Reservoir Monitoring Consortium (RMC)

Semi- Annual Project Review Meeting

An Update on RMC

Fred Aminzadeh,

Los Angeles, CA
July 22, 2015

RMC Annual Review Meeting Agenda

8:00	**Registration-Breakfast**	
8:15	**An Update on Reservoir Monitoring Consortium (RMC)**	**Aminzadeh**
8:35	**Reservoir Monitoring with 4D Seismic- Three Case Histories**	**HajNasser**
9:00	**Advanced Tracer Analysis for EOR and Reservoir Monitoring**	**Najem** (Kuwait Oil)
9:25	**Use of production geology data to monitor water influx**	**Zhao, Ershaghi**
9:50	**Coffee Break**	

RMC Annual Review Agenda, Cont.

RMC

10:05	**Wellbore Monitoring for Kick Detection and Field Testing in a Saudi Aramco Field**	**Otaibi, Bubsheit** (Aramco)
10:30	**Modeling Field Development Strategies and Their Associated Resource Requirements**	**Prohaska** (U of Leoben, Austria)
10:55	**Permanent seismic source for continuous reservoir monitoring**	**Kurosawa, Kato** (Japan National Oil)
11:20	**Research Directions for CO2-EOR Applications**	**Metin Karakas,**
11:40	**A New Method to Analyze Displacement of Fluids in EOR**	**Temizel** (Aera Energy)
12:00	**Lunch**	

RMC Annual Review Agenda, Cont.

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1:00	**Fracture Zone Identification and Permeability Prediction**	**Maity,** (Gas Technology Inst.)
1:30	**Analysis of In-Situ Stress in Hydraulic Fracturing ISH Project**	**Bubsheit** (Aramco/USC)
2:00	**Early Time Analysis of Hydraulic Fracturing Using Extended Finite Element Method**	**K. Nejad**
2:30	**Coffee Break**	

RMC Annual Review Agenda, Cont.

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2:45	**A Geomechanical Approach for Microseismic Fracture Mapping**	**Hosseini**
3:15	**Microseismic/Electromagnetics for reservoir monitoring**	**Kurt Strack** (KMS Technology)
3:45	**Experimenting with Microseismic monitoring**	**Martin Karrenbach.** (SR2020)
4:15	**Discussion/ Q&A**	**All**
4:45	**Concluding Remarks**	**Fred Aminzadeh**

RMC Objectives

➢ Identify the current key technology gaps
➢ Focus on interfaces between different disciplines
➢ Integrate data, information, expertise and workflows
➢ Maintain a balance between the short term high impact research and long term needs
➢ Develop dynamic reservoir monitoring (DRM) workflow
➢ Focus areas of reservoir types:

- ▪ Shale,
- ▪ Carbonate,
- ▪ Deep water

RMC Hybrid Structure

➢ **RMC Base Project**
- ▪ Member's Access to general results of Base RMC
- ▪ Prioritization of Base Project Mix
- ▪ Partial Access to ISP projects (with ISP member concurrence)

➢ **Individually Sponsored Projects (ISP)**
- ▪ Access to RMC Base Project Results
- ▪ ISP Member focused project
- ▪ Limited distribution of data and results
- ▪ Increased interaction between ISP member and USC

PhD Students

1. Magdalene Ante (Nigeria)
2. Abdulrahman Bubshait (Saudi Aramco)
3. Ahmed Bubshait (Saudi Aramco)
4. Rayan Dablul (Saudi Aramco)
5. Mehran Hosseini
6. Nima Jabbari (Intern at CSL)
7. Metin Karakas (Chevron Fellowship)
8. Debotyam Maity (now with Gas Technology Institute)
9. Noha Najem (Kuwait Oil Company)
10. Arman Nejad (Intern at FracGeo)
11. Mahshad Samnejad
12. Tayeb Tafti (now with Aera Energy)
13. Robert Walker (Chevron Fellowship)
14. Xiaoxi Zhao

Incoming   Current   Graduating   Graduated

Other Members of RMC Team   RMC

Some of the Collaborating Faculty

- Felipe De Barros
- Iraj Ershaghi
- Behnam Jafarpour
- Roger Ghanem
- Donald Hill (adjunct)
- Kristian Jessen
- Birendra Jha (Coming from MIT)
- Martin Karrenbach (adjunct)
- Donald Paul
- Charles Sammis
- Mohammad Sahimi

Post doctoral Fellows

- Thomas Gobel (part time- CalTech)
- Yesser HajNasser, (formerly ConocoPhillips)

Staff

- Joe Ivonetti (advisor)
- Jason Ordonez (business analyst)

USC Reservoir Monitoring Consortium

RMC

RMC Base Projects

Optimize Hydraulic fracturing for shale	**Physical Models to monitor reservoir fluid (with CUP)**	**MEQ to Map Reservoir Structure**
Time lapse Petrophysics for RM	**MEQ & Seismic Integration for Shale Reservoirs**	**Tomography Based Reservoir Modeling**

