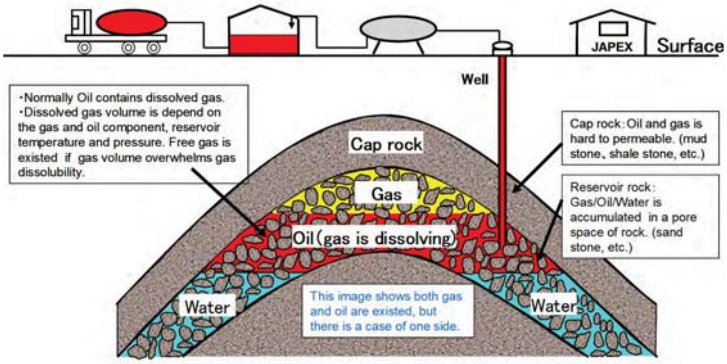
Core Analysis(1/2)
-- for estimating oil/gas reservoir


Summary

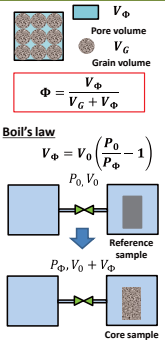
Oil and natural gas typically exist within formations (called reservoirs) several thousand meters underground, which must be drilled into to these resources. A columnar rock sample taken from a well is called a "core"; core analysis is conducted to determine reservoir characteristics such as porosity and permeability. These data are essential for estimating reserves, planning for development and predicting future oil and gas production from a reservoir.

What is Oil/Gas Reservoir?



An oil and gas deposit consists of fine-grained rock (called the cap rock), which acts as a lid, and reservoir rock, which holds oil and gas within its pore space. Estimation of the rock properties of an oil/gas reservoir is crucial to development of that reservoir.

Porosity (Helium Porosimetry)

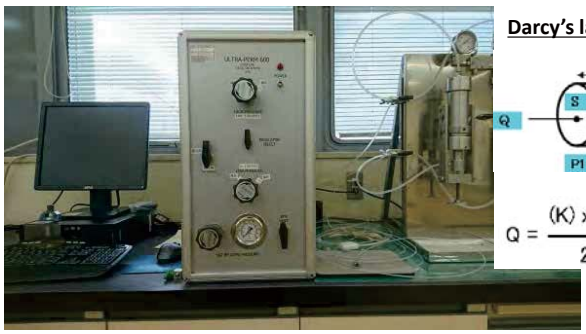


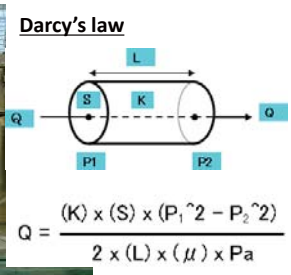
Pores are void spaces in rock and are measured as porosity, which is the fraction of the volume of void space over the total volume of the material.

» A typical method by which porosity is measured is by injecting helium gas into the core and calculating pore volume based on Boil's law.

» Oil and gas reserves in a reservoir are estimated based on the porosity of the reservoir rock.

Permeability (Air Permeametry)





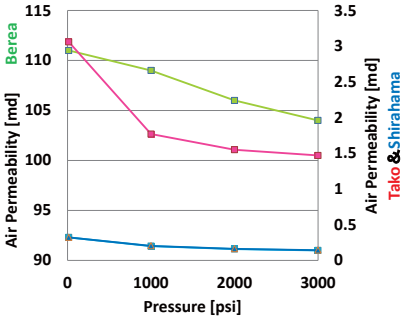
Permeability is an indicator of the ability for oil and gas to flow through the pore space of a rock.

» Permeability (unit: darcy, d) is measured by injecting air into the core at constant pressure and calculated based on Darcy's law.

» The range of measurable permeability is 1 μd to 40 d.

» Oil and gas production volume are estimated based on the reservoir's permeability.

