Poster presentation

Modeling near surface with shallow borehole information

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The characterization of the near-surface layers becomes nowadays extremely important for a clear interpretation of seismic data. The development of a detailed model of the weathered zone, and in particular a structural model with the subsurface geometries and a velocity model, allows correcting most of the problems deriving from peculiar situations. The combination of borehole and field data in a three-dimensional framework will improve the interpretation of already existing seismic data and add valuable information for numerical studies.

As a test study, we developed an integrated 3-D model of the shallow surface geology and of the shallow velocity field of an area of 187 km^2 above an underground gas storage site in the south-western part of the Paris Basin. The geology of the site is well studied and characterized at the gas reservoir level, but there are not publicly available models for the near surface geology. A few outcrops allow the observation of a shallow stratigraphic column consisting of sedimentary rocks spanning from Late Cretaceous to Pliocene. The Cretaceous sediments consist in terrigenous chalks and their weathering products, while the formations deposited during the Cenozoic are mainly continental, with the exception of one late marine episode. The youngest deposits are fluvial terraces that cover most of the area east of the facility.

The raw data used to generate the model interfaces are stratigraphic markers, lithological columns and uphole surveys derived from 512 boreholes belonging to the public repository of the Geological Survey of France (www.brgm.fr/infoterre). Topographic and geological maps and digital elevation model were additionally used to improve the reconstruction of the lithological interfaces in the model, knowing the formation limits at the topographic surface.

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

Horizons were modeled with Petrel interpolating the stratigraphic well markers. 2-D grids were generated, each representing the top surface of a specific formation, and then were subsequently used as a guide for structural interpretation. We looked for evidences of faults and strong marker displacements in the boreholes and then compared our observation with measurements of local and regional trends in the Paris Basin and with cross-sectional views of the horizons. The detection of structural anomalies, in particular localized dip and thickness variations was enhanced using edge detection and isopach maps. The obtained horizons and faults were used to define the 3D geocellular model, in which facies and velocity logs were then upscaled and distributed based on a geostatistical analysis.

The 3D geological model clearly shows the presence of an anticline in the Cretaceous sediments with a NW-SE direction (Fig.1.a). The analysis of boreholes, maps and cross-sections suggests that this anticline is dissected by preferably meridian-trending structures. The fault surfaces obtained are in agreement with the deep Triassic fault system highlighted by two depth maps as shown in Fleury et al., 1997. These faults seem to affect not only the Cretaceous but also the uppermost formations, being reactivated during Cenozoic. Most of the faults are concentrated in the facility area and have conjugate directions N10E-N30W; some of them are aligned N70E-N80E-N120E. They have short displacements that decrease upward, except for two points where it was possible to identify two faults isolating a “cone” of chalk. Such displacement features could also be accentuated by dissolution processes and alteration of the chalk driven by pre-existing fractures.

The 3-D Vp model reconstructed from the velocity well data shows a constant increase of the velocity in depth with localized velocity inversions (Fig. 1.b). To better constrain the velocity model, laboratory measurements of P-wave velocity were conducted on core plugs taken from 24 hand specimens. The measurements were conducted employing the pulse transmission method for compression (Vp) and shear (Vs) waves in dry and fully water saturated conditions. These measurements improved the understanding of the borehole velocity model explaining the anomalies observed. Such anomalies in fact can be caused by lateral heterogeneities in the characteristic facies of a specific formation, as in the case of silicified Cenozoic levels, or by porosity variations related to strong diagenesis in the Cretaceous chalks.

Further developments include using the 3D model as a starting point for numerical simulations of near-surface effects in seismic data, improving the comprehension of ambient seismic wave field attributes.

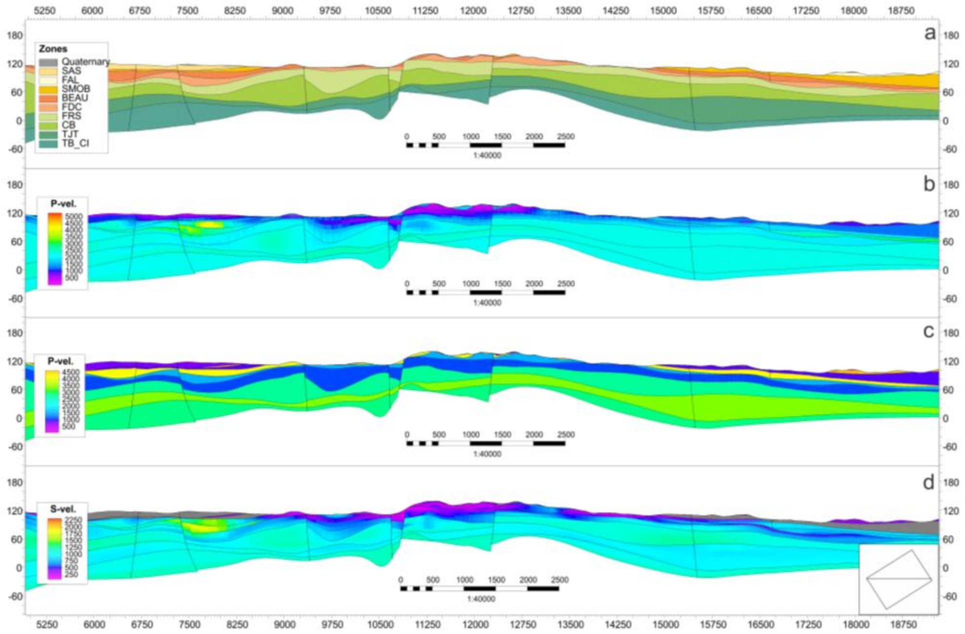

Fig.1 W-E cross sections through the 3D model showing the main lithologies (a), p-wave velocity from uphole survey data (b), p-wave velocity from laboratory measurements (c), experimental s-wave velocity derived from the application of a wet Vp/Vs ratio(d) to the Vp borehole model.

References

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