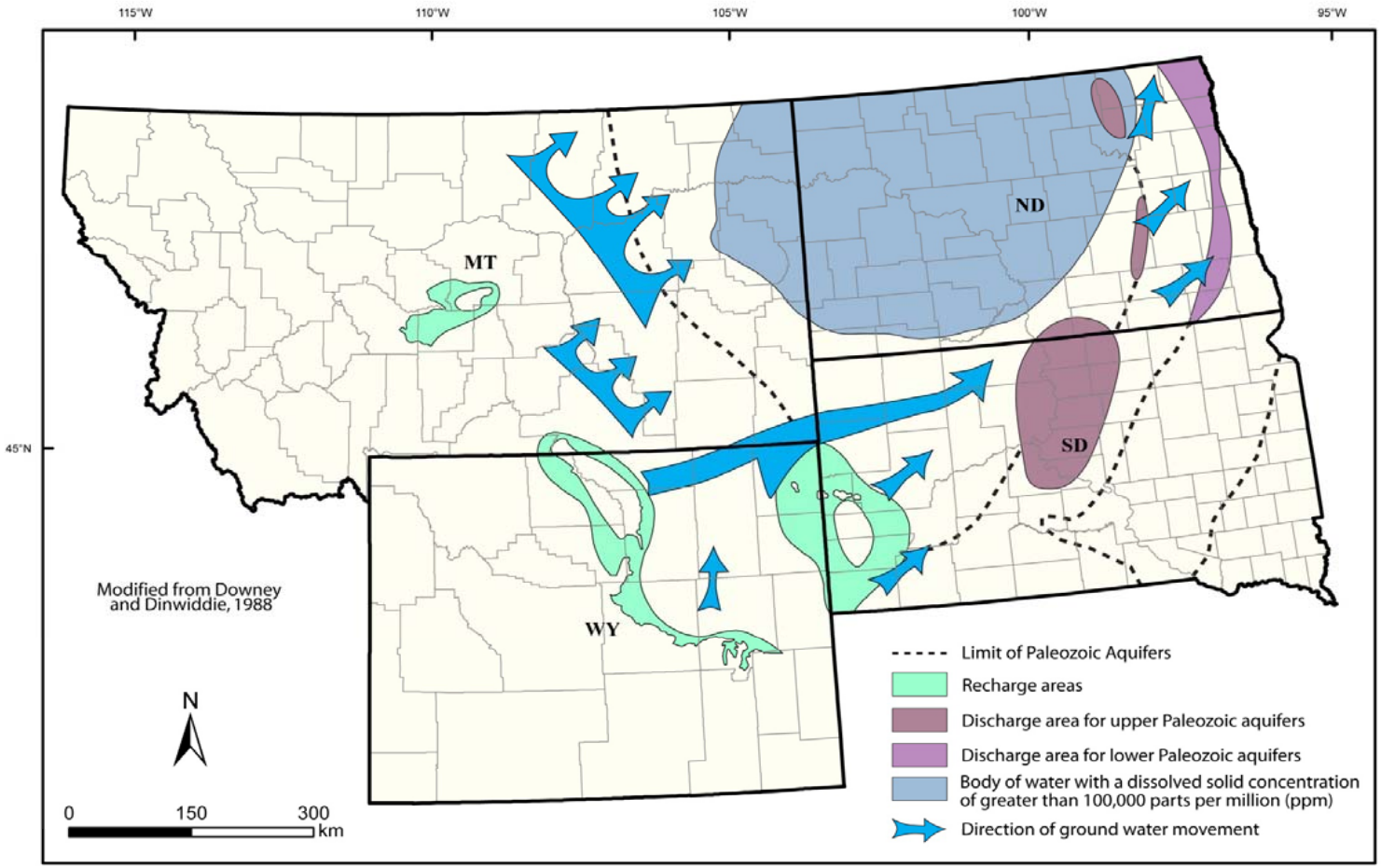

Sequestration

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- The Carbon Project will help evaluate the viability or potentially valuable sequestration sites and processes
- The Energy Park sits on top of or near partially depleted oil and gas reservoirs, coal seams, saline aquifers and other sub-surface geologic formations
- Each is identified as having “high potential” for large volume commercial CO_2 sequestration, particularly in the vicinity of the Energy Park
- Terrestrial sequestration in croplands, range and forest ecosystems also can be evaluated
- Slipstreams of flue gas and CO_2 will be used to test carbon-based commercial construction products

