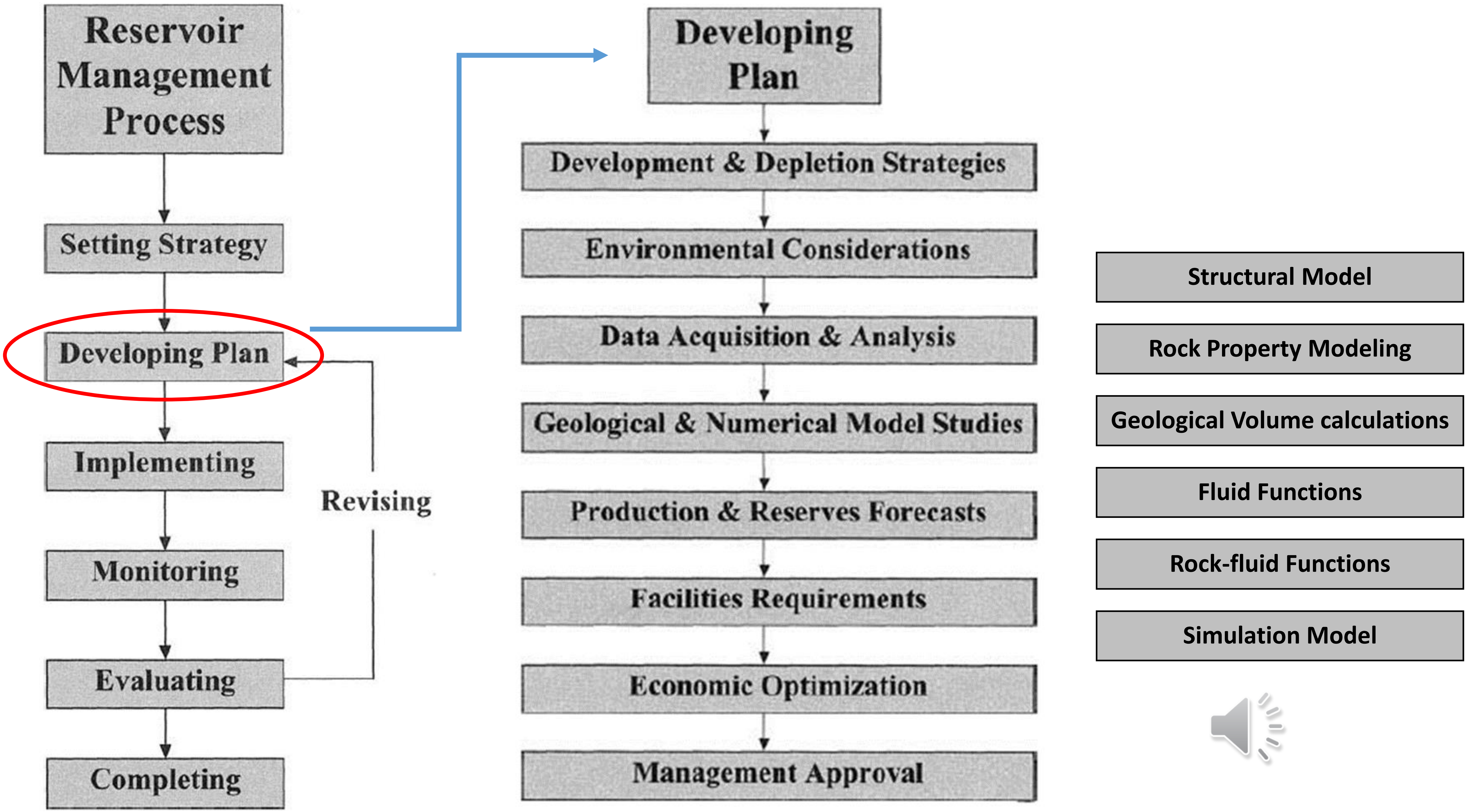
Lecture#9 Modeling of Fluid Properties

Credit to Mr. Ahmed Alher



Reservoir Management Process
Setting Strategy
Developing Plan
Implementing
Monitoring
Evaluating
Completing
Revising
Developing Plan
Development & Depletion Strategies
Environmental Considerations
Data Acquisition & Analysis
Geological & Numerical Model Studies
Production & Reserves Forecasts
Facilities Requirements
Economic Optimization
Management Approval
Structural Model
Rock Property Modeling
Geological Volume calculations
Fluid Functions
Rock-fluid Functions
Simulation Model

