Data Acquisition and Characterization

Reservoir Management | Data Acquisition and Characterization

Reservoir management requires a deep knowledge of the reservoir that can be achieved only through its characterization by a process of acquiring, processing and integrating several basic data.

In detail the main steps of this process are:

1.Data acquisition, involving the gathering of raw data from various sources, i.e.

- *Seismic surveys*
- *Well logs*
- *Conventional and special core analyses*
- *Fluid analyses*
- *Static and flowing pressure measurements*
- *Pressure-transient tests*
- *Periodic well production tests*
- *Records of the monthly produced volumes of fluids (oil, gas, and water)*
- *Records of the monthly injected volumes of IOR/EOR fluids (water, gas, CO2, steam, chemicals,…).*

2.Data processing based upon:

- *Seismic time maps*
- *Seismic conversion of time-to-depth maps*
- *Seismic attribute maps*
- *Log analyses*
- *Structural maps*

- *Cross sections*
- *Geologic models*
- *Reservoir fluids modeling (e.g. by EOS)*
- *Simulation models*

3.Data integration and Reservoir Characterization

The characterization of a reservoir aims at producing the best detailed geological reconstruction both of its geometry and of its internal structure. The overall process is, therefore, the first basic step in the development of a reservoir model, and it must consider all the available data, processed and interpreted with the best technologies always caring to be consistent with the observed historical reservoir performance.

Geophysical, geological, and engineering characterization provides also information on the initial distribution of the fluids, as well as on the hydraulic connectivity between different zones of the reservoir rocks.

Reservoir characterization aims at the detailed description of the reservoir

Typical information produced by the reservoir characterization process are for example:

- *Field and regional structure maps, including fluid-contact depth and shape and size of aquifers*
- *Isopach and porosity maps*
- *Flow units or individual producing zones; location of vertical and horizontal flow barriers*
- *Description of the depositional environment and evaluation of the effect of the diagenesis on rock transmissibility*
- *Variations in fluid saturations and permeabilities.*

The following activities are normally performed for the acquisition of the data required by the reservoir characterization.

Seismic

Seismic data acquisition is fundamental for the definition of the reservoir architecture.

Seismic allows reconstructing the reservoir geological setting through different level observations:

- *On large scale: reservoir geometry, identification of main structural features (e.g. faults), , etc*
- *On small scale: detailed structural and stratigraphycal features, fluid contacts, etc.*

Seismic response of a reservoir depends on petro-acoustic properties of the volume of rock investigated; such properties can be obtained by the interpretation of specific field data.

From seismic to structural reservoir modeling

Well Logging

Well logging plays a fundamental role for the formation evaluation process and for the assessment of production potential of a hydrocarbon process.

The log interpretation, in fact, gives a quantitative evaluation of the "in-situ" value of some important petrophysical parameter, such as:

- *Shale volume (Vsh)*
- *Gross and net thickness of the drilled layers (h_G, h_N)*
- *Depth of the fluid contacts (gas-oil, gas-water, oil-water)*
- *Porosity (φ)*
- *Water saturation (Sw)*
- *Residual hydrocarbon saturation (Sor, Sgr)*
- *Rock elastic moduli (E, G, ν, etc.).*

Depending on the wellbore status, the logs are classified as:

- Open Hole Logs:
    - *Resistivity, Induction, Spontaneous Potential, Gamma ray*
    - *Density, Sonic Compensated Neutron, Sidewall neutron*
    - *Porosity, Dielectric, and Caliper*
    - *Gamma Ray, Neutron (except SNP), Carbodoxygen*
- Cased Hole Logs:
    - *Chlorine, Pulsed Neutron and caliper.*

A flowchart to analyze well logs for reservoir characterization

Well logs and flow units, connectivity, and reservoir characterization in a wave-dominated deltaic reservoir

Core Analysis

Lab analysis on reservoir rock samples (e.g. cuttings, bottom-hole or sidewall cores) are a traditional and well-established way to obtain basic data for formation evaluation and reservoir characterization. It is common practice to carry out these analyses according to two different approaches:

Routine Core Analysis that are usually performed on thin sections and on large number of small size samples (e.g. cuttings, plugs taken from a full size core) to characterize the texture of the reservoir rock and some of its basic petrophysical properties. Among the more important properties routinely measured we can here mention:

- *Chemical and mineralogical composition*
- *Petrographic properties (e.g. grain size, sorting, rounding, and grain shape, etc.)*
- *Volume and type of residual fluid (water, mud filtrate, oil) extracted*
- *Grain density*
- *Porosity*
- *Formation factor*

- *Absolute permeability both in horizontal and vertical direction*
- *Others (e.g. Klinkenberg permeability).*

Special Core Analysis (i.e. SCAL) that are usually carried out on a limited number of samples because of the lab time and costs involved with this type of analysis. The samples are chosen in such a way to be representative of the main rock types found in the reservoir.