Characterization and Studies

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- Site characterization studies will be carried out with Stanford and BSCSP to refine and add detail to the CO_2 sequestration capacity in multiple partially depleted oil and gas reservoirs, coal seams, saline aquifers and other geologic formations for the area, as identified by DOE and BSCSP
- In addition, best practices and risk mitigation strategies will be established to demonstrate that these formations are safe and viable targets for sequestration and are capable of retaining CO_2 for millennia without adversely affecting human health, the environment or drinking water sources
- Slipstreams of CO_2 will be taken from the recovery plant and CO_2 pipeline for sequestration tests

The Characterization Study-A Multi-Phased Approach

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- Phase I
  - Data Gathering
  - Data Synthesis
  - Regional Modeling
- Phase II
  - Well Drilling & Testing
  - Well Data Modeling
  - Refinement of Regional Models
- Phase III
  - Risk Assessment
  - Risk Management
  - Regional Capacity Assessment Refinement

Phase I – Data Gathering and Synthesis

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- Data Gathering
  - Published sources including the Wyoming Geological Survey, the Wyoming Oil and Gas Conservation Commission, the Wyoming Geological Association, USGS, guidebooks and various professional publications
  - Existing well logs and cores
  - Outcrops
- Data Synthesis
  - Compile data to provide the basis for a static geologic model that includes stratigraphic, structural, compositional and fluid flow properties
- Regional Modeling
  - Use data to refine regional models in the vicinity of the project
  - Big Sky Carbon Sequestration Partnership regional Model
  - ZERT Powder River Basin Scale Model

Phase II - Well Drilling & Testing

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- Geologic information concerning units below those zones heavily explored for oil and gas is virtually nonexistent in the immediate Project area because no wells have penetrated Mississippian and older rock units.
- Water quality, reservoir, and seal information is critical to determine the potential for saline aquifer sequestration in this significant region
- Since there are multiple promising formations, but potential water quality issues, a single vertical well to test these properties for multiple formations is logical.

Phase II - Well Drilling & Testing

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- Well Drilling & Testing Data Gathering
  - Drill well to Precambrian Basement
  - Determine water quality of all potential sequestration zones
  - Provide detailed characterization of the all potential target formations
  - Extract cores from multiple targets and caps for testing
  - Run a complete set of modern geophysical logs, such as resistivity, neutron, gamma, sonic/acoustic, density, formation micro-imager (FMI), combined gamma spectroscopy (RST-A), dynamic fluid-logging (fluid-temperature and flow), and gravity
  - Efforts will be focused on determining capacity, injectivity, and containment
- Refinement of Regional Models
  - Risk Assessment
  - Risk Management
  - Regional Capacity Assessment Refinement

Phase II - Well Data Modeling

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- Use TOUGH2, TOUGHReact,TOUGH-FLAC and MODFLOW simulations to
  - refine the sequestration capacity estimates for the approximate 25x25 mile vicinity of the Energy Park
  - Determine injectivity of lithological units that could accommodate large quantities of CO_2
  - assess the seal integrity
  - assess the extent of CO_2 dissolution into formation brine
  - assess the rate and extent or inorganic and organic geochemical reactions that could permanently trap CO_2
  - identify, rank and assess risks, particularly those associated with pressure buildup
- Refinement of Regional Models

