The nonlocal irrigation model: Misleading or misunderstood?

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The treatment of irrigation as a nonlocal exchange has become the prefered form for this process in 1-D diagenetic models. A theoretical justification for this model was provided by Boudreau (1984), who showed that radial averaging of the Aller (1980) "tube model" transformed lateral diffusion from irrigation into a nonlocal source/sink in 1-D. The concept has been widely applied to various diagenetic situations and chemical species, and it is almost universally implemented in standard diagenetic computer codes (e.g., CANDI, STEADYSED, MEDIA, etc.)

In the past few years the nonlocal treatment was been criticized as being inaccurate or inappropriate in common situations. The criticism is largely accurate, but the fault lies not only with the model, but also with users, including this author, who have igored the assumptions behind its original derivation and those inherent to the original Aller model. These assumptions include linear reaction kinetics, "modest" radial gradients, and no provison for strong reactions near the tube wall. Additionally, the model describes only that portion of the solute distribution within the porewater, a fact that is relevant for oxygen, which often is mostly present in the tube.

Many of these limitations can, however, be overcome through judicious modification and/or re-development of the model. For example, sharp lateral gradients can be taken into account by a better approximation of the gradient at the burrow wall, for example, as suggested by Grigg et al. (in press). Likewise, the effects of strong nonlinear oxidation reactions near the burrow wall can be approximated by a linearized reaction at the tube wall; the 1-D diagenetic model then contains a new linear sink, rather than a nonlocal exchange term. Furthermore, a careful examination of the nonlocal model shows that the exchange coefficient is inherently a time-dependent parameter in any non-steady state situation. The latter fact means that estimates of the exchange parameter obtained with transient and steady state tracers should not, in general, agree.

References

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Modeling the effects of burrow geometry on pore-water transport in marine sediments

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Burrow-irrigation models have been widely applied to study sediment pore-water exchange and diagenesis. The one-dimensional non-local exchange model is perhaps the most commonly-used model that links burrow geometry with pore-water exchange rates. However, burrow-irrigation models are seldom rigorously tested in the field, in part because of the difficulties of accurately quantifying burrow geometries. It is difficult, therefore, to assess the validity of common assumptions of these models, such as diffusive-control of solute transport and the presence of fully-flushed burrows. In order to test these assumptions, I determined burrow geometries by CT-scanning sediment cores collected from several stations in Boston Harbor spanning a range of burrow densities. At each station, pore-water exchange rates were determined by measuring profiles of $^{222}Rn/^{226}Ra$ disequilibrium. I tested several bioirrigation models by comparing profiles of ^{222}Rn predicted by the models for stations with different burrow geometries to profiles measured at the same stations. These comparisons indicate that burrows are generally not fully flushed and that one-dimensional models do not accurately link burrow geometries with pore-water exchange mechanisms.