Characterization and HC Potential of Naturally Fractured Reservoirs

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Outlines

- Introduction
- Nature of NFRs
- Characterization of NFRs
- Identification of NFRs
- An example of NFRs - Hassi Messaoud giant oil field, Algeria
- Conclusion & recommendation
- Q & A

Introduction…
Background

What are NFRs?

- Natural fractures play an important role in their production performance
- Occur in different lithilogies at any geologic time throughout the world
- Previously regarded as non-economic & non-productive
- More complex than matrix reservoirs
- Wide ranges :Low to most Productive

Introduction…

Background

Natural fractures:

- Occur nearly in all reservoirs
- Give good porosity & permeability
- Result initially high Q_i, to decline rapidly
- Act as a barrier to fluid flow
- Cause premature gas/water breakthrough
- Severely limit field development options, if ignored

Introduction…
Objectives

- To recognize and characterize the behavior of NFRs
- To assess their formation and classification
- To assess the best identification methods
- To evaluate effect of fracture properties on NFRs performance
- To discuss on NFRs of Hassi Messaoud oil field, Algeria

Introduction…
Methodology

- Reviewing,
- comparing &
- compiling different related publications
- Desktop research

Nature of NFRs…
Problem Statement

- Many have been discovered accidentally
- Posses many inherent obstacles to proper analysis
- Based on recent studies:
  - -Ultimate Recovery from NFRs is >40MMMSTBO
  - -Significant volume of HC left in undiscovered & abandoned wells
  - -But ignored , probably due to their complexity
- So interest in studying ,dramatically increased because of their potentiality

Nature of NFRs…
Definitions

- Broadly :

-A reservoir fractures: a naturally occurring macroscopic planar discontinuity in rocks due to deformation or diagenesis result from stresses.

-NFRs: which contains fractures that created by mother nature & may have negative / positive effect on fluid flow.

Nature of NFRs…
Causes of fracture generation

- Ranges from tectonic to diagenetic origins.
  - -Tectonics : Fold ,fault…
  - -Volume shrinkage: Mud crack, magma cooling…
  - -Physical / envt'l processes: Deep/ surface erosion of the overburden.
  - -Subsidence: Paleokarstification & solution collapse.
  - -Pore fluid pressure release: Geopressurized strata, during production.
  - -Mineral /phase change & meteoric impact

Nature of NFRs…
Fracture classification

a) From experiment point of view: Based on their mode of formation:

-Shear Fractures : $\delta 1$, $\delta 2$ & $\delta 3$ are compressive under high differential stress. E.g. Fault

-Extension : $\delta 1$, $\delta 2$ & $\delta 3$ are compressive under low differential stress. E.g. Joint

-Tension: similar to extension with $\delta 3$ tensile.

