Introduction to Geologic Carbon Storage

Senate Resources Committee

Presented by:
David L. LePain, Director and Alaska State Geologist
Division of Geological & Geophysical Surveys
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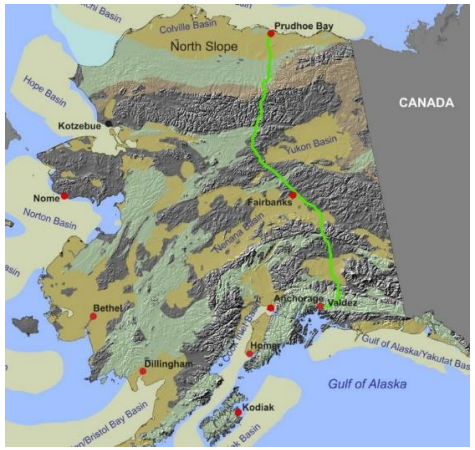
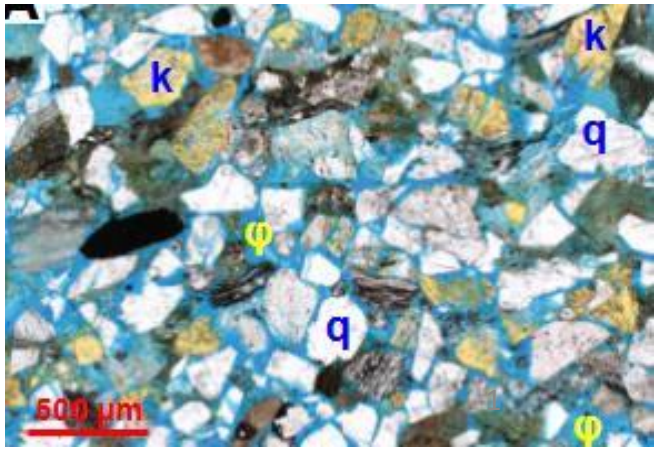


