Integrating Petrophysics in the IODP through the development of the European Petrophysics Consortium (EPC)

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Background

In the Integrated Ocean Drilling Program (IODP), three drilling platforms will be operated; a riser, non-riser and mission specific. Mission-specific platforms (MSP) will be operated by the ECORD Science Operator (ESO) and provide opportunity to extend IODP operations into areas such as ice-covered waters and very shallow water environments. The ECORD Science Operator is a three-component consortium, involving operations (British Geological Survey), curation (University of Bremen) and petrophysics through the European Petrophysics Consortium (EPC). EPC was formed by the grouping of three European-based academic institutes that are involved in petrophysics research. All three institutions have a history of involvement with ocean drilling, and particularly in relation to downhole logging. This link has been forged through individual sub-contractors with the Lamont-Doherty Borehole Research Group as part of the ODP and subsequent IODP Logging Group.

Within ESO, EPC is responsible for the planning, management, acquisition, quality control/assurance, archiving and educational outreach relating to petrophysics. Petrophysics here is defined as: (a) measurements made downhole using a variety of logging tools (the suite will be specified in the Scientific Prospectus for each MSP expedition) and (b) standard core-based petrophysical measurements made on the core both during the offshore and onshore phases of an individual MSP expedition. As a consequence, one of the most important aspects of the EPC is to decide, for each particular MSP expedition, whether the petrophysical operations are to be undertaken fully by EPC members, or whether external resources are required, either from other European and non-European academic institutions, or from industry.

Table 1. Staff comprising the European Petrophysics Consortium

University of Leicester	
Dr Tim Brewer	EPC Chair, Chief Scientist
Dr Marc Reichow	Research Scientist
Ms Jenny Inwood	Research Scientist
Mrs Janette Thompson	Administrator
University of Montpellier	
Dr Philippe Pezard	Chief Scientist
Dr Hendrik Braaksma	Research Scientist
Dr Florence Einaudi	Research Scientist
Dr Gilles Henry	Logging Engineer
Mr Akram Belghoul	PhD Student
Mrs Joelle Gastambide	Administrator
RWTH Aachen University	
Dr. Christoph Clauser	Chief Scientist
Dr Renate Pechnig	Chief Scientist
Dr Norbert Klitzsch	Research Scientist
Ms Juliane Arnold	Research Scientist
Ms Margarete Linek	Research Scientist
Mr Lothar Ahrensmeier	Technician

Management Structure

The EPC central office is located at the University of Leicester and is responsible for the management of the EPC, negotiating and representing EPC within ESO and IODP and negotiating and dealing with external organisations as required. The staffing of the EPC is shown in Table 1.

The Petrophysics Staff Scientist

For each MSP expedition a Petrophysics Staff Scientist will sail on the offshore phase and will be present during the onshore phase of the expedition. The Petrophysics Staff Scientist will be drawn from the available pool of research scientists within the EPC. The role of the Petrophysics Staff Scientist is to act as the principal liaison between the EPC and the science party during the entire MSP expedition. This role begins with the development of the Science Prospectus, within which a petrophysics plan is developed through close liaison with the co-chief scientists and proponents. The petrophysics plan involves both offshore and onshore phases and includes both downhole logging and core based measurements. These measurements must conform to the IODP minimum measurement policy. During the offshore phase, space is often limited on MSP operations and all core-logging operations are carried out in a designated logging container (Figure 1), while logging acquisition is carried out either from a designated logging container (e.g. ACEX operations) or from close to the rig floor (e.g. Tahiti). Following the offshore expedition, the EPC will undertake the final depth shifting, correlation of runs within a hole and integration of logging and multi sensor core logger (MSCL) data sets. Where necessary the EPC together with the Petrophysics Staff Scientists will oversee all onshore subsequent environmental processing of downhole data.

The onshore phase of an MSP operation takes place at the Bremen IODP Core Repository some time following the offshore expedition. During this phase the EPC provides staff, both the Petrophysics Staff Scientist and others who are responsible for the implementation, acquisition and quality control of the shore-based petrophysics. The type and amount of data collected is defined in the expedition prospectus.

EPC Facilities

At each of its three nodes, the EPC provides a petrophysical expertise base, which is available to all scientists involved in the IODP. This expertise base can provide assistance in the development and revision of drilling proposals, in the development of the expedition prospectus (specifically the petrophysics plan) and in the evaluation and interpretation of petrophysics data gathered during both current IODP expeditions and for those scientists using legacy petrophysics data.

University of Leicester

At the University of Leicester a log interpretation centre has been developed over a number of years, which employs a number of different software packages enabling the user to optimise their evaluation and interpretation of both downhole logging data

and to facilitate core-log integration. The facility is supported by a number of discrete laboratories within the department, which enable a variety of high quality core-based measurements to aid the interpretation of the petrophysics data. Educational programmes are available for students who wish to consider registering for graduate studies linked to research in the field of petrophysics. Also available through the University is access to the CALLISTO facility. CALLISTO is a joint academic-industry venture for the calibration of porosity measurements, through the deployment of logging tools in 4 water-filled tanks containing 12 rock blocks. The rocks in each tank are extremely well characterised and provide a unique facility for the testing of logging tools.

University of Montpellier

The borehole geophysics group of CNRS at the University of Montpellier is called LGHF for "Laboratoire de Géophysique et d'Hydrodynamique en Forage". It is a group of 20, with 10 permanent scientists and engineers, plus an average of 10 post-doctoral researchers and PhD students.

