Exploring Hydrogeologic Parameters Through Surface Nuclear Magnetic Resonance Across Diverse Environments

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Abstract

Quantification of in-situ hydraulic parameters is very important to the development of a hydrogeologic framework. Over the last 20 years, the surface nuclear magnetic resonance (sNMR) technique has seen significant advancements in data acquisition and data processing, emerging as an effective and viable tool in hydrogeophysics. As a non-invasive method, sNMR is valuable for determining critical hydrogeologic parameters such as porosity and hydraulic conductivity. One key advantage is the direct measurement of volumetric water content and the ability to differentiate between fractions of mobile water (found in large pores) and bound water (found in small pores), which is important for characterizing groundwater flow and contaminant transport. As applications of sNMR expand, there is an increased understanding of its effectiveness across various hydrogeophysical environments.

In the summer of 2024, diverse environments were explored with three field sites selected for sNMR data collection, each representing different lithologies. These sites included: (1, New Jersey) marine terrace sands and silt sediments forming an aquifer impacted by salt-water intrusion; (2, Kansas) sand and gravel interspersed with clay and shale; and (3, Idaho) an unconfined sand and gravel aquifer sitting above a clay aquitard. The primary objectives across these three different projects involved identifying suitable areas for well-field development, understanding the hydrogeologic framework, and obtaining hydraulic parameter estimates for groundwater flow models. The role of sNMR was to assist in interpreting other geophysical and hydrogeological data to help support the projects' objectives. Furthermore, time domain electromagnetic (TDEM) surveys were collocated with the sNMR to provide resistivity models to facilitate sNMR data inversion. The differing levels of geophysical and hydrologic data at these sites allow for an evaluation of sNMR, enhancing our understanding of its applications, capabilities, and limitations in geophysical investigations.

Preliminary sNMR data from the three field sites correspond well with the additional data available at each site. At the Kansas site, driller's logs from nearby wells indicated water levels ranging from 6 to 12 meters. These logs reveal a consistent stratigraphy comprising a thin layer of topsoil, followed by clay, and transitioning to limestone and shale at greater depths. Some logs also indicate the presence of thin layers of gravel and sand, which are the target for sNMR analysis. Spatial mapping of these sand and gravel layers beyond the well locations is now possible because sNMR results align well with the locations of the water level and sand and gravel layers identified in the driller's logs. In the case of the unconfined aquifer (Idaho), sNMR results correspond with water level data obtained from both TDEM data and driller's logs, indicating that sNMR may be useful for mapping water levels in the absence of wells. While the driller's logs offer more vertical resolution, the overall trends in water content are consistent with the lithological patterns observed. Ongoing analysis of additional geophysical and hydrogeological data from field sites will enhance understanding of the identified trends and how various environments influence geophysical narratives.