Fluid Properties

- **Introduction**
- **Reservoir hydrocarbon types.**
- **Main Oil and Gas PVT Parameters.**
- **Source of data**
- **PVT Laboratory Analysis.**
- **Field Production Data**
- **Generalized PVT Correlations**
- **Integrating the PVT Information.**
- **Vertical and Lateral Fluid Property Variations.**
- **Reservoir Water Properties**

Introduction

- Natural occurring petroleums are made up of extremely **complex mixtures of hydrocarbon molecules** and in general the resulting combination of these compounds may vary, in a reservoir deposit, from completely **dry gas** to **heavy oils** or tars.
- The properties of a reservoir fluid depend on the chemical **composition** of the hydrocarbons and the reservoir **temperature** and **pressure**. These conditions determine the physical state of the hydrocarbon itself in the reservoir, i.e. liquid or gaseous.
- The **type of reservoir fluid** is one of the main factors that influence the production behavior of a reservoir and, consequently, the choice of the most appropriate exploitation plan and **surface separation** infrastructure.

Reservoir hydrocarbon types

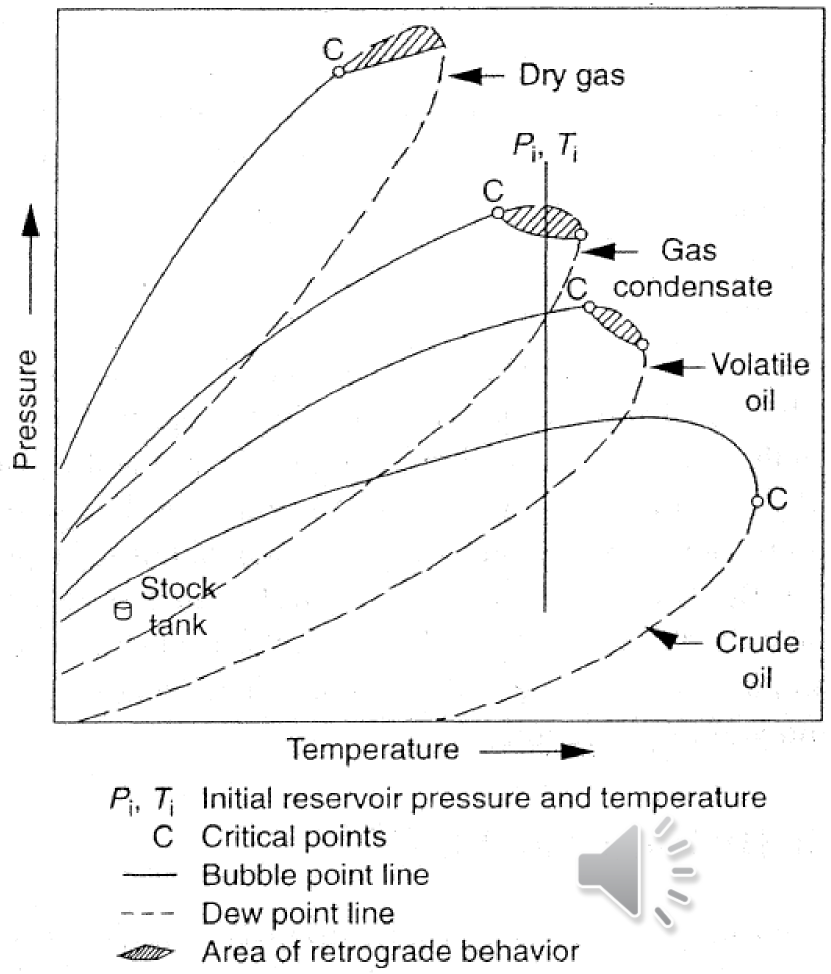
- The hydrocarbon state behaviour in the reservoir is usually described with phase diagrams, which relate the fluid state to the reservoir pressure and temperature.
- Types of reservoir hydrocarbon

Dry gas

Gas Condensate

Volatile oil

Crude oil



Main Oil and Gas PVT Parameters

The main PVT properties of oil and gas are needed to relate the observed surface volumes to reservoir volumes.

These parameters are usually determined in the laboratory through appropriate PVT tests.

