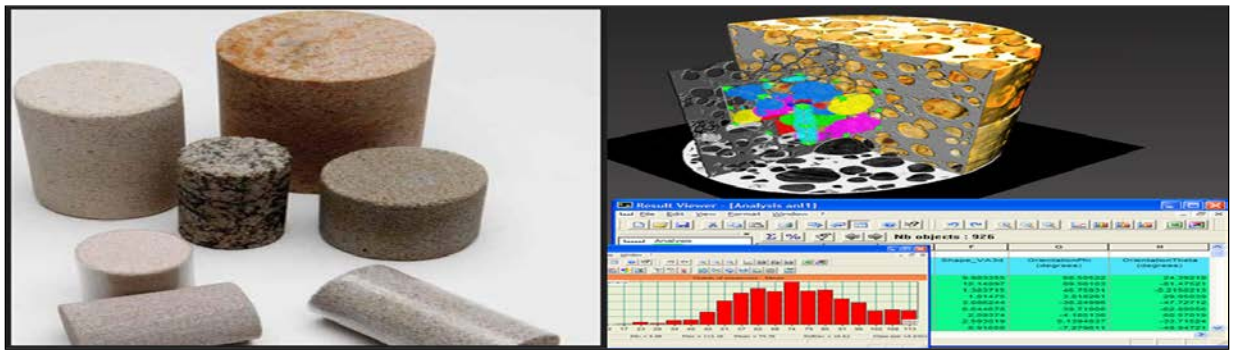
Formation Evaluation Society of Australia (FESAus) Presents:

Master Class: SCAL
"Special Core Analysis"

Date: Thursday 5th November 2015
Time: 12:00 – 18:00 (including social drinks)
Venue: IBIS Hotel (upstairs), 334 Murray Street, Perth



Special Core Analysis (SCAL) is a set of laboratory experiments & analyses that go well beyond the scope of Routine Core Analysis (RCA), offering sought-after Petrophysical parameters that can be integrated into detailed Reservoir & Formation Evaluations. Upon the class conclusion, attendees will be in a better position to appreciate the importance of quality core analysis in integrated studies.

Key issues include:

- Analysis Methodologies, Best Practices & Types of data generated
- Determination & Application of Capillary Pressure & Relative Permeability for multiphase flow
- Determination & Application of Archie Parameters & other Electrical measurements (m m* n n* CEC)
- How Representative is your data?
- Spurious Data – Are these real or apparent analysis artefacts, what's the cause?
- Variability and uncertainty of reservoir properties
- Advanced SCAL Techniques and Interpretation
- Wettability
- Displacement Mechanisms/EOR/IOR
- Pore Scale Imaging and Modelling

This Master Class will be run immediately following our regular FESAus monthly Technical meeting.

Start	End	Description			Duration	
11:45	12:00	Open For Registration, FESAus Mothly Meeting & Master Class			15 minutes	
12:00	12:30	Stand Up Lunch (For both the Monthly Meeting & Master Class participants)			30 minutes	
Start	**End**	**Presenter**	**Company**	**Presentation Title**	**Presentation Length**	
FESAus Monthly Technical Meeting: SCAL						
12:30	13:00	Rick Aldred	Independent Consultant	FESAus Monthly Meeting: The use of 3D Petrophysical Modelling to Apply Saturation Height Functions in Multi-Pore Systems	25 Minutes	+5 mins for Q&A
SCAL Master Class Session 1						
13:00	13:05	Mike Walker	FESAus	Introduction to the Master Class	5 minutes	
13:05	13:35	Kevin Flynn	Weatherford	Lab Capillary Pressure Analyses – The Good, The Bad & The Ugly!	25 Minutes	+5 mins for Q&A
13:35	14:00	Tony Kennaird	Corelab	CT Scanning at Various Scales of Measurement	20 Minutes	+5 mins for Q&A
14:00	14:30	Kevin Flynn	Weatherford	Using Archie in a Non-water wett imbibition scenario – what is the Denominator	25 Minutes	+5 mins for Q&A
14:30	14:40			**Coffee Break**	10 Minutes	
SCAL Master Class Session 2						
14:40	15:10	Kath Hodgson	ALS Oil & Gas	Characterising Core Using Whole Core Techniques	25 Minutes	+5 mins for Q&A
15:10	15:40	Max Podolyak	LR Senergy	Challenges with Clays in Sample Preperation, Testing & Analyses	25 Minutes	+5 mins for Q&A
15:40	16:05	Tony Kennaird	Corelab	Relative Permeability: Can we trust the data?	20 Minutes	+5 mins for Q&A
16:05	16:15			**Coffee Break**	10 Minutes	
SCAL Master Class Session 3						
16:15	16:45	Peter Behrenbruch / Phil Do Huu	Bear & Brook Consulting Pty Ltd	Using the Modified Purcell Model to Quality Check Capillary Pressure Lab Data and to Predict Optimal Capillary Pressure Relationships	25 Minutes	+5 mins for Q&A
16:45	17:15	Linda Stalker	CSIRO	SCAL for Geochemistry, Geomechanics & Petrophysics	25 Minutes	+5 mins for Q&A
17:15	18:00			**Open Bar and informal questions and discussions**	**45 Minutes**	**or longer**

