PETROVIETNAM - CCOP

FRACTURED BASEMENT
A CASE STUDY

By Trinh Xuan Cuong
VPI - PVN

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- Reservoir distribution
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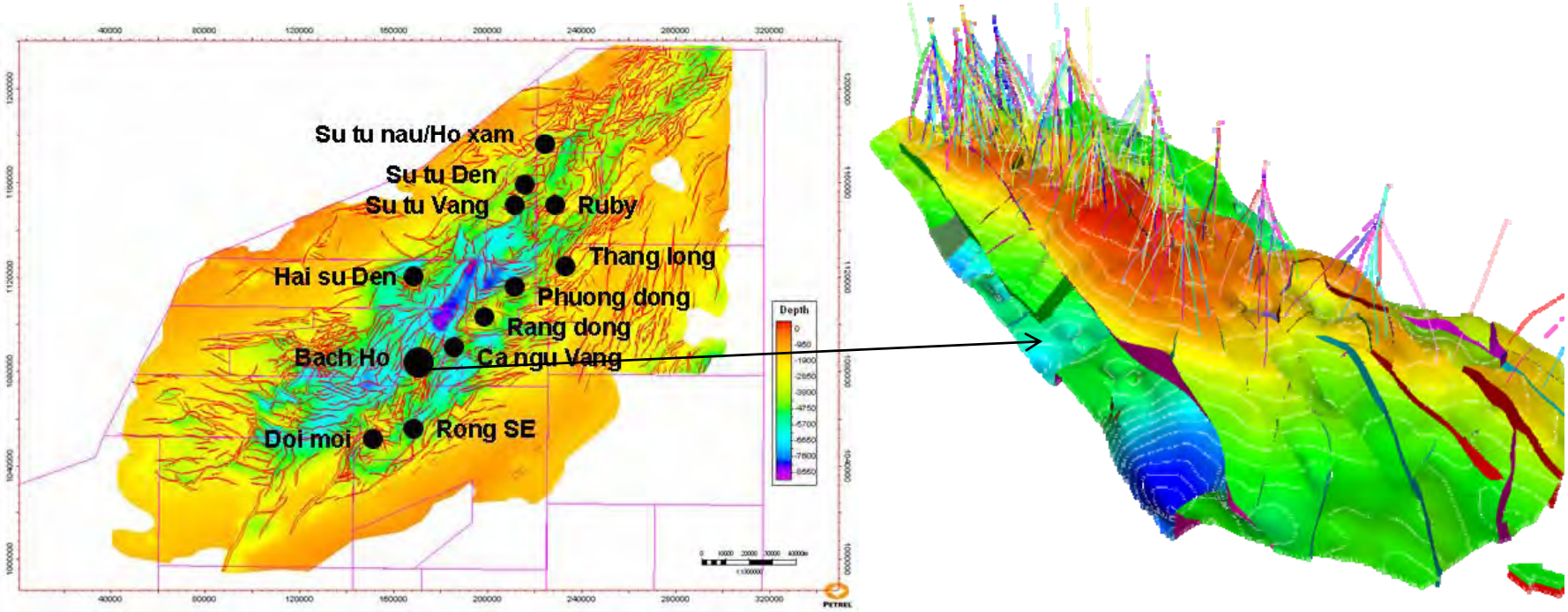
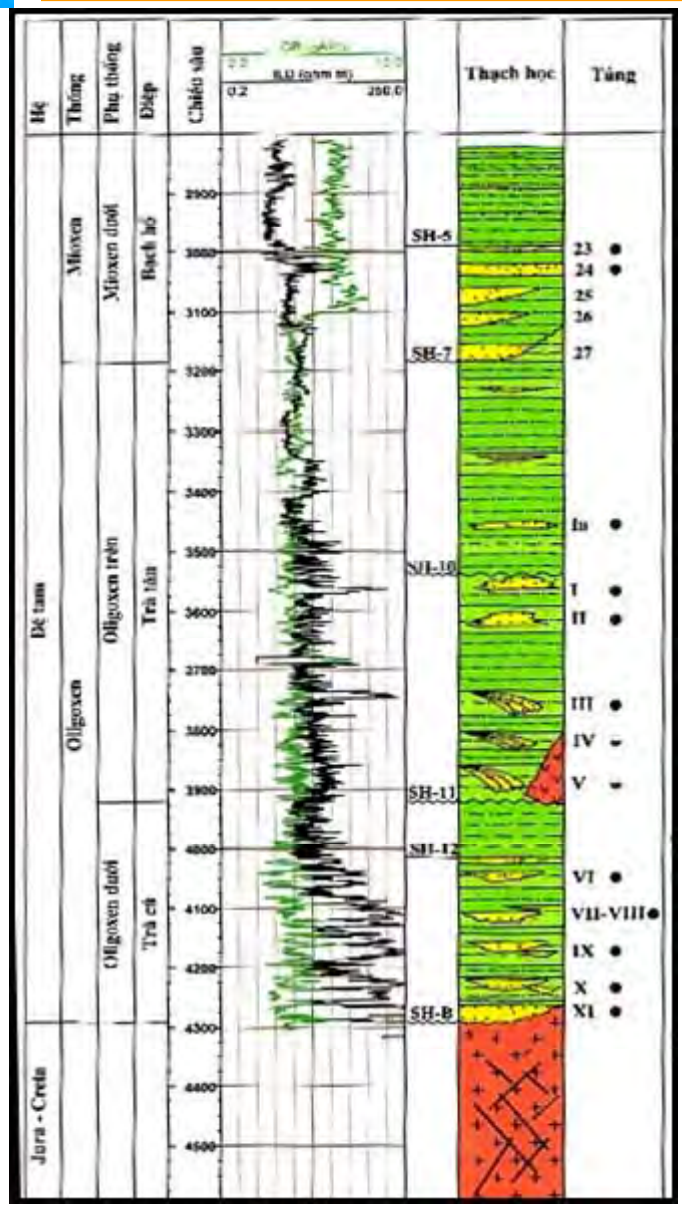
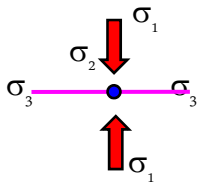
Overview

- 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
- Cummulative production upto date: ~1,200 MMbbls

