# Chapter 1: Introduction

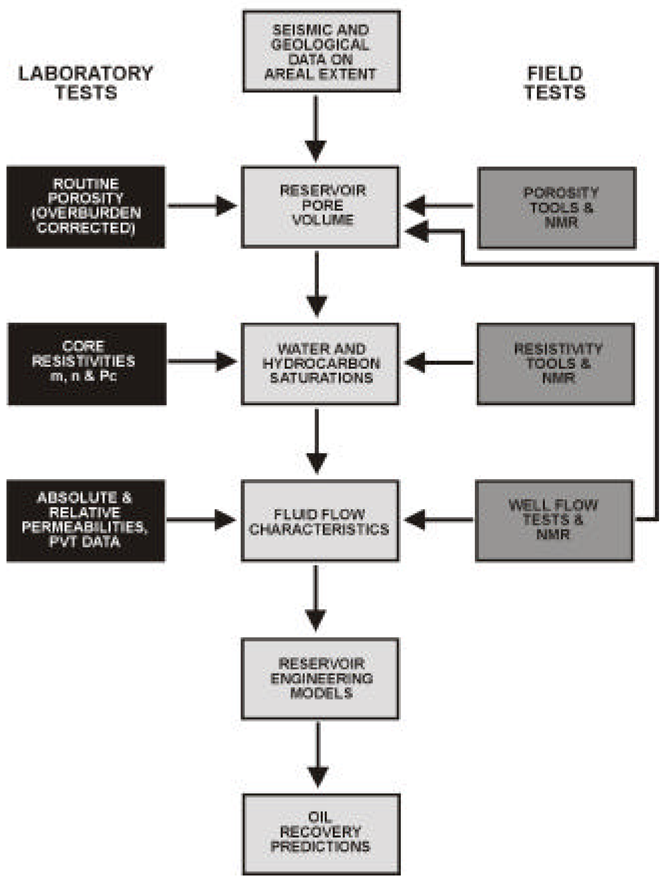
## 1.1 Introduction

This course aims to provide an understanding of the behaviour of fluids in reservoirs, and the use of core analysis in the evaluation of reservoir potential. It is intended to give the end user of special core analysis data an insight into the experimental techniques used to generate such data and an indication of its validity when applied to reservoir assessment. It has been written from the standpoint of a major oil industry operational support group, and is based upon the substantial experience of working in such an environment.

## 1.2 Core Analysis and other Reservoir Engineering Data

Special core analysis (SCAL) is one of the main sources of data available to guide the reservoir engineer in assessing the economic potential of a hydrocarbon accumulation. The data sources can be divided into field and laboratory measurements as shown in Figure 1.1.

Figure 1.1 Reservoir Engineering Data Sources




Laboratory data are used to support field measurements which can be subject to certain limitations, e.g.:

(i) Fluid saturations may be uncertain where actual formation brine composition and resistivity are not available.

(ii) Permeability derived from well test data may be reduced by localised formation damage (skin effects) and increased by fractures.

Sedimentological data can be used to predict areal and vertical trends in rock properties and as an aid in the correct choice of core for laboratory measurements.

For core analysis to provide meaningful data, due regard must be given to the ways in which rock properties can change both during the coring procedure (downhole), core preservation, and subsequent laboratory treatment.

This report is intended as a guide to the reliability and usefulness of the various RCAL and SCAL techniques generally available, and the ways which these techniques have, and will continue to be, refined in the light of current research. Maximum benefit will only be obtained from core analysis by full consultation between the reservoir engineer and the laboratory core analyst; taking all available data into account.

## 1.3 Reservoir Fluids and Drives

Hydrocarbon reservoirs may contain any or all of three fluid phases. These are;

- Aqueous fluids (brines),
- Oils, and
- Gases (hydrocarbon and non-hydrocarbon).

The distribution of these in a reservoir depends upon the reservoir conditions, the fluid properties, and the rock properties. The fluid properties are of fundamental importance, and will be studied in the first part of this course.

The natural energy of a reservoir can be used to facilitate the production of hydrocarbon and non-hydrocarbon fluids from reservoirs. These sources of energy are called natural drive mechanisms. However, there may still be producible oil in a reservoir when natural drive mechanisms are exhausted. There exist artificial drive mechanisms that can then be used to produce some of the remaining oil. The type of drive currently operating in a reservoir has a strong control on the evaluation and management of the reservoir. Consequently, drive mechanisms will also be reviewed as part of the course.