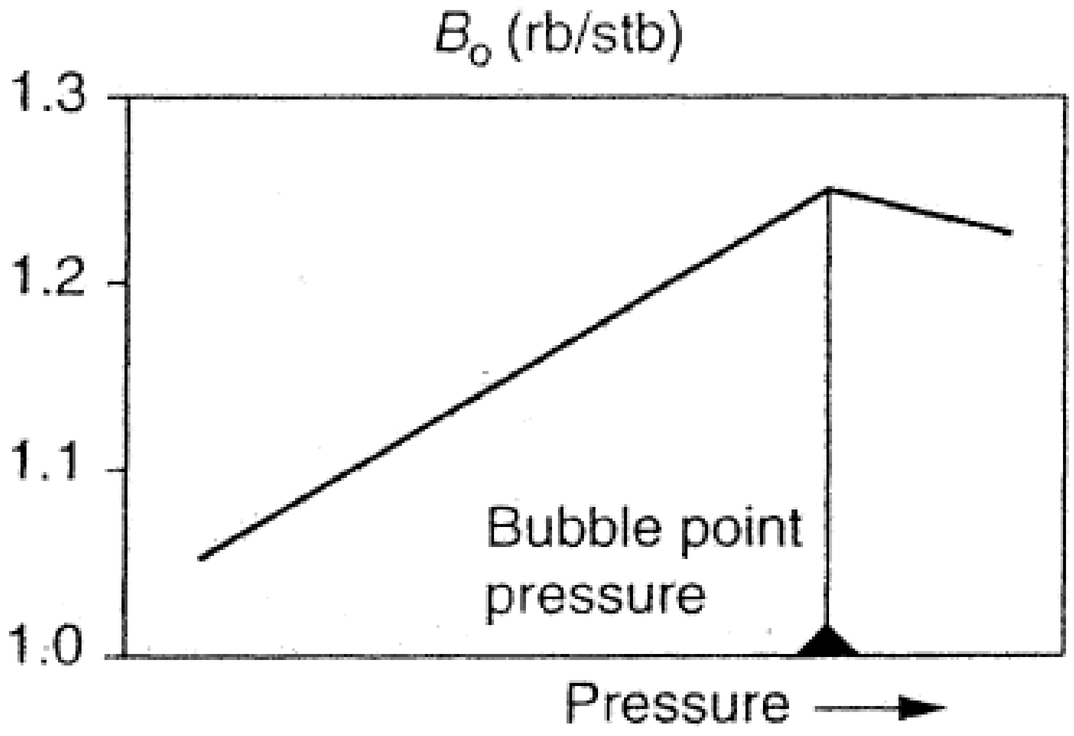
These parameters are strictly functions of pressure

Oil formation volume factor

This is the ratio between the volume of oil at the prevailing reservoir conditions and the volume at surface **(stock tank)** conditions.

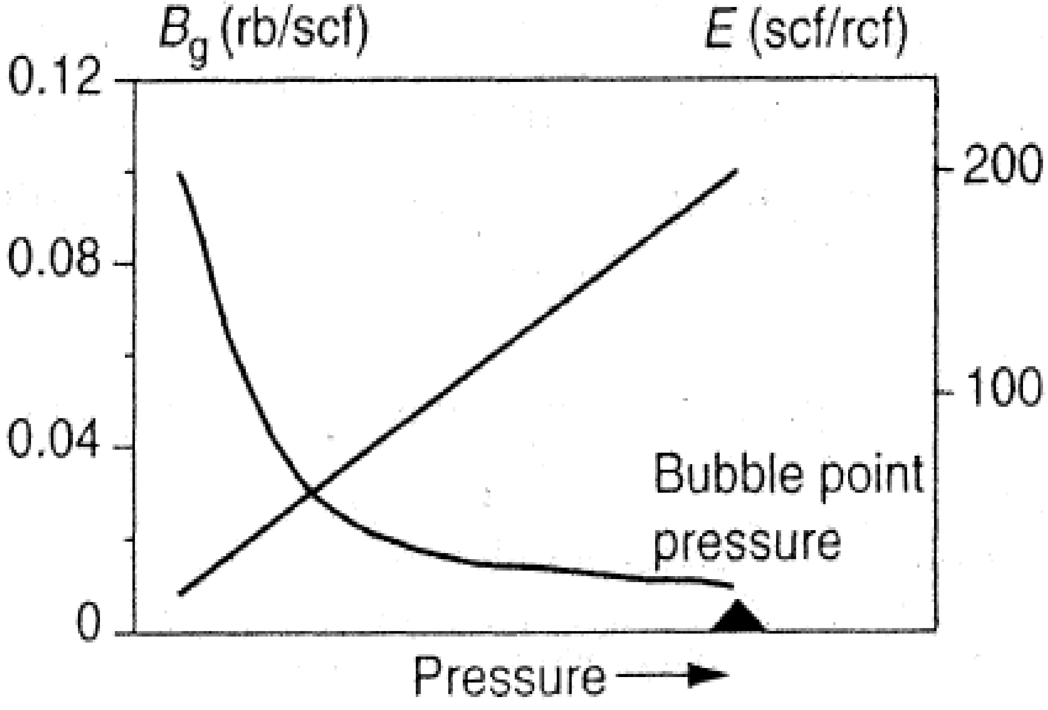
It is an a dimensional parameter and it is normally expressed as rb/stb.