4D Reservoir Monitoring

Time Shift (2001-1989)
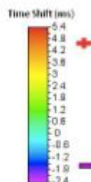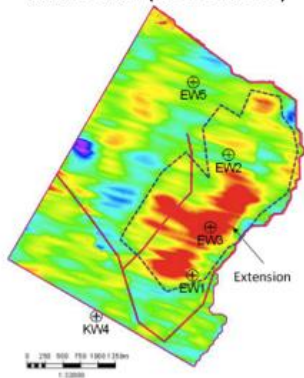
RMS (Monitor – Base) (20ms window) over reservoir interval
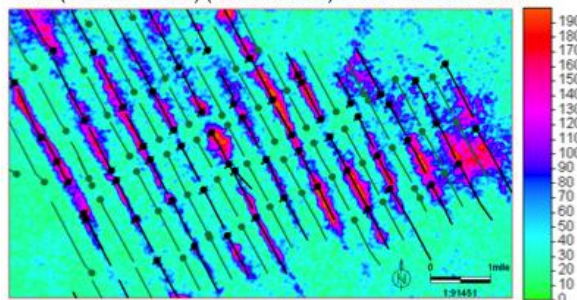
Time Shift (Top reservoir -20 ms)
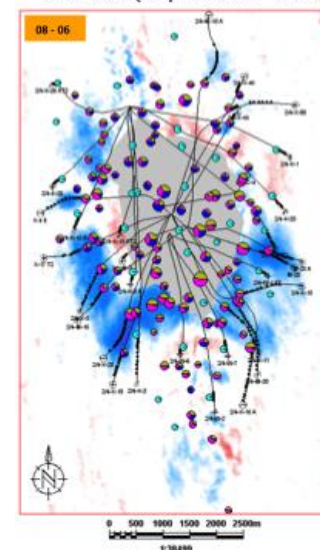
Full-field model
prediction pressure,
saturation, Geomechanics

Reservoir
Simulation

4D Reservoir Monitoring

Log Analysis
(Vp, Vs, Density)

Rock Properties

Seismic Response

Data Quality
S/N, Bandwidth

Pressure Response
Core analysis
Analogue data

Repeatability
Match Processing,
Amplitude analysis

(O'Donovan, 2000)
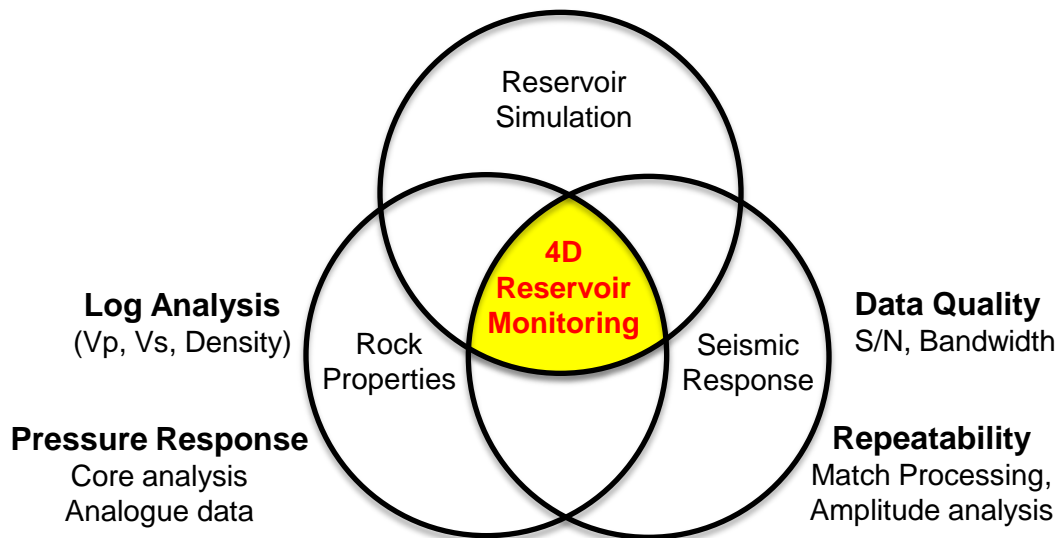
Analysis of Hydraulic Fracturing
Modeling of Fracture Initiation and Propagation