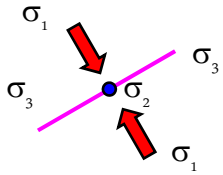


Generalized stratigraphic column of Cuu Long basin

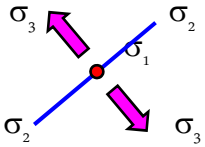




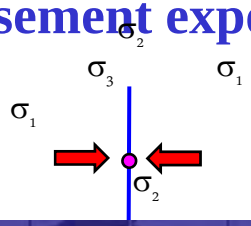
Oil migration



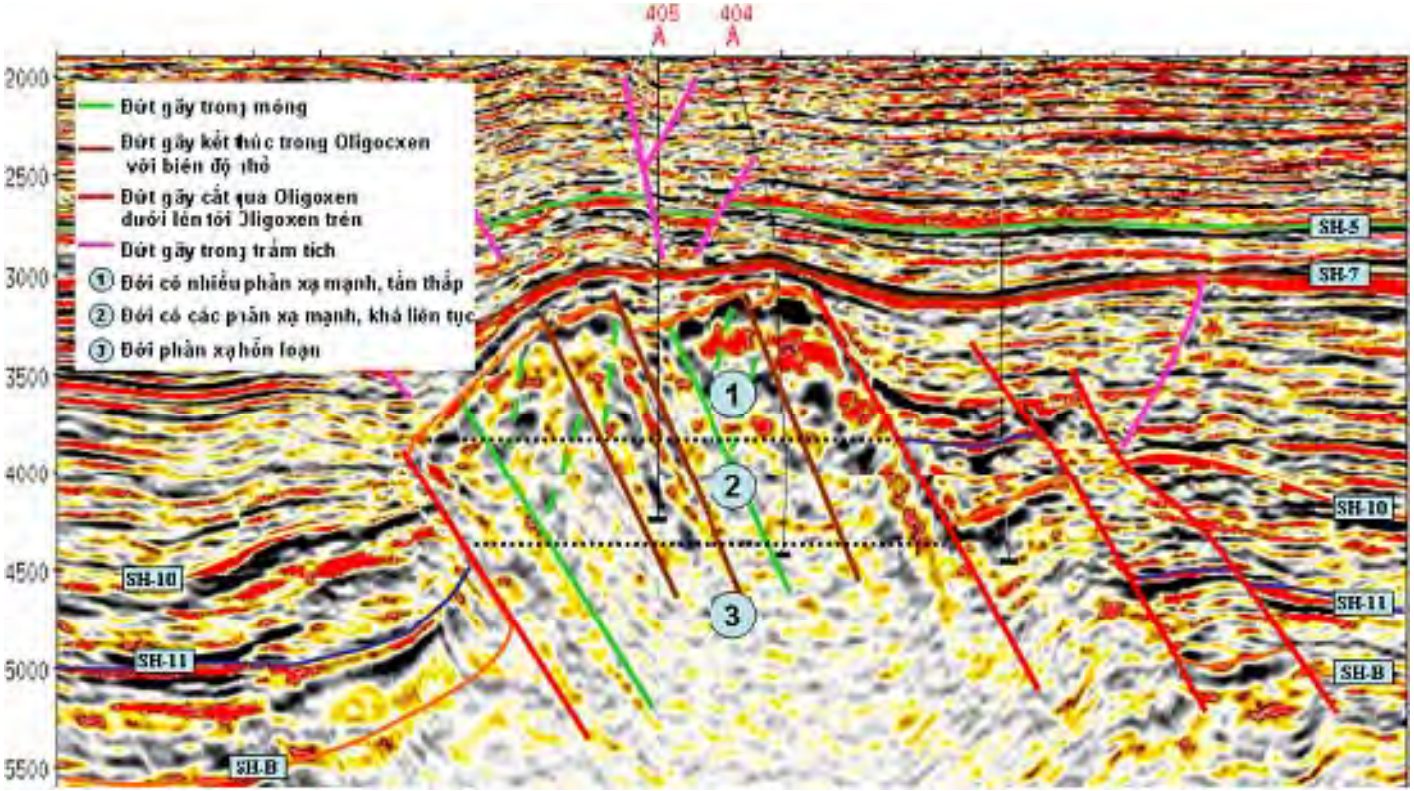
Main compression phase



Basement exposed



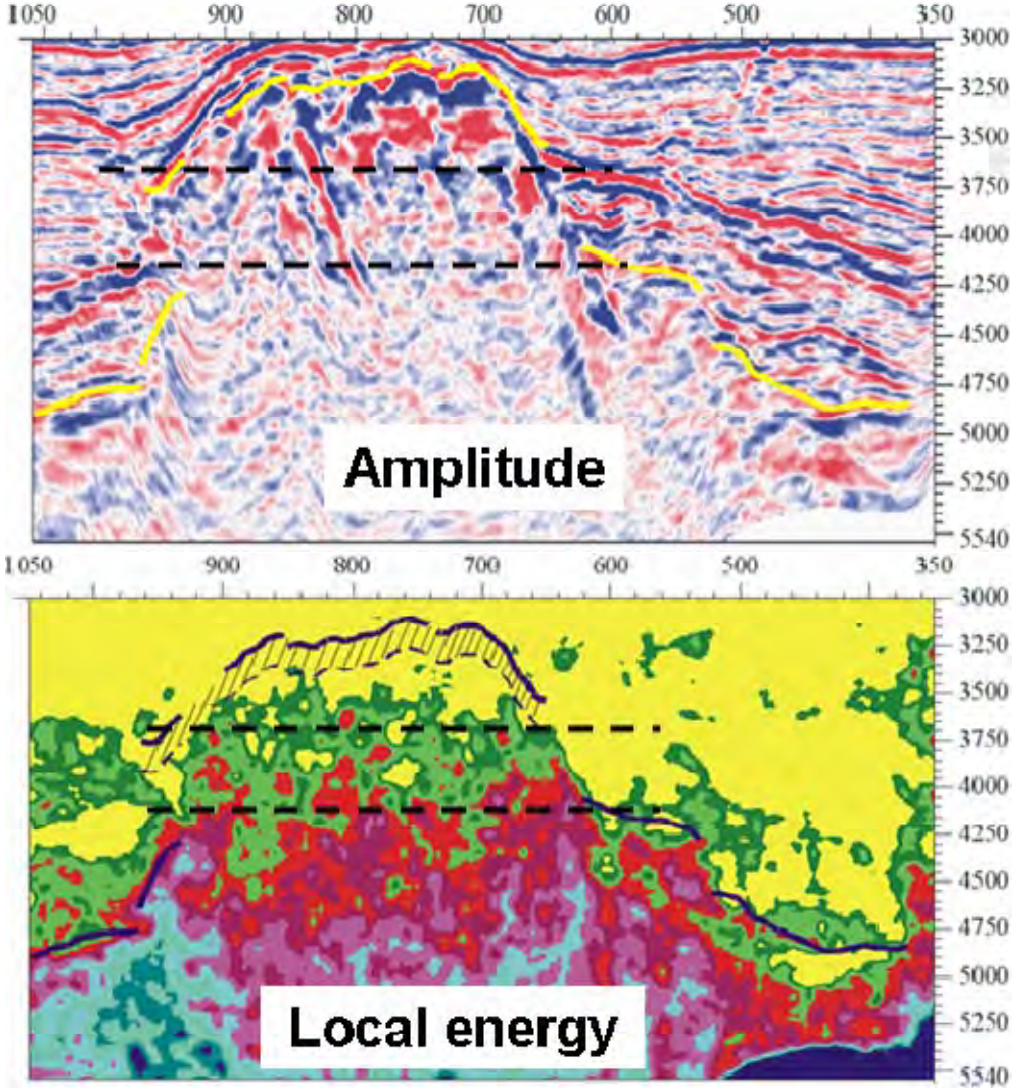
Seismic data



❖ Three zones based on seismic characteristics:

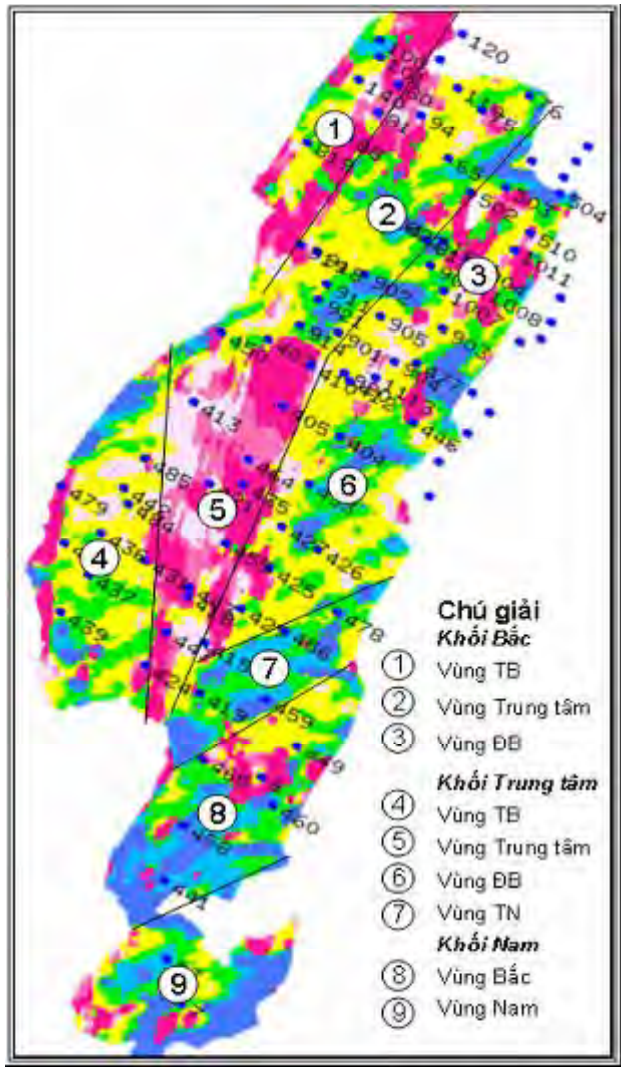
- Upper zone: low frequency, high amplitude, low continuity on the chaotic reflection background
- Middle zone : high angle reflections on the chaotic reflection background
- Lower zone : chaotic reflections

Seismic data

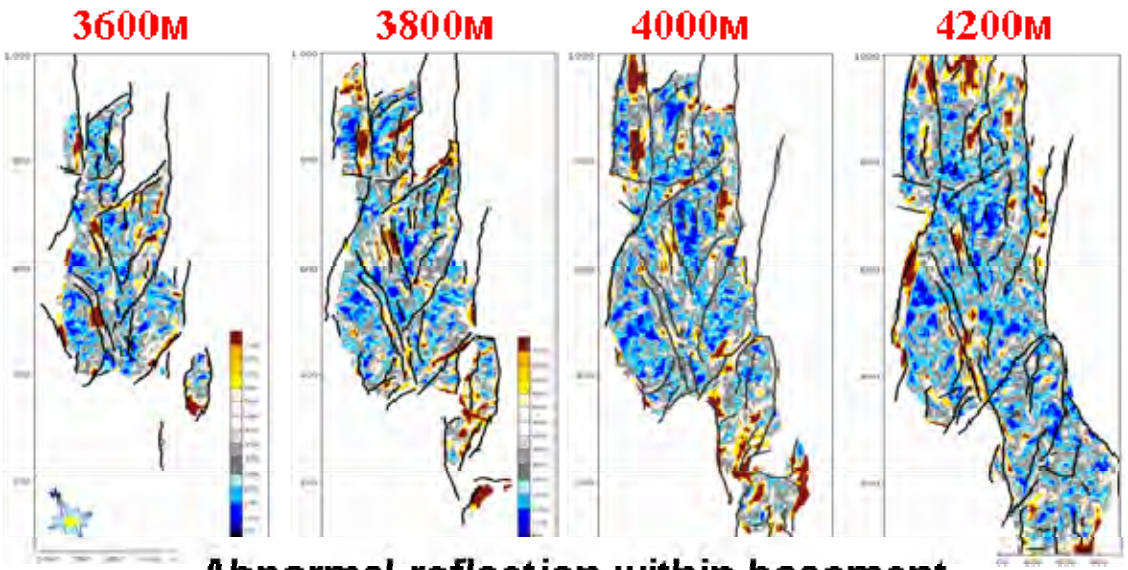


- Three zones are clear on conventional 3D PSDM as well as special processing data
  - 3700-3800m (high amplitude, low frequency ~ yellow)
  - 4250-4500m (higher frequency , good continuity ~ green)
  - Below 4500m (chaotic ~ red-magenta-blue)

Seismic data

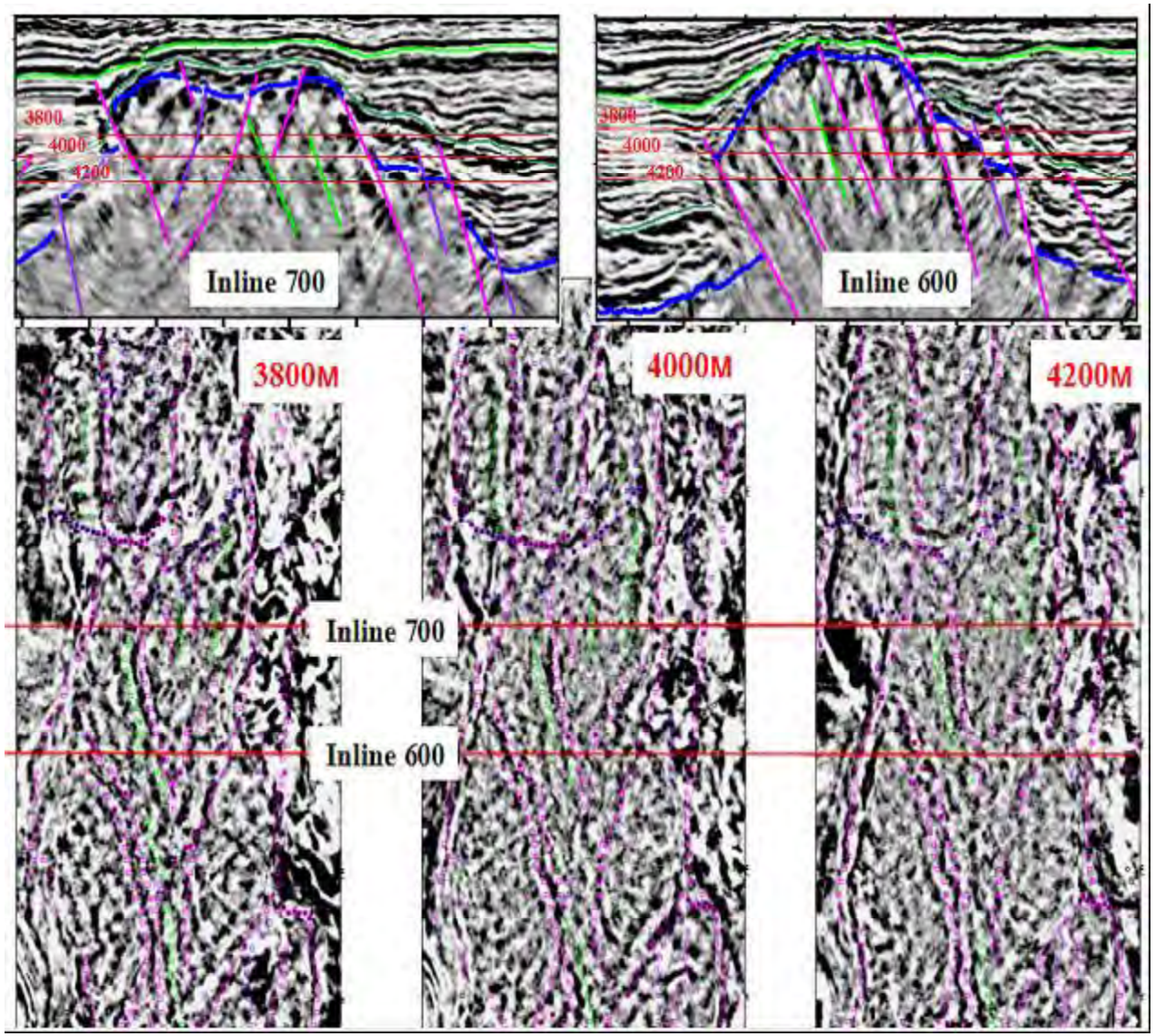


- Basement domains are clearly defined based on seismic data (both conventional & special processing)
- Different reservoir qualities in each basement domain