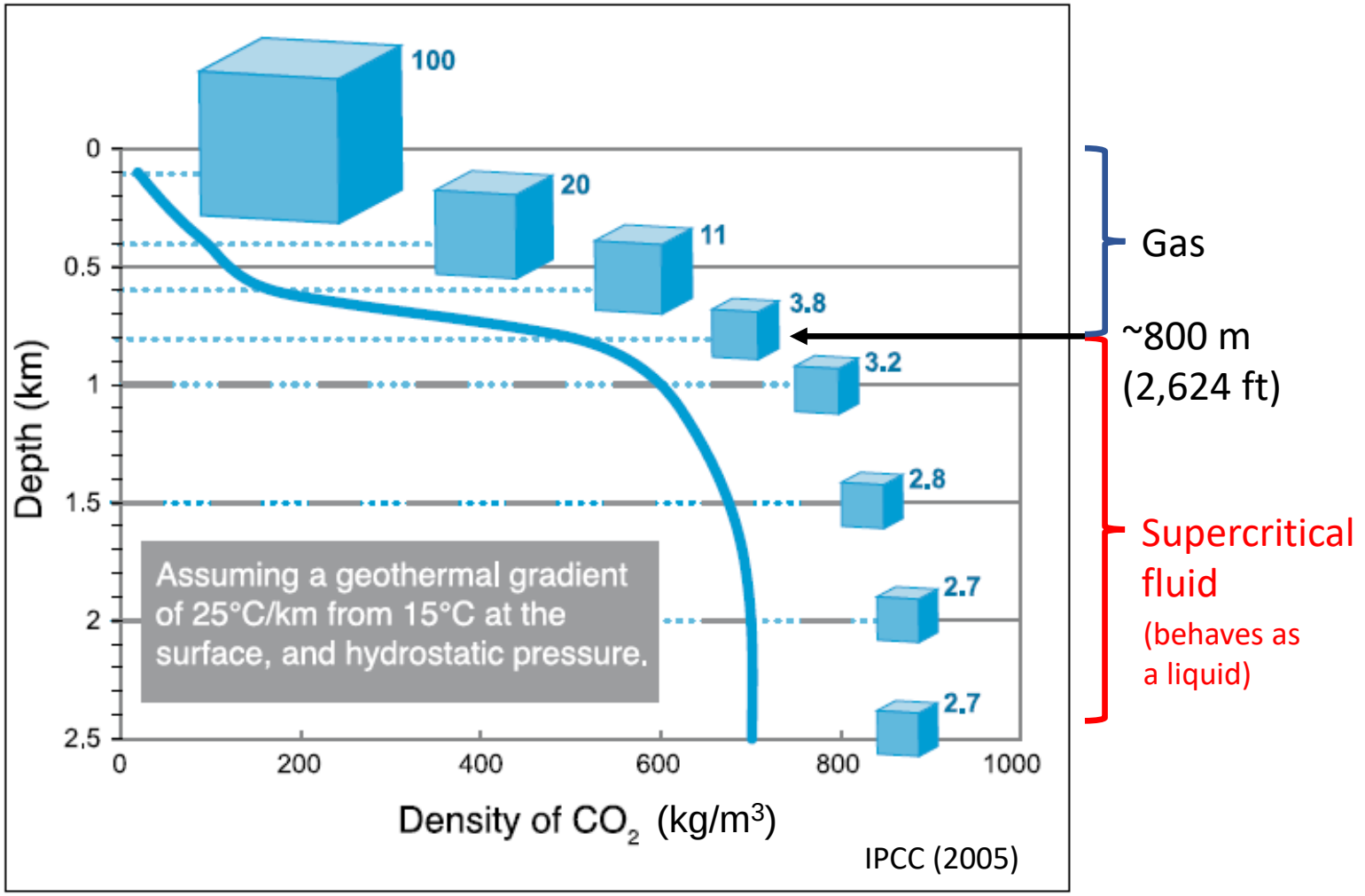


Outline

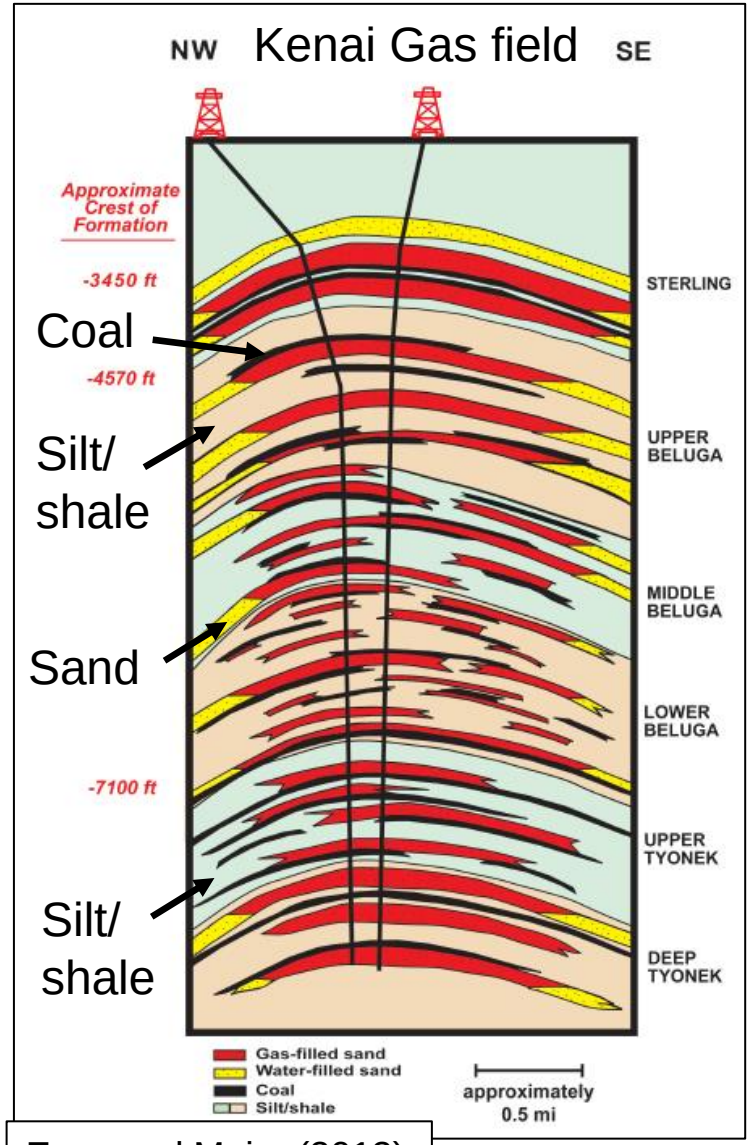
- Physical and chemical characteristics of CO_2
- Requirements for geologic CO_2 storage
- CO_2 storage mechanisms
- Storage in depleted oil fields and saline formations
- Storage in unmineable coal seams
- Geologic carbon storage in Alaska
  - Cook Inlet
  - North Slope
  - Interior sedimentary basins

Physical and Chemical Properties of CO_2

- Physical state varies with temperature and pressure
- Pressure increases with depth
- When supercritical – more CO_2 can be stored for a given reservoir volume
- CO_2 displaces pore fluids when injected
- Supercritical CO_2 is less dense than H_2O
- Buoyant
- Subsurface formations must meet certain criteria for storage

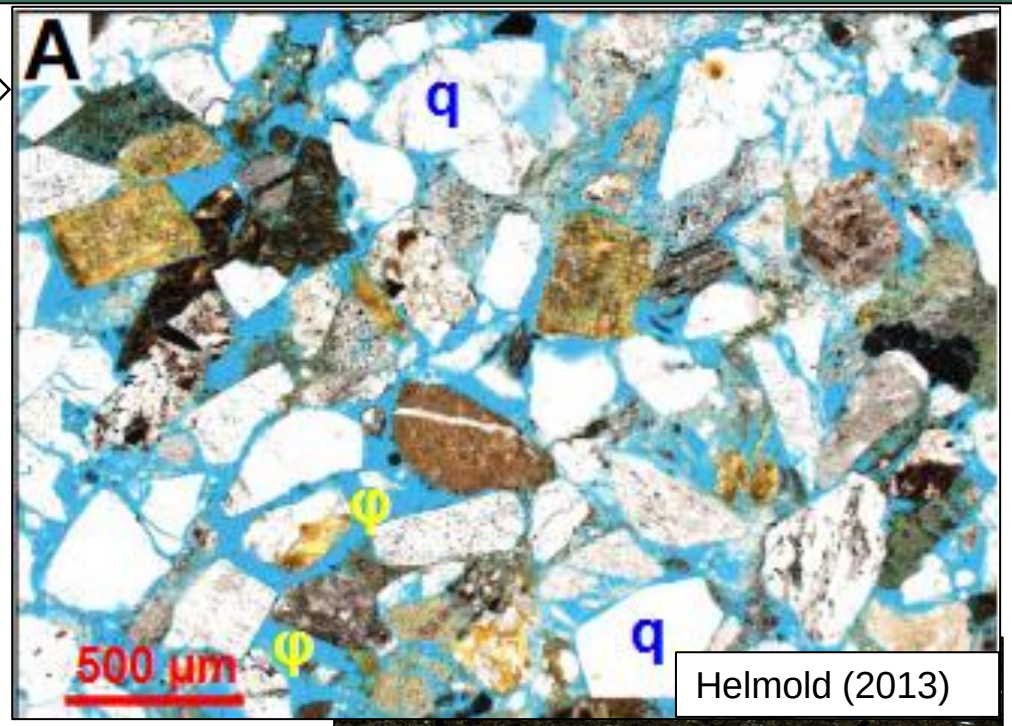


Requirements for Geologic CO_2 Storage



Enos and Maier (2013)

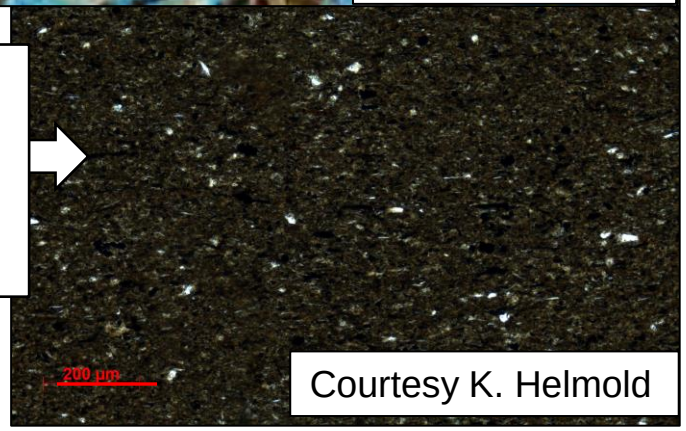
Sandstone, Tyonek Formation (porous - blue is pore space)



