A Special Core Analysis Study Of Selected Samples From Well : THYLACINE - 1

Australia

Prepared for
WOODSIDE ENERGY LIMITED

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Rock Properties
Core Laboratories Australia Pty. Ltd.
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INTRODUCTION

This report contains the final results of the Special Core Analysis (SCAL) study performed on selected core plug samples from the well Thylacine - 1. This study was initiated by Mr Jon Kelly of Woodside.

The test programme involved :

- Selection and visual inspection of samples for the study
- CT-scanning of selected samples
- Measurement / re-measurement of porosity, permeability, and grain density values
- Formation resistivity factor (FRF) analysis
- Formation resistivity index (RI) analysis
- Air-brine drainage capillary pressure by centrifuge
- Water-gas relative permeability by centrifuge
- Rock (pore volume) compressibility
- Additional core plugs drilled for mechanical strength tests (samples sent to CSIRO for rock strength analysis)

Thirteen samples which had previously undergone routine core analysis constituted the original SCAL sample selection for electrical, capillary pressure and relative permeability analyses. Four additional duplicate samples were drilled from the core for rock (pore volume) compressibility tests (suffix “A”).

Four selected samples were found to be unsuitable for analysis upon visual inspection and substitutes were subsequently re-selected. All samples then underwent CT-scanning to screen out any samples which exhibited heterogeneity. Each sample passed this phase of the screening procedure. A full list of samples which both finally underwent analysis and also which failed initial screening are listed in this SECTION 1 of this report. Please also refer to the routine core analysis report issued for this well (PRP-01025 September 2001).

A simulated formation brine of 13,500 ppm comprising 80% NaCl and 20% KCl was used during the SCAL studies conducted at Core Laboratories.

An additional eight samples were later drilled for mechanical strength tests and sent to CSIRO (see Appendix 2).

Trim ends and sample remnants for the thirteen samples which underwent electrical, capillary pressure and relative permeability tests were despatched to Julian Baker at Reservoir Solutions Limited for a petrographic study.

SUMMARY OF RESULTS

Electrical Properties

Cementation exponent “m” values, measured at 1910 psi NOBP, ranged between 1.79 to 2.01. The average “m” was 1.88. CEC corrected values of “m*” ranged between 1.93 and 2.34 with an average “m*” of 2.08. Resistivity index analysis yielded sample average saturation exponent “n” values ranging between 1.62 to 2.38. The average “n” was 2.01. CEC corrected values of “n*” ranged between 2.07 to 2.78 with an average “n*” of 2.37.

Cation exchange capacity (CEC) analyses were performed on all 13 sample trim-ends by the wet chemistry method on crushed sample. The recorded CEC values ranged from 0.97 to 8.42 meq/100gm. For comparison purposes, CEC analysis was performed using the wet chemistry method on uncrushed sample-split trim-ends of 3 core plug samples. These data were compared to CEC data generated on crushed sample-split trim-ends from the same 3 core plugs and found to be fairly similar. The conclusion was, therefore, that crushing the samples did not lead to excessively high CEC values.

Capillary Pressure

Samples tested ranged from 0.483 md to 4710 md air permeability (Kair at ambient). At the maximum air-brine capillary pressure, the selected samples yielded immobile water saturation (Swi) values between 9.1 and 38.8 percent pore volume (% PV). For most samples the requested maximum air-brine capillary pressure of 200 psi was attained. Due to shorter sample lengths, the maximum attainable capillary pressure for samples #24, #28 and #46 was 100 psi, with the 200 psi point being extrapolated using the Table-Curve programme. The data indicate a strong trend of immobile water saturation as a function of air permeability.

Air-brine capillary pressure measurements were repeated for six samples using an overburden centrifuge at 1910 psi. Up to the maximum attainable air-brine capillary pressure of 100 psi, the six samples yielded very similar values of water saturation to those recorded at ambient (zero) overburden pressure. The comparison therefore indicated that the ambient capillary pressure data do not need to be adjusted for the effects of overburden pressure – as one would expect for well-indurated samples.

Relative permeability analyses.

Water-gas relative permeability analysis (end-point) by centrifuge were conducted on all thirteen samples following the air-brine capillary presure analyses. Residual gas saturations from centrifuge water-gas relative permeability (representing a reservoir displacement mechanism dominated by capillary / gravity forces) ranged from 3.5% to 14.9%.

Although traditional comparative parameters such as Kair versus Sgr and Sgi versus Sgr do not exhibit strong trends, Kair versus gas recovery % pore volume does indicate a good trend. This plot is included in SECTION 4.

Rock (pore volume) compressibility.

Rock (pore volume) compressibility tests conducted on 4 samples indicated compressibility (uniaxial loading) values ranging from 2.40×10^{-6} to 6.28×10^{-6} pv/pv/psi at the maximum confining stress of 3,800 psi. As would be expected, the higher the porosity and permeability values of the samples, the larger the degree of compressibility exhibited through the range of pressure utilised in the tests.

SUMMARY OF LABORATORY PROCEDURES

Sample selections were made by Mr Jon Kelly of Woodside in an attachment to an e-mail dated 28th August 2001. These samples had originally undergone routine core analysis and so had been cleaned, dried and stored at ambient conditions following analysis.

All samples were screened visually initially, to determine if they were of suitable shape and size. Visual screening was followed by computerised tomography (CT) to detect any fractures or other heterogeneities which would render the samples unsuitable for analysis. Samples which failed the screening stage were replaced. Selected replacements were agreed by Woodside and they also underwent visual and CT screening.