Width of fracture
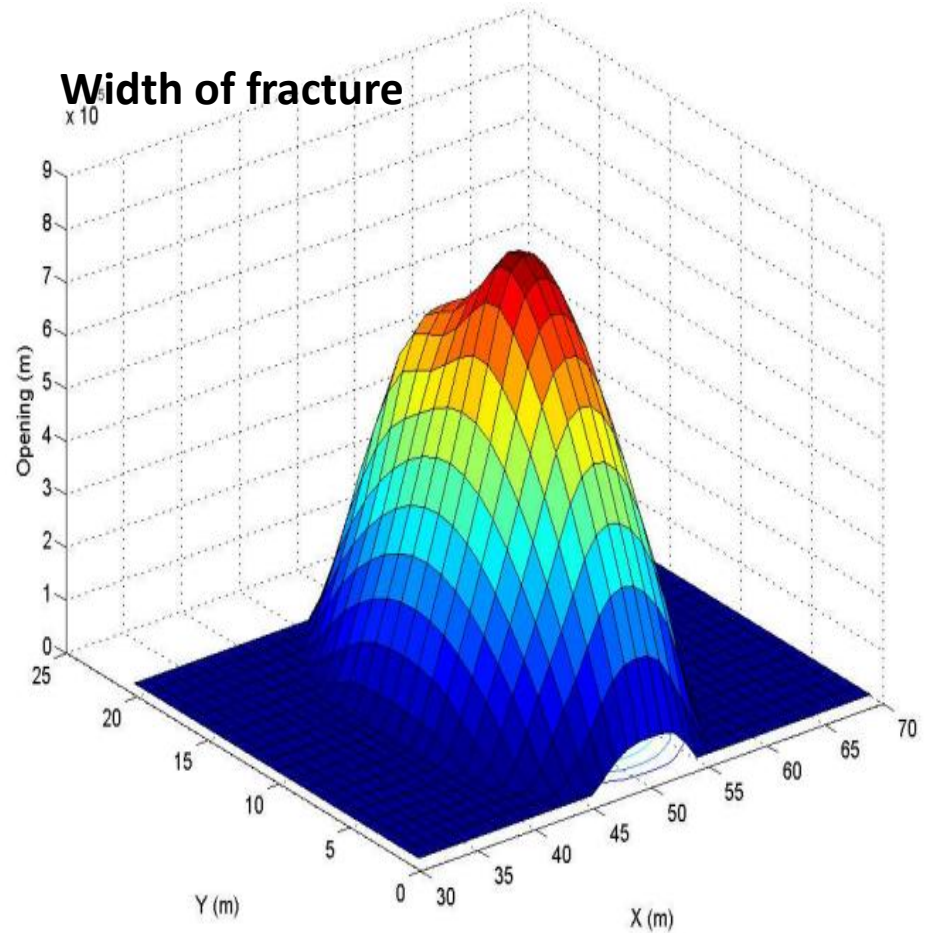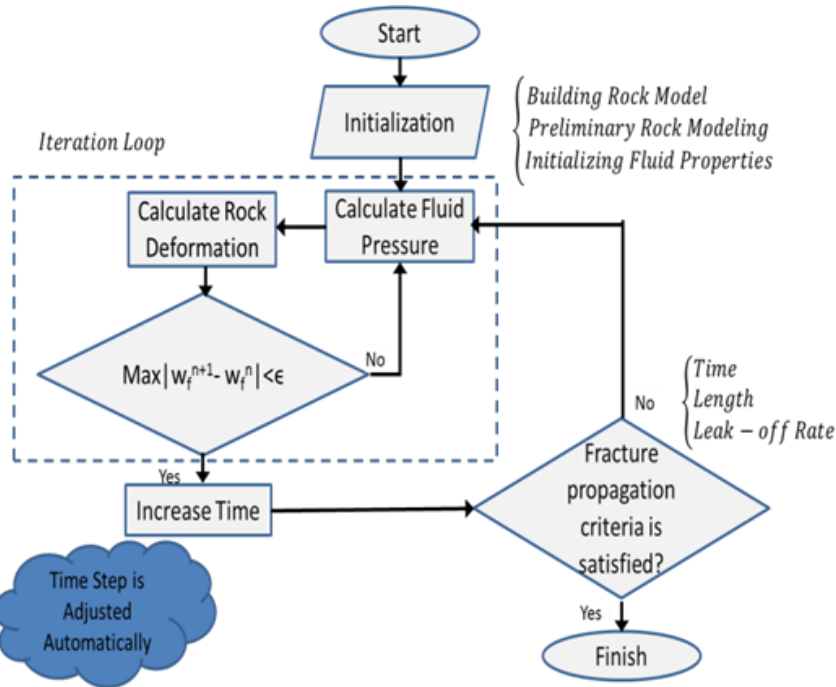
Hydraulic Fracturing Simulation
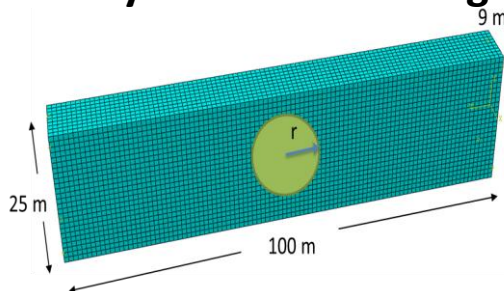
Cross section view of discretized reservoir

CO_2-EOR

RMC

Target Areas for CO2 Pilot
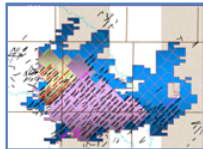
*Saturation & Pressure Distributions
Fractures, Risks & Opportunities*

Screening Studies

Reservoir Uncertainties
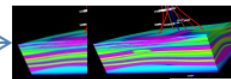
*Differential Fluid Movement,
Facies, Vertical Barriers,
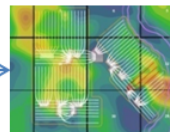High-Perm Streaks, Fracture Corridors*

CO2 Fluid Characterization
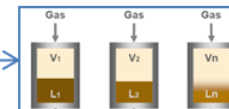
*Representative Fluid Sample
Multi-Contact Miscibility,
Asphaltine Deposition during
production*

CO2 Core Tests

*CO2 SCAL, Residual Oil
Saturation*

Sensitivity Studies

*Well and Completion
Types, Injection Schemes,
Mobility Control Agents*

Site
Selection

*Key Success Factors
Conformance, Residual
Oil Saturation, Risks &
Opportunities*

Tests under reservoir conditions
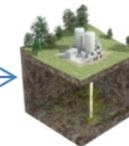
*Residual Oil , Miscibility
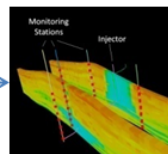CO2 SCAL, Asphaltine, Foam
Fluid & Rock Interactions*

*Technical
Success?*

Pilot Design
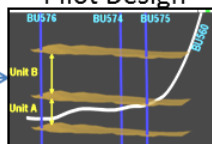
*Observation Wells
Completion Types & Control,
Reservoir and Well Monitoring,
Mitigation Plans*

Pilot Execution

*Reservoir & Well Monitoring
Injection & Production Control
Mobility Reduction
Real-time Model Update*

Pilot
Evaluation

*Lessons Learned
Data Integration &
Production Forecasting*

*Key Success
Factors Met?*
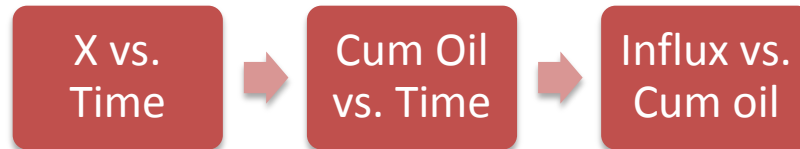
Sector / Field Development

