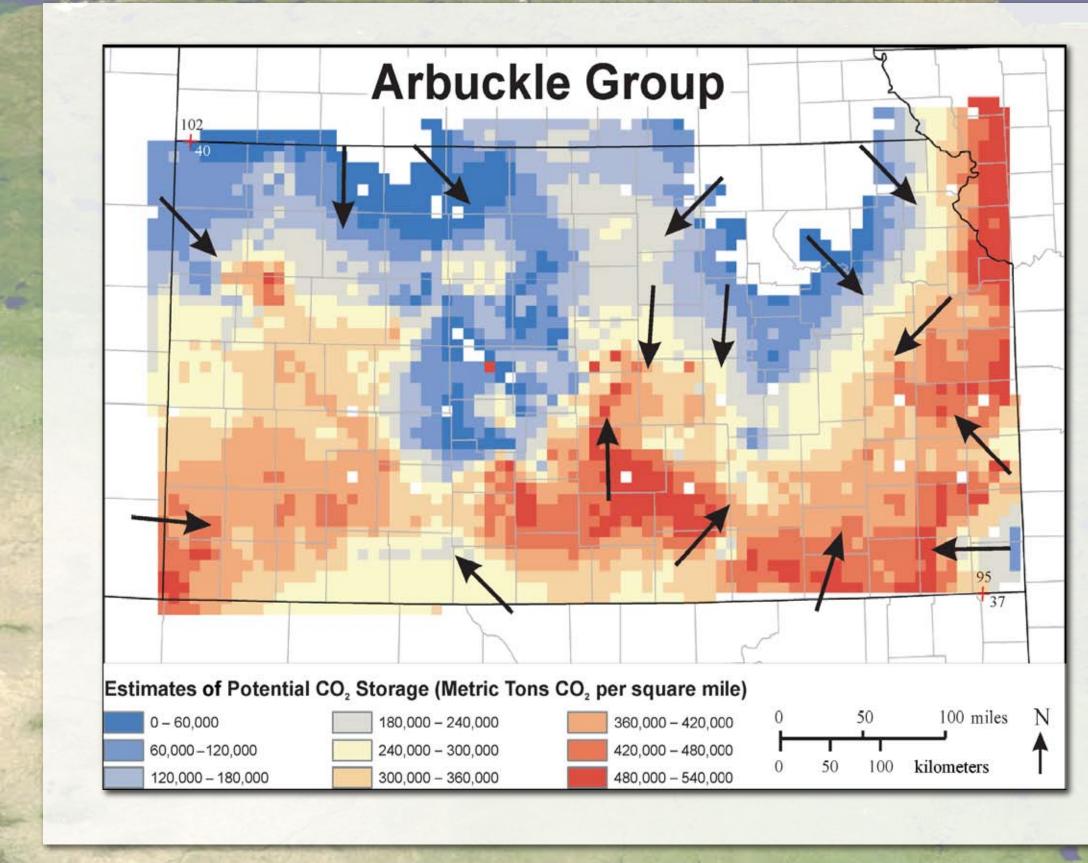
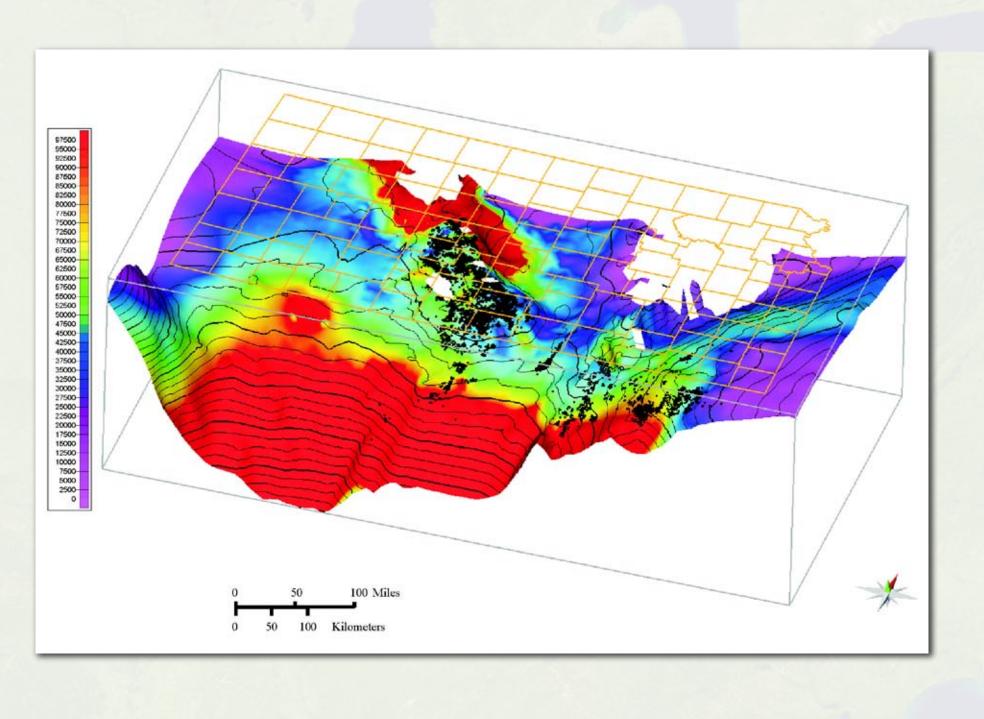
Estimates of the Carbon Dioxide Sequestration Capacity for Lower Paleozoic Aquifer Systems in the Midcontinent Region of North America