For rock (pore volume) compressibility tests, additional duplicate samples (suffix "A") were drilled adjacent to the selected routine core analysis plugs. Following visual and CT screening, these duplicate samples were cleaned in methanol to remove residual salts. These samples were dried at 90°C in a non-humidified oven prior to measurement of porosity and air permeability at ambient conditions (no applied overburden pressure).

All routine core analysis samples which had been selected for analysis were also re-dried at 90°C and porosity, permeability, grain density values re-checked and compared to originally measured values.

A complete list of samples eventually selected for analysis and samples which failed screening is contained in SECTION 1 of this report.

Saturation

All samples undergoing analysis were evacuated and pressure saturated with a simulated formation brine of 13,500 ppm concentration (comprising 80% NaCl and 20% KCl). All samples were weighed after saturation to check measured pore volumes.

Formation Resistivity

Each fully saturated sample was loaded into a coreholder at the reservoir equivalent NOBP and the electrical resistivities measured on consecutive days until they were stable, indicating ionic eqilibrium in the pore spaces. Formation factor (FRF) and cementation exponent ("m") values were then calculated.

Each sample was then de-saturated at incrementally increasing pressures using humidified air as the displacement medium. Electrical resistivities of each sample were measured at the incrementally decreasing partial saturations. When each sample had attained electrical equilibrium at each incremental desaturation stage, values of resistivity index (RI) and saturation exponent ("n") were calculated.

The trimmed-ends of the plugs which underwent FRF and RI measurements were cleaned in toluene and methanol, dried at 60°C in a non-humidified oven and then subjected to determinations of cation exchange capacity (CEC) using the ammonium acetate wet chemistry technique on crushed sample. These CEC values were in turn used to calculate idealised "m*" and "n*" values using Waxman-Smits-Thomas equations. For comparative purposes, CEC values using similar wet chemistry technique were earlier determined on uncrushed sample splits from trim-ends of three samples which later underwent the standard "crushed" analysis.

All electrical resistivity data are presented in SECTION 2.

Following the resistivity index analysis, the samples were resaturated with the simulated formation brine for the capillary pressure analysis.

Air-brine capillary pressure by centrifuge.

Samples were each loaded into individual centrifuge coreholders. Samples were spun at incremental rotational speeds effecting capillary pressure. Each speed (RPM) was maintained for a minimum of 24 hours until production was stable. The speed was then raised to the next higher speed. Volumes of brine produced were monitored using a stroboscope.

Capillary pressure and end-face saturation data were then calculated from the raw data using data reduction techniques developed by Hassler-Brunner. These results are presented within SECTION 3 of this report.

Six of the thirteen samples which originally underwent air-brine capillary pressure (i.e #14, #22, #25, #46, #62, and #80) at ambient conditions were re-saturated (100% Sw) with the simulated formation brine. All samples were weighed after saturation to check measured pore volumes. Samples were each loaded into individual overburden centrifuge core holders and the requisite net overburden pressure (1910 psi) applied. Samples were then loaded into the centrifuge and spun at incremental rotational speeds to 3000 rpm (the maximum attainable speed in the overburden centrifuge).

Capillary pressure and end-face saturation data were then calculated from the raw data using data reduction techniques developed by Hassler-Brunner. These results are also presented in SECTION 3.

Water-gas relative permeability (end-point) analysis by centrifuge.

Following the air-brine capillary pressure analyses by centrifuge, each sample was removed from the centrifuge core holders and loaded into a hydrostatic core holder and the NOBP of 1910 psi applied. Humidified nitrogen was flowed through each sample and the effective permeability to gas (Kgas) at Swi was determined.

Each sample was next loaded into individual brine-filled centrifuge cups. The samples were then spun at a maximum imbibition (equivalent to 200 psi), brine displacing air, capillary pressure to determine the end-point residual gas saturation (Sgr). The samples were removed from the centrifuge cups and the residual gas saturations were determined gravimetrically.

Each sample was then loaded into a hydrostatic core holder at 1910 psi NOBP. Brine was flowed through the samples and effective permeability to brine at Sgr was then determined.
Results from the water-gas relative permeability (end-point) by centrifuge are presented in SECTION 4 of this report.

Rock (pore volume) compressibility.

Four samples were selected to undergo rock (pore volume) compressibility analysis.

Each sample was evacuated and pressure saturated with the simulated formation brine. Samples were then loaded into a hydrostatic core holder and allowed to equilibrate at a low net overburden pressure. The net overburden pressure was then raised incrementally and the corresponding pore volume reductions monitored. The overburden pressure was raised to the next higher pressure only when pore volume reduction stabilised.

Hydrostatic compressibility data were then calculated from pore volume reduction data versus increasing overburden pressure. These data were converted to equivalent uniaxial loading following procedures outlined by Dirk Teeuw of Shell Research.

Results are presented in SECTION 5.

7th February, 2002

WOODSIDE ENERGY LIMITED.
1 Adelaide Terrace
PERTH, Western Australia, 6000

Attention : Mr. Jon Kelly

Subject: Special Core Analysis.
Well : Thylacine - 1
File : PRP-01025A

Dear Jon,

Presented here are the final results of the special core analyses conducted on the selected core and sidewall samples from the well Thylacine – 1.

Thank you for the opportunity to have been of service to Woodside Energy Limited. If you have any questions regarding these results or if we can be of any further assistance please do not hesitate to contact us.

Yours sincerely,
CORE LABORATORIES

Ajit Singh
Supervisor - Rock Properties Perth