INCREASING THE VALUE OF CORE ANALYSIS

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Abstract Too much of the core analysis historical record can loosely be described as a single page letter saying "thank you for the work...hope we get some more" and a series of tables of data. Nothing more, nothing less. No real information. As a result, trying to incorporate and compare twenty year old data with recent data becomes something of a dubious art. This paper describes some of the steps taken by Enterprise Oil to try to ensure that as much information as possible is collated and reported. The aim has been to encourage the core contractors to participate actively in the work and the reporting. Contractors handle a large volume of core and thereby have a large wealth of experience. Furthermore, when working with core the individuals will be mentally comparing and judging, forming views about the core in front of them. Yet, seldom does any of this get reported. This is wasted opportunity, added value that will not be realised. This paper will present some of the steps taken by Enterprise to improve core reports and examples where the capture of additional information has resulted in real benefits.

INTRODUCTION

The problem

Historically, too many core analysis reports (both special and routine) could, at best, be described as a series of arbitrary tabulations of data with a covering letter. No real detail of the laboratory experiments are given. Yet, without the complete description of the experiments that were performed, the worth of the data is seriously compromised. The opportunity to use such poorly reported data in combination with new data is very much limited, particularly at the equity table.

Furthermore, these traditional methods of reporting do little to help increase the understanding and comprehension of inexperienced users of core data. In fact on the contrary, some forms of reporting imply relationships between tabulated parameters that are just not correct, thereby increasing the risk that inexperienced users misuse data and/or draw incorrect conclusions.

Too often, even today, core analysis has been commissioned by people who are not the ultimate end users of the data. Furthermore, tests have been requested that are not designed for a purpose but are simply the consequence of "price list shopping" or a copy of the previous job. In either case it is likely that the laboratory will report the data with the same amount of care as that used to specify the job. In such circumstances the gain of knowledge is minimal and valuable information will have been missed.

The solution

In an attempt to try and avoid some of these problems Enterprise has evolved a set of core analysis guidelines for both routine and special core analysis. As experience has been gained, these guidelines have been refined and enhanced to become a set of fairly broad-based, but none the less explicit, work instructions for the core contractor. The primary objective in these instructions is to try to encourage the active involvement of the contractor in the work. At every stage the contractor is required to report his observations and views related to the core material and the experiments being conducted. The adherence to these instructions has certainly caused a significant increase in the size of the reports. However, such reports have generated a much greater understanding and appreciation of the data and its origins by the end users as well as consequential cost savings.

The intent of this paper is not to present the Enterprise work schedules *per se* but more to present the logic and reasoning behind the evolution of these schedules and, where appropriate, describe some of the benefits of their application.

THE ENTERPRISE APPROACH

Having encountered numerous instances where the information contained within a core report was inadequate for the job, the conclusion was reached that something needed to be done. At first verbal requests were made to the contractor to rectify perceived short comings. Unfortunately, while most contractors seemed to have some sympathies with the requirements and objectives, it became apparent that memories were remarkably short and not all requests were actioned. Eventually written requests were penned and supplied but still it seemed to be very difficult to get the message translated into the final report. Finally, in desperation ,the decision was made to formalise the written requests into a Schedule of Work as part of a contract with penalty clauses for non conformance with the requirements.

It was recognised that resorting to contract was risking alienating the very people whose help and cooperation was needed to achieve the end goal. To minimise this risk, every effort was made to ensure that the laboratory was aware of what Enterprise was trying to achieve. The reasons behind the objectives were explained in detail and the contractors asked for alternative solutions wherever appropriate. The point was repeatedly made that Enterprise did not have all the answers, that it was the contractors who had the experience and the knowledge, and that it is the contractors who handle the core, not Enterprise. What Enterprise sought was an active partnership by which we could enhance our understanding of the core analysis process and the inherent problems.

The Work schedules deal, to the best of our ability, with all facets of core analysis from catching the core through to the detailed structure of the written report. Each of these facets will now be considered in turn.

Cutting the Core

Good quality core data requires the careful design of the coring process. From the moment the drill bit starts to remove overburden material from above the future core, the fabric of the core begins to be altered. As the bit nears the future core material it begins to be exposed to drilling fluids and a whole new multitude of alteration processes commence. Then, as the core is cut and brought to surface, so much mechanical/ thermal and chemical alteration occurs that the poor piece of rock can only be described as having been subjected to "extreme trauma". The careful design of the drilling practices to minimise such trauma is beyond the scope of this paper, but the end user of core data is ill-advised if, in interpreting these data, he chooses to overlook the impact of these considerations.