Helmold (2013)

- Sand with porosity – void space
- Sand with permeability – interconnected voids
- Sand in trapping configuration
- Impermeable silt/shale – seal
- Depth >~2,600 ft
- Geomechanics

Silty shale, Nanushuk Formation (impermeable)



Courtesy K. Helmold

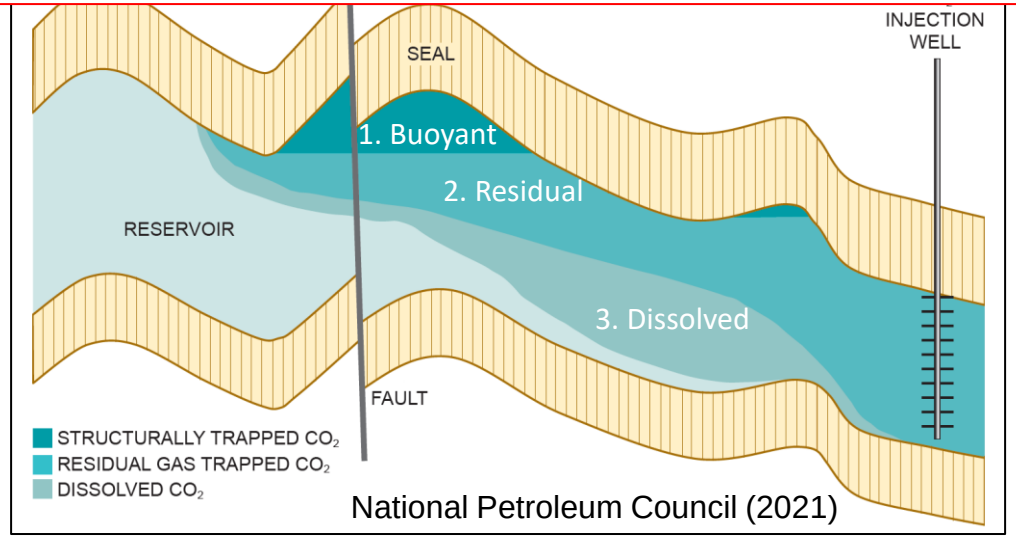
500 µm = 0.5 mm
200 µm = 0.2 mm

CO_2 Storage Mechanisms in Porous and Permeable Formations

Storage Mechanisms

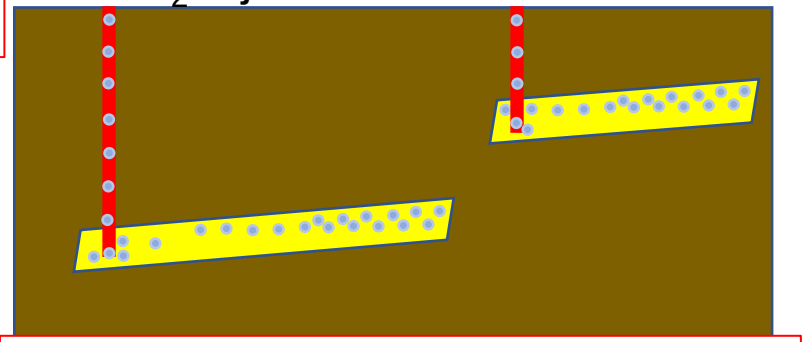
1. Buoyant trapping
2. Residual trapping
3. Solubility trapping
4. Mineral trapping

1 - Buoyant trapping in geologic structures

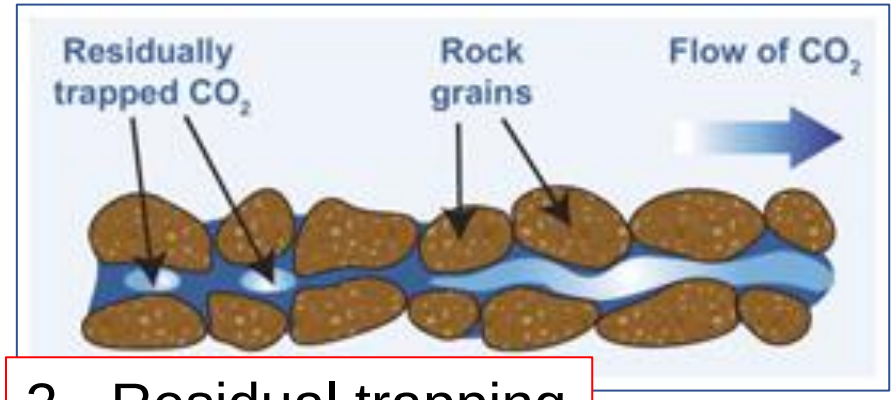


National Petroleum Council (2021)

