



# Spectral Induced Polarization Signatures of Ethanol (EtOH) in Sand-Clay Medium

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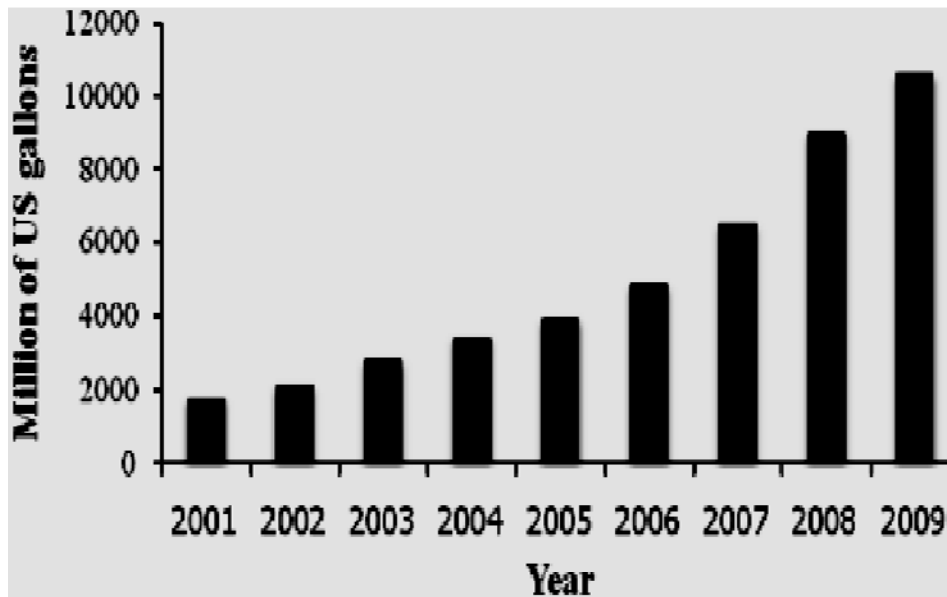
# Acknowledgements

- Funding for this research is provided by U.S. EPA under contract (EP10D000751) to Yves R. Personna
- Jeff Heenan
- Chi Zhang
- Angelo Lampousis
- Kristina Keating

# RUTGERS Background and Motivation

**Ethanol Spill:  
Production, Storage, Transportation**

## US Ethanol Fuel Production



**Source, RFA,  
Int. Trade Commission**

**November 2006 - Cambria, MN  
28,000 gals E95**



**July 2004 - Balaton, MN  
60,000 gals E95**



**Source : Mark A. Toso, 2008**

# RUTGERS Background and Motivation

- ✓ **Potential negative effects of ethanol on microbial community and water quality**

- **Toxicity to soils and aquifer microorganisms**

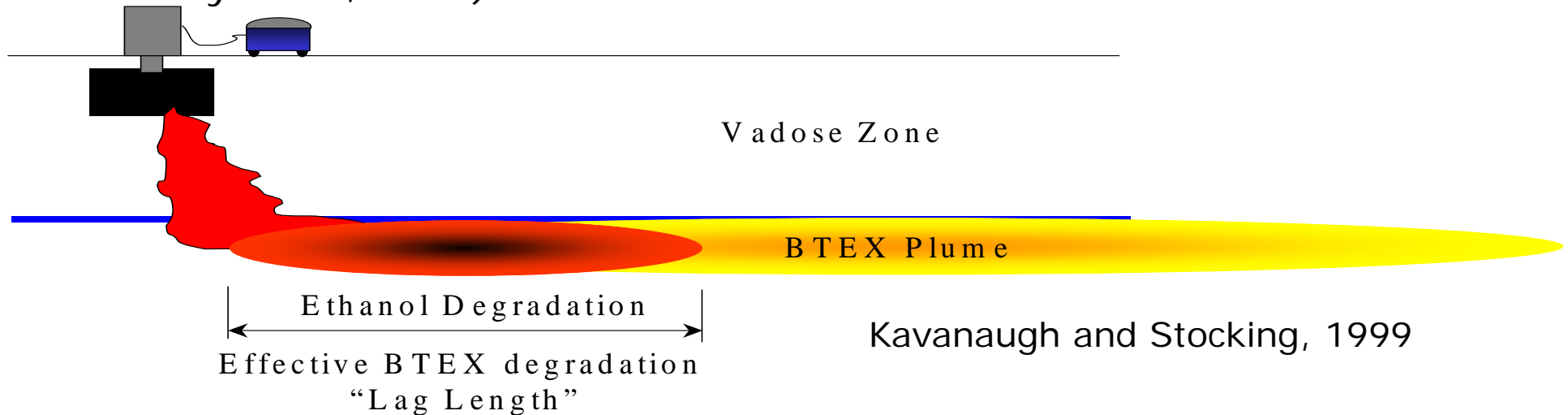
(Ma et al., 2011; Nelson et al., 2010; Capiro et al., 2008)

- **Cosolvency effects of ethanol**

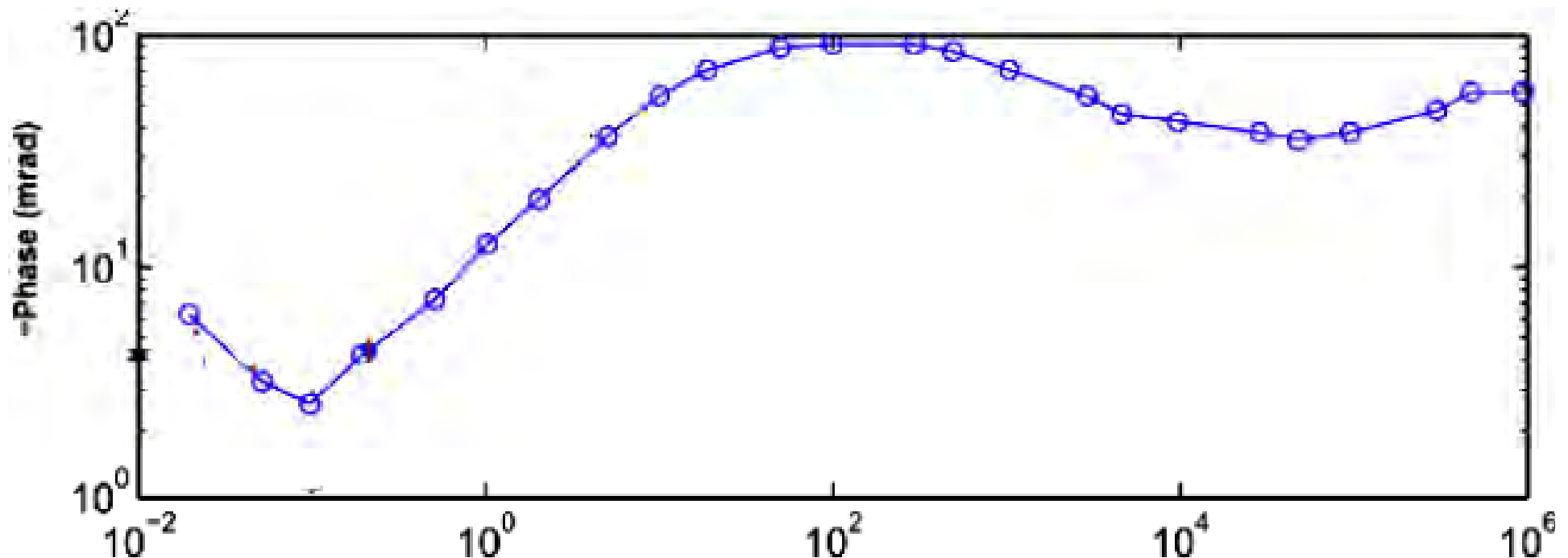
(DaSilva et al., 2002; McDowell et al., 2003; Gomez & Alvarez, 2009)

- **Reduction of natural attenuation of BTEX**

(Corseuil et al., 1998; Ruiz-Aguilar et al., 2003; Powers et al., 2002; MacKay et al., 2006)

