Geophysical Research Abstracts
Vol. 14, EGU2012-5203, 2012
EGU General Assembly 2012
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Relating bulk electrical conduction to litho-textural properties and pore-fluid conductivity within porous alluvial aquifers

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The estimate of hydraulic conductivity from Direct Current methods represents a powerful tool in aquifer characterization as both electrical and hydraulic conductivities depend on connected pore volumes and connected pore surface areas. A crucial, intermediate stage of this process is the assessment of sediments' textures and lithology from DC electrical conductivity as the electrical response of the aquifers' basic building blocks (i.e., hydrofacies) is controlled by the prevailing process of electrical conduction, electrolytic (σ_{EL}; pore-volume dominated) vs. "shale" (σ_{SH}; pore-surface dominated), determined by pore-space structure, clay distribution and electrical properties of pore fluids (σ_W).

In this work laboratory experiments were conducted and the results were interpreted through the analysis i) of a volume-averaged, macroscopic litho-textural property of alluvial hydrofacies', the coarse-to-fine ratio (C/F), as a "proxy" of the process of electrical conduction within each samples on the basis of the volume proportion between nonconductive, coarse-grained and conductive, shaly textures and ii) of the surface conduction component, produced in fresh-to-salt water environment by clay materials.

8 hydrofacies' samples were collected with an hand-auger within the outcropping alluvial aquifers of the Quaternary meander river belt of the southernmost Lodi plain (northern Italy), represented by loose gravelly-sands to sands (6 samples), fine and sandy-silty clays (2 samples).

As a first step, laboratory measurements of the bulk electrical conductivity (σ_B) of representative sub-samples, totally saturated with water with different salinity (σ_W from 125 to 1100 μs/cm), were performed. The experimental apparatus was made up by a series of polycarbonate, cylindrical cells (9cm x 12cm) equipped with external, copper plates as current electrodes and internal, copper squared-grids as potential electrodes. Electrical conductivity of each sample was obtained averaging time-repeated measures during 48 h after the samples' assemblage with a DC resistivity meter. As a second step, texture analysis was performed in order to obtain the textures' volume fractions of each hydrofacies subsamples; C/F threshold equal to 1 identifies coarse-grained litho-textural association (gravelly-sands to sands samples) and fine-grained litho-textural association.

Plot of σ_B vs. C/F generally shows an increasing conductivity with decreasing C/F ratio and increasing σ_W, that is consistent with previous studies perform on field-scale electrical conductivity datasets obtained through DC resistivity soundings calibrated on sediments outcropping the alluvial basin. The distributions of σ_B vs. C/F are fitted with a power-law regressions, showing a decreasing R2 with increasing σ_W.

A conduction model which takes into account C/F and σ_W and considers σ_B as the sum of two terms, σ_{EL} (pore-volume dominated) and σ_{SH} (pore-surface dominated), where surface conduction is treated as an equivalent shale volume conduction, was adopted. Values of σ_{EL} and σ_{SH} were computed for each sample and for increasing σ_W.