



Reservoir Geology Group's Facilities and Preparation Procedures

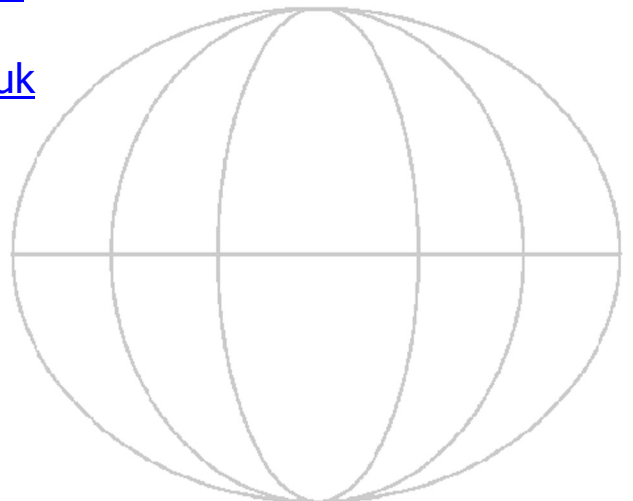
(Information not given here can be provided on request):

- **Sedimentological Core Logging**
- **Microscopy**
- **XRD**
- **Electronic goniometry measurement (fracture studies) on oriented cores**
- **SEM/Backscatter/Edax/Cathodoluminescence**

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Sedimentological Core Logging

- For ease of comparison by the Client, sedimentological core description is usually undertaken on the slabbed and resinated core slab section, thus the surface described is the same as that presented in the core photographs.
- Prior to the commencement of the core description, the sedimentologist will make sure that the entire core has been laid out in the correct order and the right way up.
- Sedimentological core description is usually undertaken at 1:50 scale, although other scales can be used at the Client's request (eg. 1:20 or 1:200).
- Core description is usually initially carried out in pencil on Corex (UK)'s blank core description sheets. This description is then scanned in and computer drafted in colour onto Corex (UK)'s standard carbonate or siliciclastic base using a vector based graphics package (eg. Adobe Illustrator). If necessary, the log base can be amended to reflect particular Client requirements. Alternatively, the core description can be entered directly into Applecore software, although this gives a more 'blocky' and stylised result as this is not a vector based drafting package.
- Detailed description of the cores for lithofacies and depositional environment identification includes lithology, grain size, visible structures, accessory minerals, authigenic pore filling mineralogy, physical structures, fossils, ichnofacies, induration, oil stain etc. and descriptive comments. The core log includes columns for core analysis data, sample data, sedimentary facies determination, any major/minor trends and cycles, sub-environment, environment, lithological unit and age. Significant boundaries (eg. Sequence Boundaries) are also highlighted.
- For consistency, the core depth of a feature (eg. bed contact) is taken from a fixed vertical 'line' in the core that is coincident with the depth of CCA/SCAL plugs, usually the centre of the core (this is particularly pertinent in highly deviated cores, where a large discrepancy could otherwise occur between plug depths and drafted core log depths if, for example, bed contact depths for drafting on the core log were taken as the depth at which the feature occurred on the left hand side of the core rather than the depth in the centre of the core – this, for example, could otherwise lead to plugs being mistakenly assigned to the wrong facies).
- Samples for petrographic analysis are taken from the cored interval to cover the range of reservoir facies (non-reservoir facies such as mudstones and siltstones are typically not sampled unless specifically requested by the Client) and variations in reservoir properties (from CCA data) observed. As such, this is usually undertaken after the core has been logged and when CCA base parameters (porosity, permeability, grain density) are available. The samples chosen should also cover similar facies over the length of the cored interval so that any depth

related diagenetic variations can also be ascertained. Additional petrographic samples may also be taken to cover 'odd ball' base parameter results, or anything of particular interest to the Client flagged by the core description. If at all possible, petrographical samples should be taken from plug trims or from the half cut adjacent to plug points, therefore allowing the cross reference of petrographical analysis data and base parameters to be as accurate as possible. For a complete petrographic data set, it is preferable to have thin section, SEM and XRD (Whole Rock and <2 micron Clay Fraction) samples taken from each sample point. If the Client does not wish to have a full suite of petrographic analysis for each sample point, XRD and SEM analysis can be dropped in preference for thin section analysis. Corex (UK) do, however, recommend that at least some XRD and SEM analysis is undertaken to accurately identify any clays and cements present (eg. highly ferroan calcite and ferroan dolomite can have a very similar blue staining in thin section making accurate identification problematic; clay morphologies and very finely crystalline clay types are often optically irresolvable in thin section) and to accurately characterise the nature of the pore system and nature and distribution of any cements and clays present (eg. is illite fibrous or platy; what is the crystallinity of the clays; what is the relative proportion of clay end members in mixed layer clays; are clays and cements intergrown; are any diagenetic relationships visible etc.).

