FRACTURED BASEMENT
A CASE STUDY

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Overview

- Oil discovered in Fractured basement of Bach ho oil field on May 1986 in Cuu long Basin, Vietnam
- Start producing from basement: 25.11.1988
- Production rate: 250,000-300,000 bopd
- Cumulative production upto date: ~1,200 MMbbls
Generalized stratigraphic column of Cuu Long basin

- **Oil migration**
- **Main compression phase**
- **Basement exposed**
Seismic data

Three zones based on seismic characteristics:

- Upper zone: low frequency, high amplitude, low continuity on the chaotic reflection background
- Middle zone: high angle reflections on the chaotic reflection background
- Lower zone: chaotic reflections
Three zones are clear on conventional 3D PSDM as well as special processing data:

- **3700-3800m** (high amplitude, low frequency ~ yellow)
- **4250-4500m** (higher frequency, good continuity ~ green)
- **Below 4500m** (chaotic ~ red-magenta-blue)
Basement domains are clearly defined based on seismic data (both conventional & special processing)

Different reservoir qualities in each basement domain

Abnormal reflection within basement
Fault system - Tectonic analysis

Fault types

- Normal faults
- Reverse faults
- Lineament faults
Main oil flow intervals from Fault zones

Flow intervals are variable and changed with time
Fracture systems

Macrofractures

- Tectonic fractures:
  - Continuous
  - Partly continuous
  - Bounding
  - Fractures in brecciated zones
  - Fractures with associated vugs
  - Dip angle: 50-90°
  - Variable fracture aperture
  - Fractures are partly to totally filled with secondary minerals
  - Fracture density are reduced with depth and distance from fault.

- Artificial fractures:
  - Drilling induced fractures
  - Reopened fractures
Fracture systems

Microfractures

- High density associated with macro fractures
- Fracture density and their length depending on macro fracture density
- Averaged length of micro fractures about 2.5 cm
- Secondary alteration processes were strong in micro fractures:
  - Partly to totally filled with secondary minerals
  - Rock was easily deformed and creating vug system associated with these fractures
- Important role and may enhance reservoir quality
Basement rocks were strongly altered by many processes

- Reservoir quality is controlled by:
  - Tectonics
  - Weathering
  - Hydrothermal alteration
    - <50°C: mordenite
    - 100-200°C: laumontite, analcime
    - >200°C: metallic sulfides of zinc, copper
  - Early oil emplacement
Dykes system

- Dykes are widely distributed within basement

- Dykes are normally parallel to tectonic fracture systems

- Rocks are differently deformed in intensity
  - Dykes, formed before exposing on to surface, were more strongly deformed and their reservoir quality is better
  - Later dykes were weakly deformed, homogenous and plays as seal/barrier rocks

- Thickness of dykes are very variable
Tight/fresh blocks in Basement

- Tight/fresh blocks are dominant and can be observed both in outcrops as well as in the wells sections.
- Tight/fresh blocks increase with depth of buried basement.
Hydrothermal activities are strong along main faults

- Strong hydrothermal zones are closely related to deep and reactive faults
- Hydrothermal activities are stronger along high displacement faults and seem to create sealing barrier between fault blocks
Domains can be defined by data from long term production.

Trends of reservoir pressures in each domain are different, it indicates that connectivity between domains is very poor.
Domains in basement

Basement reservoir can be divided into domains
Porosity and N/G with depth

- Reservoir quality is reduced with depth and laterally varied

Porosity

N/G

3800 m

4300 m

North

4400 m

Centre + South
Productive zones are dominant in the depth above 3800m (more than 62%)
Core porosity

Core broken, effective porosity is less than 5% reflecting unaltered rocks

Better core recovery, porosity can reach to 10%, fast reduced to below 6-7%.

Core porosity is less than 5%.
Permeability with depth

Permeability from DST and core analysis

From core

Analysis results are typical for less altered rocks

In the interval of 3800-4400m, perm may reach to 1000mD

Permeability reduce very quickly to 1 mD at depth of 5000m

DST/ PLT in 70 wells

Good productive intervals are dominant with perm can be up to more than 100mD

Permeability is reduced significantly, perm range is mostly below 20mD

Productive/injective zones are very rare

Permeability (measured from core or DST) reduce strongly with depth of reservoir
Basement reservoir distribution

(Trịnh Xuân Cuông, 2007)
FRACTURED BASEMENT RESERVOIR MODEL

Zone I: Very good reservoir quality; the principal reservoir
- Good porosity and permeability
- Good 3D connectivity

Zone II: Reservoir quality is variable and it acts as a potential, but patchy zone
- Weakly weathering processes, Hydrothermal processes dominant
- Breciated zones are partly to totally filled by secondary minerals
- Low boundary can reach to depth of 4300-4400m
- Good connectivity vertical and along main fault
- Poorer connectivity between parallel fault
- Average storage capacity

Zone III: Reservoir quality is not economic
- No weathering activities; Hydrothermal processes dominant
- Unaltered and weakly deformed rocks
- Almost fault zones are filled by secondary minerals
- Localized reservoir
- Very poor connectivity
- Poor flow/inject rate
Porosity types:

- Matrix (1,2)
- Microfractures (3)
- Macrofractures (4)
- Vugs/cave (5)

Basement tight blocks
Fractured Basement Reservoir Model

- Macro fractures and vugs => Macro system: Very high permeability, limited storage capacity (average 24%)
- Intergranular and micro fractures => Micro system: Low permeability, important storage capacity (average 76%)

Dual Porosity-Permeability Reservoir Model
CONCLUSION

• Basement are complex lithology & highly heterogeneous, high variation of reservoir & litho-physical parameters, difficult to predict their distribution

• Reservoir portion was formed by brecciated fault zones with associated micro and macro fractures as well as vug pores created from mechanic-chemical activities.

• Thickness of productive zones and their reservoir quality as well as their connectivity are strongly reduced with depth.

• Basement reservoir is vertically divided into 3 zones:
  • The upper most zone: above 3800m with very good reservoir quality; the principal reservoir
  • The second zone: reservoir quality is variable and it acts as a high potential, but patchy
  • The lower most zone: reservoir quality is not economic

• Basement is a Dual porosity-permeability reservoir
Recommendation

- Revise petroleum system with considering basement rocks as a potential fractured reservoir
- Reconsider regional tectonic evolution to detect productive fracture/fault system in basement
- Reprocess 3D seismic data in oil areas/provinces/basins with basement highs.
- Re-drill/re-test wells that oil shows are good and big mud volumes loosed in basement sections.
- Field works are very important and should be carried out to build analogue models for fractured/faulted reservoir characterizations
- Workshop/meeting/study cooperation on fractured reservoir should be organized frequently to share experiences
Thank you for your attention!