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Since our last meeting, I have been thinking about alternatives to the 'moving freshwater lens' idea. I came across this awesome freshwater lens sand-box experiment [Stoeckl and Houben, 2012]. In this paper, the authors document a freshwater lens experiment where colored dyes are used to track flow patterns in the density stabilized (Darcy's law) freshwater lens system. Figure 1 is one of the experimental figures from their paper. Note how the flow pattern leads to higher advective fluxes through the upper part of the platform than the lower.

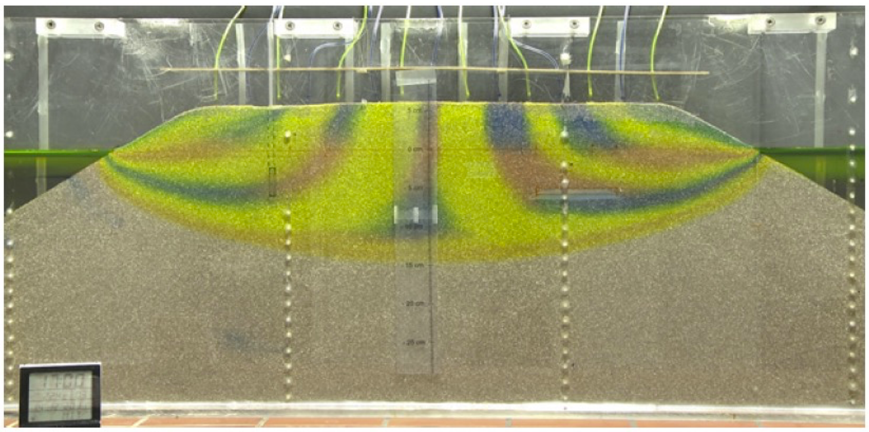

Figure 1: Sandbox freshwater lens experiment from Stoeckl and Houben [2012] using colored dyes to highlight flow field. The experiment begins with a sand island sitting in salt water, and then freshwater falls from the tubes above and establishes a steady-state lens shape.

While these results weren't shocking to me, the visuals inspired me to think more about how the flow pattern and fluid evolution could be used to generate the smooth mixing zone in the meteoric diagenesis of platforms (without needing to invoke a moving lens, although that would only help). My hypothesis was that the longer flow paths and smaller advective fluxes through the lower rocks would establish a smooth open to closed system gradient, and when sampled from a vertical section– we should see patterns that look like Clino. (An interesting aside, the greatest advective flux in this set up would be analogous to Clino–the edge of the platform). To test this idea, I set up my previous model in a simple 2d mesh where I could paste an overly simple flow field on top of the rocks and force -5 fluids in from the top. Additionally, the model is designed now so that I can pass it a parameter that represents ratio of advection to reaction for each reaction step. When rock reaction is high relative to the advective flux of the fluid, we have a model result that matches Banner and Hanson, and when the reaction is low relative to advection, it looks more like the models I showed you before. Figure 2 shows the result for the two cases.

Using relative advection patterns to drive variations in isotopes is more satisfying than moving the freshwater lens (which may be quite stable). Im happy enough with this first pass results to code up a more representative geometry and flow field to basically recreate the geometry from Figure 1. I suspect that there will be a pattern of regions that look more like Banner and Hanson, and regions that look more like Clino, which will be fascinating.

Figure 2: (Click figure to play video) Left: In this simulation, the fluids advect through the rock much faster than the rock reacts. 100 times more carbon moves through the rocks than reacts with each reaction step. Right: In this simulation, the reacts much faster relative to the advection (Banner and Hanson). 2 times more carbon moves through the rocks than reacts with each reaction step. Blue is a carbon isotopic profile, green is an oxygen isotopic profile.

References

Leonard Stoeckl and Georg Houben. Flow dynamics and age stratification of freshwater lenses: Experiments and modeling. *Journal of Hydrology*, 458:9–15, 2012.