- Once the core had been logged, a core to log shift can most easily be ascertained. This is undertaken by comparing the core gamma and core log description against wirelines supplied by the Client.
- An integrated report can then be written. This is undertaken by integrating the core description, which will provide facies analysis and depositional modelling, with petrographic studies and core analysis data in order to produce a fully interpretive report relating sedimentology and petrography to reservoir potential. A typical contents page of an integrated report is given below.

Microscopy

Equipment Used:

Thin Section Preparation:	Logitech CS10 trim saws (x2)
	Logitech LP30 lapping machine
	Logitech PM2A lapping machine
	Logitech IU20 vacuum impregnation unit
	Ultrasonic cleaning bath
	Hot plates
	Olympus petrographic microscope
Point Counter:	Swift Model F point counter and stage
Petrographic Microscope:	Nikon Optiphot Pol polarising microscope
Light Source:	Schott KL1500 swan neck fibre optic light source
Digital Camera:	Nikon Coolpix 995

Preparation Procedures:

Following procedures are applied for thin section preparation (assuming no water soluble components).

1. Cut slices from samples.
2. Dry thoroughly on hotplate. Label slices.
3. Mix blue dyed resin and impregnate samples.
4. Remove from resin and leave to cure thoroughly.
5. Lap flat surface on slices.
6. Thoroughly dry slices prior to mounting.
7. Pre-grind microscope slides to a known thickness.
8. Mount slices onto glass slides with an epoxy resin. Leave to cure.

9. Cut to approx. 200 microns thick.
10. Lap to approx. 30 microns thick.
11. Visually check thin sections under microscope. Hand finish if necessary.
Ultrasonic clean.
12. Etch with hydrofluoric acid.
13. Stain with sodium cobaltinitrate for feldspars.
14. Thoroughly dry on a hotplate to drive off any HF residue.
15. Stain with Dickson's method for carbonates.
16. Dry on hotplate.
17. Cover slip with canada balsam.
18. Wash, dry and label finished slides

XRD

Equipment/Facilities:

The laboratory is divided into two sections comprising an enclosed sample-crushing and preparation area and a separate instrumentation area. This ensures that cross-contamination, particularly from dust particles, is kept to a minimum.

The X-ray diffraction instrumentation comprises: -

XRD-1

Hiltonbrooks Generator, Copper Anode Tube

Philips PW1050 Goniometer with graphite monochromator

PW1170 Automatic sample changer

Purchased in 1997. Commissioned and totally refurbished by Hiltonbrooks Ltd.

Upgraded September 2001 to include wide-beam optics and graphite monochromator

XRD-2

Philips: PW1730 Generator, Copper Anode Tube

Philips PW1050 Goniometer with graphite monochromator

PW1710 Diffractometer Control

Purchased in 1999. Commissioned and totally refurbished by Hiltonbrooks Ltd.

Software

State of art windows package - 'HBX' developed especially for XRD interface control and 'TRACES' for diffractogram interpretation.

The diffractometers are fully inter-changeable should a malfunction occur in either one. They are serviced annually by a qualified engineer, checking in particular the alignment of the x-ray beam and peak intensities for a standard silicon disc at 28.45 and 56.12° 2 θ (theta). Weekly checks include an instrument calibration using a quartz standard and a radiation safety check using a Geiger counter. All instrument readings are checked prior to any sample analysis.

Procedures:

Whole (Bulk) Rock Analysis

To obtain a semi-quantitative measurement of the mineral components of a rock sample, it is gently disaggregated using a pestle and mortar and then 'micronised' using a McCrone Micronising Mill to obtain a X-ray diffraction 'powder' with a mean particle diameter of between 5 - 10 microns. The slurry is then dried and packed into an aluminium cavity mount, producing a randomly orientated sample for presentation to the X-ray beam. Each sample is analysed between 3° to 60° 2 θ (theta) at a step size of 0.05°/sec using X-ray radiation from a copper anode at 35kV, 30mA.

Interpretation and Limitations:

Identification of unknown minerals is achieved by using "TRACES" software to compare the X-ray diffraction pattern from the unknown sample with an internationally recognised database containing reference patterns for more than 70,000 phases. The maximum intensity of each mineral identified is measured and compared to a standard intensity for a pure sample of that mineral.

The method does not take into account any amorphous content and the results are normalised to 100% based on the assumption that the complete mineral content of the sample is accounted for in the diffractogram.

Where feasible, mineral determination will include a more detailed interpretation, particularly with respect to feldspar and carbonate compositions.