Borehole research at LGHF is focussed both on geophysical and hydrodynamical developments of instruments, experimental methods and models. Created in 2001, LGHF has built a logistical site, assembled existing and new means of shallow subsurface investigation in boreholes (down to 1500m at the most), as well as developed a series of complementary experimental sites spanning a range of varying geological and hydrological contexts. Present research interests cover the study of hydro-dispersive properties in heterogeneous porous media, salt-water intrusion in shallow coastal reservoirs, geothermal systems both on land and in the deep oceans, and CO_2 sequestration in deep reservoirs.

The field operations of LGHF are deployed from the logistical and experimental site of Lavalette located in the outskirts of Montpellier, 3 km off-campus. The site is equipped with three nearby 100 m-deep boreholes, one of which has been fully cored. It serves as a base for instrument calibration, new tool development and testing, as well as controlled experiments in the fractured marly limestone of Valanginian age. It is also a teaching site for master's students from the universities of Montpellier, Strasbourg and Pau in France.

In terms of borehole geophysical investigation, the LGHF is equipped with a series of 200 to 1500 m long winches and cables, ALT and Robertson data acquisition systems, and more than 25 downhole sensors. Among these are mm-scale borehole wall imaging tools (either optical or acoustic), a series of geophysical tools (including a fully-digital, variable frequency, sonic device with 4 receivers; several electrical resistivity sensors, both galvanic and electromagnetic; a magnetic susceptibility tool; spectral natural gamma sensors yielding U, Th and K concentrations), and borehole size (callipers) and fluid characterization tools for measuring pressure, temperature, electrical conductivity, pH, and Eh. Most of these sensors were used in 2005 during the IODP 310 MSP expedition in Tahiti.

Newly developed tools include one called "MuSET" (for "Multi-Sensor Electrical Tool") to measure the spontaneous potential from a Pb/PbCl2 unpolarizable electrode, and "SHyFT" (for "Slimline Hydraulic Formation Tester") to perform small-scale production tests in order to derive permeability, and to take in-situ uncontaminated pore fluid samples. For in-situ hydrodynamic testing, "CoFIS" (for "Controlled Fluid Injection Sonde") allows for a complete hydrodynamic characterization of the formation in the near vicinity of the hole, from permeability to storativity and dispersivity with push-pull experiments. These tools have been developed in the context of the EC-funded ALIANCE project focussed on brine intrusion in coastal reservoirs. Present developments deal with that of permanent subsurface observatories for the shallow subsurface.

In the laboratory, software packages such as GeoFrame and WellCad are available for data analysis. In addition, a laboratory for cm to dm-scale characterization of rock petrophysical properties is available within the CNRS premises at the University of Montpellier.

Figure 1. Offshore Petrophysics during the IODP Expedition 310 Tahiti Sea Level. The Petrophysics container is the pale blue container at the rear of the ship. The GEOTEK Multi-Sensor Core Logger (MSCL) is located within the Petrophysics container with co-chief Gilbert Camoin and Klaas Verwer (scientist).

RWTH Aachen University

Log interpretation and the study of petrophysical properties is one major research topic of the RWTH Aachen University geophysics group, having a tradition of more than 15 years. Research emphasis is on the characterization of rocks for geological, geothermal and hydrogeological studies, and on the physical and thermal structure of the oceanic crust with its associated time-integrated heat and mass fluxes. These require the study of physical properties in the laboratory and the analysis and interpretation of in-situ measured borehole geophysical data.

Laboratory facilities of the working group comprise several core scanners (thermal conductivity, spectral gamma, gamma density, Vp and susceptibility) supplemented by petrophysical devices for measuring hydraulic, thermal and electrical properties on core plugs or mud samples. The Aachen working group is equipped with Antares slimhole logging equipment suitable for holes drilled down to 1500 m. A suite of petrophysical tools (spectral gamma, acoustic, electric, gamma density) is available as well as a high-resolution temperature, pressure and salinity tool. Several professional software packages exist for well-log interpretation and analysis of laboratory data. Educational programmes are available for students, comprising lectures for borehole geophysics, practical exercises in logging and the integration of graduate studies in research projects. The Aachen geophysics group contributes to a new international UDEA-League master's programme for Applied Geophysics (**www.idealeague.org/geophysics**) between Technical University Delft, ETH Zurich and RWTH Aachen University, providing courses in petrophysics, log interpretation, geothermics, small-scale NMR, electrical and spectral IP methods

In the field of log interpretation, a major research topic of the Aachen geophysics group is the development of log interpretation methods for magmatic and metamorphic rocks. A log response database and log interpretation charts exist for various igneous and metamorphic rock types of oceanic and continental crust. Studies also focus on image log interpretation techniques. The target is to develop algorithms for automatic rock classification and the identification and quantification of rock morphological features of oceanic rocks.

In the field of petrophysics, several studies address thermal and hydraulic properties of porous and fractured rocks. A fractal rock model approach was developed for porosity-permeability relationships and confirmed for rocks of sedimentary basins and some crystalline rocks. More recently, petrophysical investigation also focuses on Nuclear Magnetic Resonance (NMR) technologies. A new mobile NMR core scanner was developed and methods for predicting porosity, permeability and pore-size distribution from NMR signals are currently being tested and adapted to rock types commonly found during IODP expeditions. In several research projects, petrophysical data serve as input data for numerical modeling, targeted for example to quantify groundwater flow by thermal methods, to derive thermal properties from logging data and to study on the borehole scale, the influence of both palaeoclimate and groundwater flow. The need for improved inversion methods motivated the development of a new inverse algorithm, specifically designed to allow a more general description of the physical rock properties.

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