The OFVF is always greater than 1?



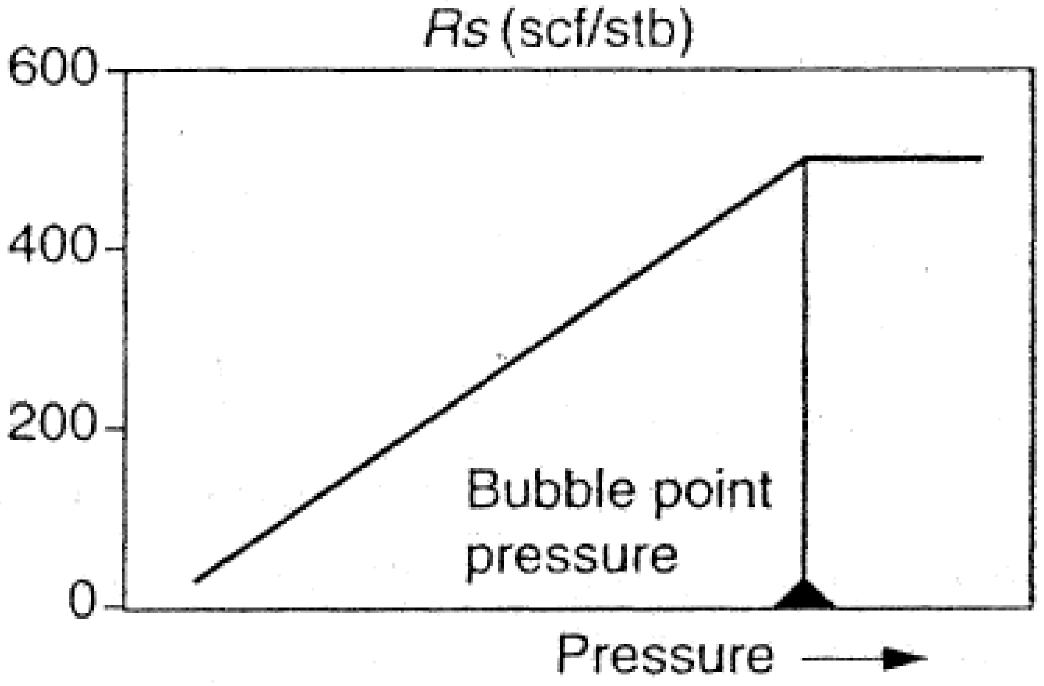
Gas formation volume factor

- This is the ratio between the volume of free gas at the prevailing reservoir conditions and the volume at surface (stock tank) conditions.
- It is also an a dimensional parameter and it is expressed as rb/scf.
- This parameter should not be confused with the gas expansion factor *E,* which is commonly used in
- gas reservoir engineering and has dimension scf/rcf.



Solubility ratio

- **It is** also called **solution Gas/Oil Ratio.** This is defined as the quantity of surface gas that dissolves in one stock tank barrel of oil at the prevailing reservoir conditions.
- It is expressed as scf/stb.



