CORRELATING ELECTRICAL CONDUCTIVITY TO UNCONSOLIDATED SEDIMENT PARAMETERS USING NUMERICAL MODELING

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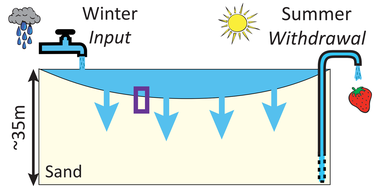
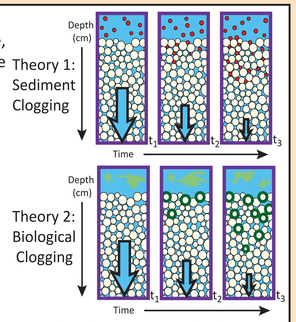
hydrogeophysics research group

1)Motivation

Why??

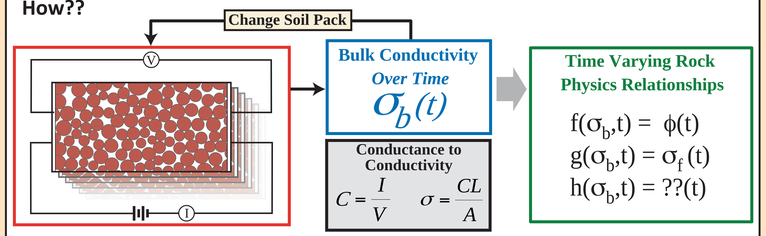
An artificial recharge pond has been created in Watsonville, California to augment groundwater resources. Infiltration rate in the pond decreases over time due to clogging.





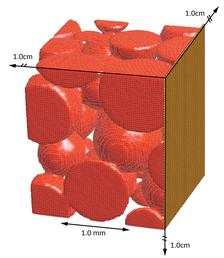
Electrical conductivity can be related to soil properties, such as porosity, through rock physics transforms (e.g. Archies Law). In dynamic systems, where soil properties are changing, we need to develop **time-varying** rock physics relationships in order to infer the perturbation mechanisms.

How??



Treat the earth as a simple circuit and use the conductance (C) to **calculate the conductivity** (σ_b). Use **rock physics** to relate conductivity to a parameter of interest.

2) The Model



The Grain Packs

Three types of grain packs:

- Uniform Random pack (Jodrey&Tory, 1979).

Packs were discretized on a three dimensional grid and bulk electrical conductivity was numerically calculated for the sample using a finite volume approximation (Pidlisecky et al. 2007).

Numbers
Random Grain Size Distributions
0.80-1.20 mm * 2 samples
1.00-1.00 mm * 2 samples
1.00-1.50 mm * 2 samples
Porosity, ϕ
Random: $0.39 < \phi < 0.43$
Discretization
Total model size: ~1.00cm^3
Voxel side: 64µm
Voxels: 16.5 million
Computer
8core, 3Ghz Xeon w/ 64GB ram
Run Time: 36 hours per model

3) Calculated Parameters

Porosity, ϕ

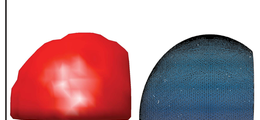
Volume of the void space (V_V) = empty voxels

Total volume of the sample (V_T) = total voxels

$$\phi = \frac{V_V}{V_T}$$

Surface Area, S_S

A Delauny mesh approximation was applied in the complicated case of three or more overlapping spheres. Otherwise, an analytical solution was used.

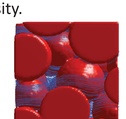


$$S_S = \frac{S_T}{V_T}$$

Tortuosity, τ

Found by particle tracking using the gradient of the electrical potential field.

The distribution calculated is less positively-skewed than hydraulic tortuosity.

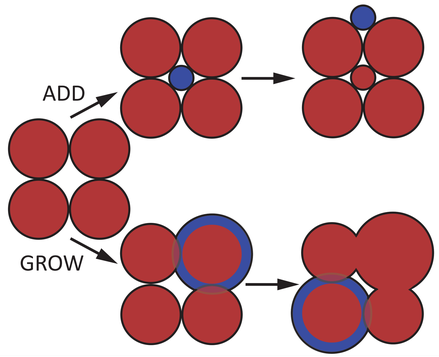


$$\tau = \frac{L_P}{L_S}$$

4) Clogging Experiments

Pack Perturbations

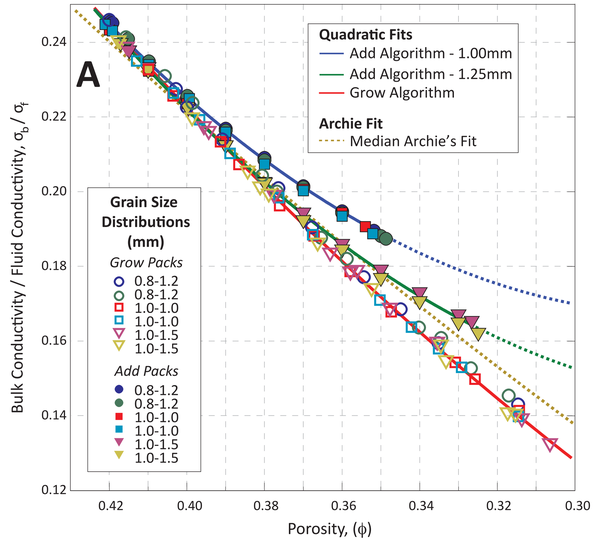
The sphere packing program generated random grain packs that had a porosity of 0.40±0.03. Thus, to explore the effects of porosity on electrical conductivity two simple algorithms were employed: a grain-addition algorithm and a grain-growing algorithm. These algorithms represent *changes* to a sediment pack over **time**.