Nature of NFRs…
Fracture classification

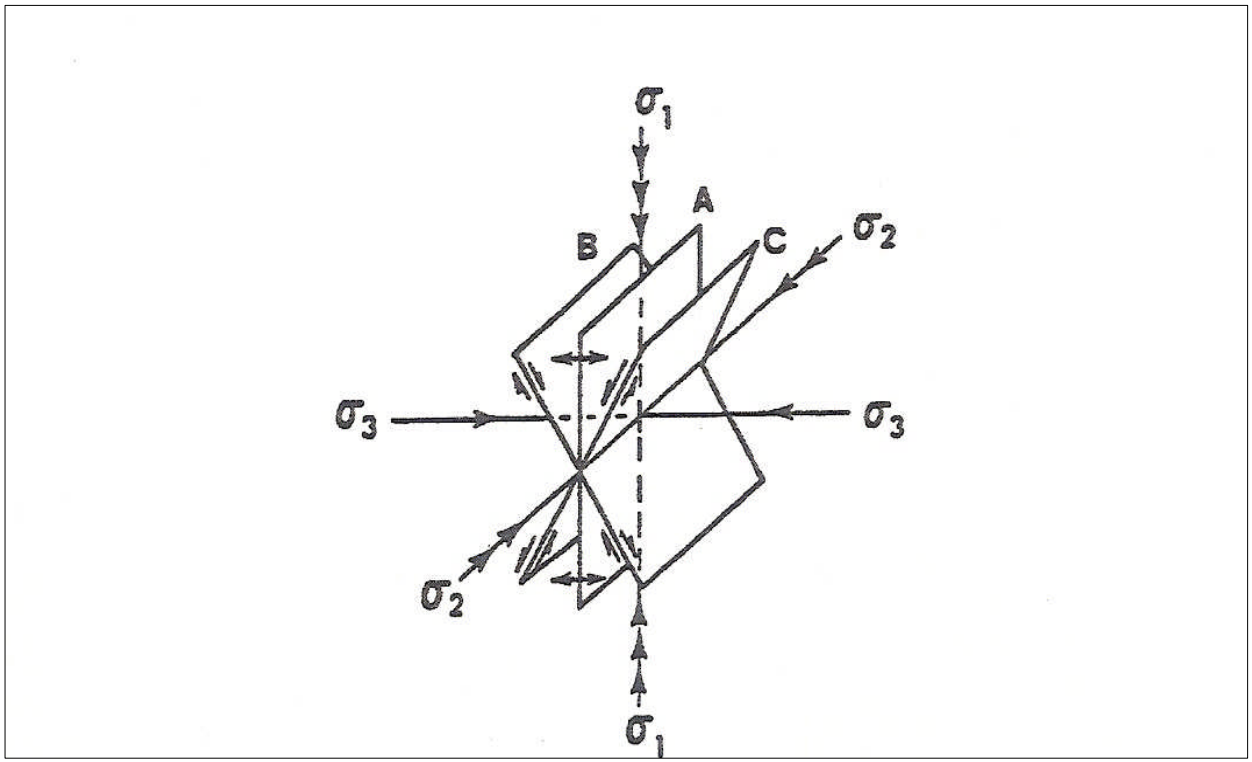


Fig : Potential fracture development in Laboratory.

Nature of NFRs…
Fracture classification

b) From geologic point of view :

- Tectonic fractures: Surface/external forces due to local tectonics, are important with respect to HC.

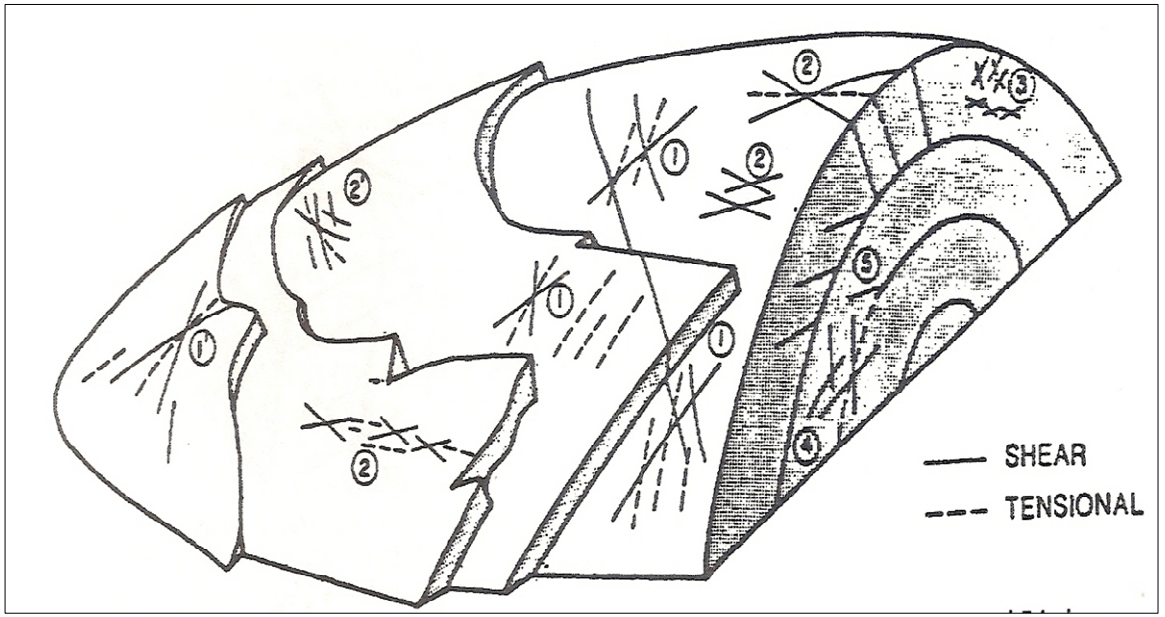


Fig: Fold & fracture

Nature of NFRs…
Fracture classification

- Regional fractures: Plate tectonic
  - -Probably due to surface forces: regional uplift.
  - -Cover large area & cut local fractures.
  - -Show no evidence of offset across the fracture plane.
  - -Perpendicular to bedding plane.
  - - Are conducive to fluid flow.

