Reservoir Dynamics & the New Geophysics

David Bamford

on behalf of:

Kes Heffer, Reservoir Dynamics Ltd

&

Stuart Crampin, British Geological Survey

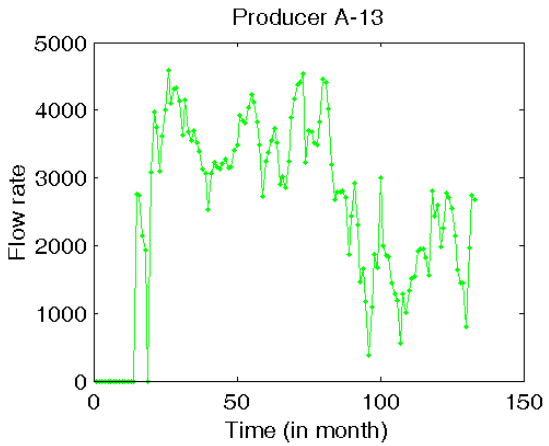
Talk outline

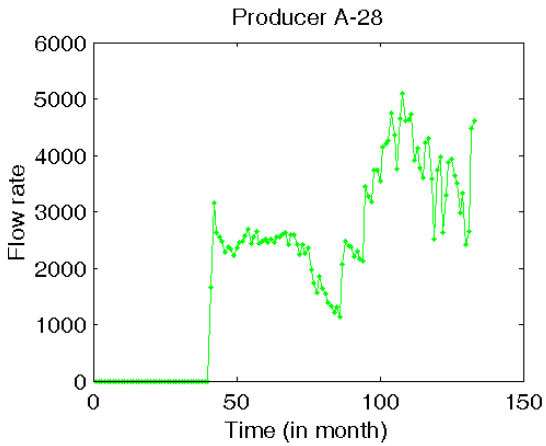
1. Interwell rate correlations
    - Flow Rate Fluctuations
    - Statistical Reservoir Analysis
    - Rate Correlation
    - Dilatancy: Basic Concept and Reservoir Physics
2. Seismic observations
    - How Aligned Cracks Occur
    - Seismic Conseqeunces of Diltancy
    - Rock Physics
    - Seismic Summary
3. Conclusions