*Sector Model
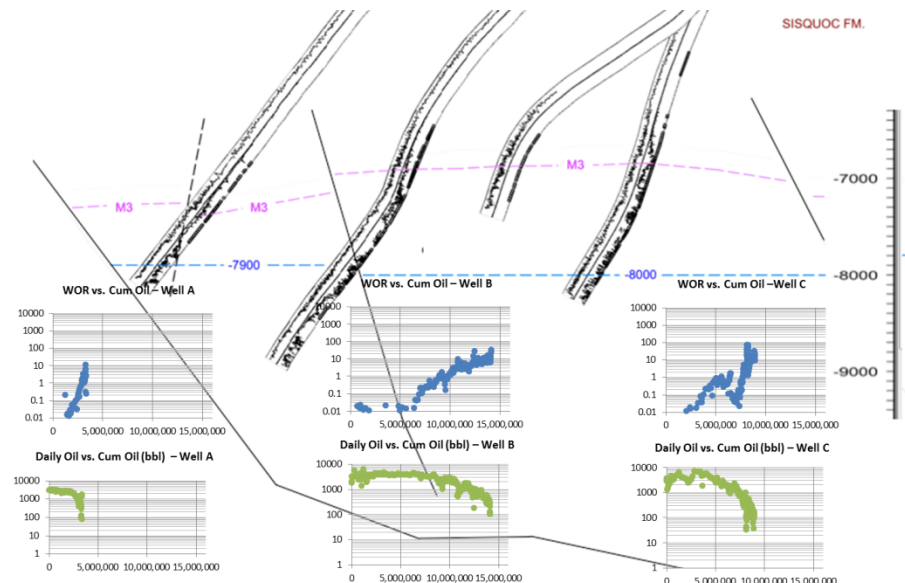Remaining Uncertainties
Risk Mitigation,
Opportunities*

Monitoring Water Influx in Compartmentalized Fractured Reservoirs

- Methodology is effective in dynamic monitoring
- Production data provides excellent opportunities to monitor water movement

X vs. Time → Cum Oil vs. Time → Influx vs. Cum oil

- Need for more frequent well tests
- Need for the development of a response library
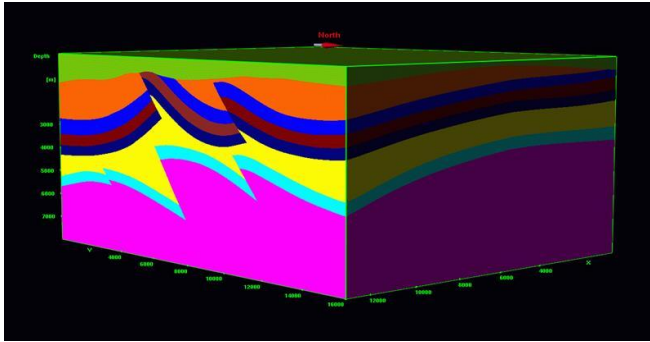
Evidence of Compartmentalization WOR

SISQUOC FM.

M3

-7000

M3 M3

-7900

-8000

-8000

-9000

WOR vs. Cum Oil – Well A

WOR vs. Cum Oil – Well B

WOR vs. Cum Oil – Well C

Daily Oil vs. Cum Oil (bbl) – Well A

Daily Oil vs. Cum Oil (bbl) – Well B

Daily Oil vs. Cum Oil (bbl) – Well C

Physical Models

3-D geological structure

A shale reservoir model in a water tank to simulate seismic response

1- **Complex geological structures**
The model has the complex structure: large-scale thrust-structure, the formation of large dip angle, high angle fault, high and steep structure characteristics.

2- **Shale Reservoir Model**
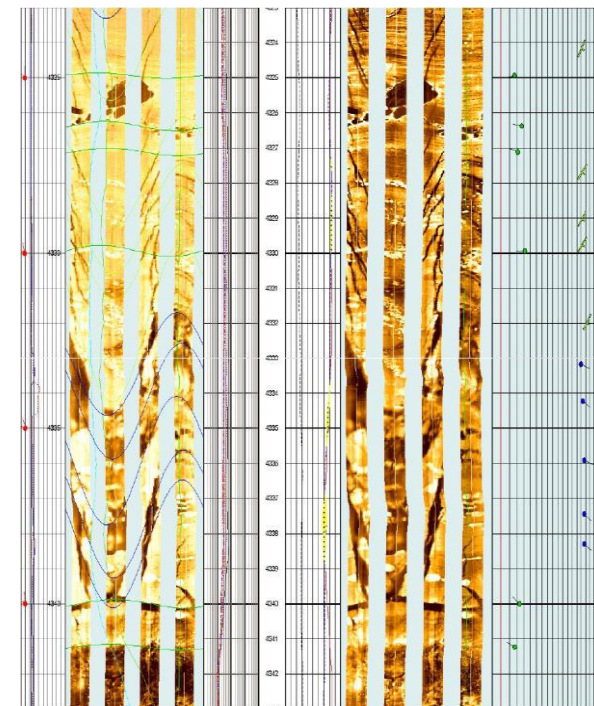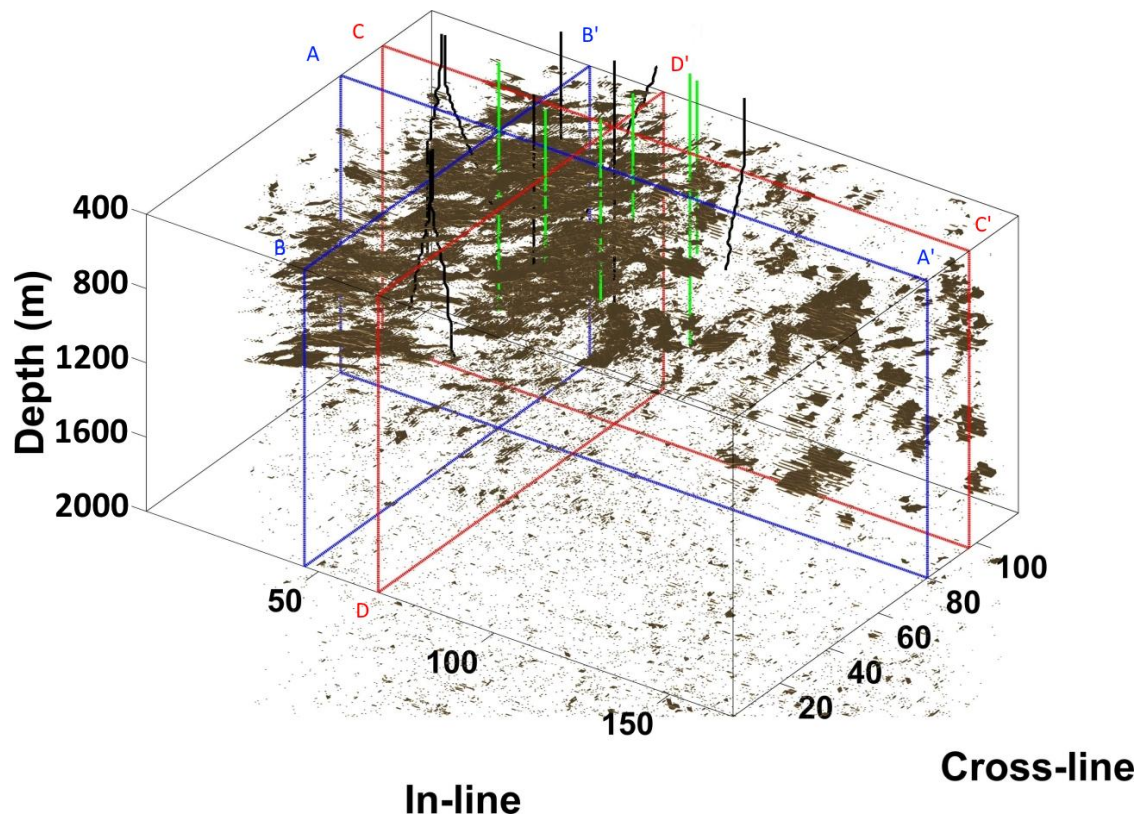The model would simulate different fracture networks for different types of shale