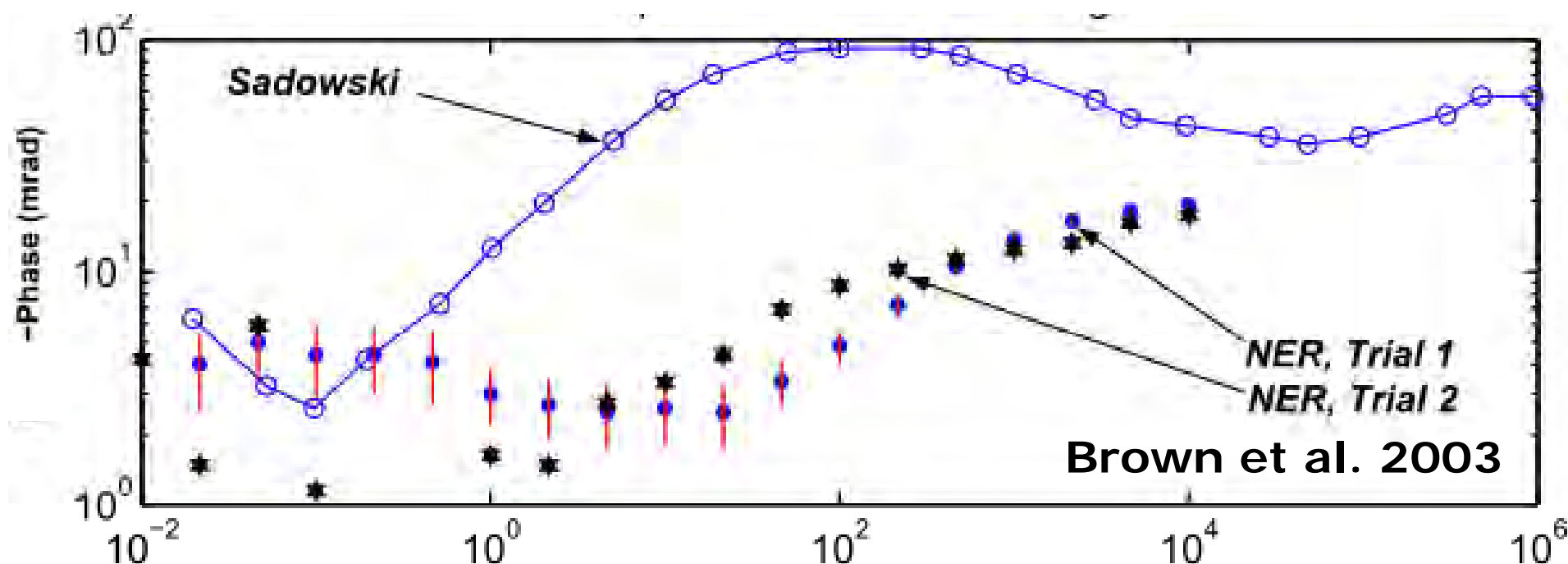


## Can Electrical geophysics be used to Monitor EtOH in subsurface?



Clay-organic contaminants (Toluene) Polarization  
**Sadowski, 1988**

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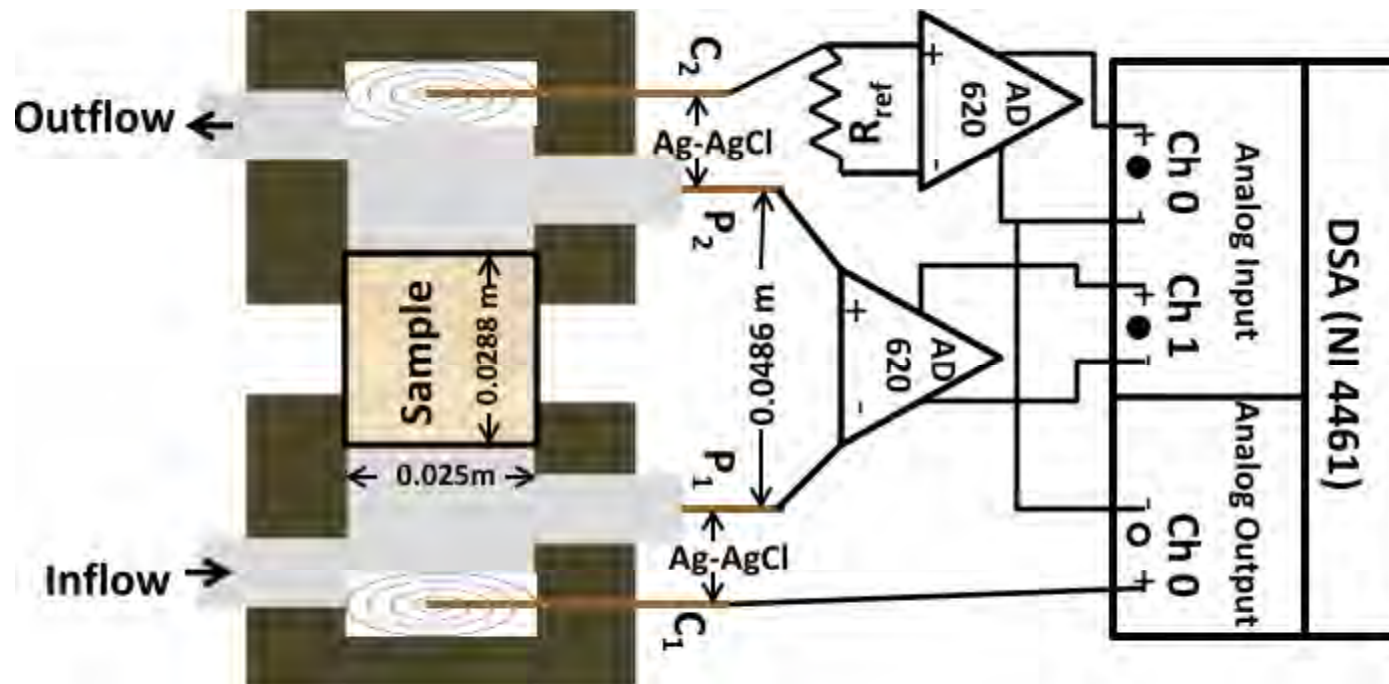
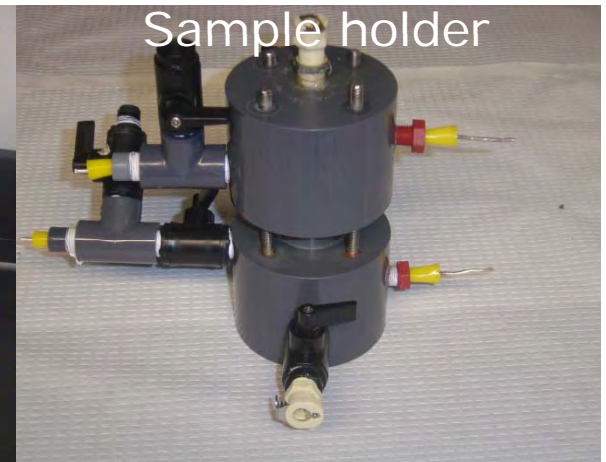
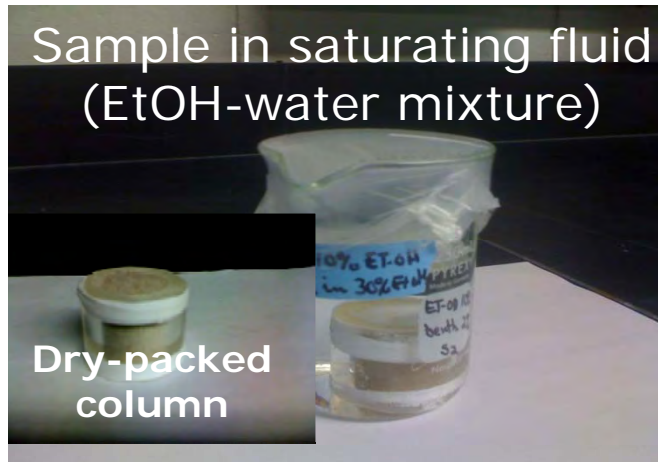


Clay-organic contaminants (Toluene) polarization

# **RUTGERS RESEARCH OBJECTIVES**

- **Determine the electrical properties of EtOH in sand-Clay medium**
- **Determine if clay-organic reactions associated with EtOH enhance or suppress SIP response**
- **Develop a model of the physico-chemical mechanism characterizing EtOH-Clay interactions**

# Experiment setup



SIP measurement (.1-1000Hz)/Dynamic Signal Analyzer (DSA)

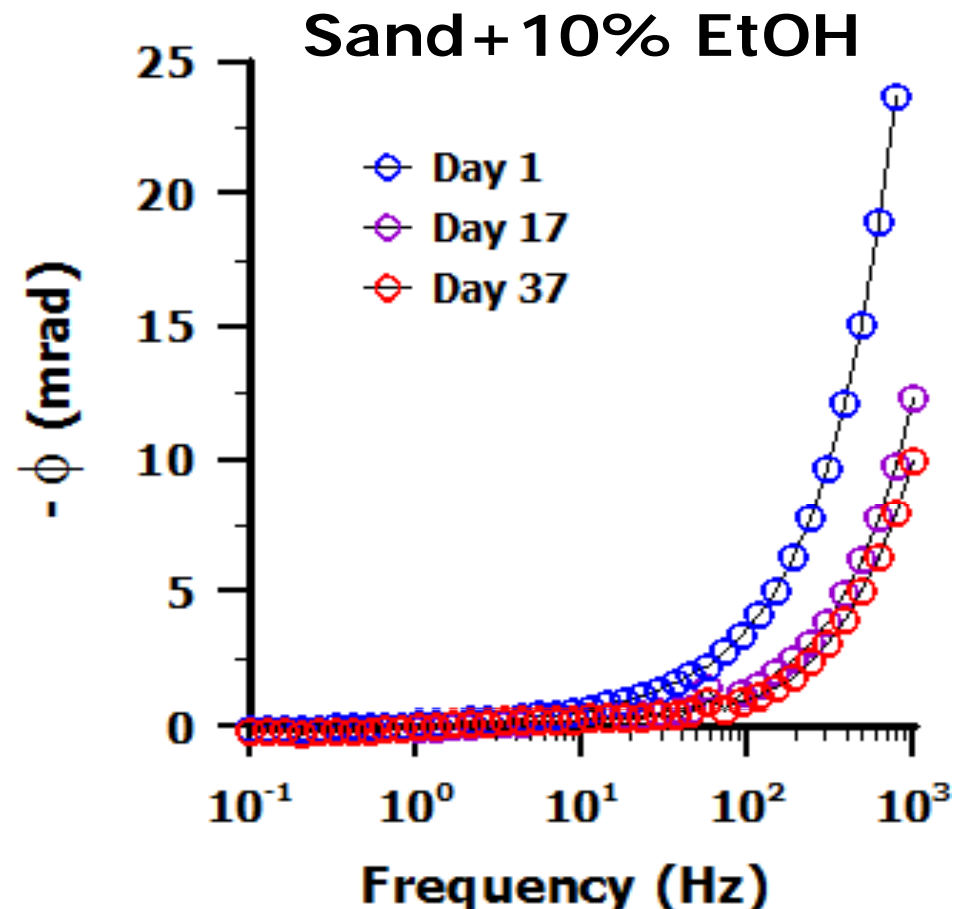
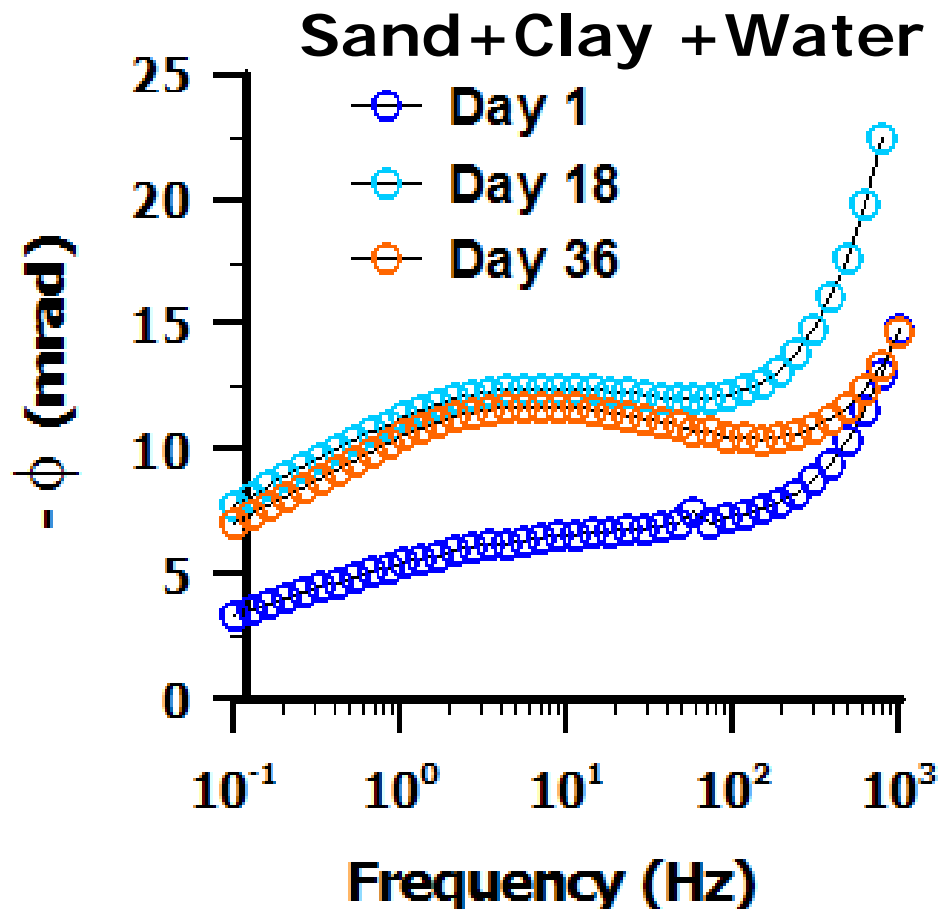
## 4 media in replicate :

- Sand + Clay ( 2% clay w/w)  
EtOH-Water Mixture (10% EtOH v/v)
- Sand + Clay (2% clay w/w)  
EtOH-Water Mixture (20% EtOH v/v)
- Blank : Sand (0% clay)  
EtOH-Water Mixture (10% EtOH v/v)
- Blank: Sand + Clay (2% clay w/w)  
Water (0% EtOH)