CO_2 Injection Wells

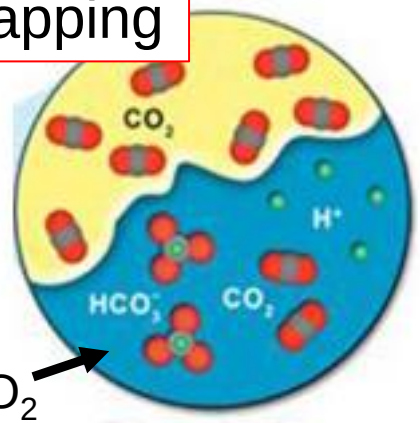


1 – Buoyant trapping related to stratigraphic pinch-out

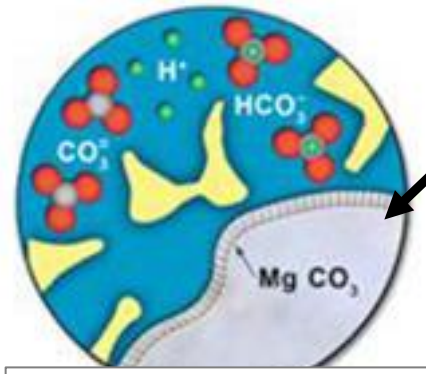


2 - Residual trapping

3 - Solubility trapping



Dissolved CO_2



Mineral precipitates

4 – Mineral trapping

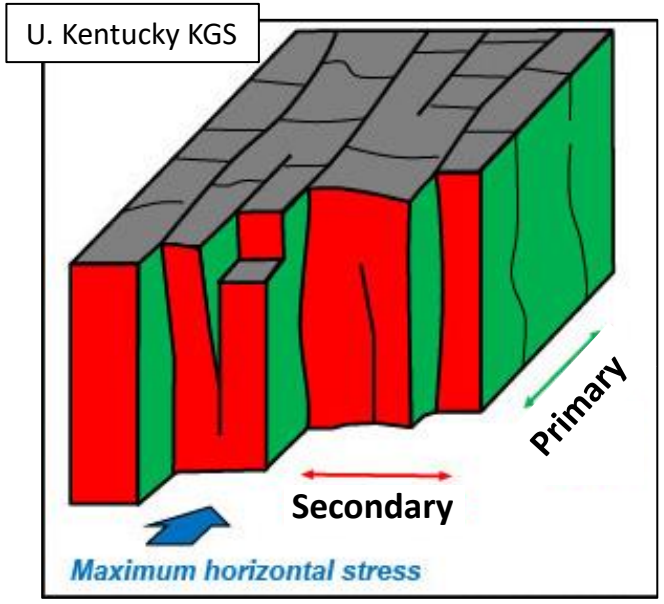
Depleted Oil Fields and Saline Formations

- Depleted oil and gas fields have:
  - Proven reservoir, trap, and seal
  - Extensive datasets that characterize reservoir properties, temperature, pressure, and water salinities
  - Sandstone body geometries and associated pore volumes are well-characterized
  - Known original oil-in-place and production history
  - Existing infrastructure
- Declining oil fields – CO_2 for EOR

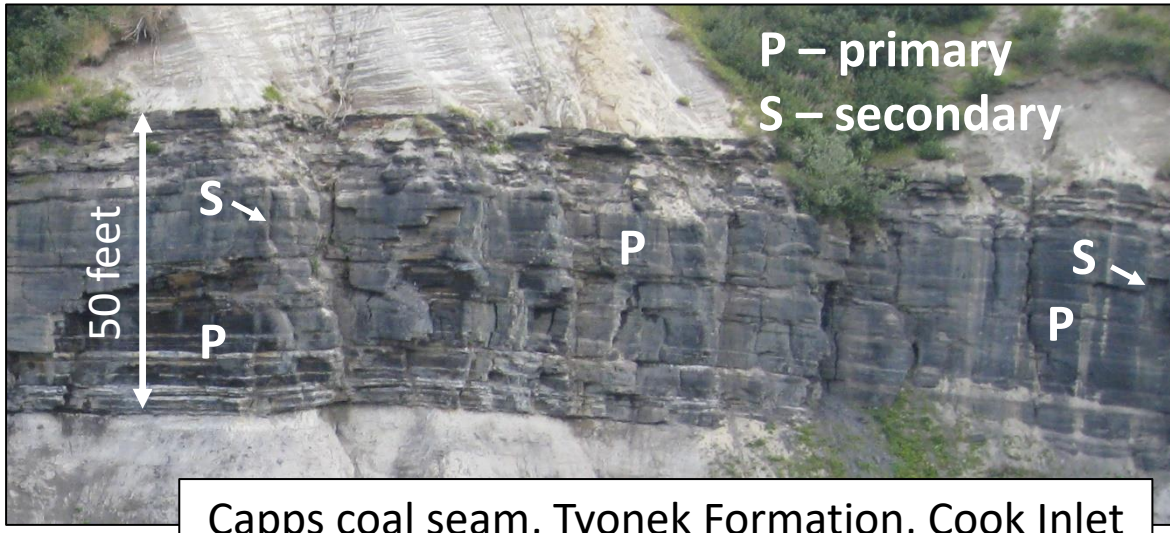
- Saline formations:
  - Total dissolved solids >10,000 parts per million
  - Non-potable water
  - Isolated from potable water sources – saline aquifers deeper and separated from aquifers by seals
  - Depositional environment of sedimentary formation influences depth to non-potable water
    - Marine – shallower
    - Nonmarine – deeper
  - Data may be lacking - not as well known as depleted oil fields

Storage in Unmineable Coal Seams

- CO_2 in coal is stored in naturally occurring fractures (cleats) and micropores in coal
- Cleats provide permeability and access to larger surface area (micropores)
- Methane (CH_4) and CO_2 strongly attracted to coal particles
- CO_2 molecules attracted more strongly to coal particles than methane – displaces methane
- Coal rank influences storage capacity (IPCC, 2005)
  - -Low rank coal – lignite – CO_2 storage capacity >10x methane
  - -Anthracite – CO_2 storage capacity = methane
- Fate of displaced methane (CH_4)?



