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Pore-Scale Induced-Polarization Modelling: A Synopsis of Basic Mechanisms

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Induced-polarization (IP) modelling aims at predicting the macroscopic electrical response of soils and rocks, or porous media in general, and understanding experimentally observed correlations with electrochemical, mineralogical, and textural properties. The underlying polarization processes are related to the transport of charge carriers through the porous medium and their accumulation and relaxation at internal boundaries, such as the mineral-pore water interface. In most hydrogeophysical applications, metallic minerals are absent and the measured electrical response is considered to be the result of an interplay of four basic polarization mechanisms: (1) polarization of the Stern layer of the electrical double layer (EDL), (2) polarization of the diffuse layer of the EDL, (3) membrane polarization, and (4) Maxwell-Wagner polarization. Mechanistic models, i.e. models based on first principles, describe polarization based on the Poisson-Nernst-Planck (PNP) equations for charge transport and the characteristic responses are the result of particular geometrical configurations and boundary conditions. Ideally, solving these mathematical problems does not only provide a model suited to explain measured data but provides insight into the underlying physical and electrochemical processes. In this contribution, we review long-known classical solutions and recent developments by integrating them into a general physical picture of polarization, which is needed to describe all relevant polarization mechanisms and assess their relative importance. The overview is rounded up by our own recent findings, which are mostly based on numerical solutions of the PNP system of equations and represent an important advance in IP modelling.