The core contractors have a wealth of experience and ideas which should help minimise this trauma and its consequent effects (see, for example, proceedings of this same symposium in 1990). To this end the core analysis contractor should ideally be invited to discuss the job and the objectives with the petrophysicist, geologist, drillers, core head/barrel contractor and mud engineers. As a minimum, the contractor should attend the pre-spud meeting and should be expected to share this experience where appropriate.

Catching the Core

Once the core arrives on surface, this is the traditional point at which drillers wash their hands of it! Commonly, Enterprise requires the selected core analysis contractor to provide a well site technician to catch the core. The reasons for this are many. If a continuous coring programme is occurring, by the time the well site geologist and mud loggers have caught, described and boxed the first core, often the next core is at, or near, surface. Hence, the staff catching the core become over tired and the risk of errors and incorrect handling is increased. These risks are reduced if there is a core contractor wellsite technician on site. Furthermore, by having the core contractor involved in the core catching process, the contractor can be made responsible for the packaging of the core for safe transit to the laboratory. With the contractor's technician catching the core, the laboratory and Enterprise can be advised if special problems are observed, and provision can be made to accommodate or rectify these.

By involving the contractor at this early stage, it is possible for the contractor to bring his experience to bear as soon as possible. Contractors can always relate stories of how they received core in the laboratory, e.g. not marked up, not boxed correctly, poorly preserved, or damaged in transit. Postulate any bad handling scenario and, yes, the contractor has probably got a story to tell. With all this experience, it seems reasonable to suggest that if the contractor is given the responsibility to provide the packaging appropriate to ensure the safe arrival at the laboratory, then it should happen.

In addition to catching the core, the laboratory technician should be given the responsibility to write a report of the observations made at the well site. This will form part of the final report and allow the end user of the core data to understand better the events that occurred at the well site. In the past, this has proved quite useful, especially where the core jammed off and less than 100% recovery was achieved. With the aid of the technicians report, it has been possible to establish a more complete understanding of when the core jammed and thence the probable point at which the core was lost (see Example 1, at end of text).

Another useful function that the laboratory technician can perform at the well site is to measure a well site core gamma ray. This service allows the core to be described in terms of the gamma ray curve and thereby permits a sleeved core to be shipped to base without cutting it up. This practise preserves the depth sequencing more correctly. It also prevents those "little pieces" of rock going missing, as often happens at the well site. The wellsite technician is responsible for preserving pieces of core for special core analysis. The core gamma can help the selection of these pieces of rock. The technician must ensure that these preserved samples are clearly labelled. Such labels will include the following information: well number, date, preserved sample number, core number, top and bottom depths and a brief sample description. Preserved samples will, of course, be preserved as quickly as possible to prevent damage due to drying and oxidation.

Arrival at the Laboratory

Continuation of the need for dialogue with the contractor is emphasised when the core arrives at the laboratory. In addition to verbal contact, the contractor is encouraged to commence a policy of written communications, each communication carrying a sequential number so that Enterprise can be assured of having received all communications.

The first such communication to the Enterprise petrophysicist is to confirm receipt of core.

The laboratory is first required carefully to piece the core together and categorise all the breaks in the core. For every break in the core, it is possible to describe the goodness of fit as either definite, possible or totally impossible to propose. This information is required to be tabulated as well as presented on the core photographs. The reason for this is that when the core data are subsequently compared to log data, it is first necessary to depth match the log and core data. This process often requires more than a simple single block shift. The moment this complexity becomes necessary, the petrophysicist needs to decide where the changes in the depth shifts occur.

Historically depth-shift changes have been subjective, merely sufficient to achieve the desired end result. However, there are many instances where more than one permutation of shifts seem equally plausible. At such times the seasoned user of data reaches for the core photographs to see if rubble, unconsolidated or shaley zones can be used to achieve the desired match. Unfortunately, too often by the time the core has been plugged and slabbed the rock in photographs is too broken up to really be of maximum use. Furthermore, where the three dimensional break in the rock can often be "felt" to click back together when handled, the two dimensional slice represented by the photographs is a much poorer substitute. Since the laboratory staff are the only ones who normally handle the core before it is slabbed, only these people know how the core truly fitted together. This knowledge needs to be captured (See Example 2 at the end of text).