Work Flow and Project Integration

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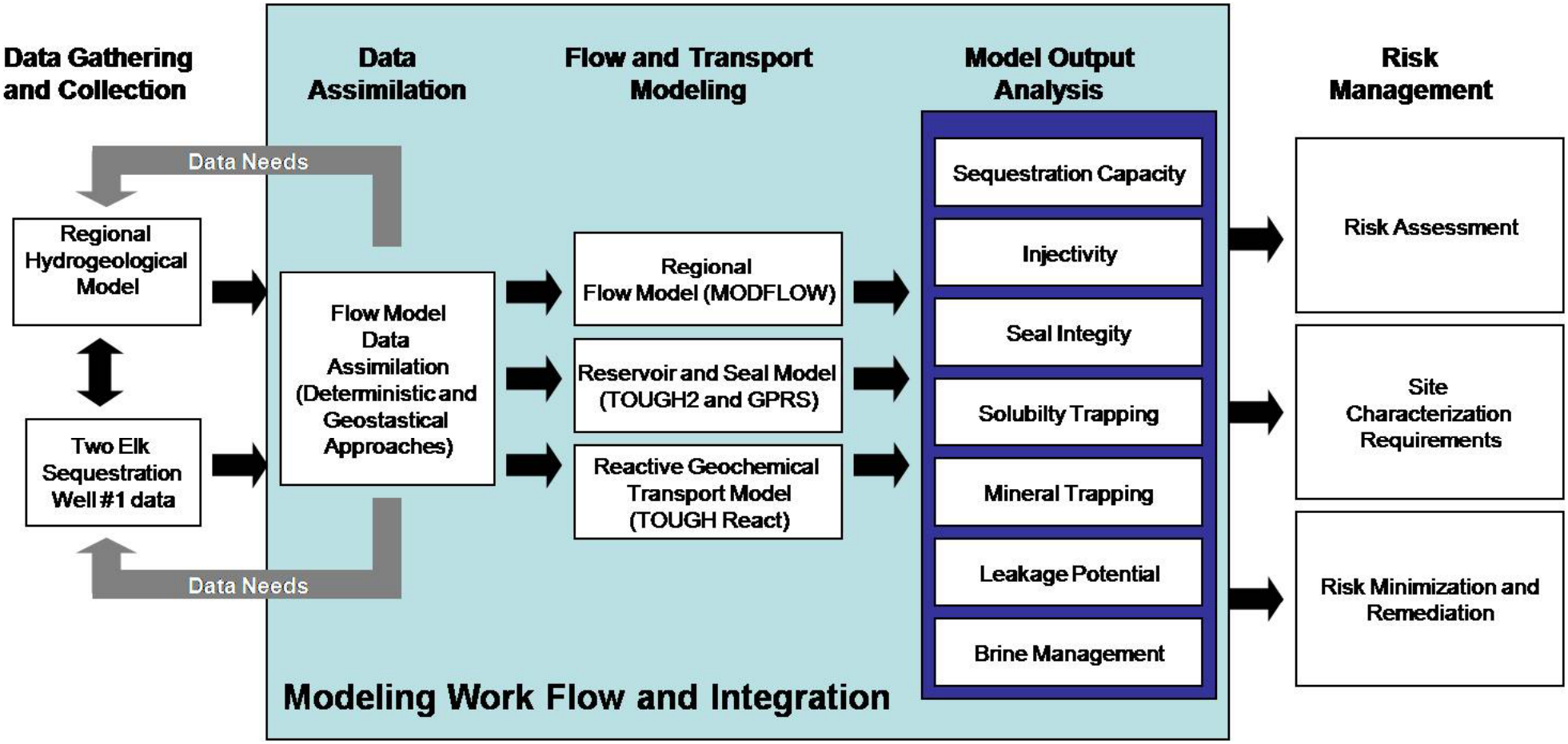