# Results and Discussion

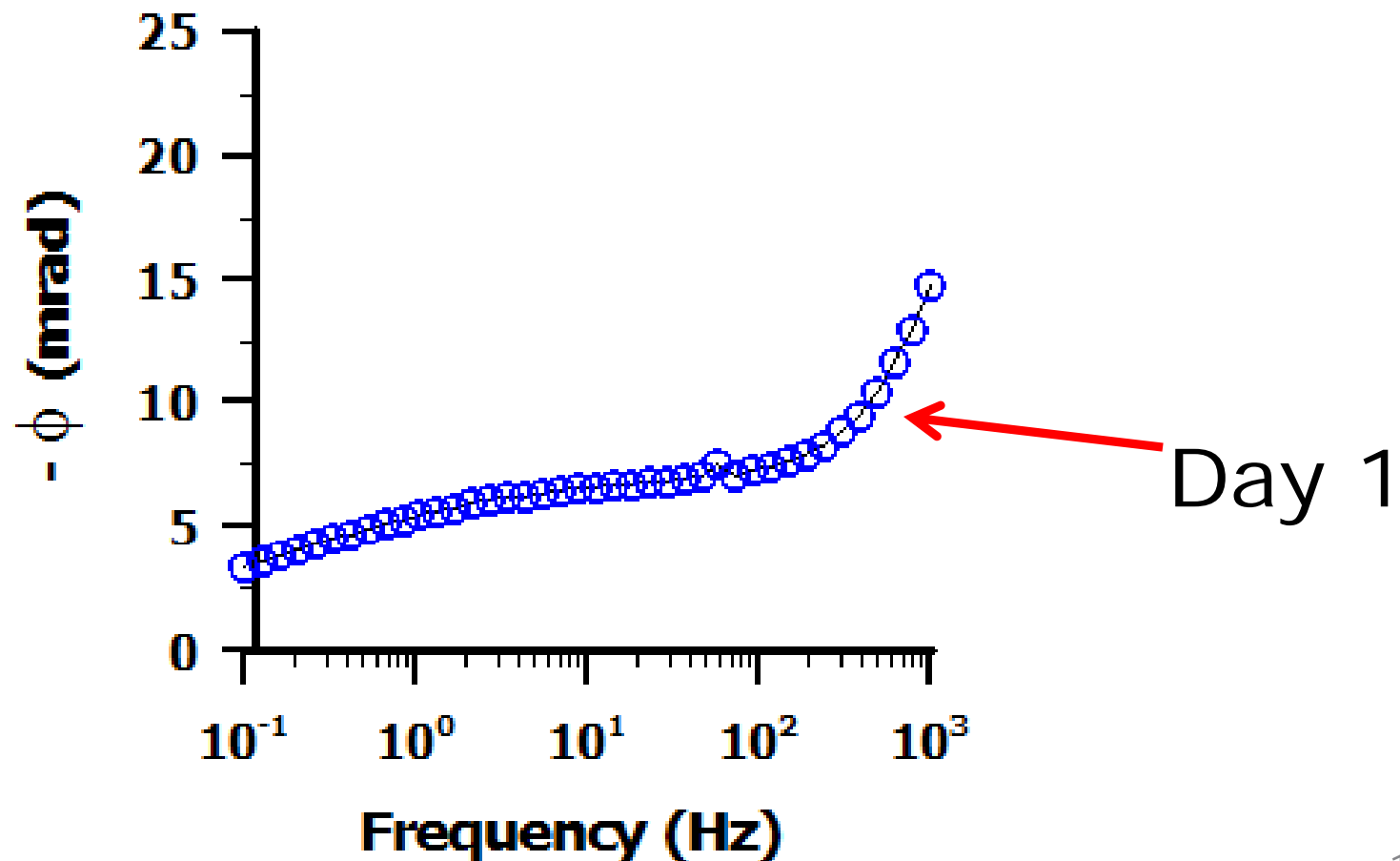
# RUTGERS Clay driven polarization effects

- Time dependent electrical response
- But clearly higher  $\phi$  response in clay



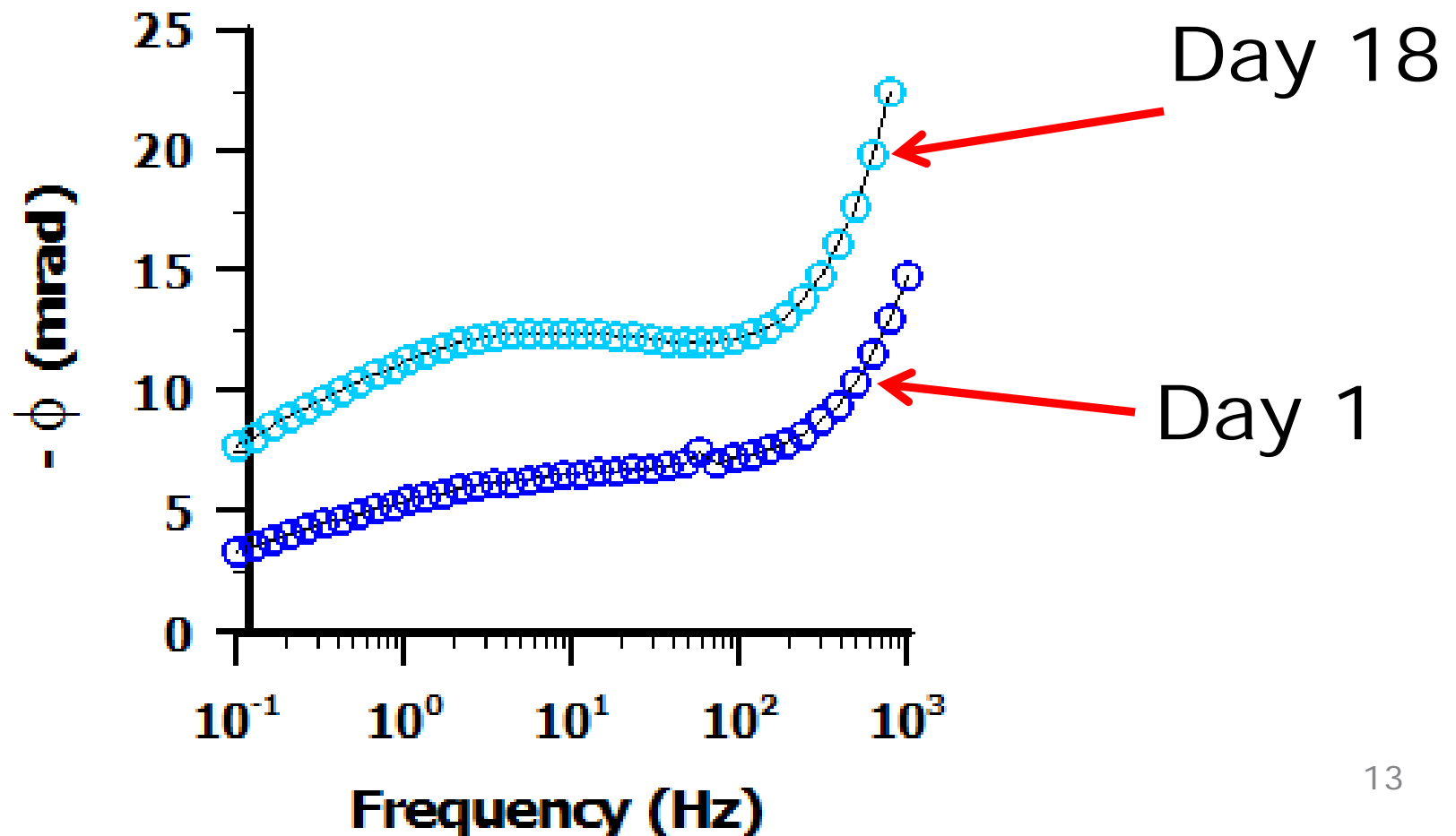
# RUTGERS Clay driven polarization effects