Basically the SCAL aim at obtaining information on

- the petrophysical properties of the reservoir rock in presence of two or three different fluids.
- the displacement efficiency of the IOR/EOR processes
- the effect of reservoir pressure decline on porosity and absolute permeability of the reservoir rock.

Among the most important SCAL usually performed we can here list:

- *Wettability evaluation (e.g. by Amott or USBM method)*
- *Capillary pressure curves*
- *Resistivity index (e.g. for Archie exponent)*
- *Two-phase relative permeability curves by steady state methods (e.g. Hafford or Penn State)*
- *Two-phase relative permeability curves by unsteady state methods (e.g. Welge)*
- *Displacement experiments (e.g. to optimize WAG cycles)*
- *Porosity and absolute permeability at varying reservoir overburden pressure*
- *Others (e.g. NMR imaging of displacement processes).*

Logs and core correlation

Core data and sequence stratigraphy

SCAL laboratory equipment and apparatus

Fluid Properties

The phase and volumetric behavior of hydrocarbon systems is commonly characterized through a set of lab experiments known as "PVT study". The type of experiments and the physical quantities to be measured depends on whether the hydrocarbon system is on liquid or gaseous phase at the initial reservoir conditions.

In the first case the system is identified as "oil" and will undergo to a "differential liberation test" in a PVT cell, where the pressure is gradually lowered by steps, keeping the temperature constant and discharging the gas volume liberated in each step.

The following basic quantities are measured during the study:

- *Initial system composition*
- *Bubble point pressure (p_b)*
- *Volume of oil both for $p>p_b$ and $p<p_b$*
- *Volume and composition of the gas liberated at each step*
- *Oil viscosity*
- *Separation tests.*

Moreover, a special set of experiments ("separator tests") is performed flashing a certain volume of oil from the initial reservoir conditions to the stock tank conditions, so as to simulate the separation process that will occur through the surface facilities.

All the data measured in a PVT study are furthermore processed to obtain the thermodynamic functions to be used in the reservoir engineering studies, i.e.: B_o, R_s, B_g, γ_g, μ_o, etc.

If the system is on gaseous phase at the initial reservoir conditions and a retrograde condensation will occur in the reservoir during the production, it is identified as "gas condensate".

In this case the PVT study will be a "Constant Volume Depletion" during which the initial pressure of a certain

volume of "gas" in "ad hoc" cell will be gradually lowered by steps, keeping constant the temperature and the cell volume. The total mass of hydrocarbons in the cell, of course, is decreased during each pressure depletion step

The following basic quantities are measured during the study:

- *Initial system composition*
- *Dew point pressure (p_d).*

And for each depletion step:

- *Volumes of gas and condensate retrograde liquid*
- *Chemical composition of produced gas phase*
- *Equilibrium gas phase deviation factor (Z)*
- *Equilibrium gas phase density*
- *Chemical composition of remaining liquid at abandonment pressure.*

All the data measured in a PVT study are furthermore processed to obtain the thermodynamic functions to be used in the reservoir engineering studies, such as:

- *Calculated cumulative produced fluid*
- *Potential liquid content of the produced gas phase*
- *Cumulative volume of liquid components produced in the well stream fluid*
- *Equilibrium gas phase density*
- *Viscosity of the Equilibrium gas phase.*

Special PVT experiments can also be performed for the reservoir engineering studies of IOR/EOR projects. For instance, in case of (miscible or not miscible) natural gas or "exotic" gas (N_2, CO_2) injection the execution of a "swelling study" is usually recommended.

Fluid analysis for fluid properties determination

Comparison between PVT experiments: flash liberation and differential liberation experiments

Well Testing

Well test is a well-established and really powerful technique for characterizing some of the basic transport properties of a porous rock, and for evaluating the performance and the potential productivity of a well.

Pressure build-up, falloff tests, interference and pulse tests can provide a good assessment of the in situ value of the effective permeability-thickness of a reservoir in addition to its pressure, as well as information on stratifications, and on the possible presence flow barriers such as sealing or partially sealing faults, strong permeability-thickness variations, etc.

Well test analysis

This short review of the data necessary for a good reservoir characterization and the techniques employed to get them, has shown that a huge amount of data is usually collected and analyzed during the life of a reservoir.

An efficient data management program-for collecting, analyzing, storing and retrieving them is, therefore, required for good reservoir management. An efficient data management system is, hence, a key issue for storing and retrieving raw and processed data into a readily accessible form.

The amount of acquired data can vary based on

- *Size of the database*
- *Size of the resource*
- *Remaining life of the resource.*

Moreover, the acquisition and interpretation of the data requires a robust quality assurance process for their validation and correct interpretation.

The validated data must be stored in a common computer database accessible to all interdisciplinary end users.

The evident benefits of readily available, high-quality data is

- Saving of time spent in reorganizing, checking, and reinterpreting data each time a study is conducted.

The central and vital role of data management and quality assurance