Natural fractures in coal – primary and secondary



Capps coal seam, Tyonek Formation, Cook Inlet

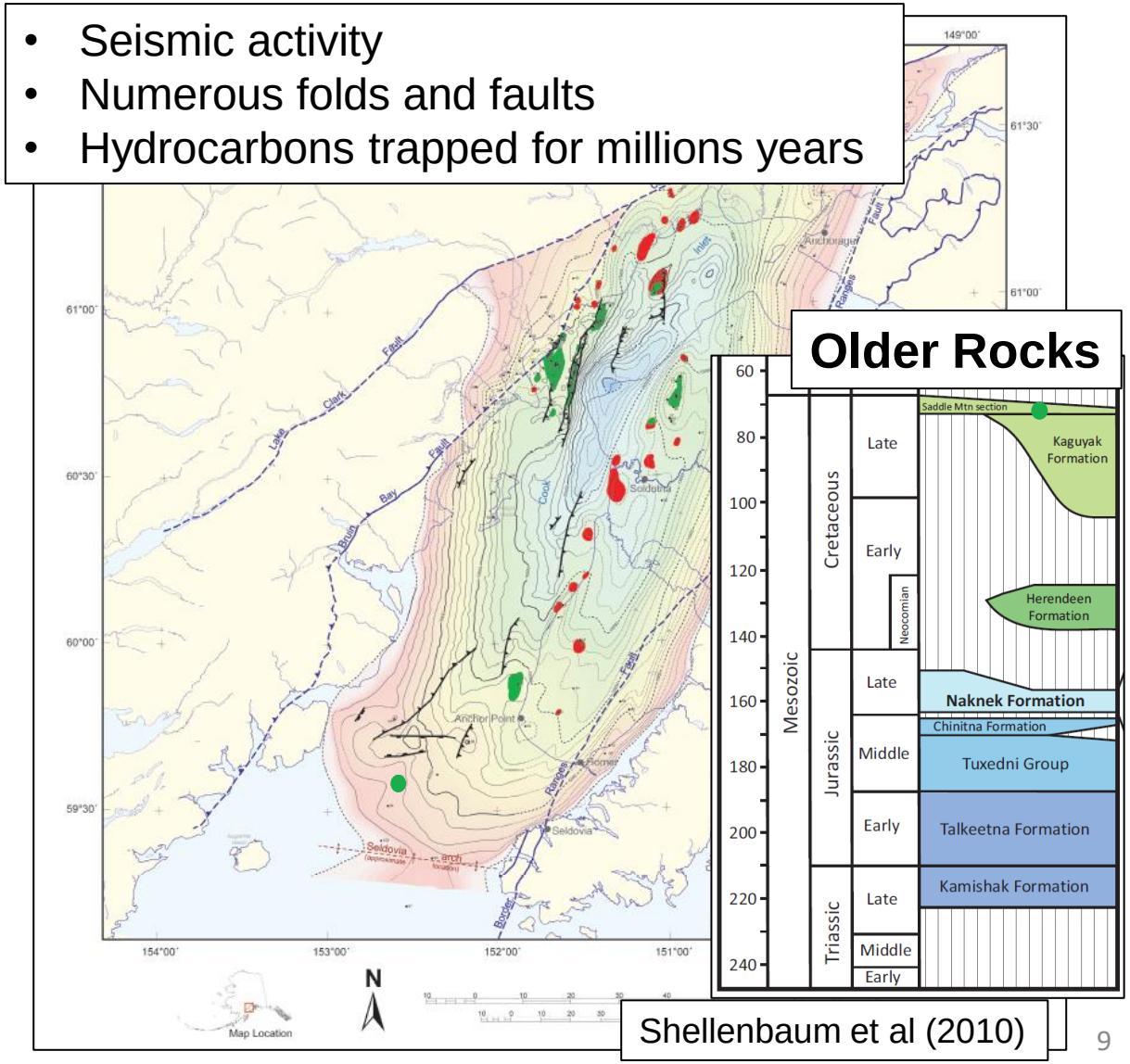
Geologic Carbon Storage Summary

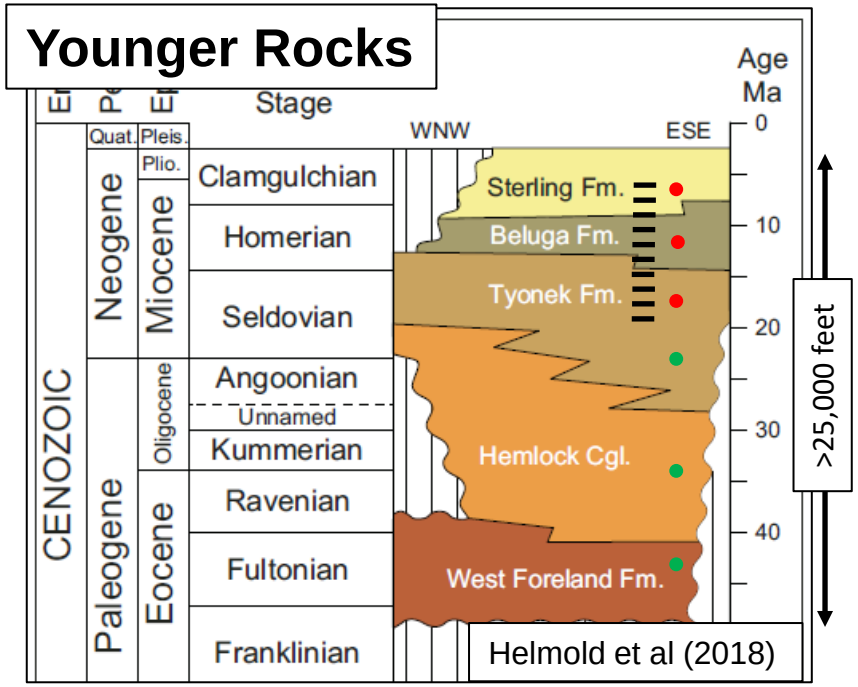
- Geologic storage options include depleted and declining oil and gas fields, saline formations, unmineable coal seams
- Subsurface formations must be deeper than approximately 2,600 ft
- Formations must have porosity and permeability
- Formations must include traps (folds, faults, stratigraphic pinchout)
- Sandstones must be overlain by impermeable formations – seals
- Monitoring during and after CO_2 injection is required – must make sure CO_2 is going where intended; if leakage is detected, must take corrective action

Cook Inlet CO_2 Storage Potential

- Thousands of feet of interbedded sandstone, mudstone, coal
- 10 oil fields – 5 relatively large *(data rich)*
- 28 gas fields *(data rich)*
- Proven reservoirs and traps
- 1.389 billion barrels of oil produced; >7.5 trillion cubic feet of gas produced
- Saline formations
- Large volume of pore space potentially available for CO_2

- Seismic activity
- Numerous folds and faults
- Hydrocarbons trapped for millions years





- Younger rocks – nonmarine
- Large volume of coal in younger rocks
- Older rocks – dominantly marine

Coal
Gas
Oil

Shellenbaum et al (2010)

Summary of CO_2 Storage Potential in Cook Inlet

CO_2 storage in depleted and declining oil fields

- Proven reservoir (porosity, permeability), trap, and seal
- Existing infrastructure
- 1.389 billion barrels of oil and 7.5 trillion cubic feet of gas production as of end November 2022 (AOGCC)
- Field sizes and cumulative production volumes provide a measure of CO_2 storage potential in existing oil and gas fields
- Seismic activity – trapped hydrocarbons prove seal capacity of mudstones not impacted