- Time dependent phase response  
Sand+Clay + Water



# RUTGERS Clay driven polarization effects

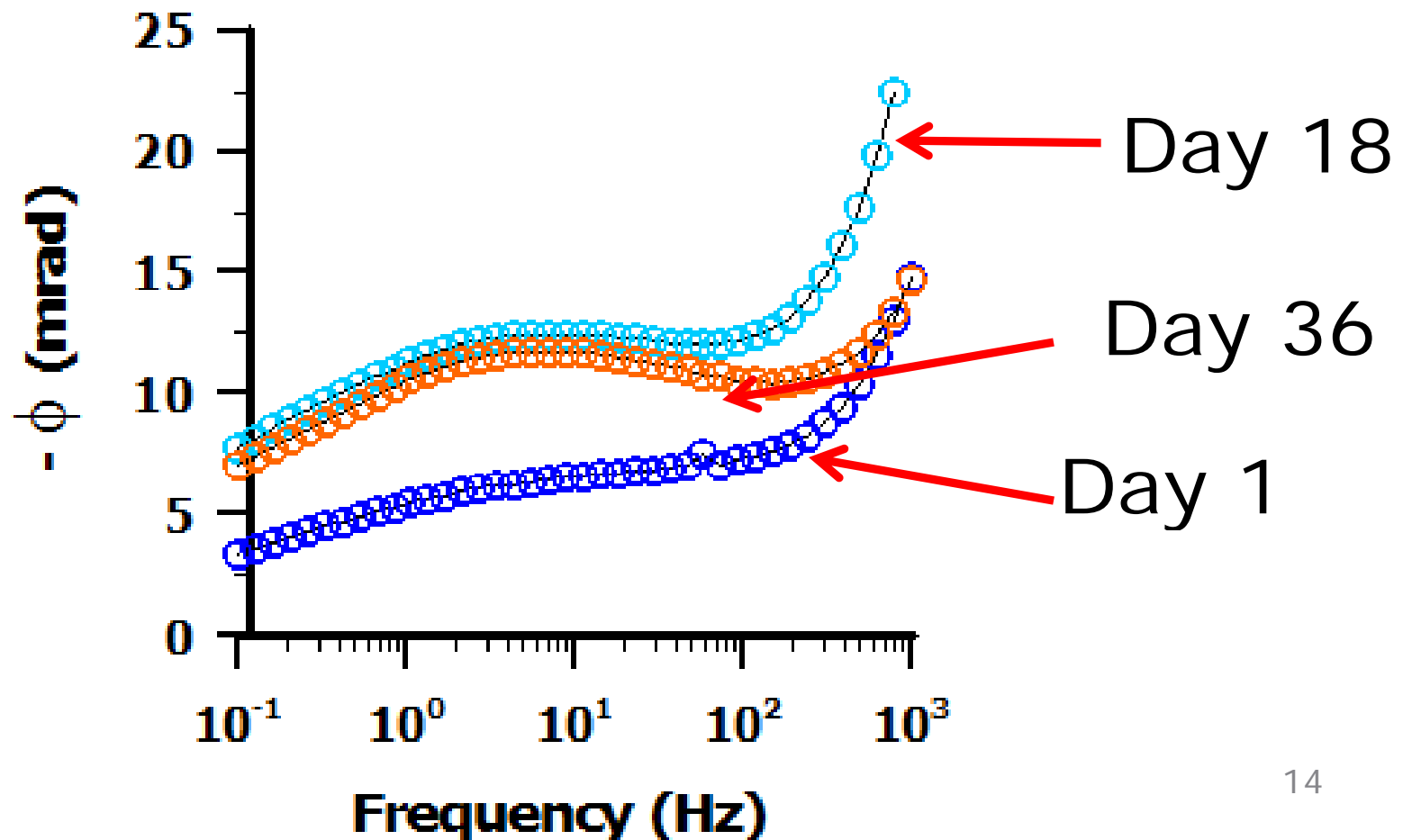
- Time dependent electrical response  
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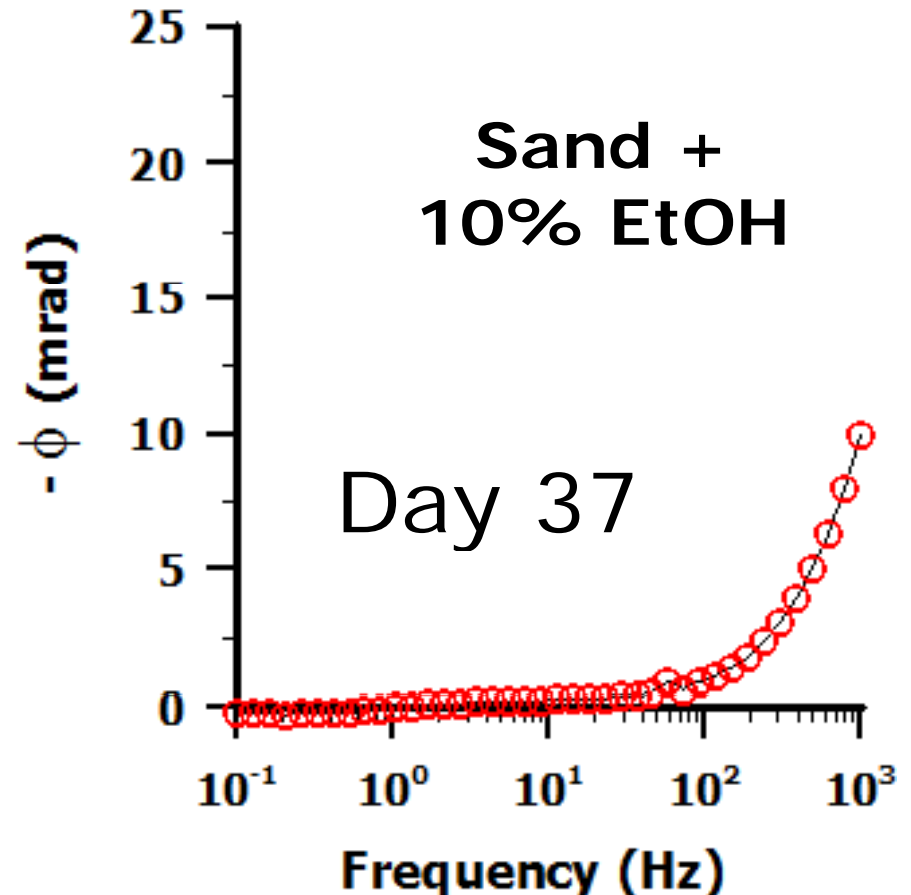
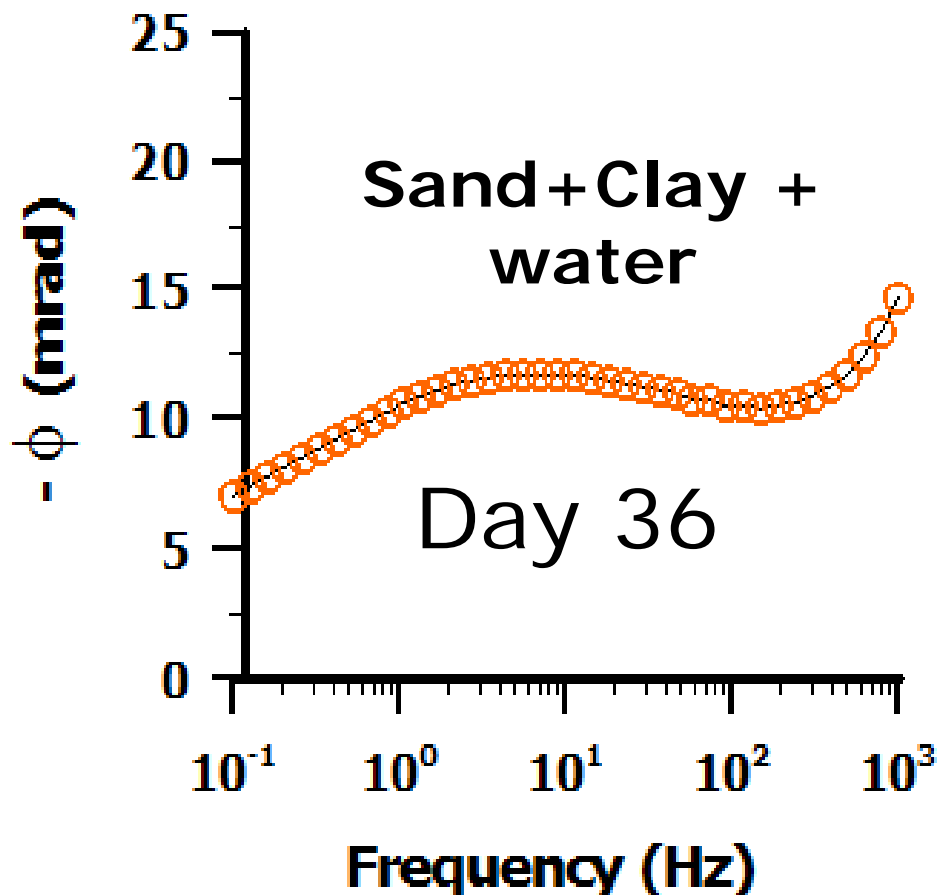
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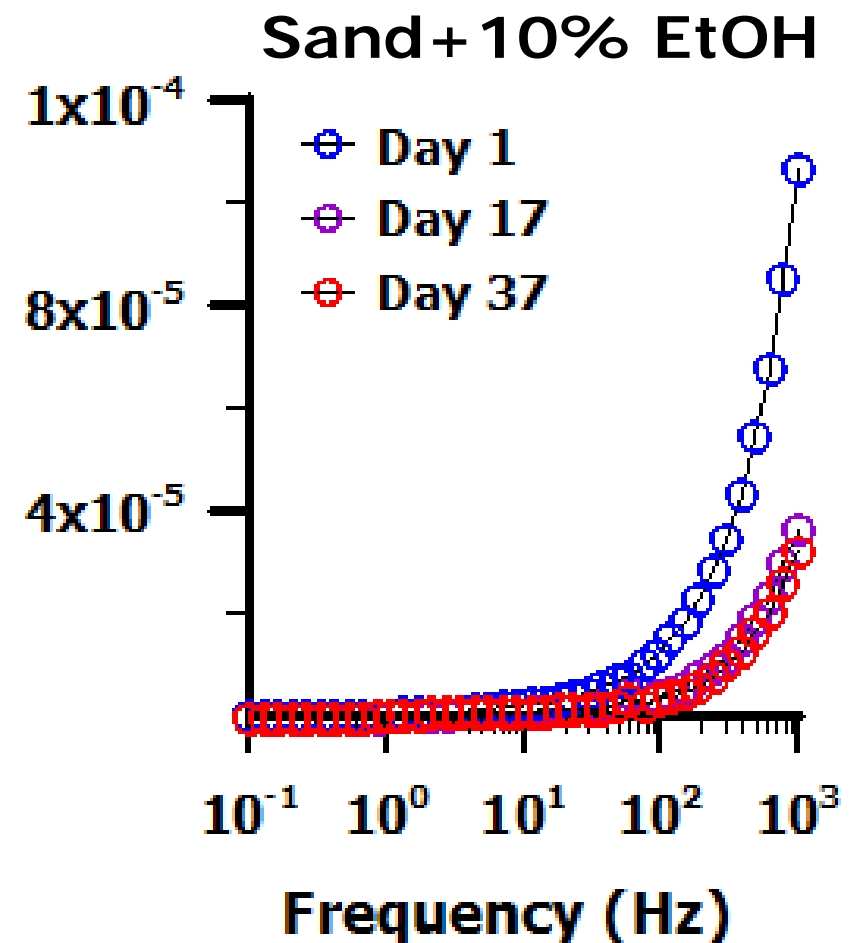
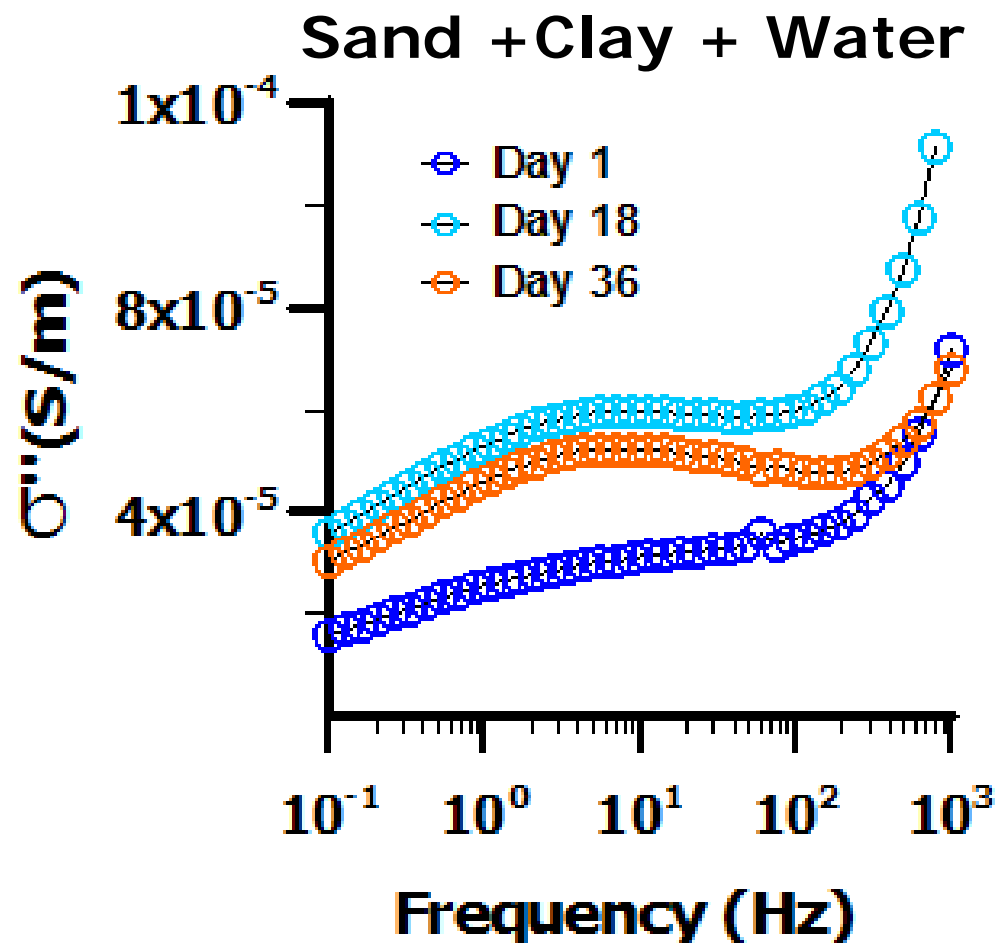


