Tracing Injection Fluids in Co-Produced Geothermal Reservoirs

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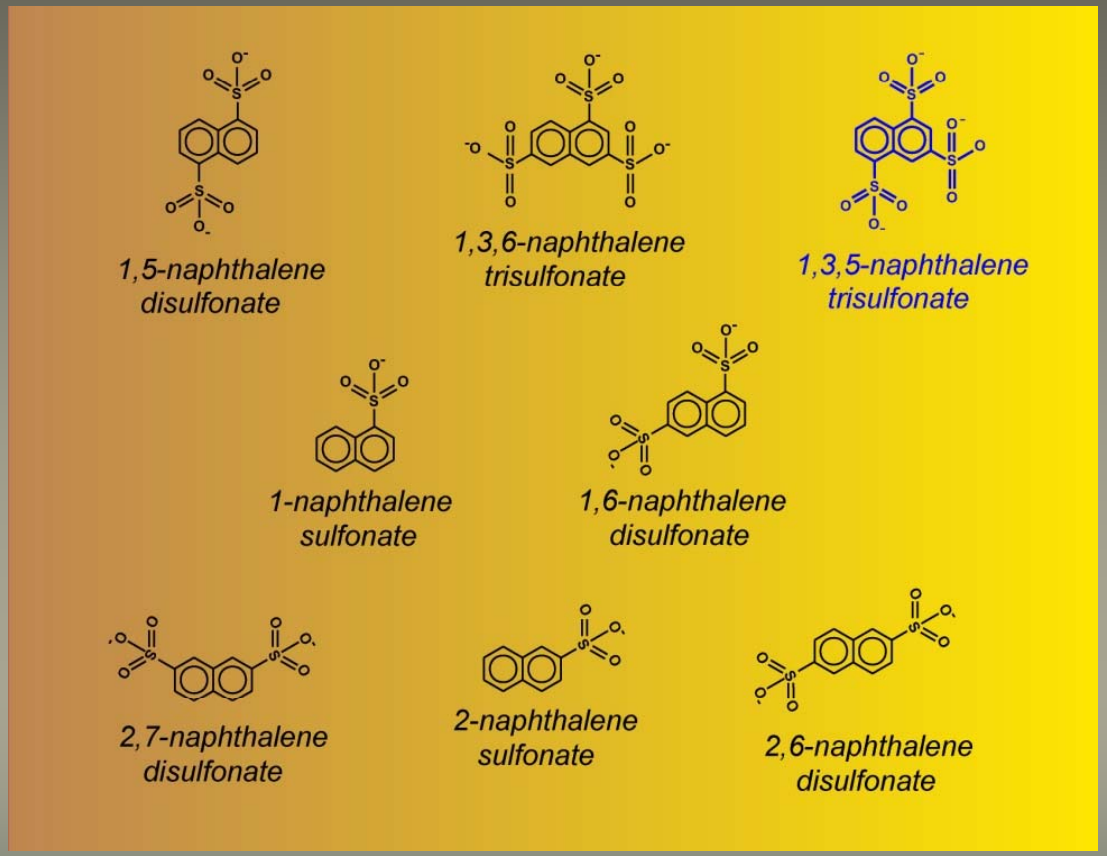
Objective

- To evaluate the use of a family of geothermal tracers, the naphthalene sulfonates, for use in co-produced geothermal fields

Eight mutually compatible naphthalene sulfonates comprise a family of thermally stable, detectable, affordable and environmentally benign geothermal tracers.



- Use temperatures exceed 330°C
- Non-sorptive on negatively charged reservoir rock
- Detectable to low-mid ppt levels
- Available in bulk and affordable