Event Fee(s)

Master Class inc. Tech Mtg, FESAus members (inc. GST) $ 225.00
Master Class inc. Tech Mtg, non-members (inc. GST) $ 250.00
Master Class inc. Tech Mtg, Students/Retirees (inc. GST) $ 50.00
Technical Meeting only, FESAus members (inc. GST) $ 30.00
Technical Meeting only, non-members (inc. GST) $ 40.00
Technical Meeting only, Students/Retirees (inc. GST) $ 10.00

RSVP: Please register on-line at www.fesaus.org by **midday Friday 30th October 2015.**

Any queries, please contact Leanne Brennan at FESAus on sec@fesaus.org.

The SCAL Master Class will be a recorded event with the webcast being posted on our website (www.fesaus.org) soon after the event. Note that webcasts are only available for viewing by FESAus members (with a current membership) for a period of 12 months, after which they are viewable by non-members as well.

Presentation Outlines and Presenters Background

The draft presentation guide included below is intended as an outline of the topic to be presented. Actual presentation content may differ and cover only subset of the points listed below considering the limited time allocated for each session.

1) **The use of 3D Petrophysical Modelling to Apply Saturation Height Functions in Multi-Pore Systems (Regular Technical Meeting Topic)**
   Rick Aldred, Independent Consultant

Formations containing multiple pore systems, such as vuggy carbonates and layered clastics, present a problem when defining and applying saturation height functions from capillary pressure data. Rather than the capillary pressure curves normally seen from homogenous formations, we see curves which have two or more separate components, related to the different pore systems in the rock.

Understanding and separating these components is relatively simple task, but building and applying a function to derive fluid saturations in a multi-pore system formation is not so easy.

This presentation describes a technique for petrophysical interpretation based on three-dimensional modelling of the formation properties, where a saturation height function can be applied even in complex pore systems.

A case study is presented from a layered clean sandstone reservoir from South East Asia. In this reservoir, although the porosity remained fairly constant between the rock types, the permeability was highly variable with thin laminations of low-permeability water-bearing sands and high-permeability oil-bearing sands. The water bearing sands dominated the resistivity measurements, so a saturation height function was used to determine fluid saturations. Owing to the multiple permeabilities present at every depth, a 3D model of the formation had to be constructed in order to apply the function.

2) **Lab Capillary Pressure Analyses to Derive Saturation/Height Data - The Pros and Cons of the Analytical Methods. (Lab Capillary Pressure Analyses – The Good, The Bad & The Ugly!)**
   Kevin Flynn, Weatherford

Capillary pressure concepts can be used by geologists, petrophysicists, and petroleum engineers to evaluate the following:

- Reservoir rock quality
- Pay versus nonpay
- Expected fluid saturations
- Seal capacity (thickness of hydrocarbon column a seal can hold before it leaks)
- Depth of the reservoir fluid contacts
- Thickness of the transition zone
- An approximation of the recovery efficiency during primary or secondary recovery.