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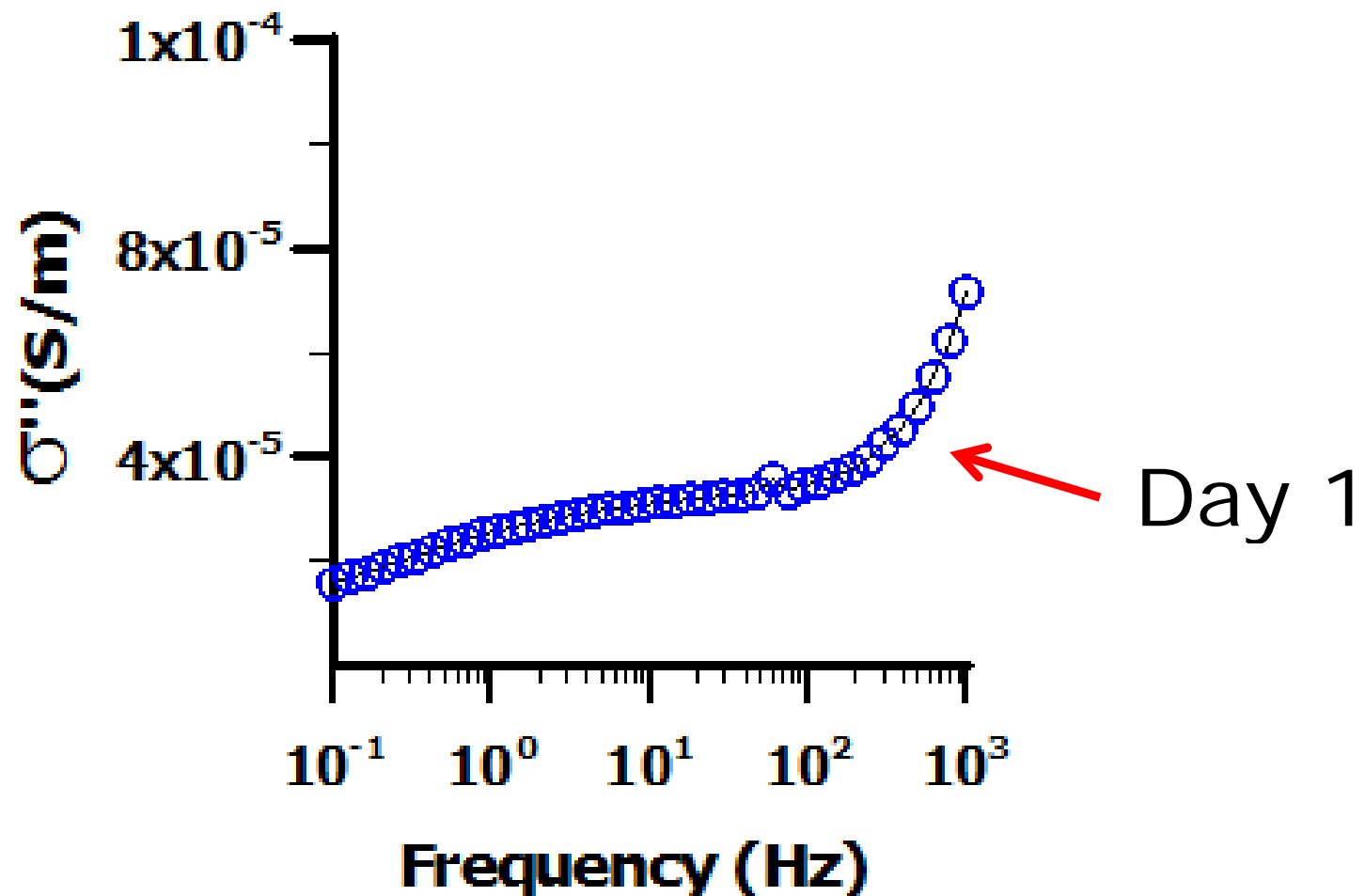
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# RUTGERS Clay driven polarization effects