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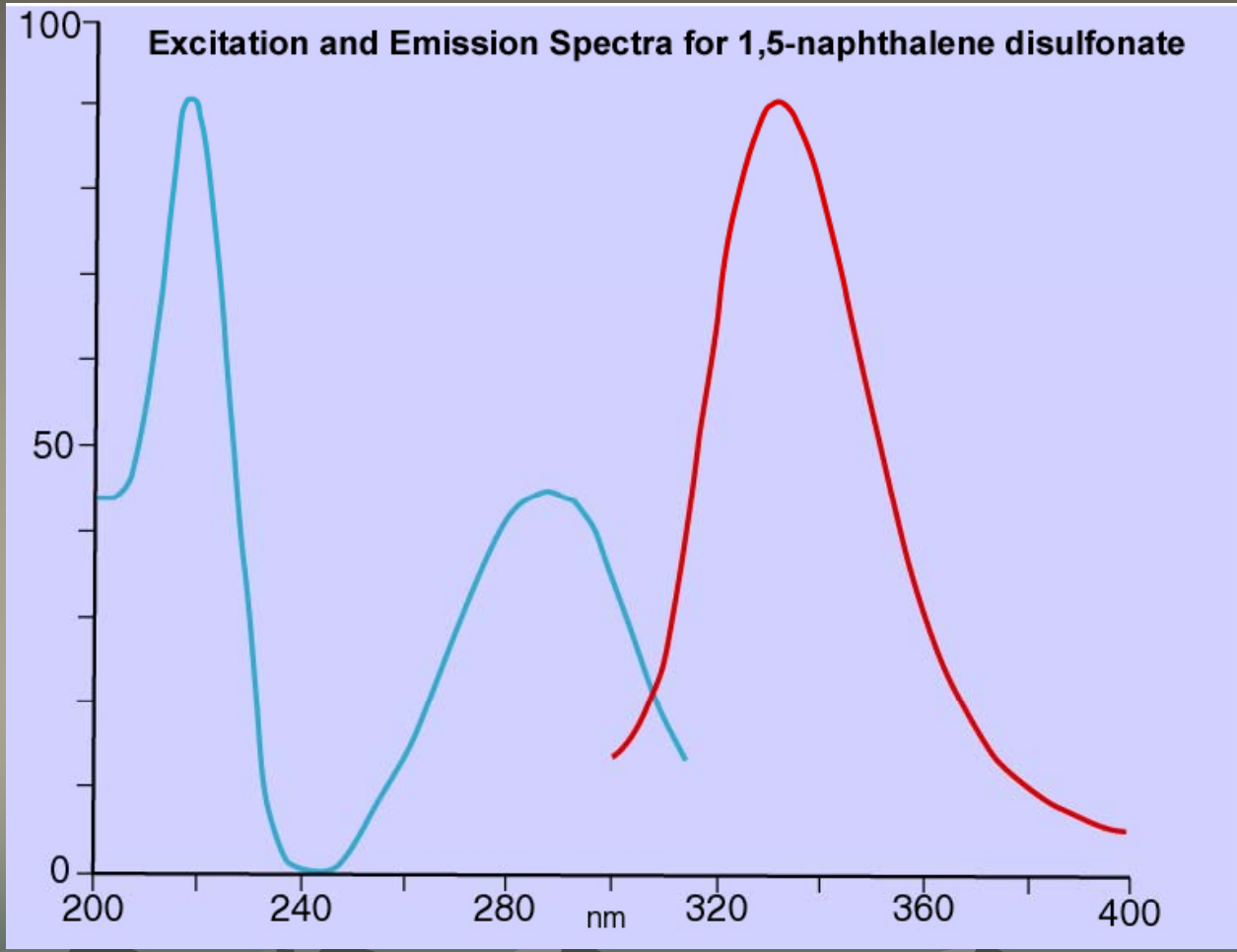
Toxicity of the Naphthalene Sulfonates

- Toxicity: neither carcinogenic nor mutagenic
- Biodegradability: environmentally persistent
- References:
  - Greim *et al*., (1994) Toxicity and Ecotoxicity of Sulfonic Acids: Structure-Activity Relationship: *Chemosphere*, **28(12)**, 2203-2236.
  - Suter, M.J.F., (1999), Trace Determinations of Emerging Water Pollutants: Endocrine Disruptors, Pharmaceuticals and Speciality Chemicals: conference in Basel, Switzerland.