Big Sky Regional Characterization

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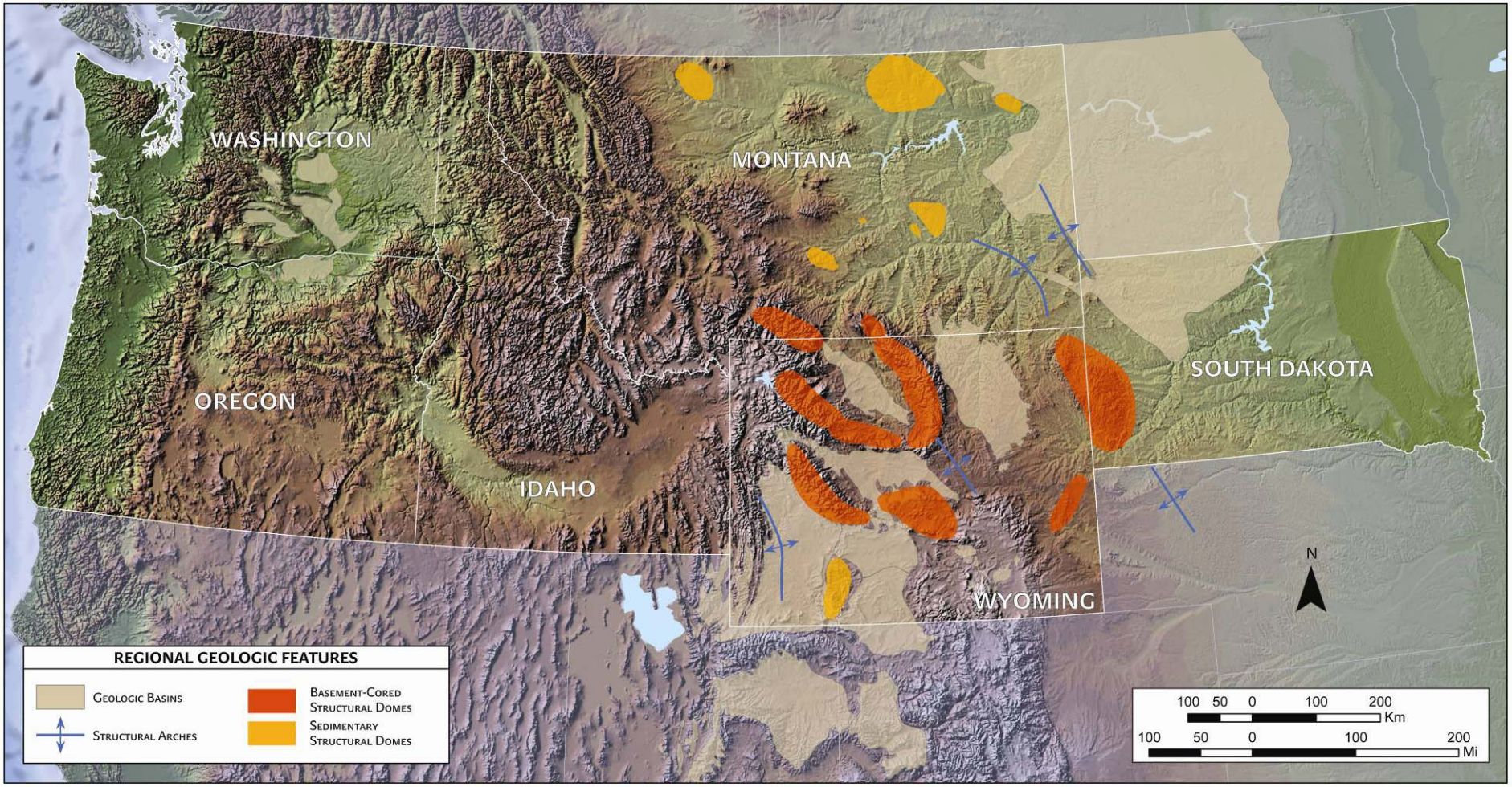
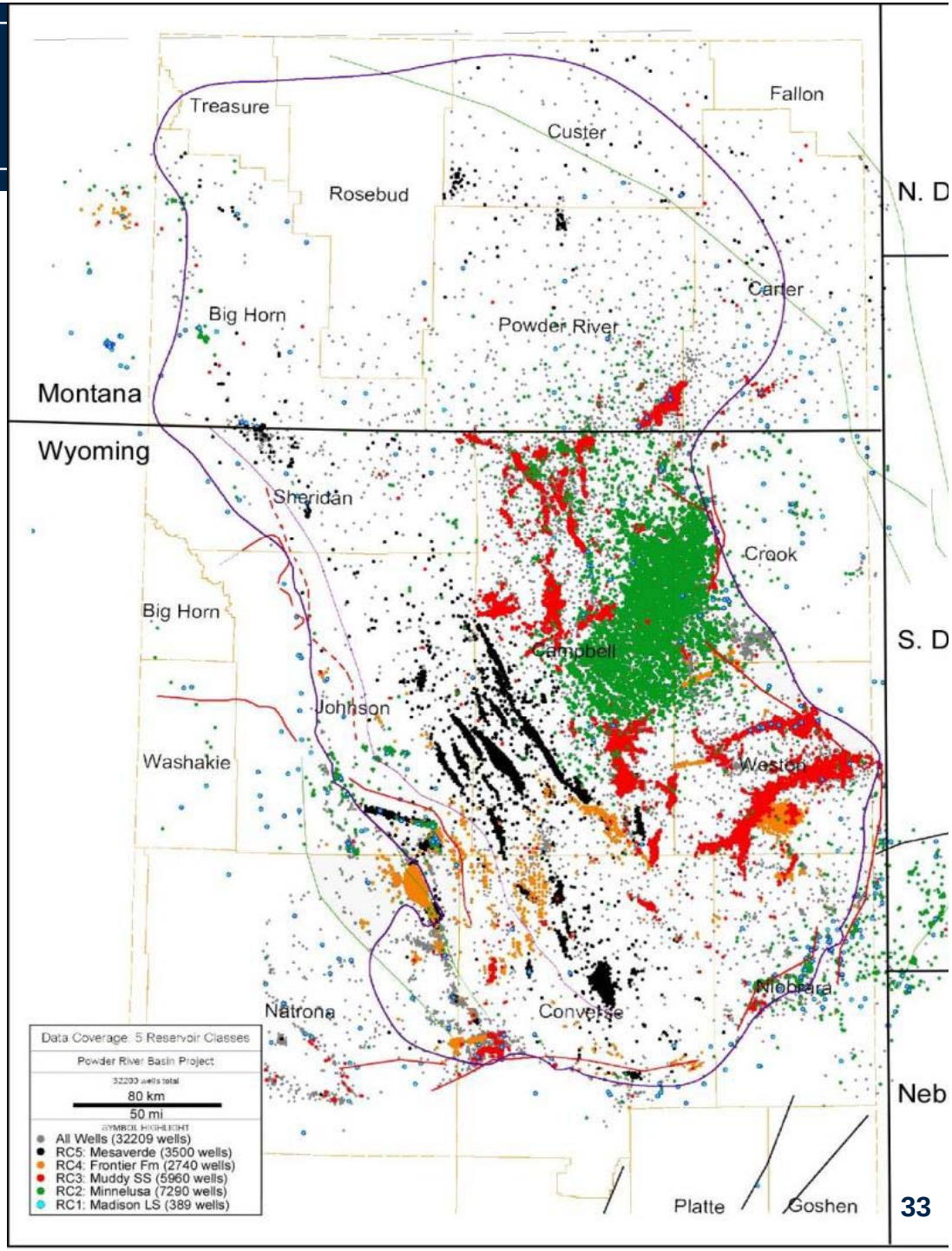


