EVALUATION OF DAMAGE FORMATION AND COMPLETION

Presented by:
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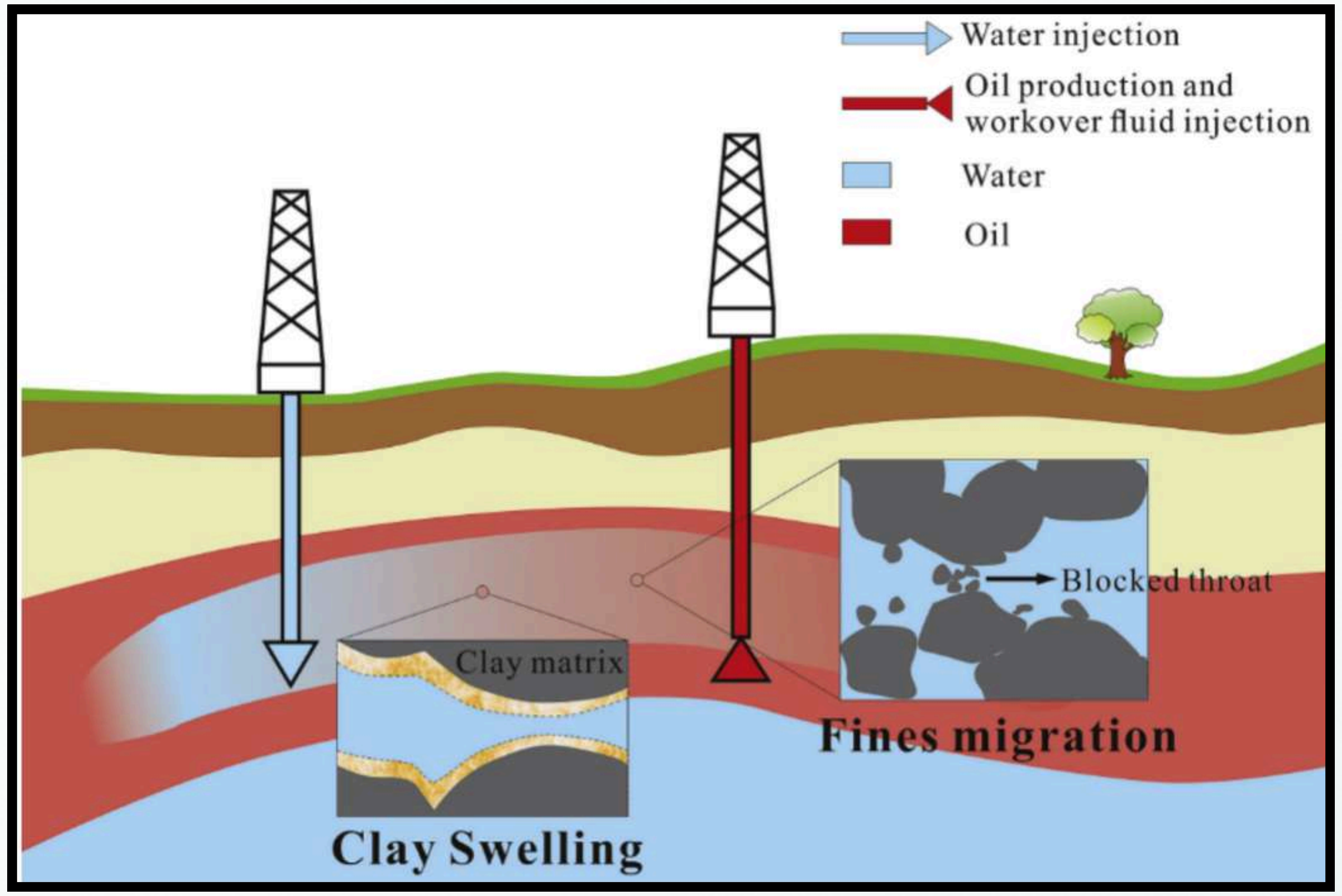
INTRODUCTION

- **Formation Damage**

  Formation damage refers to the reduction in inflow performance due to damage of the near-wellbore area, such as mud solids invasion and plugging.