With **Chinese University of Petroleum**
Prof. Wang , Prof. Yong

Fracture Mapping using MEQ, Seismic & Petrophysical Data

Cross-line

In-line

Identify fractures & generate fracture logs

HYBRID FZI ATTRIBUTE MAPPING (ANN)

$$FZI_n \equiv F\{\phi_n, Z_n, V_{Pn}, V_{Sn}, \rho_n, V_{En},\}$$
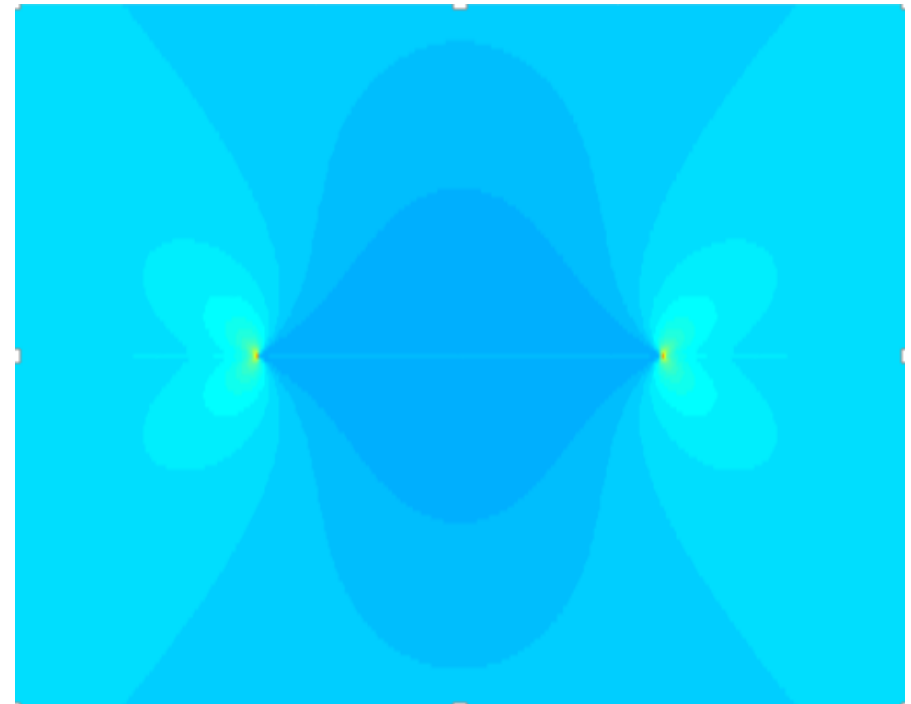
Maity, and Aminzadeh, 2015: Interpretation, 3(3), T155–T167.

Shear Potential in Different Reservoir Conditions
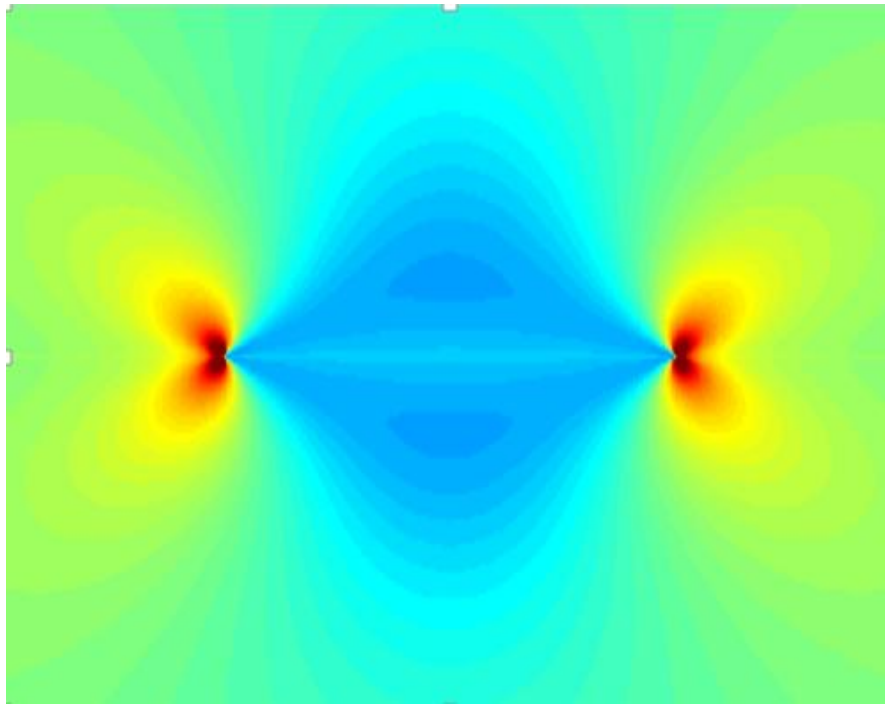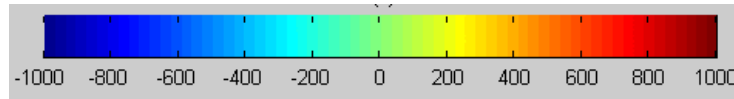
High Reservoir and Injection Pressure (psi)

