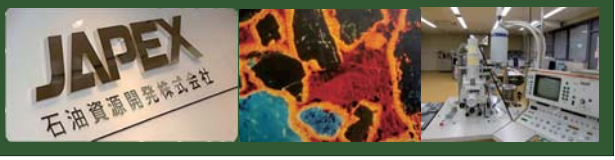
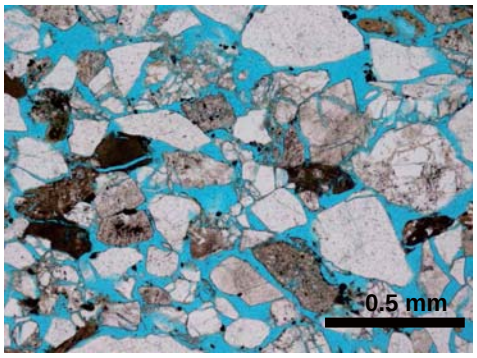
Petrological Analysis (1)
-- Applications for Reservoir Geology



Summary

The mineralogical and chemical compositions and pore characteristics of reservoir rocks exert fundamental controls over a petroleum system. The application of petrological analytical techniques to reservoir geology has proved so fruitful that modern petroleum and geothermal geology cannot be conducted effectively without it. The JAPEX Research Center has successfully employed a variety of petrological techniques in petroleum and geothermal exploration.

Resin-Impregnated Thin Sections



Thin section observation is an important first step that should be carried out in petrological analysis. Lithofacies, the progression of diagenesis and the development of porosity can be identified through these observations. At our research center, blue resin-impregnated thin sections are prepared to more easily identify pores.

XRD (X-ray Powder Diffraction)

X ray diffraction goniometer

X-ray diffraction (XRD) analysis is a basic technique for mineral identification. The diffraction peak specific to a mineral present is generated when a fixed powdery sample is irradiated with X-rays. The mineral composition and crystal structures are analyzed based on the resulting data. The diagenesis and hydrothermal alteration of the rock are thus evaluated.

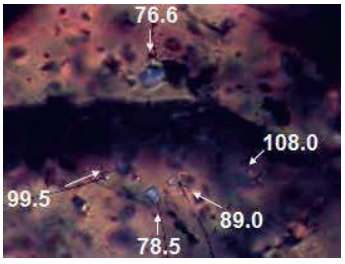
XRF (X-ray Fluorescence Spectrometry)

X-ray fluorescence (XRF) analysis is a method used to analyze a constituent element and the amount of that element in the material based on the fluorescent X-ray energy generated, and its strength, when a sample is irradiated with X-rays. The emitted fluorescent X-rays are characteristic for each element, and the strength of those characteristic X-rays is related to the quantity of the corresponding element in the sample. Furthermore, the ability of X-rays to penetrate a material is high, and this method is suitable for nondestructively analyzing solid, liquid and powder samples.

Scanning Electron Microscopy with EDS

Scanning electron microscopy enables observation of the shape of a sample's surface by squeezing an electron beam and scanning the sample's surface and detecting secondary electrons and backscattered electrons emitted by the surface. In addition, we can perform the chemical analysis based on characteristic X-ray emission with secondary and backscattered electrons and attached energy dispersive X-ray spectrometry (EDS).

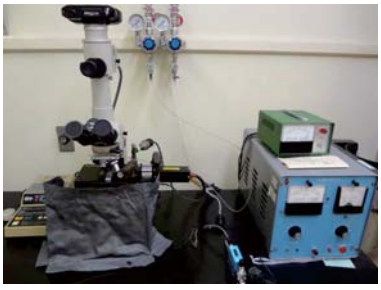
Fluid Inclusion Microthermometry

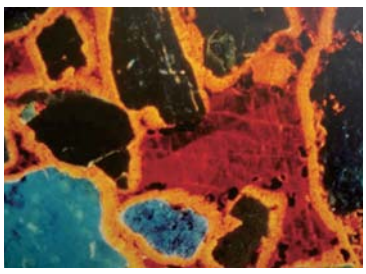


Number means homogenization temperature (Th, deg.C)

Fluid inclusion is a generic name for liquid and gas taken up inside a mineral; these inclusions can be used to estimate the physicochemical conditions under which they were trapped within the mineral. The homogenization temperature (Th) and ice melting temperature (Tm) are checked at times of heating and cooling under a microscope. The temperature and salinity (NaCl wt% equivalent) when a fluid was taken up are thus estimated.

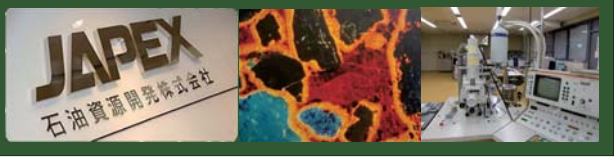
Cathode Luminescence Analysis



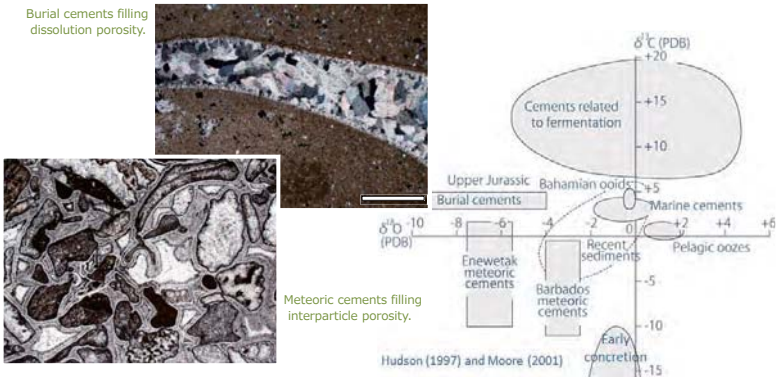


The cathodoluminescence (CL) technique involves detecting the light released when a sample is irradiated with an electron beam. This technique is used for analysis of a sample's crystal structure, very small amounts of impurities, lattice defects and crystal distortions. The range applications of this method in geology is wide; examples include the stage division of authigenic minerals and tectonic stress analysis.