Evaluating capillary pressure of potential reservoir and seal rocks is important because capillarity controls the static distribution of fluids in the reservoir prior to production and remaining hydrocarbons

after primary production. The importance of capillary pressure in reservoir studies is that many reservoir rocks can be approximated by a bundle of capillaries, with formation water being the wetting phase and hydrocarbons the nonwetting phase. As such it is important to understand the options available for capillary pressure analyses in the lab, and to ensure the correct interpretation is applied when using the data from any given lab methodology.

There are several options for test technique:

- Porous plate/pressure equilibrium
- Centrifugation
- Mercury Injection

This presentation explains the pros and cons of the three methods allowing for better understanding of the data provided.

3) CT Scanning at Various Scales of Measurement
Tony Kennaird, CoreLab

Continuous CT-scanning of the entire cored length can be used to generate bulk density, photoelectric and porosity logs for direct correlation with wireline logs.

If a fracture study is required, this can be accomplished via CT without removing the cores from their sleeves. Dual and triple porosity discrimination in carbonates is also achievable.

At the other end of the CT measurement scale, pore network characterisation allows determination of such critical petrophysical properties as permeability, porosity, capillary pressure and Archie “m”.

Both the benefits and the drawbacks of the techniques will be discussed.

4) Using Archie in a Non-water wett imbibition scenario – what is the Denominator
Kevin Flynn, Weatherford

The issue is Archie is only for a water wett system – common knowledge. The question is what do we do in an oil wett system, or non-water wett system?? How should we run analyses in the lab, how should we calculate the results, how should we interpret the results and how should we use the results. This presentation aims to highlight these issues, providing some answers and some groundwork for future answers!

To calculate Archies Saturation Exponent (n) we almost always use an RI test in a water wett system draining from 100% Sw down to Swir. The “n” is calculated from Archie as “the ratio of the partially brine saturated sample to the resistivity of the fully brine saturated sample”. That is we obtain the RI by the using the FF (the denominator), which is all fine. However, occasionally, once we reach Swir, we then restore natural reservoir wettability (by ageing the samples). This process will render the samples, less water wett, or non-water wett or maybe even oil wett. Finally the samples would undergo a Pc/RI imbibition analysis i.e. increasing water saturation. This then begs the question what should we be using as the denominator in the aged state “n” calculation?

The presentation will use real SCAL data obtain from a local major field. It will contain regional background, laboratory methodology and results, highlighting the above options and finally address the question, which is right? Or is there another option, how should we proceed for future research?

5) Challenges with Clays in Sample Preparation, Testing and Analyses
Max Podolyak & Colin McPhee, LR Senergy

Authigenic clay minerals have an effect on the intrinsic properties of petroleum rocks (porosity, permeability, electrical properties, rock strength, etc). These effects far outweigh the percentage volume distribution which clay minerals occupy in the reservoir pore system. This presentation provides examples of AP field studies which clearly show that if the clay morphology within the pore network is altered in any way during core and plug preparation or during testing in the lab, or on contact with water in the reservoir; then the impact on core petrophysical properties and rock strength can be very significant.

Firstly, ill-considered and/or inappropriate core cleaning and drying techniques can lead to significant damage to delicate clays, as a result of clay bound water removal due to high temperatures and evaporative conditions. Damage must be avoided or minimised if reliable petrophysical data are required.

Secondly, clay minerals may have a significant effect on the intact rock strength; they can influence the inter-grain mineral matrix cementation during diagenesis. At the field scale, clay reactions on contact with formation of injection water can cause chemo-mechanical weakening that triggers sand failure and production. Formations that at first appear resistant to sand failure can start to produce sand on the onset of water production.

How to find the correct balance between the effective cleaning and preservation of the delicate clay structure for further testing? This presentation illustrates that it is essential to understand the type, amount, distribution and morphology of clays before embarking on design, planning and execution of petrophysical, reservoir engineering and geomechanical testing projects. Best practices to minimize or prevent potential clay damage during core preparation and testing will be provided.

