Invasion and Reservoir Damage in Tight Reservoirs: Options of Avoiding and Stimulation Based on Damage Mechanisms*

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Abstract

Formation (reservoir) damage is normally thought of as being equivalent to “skin damage”. However, it is not always identifiable by skin measurements or calculations. Formation damage should be defined as any barrier to production within the confines of the near wellbore reservoir or wellbore completion interval that restricts maximum natural production of fluids or gases. One author states, “Formation Damage is simply any process, which would cause a reduction in the productivity and/or injectivity.” Barriers to production are normally thought of as being artificially induced during drilling, completion (cementing, perforating, hydraulically fracturing) or production (workovers), but they are also often naturally induced by the flow of native clays or fines within the reservoir, or by a natural oil wet condition of the rock.

An industry misconception exists that formation damage is not (or of less) concern in tight (low permeability) reservoirs. Gas/oil permeability can be reduced to a great extent due to the invasion of the liquid phase of the drill in or completion fluid. Deep invasion depths, enhanced by capillary forces, have been documented. Effect on productivity depends on the depth to which the formation damage occurs. The same situation can occur in hydraulically fractured formations. This emphasizes how important avoiding formation damage can be.

Primary damage mechanisms and factors that have a significant influence in tight gas reservoirs include mechanical damage to formation rock, water blocking, relative permeability reduction around the wellbore resulting from filtrate invasion and fluid leak-off into the formation during hydraulic fracturing. Formation damage may also result from physical, chemical or biological conditions, i.e., plugging of the pores with muds, formation fines, native clays, bacteria or scale precipitates, cement filtrate invasion, changing the wettability of the formation with surfactants, or by changing the water saturation of a formation with invasion of water from an extraneous source.

The discussion covers methods and tools to avoid, remediate formation damage resulting from various damage mechanisms to which tight reservoirs are subjected, and focuses on hydraulically fracturing. We conclude that avoiding and remediating are the most important issues to be resolved during exploitation of tight reservoirs, and every effort should be made to minimize both the severity and the depth of formation damage.
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The Tight Gas Reservoir

- **Traditional** vs. **Unconventional**
  - Traditional: Reservoir with permeability >10 md (oil) vs. reservoir terminal
  - Unconventional: Reservoir with permeability ≤10 md (oil) vs. reservoir terminal

- **Unconventional Intrusion Damage**
  - "Wells that cannot be produced at economic rates can recover economic volumes of gas unless the wells are subjected to a large hydraulic fracture treated or produced by a horizontal well with multilateral wells.

- **Invasion Damage**
  - By pressurization of reservoir gas
  - Excessive water influx
  - Water breakthrough
  - Water injection

- **Shut-in**
  - Shut-in gas production
  - Some produce water

- **Gas sourced in another formation, integrated and trapped**
  - Not conventional gas in a formation where trapped

- **Majority** of tight gas reservoirs are Gas Bearing reservoirs
  - Organic carbonates in sediments
  - Source marine carbonates

Effect of Formation Damage on Well Productivity

- Most forms of formation damage reduce permeability of a reservoir
  - Causes formation damage/remediation potential using non-destructive analysis
  - Use reservoir models to study effect of reduced permeability on well productivity (Figures to show this effect as related to depth of formation damage)

- **Mechanical Damage**
  - Reduces permeability by thickness of 3 to 30 m reduces productivity by 10%
  - More than 30 m reduces productivity by 50%
  - So, no well, if reduced by 50% for a distance of 12 m, result is 50% of initial well productivity

- **Chemical** stimulation
  - Stimulation efficiency varies
  - No significant improvement for 50 m

- **Example** emphasizes the importance of avoiding Formation Damage

Damage Mechanisms in Tight Formations

- **Several different forms of Formation Damage can occur during drilling**
  - Component Nomenclature and Production

Mechanical Formation Damage

- **Mechanical Formation Damage**
  - Can occur in permeable or non-permeable formations
  - Leads to various mechanical damage by rock mechanics
  - Can result from hazards of long production periods
  - Can be addressed by sand control treatments
  - Can be treated with barriers or gravel pack

Hydraulic Fracturing Formation Damage

- **Hydraulic Fracturing**
  - Can generate significant increases in well productivity
  - Involves some form of chemical damage during treatment
  - Mechanisms can vary between reservoirs

- **Chemical**
  - Coarse in permeable reservoirs
  - Leads to various chemical damage by rock mechanics

- **Environmental**
  - Can result in mechanical damage by long production periods

Conclusions & Recommendations

- **Majority** of low permeability in gas bearing reservoirs
  - Formation Damage can occur during drilling
  - Component Nomenclature and Production
  - Can be treated with barriers or gravel pack

- **Mechanical Formation Damage**
  - To be minimized during treatment (e.g., fluid loss prevention)

- **Use Methods/Apps to Avoid/Remediate Formation Damage**