Reservoir Dynamics & the New Geophysics

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Talk outline

1. Interwell rate correlations
   • Flow Rate Fluctuations
   • Statistical Reservoir Analysis
   • Rate Correlation
   • Dilatancy: Basic Concept and Reservoir Physics

2. Seismic observations
   • How Aligned Cracks Occur
   • Seismic Consequences of Diltancy
   • Rock Physics
   • Seismic Summary

3. Conclusions
Flow rate fluctuations

Producers

Injectors
Correlation measures:
Standard (Pearson, Spearman, Kendall) or Statistical Reservoir Analysis (SRA)
(developed & patented by the University of Edinburgh)

- Finds best small group of wells to model flow rate of any well of interest
Statistical Reservoir Analysis
Example of correlated wells
General characteristics of rate correlations

First principal component of matrix of rate correlations between all wells in field B – independent mode ‘explaining’ largest proportion of fluctuation variance

Long-range

Fault-related

Stress-related

Injector-Producer pairs only
broadband fluctuations
high frequency fluctuations
zero correlation
Basic concept

Production

Injection

Flowrates

fracture
dilation/closure
and rock
displacements
associated with
permeability and
rate changes
Reservoir physics

• Communications are not just Darcy fluid flow, but…
• …coupled fluid flow and geomechanics
  • incorporating pre-existing faults and/or fractures
  • influenced by modern-day stress state
• … near a critical point
  • long-range interactions = heavy microcracking
Case studies in North Sea with neotectonic setting

Maximum horizontal stress axes
(World Stress Map Heidbach et al (2008))
How aligned cracks/fractures occur

1. Beginning, with hexagonal crack distribution in the conventional ‘billiard ball’ model of grains and porosity……..

2. Increasing differential horizontal stress progressively results in aligned crack/fracture sets

Increasing differential horizontal stress
Seismic consequences of Dilatancy

1. P wave reflectivity is relatively insensitive to systems of aligned cracks/fractures.
2. S waves are much more sensitive.
3. In particular, Shear Wave Splitting (aka Shear Wave Bi-refringence) can be used to fully describe anisotropic, dilatant, rock bodies.
Summary of observations of seismic anistropy

Based on some in situ observations and lab work, Shear Wave Splitting implies that rocks are so heavily microcracked that they verge on ‘criticality’
Seismic consequences of Dilatancy

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This implies:
For truly predictive reservoir monitoring, seismic measurements need to be 3-component..........
Conclusions

• Coupled geomechanics-flow near a critical point is an integral part of reservoir physics
• Reservoir deformation in response to production appears to involve fracture interactions. Modes of deformation can change during the life of a field
• Analysis of inter-well correlations in rate histories offers a low cost means of interpreting faults or fractures between wells, complementary to other techniques; also allowing time-lapse monitoring
• 3C, probably permanent, seismic reservoir monitoring is what’s needed – as opposed to towed streamer.