Multivariate and spatial statistical analysis of Callovo-Oxfordian physical properties from lab and borehole logs data: towards a characterization of lateral and vertical spatial trends in the Meuse/Haute-Marne Transposition Zone

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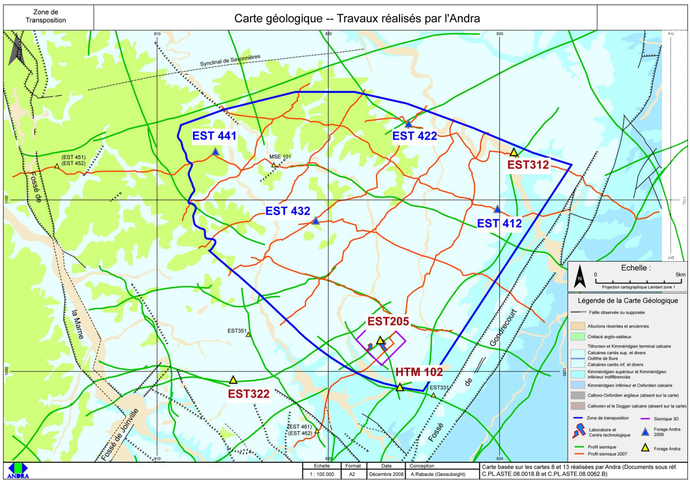

Figure 1. Meuse/Haute-Marne area. Blue contour: Transposition zone. Boreholes used in this study: blue triangles: 2007-2008 survey boreholes, yellow triangles: older boreholes.

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 and 3D seismic surveys were completed, as well as geological field observations, and an underground research laboratory was created. A 250 km2-wide Transposition Zone (Figure 1) 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.

The main objective of this study was to improve the knowledge of the spatial variability of geological and physical properties of the Callovo-Oxfordian formation. The paper focuses on the three following aspects of the study to present and discuss the methods that have been used and the results that have been obtained:

- Use of well-log data to identify equivalent homogeneous log-units on the boreholes.
- Relating log attributes to physical properties of argillites measured on cores in laboratory.
- Study of lateral and vertical spatial trends of selected physical properties (on logs and lab datasets) across the Transposition Zone (TZ).

To identify equivalent homogeneous log-units, a combination of Principal Component Analysis (PCA) and Fuzzy Cluster Analysis (FCA) was used. PCA was classically performed to reduce the number of variables to retain principal components gathering most of the original dataset variance. PCA was also used to identify isolated groups of correlated variables that could be associated to different properties of the formation. Then, FCA was applied to identify homogeneous log-units on the eight boreholes across the TZ.

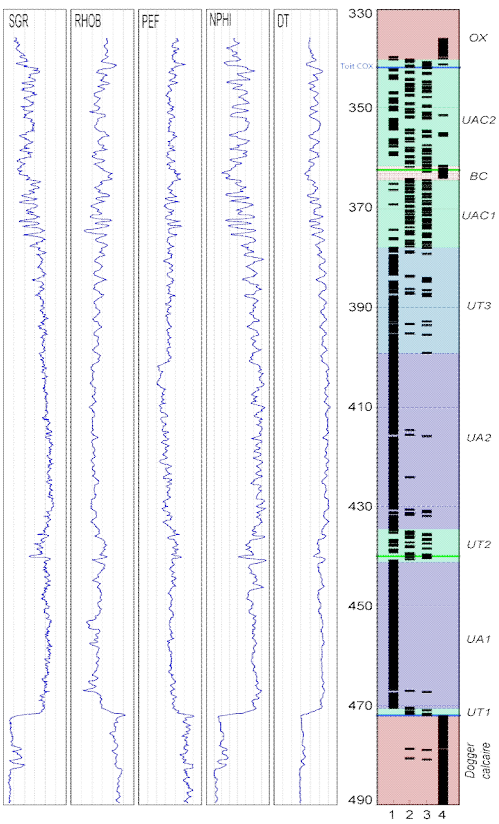

Figure 2. Example of log-unit sequence (right) obtained from statistical analysis of well-logs (curves on the left).