Nature of NFRs…
Fracture classification

- Contractional fractures: due to body forces with general bulk volume reduction

Fig: Desiccation cracks

- Surface related fractures: due to body forces

  -Erosion, unloading ,release of stored stress & strain.

Nature of NFRs…
NFR classification

Generally based on relative poroperm/ storage contribution from matrix & fracture:

- Type A -high storage capacity in the matrix and low storage in fractures. E.g. Hassi Messoud
- Type B -about equal storage capacity in matrix and fractures. E.g. Hassi Messoud
- Type C - all storage capacity is in fractures.
  E.g. Ruby field in Vietnam

Nature of NFRs…

Fracture properties that affect performance

- Fracture plane morphology: Deformed, open, mineral filled ,vuggy
- Fracture width & permeability.
- Fracture spacing/intensity.
- Fracture & matrix communication.

*Affect at any stage of field development.

Nature of NFRs…

Fracture properties that affect performance

Fig :Out crop fractures

Characterization of NFRs
Characterization

- Process for quantitatively describing reservoir properties that have significant effect.
- Requires understanding of:

-Spatial distribution of reservoir units & their petrophysics.

-Fracture geometrical characteristics.

-Different data from different scales of observation.

Characterization of NFRs…
Scales & sources of data

- Four conceptual scales:

  -Microscopic: pore, grain size distribution & rock/fluid interaction.

  -Mesoscopic: poroperm, K_{rel} ,wetability ,fractures from conventional core analysis scale.

  -Macroscopic: grid blocks scale used in reservoir simulation

  rock & fluid properties from log ,WT, seismic, outcrop.

  -Megascopic: Scale of geological model, basin size.

- Integrating these: result in parameters for simulation of NFRs

Identification of NFRs
Direct sources

- Core analysis: fabric,intensity,strength, flow interaction, mineral filling
- Impression packers: topography, type & orientation
- P transient testing :
  - -Core scale : fracture properties.
  - - Well scale: rock & fluid properties
- Downhole video & photo camera
- Drill cuttings

Identification of NFRs….
Indirect sources

- Drilling history : mud loss ,penetration rate.
- Well log analysis: Caliper,SP,GR,density, sonic, neutron ,resistivity,imaging devices, Pe…
- Manipulation of reservoir rock property data:

  -Core Φ Vs Core K……shifting from normal

  -Vertical Vs Horizontal Core K….K_v

  -Core K Vs Flow test K….. Big difference from normal

  - Neutron Φ Vs Core Φ ,Resistivity Vs Log Φ …m
- Remote sensing:extrapolation of surface informn