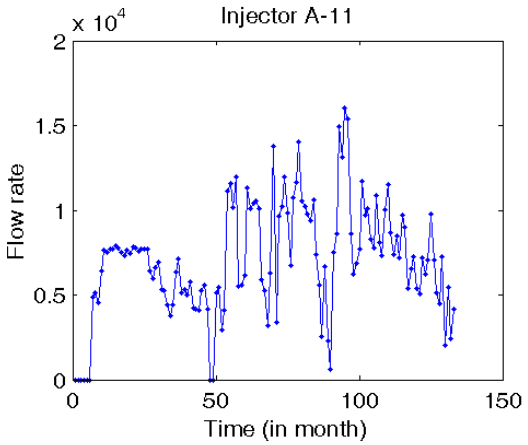
Flow rate fluctuations

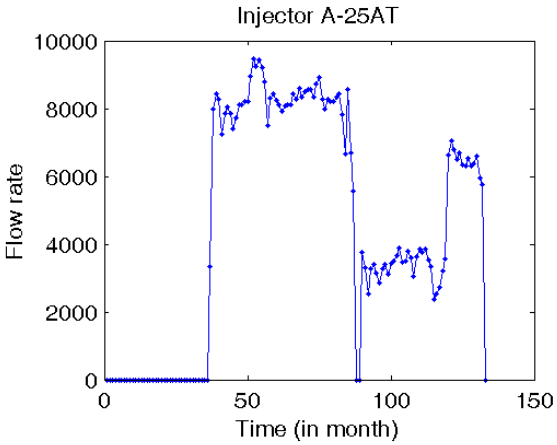
Producers

Injectors

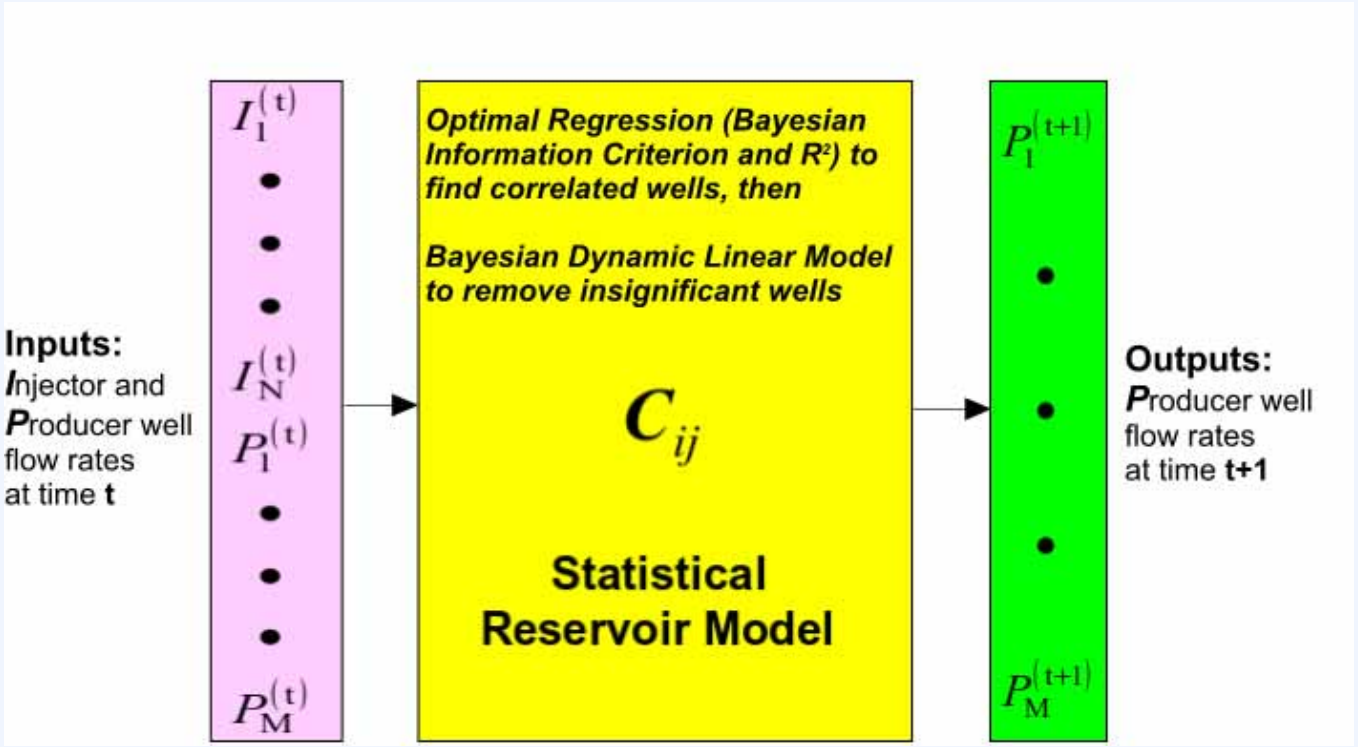