Having fitted the core together, and performed a laboratory natural gamma ray measurement, it is then necessary to start cutting plugs for analysis. It is the Enterprise view that too often core analysis methods are compromised by a requirement of the client that they want information quickly to help make testing decisions. For this reason, Enterprise cuts three sets of plugs. The first set of plugs, are referred to as "Quicklook" plugs. These are horizontal plugs that will be rapidly cleaned to give a quicklook estimate of formation properties. The second & third sets, horizontal and vertical plugs, respectively, are then subjected to identical programmes of testing which must be performed with absolute rigour and not compromised by any requirement of the client for early information. These measurements must be performed to the very best standards the laboratory can achieve.

The plugs will be cut with a diameter of 1.5 inches wherever possible. The fluid used for the plugging process is supplied by Enterprise unless it has been agreed with the Enterprise Petrophysicist to use some alternative fluid, the objective here being to try to reduce to a minimum any additional chemical alteration caused by the plugging fluid.

Once all the plugs have been cut, the laboratory is then required to fax or telex Enterprise with details of the plugs that have been cut.

ROUTINE CORE ANALYSIS

Methodology

Having plugged, the analysis begins. Quick-look plugs are analyzed for permeability, porosity and grain density. It is intended that these plugs should achieve approximately 24 hour turn around, otherwise they no longer represent quick look.

The other plugs, both horizontal and vertical, are then subjected to a consistent and uniform programme of analysis. The industry has a historical habit of assuming that the properties from the horizontal plug are applicable to the vertical plug, Enterprise does not agree with this practice and therefore subjects all plugs to the same complete programme of analysis. The preferred programme of routine analysis is to measure saturations on the plugs using a Dean Stark method, to determine porosity using Boyles law gas expansion method with the grain density being derived from this suite of measurements, and to measure permeability using Hassler equipment.

The permeability measurements are performed using nitrogen and are measured at a Hassler sleeve pressure of 200 psi, to keep the amount of mechanical stress applied to the rock to a minimum. However, in the event that the measured permeability is less than 10 millidarcies, a second measurement is made with a 400 psi confining pressure on the Hassler sleeve. This procedure is hoped to minimise the amount of gas bypassed between the plug and the Hassler sleeve itself. Recognising that all permeability measurements are simply a function of the experiment performed, Enterprise requires that the full details of the experiment be recorded as well as the permeability. To this end the inverse mean pressure on the plug is reported as well as the permeability number.

It is recognised that many reservoir engineers are end users of permeability data, and that a significant number of these engineers tend to believe that their simulators require liquid permeability not gas permeability numbers. It is also recognised that the infamous K_1 number (Klinkenberg effective liquid permeability) is no more than an uncalibrated chart look-up. Therefore

Enterprise routinely performs a finite number of full Klinkenberg experiments. With the aid of this type of information, it is then possible to devise a field-specific calibration to convert gas permeability measurements to effective liquid permeability measurements. When sufficient data has been gathered, this can be made facies specific.

The core analysis parameter that is primarily used by the log analysts and petrophysicists is porosity. These users usually wish to relate porosity to their view of down hole conditions and therefore require some sort of overburden correction. To this end, Enterprise will routinely perform overburden measurements, on a selection of plugs, to look at the sensitivity of the gas expansion porosity to the effects of overburden.

The above represents the normal routine core analysis that Enterprise will perform on core.

Post Analysis

Once the analysis has been completed it is then necessary to generate a photographic record of the core. At present it is standard industry practice to photograph in two types of light, white light and ultra violet. However, there is much that can be done to enhance the value of the photographs. As a minimum, every photograph should have the following information. All plug holes visible on the core photographs should have their plug numbers clearly identified. The preserved samples that were taken should be denoted on the photographs detailing the top and bottom depths, as should other samples that may have been removed for other analyses, typically those taken for stimulation analysis. All breaks in the core described at the time of receipt in the laboratory, can be marked on the photographs using a colour code to denote whether the core is definitely continuous, possibly continuous or just impossible to say.

Another problem, which has been quite common, is that different laboratories have different standards of presentation for ultra violet photographs. These can be improved to get a more uniform, company-to-company, well-to-well signature in ultra violet light by the inclusion of beakers of different oils and filtrates as calibrators to the photographs.

