Conclusion

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Geophysical and hydrogeological investigations are essential for aquifer characterization. Drawing on their extensive experience in geophysics applied to the oil and gas sector — as well as in geotechnical and hydrogeological studies — the authors demonstrate how conventional seismic methods, typically used in exploration and reservoir imaging, can be effectively adapted for hydrogeological investigations, particularly in karstified geological formations.

The Hydrogeological Experimental Site (HES) of Poitiers, developed for long-term monitoring and experimentation on water and mass transfer processes, has been extensively studied using both hydrogeological and geophysical methods. This book presents an overview of the various field experiments conducted at the site and highlights their respective contributions to the understanding of the karstified Dogger limestone (identical to the supra-Toarcian aquifer) of the Poitou threshold.

A 3D seismic survey was designed to acquire a volumetric image with broad horizontal coverage. Structural interpretation revealed a nearly horizontal stratigraphy with a gentle westward dip of approximately one degree, indicating the absence of significant vertical tectonic displacements. In addition to the 3D seismic survey, the HES was also analyzed using pseudo three-dimensional (3-D) Electrical Resistivity Tomography.

The 3D seismic volume was then transformed into a pseudo-velocity model using acoustic velocity logs for calibration, and subsequently into a pseudo-porosity model. This model revealed three high-porosity, and presumably water-bearing, layers at depths of 35–40 m, 85–87 m, and 110–115 m — interpreted as karstic horizons. These horizons were confirmed through acoustic logging and borehole

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wall imaging using an Optical Televiewer (OPTV). A specific acoustic attribute, K-index, was developed to identify karstic bodies. However, due to the seismic data's lower vertical resolution (on the order of meters) compared to that of logging tools (centimetric to decimetric), some karstic features were detected only by borehole logs.

The authors show that 3D seismic imaging enables the construction of a large-scale structural model that can highlight potential karstic zones. These must then be validated through high-resolution borehole investigations, such as full waveform acoustic and OPTV logging. By correlating karstic features with the stratigraphic framework, the discontinuities that control karst formation can be identified, leading to a new karstification model constrained by stratigraphy.

At the HES site, the authors demonstrate that karstic horizons in the Dogger limestone are closely associated with stratigraphic discontinuities and early diagenesis. Sedimentation hiatuses, precisely constrained by the absence of specific ammonite zones, together with the emersion of the Poitou Threshold carbonate platform, are interpreted as the primary controls on these levels, through the promotion of hardground formation and subsequent dolomitization. The aquifer is thus composed of multiple productive layers that may be hydraulically connected through faults in the vadose zone and joint systems in the saturated zone. Typically, boreholes are drilled to intersect all karstic levels, which results in mixing waters of varying pressure and chemical composition. These wells are particularly vulnerable to surface pollution, posing a risk of contamination to deeper karst systems. Therefore, a detailed lithological and paleontological description of each borehole is essential to assess the role of stratigraphy in water inflow distribution. Well logging should be systematically performed prior to completion and equipment installation, using techniques such as flowmeter, gamma-ray, OPTV, and other geophysical tools to accurately locate karstic horizons.

The karstification model proposed for the Poitou threshold has practical implications. Once a large-scale structural model and karstic levels have been identified, two key recommendations emerge:

1. acquire optical televiewer data from all available boreholes to refine stratigraphic interpretations and accurately locate karst features;
2. consider individually screening each karstic level during borehole completion. This approach allows for a better assessment of groundwater quality and vulnerability and supports the long-term management of deep karst resources as protected reserves.

The field experiments at the HES site support a multi-objective strategy for mapping karst conduit networks, based on the following key methods:

- identification of water-producing zones in each borehole. This involves logging techniques such as long normal resistivity, temperature, electrical conductivity, and flowmeter logging — the latter being particularly effective in detecting active flow zones. High-resolution borehole imaging via OPTV enables identification, localization, and sizing of fractures, vugs, and karst conduits.

Full waveform acoustic logs provide mechanical parameters (e.g., P-wave velocity) and are used in seismic inversion to define karst detection indices. Vertical Seismic Profiling (VSP) supports time-to-depth conversion and can indicate karst features through Stoneley wave analysis;

- 3D imaging of the aquifer reservoir. In karstified limestone aquifers, seismic methods are recommended to identify major karstic levels. The processed 3D seismic volume is converted into depth, then into a pseudo-velocity model constrained by acoustic logs, and finally into a pseudo-porosity model after calibration with borehole data;
- hydraulic tests. Cross-hole pumping tests are used to detect flow paths. High hydraulic diffusivity observed in slug tests aids in building connectivity maps. At the HES site, such tests differentiate wells that are hydraulically connected to the karst network from those that are not;
- tracer tests. Tracer breakthrough curves help define the number and nature of distinct flow paths between injection and observation points. These dye tracer tests also highlight the role of boreholes in the mixing of karstic levels by identifying ascending or descending hydraulic gradients within each borehole;
- combined geophysical and hydrogeological analysis. The integration of these data sets enables the detection of water-producing zones and the delineation of probable karst conduit networks.

Beyond the detailed case study of the Dogger limestone at the Poitou threshold, the authors offer a robust methodology for seismic and stratigraphic characterization that can be applied to other hydrogeological contexts and reservoir studies.