- **Completion Damage**

  Completion damage is an increased pressure drop affecting the lower completion components, such as plugging of sand screens.



Permebility alterations caused by swelling of clay and migration of fines near the wellbore region after rock–fluid interaction.

EFFECTS OF FORMATION DAMAGE

Reduced Permeability

Formation damage impairs the permeability of reservoir rocks, leading to reduced natural productivity of reservoirs.

Economic Impact

It adversely affects both drilling operations and production, impacting economic viability by reducing recovery potential.

Well Performance

Indicators include permeability impairment, skin damage, and a decrease in well performance.

EFFECTS OF COMPLETION DAMAGE

Increased Pressure Drop

It causes an increased pressure drop affecting lower completion components, such as plugging of sand screens.

Well Productivity

It directly impacts well productivity by reducing the efficiency of the completion system.

Economic Impact

It can lead to increased operational costs due to the need for additional maintenance or workover operations.

FORMATION DAMAGE MECHANISMS

Mechanical

Cause: Physical forces such as drilling, perforation, or fluid injection.

Effects: Includes wellbore enlargement, perforation crush zones, and erosion and thus limited fluid flow into the wellbore

Chemical

Cause: Incompatibilities between mud and formation fluids, such as clay swelling or deflocculation.

Effects: Permeability reduction due to pore plugging by precipitates or emulsions.

Biological

Cause: Introduction of bacteria and nutrients during operations like water injection or drilling with water-based fluids.

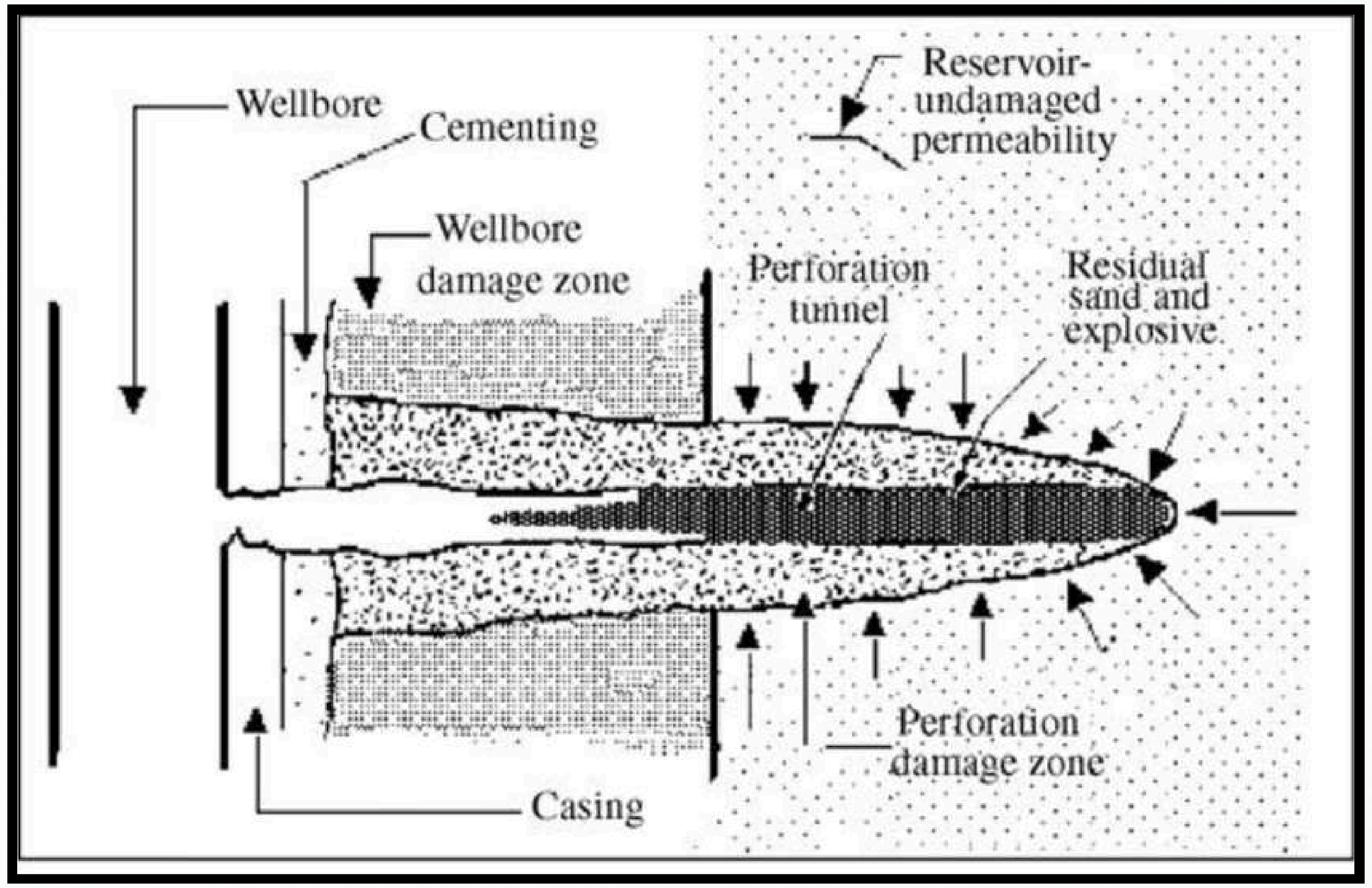
Effects: Bacteria can produce polymers that plug pores, induce corrosion, or produce toxic gases like H2S.