Having gone to great lengths to capture, analyze and photograph the core it seems not uncommon that many operators then forget about the core. Some time in the future further information might be required, but often the core is found to have been badly stored and handled. The opportunity to perform additional studies is then severely compromised by the state in which the core was left. To avoid this, it is necessary to undertake two additional services as part of the routine core analysis. The first is to instruct the contractor to manufacture a resin mounted slab. This product is made by casting a slice of the rock, approximately 1 cm thick, along with labels, in plastic resin. The slabs should contain as much information as possible, in line with the core photograph's in order to create a permanent record of the recovered core. If the core is seen to be degrading in the laboratory this slabbing process should be undertaken as rapidly as possible in order to maximize the continuity and integrity of the core material slab. Finally the laboratory is required to package the residual half core material in boxes with foam inserts and shrink wrap. This is to ensure that the material does not get further damaged in the subsequent handling and storage.

Reporting

In general terms Enterprise expects the contractor to maintain regular contact with them, keeping the company regularly appraised of the status of core analysis operations typically about once a week. Preliminary reporting will be either by fax or by telex, but the final reporting is required to be presented in three different formats. These formats are the final report, a one-off reference volume, and magnetic media.

The final report should contain the sections given in Table 1. The reasons for, and the contents contained within, each section are described below.

- Section 1 of the report should be a statement of its contents, not a letter saying thank you for the work.

TABLE 1

ROUTINE CORE ANALYSIS REPORT STRUCTURE

1	Contents Sheet
2	Tabulation of intervals cored and recoveries
3	Final box log after completion of analysis
4	Listing of preserved samples and preservation technique
5*	Enterprise well site core description sheets
6	Well site technicians report
7	Tabulation of core continuity
8	Description of plugging techniques and fluids used
9	Description of cleaning and drying techniques
10	Description of the analytical techniques employed
11	Tabulation of analysis results for "Quick look" plugs
12	Tabulation of analysis results of Horizontal plugs
13	Tabulation of analysis results of Vertical plugs
14	Tabulation of permeabilities measured at 200 and 400 psi Hassler sleave pressure
15	Tabulation of Klinkenberg data
16	Tabulation of Overburden studies data
17	Discussion of the reported routine analysis results including the laboratory technicians observations during the analysis
18	Discussion of the possible measurement errors
19	Cross plots of the above data
20	Core photographs in both white and UV light

* Supplied by Enterprise

• Section 2 in the report should be a statement of the intervals that were cored in the well and the recoveries; this information should have been gathered by the well site technician while at the well site.

• Section 3 details the final boxing of the core material at the end of the work in the laboratory; the box log should detail the core number, the box number and the depth interval of the core material to be found within that box.

• Section 4 should detail the preserved samples that were taken, by core number and by depth.

• Section 5 is not actually produced by the laboratory. It is the Enterprise well site core descriptions that are made available to the contractor. Too often this material is not readily available to the end user of the core data. Yet the geological descriptions from the well site can be actually be very useful in understanding the core.

• Section 6 should be a report by the well site technician detailing his experiences, and observations while at the well site, along with the other information that was required of him as described earlier.

• Section 7 should describe, if appropriate, the state of the core on arrival at the laboratory and, in addition, should present a tabulation of the core continuity established after piecing the core together.

• Section 8 describes the plugging techniques employed, size of the plugs and the fluids used for cooling.

• Section 9 describes the cleaning methods and drying techniques employed.

• Section 10 should then describe the analytical techniques used for the data that are to follow.

Having set the scene by describing the origin of the material and experiments that were performed, it is then possible to describe the results. Enterprise places great value on correct reporting of data. To this end, every plug should have a unique plug number and every plug should have its depth reported to one decimal place working in imperial units or to two decimal places working in metric units.

In the interests of minimising misunderstanding of data interpretation, each individual sub set of plugs is reported individually. More specifically, the vertical plugs are not the same as horizontal plugs and therefore they should be reported as separate data items, not as a single one line tabulation in a report.