A Naphthalene Sulfonate Fluorescence Spectrum



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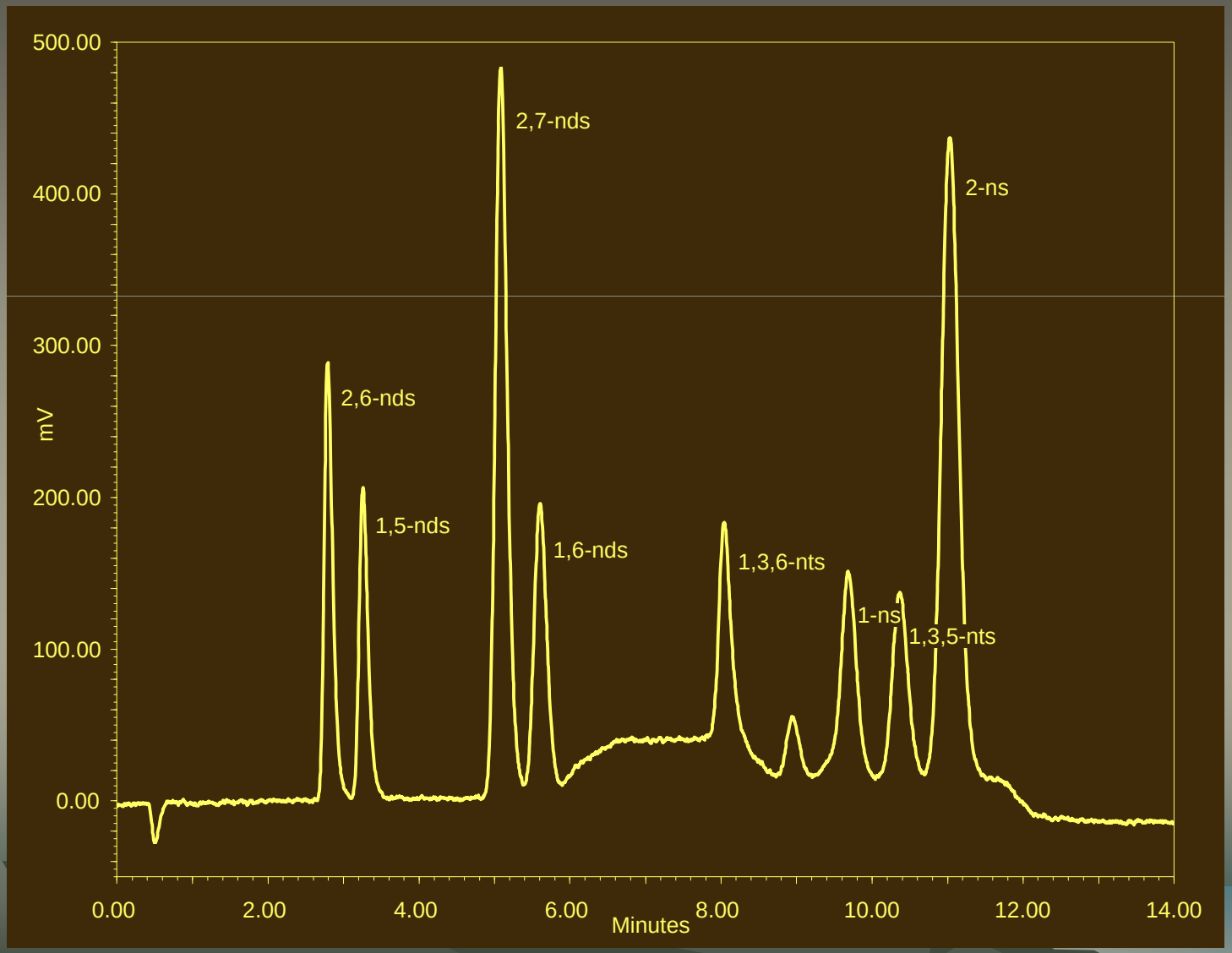
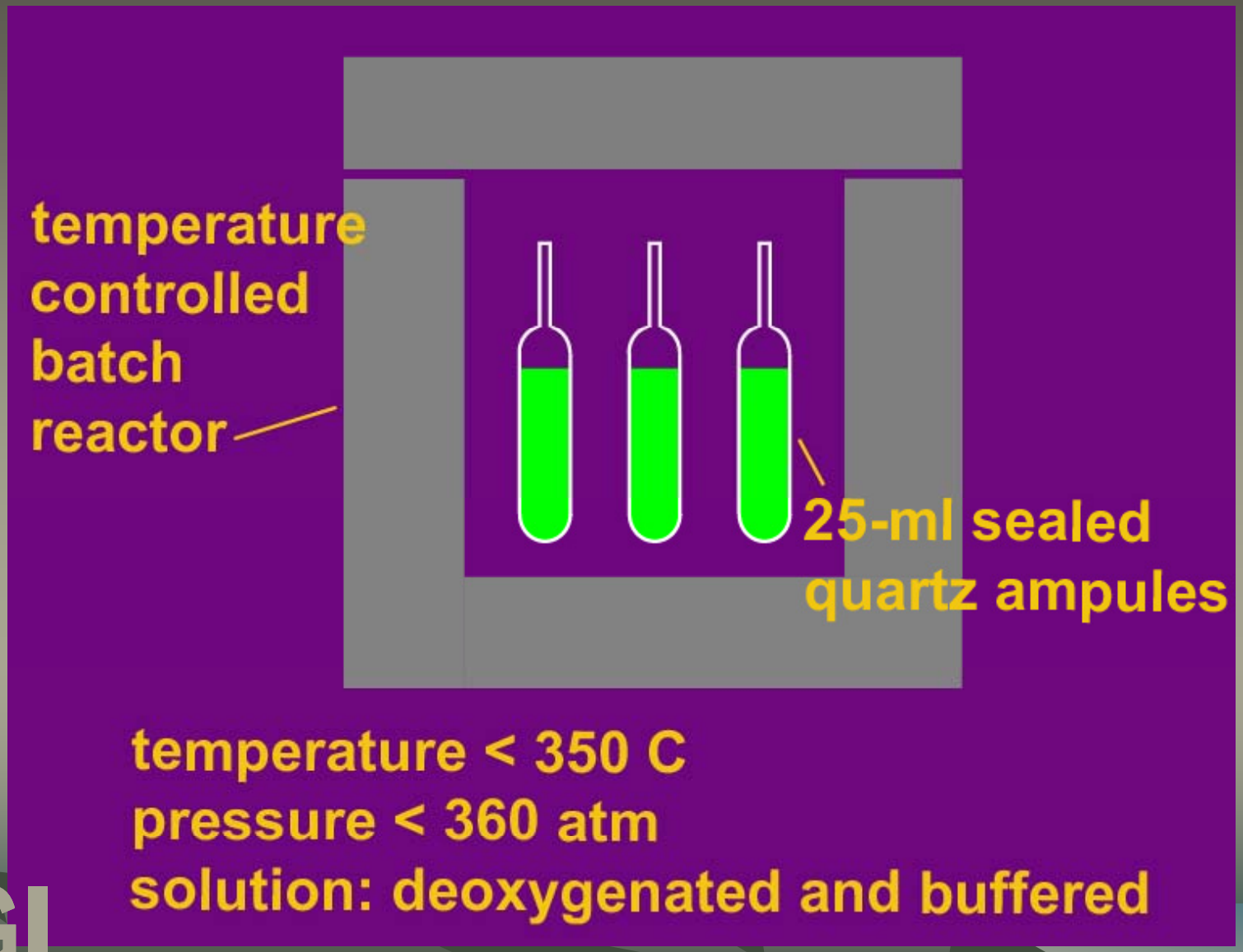
Chromatogram of Eight Naphthalene Sulfonates Obtained Using a Gradient-HPLC Method