Abnormal reflection within basement

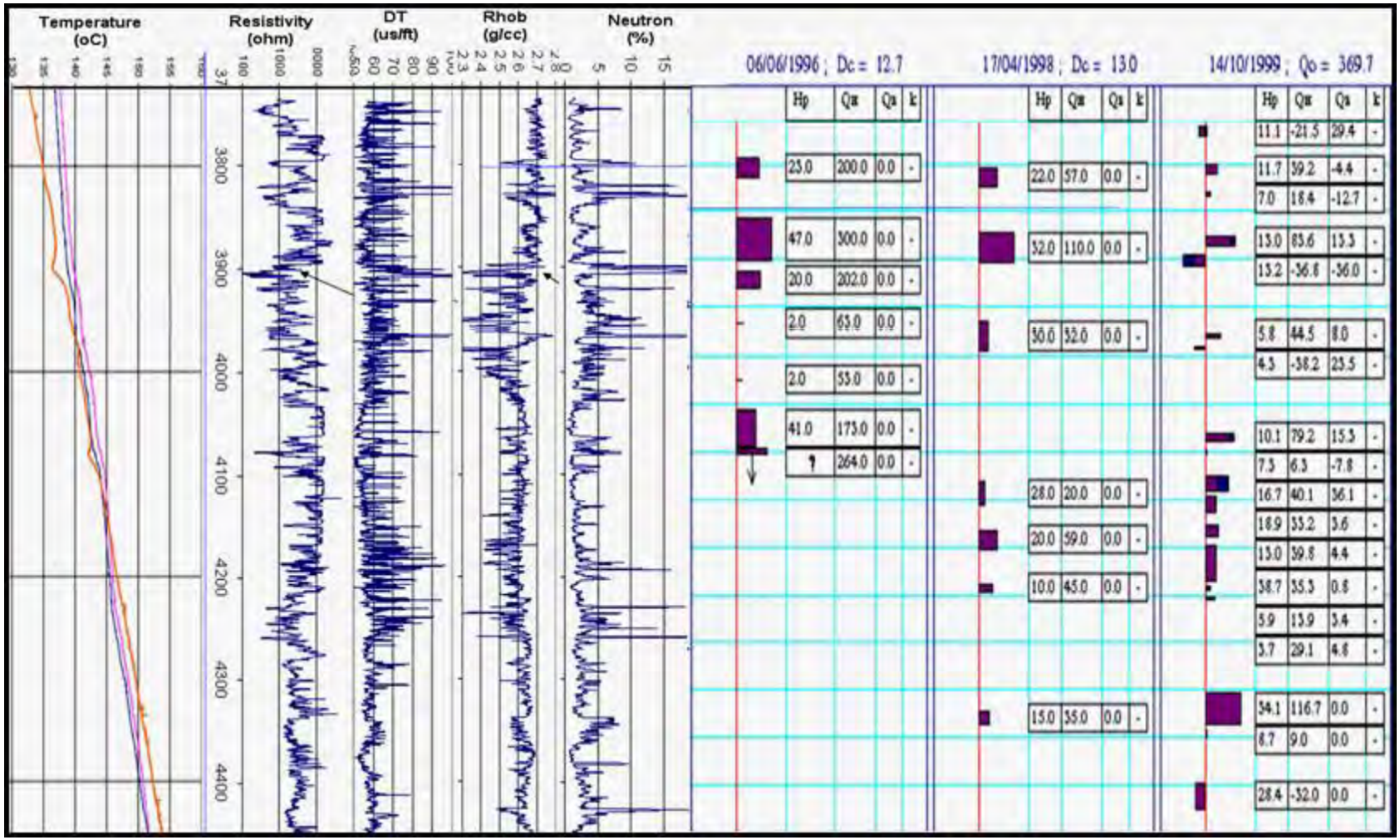
Fault system - Tectonic analysis



Fault types

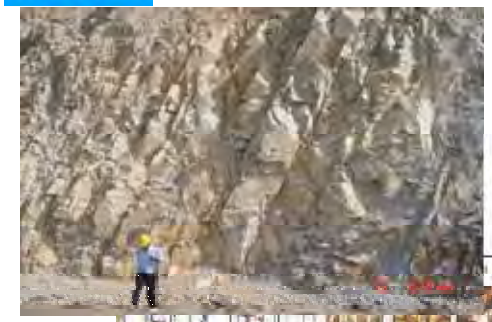
- Normal faults
- Reverse faults
- Lineament faults

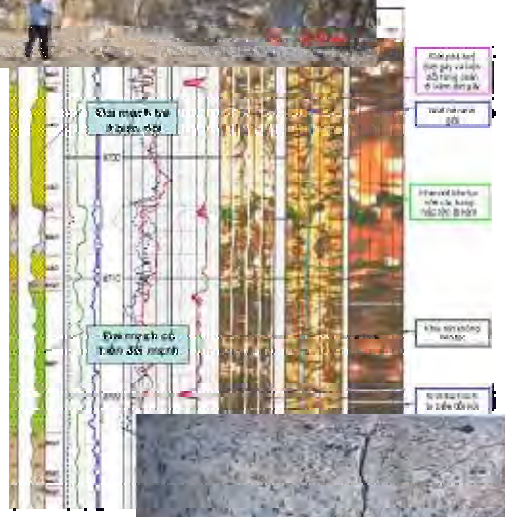
Main oil flow intervals from Fault zones

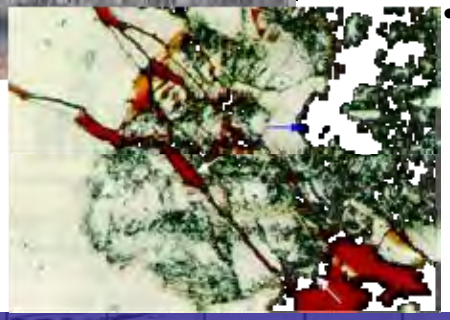


Flow intervals are variable and changed with time

Fracture systems







Macrofractures

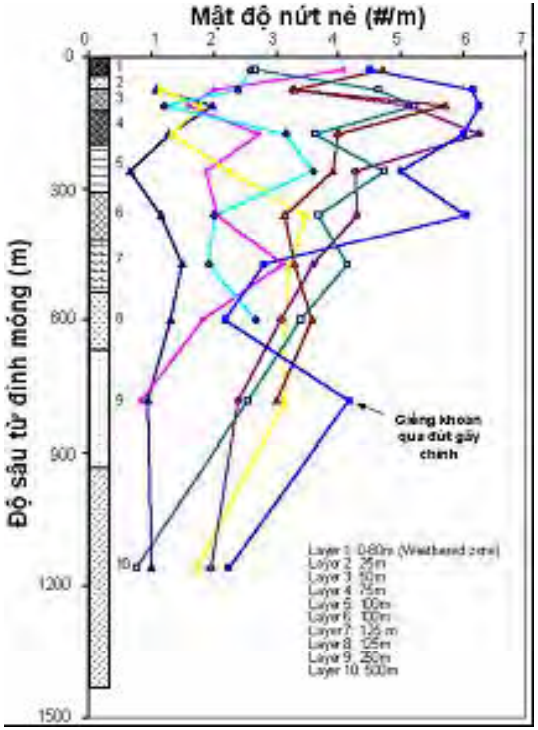
❖ **Tectonic fractures:**

- **Continuous**
- **Partly continuous**
- **Bounding**
- **Fractures in breciated zones**
- **Fractures with associated vugs**

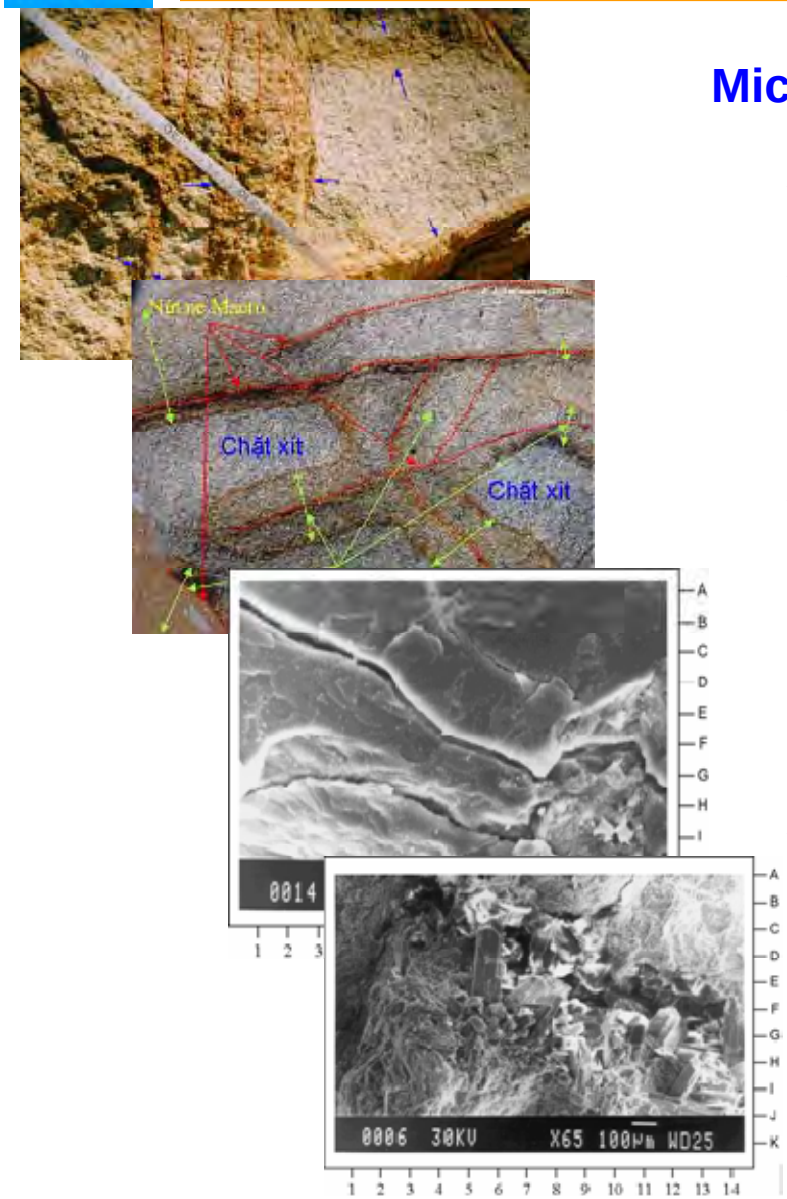
  ✓ **Dip angle: 50-90º**
  ✓ **Variable fracture aperture**
  ✓ **Fractures are partly to totally filled with secondary minerals**
  ✓ **Fracture density are reduced with depth and distance from fault.**