6) Characterising Core Using Whole Core Techniques
Kath Hodgson & Jess Maddren, ALS Oil & Gas

Advancements in whole core scanning techniques (360 degree high resolution imagery, mineralogy, composition, permeability, resistivity, mechanical and physical properties) is allowing the collection of integrated datasets on a finer scale to increase the resolution when selecting subsamples for further detailed analysis. The larger number of closely spaced data points help reduce uncertainty of interpolation between regular core analysis data points.

This presentation will look at the techniques currently available and then discuss the differences, limitations and benefits of the techniques.

7) **Relative Permeability Can we trust the data**
Tony Kennaird, CoreLab
Draft Presentation Guide:

In order to generate representative relative permeability data we need to choose test methods which consider the reservoir drive mechanism, the petrophysical and lithological characteristics of the formation and the reservoir fluids. Techniques which are apparently theoretically sound will not necessarily guarantee utilisable data.

Points to ponder may include such diverse topics as flow-rate, wettability restoration, mobility ratio, steady vs unsteady state, gravity vs viscous drive, formation damage potential and cloud point of waxy crude.

This talk will illustrate what can and will go wrong if inappropriate test decisions are made.

8) **Using the Modified Purcell Model to Quality Check CapPres Lab Data**
Peter Behrenbruch & Phil Do Huu, Bear & Brook Consulting
Draft Presentation Guide:

The incorporation of representative SCAL relationships in petrophysics and reservoir engineering/simulation is paramount to achieving realistic subsurface related answers: HCIIP, recovery factors and production forecasts.

This presentation introduces a practical capillary pressure model, the Modified Purcell (MP) model, which has been shown to give excellent results in matching lab data. The theoretical formulation (no fitting parameters) has been derived for the purpose of describing the curvature of any capillary pressure lab result, surpassing any existing methods in terms of ease of use and accuracy. The method makes use of a model space which allows detailed quality checking of lab data. The model is also able to predict relationships when four parameters are available, either known, correlated or assumed: maximum laboratory capillary pressure (lab determined, a function of fluids and the maximum thickness of a reservoir), irreducible water saturation (a function of several parameters, very importantly grain size and sorting), (model derived) capillary entry pressure (a function of the larger pore throats) and entry saturation (by definition close to 100 percent).

Several case histories, oil and gas fields, are presented to show the great versatility of the method, first in quality checking data and subsequent predicting capillary curves based on endpoint values derived from a framework for a specific field. The method encompasses centrifuge and porous plate measurements and is currently being extended to mercury injection

9) SCAL for Geochemistry, Geomechanics & Petrophysics
Linda Stalker, CSIRO
Draft Presentation Guide:

New facilities and equipment in Perth have increased access to a number of new and existing methods and approaches to SCAL, with a particular focus on carbon capture and storage (CCS) applications. The Federal Government have provided the National Geosequestration Laboratory (NGL) with $48.4m in capital equipment funding. Some of this funding has been directed at a range of rock mechanics and core-flood related equipment to complement existing facilities available through NGL Partners CSIRO, the University of Western Australia and Curtin University. Projects are underway that involve a range of methods, both old and new, but the addition of the new facilities has allowed the development of advanced workflows to interrogate core samples to maximise data gathering.

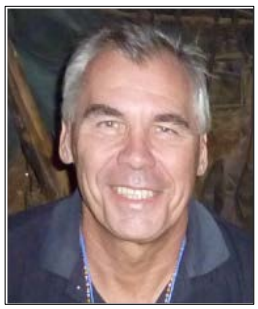
Base on a number of case studies we can demonstrate some of the advantages of the new facilities. One area of increased focus has been on “time lapse” methods for evaluating rocks before and after exposure to carbon dioxide. The purposes of this activity is to evaluate the changes in rock properties (changes in chemistry or mineralogical content, changes in porosity or permeability, changes in strength and acoustic behaviour) before and after exposure to carbon dioxide. Monitoring changes such as these can provide information on the overall behaviour of a storage (i.e. reservoir) interval and its capacity for carbon storage, or changes that could impact its permeability and therefore injection rates over time during storage. The overlying caprock may age over time in the presence of carbon dioxide and have an impact on its behaviour to act as an effective seal. These evaluations requires specific experimental testing to mimic those changes over longer time periods.

