The fundamental role of Formation Evaluation in the E&P process

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Formation Evaluation: definition

**Formation Evaluation** is the analysis and interpretation of well log data, drill stem tests, etc. in terms of the nature of the formations and their fluid content.

The objectives of Formation Evaluation are:

- to ascertain if commercially producible hydrocarbons are present,
- to determine the best means for their recovery,
- to derive lithology and other information on formation characteristics for use in further exploration and development.

From SPWLA Glossary
The E&P process

**Exploration & Discovery Evaluation**
- **FE Technologies**
  - Surface Logging
  - Well Logging
  - Coring
  - Formation Testing
  - Well Testing
- **Disciplines**
  - Geosciences
  - Drilling
  - Production (feasibility)
  - Reserve evaluation

**Appraisal**
- **FE Technologies**
  - Surface Logging
  - Well Logging
  - Coring
  - Formation Testing
  - Well Testing
- **Disciplines**
  - Geosciences
  - Drilling
  - Reservoir Engineering
  - Production (design)
  - Reserve certification

**Development & Production Optimization**
- **FE Technologies**
  - CH Logging
  - Reservoir Monitoring & Surveillance
- **Disciplines**
  - Geosciences
  - Drilling
  - Reservoir Engineering
  - Production (optimization)
Exploration Phase

In this phase, emphasis is put on well data with limited information about interwell region in terms of geology, facies and fluid distribution, dynamic data, etc. and the results are characterized by large uncertainties.

Well data are:

- surface logging (mud logging);
- core data (often routine, very seldom SCAL);
- well logs (both WL and WD);
- fluid sampling (often limited to RFT sampling);
- formation testing (often limited amount of tests).
Exploration phase

In this phase, surface and well logs play a fundamental role in the evaluation of a prospect in terms of:

- petroleum system characterization (distribution of source, reservoir and cap rocks),
- reservoir geometry,
- fluid characterization and distribution (fluid contacts),
- preliminary evaluation of HOIP and reserves by using the petrophysical interpretation of well logs (CPI).
Development & Production phases

Objectives
- Optimize the reservoir exploitation in all the phases of its production life
- Maximize recovery

Methodologies
- Reservoir development studies
- Reservoir management
Reservoir characterization

Reservoir characterization corresponds to the identification of a model (static) for the reservoir, the dynamic behaviour of which must be as similar as possible to that of the reservoir.

It involves two consecutive steps:

- the identification of data interpretation models;
- integration of these data interpretation models into a reservoir model.

Various types of reservoir data are used:

- "static" data such as geology, geophysics, geochemistry, petrophysics, which correspond to a description of the reservoir;
- “dynamic” data, such as fluid pressures, geomechanics, tracers, production logs, well tests, production, which are related to the behaviour of that reservoir.

Gringarten et al., SPE 64311
Reservoir Characterization

- Geological Model
- Electrofacies
- Rock Properties
- Seismic
- Petrophysics
- Sedimentology
- Production Tests
- Production Logs
- Fluid Pressures
- Fluid Properties
- Geochemistry
- Others...
Goals of the Reservoir Characterization are the description and the characterization of the reservoir heterogeneities that control the fluid flow combined with geological and structural model of the reservoir.

In this contest petrophysical parameters are a direct input to numerical simulators and have a strong impact on the dynamic results in terms of hydrocarbon production forecast.
FE and other disciplines

**Drilling**
- Drilling strategies
- Geosteering
- Wellbore stability
- Post drilling analysis

**Geosciences**
- Geology
- Geophysics
- Petrophysics
- Reservoir Engineering

**FE Technologies**
- Surface Logging
- Well Logging
- Coring
- Formation Testing
- Well Testing
- Well Data DB

**Production**
- Production strategies design
- Production Monitoring & Optimization
- Formation compaction & damage

**Reserves Evaluation**
Geosciences are composed by a variety of disciplines:

- Geology
- Geophysics
- Petrophysics
- Reservoir Engineering
In the Oil Industry, **Geology** is composed by a variety of subdisciplines:

- Operational Geology
- Stratigraphy
- Sedimentology
- Petrography
- Structural Geology
- Geochemistry
- Geomechanics
Geophysics

The study of the physics of the Earth, especially its electrical, gravitational and magnetic fields and propagation of elastic (seismic) waves within it. Geophysics plays a critical role in the petroleum industry because geophysical data are used by exploration and development personnel to make predictions about the presence, nature and size of subsurface hydrocarbon accumulations.

