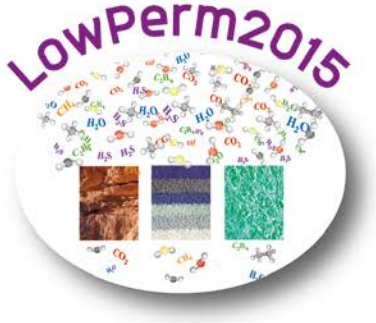

Low Permeability Media and Nanoporous Materials
From Characterisation to Modelling
Can we do it better?

Rueil-Malmaison, France ■ 9-11 June 2015

Conference Highlights

International scientific event organized by IFP Energies nouvelles, LowPerm2015 was a platform for sharing ongoing research led by professionals from a variety of disciplines and application fields, all dealing with low-permeability media and nanoporous materials (hereafter called LowPerm materials). The attendees of the event were interested in unconventional fossil fuel resources, nuclear waste storage, material sciences, chemical engineering, polymer-based materials for packaging or separation, catalytic materials, etc.

LowPerm materials were addressed quite comprehensively in order to highlight common cross-disciplinary areas of interest and challenges. The program included three main oral sessions, mixing the disciplines: (1) Characterisation at pore scale; (2) Competing physicochemical processes involved in fluid transport mechanisms at pore scale; (3) Low to very-low permeability media and nanoporous materials at macroscopic scale. Two multidisciplinary poster sessions and seven keynote lectures completed the program. In addition, at the end of the conference, our keynote observer, Henri Van Damme (MIT, USA), summarized the main points raised by LowPerm2015. A few of them are listed below.

The conference shed light on some promising **new experimental characterisation systems,** such as neutron tomography, but also on some very interesting information provided by nuclear magnetic resonance (NMR) relaxation. Several presentations and a lecture given by Jean-Pierre Korb (Lab. PMC - Ecole Polytechnique - CNRS, France) underlined the crucial role of this technique in helping us to understand where molecules are located in the pore volume, in which type of pores and if there are connections between the different types of pores and molecules.

In spite of the progress made with characterisation techniques, a comprehensive understanding of all aspects on the nanoscale - for a decimeter-long material sample, for example - is still a dream. During his lecture, Pierre Levitz (UPMC, France) showed that this objective is probably too ambitious, at present, but that having a good idea of (1) the **geometry and connectivity of the porous space** and (2) the **intrapore dynamics**, provides us with a useful picture of the dynamic processes at work in LowPerm materials (fractured or otherwise). Concerning connectivity, Andrew Aplin (Durham Univ., UK) emphasized in his lecture that it is very difficult to determine the extent to which pores are connected in organic matter. This information is, of course, crucial when it comes to more accurately evaluating the potential of a shale play, for example.

Several presentations focused on understanding the various **competing transport phenomena** occurring in these LowPerm materials. **Slip phenomena** were covered several times, with discussions based on the Knudsen number and examining the fact that Klinkenberg treatment/correction is likely to be insufficient and needs to be improved, since dealing with these dimensionless quantities may not be enough in such complex 3D media. **Diffusion** is, of course, an important transport mechanism in these materials. In fact, in these very confined media, the diffusion of molecules is similar to molecules travelling in a kind of tube, the size of which is essentially the size of the molecule itself. Eliane Espuche (Univ. Lyon 1, France) nicely described this phenomenon, which is shared by all LowPerm materials, in her lecture, when she talked about the diffusion of dissolved molecules through polymer barrier defects. In the case of fluid mixtures, which can be encountered in kerogen for instance, a presentation showed that collective diffusion processes were correctly captured by a Maxwell-Stephan approach (in which we consider that the driving force for transport is counter-balanced by a friction force proportional to the difference in velocities between the molecules in question). Finally, since numerous transport mechanisms play a major role in LowPerm materials, Henri Van Damme posed a provocative question in his closing arguments: "**Should we stick to permeability as the main parameter for describing the transport properties of porous media?**" Henri Van Damme suggested a switch to **permeance,** which is actually a more integrative quantity that can address various transport regimes and mechanisms.

The **role of interfaces** was also extensively discussed. Xiaolong Yin (Colorado School of Mines, USA) gave a very challenging lecture prepared by Yu-Shu Wu (Colorado School of Mines, USA) on the influence of Laplace pressures on liquid-vapor equilibrium, which can modify the fluid phases we are dealing with, and, consequently, have a significant impact on the transport of these phases. Another aspect of interface phenomena was raised by Marc-Olivier Coppens (UCL, UK) and concerned **surface barriers**. He showed that there is extensive experimental evidence highlighting the significant role of defects on the surface and inside zeolite crystals on diffusivities (especially for applications involving small crystals). The mechanisms of these surface barriers are currently far from fully elucidated and there is plenty of scope for exciting and challenging theoretical/experimental investigations. The impact of interface phenomena was also tackled in a discussion on porous silicon, which exhibits an experimentally measured permeability far below its theoretical one, despite the fact that the geometry of the system is very simple (parallel tubes crossing a membrane).

Another important question discussed during the conference was the **coupling between the transport and mechanical properties** of LowPerm materials, very often examined together with their multiscale/heterogeneous character. Finally, another interesting coupling underlined by Henri Van Damme, and requiring further study, concerns **electrokinetic effects** at the pore scale in confined porous media, which can have a significant impact on transport properties at a macroscopic scale. This coupling was discussed by Anthony Szymczyk (Univ. Rennes 1, France), for instance, who focused on membranes exhibiting heterogeneous fixed-charge distribution, which can have a positive or negative impact on macroscopic separation performance.

Participation highlights: 37 talks, 24 posters, 100 participants from Europe, North America, Canada and Asia (11 nationalities were represented), 68% academics, 24% students, 8% industrial players.