Thermal

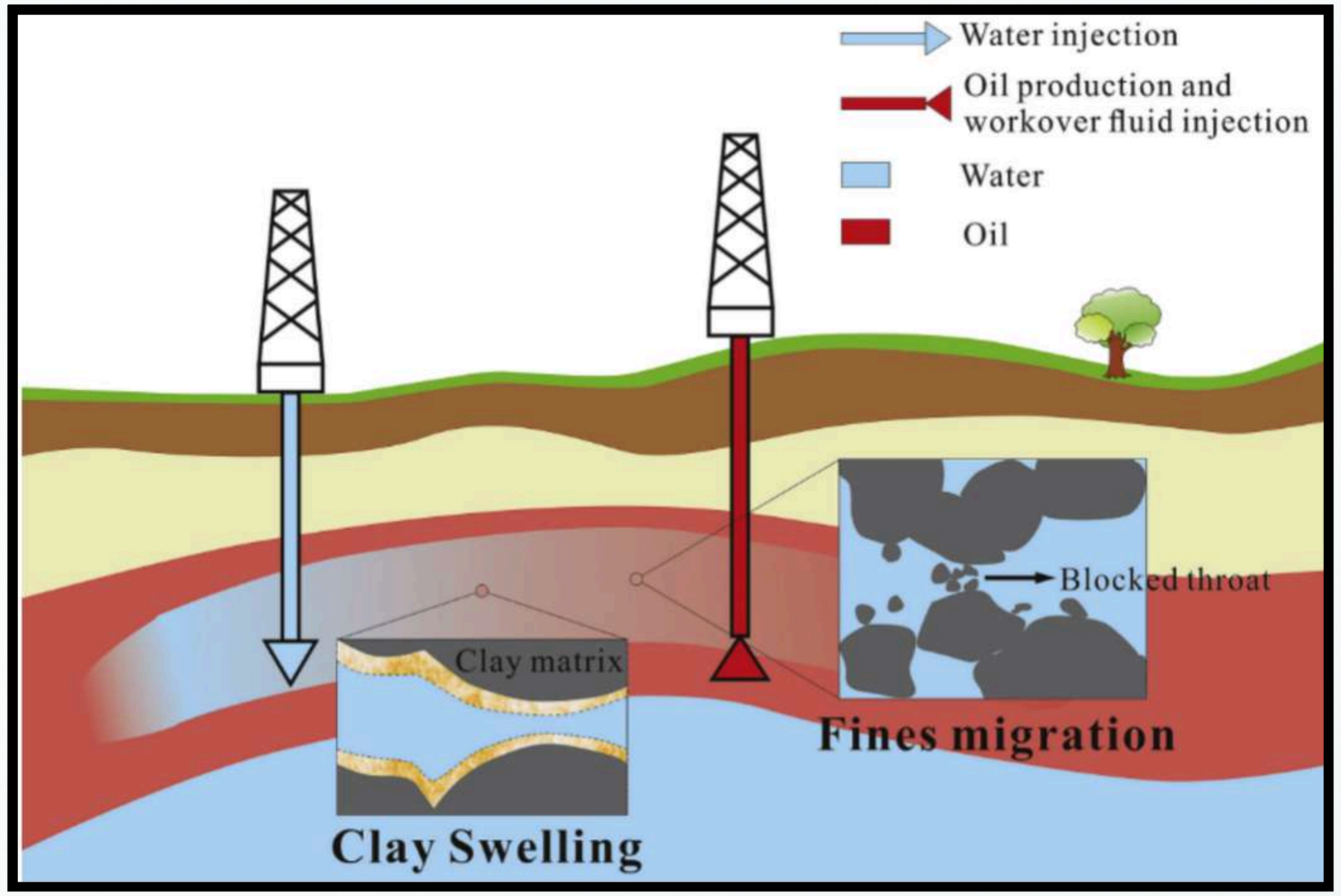
Cause: Extreme temperature changes during thermal recovery processes.