Porosity & Permeability Under Confining Pressure



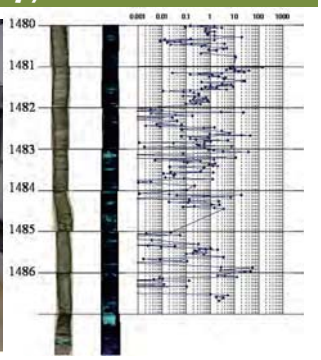
In oil and gas reservoir, overburden (confining) pressure affects porosity and permeability. Porosity and permeability under confining pressure are also usually measured in our laboratory.

» Relationship between porosity/permeability and confining pressure is estimated up to 70MPa.

» Measure is conducted for 12 to 18 plug core automatically.

» Range of measurable permeability is 1μd to 5d.

PDPK(Profile Permeametry)



The permeability of the rock (whole core) surface is measured simply and sequentially.

» Nitrogen gas is sprayed onto the surface of a rock sample and the permeability of the rock is calculated from the pressure decline of the gas.

» The distribution of permeability through the entire sample is measured in a short period of time.

Resistivity

Archie's Equation

$$R_o = F \cdot S_w^{-n} \cdot R_w$$

$$F = a \cdot \phi^{-m} = \frac{R_o}{R_w}$$

$$(S_w = 100\%)$$

Oil and water saturations are estimated to measure the resistivity of the reservoir rock.

» The ratio of the resistivity of the formation water to that of the core saturated with formation water is called the resistivity factor, which is a unique value for each rock and is a function of porosity based on Archie's equation.

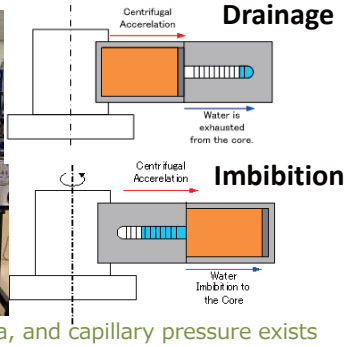
» The results of measuring resistivity are also applied for electrical logging estimations.

Core Analysis(2/2)
-- for estimating oil/gas reservoir


Summary

Oil and natural gas typically exist in formations (called reservoirs) several thousand meters deep, and drilling into gas/oil reservoirs is necessary to extract them. A columnar rock sample taken from a well is called a "core"; core analysis is conducted to determine reservoir characteristics such as porosity and permeability. These data is essential for estimating reserves, planning for development and predicting future oil and gas production from a reservoir.

Capillary Pressure (Centrifuge)

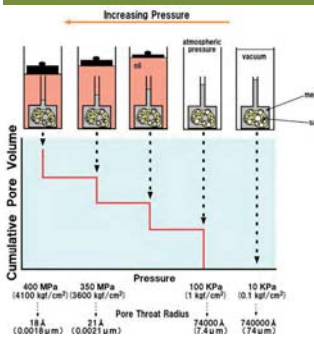



Reservoir rock consists of porous media, and capillary pressure exists between different fluids, such as oil and gas, in those media. Capillary pressure affects fluid flow and saturation in a reservoir and is often measured using a centrifuge.

» Capillary pressure is estimated from the centrifugal force calculated based on the rotation speed and the effluent volume that passes through the core.

» For any given confining pressure and temperature (up to 90°C), capillary pressure can be measured.

Capillary Pressure (MICP)



Lucas-Washburn's Equation

$$P_{c(Oil/water)} = -P_{c(Air/mercury)} \frac{(\sigma_{Oil/water} \cdot \cos\theta_{Oil/water})}{(\sigma_{Air/mercury} \cdot \cos\theta_{Air/mercury})}$$

$P_{c(Air/mercury)}$: *measured*

$\sigma_{Air/mercury} = 476[mNm^{-1}]$

$\cos\theta_{Air/mercury} = -0.766(\theta = 140°)$

$\sigma_{Oil/water} = 48[mNm^{-1}]$

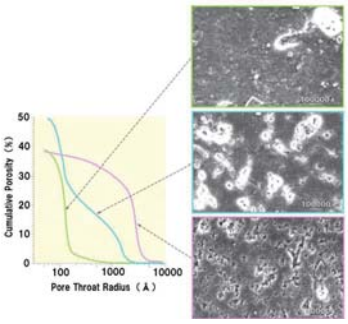
$\cos\theta_{Oil/water} = 0.866(\theta = 30°)$

MICP (mercury injection capillary pressure) is used to measure the capillary pressure of samples too small or brittle to core.

