Genetic Classification of Natural Fractures: A Key to Understand Flow in a Giant Carbonate Field*

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Abstract

Fractures are one of the main features that impact reservoir quality in carbonates. They record the history of the chemical and physical processes undergone by the reservoir from deposition through burial. These processes dictate the distribution and intensity of different fracture types and their effective flow properties. Understanding fractures from a genetic perspective helps develop better conceptual models that compensate for the often skewed distribution of wells, and the lack of uniformity in the data.

Three distinctive fracture generations can be distinguished in the Kashagan core. (1) During deposition processes associated with exposure and gravitational instability along the margin of the build-up result in early fracturing (Generation A). A-fractures are filled by carbonate, volcanic debris or early marine cements. (2) During burial fractures formed as a result of vertical loading and compaction (Generation B), and mostly in association with pressure dissolution surfaces (stylolites). Both types of structural features were effectively closed and unable to transmit fluids at the time of their formation. (3) During the reservoir charge, elevated fluid pressure led to breaching of the top seal. A fine network of small hairline fractures (Generation C) developed in the tightly cemented rocks, while existing fractures (A and B) were enhanced and in cases reactivated. Through integration of core and image logs a set of guiding principles is defined to identify fracture generations in wellbore images away from where there is core control. Interpretation results show that syndepositional fractures are more abundant along the rim, while burial fractures are ubiquitous in platform and rim. Core-to-log integration also proves that the resistivity signal of a fracture is no guarantee for its dynamic potential. Instead losses experienced while drilling are used as a proxy for excess permeability, in the absence of well test or production data. Lost circulation events and PLTs are evaluated using observations from core and image logs to determine the causes. Results suggest that A-Generation drives the large scale fracture permeability in the rim. In the platform, losses are mostly related to B-fractures. This provides a modeling approach more closely tied to geological processes and consistently integrated among data types. It can be used to distribute fractures based on the inferred spatial variability of causative processes within the reservoir over time.
References Cited

Collins, J., W. Narr, P.M. Harris, T. Playton, S. Jenkins, T. Tankersley, and J.A.M. Kenter, 2010, Lithofacies, depositional environments, burial diagenesis, and dynamic field behavior in a carboniferous slope reservoir, Tengiz Field (Republic of Kazakhstan), and comparison with outcrop analogs: SEPM Special Pub 105, p. 50-83.

Genetic Classification of Natural Fractures:
A Key to Understand Flow in a Giant Carbonate Field

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• Not all fractures form the same, so why do we then model them together?

• North Caspian reservoirs as an example of how a genetic characterization of natural fractures can improve reservoir description and development of concepts to predict fracture occurrence

• This is the result of a 3 year study involving 45+ wells with core and/or wellbore image logs

• All interpretations and conceptual models are supported by core observations
Geological Setting

CHCD wells mostly in the rim

Collins et al. (2003)
A-Generation Fractures: Syn-depositional

Characteristics

- Opening mode: dip slip; sinuous to irregular
- Dip > 60°; width to 80 mm, variable; non-matching walls
- Analog data suggest 90+ m height, and m-km scale lengths
- Partially filled with clay, carbonate debris or early marine cements
- Abundant near exposure surfaces and outer platform to slope transition
- Pre-date all other structures

Clay / Debris
Bitumen
Carbonate Micrite
B-Generation Fractures: Burial Related

Characteristics

- **Opening mode**  dip slip; irregular, branched to crossing networks
- **Dip > 60°; width to 30 mm**, high L:W ratio
- Mostly filled with **blocky calcite, bitumen**; late dissolution
- Medium to high abundance **in swarms**
- **Post-date Gen A joints; pre-date / coeval with stylolites**

![Smaller, Filled Joints](image1)
![Large, Partially Open Joints](image2)
![Late Corrosion](image3)

SB5

SB5: stylolites

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AAPG Annual Convention & Exhibition 2016
C-Generation Fractures: Overpressure

Characteristics

- **Opening mode**: ~ planar, sub-mm to cm scale spacing
- **Dip**: > 75° or < 15°; **width** < 0.1 mm; high L:W ratio, <20 cm long
- **Stained dark brown**: locally pitted along trace
- Abundant in **boundstones** and tightly **cemented** grainy lithofacies
- **Post-date most structures**: may pre-date minor late stylolites