CO_2 Storage in saline formations

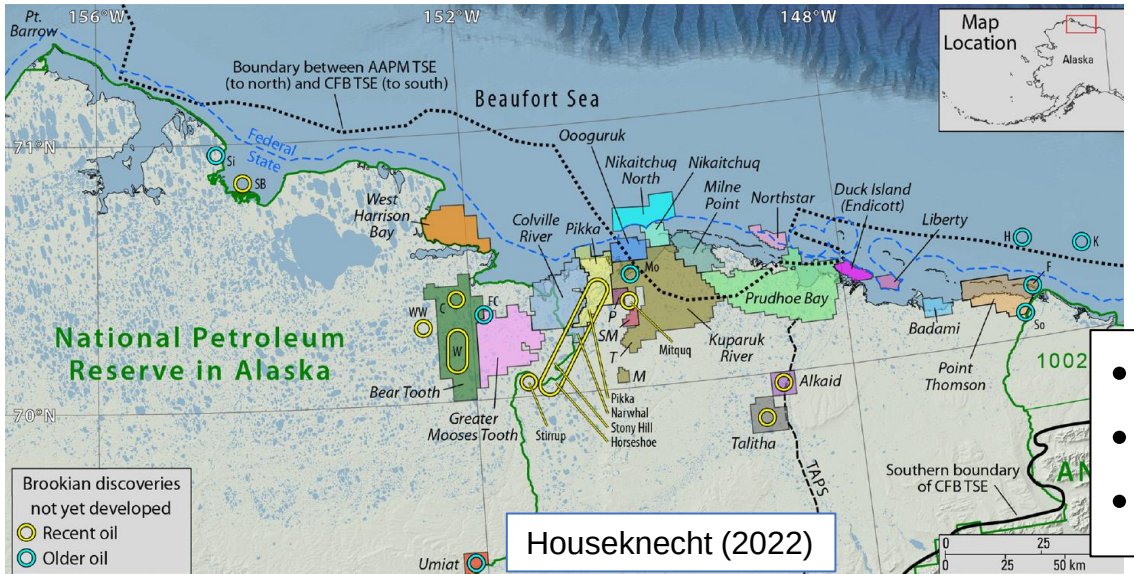
- Large pore volume – huge potential
- Uncharacterized

Unmineable coal seams

- Huge coal resource in basin
- Estimated storage potential – 43 billion tons (Shellenbaum and Clough, 2010)
- Fate of displaced methane? Must be captured

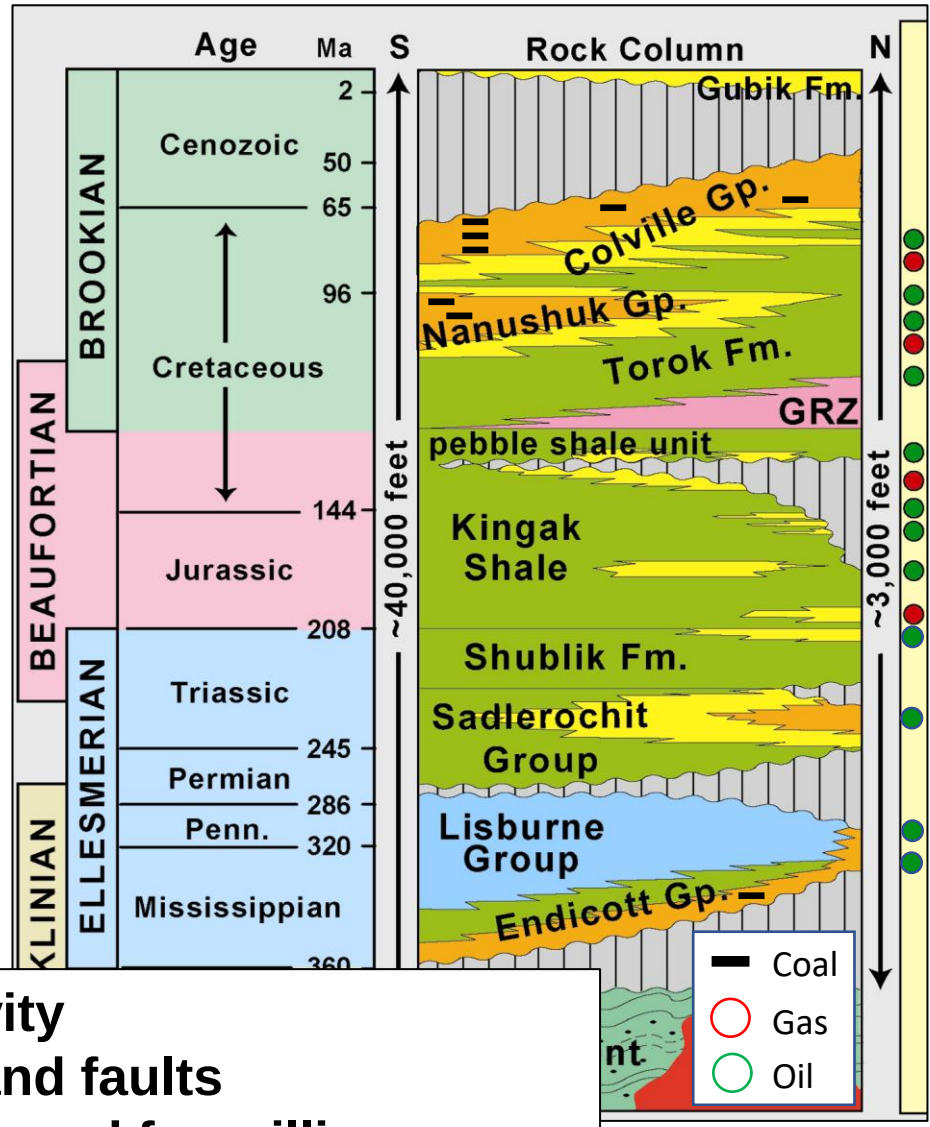
North Slope CO_2 Storage Potential

- Thousands of feet of interbedded sandstone and mudstone
- Abundant coal west of Umiat (Federal and Native land)
- More than 70 oil accumulations and several gas accumulations discovered since 1944 – several with original oil in-place > 1 billion barrels
- 17.88 billion barrels oil produced through November 2022 (AOGCC)
- Proven reservoirs and traps – many large fields in decline
- Saline formations are extensive
- Large volume of pore space potentially available for CO_2



Houseknecht (2022)

