Carbonate Reservoirs

(Output from ITF Theme Day, The Geological Society, London)

Collaborative Approach to Technology Investment

The Industry Technology Facilitator (ITF) is a not for profit organisation owned by, and with access to funds from major oil and gas operating and service companies that comprise its membership. ITF has an impressive track record in delivering finance to help develop new initiatives for oil and gas technologies from early stage joint industry projects (JIPs) through to field trials and commercialisation. Since 1999, ITF has supported **135** projects worth in excess of **£39 million** in funding. ITF's key objectives are to identify technology needs, foster innovation and facilitate the development and implementation of new technologies.

A fundamental element of ITF's role as an internationally recognised champion for facilitating research, development and deployment of technology innovation within the upstream oil and gas industry is to engage with key industry sources. ITF uses a proven process, working in collaborative participation with both its Members and industry to identify technology needs and potential solutions.

The ITF process, illustrated below as a step-by-step course of actions, endeavours to bridge the gap between the industry's large global players and development community with the ultimate aim of implementing new technology solutions:

STEP 1 - Understand and Identify Technology Needs

STEP 2 - Engage the Development Community / Invite Proposals

STEP 3 - Evaluate Proposal Submissions

STEP 4 - Secure Funding

STEP 5 - Assist the Launch of JIPs

STEP 6 - Facilitate the Implementation of Technologies

ITF has contractual confidentiality arrangements with all its Members and will enter into a parallel agreement with all developers submitting proposal applications. Proposals will be submitted to our Members only for the purpose for which they are provided, i.e. assessment for funding support and implementation.

Proposals submitted under this Theme will be reviewed for financial sponsorship by **all ITF Members** therefore this is an excellent opportunity to gain a global audience in seeking support for your technology. The focus of all ITF themes is to

identify technologies which bring clear benefits to sponsors but which require assistance in **research, development, and / or field trial.**

For details of ITF's full Portfolio of Members, please visit our Website – www.oil-itf.com

Background to the Theme

Carbonate reservoirs contain a significant proportion of the world's oil and gas reserves (some sources estimate more than 60% of the world's remaining oil and 40% of gas reserves in place). These reservoirs present considerable technical challenges and risks, but also opportunities to develop new technologies and processes.

ITF, on behalf of its members, is establishing a theme to improve our understanding of carbonate reservoirs. Complexity within carbonates is due to heterogeneity at all scales resulting from the depositional environment, biochemical origin and processes such as compaction, lithification, and other diagenetic events which all affect reservoir quality. Physical models and rock properties relationships are not well understood. Additional tools and technology are required to improve our understanding of the rock properties and rock fabric.

Defining the reservoir heterogeneity through better/higher resolution imaging (and other techniques) will improve the ability to 'see' reservoir architecture and quality. There is a need to improve our ability to predict structurally controlled reservoir heterogeneity – fractures and/or faulting. Improved simulation methods will enable more accurate prediction of reservoir performance and recovery factors. Prediction and better management of the heterogeneity in terms of lithology is required, typically this relates to dolomites versus limestones.

Theme Timeline

Each ITF Theme follows a nine month timeline from Theme Day to Theme Completion. The following list of tasks describes the key milestones and their associated date:

- Theme Start / Theme Day 12/03/2009
- Call for Proposals Issued 14/05/2009
- **Deadline for Receipt of Proposals** **06/07/2009**
- Publish to Members for Review July 2009
- Member Review and Voting August 2009
- Technical Clarification Meeting September 2009
- Members finalise commitment to sponsor December 2009

Open Invitation to Global Technology Developers

This document aims to stimulate proposals from global development expertise which meet the specific requirements for Carbonate Reservoirs. ITF and its Members will jointly assess all submitted proposals and our Members will potentially fund those proposals of greatest interest.

ITF and its Members will not prescribe specific technology solutions, but instead use the output gathered from the Theme Day to stimulate innovative proposals that offer potential solutions to identified needs. Key technology drivers, as identified by ITF Members, are the desire to produce fields in a more cost effective and efficient manner.

This is an open invitation to any organisation seeking sponsorship for **innovative technologies** in the oil and gas industry to submit proposals for **research, development, and / or field trial** in the following areas, associated with the identified needs relating to carbonate reservoirs:

- **Rock Typing & Upscaling**
- **Permeability Prediction**
- **Microporosity**
- **Seismic Characteristics of Carbonates**
- **Dolomite Geometries**
- **Fractures**
- **Chalk**
- **Reservoir Engineering (Production Forecasting)**

The list of detailed technology challenges are identified within each area that are of explicit interest to ITF Members in the 'Specific Technology Requirements' below. This information highlights key elements required but allows for innovation and flexibility in interpreting the most appropriate technical solutions.

