Methodology for Constructing Reservoir Maximum Pore Pressure Maps to Meet Class VI Constraints and Prevent Earthquakes
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### EPA Class VI Based Pressure Limits

The CO2 sequestration capacity of saline aquifers in the U.S. has been estimated based on pore space considerations. Injection of CO2, however, is regulated by the EPA via the Class VI injection permit, which restricts the maximum pressure in the injection zone to 90% of the formation Fracture Gradient. This limitation will govern how much CO2 can be economically injected and stored in the coming decades as we transition to non-fossil fuel sources of energy. A methodology is presented to construct regional maps of the allowable increase in pore pressure which can assist in identifying suitable locations for sequestration. The approach is demonstrated for the Cambro-Ordovician Arbuckle aquifer in Kansas.

As per Class VI Rule, the maximum allowable pore pressure in the Injection Zone, \( P_{\text{max}} = 0.9 \times \text{Fracture Gradient} \)

\[ \Delta P_{\text{max}} = 0.9 \times \text{Fracture Gradient} - \text{Existing Pressure} \]

### Protection of Drinking Water Aquifers

Commercial scale injection of CO2 is expected to cause large increases in pore pressure in saline aquifers. These aquifers are currently used to dispose liquid waste. There are a large number of waste disposal wells in Kansas through which brines in the injection zone can migrate into overlying freshwater aquifers. Therefore, it is beneficial to limit the increase in injection zone pressures so that brines cannot migrate into freshwater aquifers. A methodology is presented to develop regional maps of the allowable increase in pore pressures to prevent brine migration, and the approach is demonstrated for the freshwater aquifers in Kansas.

### Seismic Based Pressure Limits

Injection of liquid waste in the Arbuckle is associated with earthquakes in Kansas. A methodology is developed to construct regional maps of the maximum increase in pore pressure that can be induced without causing earthquakes for assumed fault properties and stress field. The approach is demonstrated for faults in the Arbuckle aquifer in Kansas.

**Steps:**
1. **Determine Fracture Gradient by Conducting Step Rate Test**
   - Formation fractured at 2,300 psi at ~ 5,000 ft
   - Fracture Gradient ~ 0.8 psi/ft

2. **Determination of Existing Pressure in Middle of Arbuckle Aquifer**

3. **Maximum Allowable Increase In Pore Pressure in mid-Arbuckle (psi)**

4. **Determination of Brine Density**
   - Brines Density (Kg/m³)
   \[ = 0.005255 \times \text{TDS (mg/l)} \]

5. **Determination of In-situ Heads and Distance to Base of Freshwater Aquifers**

6. **Maximum Allowable Increase in pore pressure for assumed fault properties and stress field. The approach is demonstrated for the Cambro-Ordovician Arbuckle aquifer in Kansas.**

### Commercial scale injection of CO2 is expected to cause large increases in pore pressure in saline aquifers. These aquifers are currently used to dispose liquid waste. There are a large number of waste disposal wells in Kansas through which brines in the injection zone can migrate into overlying freshwater aquifers. Therefore, it is beneficial to limit the increase in injection zone pressures so that brines cannot migrate into freshwater aquifers. A methodology is presented to develop regional maps of the allowable increase in pore pressures to prevent brine migration, and the approach is demonstrated for the freshwater aquifers in Kansas.

**Protection of Drinking Water Aquifers**

**Required Pressure For Migration of Brines in Drinking Water Aquifers**

\[ \text{Required Pressure} = (\text{Elevation of Base of Drinking Water Aquifer} - \text{Elevation of Arbuckle Insitu Heads}) \times \text{Density of Arbuckle Brine} \]

**Step 1:** Determination of Brine Density

- Brine Density (Kg/m³)
  \[ = 0.005255 \times \text{TDS (mg/l)} \]

**Step 2:** Determination of In-situ Heads and Distance to Base of Freshwater Aquifers

- Distance (ft) between Arbuckle Brine Levels and Base of Dakota Aquifer

**Step 3:** Determination of Maximum Allowable Pore Pressure in Arbuckle Aquifer to Prevent Migration of Brine into Freshwater Aquifers