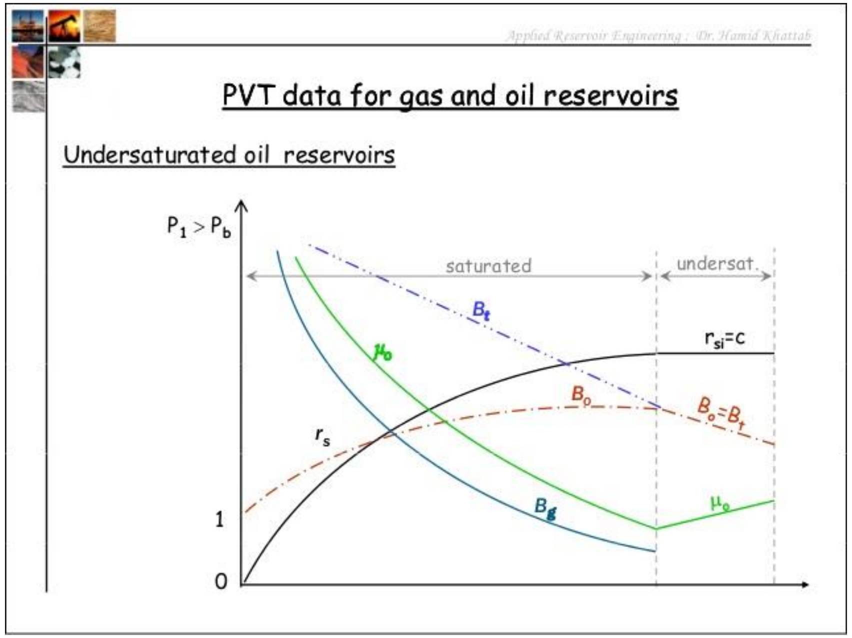
Other Oil and gas properties

- **Oil and gas compressibility,** Oil compressibility expresses the expansion of the fluid phase above the bubble point and has units 1/psi. The fractional oil recovery above the bubble point is closely related to this parameter. Gas compressibility is normally derived from correlations.
- **Oil and gas viscosity,** These parameters are needed to describe the fluid flow in the reservoir and are expressed in centipoises, cP Oil viscosity is usually determined from PVT tests, while gas viscosity is readily available from existing correlations
- **Oil and gas densities,** Densities as a function of pressure are used to compute the vertical gradients of the fluids in the reservoir. They can be computed from PVT measurements or obtained from existing correlations.

Source of data

In general, three types of PVT data sources are available in a typical reservoir study:

- Experimental laboratory analyses on bottom hole or surface recombined fluid samples.
- Field production data.
- Generalised correlations.



Fluid Sampling

- Reservoir fluids are usually sampled early in the life of a field, in order to gain information about the initial state of the hydrocarbon accumulation.
- There are basically two procedures for sampling reservoir fluids
- **bottom hole sampling** In bottom hole, or subsurface sampling, a sampler is run in the borehole to the reservoir depth and a fluid sample is collected at the prevailing bottom hole pressure.
- **Surface recombination** Recombined fluid samples are created in the laboratory by recombination of separate volumes of oil and gas taken at separator conditions.

PVT Laboratory Analysis

- There are three main PVT experiments that are routinely per-formed on reservoir fluid samples:
- **Flash Expansion**
- **Differential expansion**
- **Flash separator tests**

Flash Expansion

- In this experiment the fluid sample is charged to the PV cell and raised to the initial reservoir pressure and temperature.
- Data are collected through an isothermal expansion, i.e., lowering the cell pressure in a number of stages, while keeping the temperature constant.
- When the bubble point is reached, gas is liberated from the liquid phase however no fluid is withdrawn from the cell during the experiment, therefore the overall hydrocarbon composition in the cell remains unchanged. For this reason, this test is also called **equilibrium** expansion (or vaporization).
- The test is used to compute the **bubble point pressure** and the fluids relative volumes at different pressure steps. Data are usually normalized to the bubble point volume.

Differential expansion

- This experiment is identical to the flash expansion until the bubble point pressure is reached. However, at each lower pressure, the total amount of
- **gas liberated** during the last depletion stage is **removed** from the cell and therefore the overall composition of the hydrocarbon in the cell changes at each stage of the experiment.
- the remaining phases becoming progressively richer in heavier hydrocarbon compounds.