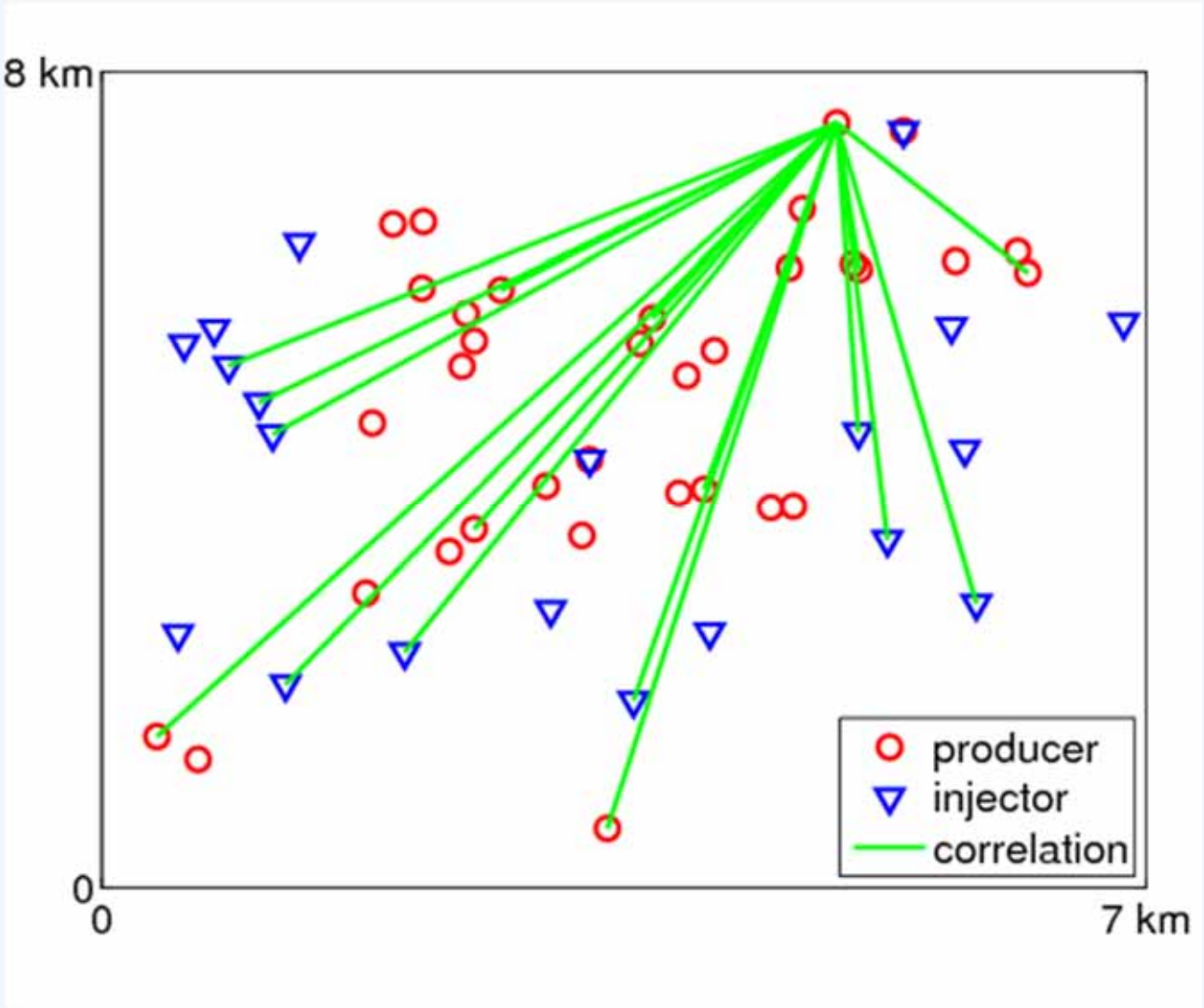


Correlation measures:
Standard (Pearson, Spearman, Kendall)
or Statistical Reservoir Analysis (SRA)
(developed & patented by the University of Edinburgh)