Decay Kinetics: Experimental Approach



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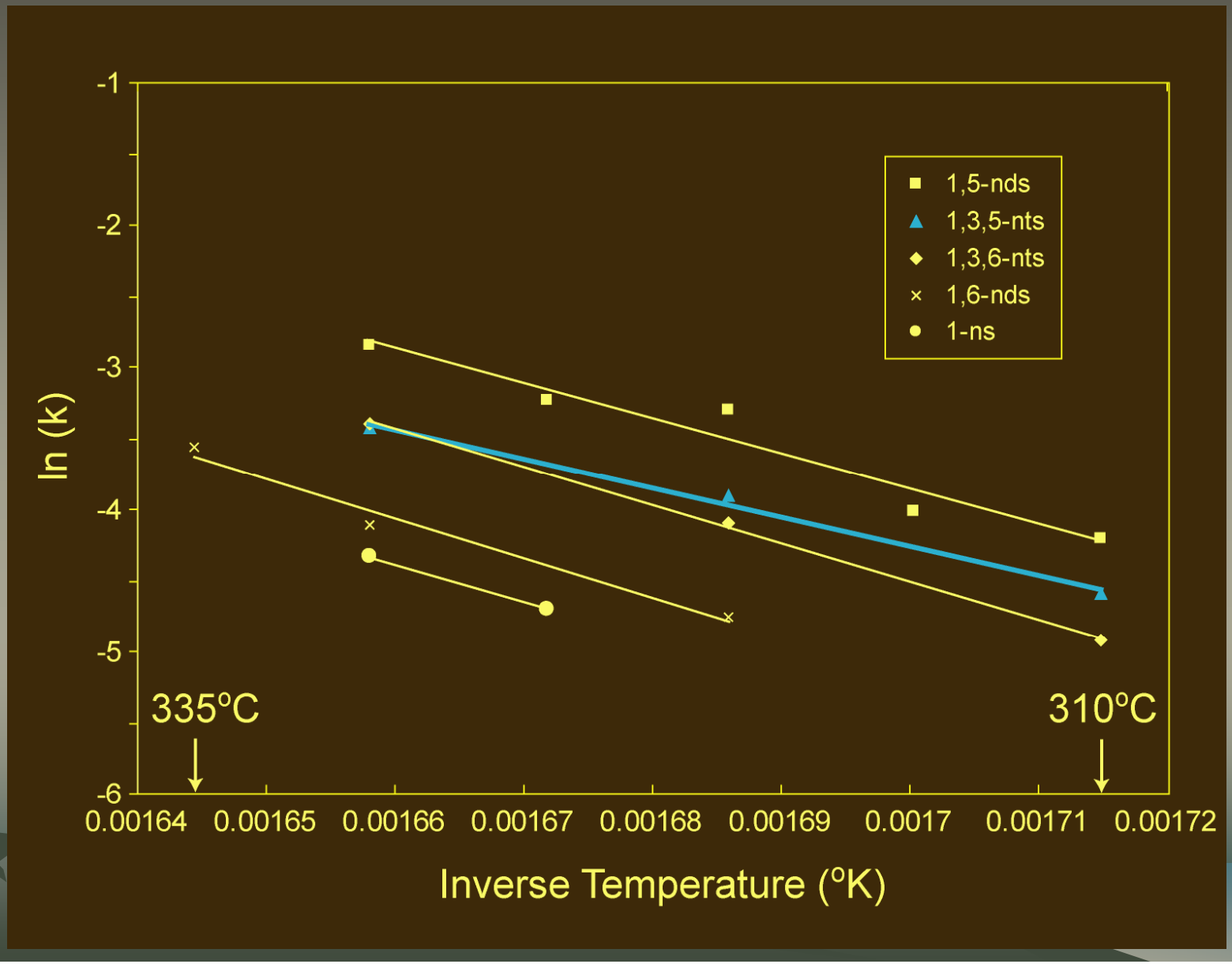