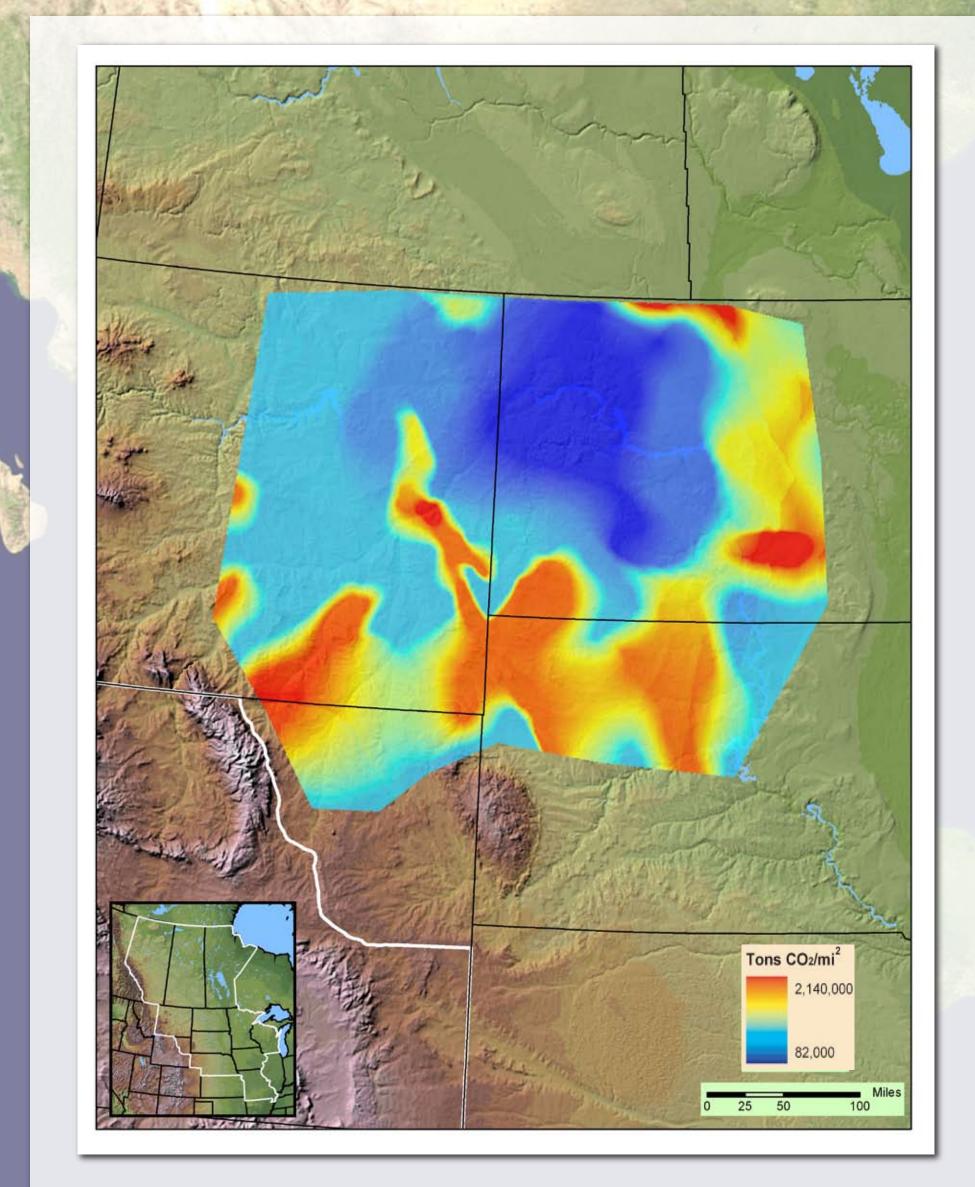
Saline aquifers within the midcontinent region of North America have the potential to store vast quantities of anthropogenic CO2. The lower Paleozoic (Cambrian to Mississippian) aquifer systems extend from Oklahoma and Missouri in the south to Saskatchewan and Manitoba, Canada, in the north, comprising one of the largest regional-scale aquifer systems in North America. Understanding the regional continuity, hydrodynamic characteristics, and fluid properties of these regional-scale aquifer systems provides a basis to evaluate CO₂ sequestration potential. Large-scale relational databases and geographic information system tools are used to integrate temperature, pressure, and water geochemistry data from numerous wells to evaluate the potential for geologic CO₂ sequestration in the midcontinent lower Paleozoic aquifer systems. Specifically, a model was developed using a calculation that relates the pore volume in the formation as the product of area, thickness, and porosity, and the solubility of CO2 in the formation water (which considerd the effect of salinity), at spatially varying pressures and temperatures. Depth to the top of the formation was also considered, with a minimum depth of 2500 feet being set to protect potable aquifers. Additional tools provide the ability to query and analyze geochemical data within a geospatial context from numerous saline aquifers across North America. Specific stratigraphic units that were evaluated include the Madison Group (Mississippian) and the Arbuckle Group (Cambrian-Ordovician). The reconnaissance-level potential storage capacity estimates generated by this approach suggest that over 100 billion tons of CO₂ could be stored in these aquifer systems.