❖ **Artificial fractures:**

- **Drilling induced fractures**
- **Reopened fractures**

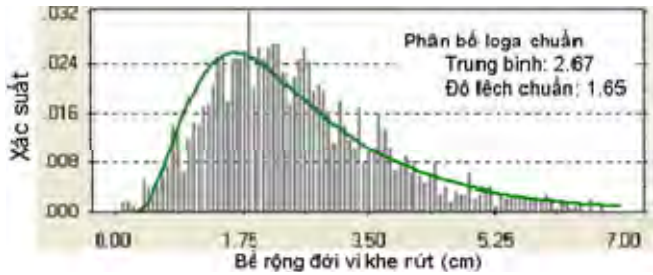


Fracture systems

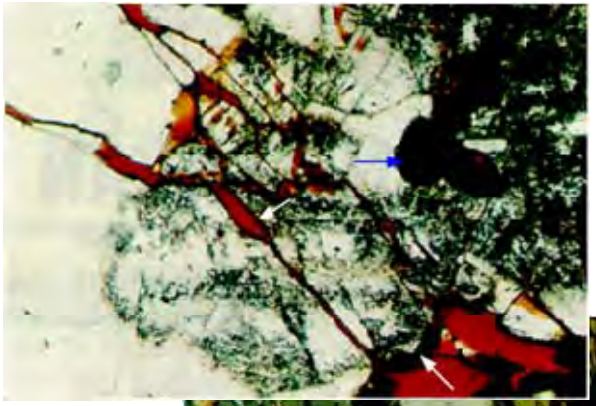


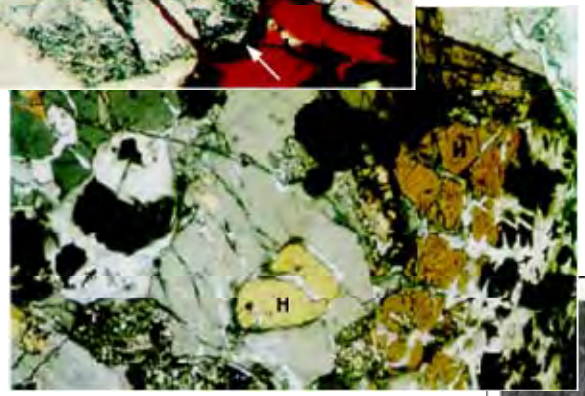
Microfractures

- 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

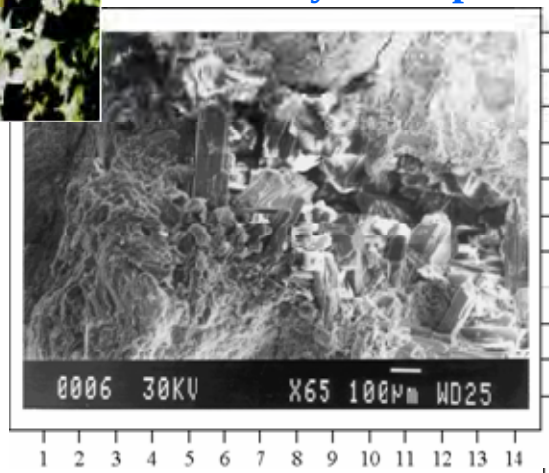


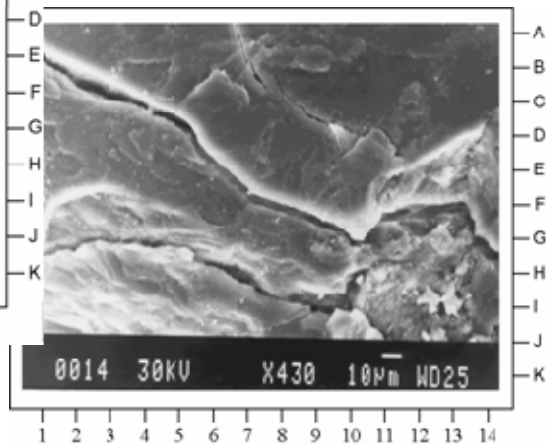
Basement rocks were strongly altered by many processes





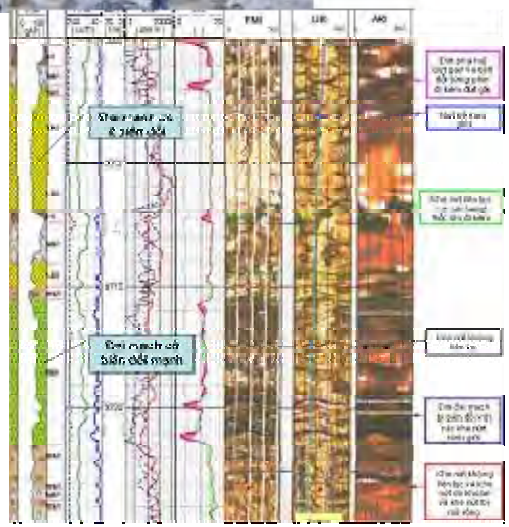
- **Reservoir quality is controlled by:**
  - ➢ **Tectonics**
  - ➢ **Weathering**
  - ➢ **Hydrothermal alteration**
    - **<50°C: mordenite**
    - **100-200°C: laumontite, analcime**
    - **>200°C: metallic sulfides of zinc, copper**
  - ➢ **Early oil emplacement**





Dykes system

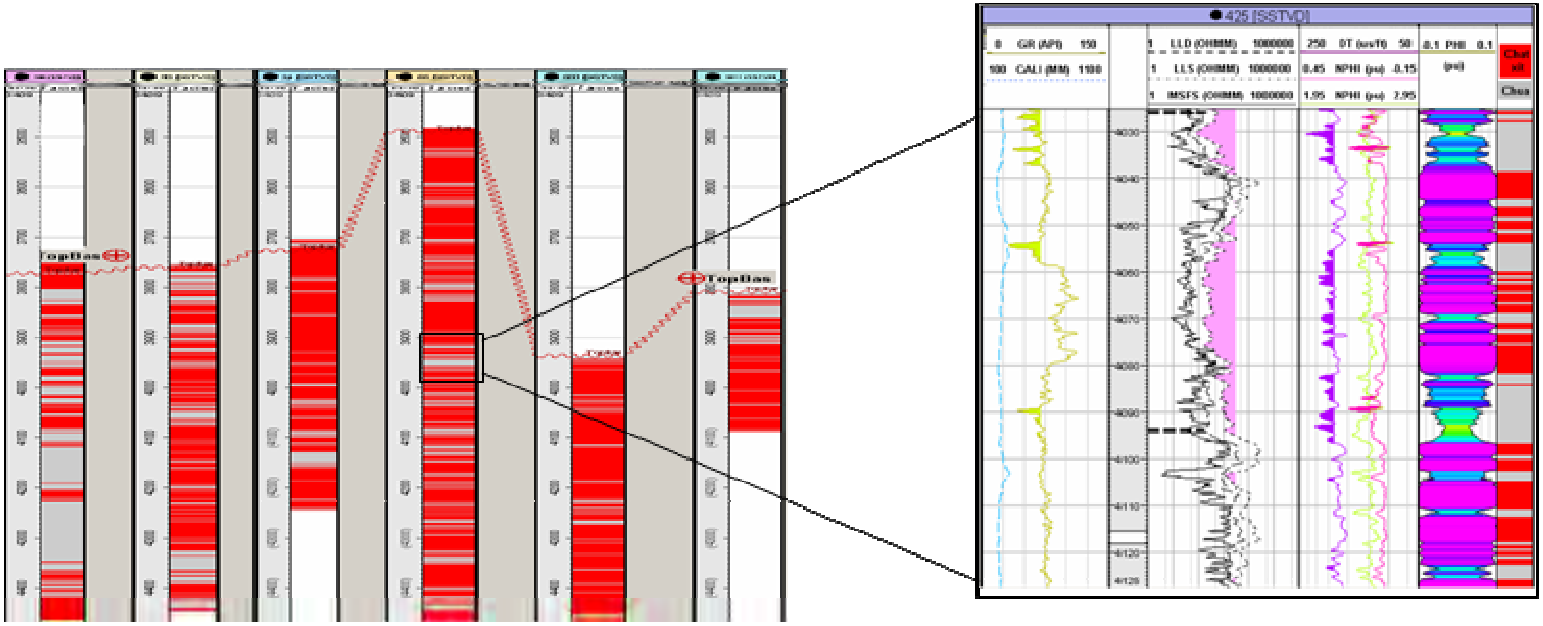
- Dykes are widely distributed within basement
- Dykes are normally parallel to tectonic fracture systems
- Rocks are differently deformed in intensity
  - Dykes, formed before exposing on to surface, were more strongly deformed and their reservoir quality is better
  - Later dykes were weakly deformed, homogenous and plays as seal/barrier rocks
- Thickness of dykes are very variable



