Analysis and modeling of spatial trend and spatial uncertainty of physical rock properties in the Callovo-Oxfordian claystone formation from a 3D high resolution impedance cube

Michel Garcia **(KIDOVA), Jean-Baptiste Mathieu (KIDOVA), Béatrice Yven (Andra)**

KIDOVA, 155, avenue R. Salengro, 92370 Chaville, France
Andra 1/7 Rue Jean Monnet, 92298 Châtenay-Malabry Cedex, France.

The geological exploration of the Meuse/Haute-Marne area began in 1994. Several boreholes were drilled, and the Callovo-Oxfordian argillite, thought to become a potential storage formation, were cored and logged. 2D seismic surveys were completed, as well as geological field observations, and an underground research laboratory was created. A 250 km^2-wide Transposition Zone was delimited, which was subject to further investigations in 2007 and 2008, including another series of coring and logging in four additional boreholes, and a tighter 2D seismic survey. From this work, a restricted 28 km^2 wide zone of interest (ZIRA) was identified as possible future repository area (Figure 1). In 2010, a 3D seismic survey was carried out to derive from it depth-converted seismic horizons and a 3D high resolution impedance cube that is 37 km^2 wide and covers the ZIRA. They were used to build a structural and geological model of the 3D seismic survey area that is suitable for safety assessment. The structural model is presented in the associated article of Yven *et al.* (2015) [1]. This article focuses on the geological model with the estimation of flow and transport rock properties.

Safety assessment studies require rock properties of the Callovo-Oxfordian claystone formation (COX) as input to simulate THM phenomena that should result from the implementation of a geological repository in the ZIRA. Up to eight types of flow and transport rock properties must be characterized and modelled in the COX: clay content, total porosity, bulk density, thermal conductivity, specific heat, diffusion coefficient, accessible porosity for different components and permeability. The intended repository being the source of all the physical phenomena to simulate, the geological model must be precise enough in and around the ZIRA to capture the spatial distribution and the heterogeneity of rock properties that are consequential for safety assessment. The particularity of this study is that no borehole, hence no rock data, are available within the 3D seismic survey area where the rock properties must be estimated. Consequently, relationships had to be inferred, between the seismic impedances (P-wave and S-wave impedances IP and IS) and the rock properties, from faraway wells where both types of data are present. These relationships were then used to estimate the spatial trends and spatial uncertainty of rock properties from 3D seismic data in the COX. Not all rock properties were successfully estimated this way. Only clay content, total porosity, bulk density and thermal conductivity were correlated with IP and IS, the clay content being best correlated.

The proposed approach required to address several issues.

- Change of support issues to relate at best rock property data representative of a small scale (30 cm for well-logs data, less for lab data), to 3D seismic impedance data corresponding to 7.5 m high support. The way to proceed to upscale rock properties depends on the available data (regularly spaced logs data vs. sparse lab data on cores) and the additive nature or not of the property (arithmetic vs. nonlinear averaging).

- Data integration issues to combine strongly correlated IP and IS data as spatial trend information on rock properties. Multivariate polynomial regression was used to derive and extrapolate "geophysical" estimates of the rock properties from IP and IS. The latter being known everywhere within and around the ZIRA, the "geophysical" estimates were used as spatial trend information about the corresponding rock properties.
- Bivariate statistical issues to infer and extrapolate bivariate distribution models that fully and properly describe the nonlinear relationships between "geophysical" estimates and rock properties. An innovative regression-based bivariate histogram smoothing method was used (Figure 1).
- Uncertainty estimation issues to quantify local uncertainty about rock properties from previously inferred bivariate distribution models. The smoothed bivariate histograms fully defining the relationships between "geophysical" estimates and rock properties, they were used to derive confidence intervals.

This approach allowed to estimate rock properties of the COX everywhere within the 3D seismic survey area and to quantify local uncertainty (Figure 2). The article will detail the approach and will present results obtained for different rock properties.

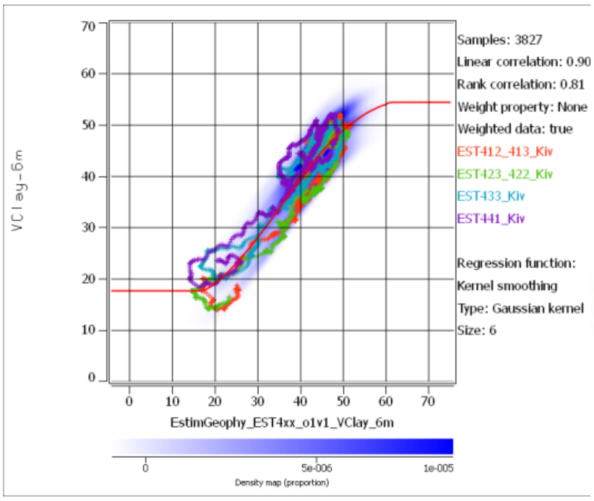

Figure 1: *Scatterplot and associated smoothed bivariate histogram (density map) of clay content vs. its "geophysical" estimate.*

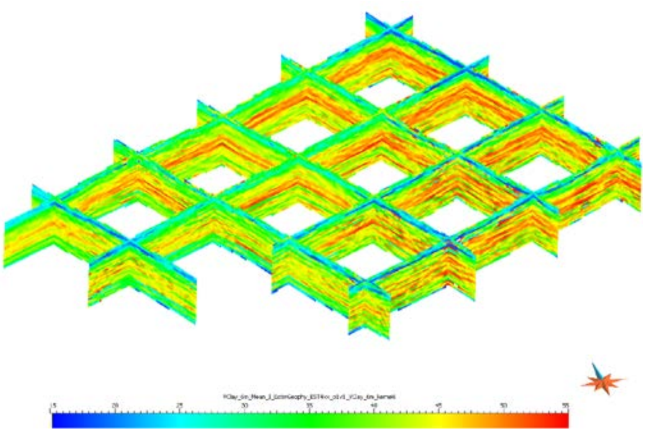

Figure 2: *3D view of mean clay content estimated at the 3D seismic grid scale (6 m high).*

References

[1] Yven B., Mathieu J.-B. and Garcia M.H., 2015. Geometry of the Callovo-Oxfordian claystone formation from depth-converted 3D-high resolution seismic data: modelling and spatial uncertainty. Submitted at the 6th conference on Clays in Natural and Engineered Barriers for Radioactive Waste Confinement, Brussels, Belgium.