The entire Arbuckle aguifer underlying Kansas has the potential to sequester a large quantity of CO₂. Sequestration volume assumes solubility in brine. If the displacement is more significant, the volumes will be significantly greater. The layer can be accessed and gueried through the NATCARB Web site (NATCARB, 2005) (Carr and White, 2003). The interpreted flow pattern of fluids in the lower Ozark Plateau is superposed on the map.

Three-dimensional view of the TDS in Arbuckle brines (color CI = 2500 ppm TDS) overlain on Arbuckle structure with leases producing oil from the Arbuckle Group (black dots. n = 12.436). All TDS concentrations more than 100 000 ppm are shown in red. Data were derived from Arbuckle water samples from various sources (2929 records). The map is constructed with a grid of 26,400 ft (8050 m). Note the coincidence of changes in the TDS concentration and the limits of known Arbuckle production. Dense brines around the Cambridge arch, along the northeastern side of the central Kansas uplift, and in small northwest-trending areas of increased TDS concentrations on the uplift seem to be associated with areas of vertical structural movement where the Arbuckle has been removed by erosion Areas where Arbuckle has been removed by erosion are shown as white. Sample data are available from the Kansas brine database (Kansas Geological Survey, 2005b).





The Mississippian Madison saline aquifer system has been evaluated for its regional continuity, hydrodynamic characteristics, fluid properties, and ultimate storage capacities using published data. The unique lateral extent of these aquifers, the current understanding of their storage potential gained through produced fluid disposal, and the geographic proximity to major CO₂ sources suggest they may be suitable sinks for future storage needs. For example, reconnaissance-level calculations on the Mississippian system i the Williston Basin and Powder River Basin suggest the potential to store upwards of 60 billion tons of CO₂ over the evaluated region. Results of the evaluation are stored in an interactive Web-based decision support system for future integration into a national carbon sequestration database.