The method for submitting a proposal is described later in this document but you can also learn how to submit a proposal by going to our website www.oil-itf.com

Specific Technology Requirements

*(Any submitted proposal **must** address one or more of the following identified requirements)*

Rock Typing & Upscaling

There is a need to fully characterise the pore network and to find the relationship between the geological data (facies and diagenesis) and the petrophysical data. New rock typing workflow approaches are needed. There is a historic problem of linking geology to petrophysics. Rock typing provides a way of populating the static model initially. In particular this call is seeking the following requirements:

- How to better characterise the electro-facies that represent the geological & petrophysical properties?
- Improved links between pore networks and the petrophysical properties of rocks – geophysical, Vp (compressional sonic), Vs (shear sonic) relative permeabilities and wettability at the plug (or optimal) scale. The optimal scale of description will depend on what is being studied.
- How to extract more valuable information from low quality data e.g. can rock types be characterised from small cuttings samples?
- Development of new methods from which to derive reservoir characteristics other than rock typing, especially permeability. Consideration should be given to the value of data and guidance on what data needs to be collected.
- New data acquisition techniques are requested which provide reliable permeability data as an alternative to core sampling. Permeability prediction is the key and rock typing provides a means to this end.
- Permeability information is currently obtained from core; consideration should be given to what could be obtained in the absence of core data? For example, how are NMR data and pore geometries linked?
- New workflows are required to obtain reservoir qualities.

Upscaling:

- How to predict what is *between* the wells and extrapolate the data from logs particularly in areas where there is a lack of information.
- There is a question of wider-scale reservoir model population.

Permeability Prediction

- How to link rock typing to permeability?
- Improved in-situ (downhole at the wellbore face) permeability measurements.
- Improved understanding is required of the processes that lead to permeability improvement or reduction.
- How can the heterogeneity be addressed?
- Some flow units are hard to assign a permeability value to, what value should be input to the reservoir simulator?
- What is the porosity distribution: micro, macro, mega and what is the relationship between them?

- Improved understanding of 'Super k' zones (highly permeable zones within a reservoir)
- What are the diagenetic properties/processes and what is the permeability relationship to this and to the stratigraphic architecture?
- What is the role of fracturing?
- What is the appropriate data type to collect e.g. mercury measurements on cuttings?
- What is the importance of anisotropy for stress related permeability?
- Improved understanding of carbonate permeability distribution:
    - To more accurately model the intrinsic carbonate geometry in 3D
    - Ways to constrain carbonate geometries stratigraphically.
- There is a need to calibrate predictions against observations from real fields and to understand which methods work best.
- How best to handle reconciliation of the well test interpretation versus matrix permeability?

Microporosity

Microporosity or more specifically the *'quantitative pore network characterisation of microporous carbonates'.*

The definition of microporosity varies within the industry. In this context microporosity is defined as a pore diameter of one micron or less. There is a need to characterise the pore networks below one or two microns. Permeabilities are less than 10mD.

- Tool development is required to characterise the pore networks below one or two microns. This fine detail exceeds the resolution of CT-scans and other techniques, which could otherwise be deployed.
    - How can we image this size of the pores?
    - The epoxy method is not quantitative, which is a limitation.
- What role does microporosity play in flow and production?
- How do you measure what is present in the pores and does the content change?
- Is there a relationship between the micro and macro pore network system?
- How did the microporosity get there in the first place? What is its distribution? Improved understanding of the processes and formation of microporosity is required.
    - Microporosity forms in low Mg calcite-dominated reservoirs and may be seawater driven. Microporosity is a diagenetic process.
- There is a need for a quantitative link to SCAL (Special Core Analysis) i.e. capillary pressures, relative permeability.
- Is there a link to the height above the free water level?
- What are the well production profiles?
- There is a need to calibrate with well cuttings.

Please also refer to the section on 'chalk' as microporosity is an important feature of chalk reservoirs.

Seismic Characteristics of Carbonates

- How can we improve the image?
- How can we overcome the low impedence (particularly of features such as voids)? The low impedence response of differing fluids is masked by the rock itself; this is especially the case in 'stiff' carbonate reservoirs.
- What is the 4D response of carbonates to production?
    - Is the rock physics modelling good enough? Can it be improved to allow the use of 4D and AVO?
- Compared to clastic reservoirs it is hard to go from logs to modelling of seismic (this is informed by the rock physics model).
- Some carbonate reservoirs exhibit a 4D response, but not others, why is this? It seems to work in soft carbonates.
- There is a need to image the front of a waterflood, but this may occur in very thin layers that are hard to image on seismic.
- Placing the source downhole may provide the higher resolution which is required.
- There is a need to separate the lithology effects versus the fluid effects. The 4D effect is different again.
- The 4D changes in chalk can be confusing – compaction and geomechanical effects need to be considered.
- How are velocities within carbonates affected by rock fabrics and the rock physics?

Dolomite Geometries

Improved understanding of fault related dolomite bodies and their associated petrophysical properties and geometry is required in order to optimise the field development and production of dolomite reservoirs. Further development of quantitative predictive tools is needed.