Schlumberger Oilfield Glossary
Geophysical methods

- Seismic
- Magnetometry
- Gravimetry
- Magnetotelluric
- Electrical surveys
- Electro Magnetic sounding
- Georadar
Petrophysics

**Petrophysics** is the study of rock properties and their interactions with formation fluids.

**Main Petrophysical properties** are:
- Porosity
- Permeability
- Water saturation

**Main Petrophysical tools**
- Cores
- Well logs
Formation Evaluation Process

Main steps of the process are:

- planning of the well data acquisition,
- acquisition phase with Quality Control,
- pre and/or post processing,
- interpretation,
- integration.
Pressure analysis

Fluid contacts
Geosteering

The intentional directional control of a well based on the results of downhole geological logging measurements rather than three-dimensional targets in space, usually to keep a directional well bore within a pay zone.

In mature areas, geosteering may be used to keep a well bore in a particular section of a reservoir to minimize gas or water breakthrough and maximize economic production from the well.
Advanced Geosteering is achieved mainly by deep Looking Ahead and Around capabilities:

- seismic
- electromagnetic
- high density telemetry
- Real Time integrated geological & geophysical interpretation
- 3D fast visualization techniques (IT)
Cased Hole Logging

Production logging provides down hole measurements of fluid parameters on a zone-by-zone basis to yield information on the type of fluid movement within and near the wellbore during production or injection.

Major applications of production logging include:

- evaluating completion efficiency
- detecting mechanical problems, breakthrough and coning
- providing guidance for workovers,
- enhanced recovery projects
- evaluating treatment effectiveness
- monitoring and profiling of production and injection
- detecting thief zones, channelled cement
- single layer and multiple layer well test evaluation
- determining reservoir characteristics
- identifying reservoir boundaries for field development.
Production logging

The family of production logging tools comprises:

- thermometers
- fluid density sensors (gradiomanometers, nuclear)
- hold-up meters
- flowmeter spinners (continuous, fullbore, diverters)
- manometers (strain gauge, quartz gauge)
- calipers (multifinger)
- noise sensors (single frequency, multiple frequency)
- radioactive tracers
- gravel pack logging.
Integration: Shared Earth Model

Shared Earth Model & Reservoir Characterization Process: circular and not linear!

A very good example of effective integration among different disciplines where Formation Evaluation plays a key role in every phase.

J. Nieto et al. 2004
Petrophysicists are involved in the whole modeling process contributing with their knowledge of many data types and how these data interact!

J. Nieto et al. 2004

Integration: Shared Earth Model
Interpretation/Integration

Integrated interpretation of well data can strongly reduce uncertainties in Formation Evaluation and in Reservoir Characterization studies.

Integration is a combination and coordination of separate and diverse elements or units into a more complex or harmonious whole. Since it implies the creation of a more complete or harmonious whole, integration can therefore be considered as a process whereby extra value is produced.

(Integrated Reservoir Studies – Luca Cosentino – Edition TECHNIP - IFP)

Extra value gained through integration can be expressed either in more complex but verified geological models or as a higher reliability in a simplified but stable model.
Integration: … a seamless profession …

… in recent years we have been singing the praises of integration between Geosciences disciplines …

… lets just knock down the remaining physical and perceived walls and merge geophysics, geology, petrophysics and engineering into a seamless profession …

Patrick Corbett, 2005
“A changing Role for the petrophysicist?”
Organizational challenges

- Integration and use of shared earth models require a high level of Knowledge and Resources Management (human & Hardware/Software), not always present in actual organization of companies.

- New generation of professionals need to be educated to team working and managers must facilitate cross fertilization initiatives and cooperation among the different disciplines.

- Technology champions are still necessary but, please, no more “Prima Donna”!
About integration ...

Symphonic Orchestra:

a good example of an integrated team
Conclusions

- Formation Evaluation techniques play a fundamental role in the hydrocarbon E&P process being used in all the different phases of the process itself.

- Effective use of these Formation Evaluation techniques require high level of integration that can only be achieved by effective team working and adequate knowledge and resource management.