- Time dependent  $\sigma''$  response

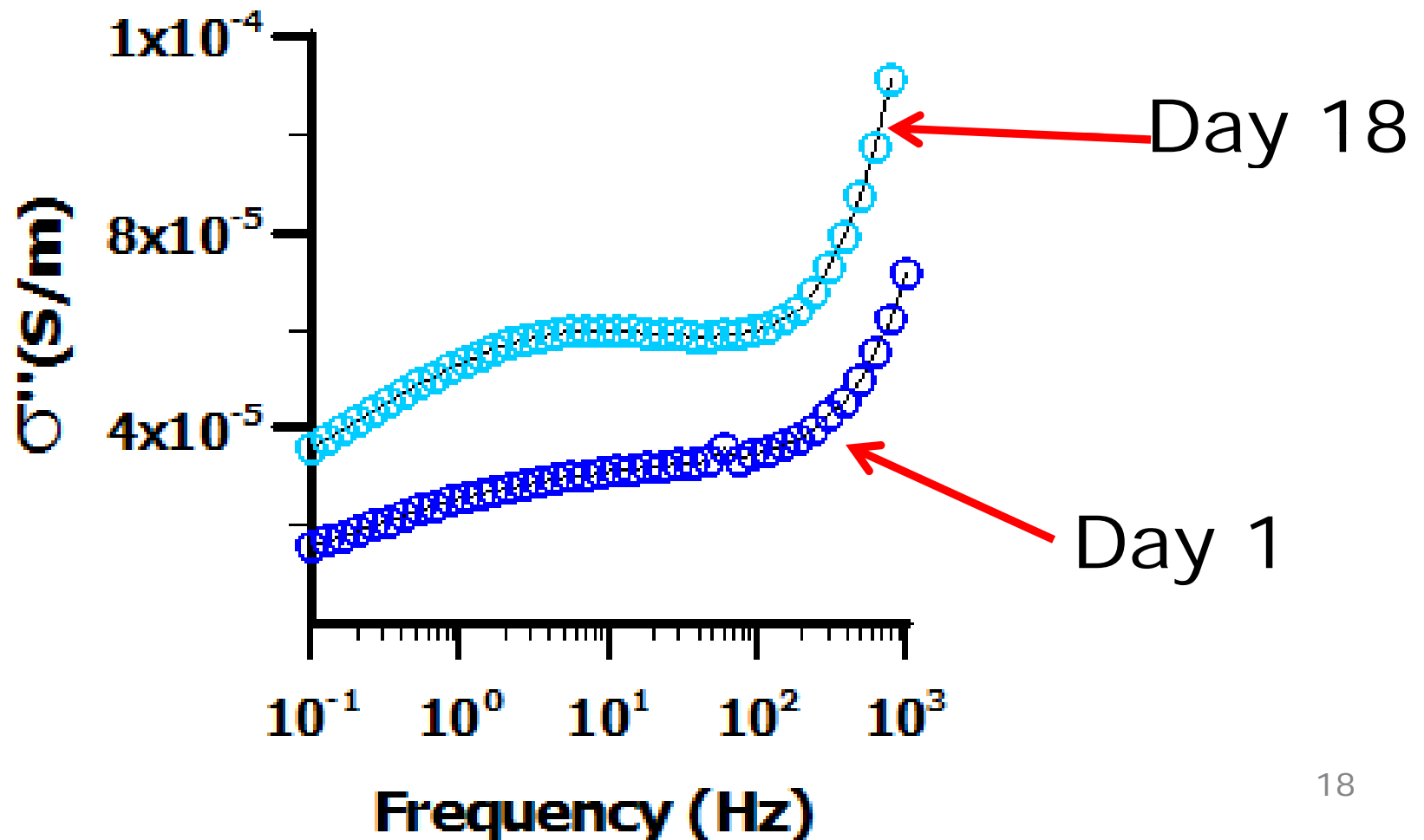
Sand+Clay + Water



# RUTGERS Clay driven polarization effects

- Time dependent electrical response

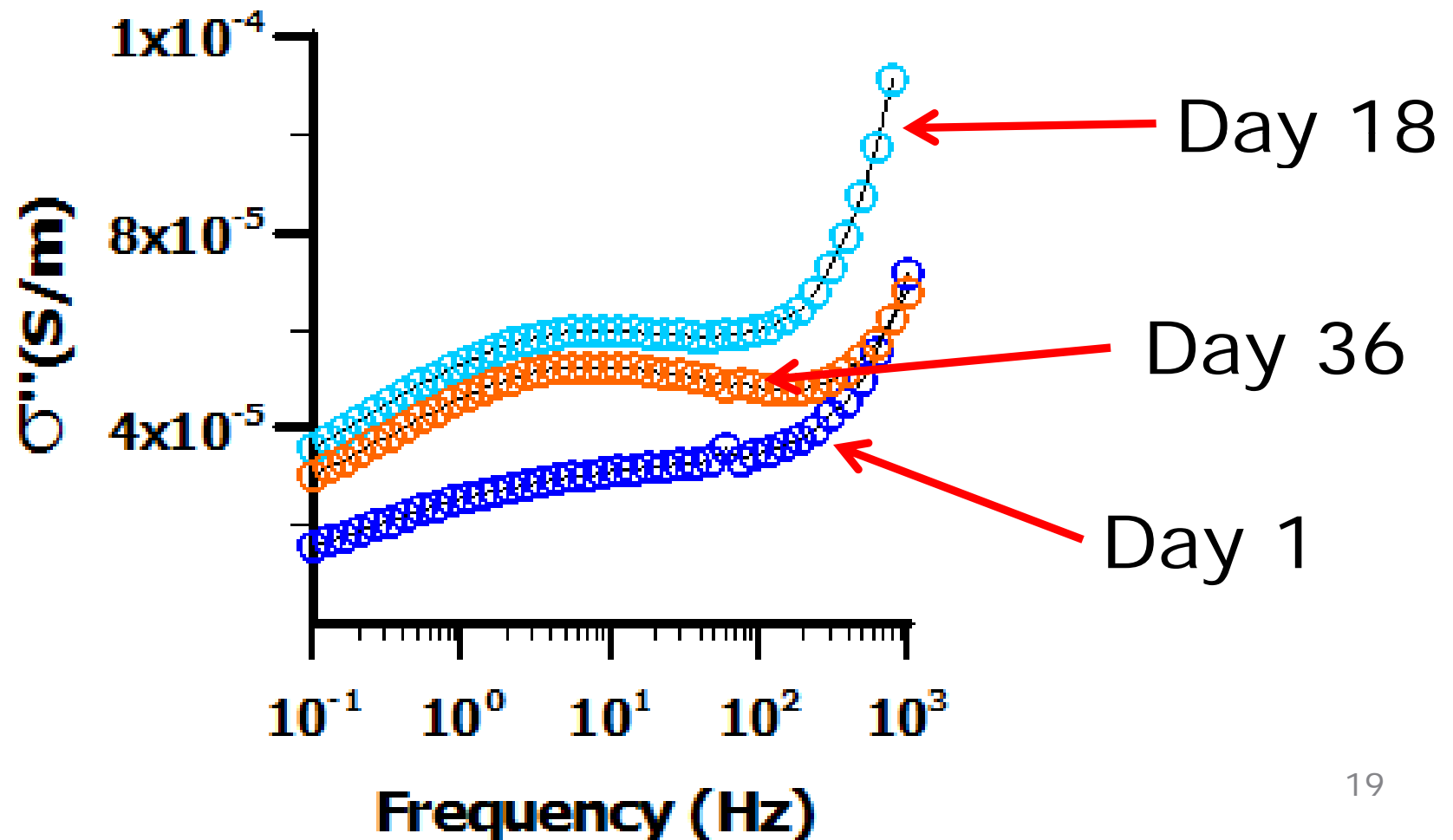
Sand+Clay + Water



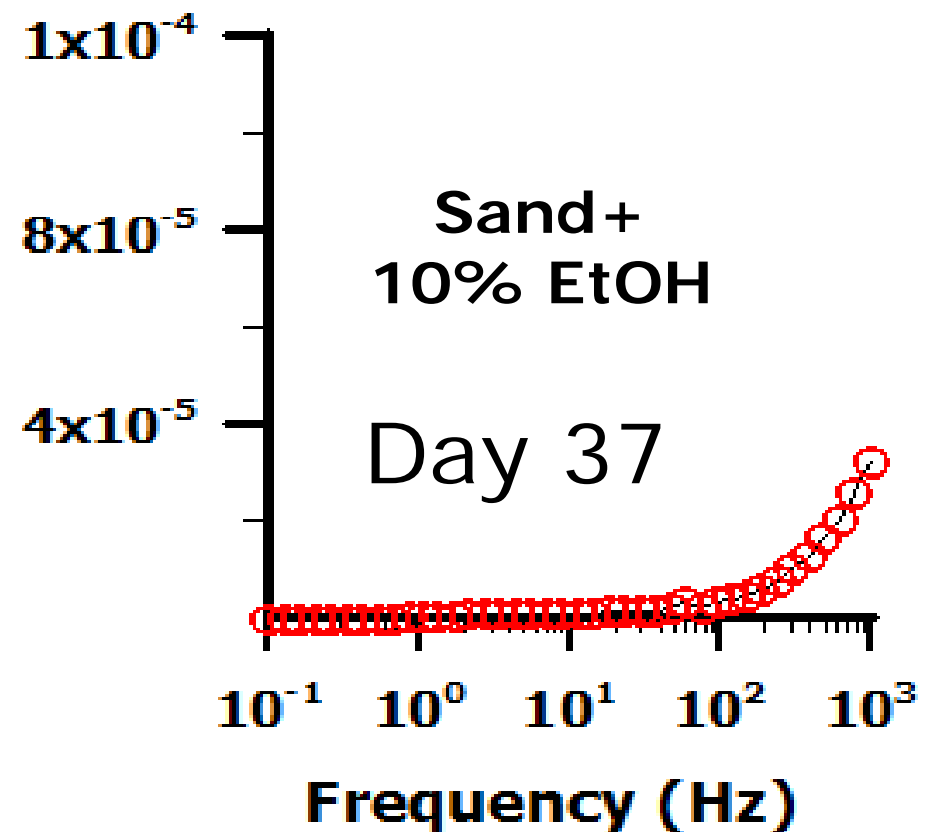
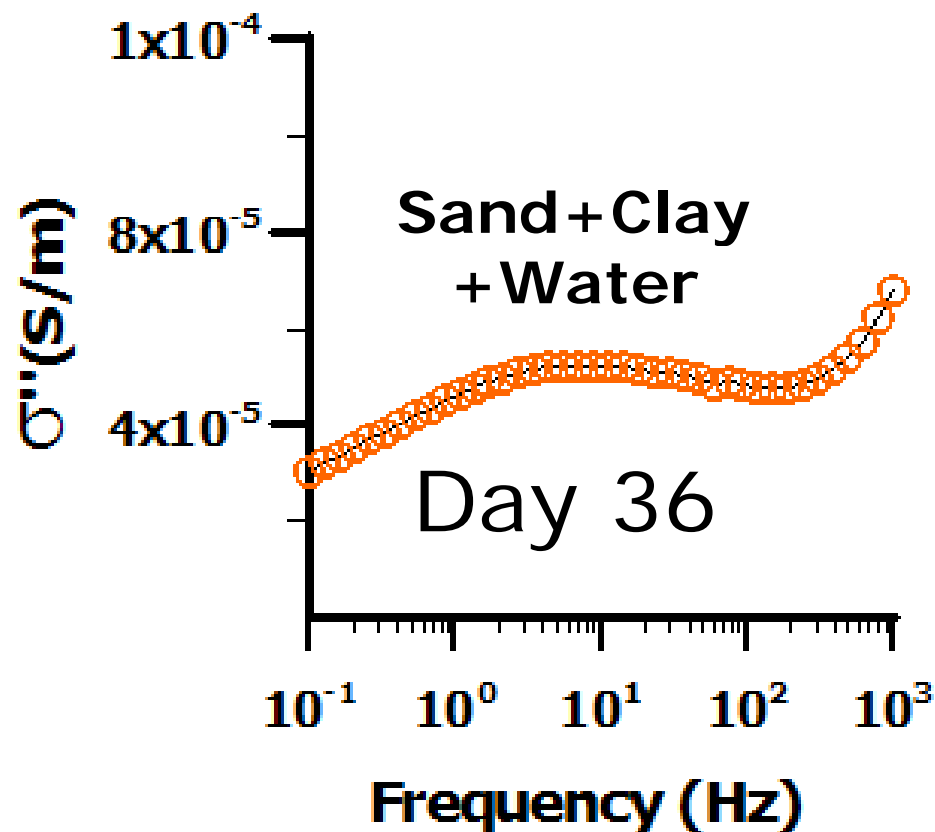
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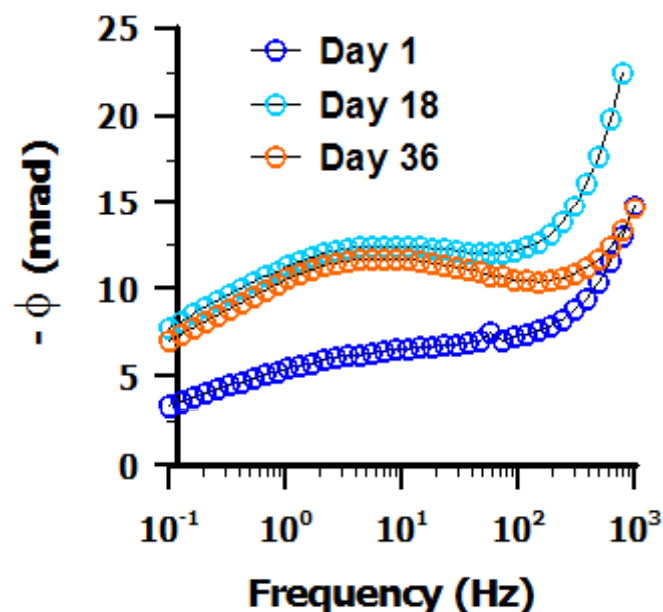


Clearly higher  $\sigma''$  response in clay

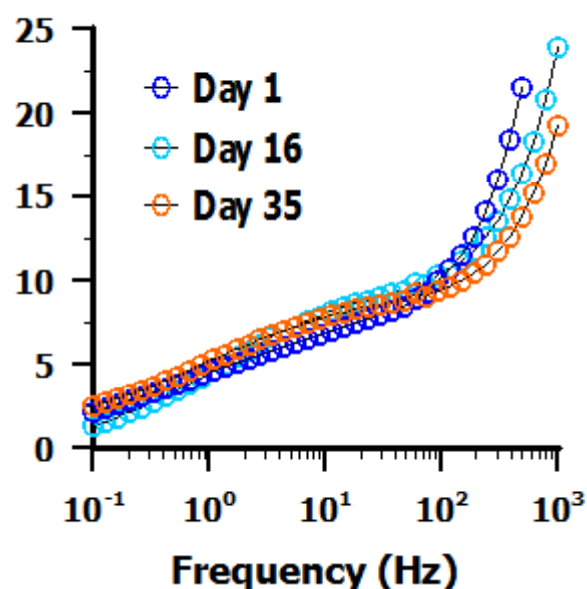


- Clear evidence of suppression of clay-driven polarization by EtOH
- Relative decrease in  $\phi$  as EtOH increases