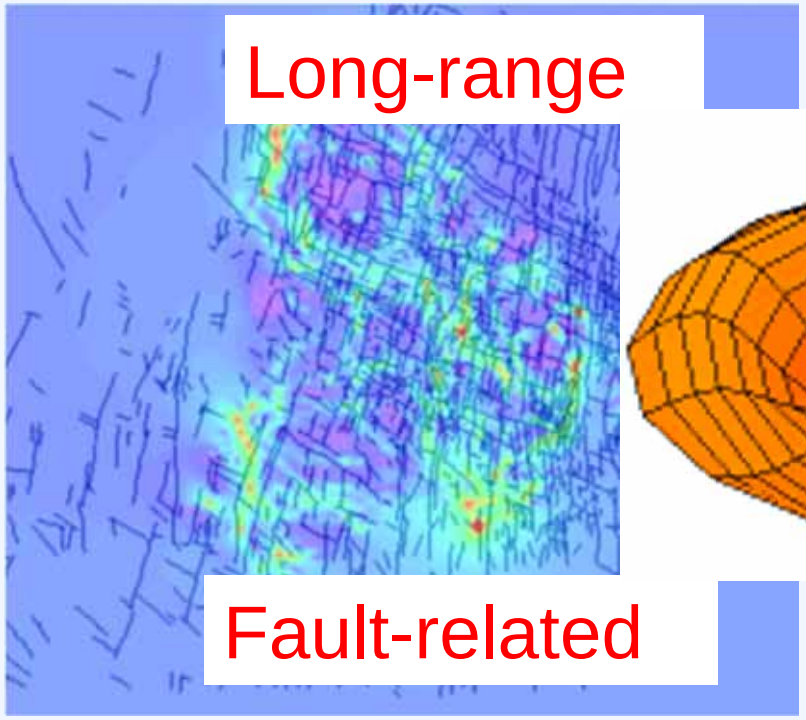
- Finds best small group of wells to model flow rate of any well of interest

