AAPG Annual Convention
Salt Lake City, Utah
May 11-14, 2003

Integrated Characterization for CBM : The RECOPOL example

BOSSIE-CODREANU, DAN, Institut Francais du Pétrole ; WOLF, K.H.A.A. & BRUINING, HANS, Delft University ; KROOSS, BERND & BUSCH, ANDREAS, Rwth

The main goals of the RECOPOL project is to study, plan and implement a CO2 sequestration operation along with a possible CH4 production in coals found in the Upper Silesia Basin. This implies a thorough understanding of the mechanisms governing CO2 and CH4 adsorption, diffusion, and Darcy flow as well an integrated petrophysical characterization consisting of properties distributions such as porosity and permeability, along with determination of the relative permeability and capillary pressure curves at the scale of the chosen pilot. A methodology had to be found for this study, in order to provide accurate and above all coherent data integrated at various scales.

The integrated study is based on:
• The development of a lnK vs. PHI relationship based on the generation of ''virtual cores'' at the meter scale based on the integration of cleat statistics within a volume of 10m3, out of which 1m3 values of PHI and K are computed (this m scale was chosen on purpose so as to be the same as the log resolution.
• A log analysis of all wells within the studied area, leading to a porosity profile, along with a permeability profile using the lnK vs. PHI relationship developed above.
• The definition of flow-units in each well and their areal correlation
• The definition of numerical layers, respecting the flow-unit resolution, and using a larger resolution in the areal direction (up-layering methodology).
• Correlation of flow-units between wells using geostatistical methods.
• Diffusion characteristics were performed through laboratory experiments, image analysis, pore size distribution estimation using mercury porosimetry and NMR measurements. These data were integrated within model formulations developed at Aachen University, Delft University and IFP.
• The relative permeability was estimated using the laboratory capillary pressure.
• Direct porosity and absolute permeability measurements were determined from cuttings, using an original method developed at IFP.

The methodology used is based on an original method based on image analysis and statistical integration of information such as cleat length distribution, fracture density and fracture frequency, aperture distribution and cleat orientation. Based on CT scans of large cores (30cm*30cm*30cm) and using various filters, cleats are recognized (macro and part of the meso network). Quantification of the various statistics are done by hand or using cutting analysis (method developed at Delft university for orientation distribution of cleats), used along with image analysis. The integration is used using a software developed at IFP which from fractal fracture distributions can calculate porosity and permeability at any scale chosen within a 3D block generated with statistics obtained from field samples. Anisotropy and aperture distributions are accounted for. Based on previous work performed within the ICBM project (EC project), the method allows relatively quickly a realistic relationship. Furthermore, image analysis allows an insight on the cleat continuity and kinetics of diffusion since the distance between cleats distribution is determined.

Log analysis used were Russian logs (GR, neutron, density and resistivity suite). Due to the difficult direct interpretation of these, an original method of analysis was developed, based on the generation of a ''composite'' log, based on the normalization of all logs and on the generation of an ''exaggeration log response'', combining responses increasing in front of coal and those decreasing in front of coal. The ExaLog is used on one hand to identify coal zones and quantitatively to correct porosity calculations based on the density porosity determination. Since deep and short laterologs were not available we considered the method as adequate.

Based on the results of the two analysis above porosity and permeability profiles were generated for each well at the meter scale. The layering was determined using the flow-unit concept, meaning that porosity and permeability were used to determine the layering. Geological interpretation based on cross-sections along with more sophisticated automatic methods were tried (neural networks, FU methods). The flow-unit identification on all wells was standardized on all wells for coherence purposes. Interpolation of flow-units was performed using geostatistical methods. porosities and permeabilities were associated to each flow-unit according to a random drawing within each PHI and K distribution associated to a flow-unit.

The above procedure lead to the generation of :
- a 3D block of flow-units
- a permeability 3D block and a porosity 3D block

The only up-scaling was performed in the areal direction, since the vertical resolution was kept as originally obtained from the log and flow-unit analysis

The other issues pertaining to the coal characterization concern the diffusion coefficient and the kinetic coefficient of diffusion to be used within the modeling stage, along with a representative capillary curve and relative permeability curve. Thus a Purcell mercury injection experiment was performed, giving us a capillary curve which was then corrected assuming that coal as measured is not stressed (and thus not representative of the in-situ situation). The Purcell experiment was interpreted in terms of pore distribution. Along with this experiment, RMN analysis of pore distributions as given by T2 measurements was also performed. The results were then used by

The full data set was then re-assessed, stressing coherence between data. Those phenomena which might occur in reality (ex. swelling) but which are not currently handled by ECBM simulators are not directly addressed by this approach. Nevertheless their impact was discussed during the re-assessing stage.

Example of results from each stage are given, with a discussion of their strength and weaknesses. Modeling approaches and inherent uncertainties are also discussed in terms of their impact on production/injection results and recommendations are given.