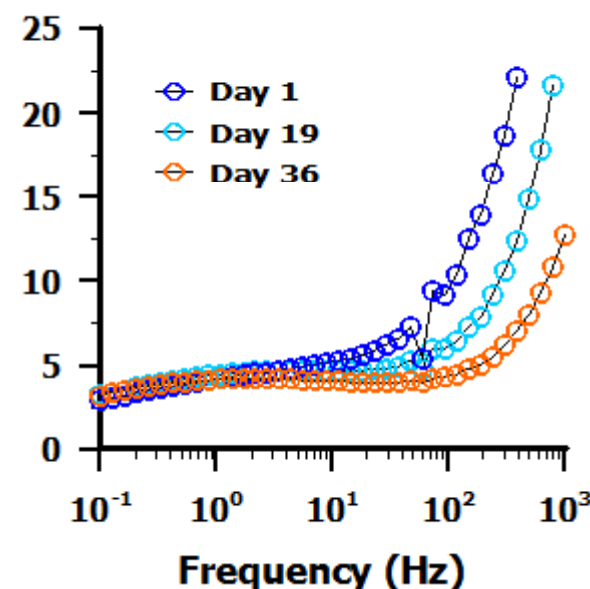
0% EtOH  
Sand+Clay



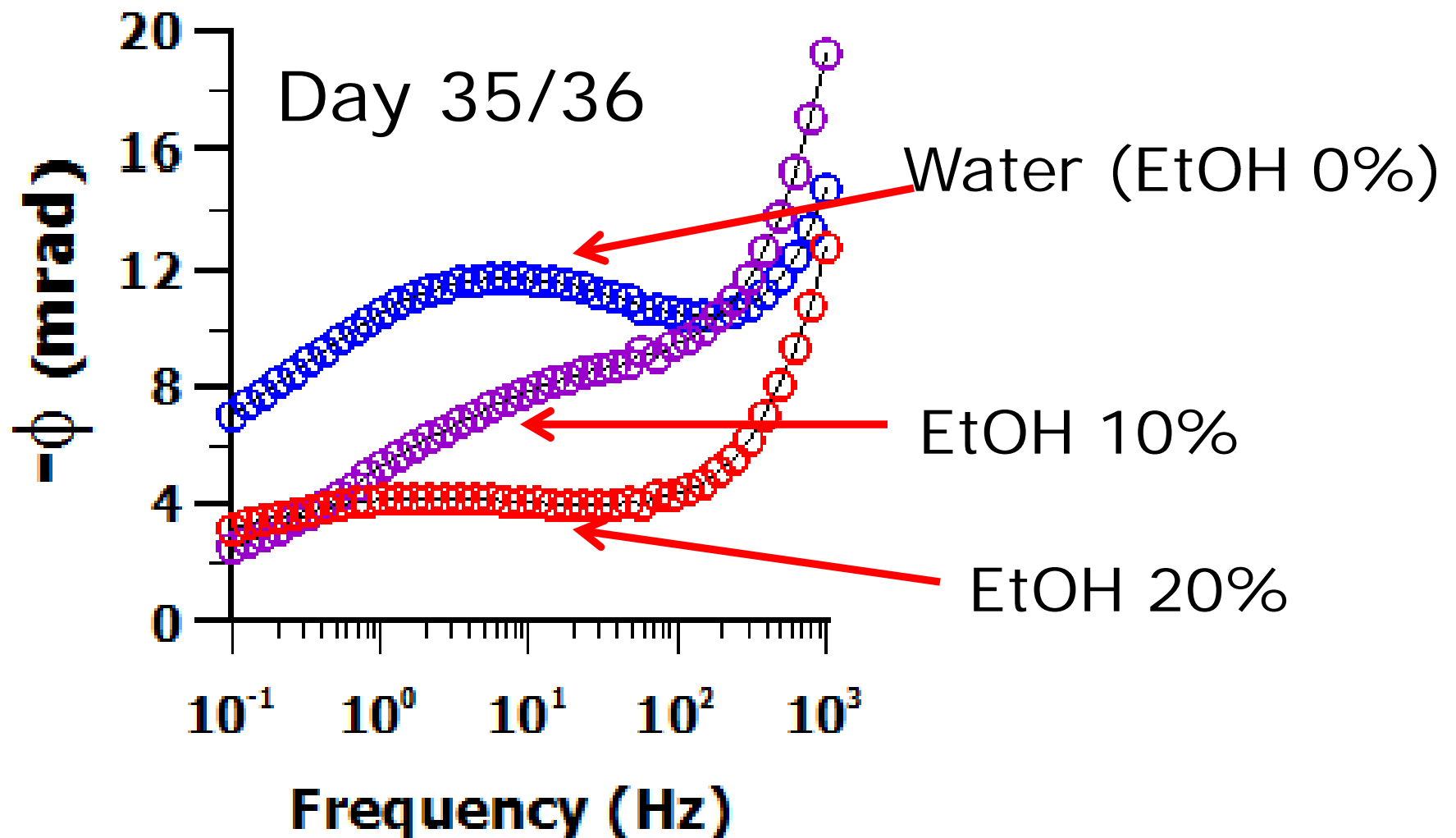
10% EtOH  
Sand+Clay



20% EtOH  
Sand+Clay

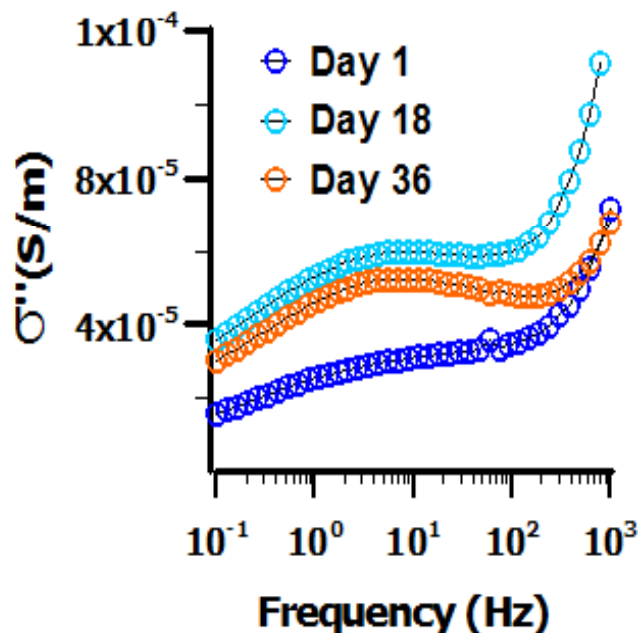


- As EtOH increases (0%, 10%, 20%), the clay-driven polarization effects are suppressed

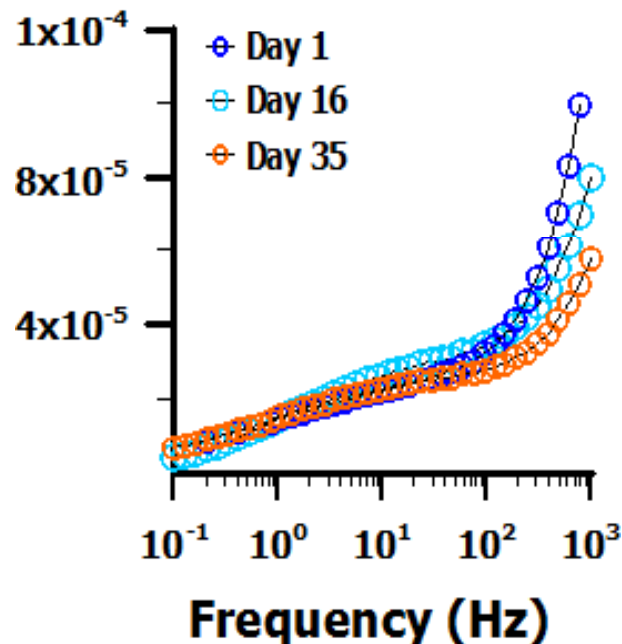


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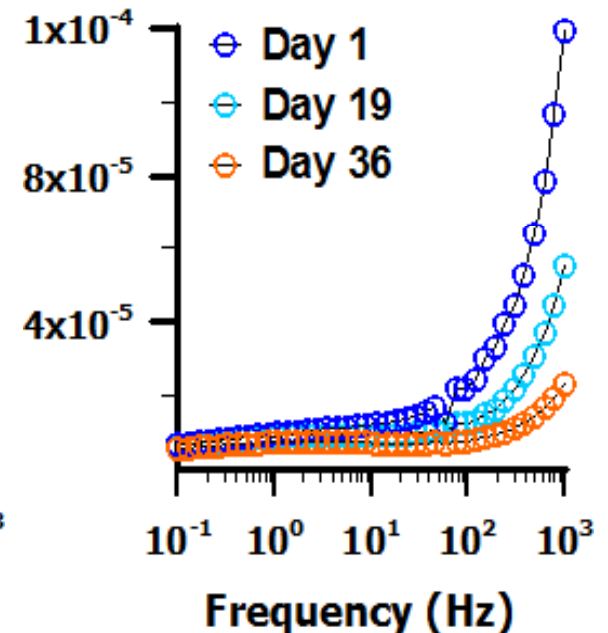
0% EtOH  
Sand+Clay



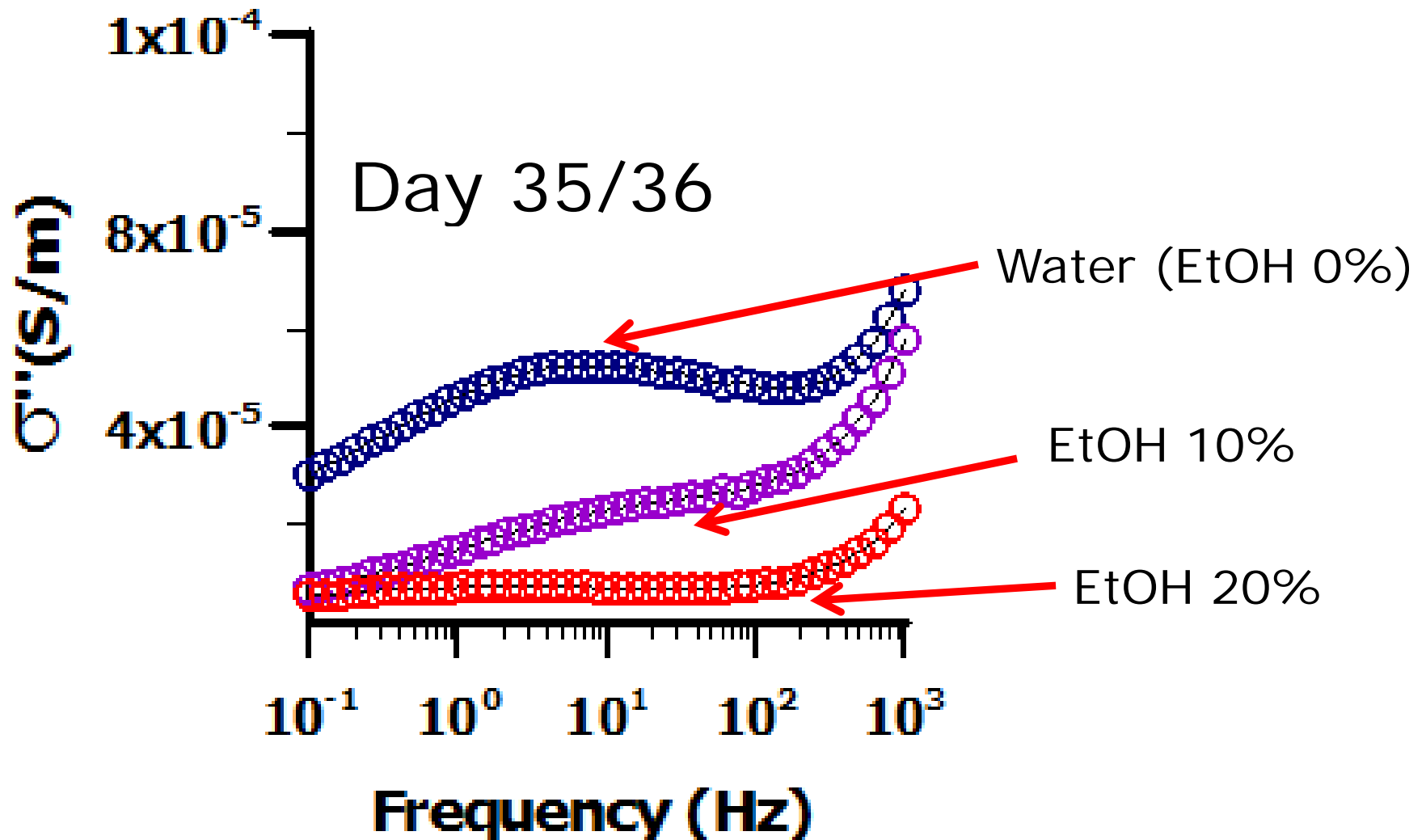
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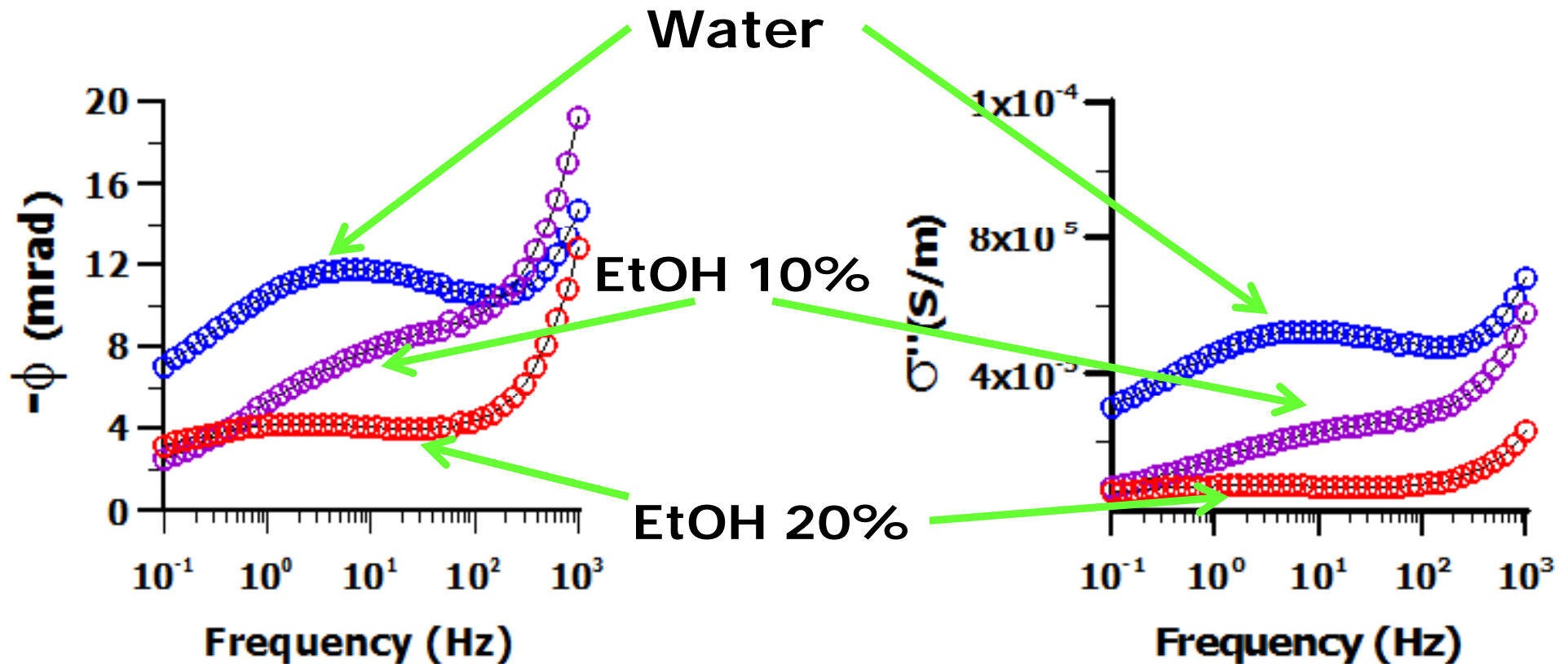
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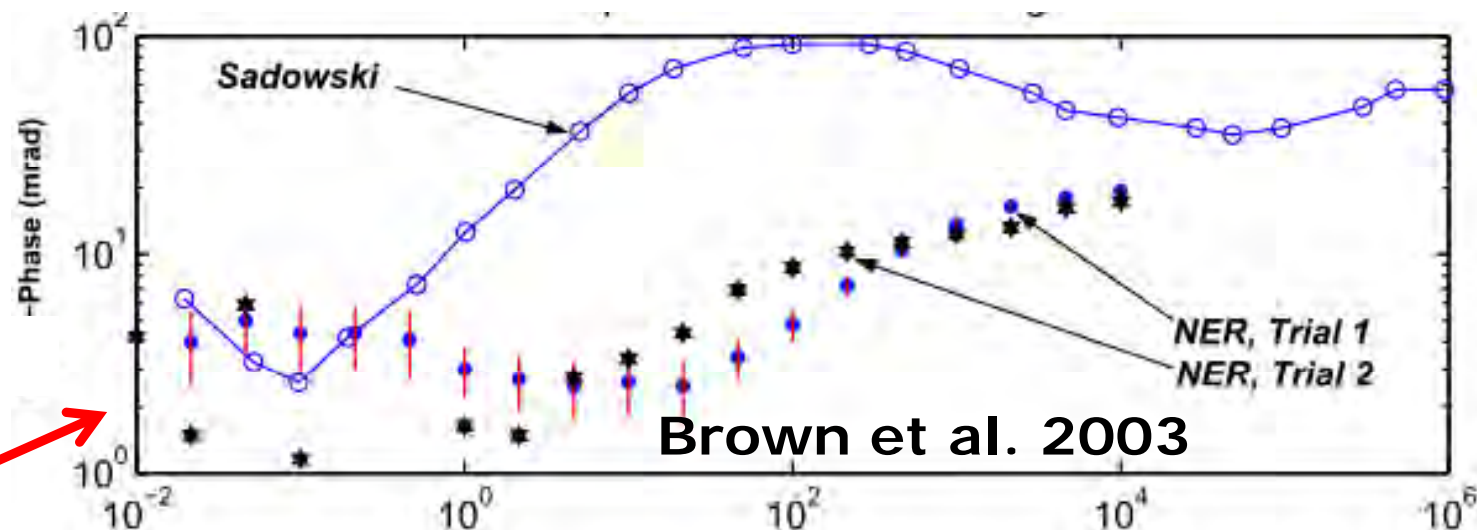
# RUTGERS Effects of EtOH : $\phi$ and $\sigma''$