Regional Context ZERT Basin Scale Model

- Multiple reservoir types
- Capture heterogeneities
- Utilize a large data set
  - 32,000 well logs
  - Cores
  - Outcrops
- Use to study multiple project / basin scale issues
- Use to test large flow models
  - LANL PFLOTRAN 2010 Innovative and Novel Computational Impact on Theory and Experiment (INCITE) award.
  - U. Stuttgart parallel computing grant



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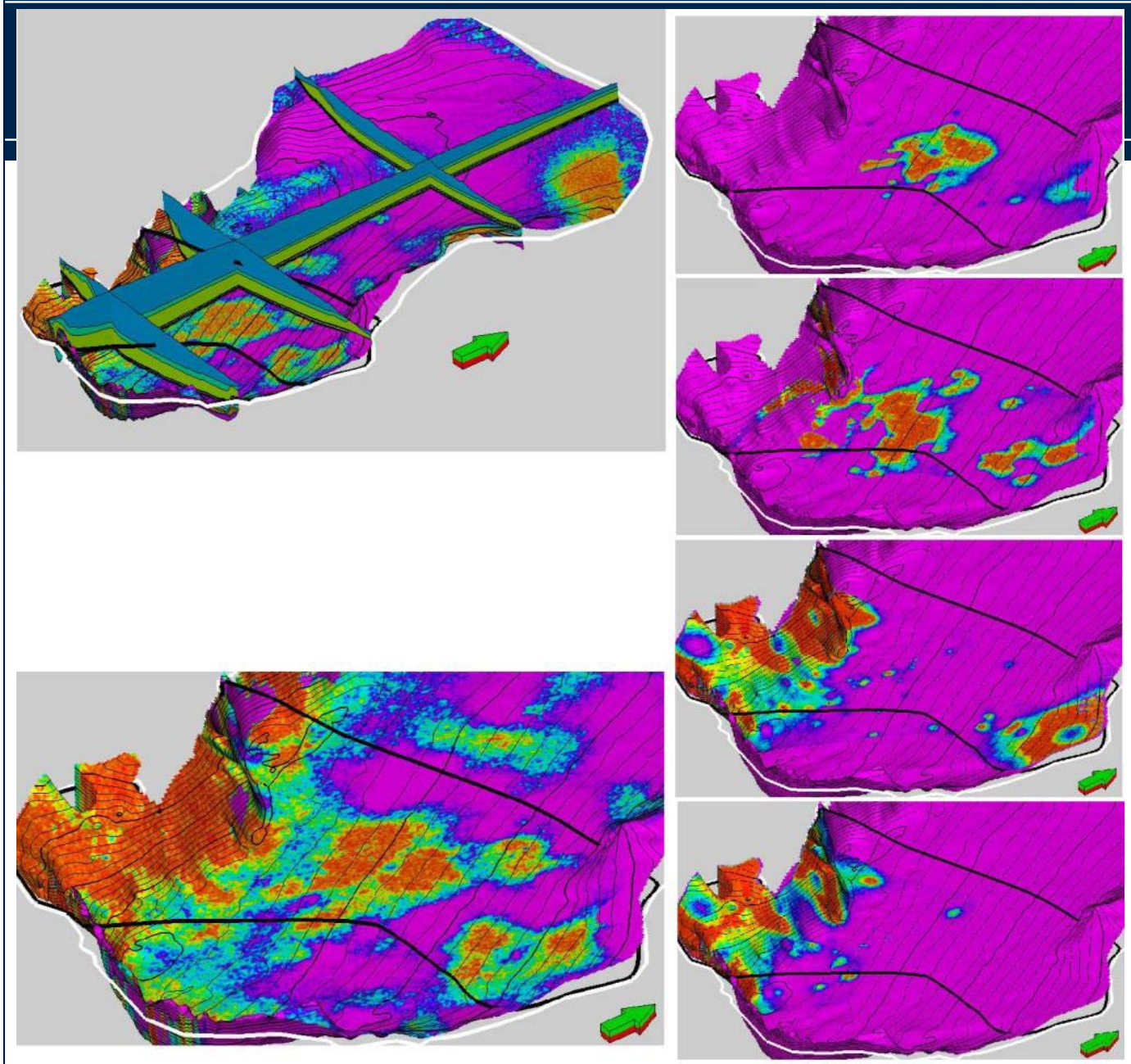

Images from 3D modeling package. Upper left shows porosity distribution in RC4 with fence diagram. Lower left shows sector model boundaries and general porosity distribution based on averaging the entire RC4-6 50-60 m thick interval. Right, from bottom to top, the four high frequency sequences document better the porosity distribution. The colors represent porosity (purple to red is equivalent to 0% to 18% porosity).