Geochemical and Physical Aquifer Property Heterogeneity: A Multi-scale Sedimentologic Approach to Reactive Solute Transport

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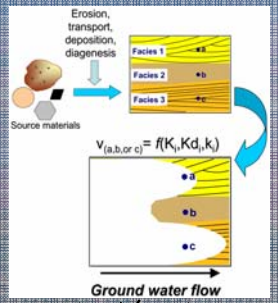
Hypothesis:

We hypothesize that geochemical and physical hydrologic properties that control reactive solute transport (transformation included) in sedimentary aquifers are correlated to lithofacies.



Conceptual model:

Lithofacies have distinct distributions of the hydrologic transport parameters hydraulic conductivity (K), sorption distribution coefficient (K_d), and anaerobic transformation rate constant (k_n). Chemical and physical differences arise from varying proportions of source materials (rocks, autochthonous carbon sources, etc), sorted by erosion, transport, and depositional processes, overprinted by subsequent diagenesis and result in predictable contaminant velocity variation between facies.

Context and Objectives:

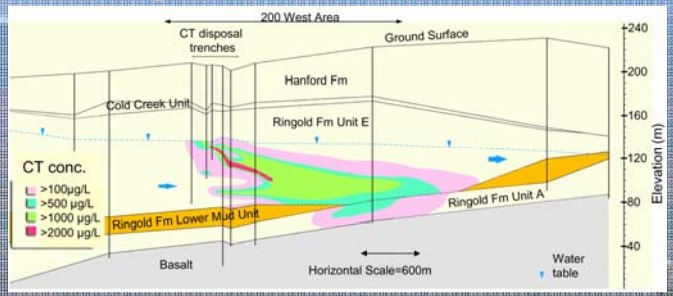
It is estimated that 750,000 kg of carbon tetrachloride (CT) was discharged to the subsurface environment at the Hanford site. The current contaminant plume in the saturated zone lies within the Ringold Formation. The contaminant plume is greater than 11 km^2 (aerial distribution) and more than 60 m thick (diagram upper right). In addition to flow heterogeneity, risks predictions from CT transport modeling are strongly affected by both sorption and abiotic transformation reactions, for which no site specific information is currently available.

The proposed project seeks to test the hypothesis for a portion of the unconfined aquifer at the Hanford site using CT as a model solute. The representative geochemical and physical aquifer properties selected for quantification in the proposed project are the properties that control CT transport, as listed above. We will combine observations at outcrop analog sites (to measure lithofacies dimensions and statistical relations) with measurements from archived and fresh core samples (for geochemical experiments and to provide additional constraint to the stratigraphic model) from the Ringold Formation to place local-scale lithofacies successions, and their distinct hydrologic property distributions, into the basinal context, thus allowing us to estimate the spatial distributions of properties that control reactive solute transport in the subsurface.

The objectives of the proposed project are to:

- Determine the significance of lithofacies in explaining the variance of *K* and reactivity to CT, indicated by K_d, for the Ringold Formation at the Hanford Site through intensive sampling and analysis, and rigorous statistical testing. We will also measure k_n and conduct detailed characterization of selected samples representative of saturated Ringold Formation Units to characterize differences in transformation rate and the controlling geochemical properties;
- Develop a sequence stratigraphic framework for the sedimentary basin, built on our measurements of lithofacies geometries and spatial distributions, and use this to model the distribution of lithofacies at the Hanford Site through application of transition probability geostatistics;
- Combine the simulated lithofacies spatial distributions and the observed *K*, K_d and k_n for each lithofacies to create models of the spatial distributions of reactive transport properties for a portion of the CT contaminated site; and
- Use the improved site model in preliminary numerical solute transport simulations to demonstrate its effects on our understanding of CT fate and transport in the Ringold Formation.

Cross-section (SW-NE) through CT disposal area showing that CT occurs throughout the depth of the unconfined aquifer (after Williams et al. (2005). Borehole sampling locations shown by vertical lines.



First steps – regional stratigraphy from outcrop analog sites and core samples provides local scale context; guides sample selection for studies of reactivity.

Materials reactive towards CTET have been identified.

Project Team:

Jacob Mongrain (Univ of New Mexico), George Last (PNNL), Bruce Bjornstad (PNNL), Chris Murray (PNNL), Richelle Allen-King (Univ at Buffalo), Gary Weissmann (Univ of New Mexico). Not pictured are Tim Scheibe (PNNL) and Guohui Wang (Univ. Buffalo)

Exposures of the Ringold Formation along White Bluffs. These outcrops lie approximately 22 km east of the CT plume study area.