Forward rock-physics approach applied to the case of saltwater intrusion

1. A rock-physics transform is often a necessary step in solving groundwater problems geophysics is involved as it links a geophysical measurement to one or more geological properties of interest.
2. Electrical resistivity-based geophysical methods, already a mainstay in environmental geophysics, have been used with increasing frequency due in large part to the development and popularization of the airborne electromagnetic method.
3. The electrical resistivity measured in these methods (the bulk resistivity) is known to depend on the electrical properties of the sediment and those of the fluid(s) saturating the sediment.
4. A reliable estimate of the relationship between facies, fluid saturation, salinity, and bulk resistivity are of great interest. However, …..
5. Most development of data-driven models has focused on predicting facies from wireline logs. In most cases, a wealth of data is incorporated into these inverse rock-physics transforms
   1. We predict facies from wireline well log data for a fluvial deposit system offshore Norway. The wireline well logs used are sonic, gamma ray, neutron porosity, bulk density and resistivity (Lindberg et al using a 2-layer convolutional Hidden Markov Model)
   2. (Kadkhodaie-Ilkhchi et al comparing 3 ML techniques)
6. While effective methods, most machine learning and MCMC approaches have been applied to the wealth of wireline data to predict rock facies, the vast majority of which is not available in most locations, making the calibration only tenable in wells; beyond this, only in wells where a large amount of data has been collected.
7. In the field of environmental geophysics, estimating facies from wireline data is rarely an objective, since well completion reports are expected to contain lithology information as a requirement. More frequently, the goal of an environmental geophysicist is to estimate the relationship between lithologic and fluid characteristics and a surface or airborne geophysical measurement. In this sense, wireline data are used as a calibration tool, for the rock physics transform and/or for an inversion of collected geophysical data.
8. In the past decade, there has been a push to move away from the inverse rock-physics transform (e.g. inverted resistivity grid 🡪 lithology grid) and toward a forward rock-physics transform (e.g. lithology grid 🡪 resistivity grid) (Moysey, Singha, Hermans, Caers,…)

**Objectives:**

1. Create a reliable rock-physics transform to convert my saltwater intrusion simulations into a grid of bulk resistivity values for AEM simulation
2. Explore a new, data-driven method for creating the rock physics transform
3. (?) Evaluate the efficacy of fluid resistivity logs for groundwater geophysics applications

**Motivation**

1. A rock-physics transform is often a necessary step in solving groundwater problems geophysics is involved
2. In the past decade, there has been a push to move away from the inverse rock-physics transform (e.g. inverted resistivity grid 🡪 lithology grid) and toward a forward rock-physics transform (e.g. lithology grid 🡪 resistivity grid) (Moysey, Singha, Hermans, Caers,…)
3. The forward rock-physics transform can help solve complicated geophysical questions where the inverse rock-physics approach may fail
4. However, most of the new frameworks using the forward rock-physics transform use simplistic rock-physics transforms (pixel-based correlation, Archie’s law), despite that the stochastic frameworks that often employ the forward rock-physics transform are not beholden to a deterministic function (e.g. Archie)
5. We propose a data-driven approach to the forward rock-physics transform applied to the case of estimating bulk resistivity in a coastal environment where both lithology and salinity are highly variable.