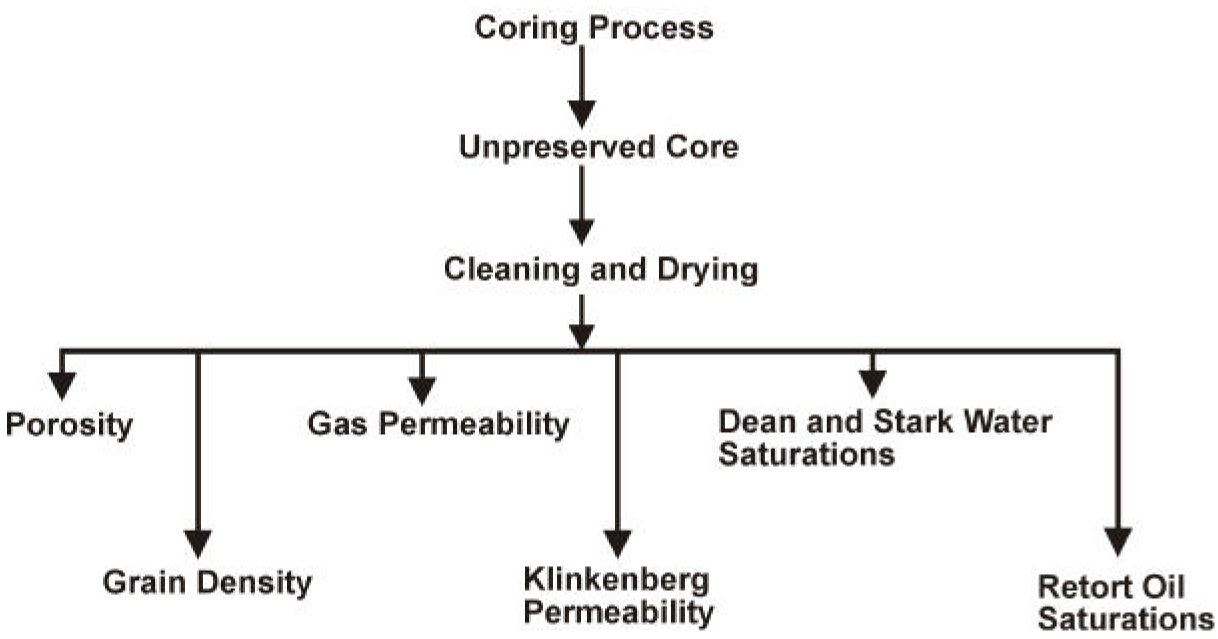
## 1.4 Routine Core Analysis (RCAL)

Routine core analysis attempts to give only the very basic properties of *unpreserved* core. These are basic rock dimensions, core porosity, grain density, gas permeability, and water saturation. Taken in context routine data can provide a useful guide to well and reservoir performance, provided its limitations are appreciated. These limitations arise because routine porosity and permeability measurements are always made with gases on cleaned, dried core at room conditions. Such conditions are distinctly different from the actual reservoir situation. Thus routine data should be applied to the reservoir state with caution. This is especially true for permeability measurements. *Routine core analysis data is cheap*, and often form the great majority of the dataset representing reservoir core data. A schematic diagram of common RCAL measurements is given as Figure 1.2.

Routine porosity data are generally reliable, being little affected by interactions between minerals and reservoir fluids. Correction for overburden loading is usually all that is required.

Routine permeability results can misrepresent the reservoir situation as reservoir fluids often interact with the minerals forming the pore walls. This is frequently the case because these interactions cannot be allowed for in routine measurements. Correction can be only made for the compressibility of gases used. Thus the Klinkenberg correction converts gas permeability to 'equivalent liquid permeability' ($K_L$) but still assumes no fluid-rock interaction. An actual liquid, brine or oil, usually gives a lower permeability than $K_L$. If interface sensitive clays are present in the reservoir, drying can destroy them and $K_L$ *may be one or two orders of magnitude greater than an actual brine permeability* measured on preserved, undried, core. An example of this effect is seen in the Magnus field and was demonstrated by Heaviside, Langley and Pallatt [1]. Permeability is affected by overburden loading to a greater extent than porosity. This must be allowed for when applying routine data to the reservoir situation.

**Figure 1.2 Routine Core Analysis**




Each of the RCAL measurements made is discussed in detail, covering; the theory, test methods, and limitations of alternative methods. The topics covered will include:

Chapter 4. Unpreserved core cleaning and water analysis.
Chapter 5. Sample dimension, porosity and grain density measurements.
Chapter 6. Gas permeability.