- Sections 11, 12 and 13 of the final report are tabulations, for the quick look plugs, for the horizontal plugs and for the vertical plugs, respectively.
- Section 14 is a tabulation of permeabilities measured at 200 and 400 psi Hassler sleeve pressure. This tabulation enables easy comparison of the two permeabilities measured for the identification of gas bypass.
- Section 15 is a tabulation of the Klinkenberg measurements that have been performed.
- Section 16 is a tabulation of the results of overburden studies.
- Section 17 is perhaps one of the most useful sections. This is the section where the laboratory is invited to discuss the results that have been reported and to include the observations made by the technicians on the workbench. It is the observations of these people that potentially can add significant understanding to your data.
- Section 18 comprises a discussion of the possible measurement errors. This section is an opportunity for the contractor to educate the user of the data, to indicate what the contractor believes his error margins are for the reported measurements. It is also a mechanism by which the end user can become a little more familiar with the data and a little more educated about his use of the data.
- Section 19 contains the traditional cross plots that laboratories seem to like to put into core reports.
- Section 20 contains the core photographs including a key to the coding used to flag the breaks in the core.

A final report with so many sections is, as already stated, quite a large volume. However the fundamental objective has been to try to achieve a single report that contains enhanced collation of information for the end user. The format presented is believed to be very effective.

In addition to the final volume described above, the other hard copy volume that is specified is the so-called the reference volume. This one-off volume contains copies of all the laboratory worksheets; emphasis is placed on the word "copies". The production of this report is not meant to generate significant additional work for the laboratory. Additionally the sanitising of the worksheets could well cause transcription errors and/or loss of information form the work sheets. For these reasons only photocopies of worksheets are required.

The reference volume should also contain details of all of the appropriate calibration certificates, orifice plates, pressure transducers, etc. Finally, the reference volume should contain details of all the equations employed in the laboratory and how these equations, and the information contained on the work sheets, can be used to derive the reported values. Complementary to this, worked examples should be presented to demonstrate how the above equations are employed.

The final requirement for routine core analysis reporting is that all data, including the core gamma ray measurements, are put onto some form of magnetic medium to facilitate the loading of the data onto the computer.

SPECIAL CORE ANALYSIS

Methodology

The oil industry makes quite a distinction between routine core analysis and special core analysis and, in a sense, Enterprise has already merged the two by performing both Klinkenberg and Overburden studies as part of a routine package of measurements. In reality, the only distinction between special core measurements and routine measurements is that the former generally take longer to perform and in consequence are more costly. For this reason, it is very important that the objective and purpose of the special core study be clearly understood and stated. Prior to sending any materials to the analysis laboratory, it is recommended that considerable discussion be held with the laboratory to describe what the objectives are and how they could be best achieved. Such discussions should not only discuss the type of test to be performed; they should also encompass the nature of the available core materials and the fluids that should be used.

The result of the foregoing is that at the point of the laboratory starting any study, it should be in possession of a formal written statement detailing the study objectives. It should also have a detailed written statement of the tests to be performed, the fluids to be used and the sequence of the tests. In addition there should be a set of plug selection notes that detail why the plugs were chosen and for what purpose. With all this information, the laboratory and the client are then properly prepared to perform a costly and lengthy study. Since special core studies tend to be quite singular, it is not really appropriate for this paper to discuss further the considerations that determine the precise form of special core studies. What is appropriate, however, is to discuss how the final report should be put together.

Reporting

The problem with historical special core analysis reports is understanding why the study was performed. To prevent this problem recurring with contemporary reports, Enterprise has evolved a number of enhancements to special core analysis reporting. These help improve understanding of the pattern and objectives of the commissioned study. In common with routine core analysis, the reporting of special core analysis is required in three different formats. A final report, a reference volume and magnetic media.

The Enterprise structure for the special core analysis final report is described in table 2.

- Section 1 of the report, as with the routine analysis report, is the contents sheet.
- Section 2 is a clear definition of the objectives of the study.
- Section 3 is a description of the programme of measurements to be performed to achieve the objectives outlined in the previous section
- Section 4 describes the motives for the plug selection.

TABLE 2

SPECIAL CORE ANALYSIS REPORT STRUCTURE	
1	Contents sheet
2*	The objectives of the study
3*	Description of programme of measurements to be performed and why
4*	Description of the reasons for the plugs selected
5	Plug history sheets including photograph of plug
6	Description of first laboratory experiment i Tabulation of results ii Plots of results iii Discussion of results including laboratory operator observations Sections 6, i, ii and iii repeated for each laboratory experiment Appendix - Physical properties of fluid used in the study

* Supplied by Enterprise

Information pertaining to 2, 3 and 4 is supplied by the client. NB: The client should be aware of what he is doing and should be creating a rigorous audit trail as to why he is doing it and why he is spending his company's money.