High Reservoir Pressure (psi)

RMC Individually Sponsored Projects (ISP)

RMC -ISP

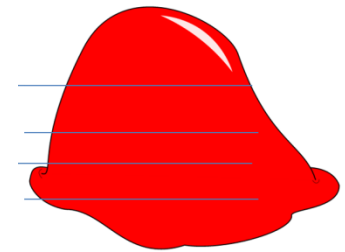|		
Next Generation Visualization **X**	Tracer Analysis for EOR/ Reservoir Monitoring **KOC**	Monitoring kick and overpressure **NETL/Aramco**
In-situ Stresses for hydrofacture (ISH) **Saudi Aramco**	Advanced Hydraulic Fracturing Test Bed **DOGGR?**	HCI with Absorption and Anisotropic AVO **X**

Individually Sponsored Project (ISP)
Smart Tracer Technology

Single phase flowmeters

Pressure/temperature sensors

Zonal isolation packers

Microseismics

adapted logging devices

Sliding sleeves and chokes

Fiber optic DT sensors
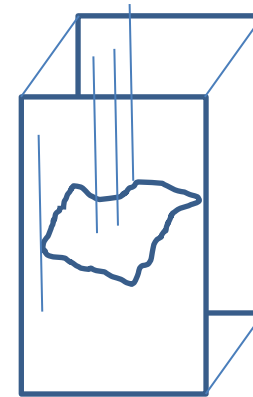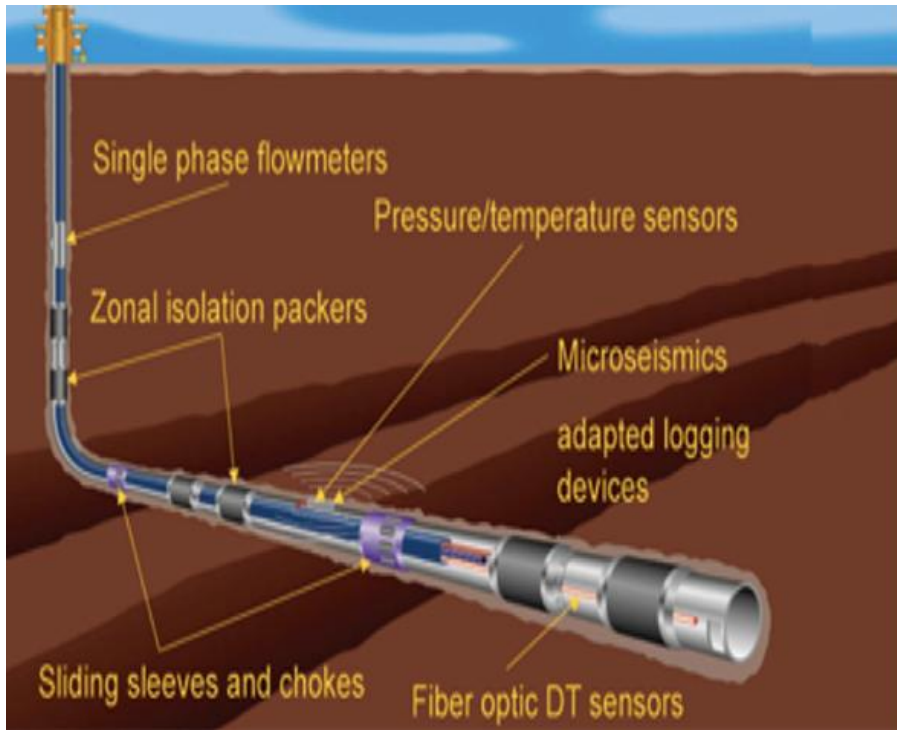
Data Response & Interpretation