Effects: Can alter mineral stability, leading to precipitation or dissolution that affects permeability

FORMATION DAMAGE MECHANISMS



Mechanical Formation Damage



Chemical Formation Damage

DIAGNOSTIC METHODS

Well Testing and Logging

- **Description:** Measures parameters like epidermal coefficient, permeability after damage, and additional pressure drops to characterize formation damage.
- **Advantages:** Provides direct field data; classical method for damage assessment.
- **Limitations:** Results can be influenced by multiple factors; difficult to isolate specific damage types.

Decline Curve Analysis

- **Description:** Uses production data trends (Arps, SEPD, Duong models) to qualitatively determine if production decline is due to formation damage or other factors.
- **Advantages:** Quick analysis using available production data.
- **Limitations:** Primarily qualitative; limited accuracy in tight or unconventional reservoirs.

DIAGNOSTIC METHODS

Nuclear Magnetic Resonance

- **Description**: Detects fluid distribution, pore size distribution, and porosity changes within core samples through electromagnetic signals.
- **Advantages**: Non-destructive; accurate pore-scale analysis.
- **Limitations**: Expensive equipment; interpretation complexity.

AI Expert Systems

- **Description**: AI-based systems leveraging expert knowledge and programmed rules to diagnose formation damage and recommend solutions.
- **Advantages**: Clear knowledge structure; guided decision-making.
- **Limitations**: Lacks learning capability without updates; relies on expert knowledge quality.

DIAGNOSTIC METHODS

Electron Microscopy (SEM/TEM)

- **Description**: High-resolution imaging techniques providing detailed surface morphology and mineralogical composition at micro-to-nanoscale.
- **Advantages**: High-resolution visualization; effective for qualitative damage analysis.
- **Limitations**: Requires specialized equipment and expertise; limited sample size.

X-Ray Computed Tomography (CT Scan)

- **Description**: Non-destructive imaging providing detailed internal structural visualization of cores before and after fluid exposure.
- **Advantages**: Excellent visualization of internal pore structure changes; non-invasive.
- **Limitations**: High cost; limited resolution in dense rocks.