• Section 5 reflects perhaps the most useful and innovative enhancement that has been introduced. In the early days it was found to be quite difficult to read some special core analysis reports and to understand the exact chronology of the measurements. Frequently it was not possible to ascertain whether measurements were made before or after the application of stress cycles. Certainly it is always possible to speculate about the exact sequence of measurements, but one can never be sure. This uncertainty has impacted adversely upon the understanding and interpretation of measurements.

For these reasons, Enterprise created the plug history sheet, an example of which is given in Plate 1. The plug history sheet in its current form presents both a brief summary of the experiments that have been performed on the sample and a record of the plug itself, being photographic, narrative and dimensional. All of these parameters are of significant value in understanding the subsequent measurements that have been performed on the plug. NB The plug history sheet presented on Plate 1 is an early example and the dates the measurements were performed is missing. After the plug history sheets, the report then presents the results by experiment. Each experimental type is reported in four subsections. The first is a description of the laboratory experiment, the hardware and the equipment used. The next section is a tabulation of the results. The following section contains the traditional plots of the results. The final section comprises a discussion of the results, including any observations that the laboratory operators may have made.

• The final appendix section of the report should present measured physical details of the fluids used for the study. In particular, chemical analysis, resistivity as a function of temperature, viscosity and pressure relationships.

As with the routine core analysis, in addition to the final report it is required that the laboratory produce a special one-off reference volume for each

TABLE 1.1

BASIC PROPERTIES

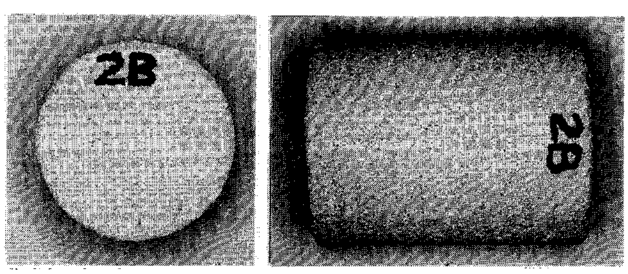
COMPANY : ENTERPRISE **WELL :** **JOB NO : SC 8864**

SAMPLE : 2B **DEPTH : 8837.40 Ft**

LITHOLOGICAL DESCRIPTION

Sandstone, grey, massive, moderately indurated, very fine to fine grained, well sorted, angular to sub-rounded, wispy silty micaceous laminations, rare carbonaceous fragments, mica, rare glauconite, calcite patches, very rare pyrite, common well developed syntaxial quartz overgrowths, pore lining clay moderately visible primary intergranular porosity.

SAMPLE PHOTOGRAPHY **BASE PARAMETERS**



ϕ	:	20.97%
P.V.	:	11.538 cc
G.D.	:	2.65 g/cc
Ka	:	141.9 mD
Kl	:	130.9 mD
Kw	:	108.7 mD
B.V.	:	55.030 cm^3

AREA : 11.122 cm^2 LENGTH : 4.948 cm

(*See* Colour Plate I at the back of this publication.)

TABLE 1.1

SAMPLE HISTORY SHEET

TESTING SEQUENCE	FLUIDS	MEASUREMENTS	DATA
SAMPLE : 2B DEPTH : 8837.40 Ft			
Phase 1			
Plugging	Refined Mineral Oil	-	-
Cleaning	Toluene, Methanol	-	-
Humidity Drying	Air (60°C, 40% Relative Humidity)	-	-
Porosity Determination	Helium	ϕ	20.97%
Grain Density Determination	Helium	G.D.	2.65 g/cc
Gas Permeability Determination	Nitrogen	Ka	141.9 mD
Klinkenberg Corrected Permeability Determination	Nitrogen	Kl	130.9 mD
Sample Saturation	Simulated Formation Brine	-	-
Brine Permeability	Simulated Formation Brine	Kw	108.7 mD
Phase 2			
Formation Factor	Simulated Formation Brine	FF	15.70
		m	1.76
Formation Factor at	Simulated Formation Brine	FF @ 3500 psi	21.68
Overburden (increasing and	Simulated Formation Brine	FF @ 4250 psi	22.38
decreasing overburden pressure)		FF @ 5000 psi	23.09
		FF @ 3500 psi	22.55
		ϕ @ 3500 psi	19.57%
		ϕ @ 4250 psi	19.41%
		ϕ @ 5000 psi	19.31%
		ϕ @ 3500 psi	19.45%
		m @ 3500 psi	1.885
		m @ 4250 psi	1.895
		m @ 5000 psi	1.908
		m @ 3500 psi	1.977
Cation Exchange Capacity (Determination on Sample Trim)	Wet Chemistry Method	meq/100g	0.252