Blob- EOR/IOR 3D Geomodel

A novel approach using downhole sensing and dynamic simulation is now being developed to address \challenges and aid in the identification of pathways, improve sweep efficiency and indicate Sor.
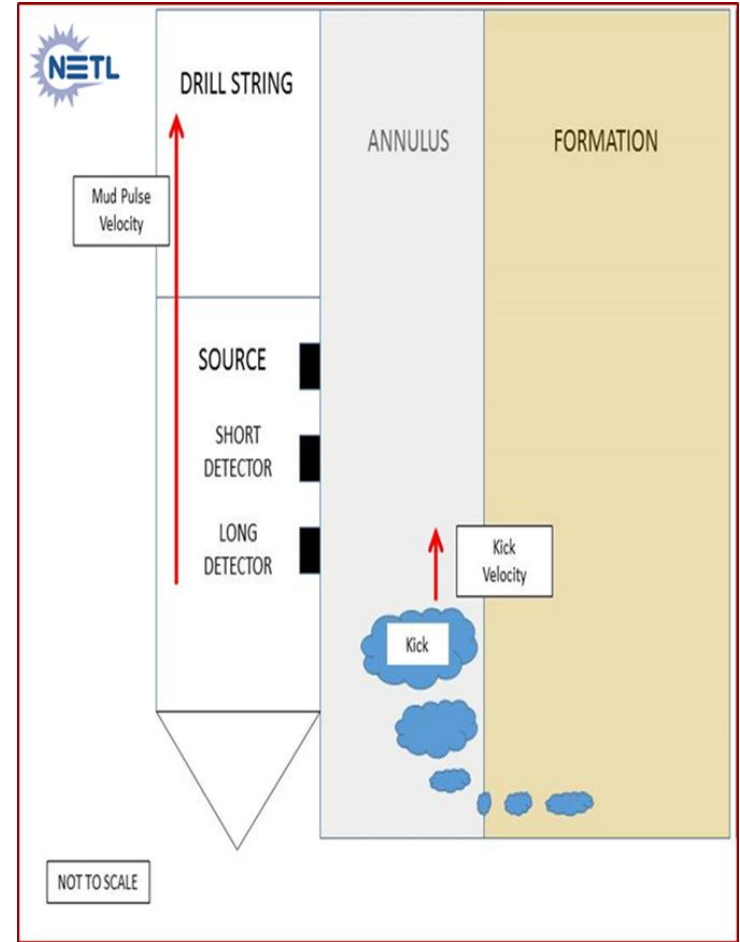
Individually Sponsored Project (ISP)
Real Time Kick Detection at the Bit
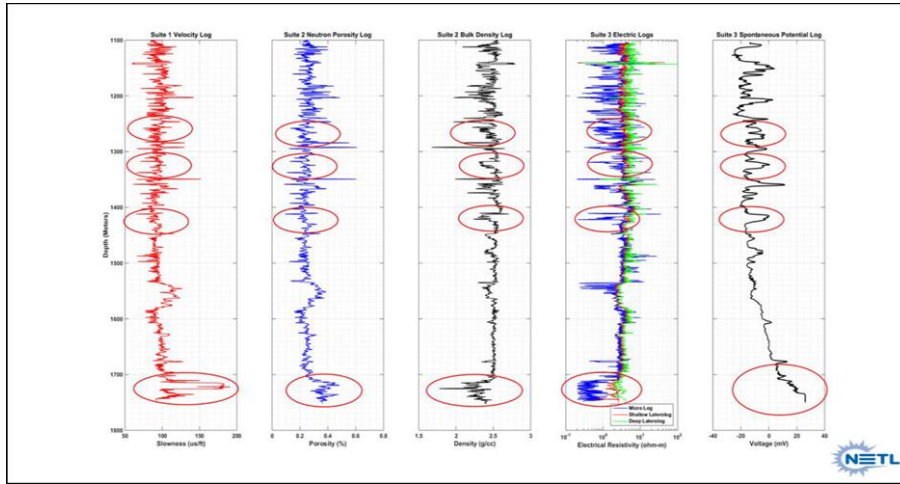
In collaboration with NETL and Saudi Aramco, the algorithms will be validated and tested by using historical well log measurements of wells that encountered number of kick events.

After the validation phase to ensure working under field conditions, the algorithms will be trail tested with real time wellbore data.
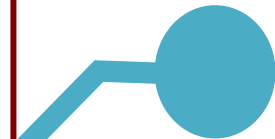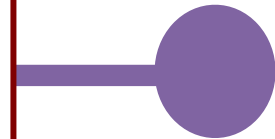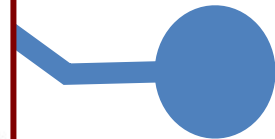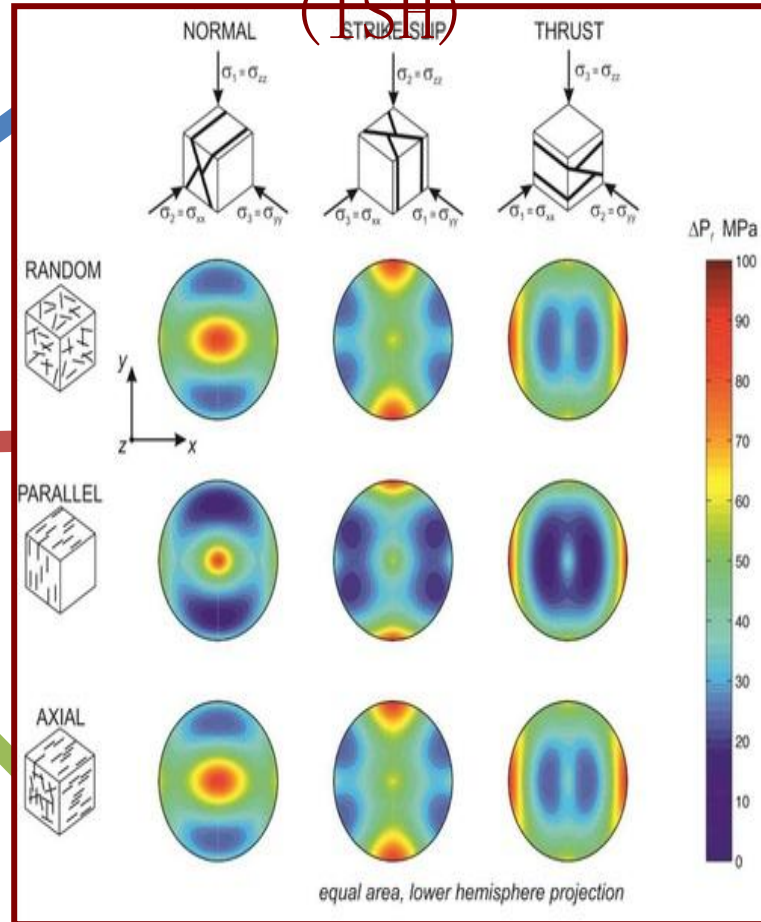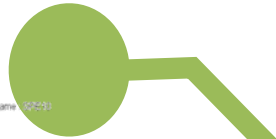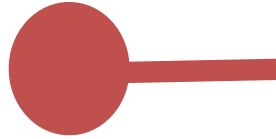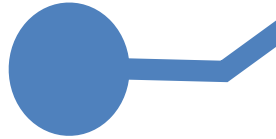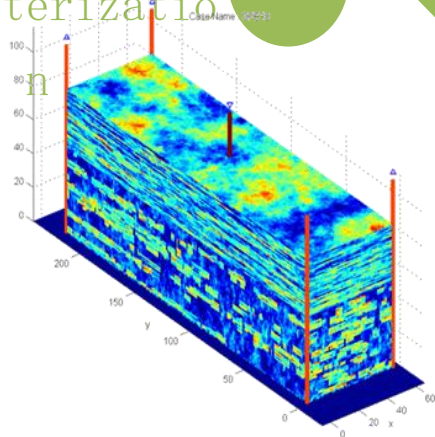
Individually Sponsored Project (ISP)
In-situ Stress in Hydraulic Fracturing (ISH)
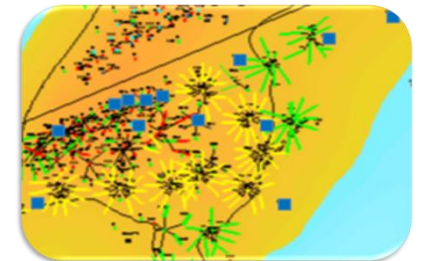
RMC