PREVENTIVE MEASURES

1. Optimal fluid choice for drilling, completion, and workover

- Selection of fluids compatible with formation mineralogy to prevent clay swelling, fines migration, and emulsion formation
- Determination of fluid properties like pH, salinity, density, and chemical additives to maintain well productivity

2. Understanding geology and reservoir characteristics

- Analyzing formation mineralogy, pore structure, and fluid properties to identify potential damage mechanisms
- Techniques like XRD, SEM, and petrophysical studies to develop formation-specific protection protocols

PREVENTIVE MEASURES

3. Optimized completion design based on formation properties

- Preparing perforation strategies and sand control methods to match specific formation characteristics,
- Suitable completion designs considering stress conditions and grain size distribution to maintain formation integrity

4. Proper fluid displacement techniques

- Ensuring efficient displacement of drilling fluids by completion fluids to prevent fluid mixing and associated damage
- Proper spacers with appropriate flow rates and rheological considerations for effective displacement

TREATMENT TECHNIQUES

Chemical Stabilizers

Specialized chemicals that modify surface charges on clay particles, creating bridges between particles and formation surfaces to prevent detachment and migration of fines.

Reducing Production Rate

Controlled production strategy maintaining rates below critical thresholds where drag forces would dislodge formation particles, preventing further damage through gradual, managed flow establishment.

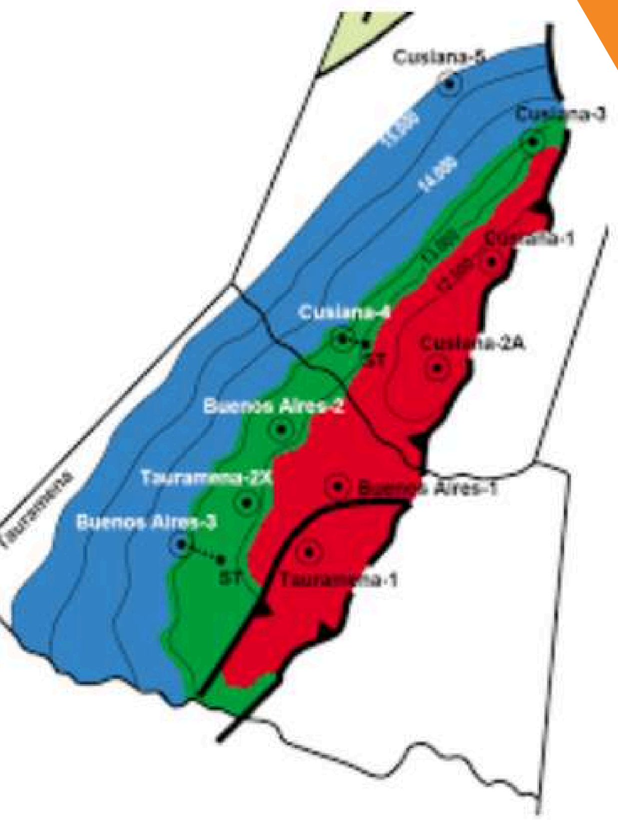
Increasing flow area

Engineering approach that creates multiple flow pathways to reduce localized fluid velocity and pressure gradients, distributing production across a wider formation surface area to minimize damage mechanisms.

Acidizing & hydraulic fracturing

Stimulation techniques that create new flow channels by either dissolving damage-causing minerals with acids or generating conductive fractures that extend beyond damaged near-wellbore regions.