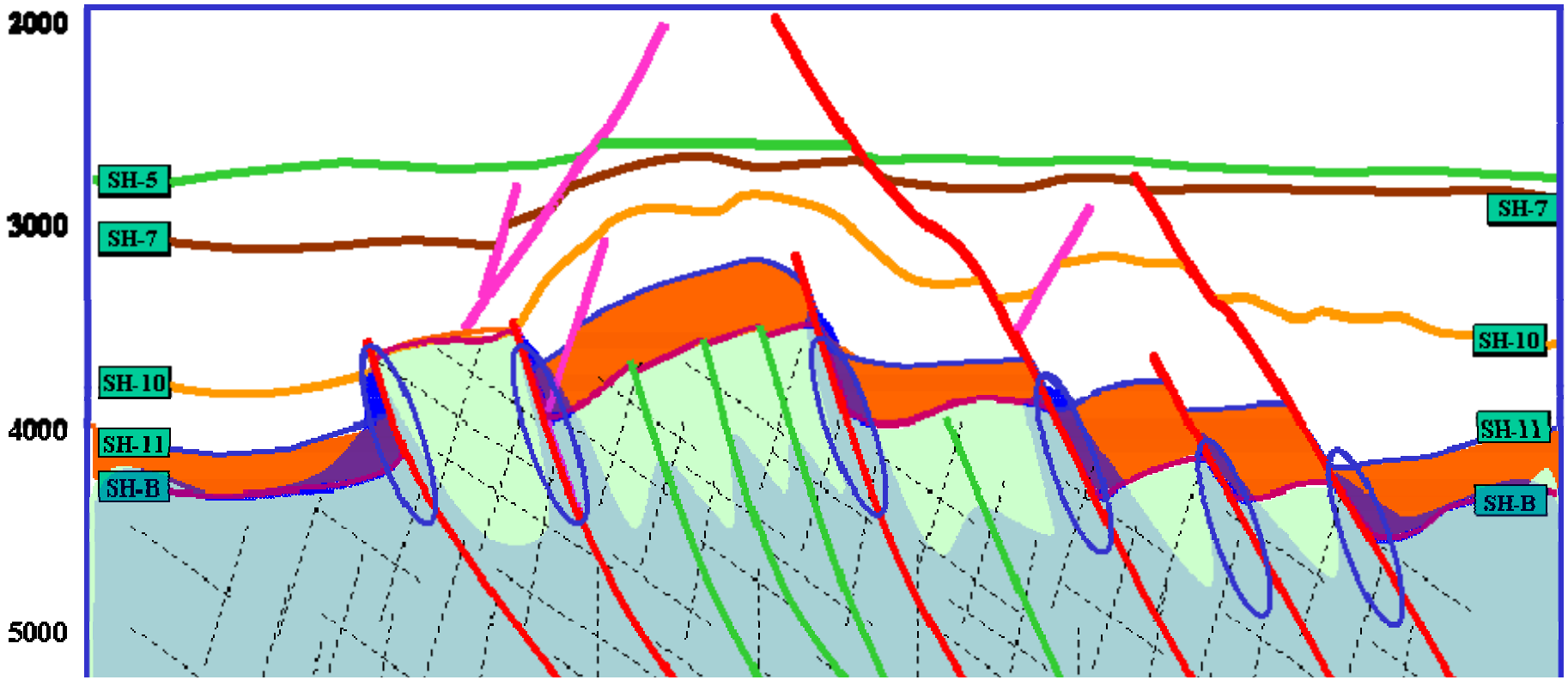
Tight/fresh blocks in Basement

- 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

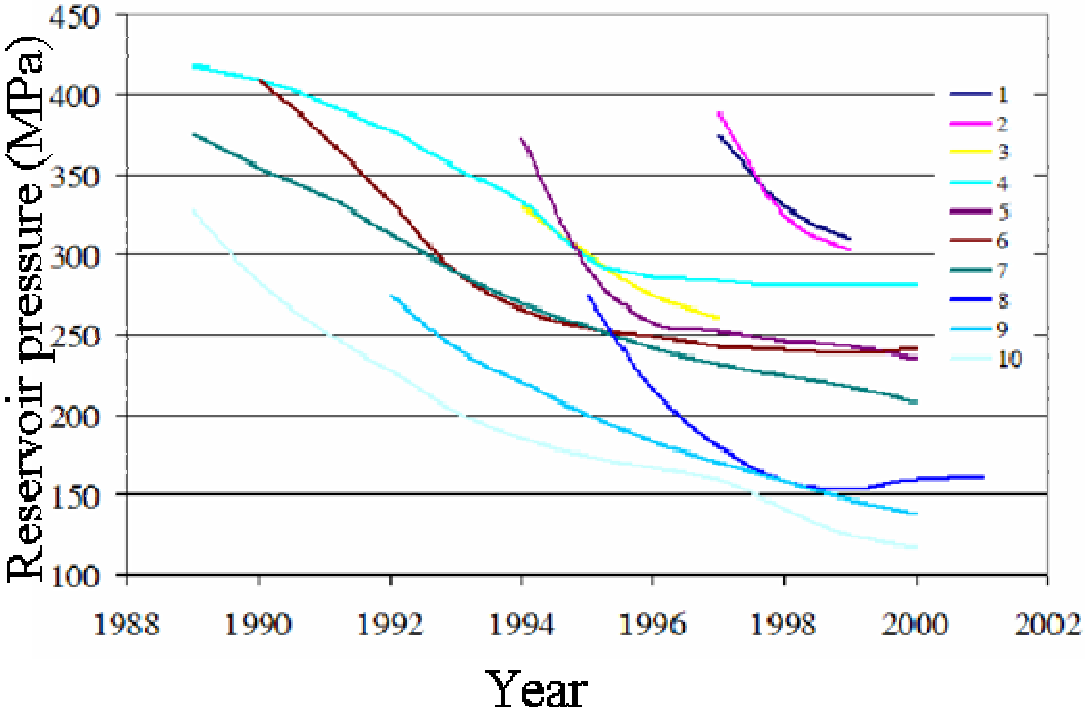


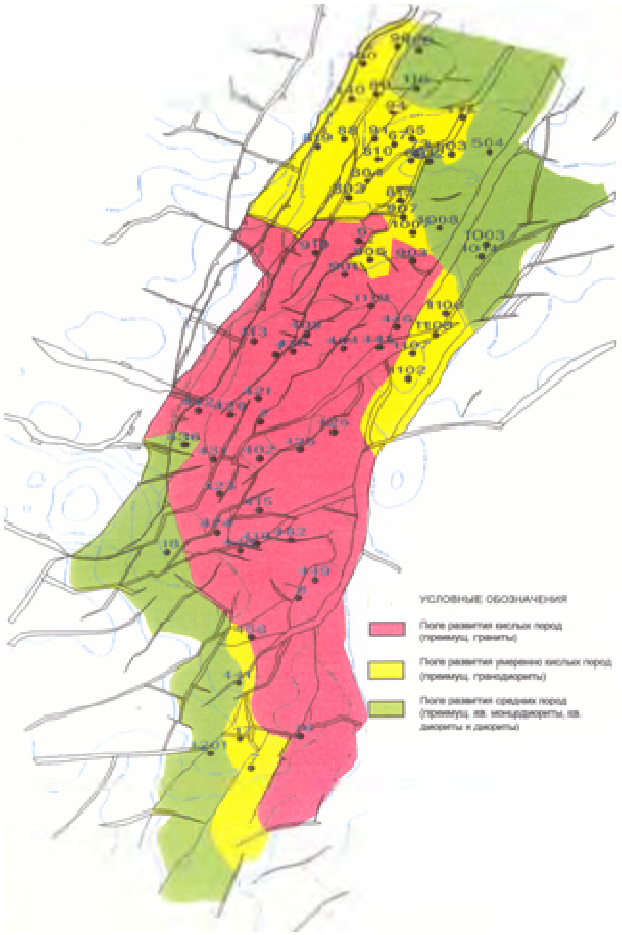
Hydrothermal activities are strong along main faults



- **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**

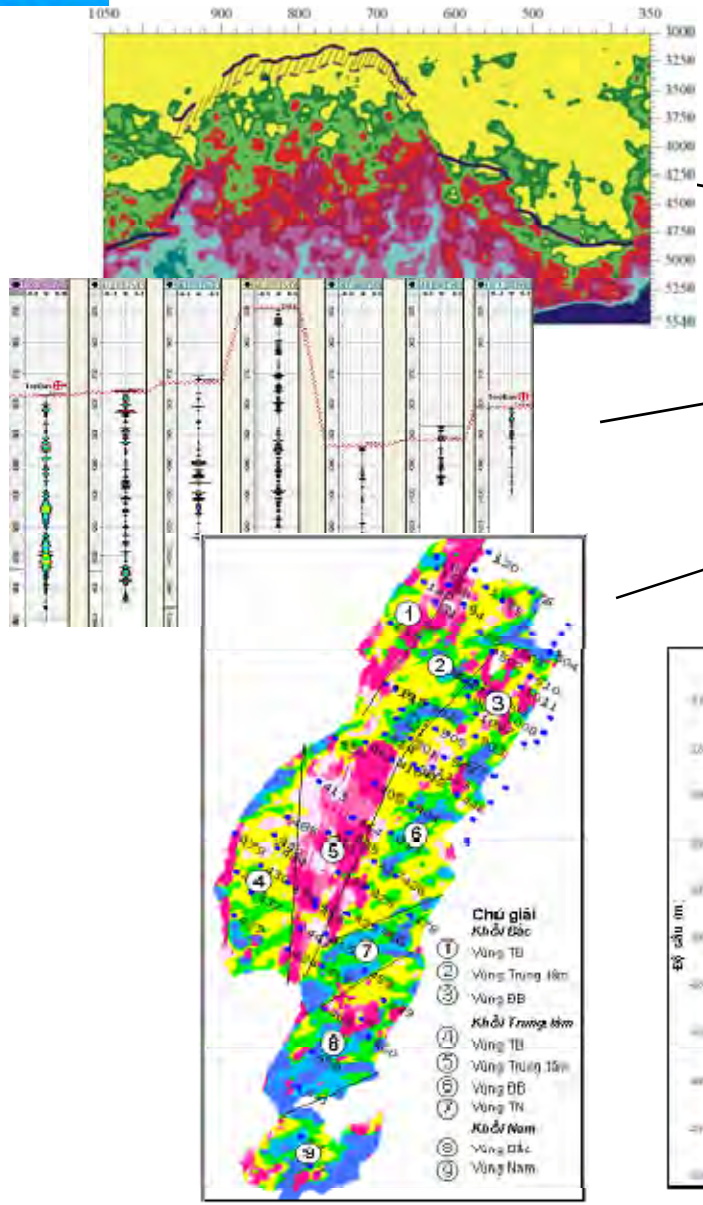
Domains can be defined by data from long term production