Statistical Reservoir Analysis
Example of correlated wells



General characteristics of rate correlations

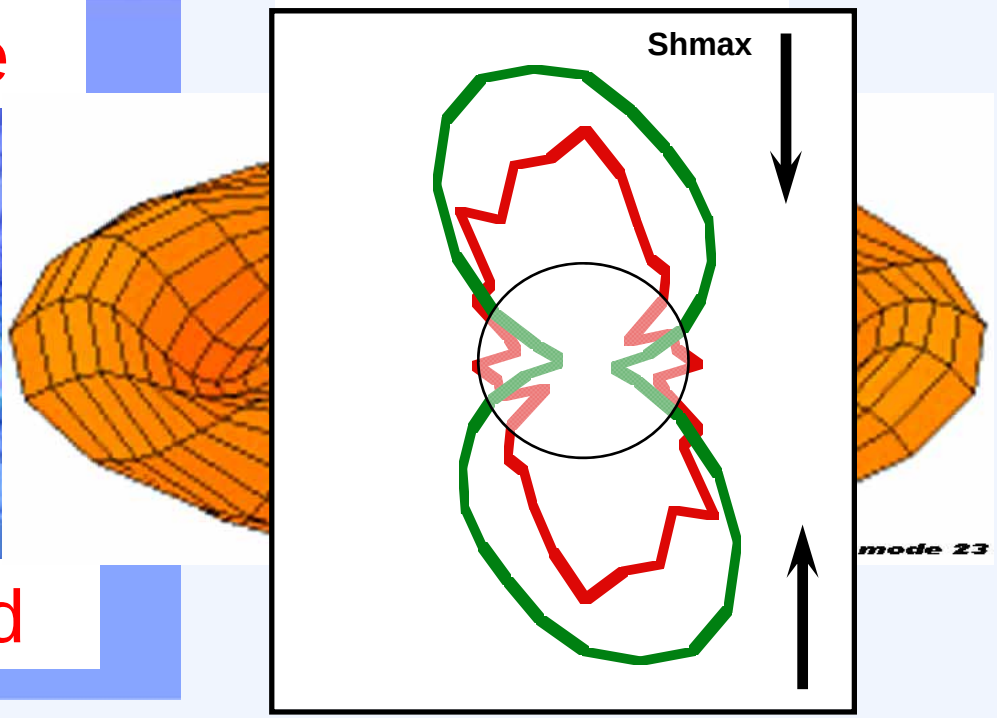
Long-range



Fault-related

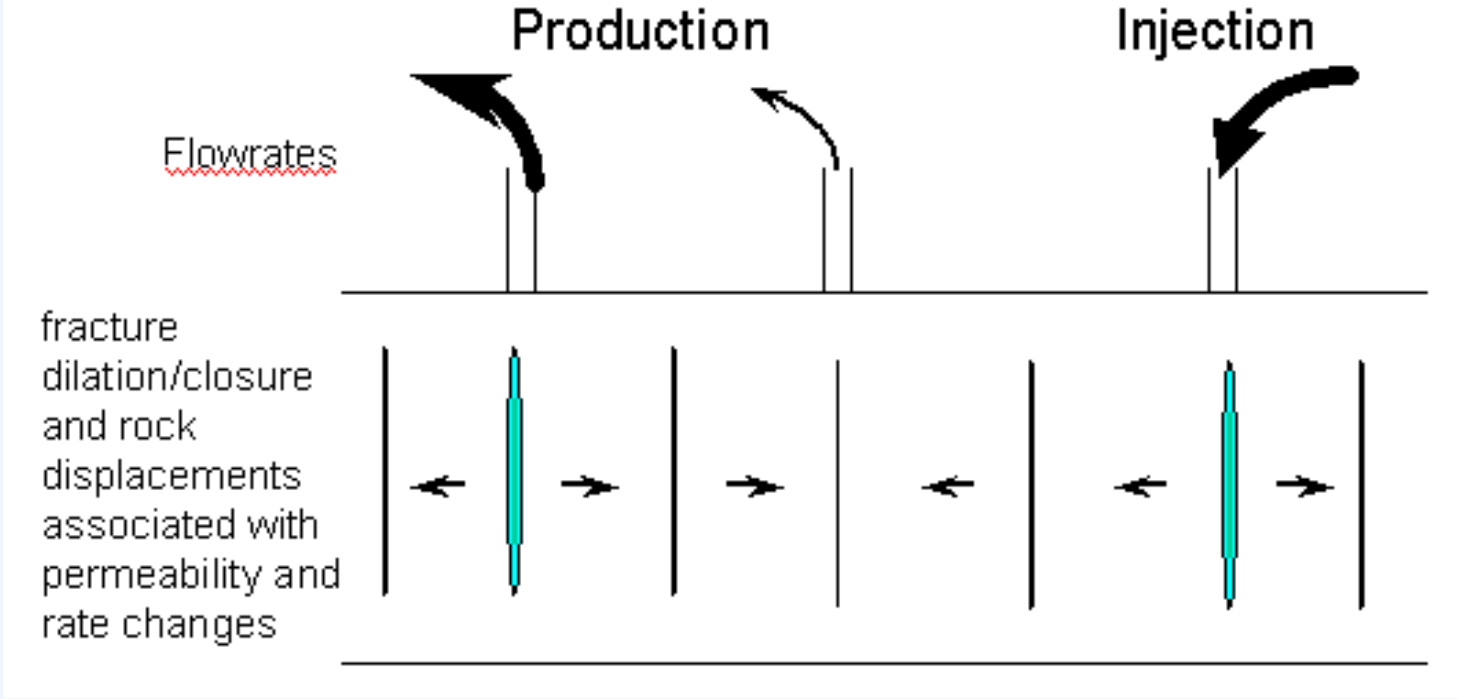
First principal component of matrix of rate correlations between all wells in field B – independent mode 'explaining' largest proportion of fluctuation variance

Stress-related



Injector-Producer pairs only
broadband fluctuations
high frequency fluctuations
__ zero correlation