FORMATION DAMAGE IN CUSIANA RESERVOIR - OVERVIEW



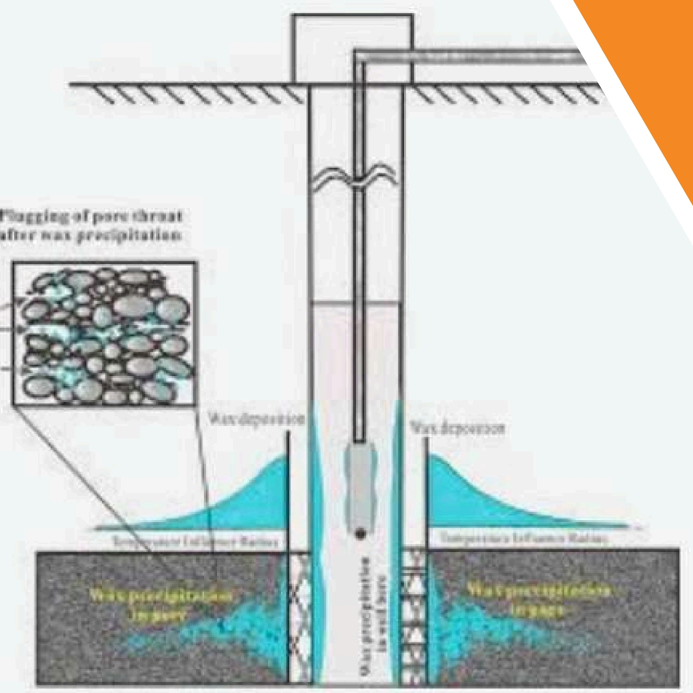
Reservoir Background

- Located in Llanos Foothills, Colombia
- Depth ~16,000 ft; high-pressure conditions
- Sandstone reservoirs (Mirador, Barco, Upper Guadalupe formations)
- High deliverability (>12,000 BOPD) due to quartz-cemented quartz arenites with minimal clay/carbonate cements

Formation Damage Concerns

- Mechanical skin damage significantly impacting well productivity
- Difficult drilling conditions: wellbore instability, mud losses, stuck pipe
- High sensitivity to operational practices during drilling and completion phases

FORMATION DAMAGE MECHANISMS IDENTIFIED



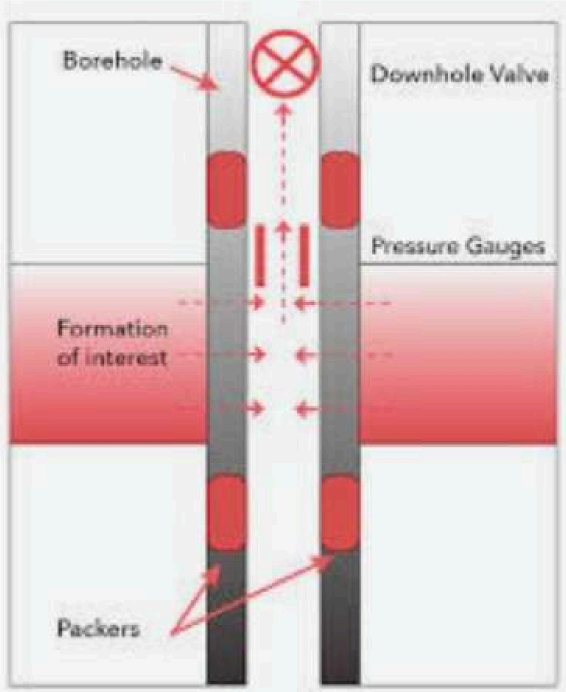
Key Damage Mechanisms

- Loss of drilling fluids and solids into reservoir intervals causing plugging and permeability impairment
- High mud weight overbalance causing fluid invasion and formation damage
- Inefficient perforation practices leading to inadequate cleanup and restricted flow paths
- Improper kill pill designs causing chemical incompatibility and plugging
- Poor filtration control leading to excessive filtrate invasion and solids deposition

Operational Phases Analyzed

- Conceptual planning phase
- Drilling fluid (mud) system selection and management
- Wellbore stability constraints & mud losses
- Completion brine selection & perforating parameters

EVALUATION METHODS FOR FORMATION DAMAGE AT CUSIANA



Drill Stem Testing (DST)

- 16 DSTs evaluated over 2-year period
- Mechanical skin damage (Sd) calculated from pressure transient analysis
- High mechanical skin damage observed (Sd > +10) linked to operational issues:
  - Excessive fluid loss into formation
  - Mud cake quality and filtration issues
  - Perforation technique inadequacies

Correlation with Other Data Sources

- Integrated analysis using:
- Core analyses (porosity, permeability)
- Open-hole log data interpretation
- Long-term production test data
- Technical service laboratory analyses (fluid compatibility tests)

SOURCES

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