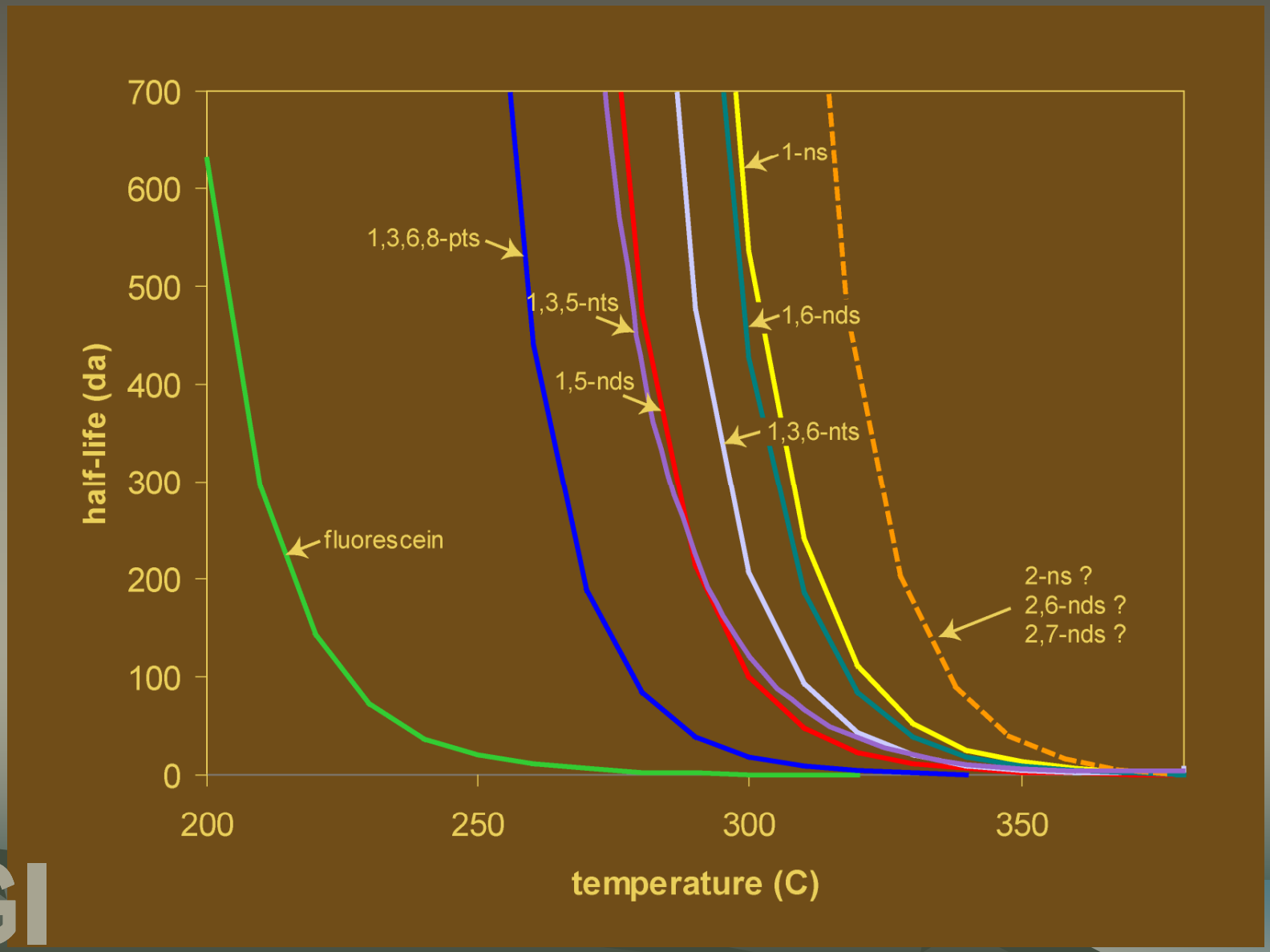
Arrhenius Plots for Alpha-Substituted Naphthalene Sulfonates