To do any of these evaluations, a detailed workflow has to be prepared that allows for the testing of materials before and after exposure to carbon dioxide in a non-destructive manner but also allows for direct comparisons to be made of the same areas of a given rock sample. Time-lapse fluid geochemical evaluation during core-flood experiments have been conducted and the mineralogical and physical properties of core samples have been measured to evaluate changes and can be compared with modelled expectations.

Other examples of SCAL methods available will be presented to show the range and benefits of handling samples through a continuous workflow and how this improves overall quality and robustness of the results and interpretations that can be made.

Presenter Brief Biographies and Experience:

Rick Aldred is a petrophysicist with 35 years oil industry experience, including 15 years with operating oil companies, 10 years with logging companies providing petrophysical consulting services and 10 years in petrophysical software development. He has a Joint (Hons) degree in Geology and Physical Geography from Keele University in England and has subsequently worked in the North Sea, North Africa, Middle East, Indian Subcontinent, South East Asia and Australia. He currently works as an independent consultant based in Brisbane, Australia.



Tony Kennaird has worked for Core Laboratories for 39 years in technical, supervisory and managerial posts in the UK, Singapore, Malaysia, China, Vietnam and Australia. He has analysed clastic and carbonate formations from all over the world and has published more than 30 technical papers and notes on the subject of core analysis. Tony has frequently presented topics at SPE and SPWLA events and conducted numerous industry schools.

Kevin Flynn has over 30 years industry experience, predominantly in Special Core Analysis. He came from a compute background before joining Robertson Research in the UK in the early '80s as a Junior Trainee Lab Technician. Kevin spent many years in the laboratories in North Wales and Aberdeen before concentrating on data and reports. He also spent two years developing the Research laboratory which included a full Reservoir Condition Water-Oil Relative Permeability test rig. In 1992 Kevin took over the SCAL operation as Unit Head. Kevin joined ACS Laboratories in 1994 as a SCAL Manager. After establishing the Special Core Analysis laboratory in Brisbane and developing the Formation Damage laboratory, Kevin was promoted to Regional Manager in 1998. In 1999 Kevin's responsibilities were expanded to include all advanced technical services including coreEVALTM, Consulting Services and Drilling Mud Properties. Since the late 90's Kevin has held a senior manager position (Regional Manager, General Manager) initially with ACS Labs before ACS joined the global Weatherford Labs group where Kevin is the Business Unit Manager for all Weatherford Labs operations in Australasia. Kevin is a member of the SCA, SPE, FESQ, SPWLA & PESA and authored several technical papers on Special Core Analysis.

Max Podolyak is a Senior Core Analysis Advisor in Senergy's Asia Pacific headquarters located in Kuala Lumpur. He graduated with a degree in geology and rock physics from Moscow State University, Russia. Currently Max is enrolled in the Master's degree programme in Petroleum Engineering at Heriot-Watt University. Max has 8 years of practical and consultancy experience in Core Analysis. He started his career working with RESLAB in the UK (currently Weatherfordlabs) as a special core analyst and was involved in the planning and operations of a number of major petrophysical and reservoir engineering core studies. He joined LR Senergy in 2012 as a Senior Engineer, where he regionally provides consultancy services, technical support and training to operating companies on a range of core analysis issues. Amongst others these include design, management and interpretation of core test studies, as well as integration of core analysis data with engineering software platforms.