## 1.5 Special Core Analysis (SCAL)

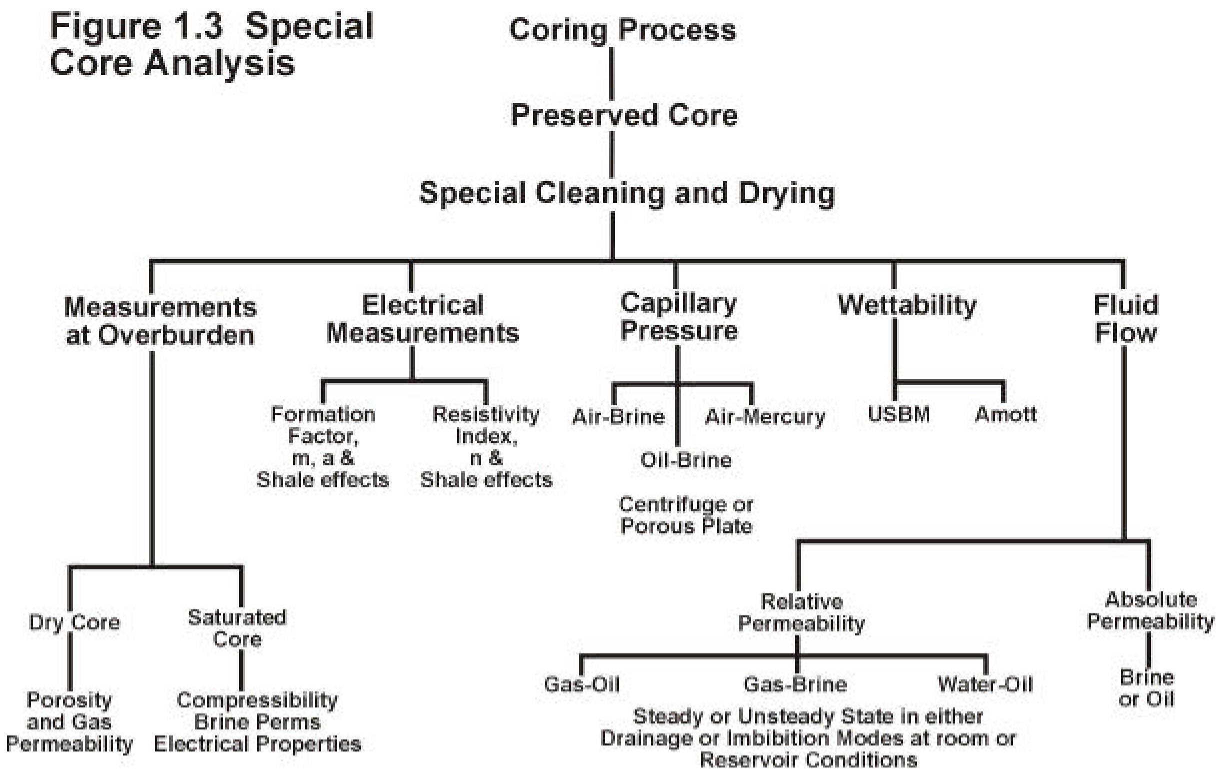
Special Core Analysis attempts to extend the data provided by routine measurements to situations more representative of reservoir conditions. SCAL data is used to support log and well test data in gaining an understanding of individual well and overall reservoir performance. However, SCAL measurements are more expensive, and are commonly only done on a small selected group of samples, or if a difficult strategic reservoir management decision has to be made (e.g. to gasflood, or not to gasflood).

Tests are carried out to measure fluid distribution, electrical properties and fluid flow characteristics in the two and occasionally three phase situation, and are made on *preserved core*. A schematic diagram of common SCAL measurements is given as Figure 1.3.

Porosity and single phase gas or liquid permeabilities are measured at overburden loadings so that the room condition data can be corrected.

Wettability and capillary pressure data are generated by controlled displacement of a wetting phase by a non wetting phase e.g., brine by air, brine by oil or air by mercury. These systems usually have known interfacial tension (IFT) and wetting (contact) angle properties.

Figure 1.3 Special Core Analysis




Conversion to the required reservoir values of IFT and contact angle can then be attempted to give data for predicting saturation at a given height within a reservoir. Electrical properties are measured at formation brine saturations of unity and less than unity, to obtain the cementation exponent, resistivity index, and excess conductivity of samples. These are used to provide data for interpretation of down-hole logs.

Relative permeability attempts to provide data on the relative flow rates of phases present (e.g. oil and water or gas and water). Fluid flow is strongly influenced by fluid viscosities, and wetting characteristics. Care has to be taken that measurements are made under appropriate conditions, which allow some understanding of the wetting characteristics. The data generated allows relative flow rates and recovery efficiency to be assessed.

Each of the SCAL measurements made is discussed in detail in the relevant chapter, covering the theory, test methods, and limitations of alternative methods. The topics covered will include:

| | |
|---|---|
| Chapter 4. | Preserved core; methods of preservation and requirement for preserved core. |
| Chapter 5. | Porosity at overburden pressures. |
| Chapter 6. | Gas and liquid single phase permeabilities at overburden conditions. |
| Chapter 7. | Wettability determinations; techniques available and limitations of data obtained. |
| Chapter 8. | Capillary pressure measurements; techniques available and limitations of data obtained. |
| Chapter 9. | Electrical measurements; resistivity index and saturation exponent, formation factor at room and overburden pressure, and cementation exponent. |
| Chapter 10. | Relative Permeability; Theory, Techniques available, limitations and application of data. |
| Chapter 11. | Typical SCAL programmes. |

## 1.6 Arrangement of the Text

Effective assessment of reservoirs begins with an understanding of the properties of reservoir fluids, which is covered in Chapter 2. Chapter 3 discusses the various reservoir drives encountered in reservoir management. Chapter 4 discusses coring, core preservation and handling, which is of relevance mainly to SCAL studies. Chapters 5 and 6 cover RCAL porosity and permeability measurements, together with extensions to overburden pressure for SCAL studies. Chapters 7 to 10 cover various wettability, capillary pressure, electrical, and relative permeability measurements commonly practised in SCAL studies. Chapter 11 briefly examines typical SCAL work programmes.