

COMBINING ADVANCED GEOPHYSICAL LOGGING METHODS TO INCREASE RESOLUTION AND HYDROGEOLOGIC CHARACTERIZATION OF SAPROLITE AND THE SAPROLITE-TO-BEDROCK TRANSITION ZONE

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Saprolite, residual soil derived from in-situ weathering of bedrock, is present across much of the Piedmont Plateau in the eastern U.S., as well as many other regions in humid temperate and tropical climates where crystalline bedrock is exposed at surface. Saprolites are an important part of the Critical Zone, connecting the atmosphere/climate and surface hydrology to groundwater hydrology, and providing water recharge and storage to fractured bedrock aquifer systems. High resolution and quantitative characterization of in-situ geologic/hydrogeologic properties of saprolites and the saprolite-bedrock transition zone, and their heterogeneity, is often limited or non-existent, resulting in a poor understanding of the hydrogeologic processes that link the vadose and saturated zones in saprolites to underlying bedrock aquifers.

A series of research boreholes on the West Chester University Campus in eastern Pennsylvania, U.S. intersect the surficial soils, saprolite and the saprolite transition zone before entering the underlying bedrock aquifer system. A suite of borehole geophysical logging measurements were conducted in one of the boreholes MW-8 in September 2021 as part of a Field Hydrogeophysics Workshop, including Borehole Magnetic Resonance (BMR) logging. BMR tools measure lithology-independent volumetric water content (total porosity in the saturated zone), as well as the pore scale movability of the water (pore size distribution in saturated conditions) using well-proven NMR measurement and processing methods. In turn, with additional information about the lithology, these downhole BMR measurements are used to derive moveable water volume (specific yield in the saturated zone), and capillary and clay bound water (specific retention in the saturated zone), as well as to estimate hydraulic conductivity that can be calibrated with well or core hydraulic tests. The BMR logs from MW-8, coupled with the EM conductivity log, provide high resolution delineation of hydraulically conductive portions of the saprolite transition zone, including a productive water zone that correlates with a screened interval in the offset MW-7 at similar depths. Above this zone the total porosity is high (25-40%), along with an increase in electrical conductivity, corresponding with the silt-rich, highly chemically weathered middle and upper saprolite zones. Upon closer review of gamma, induction and other logs, there appears to be several additional thinner and lower porosity hydraulically conductive zones below the main production interval that could potentially be hydraulically isolated, overall porosity decreasing with depth to the crystalline bedrock. Observations while drilling encountered several “false bedrock” zones before penetrating the true bedrock, also suggesting potential isolation from the main zone of interest.

This paper examines how the BMR is used to provide high resolution hydrogeologic characterization of saprolite, revealing that the saprolite transition zone at the West Chester University research site is more complex than first anticipated, with multiple hydraulically conductive zones present. The BMR, EM conductivity and other log results from MW-8 are compared with measurements from offset boreholes to determine if additional information and insights about the saprolite profile and lateral continuity can be gleaned.