- Marine and nonmarine rocks
- Coal
- Infrastructure



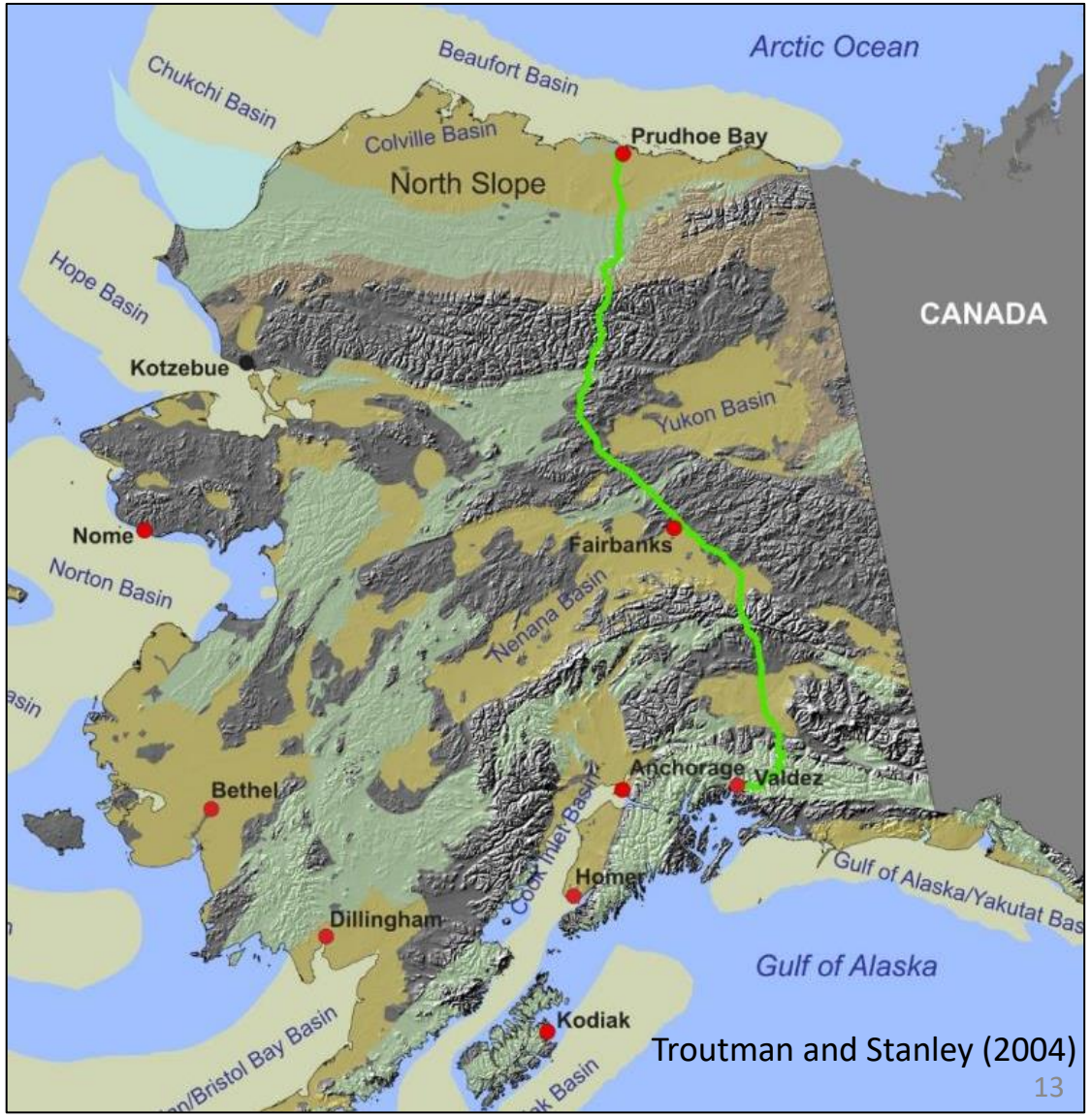
- **Low seismic activity**
- **Numerous folds and faults**
- **Hydrocarbons trapped for millions years**

Summary of CO_2 Storage Potential on North Slope

- Cumulative oil production from North Slope fields through November 2022 – 17.88 billion barrels of oil
- Many fields with original oil-in-place volumes estimated >1 billion barrels and recoverable oil volumes > 300 million barrels
- Large legacy fields have been in decline for decades – EOR potential
- Field sizes and cumulative production volumes provide measure of CO_2 storage potential in declining fields – **U.S. Geological Survey estimates 0.9 billion metric tons mean recovery replacement storage**
- U.S. Geological survey estimates mean total CO_2 storage potential at 270 billion metric tons (USGS Circular 1386; includes only deep saline formations and existing oil fields)
- Storage in unmineable coal seams estimated at 5.83 billion tons (Shellenbaum and Clough, 2010) – displaced methane must be captured

Interior Sedimentary Basins

- All basins are data poor
- Best known are Susitna, Nenana, and Yukon Flats
- Sedimentary rocks filling basins are nonmarine (river, coal swamp, flood plain, and lake deposits)
- Potable water extends to greater depths
- Nonmarine settings tend to have laterally discontinuous reservoirs and seals
- No infrastructure



Troutman and Stanley (2004)