Saline Aquifer Storage Calculation $Q = 7758 * (A) * (T) * (\phi) * (CO₂s)$

Q = CO₂ remaining in the aquifer after injection (ft³)

 $7758 = (43,560 \text{ ft}^2/\text{acre}) \text{ X } (.178 \text{ bbl/ft}^3)$

T = Producing interval thickness (f

A = Area (acres)

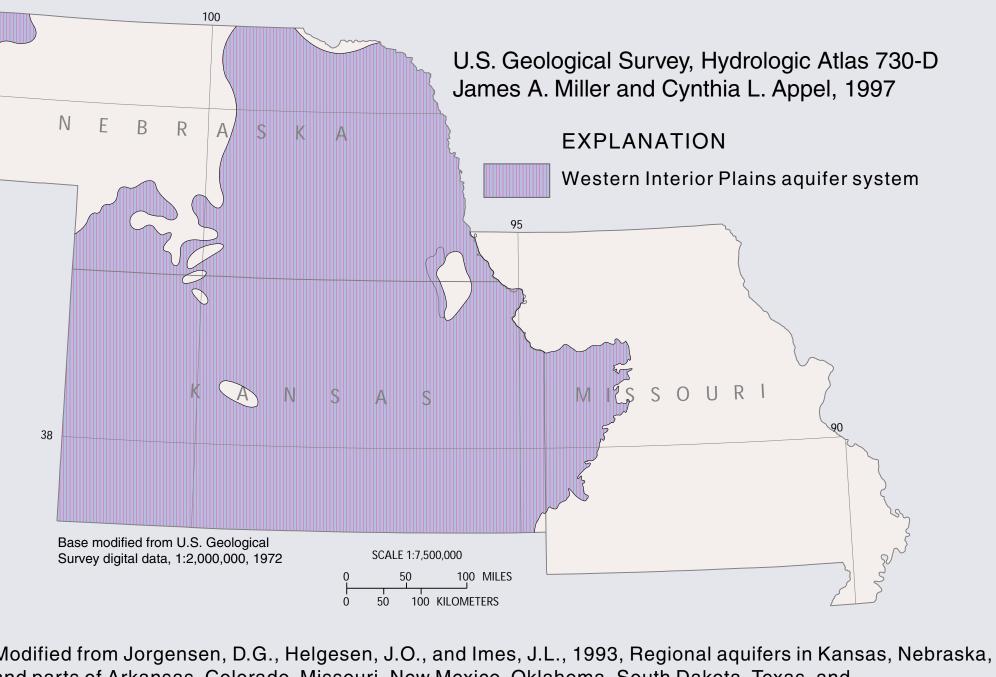
φ = Average reservoir porosity (%)

 $CO_2s = Solubility of <math>CO_2$ (ft³/bbl)

As part of the National Carbon Sequestration Database Project (NATCARB) and Plains CO₂ Reduction (PCOR) Partnership, programs were developed to estimate the amount of CO₂ that could be sequestered in saline aquifers. Estimates are based on subsurface temperature, pressure and salinity conditions. For the CO₂ solubility calculator, an RDBMS table was constructed to provide estimates of the solubility of CO₂ in aguifer water; data for the table are empirical (Martin, 1951; Johnson et al., 1952; Crawford et al.

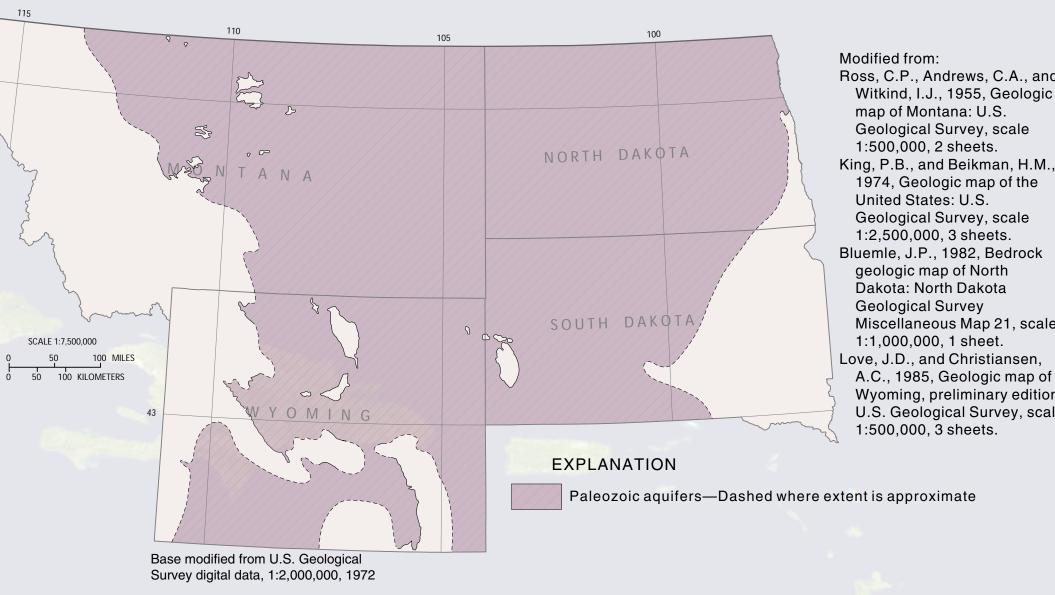
1963; Holm, 1963; Chang et al., 1996). The tool is designed to access an automated lookup table to estimate the solubility of CO₂ as a function of pressure and temperature interpolation between empirical curves. Second, the CO₂ solubility is corrected to the salinity of the water (independent of pressure and temperature). This approach provides a first-order estimate for solubility of CO₂ in saline aquifers. The program is used to generate the sequestration maps shown here.