Thermal Stability Comparison of Fluorescent Tracers



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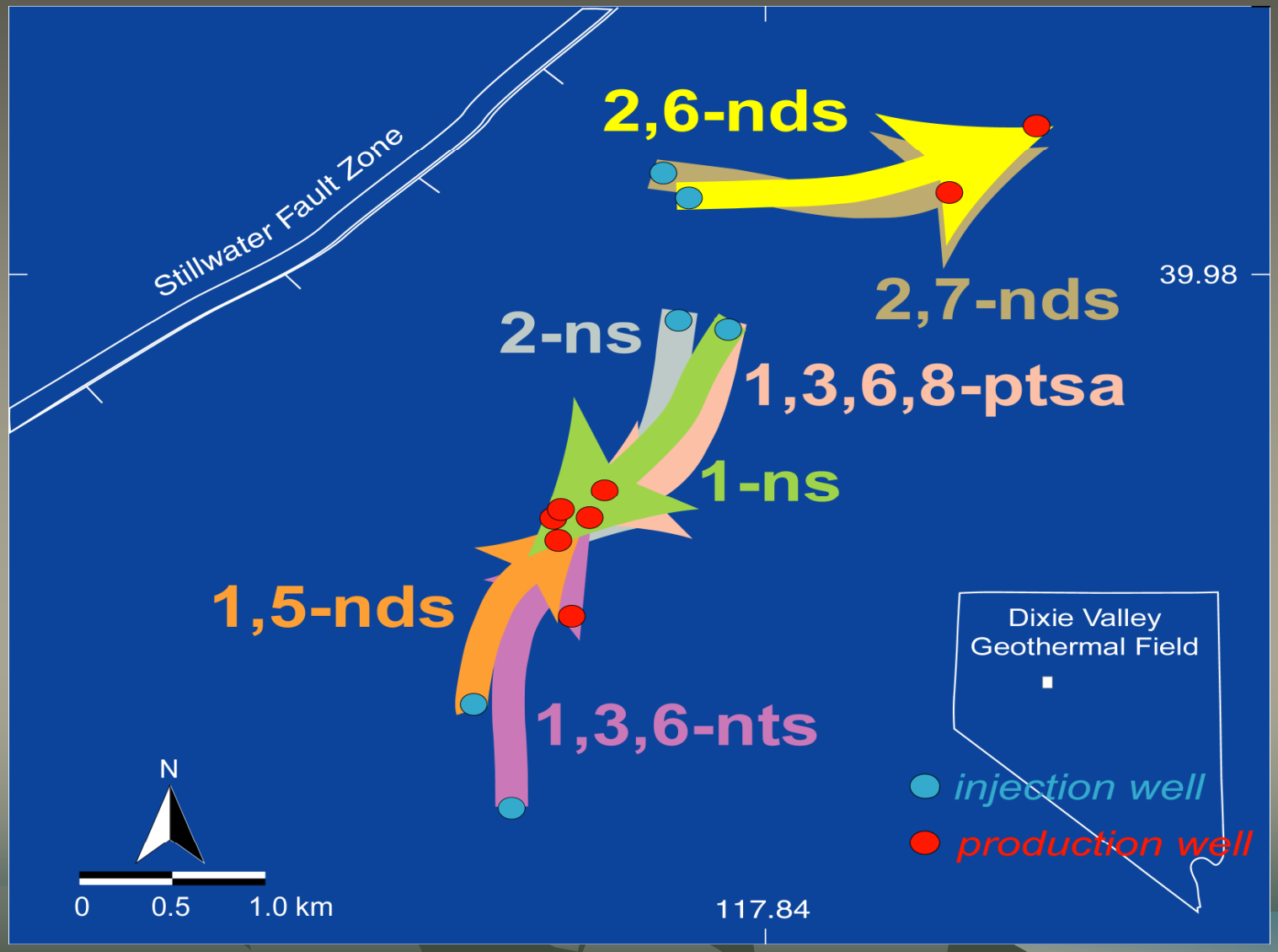
Summary of Polyaromatic Sulfonate Tests at the Dixie Valley, Nevada Geothermal Field