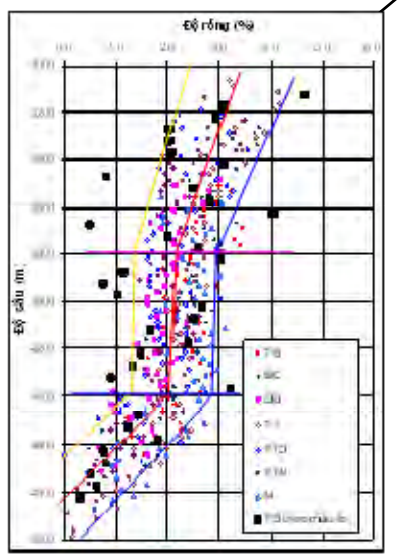


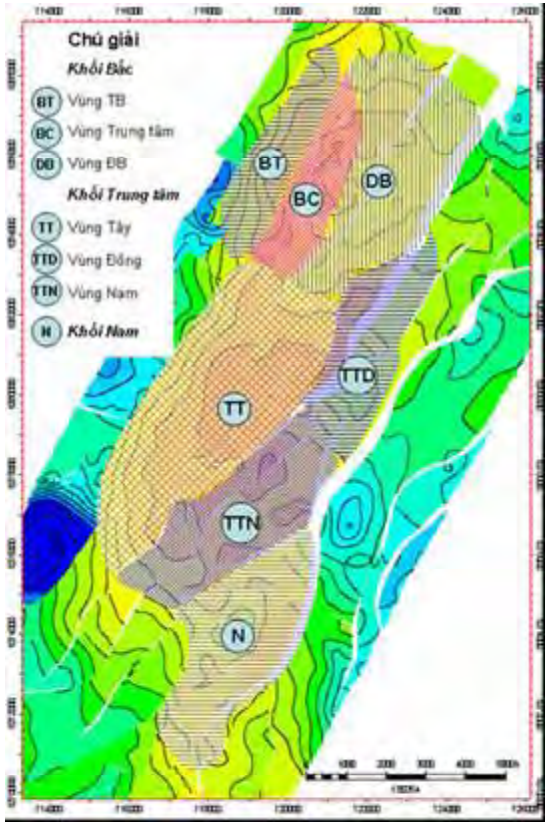


Trends of reservoir pressures in each domain are different, it indicates that connetivity between domains is very poor

Domains in basement

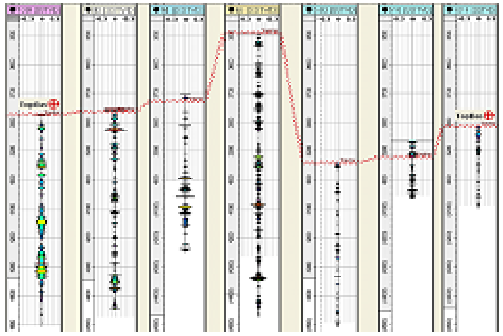


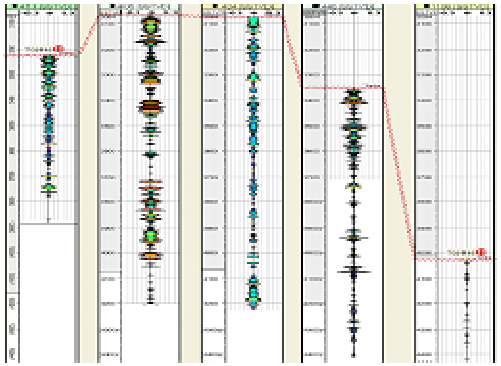


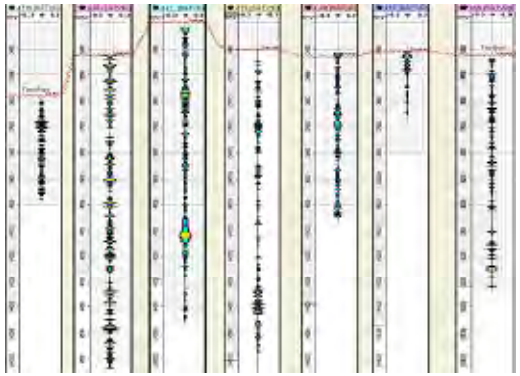


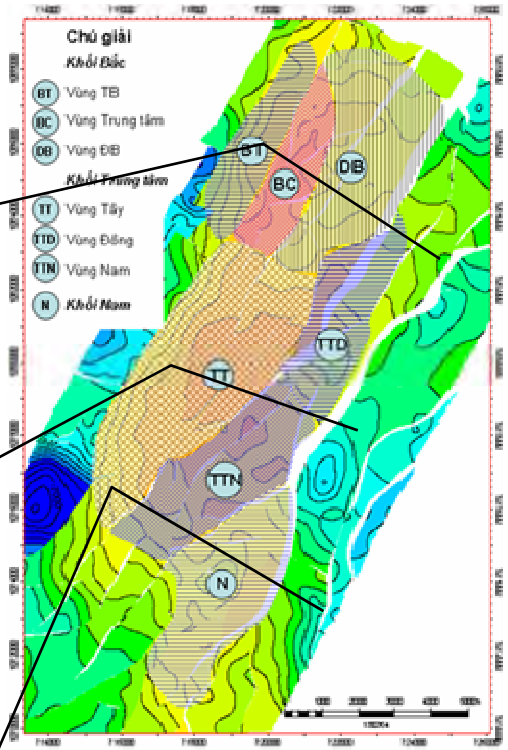
Basement reservoir can be divided into domains