Extent of Saline Aquifers in the Midcontinent Region



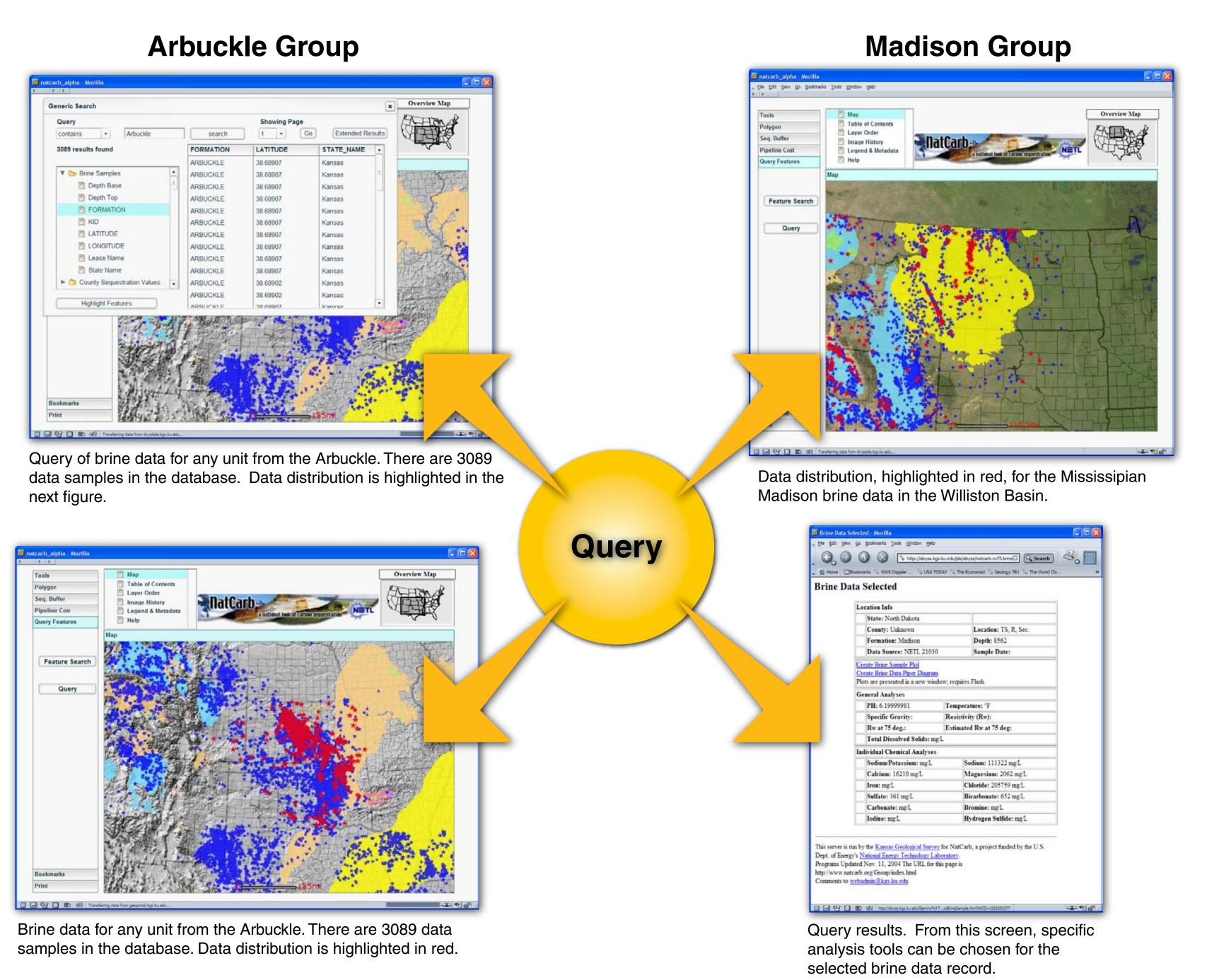
Wyoming—Geohydrologic framework: U.S. Geological Survey Professional Paper 1414-B, 72 p

