Seismic to Geological Modeling Workflow, an Integrated Approach to Determine the Reservoir Quality of a Natural Fractured Limestone Reservoir: Oseil Field Example*

Arie Krisna Lopulisā¹, Roy Andrianto¹, and Anggoro S. Dradjat¹

Search and Discovery Article #20144 (2012) **
Posted May 14, 2012

*Adapted from oral presentation given in Bali, Indonesia at the Geoscience Technology Workshop (GTW) on Reservoir Quality of a Fractured Limestone Reservoir, 15-17 February 2012
**AAPG©2012 Serial rights given by author. For all other rights contact author directly.

¹CITIC Seram Energy Ltd (randrianto@citicseram.com)

General Comments

Oseil field, on the island of Seram, eastern Indonesia, is used as the example to apply an integrated approach to determine the quality of a naturally fractured limestone reservoir. Field data include:

- Discovery date 1998
- Type hydrocarbon heavy oil
- Reservoir type fractured limestone
- Limestone type oolitic, mudstone/wackestone-grainstone
- Age and name of reservoir Jurassic Manuseal Formation

The following is the conclusion resulting from following the workflow associated with this approach:

- Integration of well and seismic data provides better comprehensive understanding.
- The result of seismic fracture intensity is aligned with the well.
- Total loss circulation during drilling correlates with the intensity of fractures.
- Seismic attributes should constantly be utilized to identify anomalies.
- More effort is needed to incorporate mud loss and drilling parameter into the update model.
Seismic to Geological Modeling Workflow, an Integrated Approach to Determine the Reservoir Quality of a Natural Fractured Limestone Reservoir: *Oseil Field Example*

Arie Krisna Lopulisa
Roy Andrianto
Anggoro S Dradjat

CITIC Seram Energy Ltd
Agenda

• Introduction

• Background

• Workflow
  1. Fracture Analysis
  2. Seismic Anisotropy
  3. Geological Modeling
  4. Discrete Fracture Network
  5. Well Placement
  6. Seismic Attribute

• Conclusion
Introduction

Regional Geology

Basement (Metamorphic)

Pre-Thrust

Syn-Thrust

Post-Thrust

Sub-Foreland Basin

Incipient Rifting

Compression/Uplift

Listric Reactivation

Extension/Transensional Reactivation

Uplift

Compression/Uplift

Uplift

Incipient Rifting

Dominantly Carbonate

Upper: Carbonate (Massive)

Lower: Sandstone & Mudstone

Sandstone & Mudstone

Shale

Sandstone & Mudstone

Dominantly Sandstone & Mudstone + Carbonate

Sub-Foreland Basin Salas Complex

AAPG-EAGE Joint GTW on Fractured Carbonate Reservoir
Introduction

Oseil Field Depth Structure Map

General Info:
- Discovery of Oseil: 1998
- First Oil: Dec 2002
- Hydrocarbon Produced: Heavy Oil
- Reservoir type: Fractured Carbonate
- Formation name: Manusela Fm
- Age: Jurassic
- Limestone type: oolitic limestone, mudstone/wackestone - grainstone
Background

Main Challenges in Oseil Field

- High Heterogeneity Reservoir
- Fast & Severe Water Break-through
- Complex Fracture System
- Time Depth Conversion
- Drilling / operation challenges (total loss)
- Remote areas - high operating cost
Background

Study Purpose

• Better understanding of the Reservoir

• Increase accuracy in Well Placement

• Increase Production
Workflow

Well based Fracture Analysis

Seismic Anisotropy for Fracture detection

Geological Modeling

Volumetric

Well Placement

Simulation

Discrete Fracture Network

Limitation of data availability
Fracture Analysis

Workflow - Well Based Fracture Analysis

PRODUCTION ZONE
At 6882’-6875’ TVD (193 feet)

BRIDGE PLUG, cementing at 6875’-6885’ TVD

UPPER FRACTURE ZONE
• Low angle

LOWER FRACTURE ZONE
• High angle

OS-2
OS-4
OS-1
OS-3
NUA-3
NUA-1
NUA-2
NUA-1st

Oseil 4
Natural Fractures

Oseil-4a Well
Workflow - Well Based Fracture Analysis

Fracture Analysis based on core data

Cross beds of oolitic and peloidal grainstone, porosity reduced by calcite cement. Oil stain (dark outline) on cross beds.