Porosity and N/G with depth



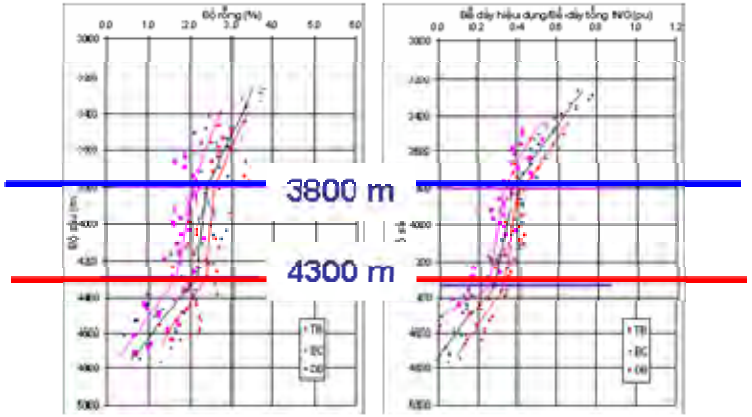




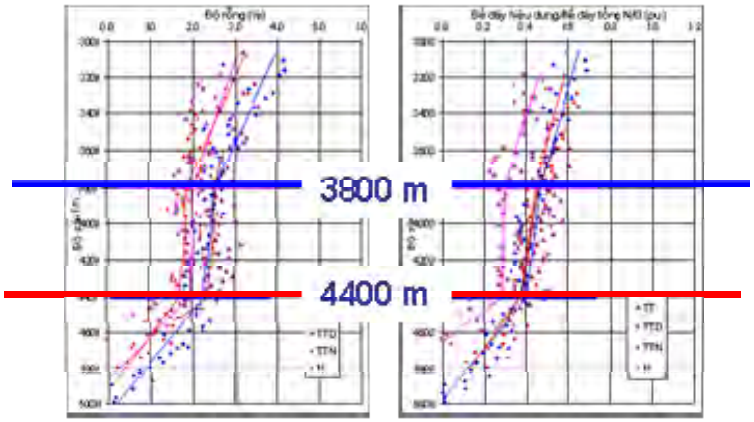


- **Reservoir quality is reduced with depth and laterally varied**

Porosity **N/G**



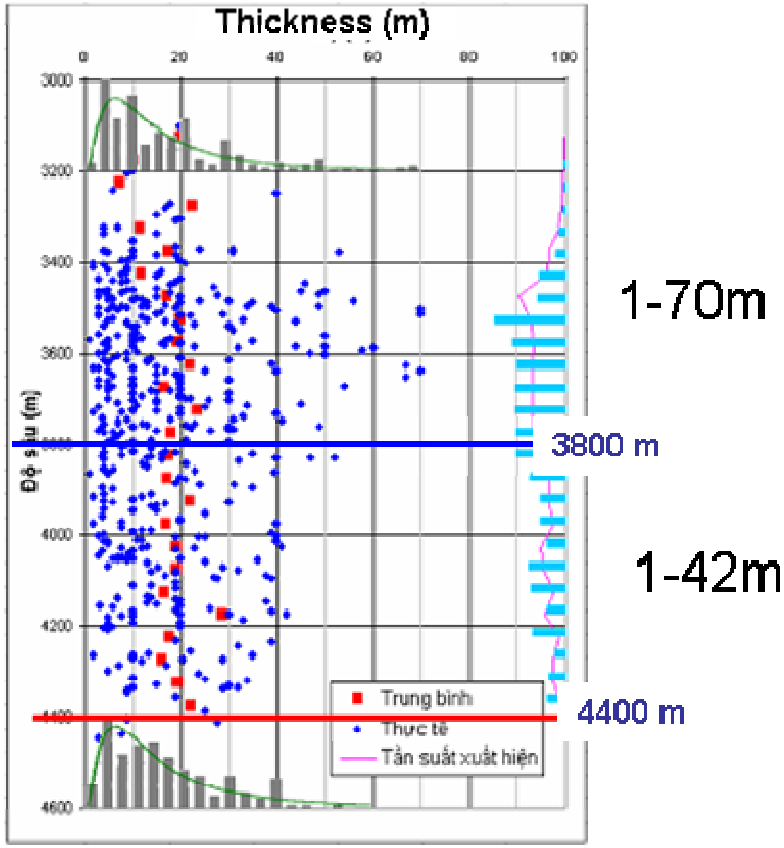
North



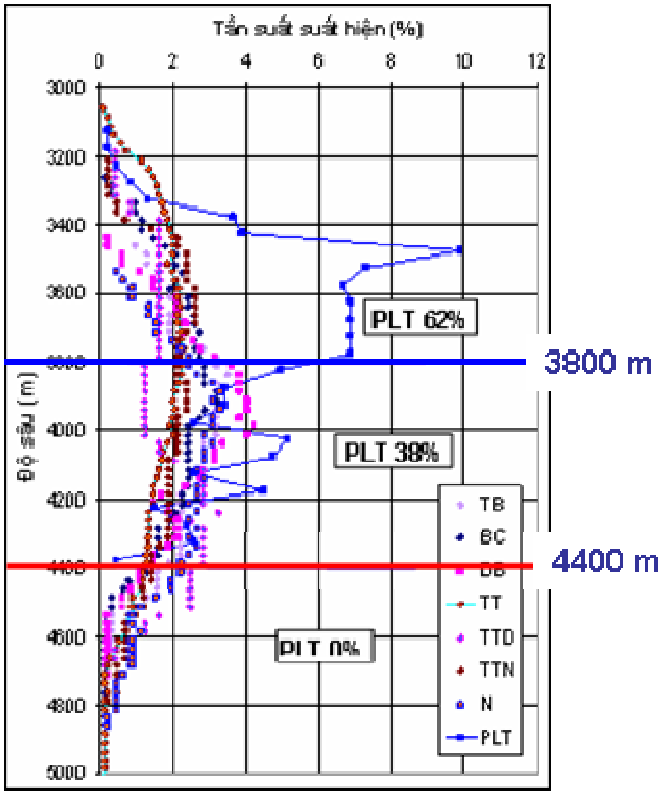
Centre + South

N/G with depth

PLT/Testing data



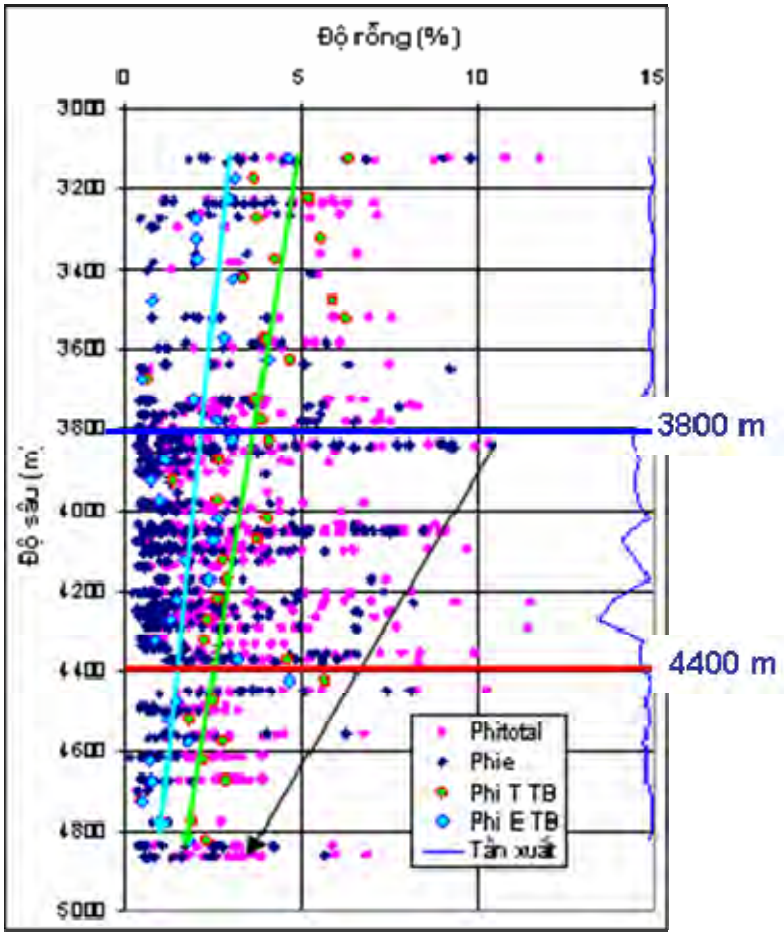
Frequency of productive zones with depth



Productive zones are dominant in the depth above 3800m (more than 62%)

Porosity with depth

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

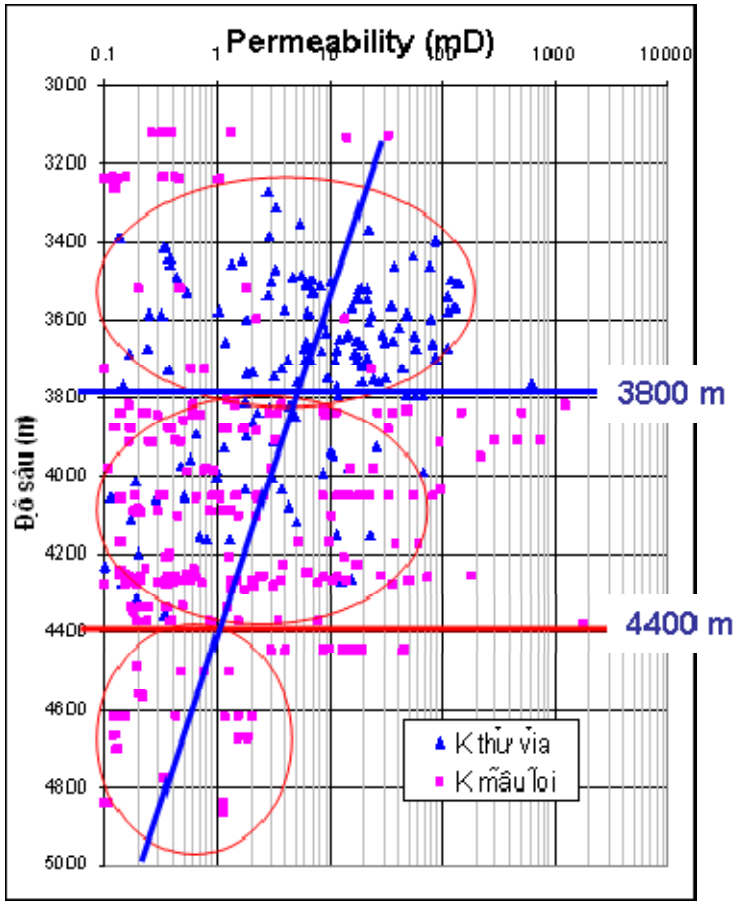
Permeability from DST and core analysis

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

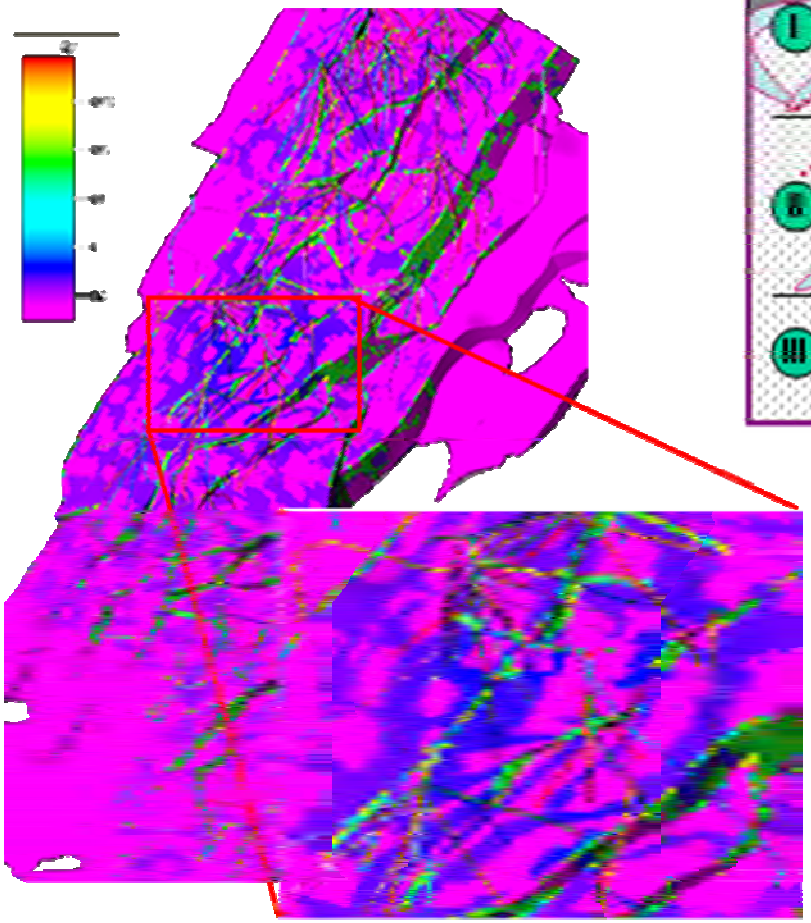
Permeability is reduced significantly, perm range is mostly below 20mD

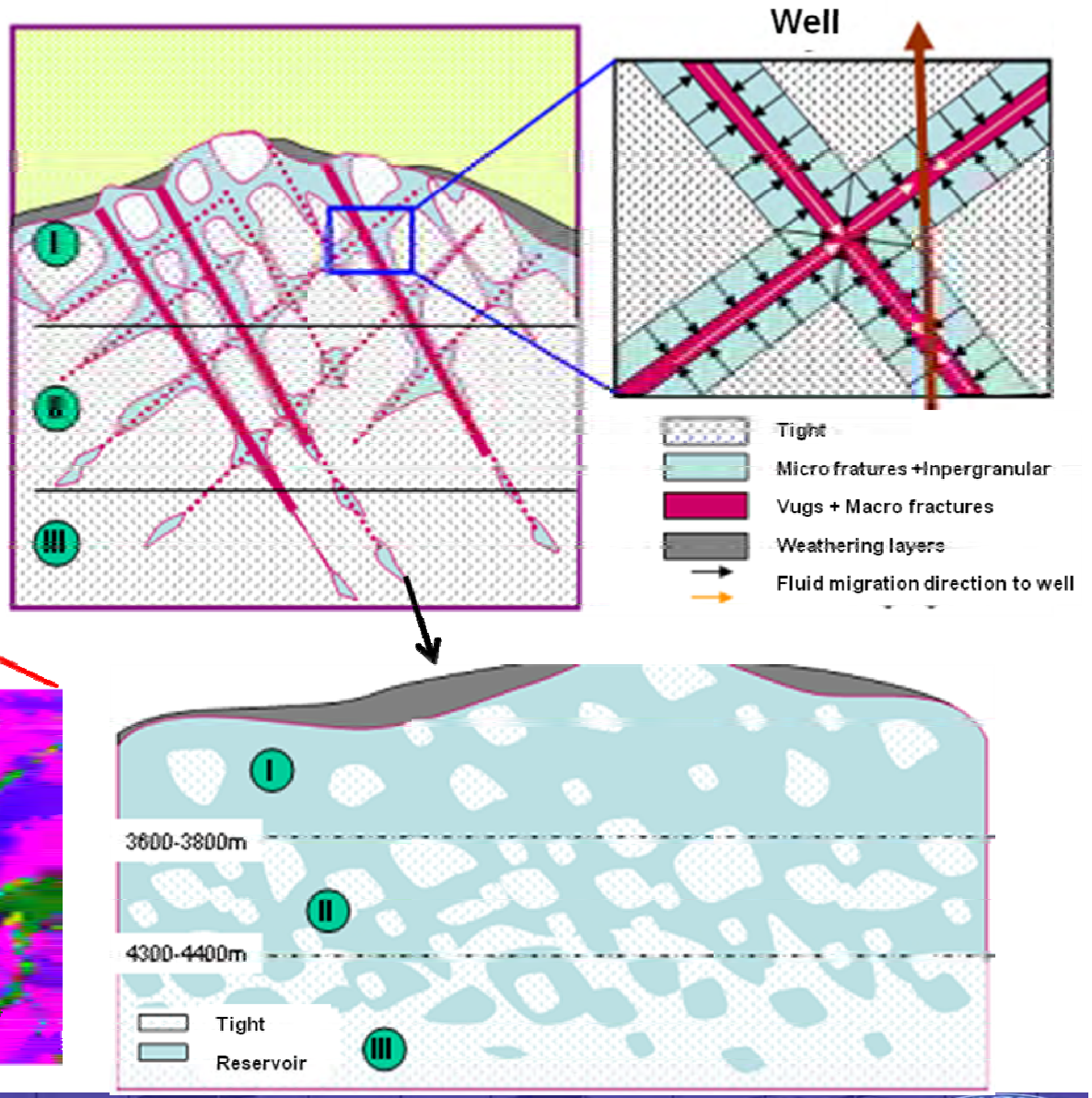
Productive/injective zones are very rare