Peter Behrenbruch is currently an independent consultant with over 40 years of industry experience. Commencing his career in Canada in the early '70s, Peter worked for Shell in Europe in the late '70s before migrating to Australia, working for Woodside in the early '80s, involved in implementing the initial phase of the North West Shelf (LNG) Development. He subsequently worked for BHP Billiton for 16 years, involved in many Timor Sea developments and other Australian offshore projects (project manager for the Skua and Griffin developments, feasibility stage), as well as worldwide operations, including Deepwater Gulf of Mexico, North Sea and Vietnam. His next major engagement was in academia, where he started the School of Petroleum Engineering and Management at the University of Adelaide in 2001 ($25 million grant by Santos), and as inaugural Head of School, saw the first students graduate in 2005. He subsequently re-joined the industry in 2007 and was responsible as project director for establishing first production from the Puffin field, Timor Sea (AED Oil and SINOPEC). Over the last few years, Behrenbruch has established Bear and Brook Consulting, engaged in consulting, teaching of university and industry courses, and research and development activities in the area of special core analysis. Behrenbruch has been involved with the SPE for many decades and most notably was on the SPE Board of Directors when he was also Director Asia-Pacific in the late '90s. He was instrumental in establishing the SPE Vietnam section while working in Saigon in the early to mid '90s.

Kath Hodgson, Business Development Geologist Western Region for ALS Geochemistry, is an Exploration Geologist with 20 years' experience in the exploration and mining industry around Australia and Africa. Kath's experience ranges from regional grass roots exploration activities to resource development in both open pit and underground mining environments, and includes management of geological database and sample preparation facilities for large scale resource and mine development programs. She has worked on a variety of gold and base metals deposits in Tasmania, Central Australia, the Yilgarn, Ghana, Tanzania and Zambia, for companies ranging from joiner and mid-tier mining and exploration groups to majors including AngloGold Ashanti and Barrick Gold. With experience in both sample generation and analysis, data management and implementation of new technologies such as 3D core scanning and hyperspectral mineral mapping, Kath has a thorough understanding of Mining and Exploration analytical requirements. This is coupled with a passion for proving the best possible service to clients, including new and alternative technologies, assisting clients obtain the maximum possible value from their samples.

Linda Stalker is the Science Director for the National Geosquestration Laboratory (NGL), a partnership between CSIRO, the University of Western Australia and Curtin University. There she works collaboratively with the partners on a number of carbon capture and storage projects, including the South West Hub CCS project with the Western Australian Department of Mines and Petroleum. Prior to joining CSIRO in 2000, Linda worked as a senior geochemist at Statoil in Norway. She holds a PhD in Organic Geochemistry and a BSc. Hons in Applied Geology.

Presentation Co-Authors Brief Biographies and Experience:

Jess Maddren is currently the General Manager for ALS Oil & Gas - Reservoir Labs in the Australian region. She is as a Geologist with experience in the field and in laboratories for internal company projects and then as a part of a service provider that was acquired by ALS in 2013. As well as experience as a mine and exploration geologist for BHPB she worked in the BHPB technology division providing geological and mineralogical support across the different commodities in the region including key projects in geochemical distribution of contaminants for basin modelling in ore deposits, mineralogy and mineral processing including geology to plant mineral behaviours and recently in the CBM/CSG industry as an analytical laboratory provider with a focus on reproducibility of results and decrease in uncertainties of analysis to increase certainty in reservoir modelling. Jess is currently in Houston working with the ALS Reservoir Laboratories team with their new lab with a passion for raising standards in the analytical industry and for the new whole core scanning techniques to increase frequency of analysis, decrease spacing between analysis to increase relationships with geological interpretations, decrease uncertainty in modelling and reduce costs or datasets that do not correlate.

Phil Do Huu has been employed as principal petroleum engineer by Bear and Brook Consulting since early 2014, being responsible in 2015 for computer programming new methodologies for the development of a comprehensive core data evaluation, analysis and modelling system. He commenced his career in Vietnam after doing postgraduate work at the University of Adelaide, the School of Petroleum Engineering and Management (now the Australian School of Petroleum), first teaching (2006-07) at the Ho Chi Minh City University of Technology and subsequently working as a senior reservoir engineer (2008-14) at Cuu Long, a Joint Operating Company between Petrovietnam and foreign parties.