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Independent Oil and Gas Producers

Naturally Fractured Reservoirs

Course Outline

Approximately 85 percent of the course will be devoted to the relationship between geology, log interpretation, well testing, and primary-secondary recovery of naturally fractured reservoirs. Techniques published recently by the instructor for determination of flow units, rock fabric, pore throat aperture, permeability, capillary pressure and height above the free water table, as well as a new triple porosity model for petrophysical analysis of naturally fractured reservoirs are covered in class.

Geologic Aspects

- Definitions. Reasons for generation of fractures (tectonic - fold and fault related, regional, contractional and surface related fractures)
- In-situ stresses, paleo stresses. Mechanical behavior of rock
- Storage in matrix and fractures. Naturally fractured reservoirs of Type A, B and C. Oil and gas recovery associated with each type of reservoir.
- Migration and accumulation of hydrocarbons in naturally fractured reservoirs
- Sources of information:
    - Direct: Core analysis, downhole cameras
    - Indirect: Log analysis, well testing, inflatable packers, production history
    - Radius of curvature
    - Mapping of fracture trends

Petrophysics

- Dual and triple-porosity models for matrix-fractures, matrix-vugs, fractures-vugs, and matrix-fractures-vugs
- Cross-plotting techniques
- Porosity exponent, m, in naturally fractured reservoirs

- Water saturation exponent, n, in naturally fractured reservoirs
- Water saturation in matrix, fractures and the composite system. Validation
- $P^{1/2}$ statistical analysis for calculating water saturation
- Total, matrix, vug and fracture porosity. Validation
- Flow (hydraulic) units, rock fabric, pore throat aperture, Winland r35, permeability, capillary pressure, height above the free water table
- Fracture Completion Log
- The uncertainty of calculating hydrocarbons-in-place
- Use of sonic amplitude, variable density, dual-induction, laterolog, spontaneous potential, density correction curve, combination sonic-neutron, combination sonic-density, combination neutron-core porosity, borehole televiewer, spectralog, combination sonic-neutron-density, short and long normal, dipmeter, production index, temperature, sibilation, and FMS/FMI/EMI logs in the evaluation of naturally fractured reservoirs.

Well Testing

- Conventional interpretation
- Naturally fractured reservoirs interpretation
    - Parameters lambda and omega
    - Fracture permeability
    - Fracture-matrix average permeability
    - Fracture porosity
    - Average total porosity
    - Size of matrix blocks
    - Effect of matrix block shape (tectonic, regional and/or contractional fractures) and partial secondary mineralization on pressure drawdown and buildup data
    - Skin due to formation damage
    - Pseudo skin due to partial secondary mineralization within natural fractures
    - Pseudo skin due to turbulence, partial penetration, wellbore deviation, perforations, anisotropy and natural fractures
    - Radius of investigation equation for fractured reservoirs
    - Variable-rate buildup and drawdown
    - Effect of a single sealing fault on pressure data
    - Effect of two sealing faults intersecting at any angle
    - Bounded reservoirs
    - Horizontal wells, effect of x, y, z anisotropy
    - Type Curves
        - Obtaining a good match
        - Uniform flux vertical fractures
        - Infinite conductivity vertical fractures
        - Finite conductivity vertical fractures
        - Horizontal fractures
        - Effective reservoir permeability

        - Fracture half-length
        - Dual porosity systems: (a) With or without hydraulic fractures, (b) Outer boundaries with or without pressure maintenance.
    - Pressure Interference, isotropic and anisotropic reservoirs
    - Gas Wells

Completion Methods

- Open hole
- Perforated completions
- Advantages and disadvantages
- Hydraulic fracturing and acidizing

Tight Formations and Coalbed Methane

- Log interpretation
- Performance forecast
- Calculating fracture porosity of coalbed methane reservoirs

Horizontal Wells

- Advantages and disadvantages
- Use and misuse
- Improvements in productivity

Primary Recovery

- Saturated and undersaturated reservoirs
- Fracture compressibility
- Effective compressibility
- Relative permeability curves for fractures, matrix and the composite system
- Material balance, gas-oil ratio and oil saturation equations for stress-sensitive depletion and gas cap-drive reservoirs
- Water-drive reservoirs
- Recovery as a function of pressure and time
- Well spacing
- Water and gas coning through fractures
- Production decline type curves
- Gas reservoirs

Secondary Recovery

- Gas injection in stress-sensitive fractured reservoirs
    - Material balance, gas-oil ratio, and oil saturation equations
    - Depletion and gas cap drive reservoirs with dispersed gas injection

- Recovery as a function of pressure and time
- Well Spacing
- Water Injection
    - Co-current and counter-current imbibition
    - Areal sweep efficiency
    - Importance of fracture orientation
- Water influx from conventional unfractured aquifers
- Water influx from naturally fractured aquifers

Case Histories

- Special features of naturally fractured reservoirs in sandstones, carbonates, shales, chert, and basement rock
- Simulation of naturally fractured reservoirs.
- Micro-simulation of naturally fractured cores
- Undiscovered naturally fractured reservoirs, why and how?

Economic Considerations