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Modeling Dielectric-constant Values of Geologic Materials: An Aid to Ground-penetrating Radar Data Collection and Interpretation

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ABSTRACT

Ground-penetrating radar (GPR) is a near-surface geophysical imaging technique used for non-intrusive subsurface geologic and engineering investigations. Dielectric constant is a critical parameter for GPR surveys because it controls propagation velocity of electromagnetic waves through material, reflection coefficients across interfaces of different materials, and vertical and horizontal imaging resolution. Dielectric constant in rocks and sediments is primarily a function of mineralogy, porosity, pore fluids, frequency, geometries, and electrochemical interactions between rock components. Reported dielectric-constant values for sedimentary rocks provide general ranges of expected values, but these values may not adequately represent rocks in specific field conditions.

Time-propagation mixing modeling, a forward-modeling technique, was performed and showed good correlation between modeled and measured dielectric constants of selected sandstones and limestones. Additional models were constructed to investigate the role of lithology and fluid saturation on dielectric constant and GPR response. Three modeled rock examples of variable mineralogy, porosity, and saturation illustrate that bulk dielectric constant, which generally ranges from 2 to 38 in the materials modeled, is primarily controlled by water saturation and, secondarily, by porosity and mineralogy, although these variables are interdependent. Without data stacking, differences in dielectric constant must be greater than 2 to produce reflections that can be recorded above background noise. For the examples modeled, saturation differences of less than 35% between layers produced reflection signals above background noise, but in completely dry material, normal mineralogic and porosity differences may not produce discernible reflections without stacking.

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