Flash separator tests

- These tests are performed by connecting the PV cell to a single or multi-stage separator system, and flashing the reservoir fluids through the separator system to stock tank conditions.
- The resulting volumes of gas and residual oil are measured at the end of the experiment.
- Note that, in the case of a single separator, this test approximates a flash liberation under non-isothermal conditions, while in the case of a multi-stage separator it is closer to a differential test.

Laboratory Data Conversion for Reservoir Engineering Applications

$$B_o = B_{o_D} \frac{B_{o_{bF}}}{B_{o_{bD}}}$$

with:

B_o	corrected oil formation volume factor, often called **composite** B_o
B_{o_D}	differential oil formation volume factor at any pressure stage
$B_{o_{bF}}$	flash oil formation volume factor at the bubble point
$B_{o_{bD}}$	differential oil formation volume factor at the bubble point

$$Rs = Rs_{i_f} - (Rs_{i_D} - Rs_D) \cdot \frac{B_{o_{bF}}}{B_{o_{bD}}}$$

with:

Rs	corrected solution gas oil ratio, often called **composite** Rs
Rs_{i_f}	flash initial solution gas oil ratio
Rs_{i_D}	differential initial solution gas oil ratio
Rs_D	differential solution gas oil ratio at any stage

Field Production Data

- These kind of measurements can be considered as **low precision data,** in the sense that the PVT properties cannot be estimated with precise values, as happens in the laboratory.
- However, they provide **direct information** about the actual behavior of the reservoir, free from any sampling or analytical error.
- At least three field production parameters can be utilized to verify the analytical results; **static pressure**, **gas oil ratio** and **API gravity**.

Generalized PVT Correlations

- Generalized PVT correlations have been used since the 1950's to obtain a simplified description of reservoir fluid properties based on surface measurements.
- The main PVT parameters (saturation pressure, formation volume factors and solution GOR), correlations can be applied with the previous knowledge of some basic production parameters, i.e., the **API** gravity of the produced oil, the **gas gravity** of the associated gas, the **producing GOR** and the **reservoir temperature**.
- The most common of these correlations have been derived by **Standing**,

Integrating the PVT Information

As the same for other integrations of the reservoir properties there are no general rules, but there are some guidelines.

- Laboratory procedures provide the most precise source of information concerning the reservoir fluid properties.
- Differential data should always be corrected for actual separation conditions, by means of flash separator test results.
- The results of the laboratory analyses must be compared with field production data
- Generalised empirical correlations may provide adequate models of the PVT behavior of the field. They are used when laboratory tests are not available or are not considered representative of the actual reservoir fluids.
- Generalised correlations can also be used to match the laboratory results and, being based on surface production parameters, they make an interesting integration tool, which allow for the spatial modelling of the reservoir fluid properties.

Vertical and Lateral Fluid Property Variations

- It is commonly assumed that hydrocarbon reservoirs are uniformly saturated, with a constant amount of gas in solution, which implies that the same initial saturation pressure is present in any part of the field.
- In fact, many reservoirs exhibit vertical and/or lateral variations in PVT properties. Typically, for example, steeply dipping or thick reservoirs show a vertical compositional gradient, with higher proportions of heavier hydrocarbon compounds towards the bottom of the accumulation.
- The process responsible for the existence of this gradient is commonly known as **gravitational segregation.**

Vertical and Lateral Fluid Property Variations

- Lateral hydrocarbon properties variations are observed.
- For example in reservoirs with great lateral extent or in the presence of **large permeability barriers**.
- These variations can be related to primary processes (migration) or secondary processes (biodegradation, alteration), which determine incomplete fluid composition equilibrium across the field.

Reservoir Water Properties

- Reservoir water always closely related to hydrocarbon accumulations and must be carefully considered in any integrated reservoir study.
- On one hand, water properties are important in the petrophysical computation and consequently on the OOIP determination.
- On the other hand, when considering the dynamic model of the reservoir, water properties have to be determined for a number of reasons, ranging from the evaluation of its expansion capability for material balance calculation, to compatibility issues related to waterflooding projects.

What Are You Going To Do In The Next Report?

- Read and understand the PVT report for well BU1 and well BU16

- Convert the unit of RS, BO, BG, Oil viscosity, and oil density, and Bg to the field unit.

- For each property, plot the the property Vs. the pressure for the two wells in the same page.

- Make comparison and discussion about the similarities and differences.

- Write a good a report. Enjoy!