Thank you

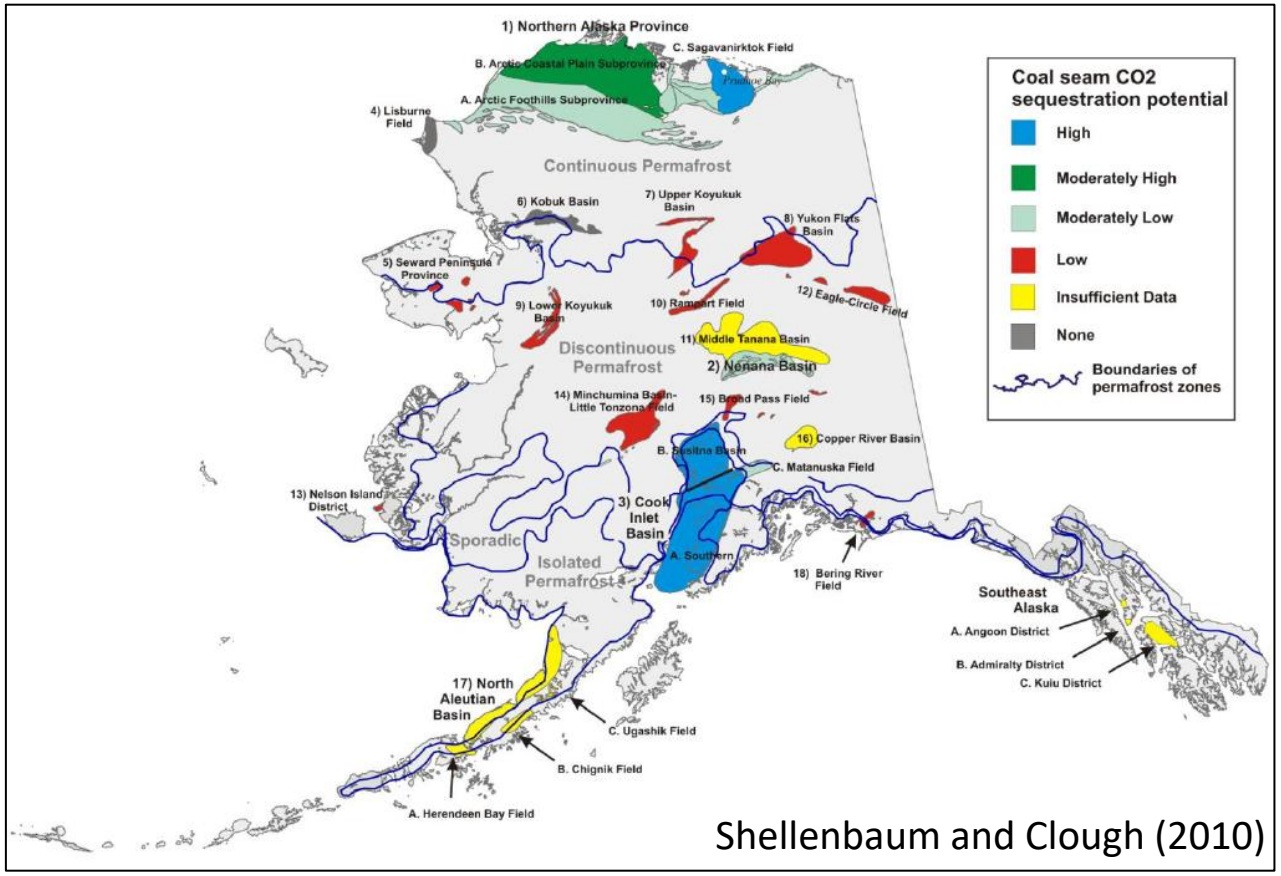
David LePaine
Director and Alaska State Geologist
Division of Geological & Geophysical Surveys
David.LePain@alaska.gov

View to west showing platforms in upper Cook Inlet

Appendix

Summary of CO_2 Storage Potential in Alaska

Coal Seam CO_2 Sequestration Potential

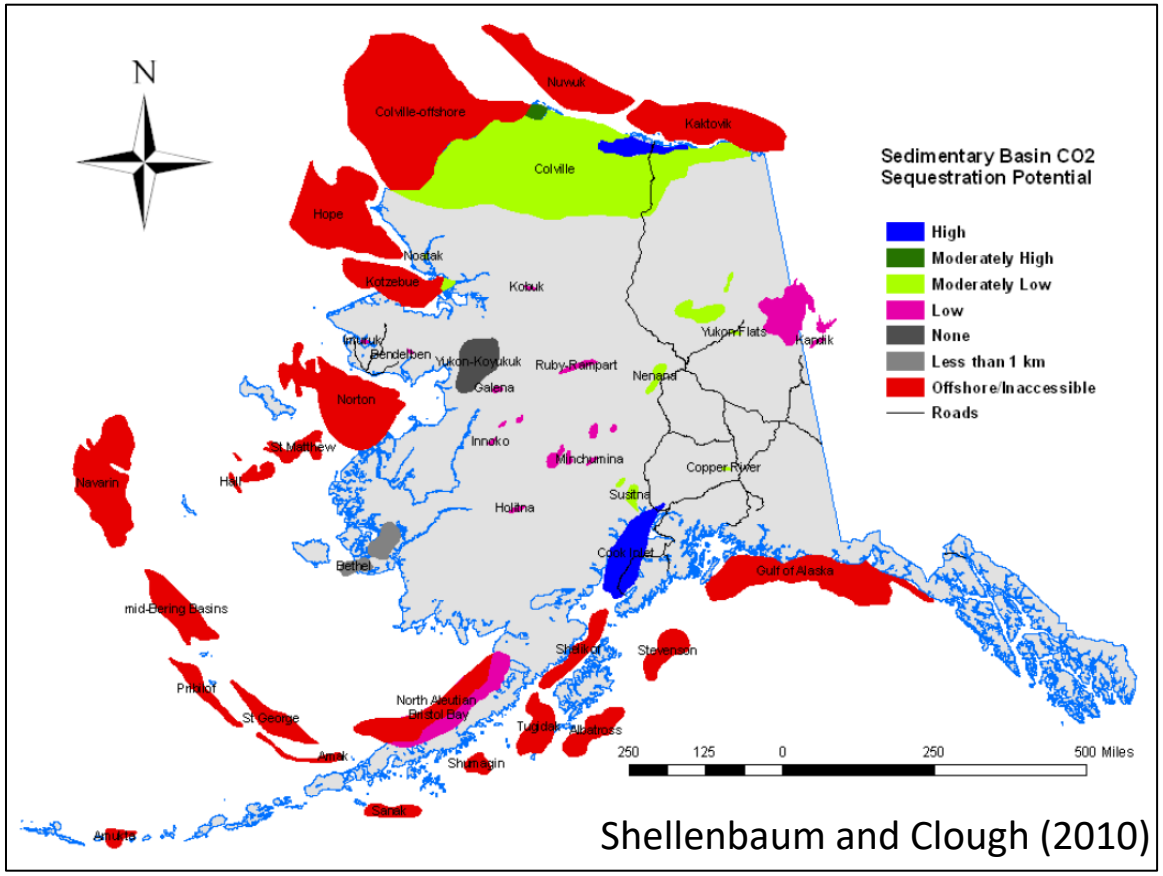


Shellenbaum and Clough (2010)

Total storage capacity in coal seams (all basins): 49.24 Gt

North Slope: 5.83 Gt Cook Inlet: 43 Gt

Saline Formations



Shellenbaum and Clough (2010)

Saline formations storage capacity – qualitative estimates only

Gt = gigaton (billion)