» The capillary pressure of reservoir fluids is estimated using the Lucas–Washburn equation based on the measured mercury injection volume and pressure.

» The range of mercury injection pressure is up to 400 MPa.

Pore Size Distribution (Mercury Porosimetry)

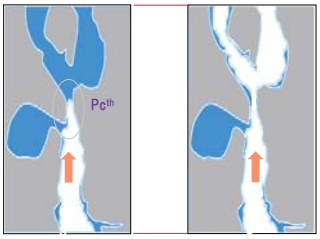



Reservoir rock contains various pore sizes, which affect rock properties such as permeability. Pore size distribution and volume are measured using mercury porosimetry.

» The distribution of pore sizes (diameters) between 4 nm and 200 μm in a rock is estimated by injecting mercury into a rock sample.

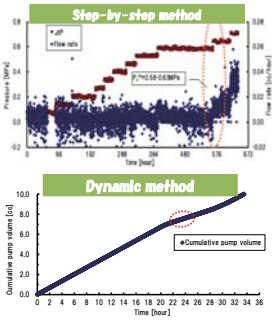
» The size of the sample used for this measurement is small, normally approximately 0.25 g.

Threshold Pressure



Pc^{th} : *Capillary threshold pressure*

P_{inj} : *Gas Injection Pressure*

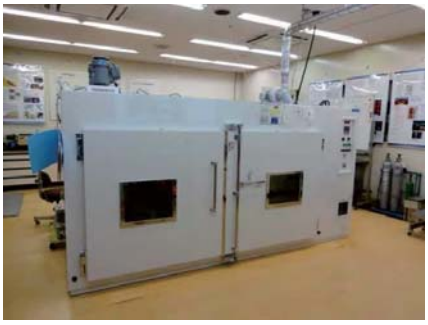
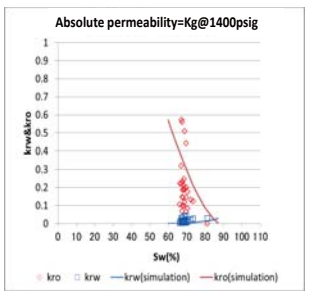


It is important to estimate the maximum capillary pressure (called threshold pressure), at which oil and gas are held by the cap rock in the reservoir.

» Threshold pressure is estimated to determine the minimum pressure at which pressurized gas flows step-by-step through the core.

» Threshold pressure can be measured more quickly using a dynamic method than using a step-by-step methody-step method.

Relative Permeability (Core Flooding)

The permeability of each reservoir fluid, such as oil or gas, correlates with the saturation of that fluid in pores. This property is called the relative permeability and is estimated from the results of a core flooding test performed at reservoir conditions.

» Temperature range: room temperature to 150°C.

» Not only relative permeability but also oil recovery with IOR (improved oil recovery) techniques are estimated based on the results of core flooding tests.

Key Points

For oil and natural gas development, it is crucial to estimate reservoir properties. For high-quality development planning, rock and fluid samples taken from the reservoir must be measured and analyzed.
To estimate reservoir properties, the following core analyses are conduct with the apparatuses of our laboratory:

(1) Porosity : pore volume (volume of oil and gas reserves)
(2) Permeability (mobility of reservoir fluids)
(3) Resistivity (saturation of reservoir fluids)
(4) Pore size distribution
(5) Capillary pressure, threshold pressure
(6) Relative Permeability