Close-up whole core photographs well NUA-3 of Manusela Formation

AAPG-EAGE Joint GTW on Fractured Carbonate Reservoir
The correlation of fracture intensity between the 3 exploration wells and the seismic inversion result shows a good match.
CITIC Seram Energy Limited

Workflow - Geological & Fracture Modeling

Geological & Fracture Modeling of Oseil field

- High-quality static reservoir model is required to perform simulations in order to predict the fluid dynamic

- A 3D reservoir model enables us to integrate multidata (well data, seismic data, conceptual models, production data) for a more reliable result

- Ability to generate and simulate a dual-poro dual-perm reservoir behavior
Workflow - Geological & Fracture Modeling

Geological & Fracture Modeling of Oseil field

Geological Modeling

Volumetric

Fracture Modeling

Simulation
CITIC Seram Energy Limited

Workflow - Geological & Fracture Modeling

Example : Matrix Porosity Modeling Result

POR Histogram
Blue = 3D Model
Green = Upscaled Well-logs
Red = Raw Log

Variogram Analysis
Major Dir : 133
Minor Dir : 0.1097
Major Range : 4985
Minor Range : 928.2
Vert. Range : 38.7
Nuget : 0.225
Fracture Modeling

Workflow - Geological & Fracture Modeling

Fracture Interpretation
Based on image log & core data
(Fracture Orientation, Geometry, etc)

Fracture Analysis

Model Parameters

Discrete Fracture Network

Upscale

DPDP Simulation

Fracture Intensity Cube result--to control Fracture Distribution
Workflow - Geological & Fracture Modeling

Input for Model Parameter

Model parameters are the object that controls the intensity of the fracture, called fracture drivers.

- Lithological/Facies drivers
- Seismic drivers
- Mechanical drivers

Main input for the fracture distribution

Main input for the area extension of the fracture
Workflow - Geological & Fracture Modeling

Discrete Fracture Network

- A fracture network is a group of planes representing fractures.

**Distribution Method:**
Use the Intensity from distance to fault and seismic fracture intensity

**Geometry:**
Fracture Aperture, QC with the data from image log & core data

**Orientation:**
Main trend of azimuth/dip should be inline with the fracture from well
Workflow

The Well Placement in Oseil Field

- Undrained area
- The distance from oil-water contact and target zone in upper part of Manusela fm
- Fracture intensity
- Interference well analysis
- Avoid the fracture directly connected to aquifer zone
- Horizontal length
Workflow - Well Placement

Well Placement Results

• 4 new development wells were proposed & designed based on this integrated study

• The positive economic results shown from these 4 wells. The most successful well (Os-2 ST2) and Os-16 well with < 0.5% water cut.
Undrained Area

Undrained Area (tendency of drainage area is to follow the direction and dip (relatively vertical) of fracture.

Oseil-2 Area Saturation Distribution

OS-2ST2 INITIAL WELL CLEAN UP AND TEST DAILY AVERAGE

AAPG-EAGE Joint GTW on Fractured Carbonate Reservoir
Undrained Area (tendency of drainage area is to follow the direction and dip (relatively vertical) of fracture.

**OS-16 Initial Well Test (ESP) - Daily Average**

- **Oil Production (BOPD)**
- **Gas Production (MCFD)**
- **WC (%)**

- **17 Dec. 2011:** ESP tripped by O/C
- **9 Jan. 2012:** ESP back online

**Calendar Dates:**
- 11-17 Dec. 2011
- 1-7 Jan. 2012
- 8-14 Jan. 2012
- 29-5 Feb. 2012
Avoid the fracture directly connected to aquifer zone
Well with early water break-through

- New well with TD shallower—60 ft—than nearby well
- Both penetrate the high intensity fracture zone with total loss encountered at bottom of the well
- New well suffers early water breakthrough with water-cut reaching 95%

The distance between Os-9 and Os-18: 300m

Seismic Inversion section of Os-1, Os-9 to Os-18

Fracture Intensity
Barrier
Low TAwC

TD=7476' MD / 5424' SS
TD=7232' MD / 5366' SS
5300' SS
TD=7232' MD / 5366' SS
5300' SS
Workflow - Seismic Attribute

Ant-Track result -- Avoid the fracture directly connected to aquifer zone

[Image of seismic attribute analysis]

Big fracture/fault zone??

[Graph showing Oseil-18 daily average well test - before & after cement plug]

Before cmt plug : 1035 BFPD, 95% WC, PI 48
After cmt plug : 305 BFPD, 18% WC, PI 4

Potential Source of Channeling Water

Equivalent Depth with Os-9 (Top Manusela):
- 5319' SS

Less Permeable to Excellent

Permeable

TD=7232' MD / 5365' SS

7107'MD/5330'SS
(end of Tail pipe)

7152'MD/5345'SS
(Max. Top of Cement)

7066'MD/5314'SS
(OH Packer)
Conclusion

• Integration of well & seismic data provides better comprehensive understanding

• The result of seismic fracture intensity is aligned with the well

• Total loss circulation during drilling correlates with the intensity of fractures

• Seismic attributes should constantly be utilized to identify anomalies

• Need more effort to incorporate mud loss and drilling parameter into the update model
Questions
Thank You