In order to characterise the host rock and to quantify how it has been affected it is necessary to address a number of questions, such as:

- What is the fault control (fluids move along them)?
- How do we define the 3D volume?
- What are the fluid & temperature characteristics?
- Has matrix porosity been preserved?
- What is the lateral distribution?
- Has over dolomitization occurred?
- What has been the impact on porosity development?
- How does this relate to petroleum systems and hydrogeological control, what role can reactive transport modelling (RTM) play?
- There is a need for improved seismic detection of dolomite bodies.
    - Are they fault-controlled or stratiform geometries?
- Anhydrite cements develop in association with dolomites – what is the nature of this relationship?

Fractures

Please keep the focus of proposals on fractures as they relate specifically to carbonate reservoirs. There is a need to understand the fracture volume distribution within a carbonate reservoir as this can significantly add to reserve estimates. Improved understanding of the microfracture phenomenon and the contribution it makes to production is required. More efficient models are required in order to relate production history to fracture characteristics. In order to achieve these objectives a number of questions should be addressed in proposing new models:

- What are the characteristics of the matrix-fracture interaction?
- What are the fracture dynamics:
    - fractures versus time
    - fractures versus rock types
    - fractures versus mechanical stratigraphy
- What are the effective recovery factors from fractured carbonates?
- What is the role of stylolites (pressure solution seam) as conduits within the reservoir?
- What is the role of anisotropy – why are some fractures conductive and others closed?
- Can we predict if fractures are open or deal with 'evil fractures' (can these problematic fractures be mitigated i.e. closed)?
- What is the likelihood of fractures versus faults developing around salt domes?
- There is a need to characterise and predict fracture swarms, however they are often sub-seismic in scale which is problematic.

Chalk

Chalk presents many of the challenges already described, but in addition it has a specific set of issues which should be considered. Much of the production is derived from microporosity rather than macroporosity. There is a need to differentiate between microporosity and micro-microporosity (going beyond one micron). It is important to improve the understanding of diagenesis, flow barriers and silicification.

- What is the depositional diagenesis?
- What are the geomechanical properties?
- There is a need to characterise the depositional facies and link these to their petrophysical characteristics – what is making a difference?
- Transition zones are a big challenge, there is a need to characterise them and link this to production – what is their production profile?
- Chalk in Northern Europe has been inverted tectonically - how much of an impact has this had on relative permeability due to drainage and imbibition?

Reservoir Engineering (Production Forecasting)

Depending on the recovery mechanisms and reservoir environment, it is necessary to understand the key heterogeneities that need to be considered for the production profile. Recovery factors in some conditions can be less than 10%; hence, some of the consideration for improved production strategies to maximise recovery should be considered, including:

- Profile modification is an important aspect of reservoir management (methods for water shut-off) especially in 'Super k zones' (highly permeable zones). Novel technology/methods for improved water shut-off are required.
- Upscaling Kv – how to get from one rock type definition to reservoir models.
- How can the reservoir characteristics be inferred from production data?
- Improved stimulation methods in order to enhance the production.

Process for Submitting a Proposal

1. **Register Interest with ITF**
   Register your interest as early as possible by sending an email to Colin Sanderson at c.sanderson@oil-itf.com

2. **Visit the ITF Website -** www.oil-itf.com
   On the ITF Home page, click on the "How to Submit a Proposal" button or follow this link to access all the information required to submit a proposal.

3. **Read the 'Project Application Guidance' Document**
   This document is available to view or download from the 'ITF Downloads' / 'Proposal Submission' section of the ITF Website. Reading this document prior to submitting a proposal is essential. If you require further clarification or are unsure if your proposal is suitable for submission, please call ITF (ITF Contact Information appears later).

4. **Download and Complete the 'Project Application Form'**
   This form is available to download from the 'ITF Downloads' / 'Proposal Submission' section of the ITF Website.

5. **Download and Complete the 'Project Presentation Template'**
   This template is available to download from the 'ITF Downloads' / 'Proposal Submission' section of the ITF Website.

6. **Email the Completed 'Project Application Form' and 'Project Presentation Template' to ITF**
   Email the Completed 'Project Application Form' in Microsoft Word format (not PDF) and the 'Project Presentation Template' in Microsoft PowerPoint format (not PDF) to Colin Sanderson at c.sanderson@oil-itf.com by **no later than 6th July 2009**. Proposals received after this date may not be processed.

Qualifying Technologies

In order to qualify for potential sponsorship, technologies submitted in response to this Call for Proposals must:

- be applicable to at least one of the identified requirements
- be novel or innovative
- demonstrate a clear business case for support
- have a clear and demonstrable path to commercialisation and implementation

Note: Proposals submitted to any other ITF Call in the past nine months or any previously unsuccessful applications should not be resubmitted without first consulting ITF (contact information provided later in this document).

Qualifying Organisations

Proposals are invited from any organisation including SME's, academia, research institutions, large organisations, consortiums or alliances. Proposals may be submitted by a national or international organisation, and equal opportunities will be extended to all proposers. Please keep in mind however that should your proposal be taken forward, you will be required to participate in meetings and make presentations to interested parties in the UK and in the English language (teleconference and video conference are acceptable).

ITF Contact Information

If you would like to discuss any matters related to this call or any other issue related to ITF, please contact any of the following people:

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