![SB5](image1)

![C](image2)

![C](image3)
**Log-without-Core Fracture ID Criteria**

### A - Fractures
- Continuous to quasi-continuous sinusoids
- Strong resistivity signal (cond / res)
- Not associated with DITFs
- Below and near sequence boundaries
- Non-planar surface geometry
- Below and near clay seams

### B - Fractures
- Enhanced in tensile wellbore regions
- Sub-parallel to S\(_{H_{\text{max}}}\)
- Form clusters along the wellbore
- Low dispersion in orientation
- Mostly semi-continuous
- Bounded by stylolites
A-Generation Fractures: Orientation and Abundance

Fracture density (P32)
Dynamic Potential of A-Generation Fractures
Syn-depositional (A-Gen) Fractures Conceptual Model

Canning Basin (WA) - Courtesy of Ned Frost

Gen A, Rim-Parallel Fractures
B-Generation Fractures: Abundance & Dynamic Potential

Wells with Lost Circulation Zones (LCZs) in Late Visean A1

Fracture density (P32)

Well name

Bash
Serp
Lvls

# LCZs in Platform Wells

# LCZs in LVIS Platform Wells
B-Generation (Burial) Characteristic Regions

1. B-Gen in fault damage zones
   Highest fracture densities observed
   Fractures mostly open with strong dissolution overprint
   One of the main drivers of massive losses and CHCD
   Depth extend is uncertain due to lack of reflectivity in boundstones

2. B-Gen in the slope
   Not well characterized as well are drilled in CHCD mode
   Potentially cemented so lower effective fracture density
   Late dissolution may enhance fracture properties

3. B-Gen within A-Gen region
   High fracture density
   Mostly filled fractures with bitumen and calcite
   Flow contribution mostly overwhelmed by A-Gen
   Different scale between A and B represents modeling challenge

4. B-Gen in the back rim
   Conceptually related to compaction bend
   Medium-High fracture density
   Often plugged with bitumen

5. B-Gen in the platform
   Moderate fracture density
   Mostly open fractures
   Develop as clusters within certain stratigraphic intervals

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**B-Gen Fractures**
- Areas of increased density in platform
- Areas of increased density in slope/margin

**A-Gen Fractures**
- Higher
- Lower
- Probability / Density
- Outer Platform / Slope transition
Dissolution and the Non-Matrix Continuum Dilemma

Solution enhanced B-Gen fracture

Scale

1:60

resistivity

N | E | S | W | N

Large fractures or caverns?

Solution enhanced A-Gen fracture

modified after Palmer (2007)
• Genetic fracture characterization, although time intensive, allows development of robust geologic concepts for reservoir modelling.

• A process-based modelling strategy is used in this example:
  • A-Gen (syn-depositional) fractures. Related to gravitational instability around the outer-platform/slope transition. Likely to control large scale flow along the rim.
  • B-Gen (burial-compaction) fractures. Ubiquitous, high density but smaller than A-Gen. Diagenetic overprint results in characteristic regions that need to be modelled separately.

• All fracture generations are affected by late dissolution processes which makes challenging to:
  • Estimate fracture porosity and effective properties.
  • Establish the boundary between enhanced fractures and karts.

• In the absence of reliable PLT/production data, Lost Circulation Zones can provide valuable information on the permeability structure of the fracture network.
Kashagan Field Studies Team (2012-2015):
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Thank you!
Supporting Slides
Open, Effective and Conductive Fractures

The resistivity character of fractures in image logs is no guarantee of their dynamic potential.

Well A
- Fracture is conductive, open and effective
- >150 m³ lost in this feature

Well B
- No losses. No core
- Fractures are resistive and likely filled

Well C
- No losses. In core, fracture is filled with clay
- Fractures are conductive and filled

The resistivity character of fractures in image logs is no guarantee of their dynamic potential.
Fracture Genetic Styles and Burial History

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Early HC charge

Collins et al. (2010)
Non-Matrix Conceptual Model
Tension cracks Basinward
Faulting along the Rim

PSTM Depth H:V = 1:2

Observed fault

Projected fault

OWC