Clay Mineral Analysis

Although clay minerals are evident in whole rock diffractograms, the most satisfactory method for their quantification is to extract and separately analyse the clay fraction. Separating the <2 micron fraction is achieved by ultrasound, shaking and centrifugation. The total weight of clay extracted is obtained by removing 20ml of the clay suspension and evaporating to dryness. Size fractions other than <2 micron (e.g. 2-16 micron) are obtained by varying the centrifuge speed and time. The clay XRD mount is obtained by filtering the clay suspension through a Millipore filter and drying the filtrate on the filter paper. The samples are analysed as an untreated clay, after 'glycolisation' overnight and following 'heating' at 380°C for 2 hours and 550°C for one hour.

The initial scan for these four treatments is between 3° and 35° 2 θ (theta) at a step size of 0.05°/sec using X-ray radiation from a copper anode at 35kV,

30mA. The untreated sample is also analysed between 24-27° 2 θ at a step size of 0.02 °/2 sec to further define kaolinite/chlorite peaks.

Interpretation and Limitations:

Diffractograms from the four clay treatments are overlain to identify the clay mineral assemblages present and to assess the effect this treatment has had on this assemblage. Peak intensities are measured and incorporated in a formula to indicate the relative amounts of clay minerals present. This data is then used to quantify the clay minerals with respect to the whole rock by reference to the amount of <2 micron clay fraction which has previously been extracted. An indication of the clay mineral crystallinities can be given by assessment of the peak width for each component. Where applicable the relative intensities of the chlorite 001 and 003 peaks can be used to measure the total heavy metal (predominantly Fe) content of the mineral. The method assumes that there is little or no amorphous material present and that there is a 1:1 linear relationship between the ratio of the 24.8° kaolinite peak to the 25.1° chlorite peak.

Electronic goniometry measurement (fracture studies) on oriented cores

Corex has an accurate and easy to use PC-based Computer Aided Goniometer (CAG) for sedimentary dip description and fractured reservoir. A hand guided stylus arm and rotational control are used to rapidly measure and digitise planar features, bedding, stylolites and slickensides. The position of the stylus and rollers are automatically measured and entered into the computer, with the measurement accuracy better than 2 degrees.

The goniometer automatically records strike and dip information and displays it on the computer screen. Fracture description including type (open, partially open penetrative, partially open non-penetrative closed, induced), origin, presence of filling mineral, and presence of hydrocarbon or stain together with bedding types can be entered through the interactive menu driven software

Measured planes that can be used as both quality control for, and a supplement to dipmeter and/or FMS derived orientation data. CAG allows measurement of planes at spacing finer than that of dipmeter, which are identified and classified for later analysis and interpretation.

Displays and printouts include fracture type, rose diagrams of strike, azimuth plots, dip histograms fracture Vs depth and bedding Vs depth plots.

Integration of facies type, depositional modelling and dip log results allows determination of sandbody size, morphology, orientation and elongation direction, locating directions of thickening and thinning, defining structural controls on fracturing.

Such studies provide:

- Oriented Sedimentary structures
- Palaeocurrent analysis
- paleoslope trends
- Oriented depositional models
- Structural analysis
- Fracture pattern analysis
- Palaeogeographic reconstructions
- Sandbody elongation trends for reservoir modelling
- Realistic reservoir correlations

SEM/Backscatter/Edax/Cathodoluminescence

Equipment Used:

SEM: Phillips 505

EDAX: Link Analytical AN10 55S

Gold Coater: Polaron Equipment Ltd SEM Coating Unit E5000

Methodology Applied:

Freshly broken fragments of the cleaned and dried core samples are mounted individually on to standard SEM stubs, using Araldite Rapid Resin as the adhesive. Prior to high resolution/high magnification analysis by SEM, the samples are coated with gold by sputter coating to prevent charging under the SEM electron beam. During the analysis, identification of minerals is aided by the use of Energy Dispersive X-ray Analysis (EDS), which provides the elemental composition of the mineral analysed.

Testing Procedures:

The gold coated sample stubs are placed in a vacuum chamber where an electron beam is fired at the specimen, liberating low energy secondary electrons. Samples are viewed on a screen at high resolution/high magnification. By examining the entire sample, a full analysis can be obtained. This includes a description of textural data, detrital mineralogy, authigenic components and diagenesis, and also allows for the appraisal of the pore system and reservoir quality. Testing includes the identification of minerals from elemental composition by using the EDS, and obtaining digital photomicrographs of the sample to be included in the report.

Cathodoluminescence is an optical and electrical application, whereby a beam of electrons is generated by an electron gun (e.g. cathode ray tube) and then impacts on a luminescent material, causing the material to emit visible light. The most common example in geology and mineralogy is a scanning electron microscope with specialized optical detectors, and an optical cathodoluminescence microscope, used to examine internal structures of minerals and/or rocks, in order to get information on the composition, growth and quality of the material. Corex's Cathodoluminescence device is an integral part of the Corex SEM.