Petrological Analysis (2)
-- Applications for Reservoir Geology



Carbon and Oxygen Stable Isotope Analysis

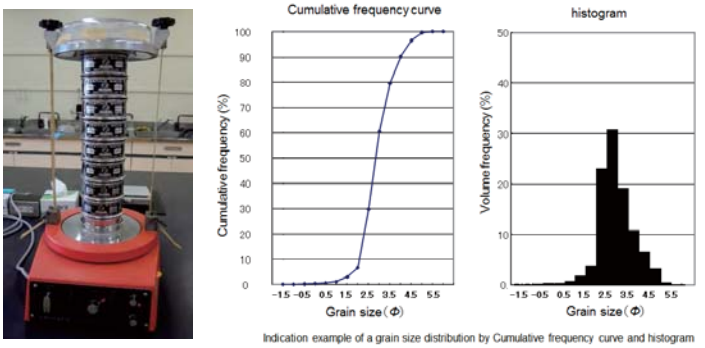


CO_2 gas from reactions between carbonates and phosphoric acid is measured. The isotopic ratios of carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) vary between depositional/diagenetic environments.

$\delta^{18}O$: water temperature and salinity of the formation fluid

$\delta^{13}C$: mixing of carbon sources (biogenic/thermogenic/volcanic)

Grain Size Distribution Analysis



Indication example of a grain size distribution by Cumulative frequency curve and histogram

Grain size distribution analysis includes various technique, but the sieve method is used here because of the number of samples that can be analyzed and the wide range of adaptations to grain fabric of sandstone reservoir available. The results of this analysis are expressed as an accumulation frequency curve or weight histogram, and may require calculations of sorting, skewness and kurtosis. These data are used in evaluation of the depositional environment.

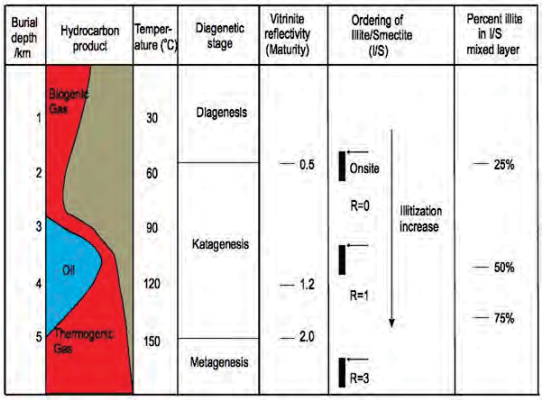
Thermal Conductivity Measurement

Thermal conductivity is an index used to evaluate heat movement phenomena according to Fourier's law. For an object close to two heat sources with the different temperatures, a temperature incline reaches a steady state (flat) within several minutes. The constant λ, here called the thermal conductivity, by the heat capacity (quantity of heat flux) to flow at this time in proportion to a temperature incline is shown in expression (1). $J = -\lambda \mathrm{grad} T$ - - - (1)

Magnetic Susceptibility Measurement

Magnetic susceptibility refers to magnetization, which indicates the strength of the magnetic field. This value depends on whether the rock includes magnetic minerals such as the magnetite. This value can be used for identification and comparison of the rock, and as an index of the degree of hydrothermal alteration.

What Can Petrological Analysis Tell Us ?



Revised Waples (1980) and Tissot and Welte (1984)

In the exploration and evaluation of oil, gas and geothermal resources, petrological and mineralogical analyses are essential to understand reservoir rock properties. These properties vary in terms of grain size, sorting, burial depth, lithofacies and rock type. In addition, although initial interparticle porosity is important, the property of porosity change considerably through diagenesis and/or hydrothermal alteration. For carbonate rocks, reservoir rock properties are particularly transformed by diagenesis. These conclusions are based on petrological analysis.

Key Points

The JAPEX Research Center conducts the following petrological analyses to explore and evaluate oil and gas reservoirs and geothermal fields:

(1) Resin-impregnated thin sectioning and observation
(2) XRD (X-ray powder diffraction)
(3) XRF (X-ray fluorescence spectrometry)
(4) Scanning electron microscopy with EDS
(5) Fluid inclusion microthermometry
(6) Cathodoluminescence analysis
(7) Carbon and oxygen stable isotope analysis
(8) Grain size distribution analysis
(9) Thermal conductivity analysis
(10) Magnetic susceptibility analysis

The most frequently applied analyses are resin-impregnated thin sectioning and observation, XRD, XRF, and fluid inclusion microthermometry. Pore size distribution measurements are also important for evaluating the pore systems in a rock.

We hope that you will find this brochure useful, particularly the above key points. We look forward to your feedback and future cooperation.