Identification of NFRs….
Natural Vs induced Fractures

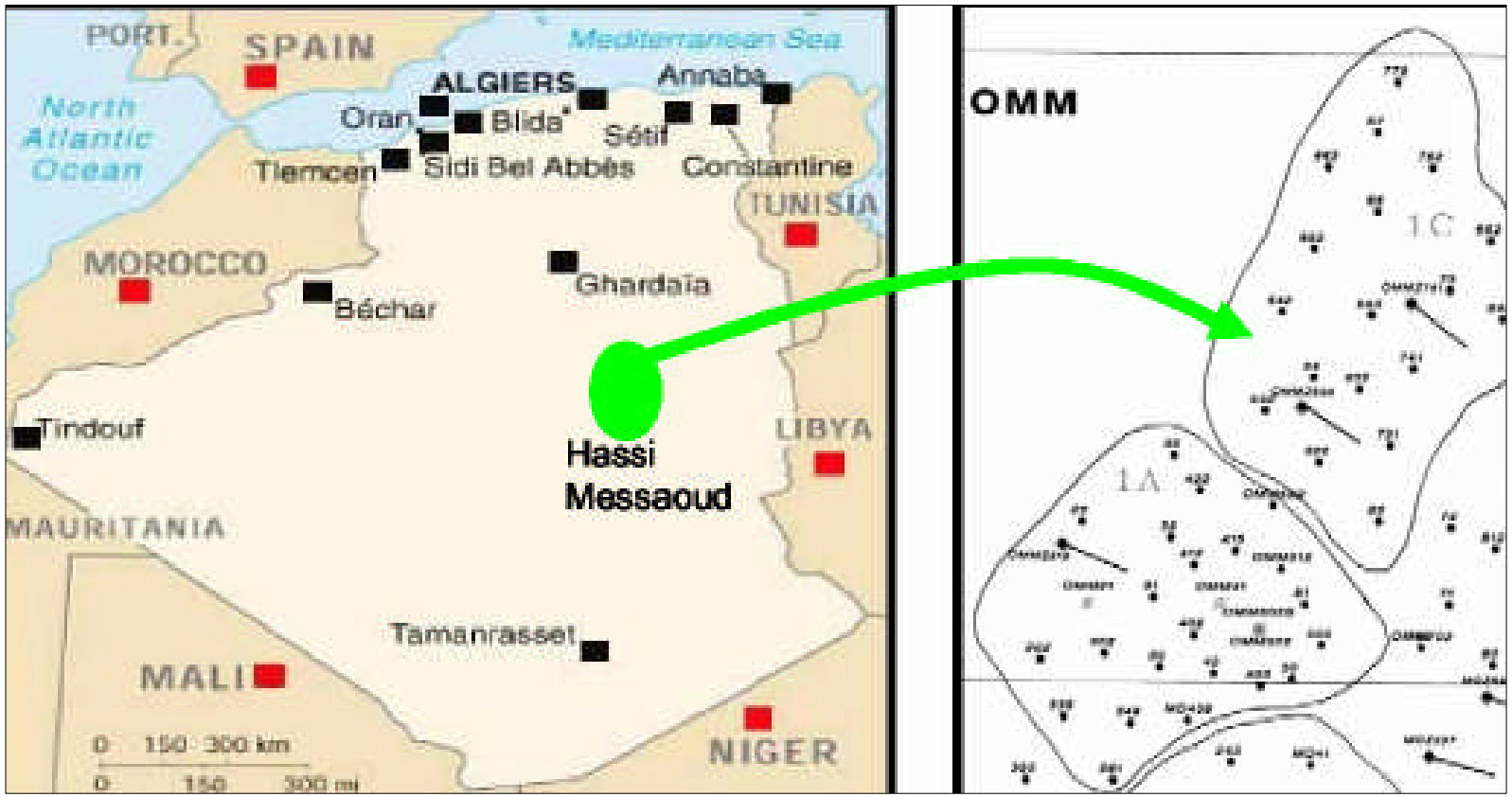
- Natural:
  - -Surface morphology: Slickenside, planar geometry
  - -Cementation: Mineral growth parallel to displacement
  - -Measurable offset /parallel set enclosed within core
  - -Stylolite,oil staining material
- Induced:
  - -Fresh break
  - -Concoidal or irregular fractures
  - -Uncemented vertical fracture

Hassi Messaoud major oil field-Ra
Introduction

- Lies in sand dunes of Sahara
- Algeria's first and largest, discovered in 1956
- Has NFRs of Cambro-Ordovician sandstone
- One of the world's largest field: Currently 380,000 STB/d high quality 48 API crude
- 15% of total reserve produced
- Contain >6.4 B bbls: 70% Algeria's proven reserve
- Faults : important for successful production
- Reservoir has 4 layers: Ri,Ra,R2& R3

Hassi Messaoud…
Ra :Zones 1A & 1C

Fig: Location map of zones 1A & 1C



Hassi Messaoud …
Geology

- Typically matrix K <10mD , with average Φ ~ 6 %
- Coarse to fine grained quartzite intercepted with clay intervals
- Facies tract transitions with in cycles produce lateral variation
- Clean sand package but diagenesis cause complexity in the lithology & morphology
- Major NW to NE trending strike-slip faults are present-cross cut by many small scale faults

Hassi Messaoud …

Faults & fractures: Zones 1A &1C

- Both have numerous sealing & non-sealing faults
- Zone 1A: Type B reservoir

  -Less faulted zone

  -Multiple episodes of fault & diagenesis

  -Some faults have sealing potential along the S-S fault.
- Zone 1C: Type C reservoir.

  -Intense faults that act as migration path way.
- Fracture intensity decrease from main faults.
- High risk of water /gas breakthrough

Hassi Messaoud …
Heterogeneity & Transmissibility.

- Heterogeneity around faults is in the form of :

  -Variation in reservoir thickness: decrease from E to W.

  -Rapid change in poroperm: Zone 1C quality is lower.

  -Changing fault seal properties

  -Variable production performance

- Producibilty of the field controlled by:

  -Faults.

  -Timing of HC migration.

  -Intensity of structural deformation.

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Influence of rock matrix

- Matrix blocks store must of the fluid, but low K.
- Fractures don't store , but high K.
- Matrix-fracture fluid transmissibility govern capacity of NFRs.
- As fracture intensity is too high ,matrix storativity is negligible: as zone 1C
- High storativity matrix & high K fractures: as in less faulted zone1A: Dual porosity system.