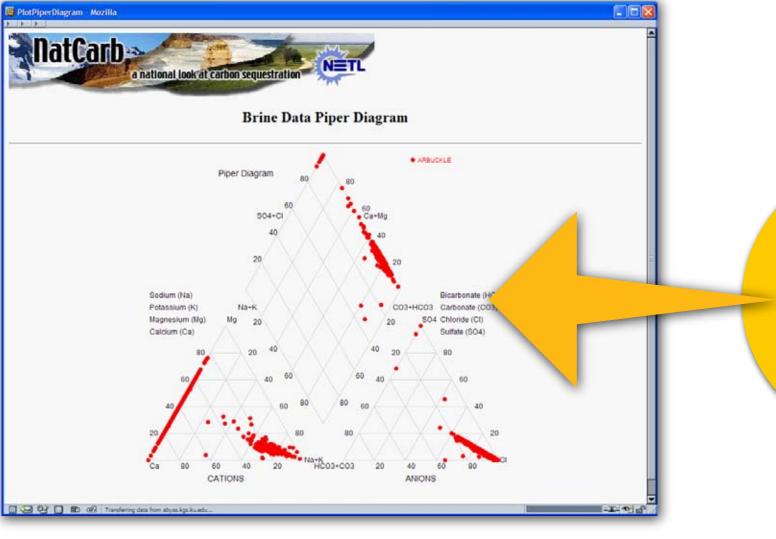
The Western Interior Plains aquifer system extends over large parts of Kansas and Nebraska and a small part of Missouri. The Arbuckle Group is within this

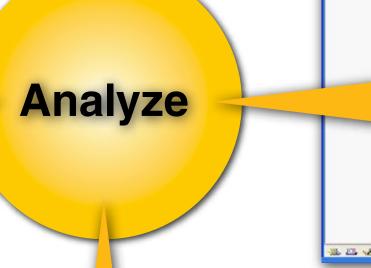


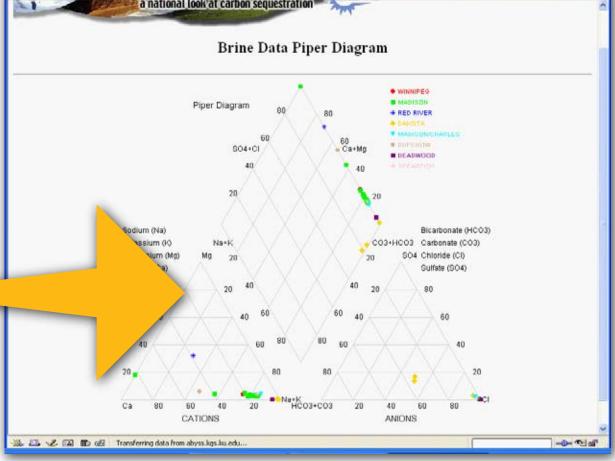
Paleozoic aquifers extend over large areas in the subsurface of North Dakota South Dakota, Montana, and Wyoming. The aquifers commonly contain highly mineralized water where they are deeply buried. The Madison Group is contained within this system.

Steven A. Smith, Energy & Environmental Research Center Timothy R. Carr, Kansas Geological Survey David W. Fischer, Fischer Oil and Gas Jeremy D. Bartley, Kansas Geological Survey Wesley D. Peck, Energy & Environmental Research Center James A. Sorensen, Energy & Environmental Research Center









Piper diagram of brine samples from North Dakota code