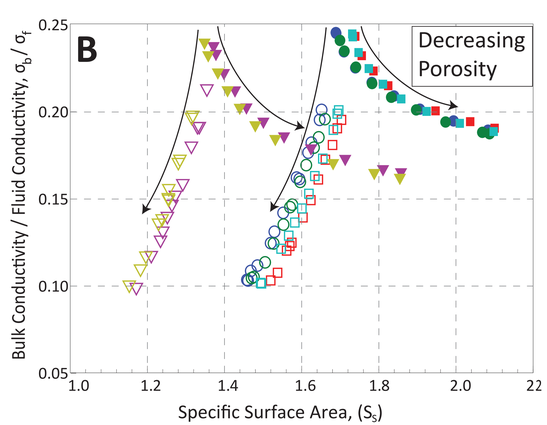


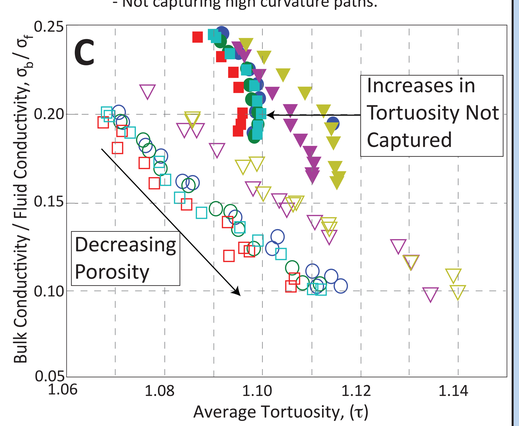
ADD
Represents addition of fines to the soil matrix through the random addition of non-overlapping, voxel centered spheres.

GROW
Represents pore throat clogging caused by a biofilm. This model has been used to represent grain cementation (Roberts and Schwartz 1985).

5) Results







(A) Pack Perturbations

- Add algorithm creates packs which are more conductive than the Grow algorithm.
- Two approximate separation points from the Grow algorithm: related to average grain size.

Creating a rock physics transform (i.e. fitting the data)

- Sorted into three groups:
  - Grow Algorithm;
  - Add Algorithm: average grain size of 1.25mm;
  - Add Algorithm: average grain size of 1.00mm.
- Fit best by a quadratic relation.
- Not fit well by Archie's Relation (Archie, 1942).

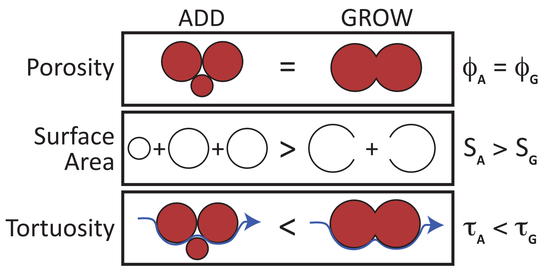
(B) Specific Surface Area

- **Grow algorithm:**
  - Positive non-linear relation
- **Add algorithm**:
  - Negative non-linear relationship
- Helps explain grain size specific differences within the Add algorithm.

(C) Tortuosity

- **Grow algorithm**:
  - Negative linear relationship
- **Add algorithm**:
  - Negative non-linear relationship.
  - Unreliable at low porosities.
  - Not capturing high curvature paths.

6) Conclusions



Take home message:

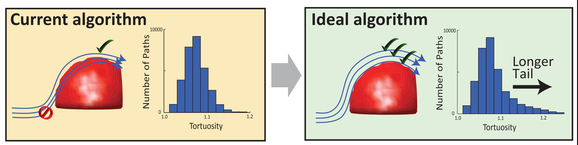
1) ADD and GROW Algorithms yield different **rock physics relationships** as ϕ changes **(i.e. time-varying relationships)**.

2) For the packs considered here, Tortuosity appears to scale with surface area.

7) Future Work

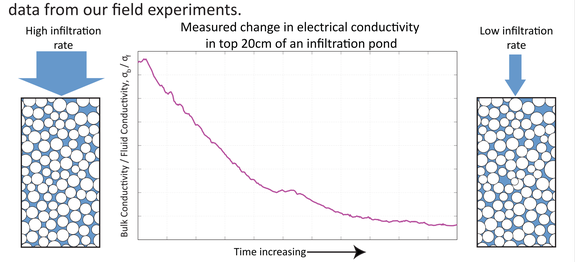
Improving the Model

The tortuosity calculation needs to be able to handle high curvature interfaces to further explore relationships between electrical conductivity and tortuosity.



Applying the Model

Time-lapse conductivity data have been collected from multiple probes in an artificial recharge pond. We wish to use the results of our ADD/GROW experiments to infer the mechanism that is responsible for the reduced infiltration rate. However, to do this we need to link porosity (as measured here) to time (as measured in the field). This necessitates the inclusion of addition flow data from our field experiments.



8) References & Acknowledgments

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