Hassi Messaoud …
Influence of rock matrix

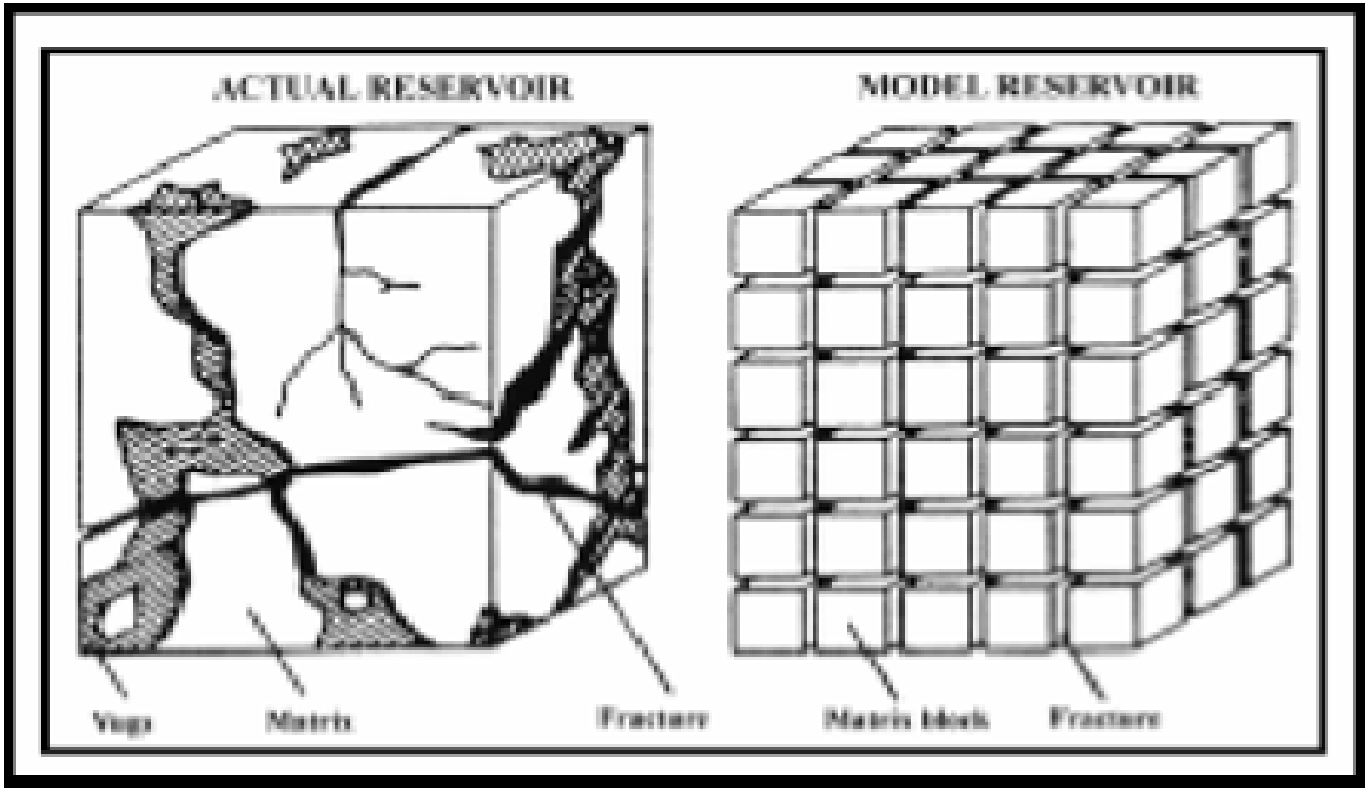

Fig :Idealization of Fractured reservoir

Hassi Messaoud …

Compaction phenomenon & dual porosity.

- Initially overpressured reservoir (0.7psi/ft)
- First class of well :
  - -Kh & Φ reduce as production years increase.
  - -Single porosity system.
  - -Fractures closed due to production
- Second class of wells:
  - -Invariant Kh regardless of production years.
  - -Show dual porosity behavior.

Conclusions & Recommendation

NFRs:

- Occur in different lithologies of all ages.
- Classifications can reflect their origin.
- No single technique is available to detect & characterize them but integrating.
- Good potential but challenging approaches.
- Are heterogeneous with single or dual porosity systems & fracture properties play significant role.
- With current rising oil price, I recommend that to closely study & use latest integrated techniques to exploit NFRs.

THANK YOU