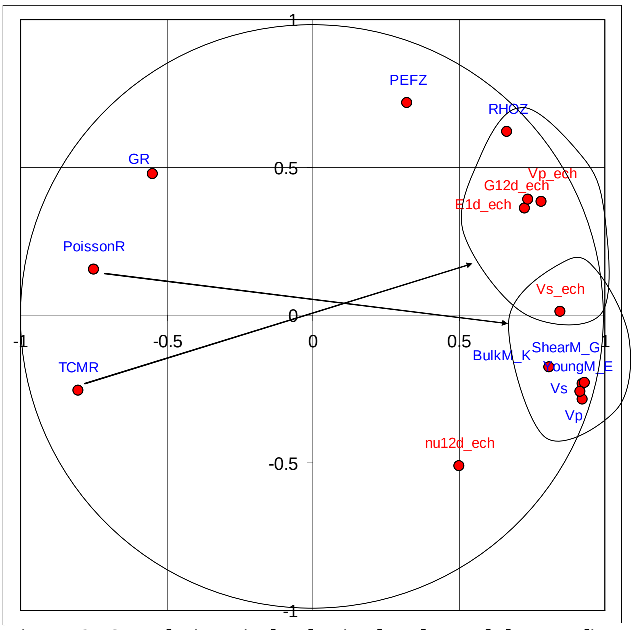

Figure 3. Correlation circle plot in the plane of the two first principal components (C1, C2) showing groups of correlated log and lab properties. The PCA relies on rank (Spearman) correlations.

Well-logs data being much more numerous and better (more regularly) distributed along boreholes than lab data measured on rock samples, relations and correlations were sought between the two types of data to identify log attributes that were likely to provide relevant information about the spatial continuity of rock properties as measured on cores in laboratory. To do so, multivariate statistical analysis methods, including principal component analysis based on linear or rank (Spearman) correlations, were carried out (see Figure 3). They show that well-log compressive velocity (Vp) is well correlated to static Young modulus and compressive strength measured on cores, and that downhole bulk density and Total CMR porosity are well correlated to dynamic Young modulus, dynamic shear modulus and compressive velocity on cores.

Studying the spatial continuity and trends of properties in argillaceous units was a primary objective of the study. To do so, the spatial analysis was first conducted on the well-log properties that proved to be well correlated to properties measured on cores, lab properties remaining the reference physical properties. Lateral and vertical spatial trends were observed and interpreted on the selected well-log properties (see Figure 4). In order to confirm that these spatial trends were effective and could apply to physical properties measured on cores, the spatial continuity of some correlated lab properties was studied. Similar trends were found that validated the approach of using log properties for characterizing the spatial continuity of core physical properties.

References:

Garcia, M., Rabaute, A., 2009. Zonage géomécanique sur la Zone de Transposition. Application aux forages de la campagne de reconnaissance 2007-2008. C.RP.0KID.09.001, *ANDRA Report*, Châtenay-Malabry, France.

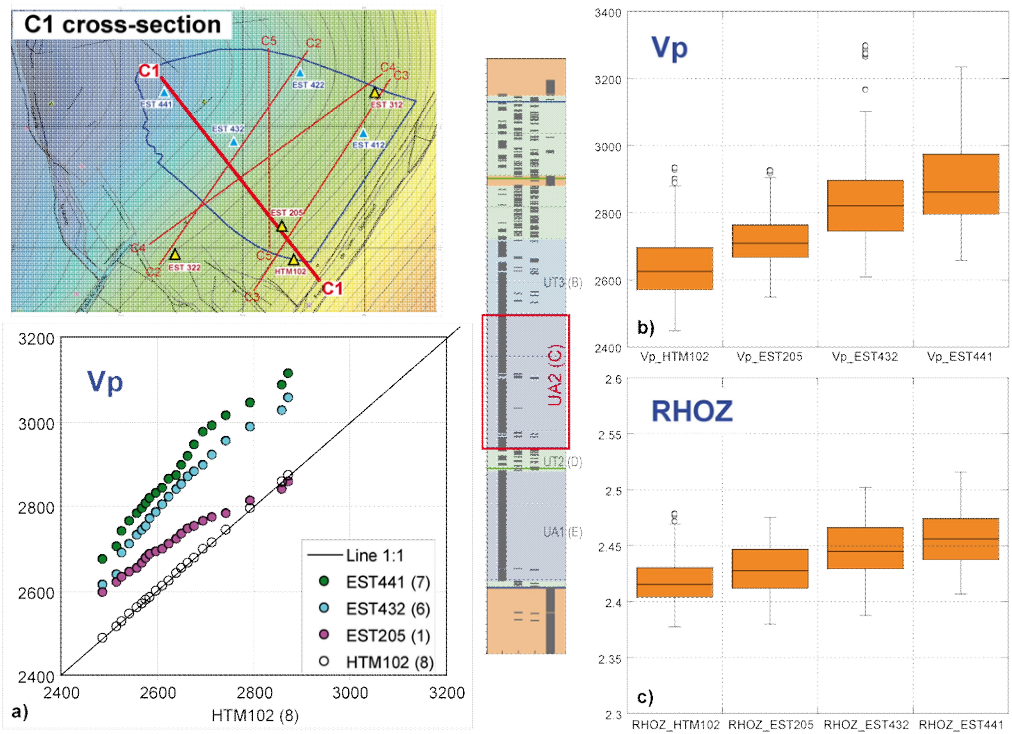

Figure 4. Typical spatial trend observed in argillaceous unit UA2 on log properties and confirmed by performing spatial analysis of physical properties measured on cores in laboratory.