The variation in  $\phi$  and  $\sigma''$  during the suppression effects Of EtOH on clay-driven polarization is consistent.

Day 35/36

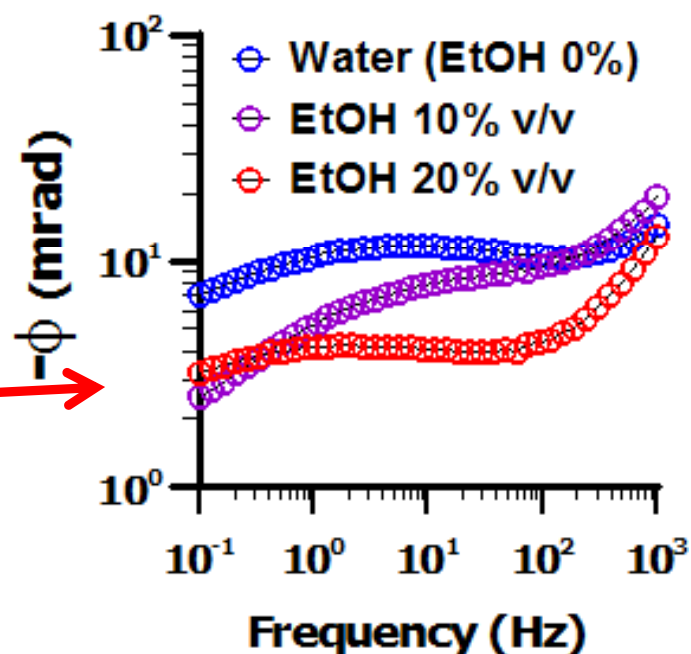


## Clay-organic Interactions



Increase in polarization documented in the literature ???

Here, we observed a decrease in polarization



## Possible Explanations of EtOH Suppression effects

### 1. EtOH-Water Solvation/ complexation

Reduction of solution ion mobility

### 2. EtOH-clay minerals interactions

Alterations of Clay-mineral surface and its capacity to hold charges

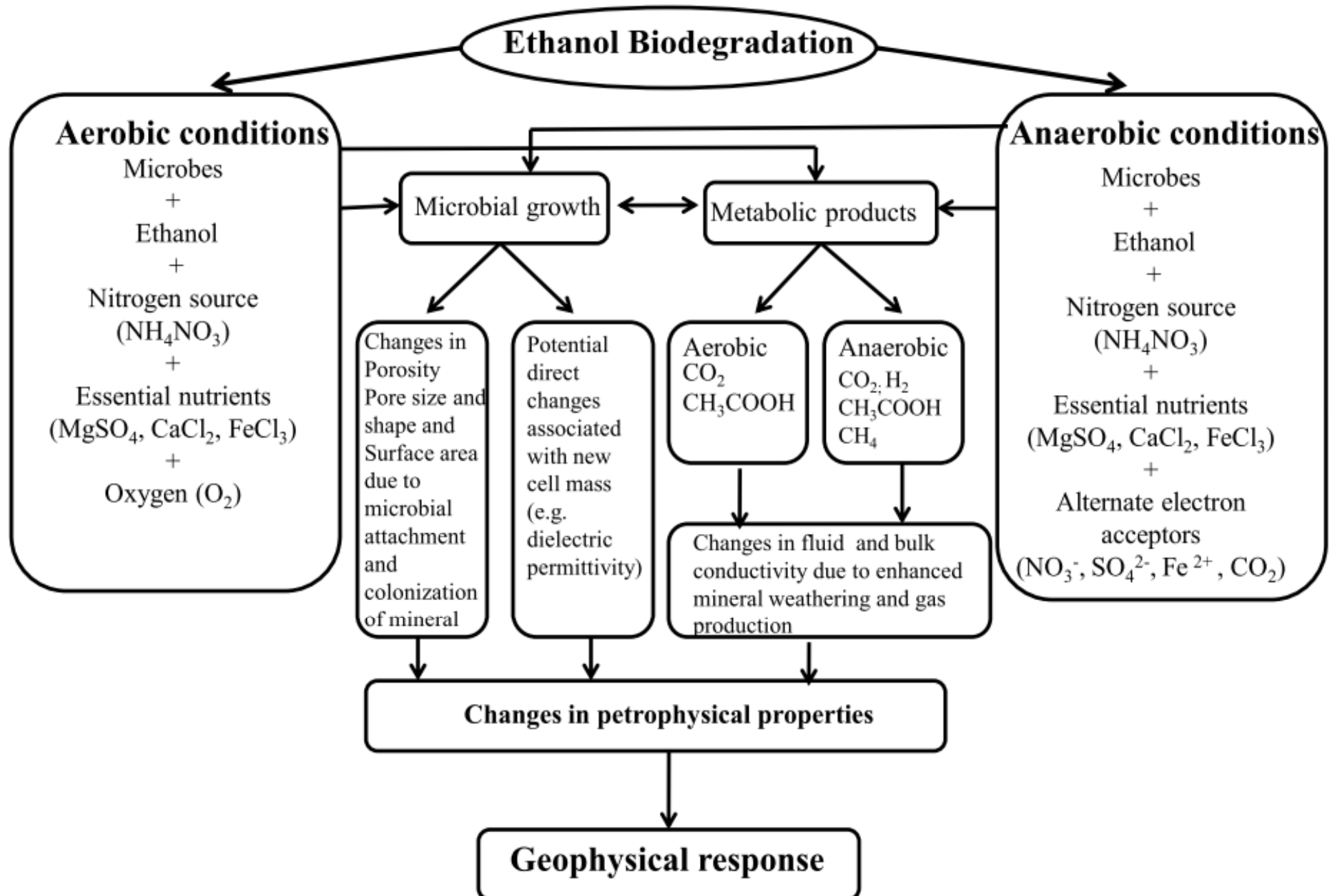
### 3. Alterations of the EDL

Alterations of migration and redistribution of ions in the EDL

# RUTGERS Conclusion and Future Work

- Our findings are different from previous works on clay-organic interactions
  - Clay-organic contaminant : Increase polarization (reported elsewhere)
  - Clay-EtOH : suppression of polarization (our finding)
- Consistent reduction in both  $\phi$  and  $\sigma''$
- On-going Cole-Cole and Debye decomposition approaches for determining IP parameters
- **Future Work** : focus on SIP signatures of ethanol biodegradation

# Rationale of Ethanol Biodegradation Pathways and Geophysical Response (Inspired from : Maier, 2000 and Atekwana et al., 2006)



**THANKS !!!**