study which incorporates the laboratory work sheets, plus calibration certificates, experimental theory and equations, and examples of how to use these equations to derive the reported parameters.

The final requirement of the reporting of the special core analysis is again that the laboratory provide all the reported results in some form of magnetic media.

EXAMPLES

The following examples of reporting illustrate the benefits that can be derived by following the procedures described above.

Example 1

Reproduced below is a section of text from the contractor's wellsite technician's report from one of the Enterprise wells:

"Intervals Cored and Recovered

Core No.1 Cut 34ft Recovered 3.5ft Recovery 10.3%
Core No.2 Cut 60ft Recovered 59.8ft Recovery 99.7%
Core No.3 Cut 38.5ft Recovered 38.5ft Recovery 100%

General Wellsite Observations

The following observations were made during coring and subsequent core recovery by our technicians present at the wellsite during coring procedures.

Although a good drilling break occurred uphole of core No.1, this interval, approximately 25-30 ft thick, was not cored and the first core was cut commencing at 5559' after a second drilling break.

After only 3-4 ft, it was noted that the coring contractor felt that the barrel had jammed off, but a decision was taken to continue coring.

A total of 34 ft was cut prior to the barrel being pulled. The disappointing recovery may have been due to the following; the barrel did jam off after only 3.5 ft, probably caused by the hard shale band occurring at 5562 ft. This can be a common occurrence if the underlying sediments are poorly *consolidated and therefore have difficulty in pushing the harder shale sequence into the core barrel.*

Whilst recovering the 3.5 ft from the core barrel, it was noted that the drilling mud within the barrel was in the form of a thick slurry and may therefore have contained unconsolidated material. A sieve analysis of this sand is included within this chapter. The 3.5 ft recovered was removed by hammering the inner barrel. Cores 2 and 3 showed excellent recovery and slid easily from the inner barrel without hammering."