A Waterflood at the Aneth, Utah Petroleum Field

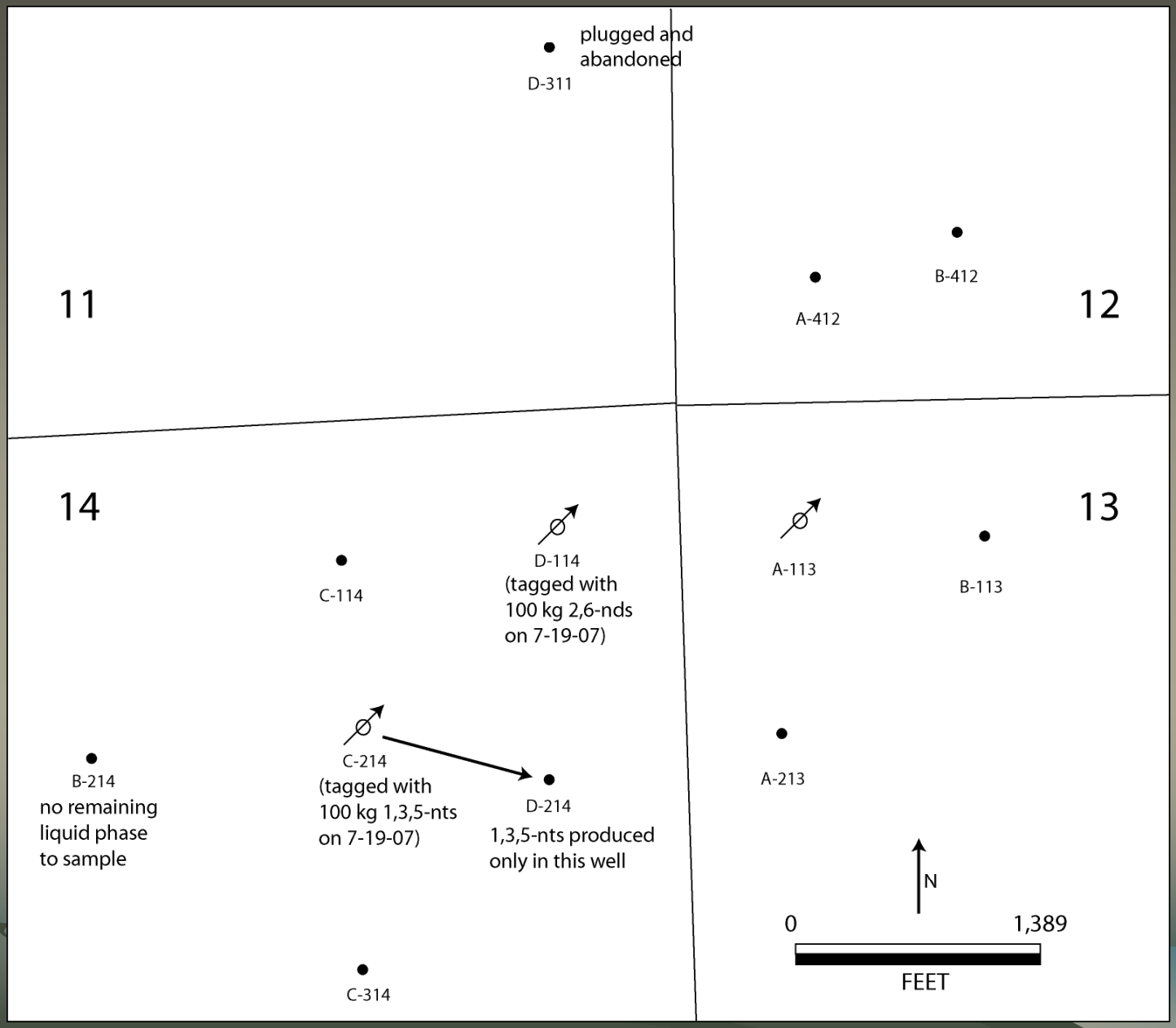
Challenges in the Analysis of the Naphthalene Sulfonates in Oily Water

- Although very promising for waterflood tracing (due to their strong anionic charge), the naphthalene sulfonates had never before been used in a waterflood tracer test.
- An ion exchange clean-up procedure was developed in order to prepare the samples for reverse-phase HPLC analysis.
- 100% recovery of standards was confirmed.