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

Basement reservoir distribution

(Trinh Xuan Cuong, 2007)





FRACTURED BASEMENT RESERVOIR MODEL

- Strongly influenced by weathering processes
- Variable weathered zone thickness
- Low boundary varies from 3600-3800m

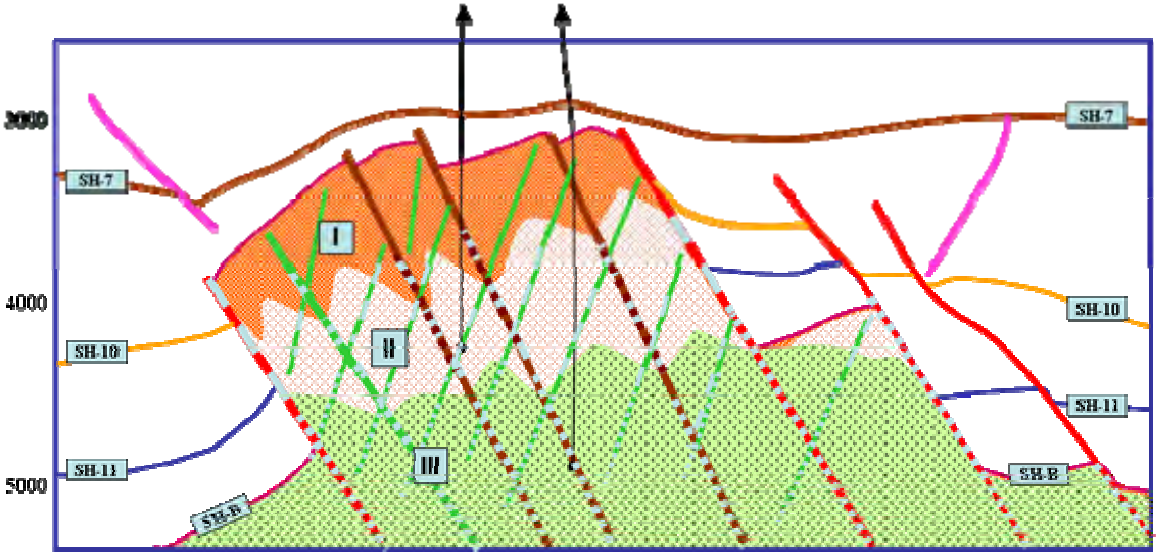
❖ Zone I: Very good reservoir quality; the principal reservoir

- Good porosity and permeability
- Good 3D connectivity

- 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

❖ Zone II: Reservoir quality is variable and it acts as a potential, but patchy zone

- Good connectivity vertical and along main fault
- Poorer connectivity between parallel fault
- Average storage capacity



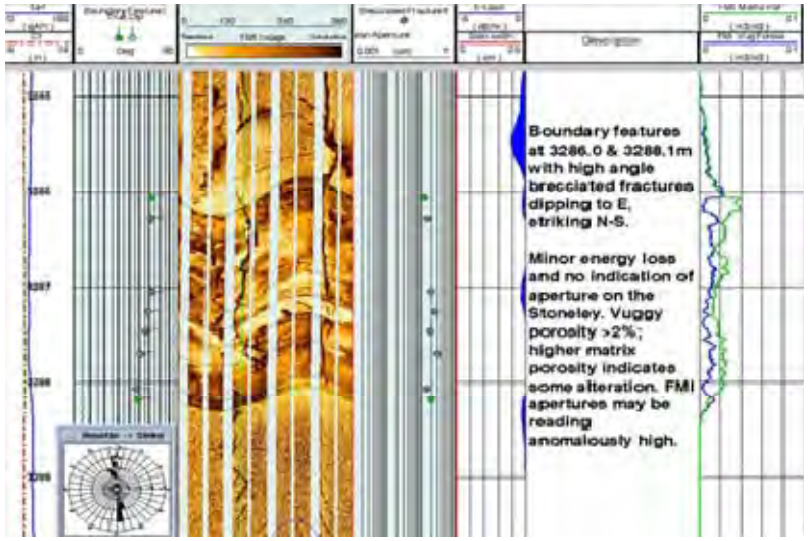
❖ Zone III: Reservoir quality is not economic

- Localized reservoir
- Very poor connectivity
- Poor flow/inject rate

- No weathering activities; Hydrothermal processes dominant
- Unaltered and weakly deformed rocks
- Almost fault zones are filled by secondary minerals

FRACTURED BASEMENT RESERVOIR MODEL

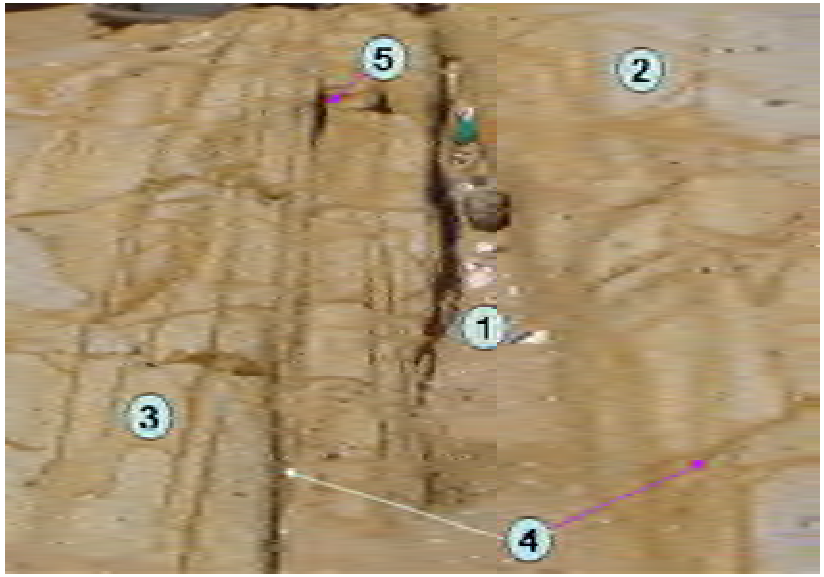
Reservoir and non reservoir rocks



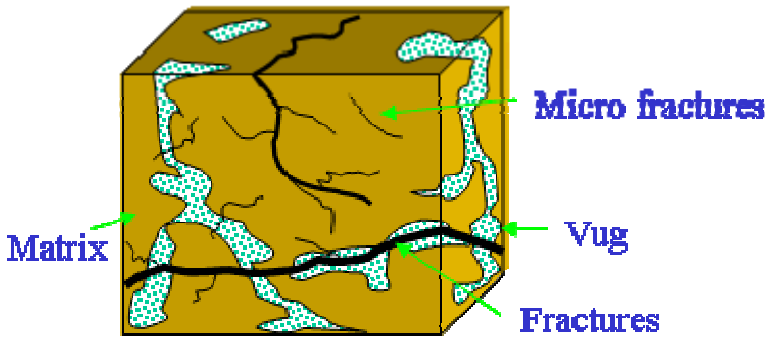
Porosity types:

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

Basement tight blocks

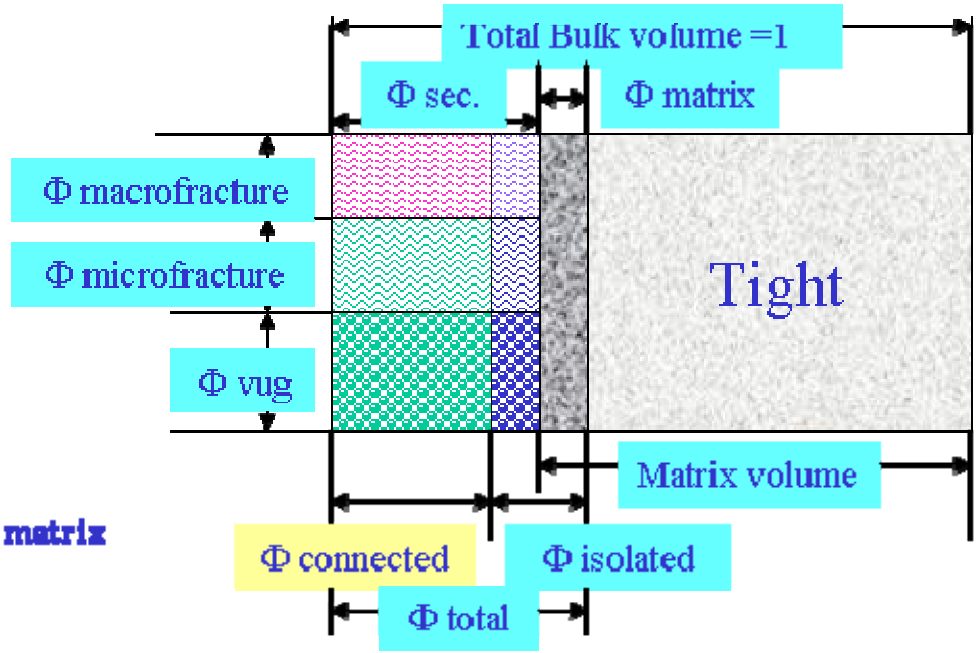


FRACTURED BASEMENT RESERVOIR MODEL



(Modified from Warren and Root 1963)

Φ total = Φ marcofracture + Φ micofracture + Φ vug + Φ matrix
= Φ secondary + Φ primary
= Φ connected + Φ isolated



Dual porosity-permeability reservoir Model

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

CONCLUSION

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

- Reservoir portion was formed by breciated 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!