Basic concept

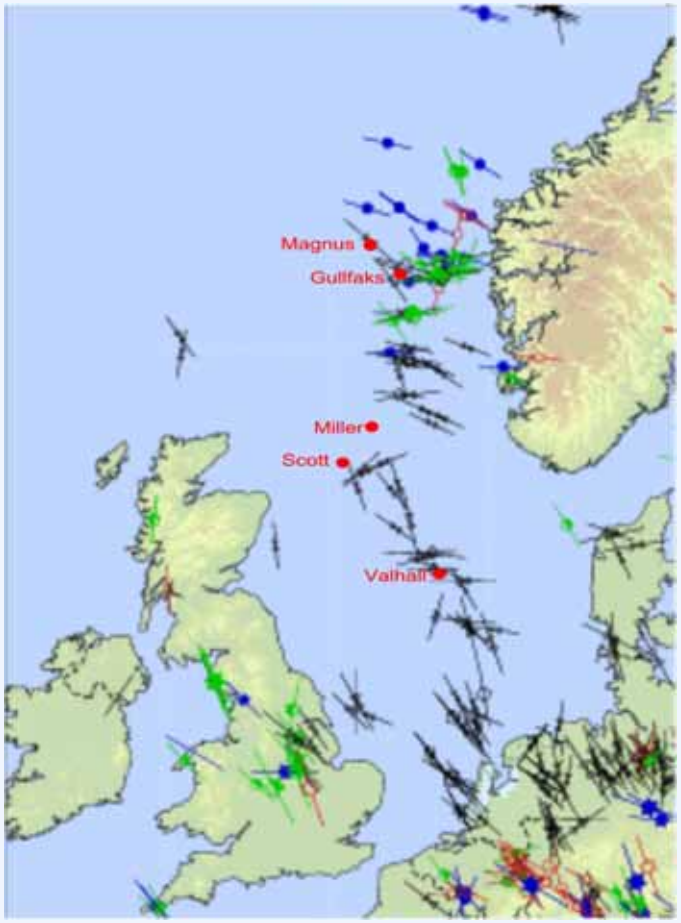


Reservoir physics

- 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

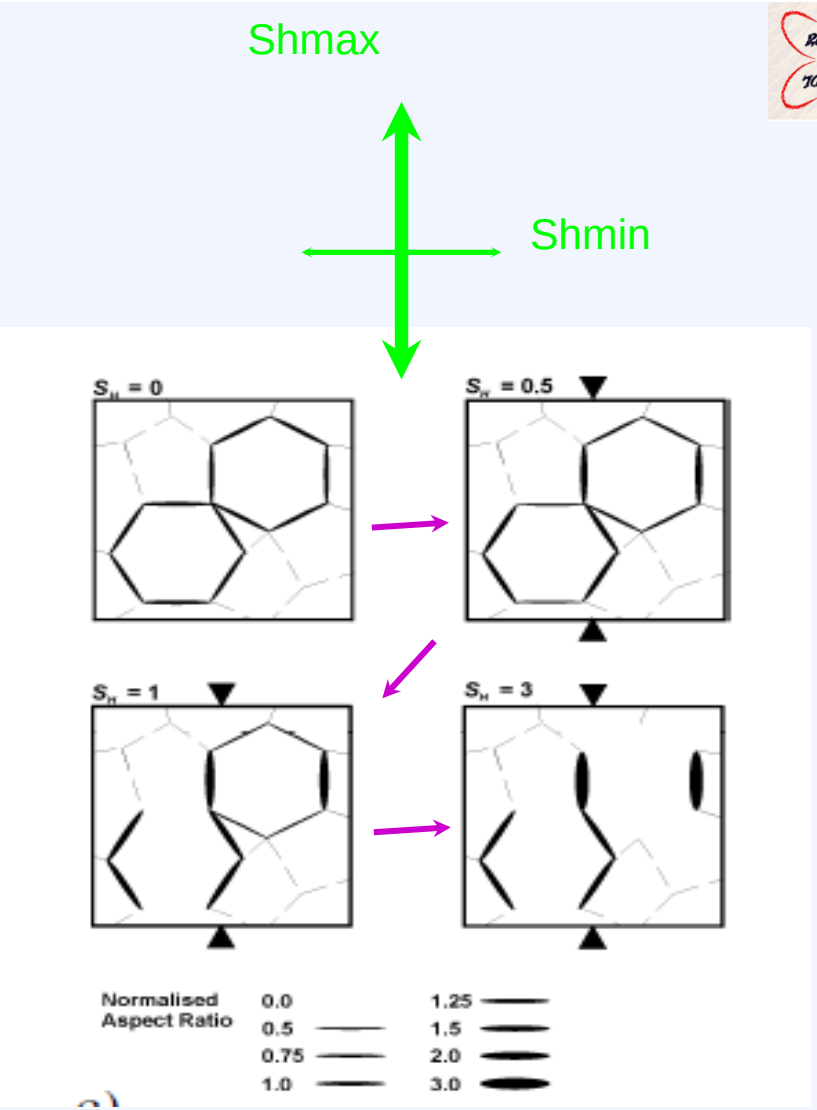
Case studies in North Sea with neotectonic setting