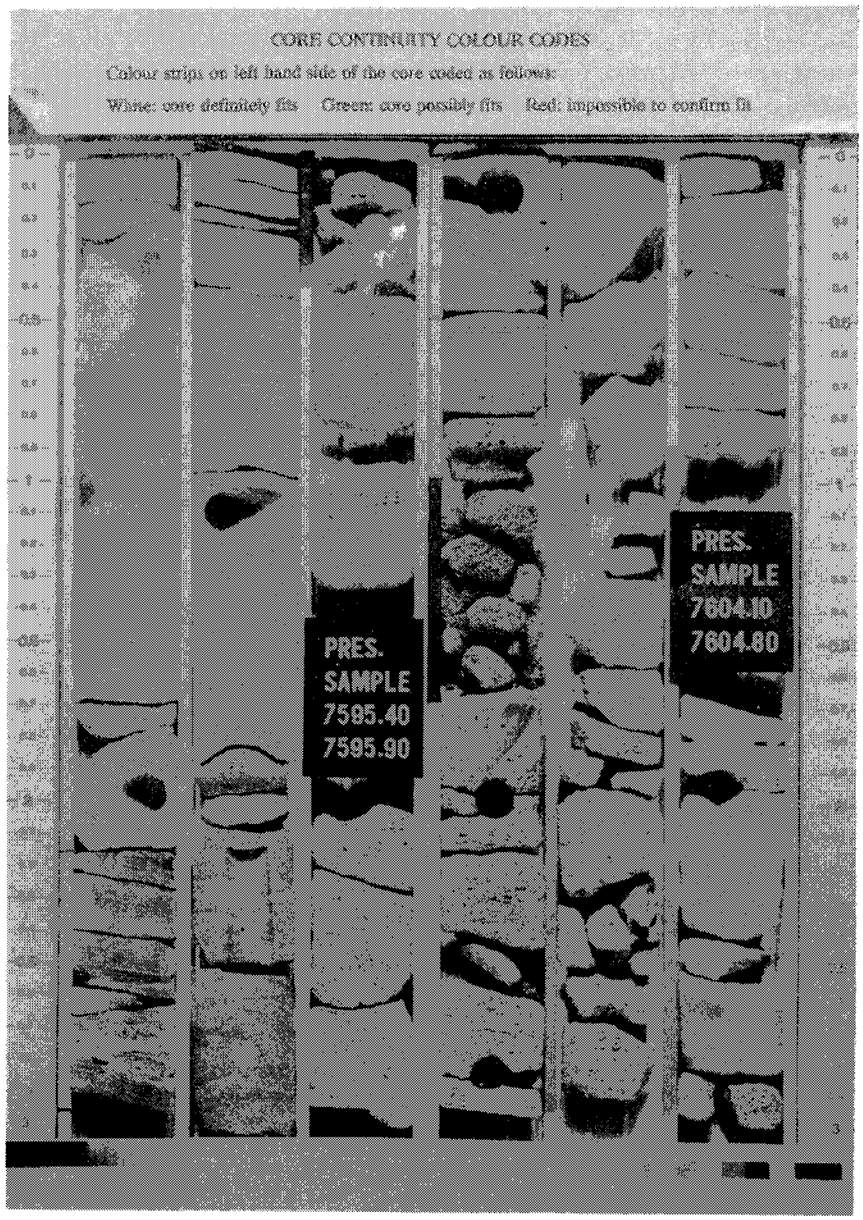
This section of report illustrates a number of benefits derived from having proactive involvement of the core contractor. Firstly, the reader of the report is strongly helped in his task of trying to locate the origin of the 3.5 feet of core recovered in core 1. Secondly, a hypothesis is offered to explain the poor recovery. Thirdly, evidence to support the hypothesis is offered. Additionally, the initiative of the technician is demonstrated by his collecting and analyzing the unconsolidated sand material. Some of this information might have been obtainable or inferable after the event, but it is most unlikely that it would then have become part of the historical record.

Example 2

Plate 2 is a photograph of core material with core break information represented as coloured strips to denote the characterisation of the individual breaks.

With the help of such products it is possible to state with certainty where the core was considered to be continuous and consequently where changes in depth shift are inappropriate. Use of this sort of information from the outset causes the depth shifting process to be achieved much more quickly and with less equivocation.

Such information also helps in circumstances where the core in the boxes is upside down.



(*See* Colour Plate II at the back of this publication.)

Example 3

In one of our wells a contractor volunteered the following observation.

"Additional Observations

An interesting phenomenon was observed during the slabbing of the cores from this well. A diamond impregnated saw blade was used which normally has a life in excess 5000ft of core being slabbed. However, a relatively new blade was used in the slabbing of this core and, during the process, became totally worn and had to be replaced. It is therefore possible that certain sections of the core may contain abrasive minerals which should be identified during the sedimentological and petrographic study."

When questioned about this comment, the laboratory was able to confirm that the first saw blade that they used was a normal smooth disc with diamonds around the circumference and it cut less than 20ft. A second blade of the same design also cut a similar length before failing. At this point the laboratory contacted the blade manufacturers. Saw blades are not cheap and the volume of core to be slabbed was not insignificant! The blade manufacturers confirmed that there was no manufacturing fault with the original blades but recommended that a notched blade with 6mm gaps should be used. This was done with great success.

This problem was discussed with drilling engineers and it was confirmed that they, too, were having problems with the cutting this material. To date, three core heads had been used to cut 100ft of core. As a direct consequence of this conversation, a toothed core head was employed on subsequent wells and on each occasion a single core head cut at least six cores and over 300ft of core. The cost savings per well turned out to be about $6 x 15k.

CONCLUSIONS

Having spent some 10 years distilling these views and these procedures into their current format, it is somewhat disappointing to find that in 1960 the API produced a Recommended Practice for core analysis, RP40, in which there is a section called Reporting. This starts "The major value of the testing programme can be lost by inadequate reporting". The laboratories consistently state that they work to this procedure, yet the historical record demonstrates quite clearly that they work to parts of the procedure but not to all of it. I believe that the authors of RP40 knew and recognised this truth. **That the answers we produce are no more than the consequence of the experiment we perform and, without the experimental details, the values reported are just numbers on a sheet of paper.**

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Sample Preparation