Determine regional fracture

Seismic attribute

Fracture characterization
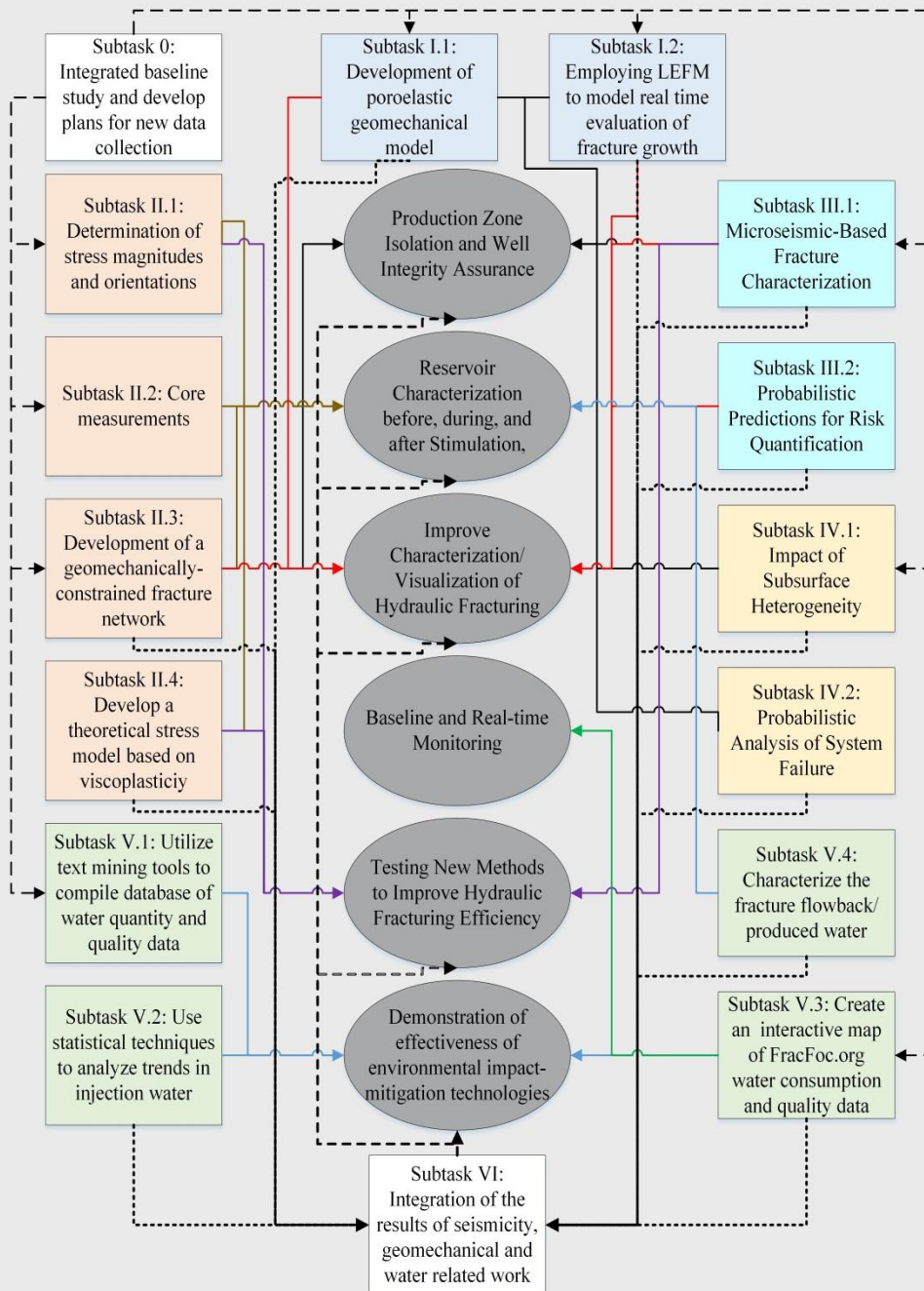
Well logs

Velocity models

Cores analysis

Enhance efficiency and safety of shale production

Conclusions

➢ Reservoir Monitoring is a truly multi-disciplinary problem

➢ RMS offers the expertise and know how from different USC entities

➢ RMC base provides a platform for low cost technology development and application with leveraging opportunities

➢ RMC ISP offers a focused R&D with the priorities of different companies and other organizations

➢ Leveraging Opportunities with ISC and other programs