Maximum horizontal stress axes
(World Stress Map Heidbach et al (2008))



How aligned cracks/fractures occur

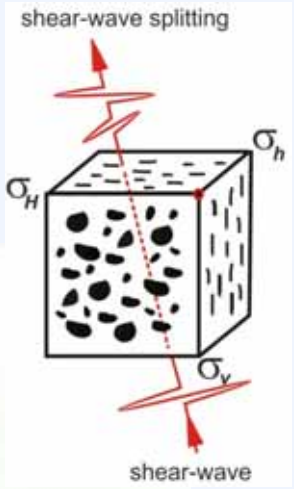
1. Beginning, with hexagonal crack distribution in the conventional ‘billiard ball’ model of grains and porosity…….
2. Increasing differential horizontal stress progressively results in aligned crack/fracture sets

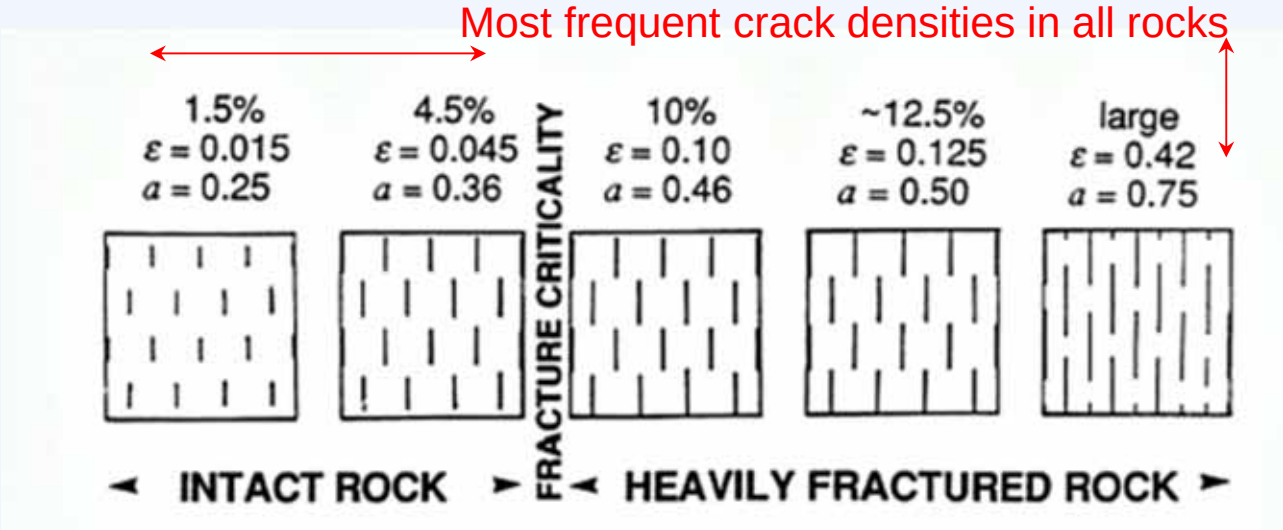


Increasing differential horizontal stress

Seismic consquences 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 consquences 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

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.