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Building a 3D geological near surface model from borehole and laboratory data

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The interpretation of active seismic survey data usually results in a subsurface P-wave velocity model. Such models commonly do not include the near surface, but end a few hundreds of meters beneath the Earth's surface. However, near surface effects, such as low-velocity zones or topography can influence the seismic signal significantly. Therefore, it is important to extend the P-wave velocity model all the way to the Earth's surface. As a test site of this study, we use the underground gas storage facility in Chémery (France), located at the south-western border of the Paris Basin.

Velocities and lithological data of the shallow formations can be found in a public dataset, which collects data of a large number of short boreholes (BRGM online catalog: infoterre.brgm.fr/viewer). From the lithological data a structural model defined by surfaces gridded from well markers and faults derived from the analysis of these surfaces, is generated. The generation of the structural model comprised some major challenges, mainly because the borehole data represent 1D vertical pinpoints into the subsurface, rather than 2D sections as it is the case for most seismic surveys. This complicated the cross-correlation between the boreholes and the interpolation of the lithological formations in the 3D space. After the structural model has been generated, the velocity logs were upscaled to the model and interpolated to generate a near-surface P wave velocity model.

To better constrain the velocity model, laboratory measurements of P-wave velocity were conducted. We collected 24 hand specimens from outcrops, from which we drilled core plugs. The sampled lithologies are 6 different sedimentary rock types, mostly calcarenites. The measurements were conducted employing the pulse transmission method for compression (Vp) and shear (Vs) waves in dry and fully water saturated conditions. Density and porosity were measured with two different methods: (1) with a helium pycnometer, and (2) measuring the variation of weight for dry and fully saturated conditions. Porosity ranges between 0% and 45%. In fully saturated conditions, Vp values increase on average by 10% compared to dry conditions while the Vs values decrease on average by 15%. Alteration of outcrop samples can affect the elastic moduli of the rocks significantly and has to be taken into account.

The laboratory velocity measurements were then compared with the uphole velocity logs and the data were used to generate a 3D near-surface model of petrophysical properties for the lithological units in the study area. In the future, this velocity model will be used to better interpret a passive seismic acquisition campaign that was held in the area to record low-frequency seismic waves above the reservoir.