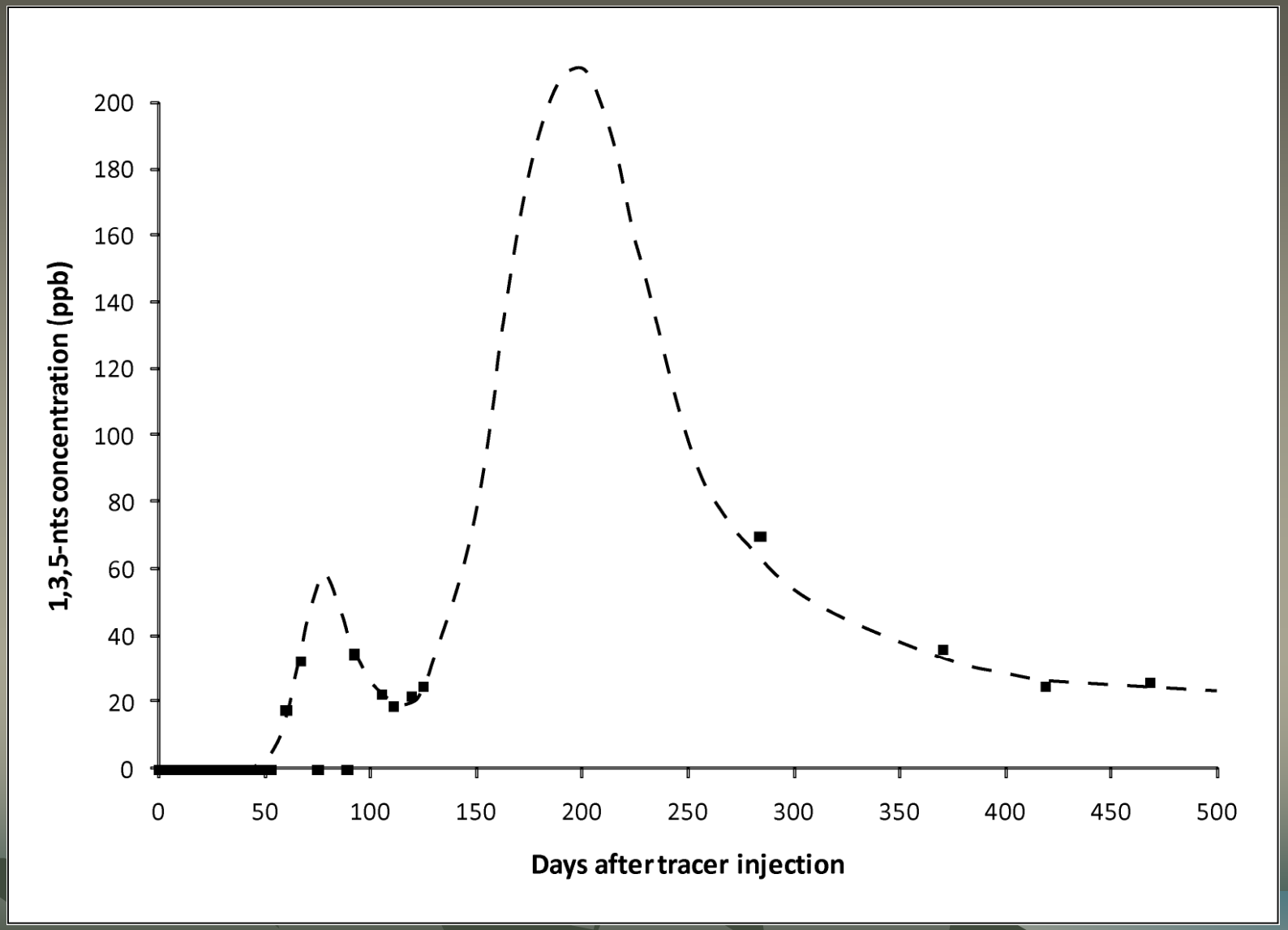
The Tracer Test at the Aneth, Utah Petroleum Field

- Two injection wells tagged
  - 100 kg of 1,3,5-naphthalene trisulfonate (1,3,5-nts) injected into well C-214
  - 100 kg of 2,6-naphthalene disulfonate (2,6-nds) injected into well D-114
- Four surrounding production wells intermittently sampled over the subsequent year and analyzed for the two tracers.

Plan View of a Western Portion of the Aneth Field



Production of 1,3,5-nts to well D-214



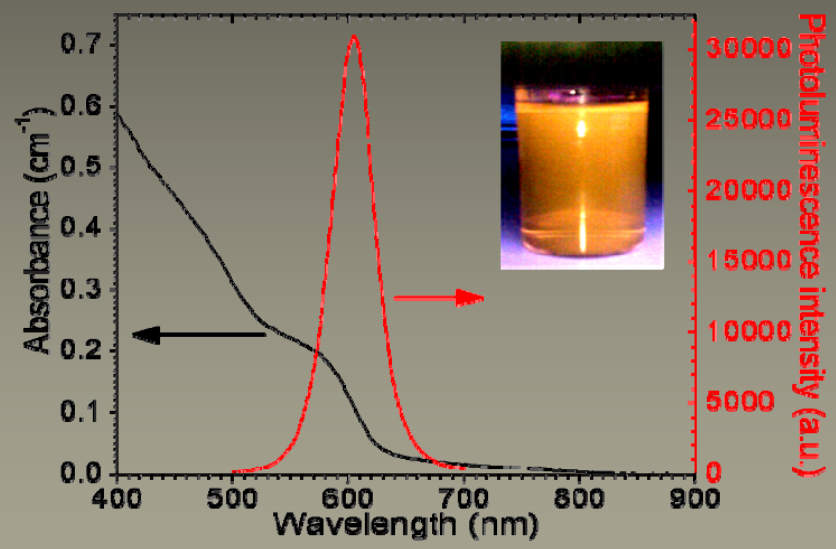
Conclusions and Recommendations

- The naphthalene sulfonates were shown to be effecive tracers for use in a waterflood at the Aneth, Utah petroleum field
- A novel sample clean-up procedure was developed as a method of preparing the oily-water samples for HPLC analysis.
- Sparse sampling has cost advantages, but can result in ambiguous data.

Future Directions in Co-Produced Fluid Tracing: Quantum Dots

Modification of quantum dot surfaces allows for interaction with the fracture surfaces and pores that can then be used to infer the surface area for heat exchange:

- *Thermal decay*
- *Contrasting diffusivity*
- *Reversible sorption on negatively charged rocks*



Optical absorption (black) and photo-luminescence emission (red) spectra of water-soluble silica-encapsulated quantum dots. **Inset:** Emission photograph of quantum dots excited by a broadband UV lamp.