

Quantitative modeling of pore water O₂ and pH microprofiles in deep-sea sediments: CaCO₃ dissolution

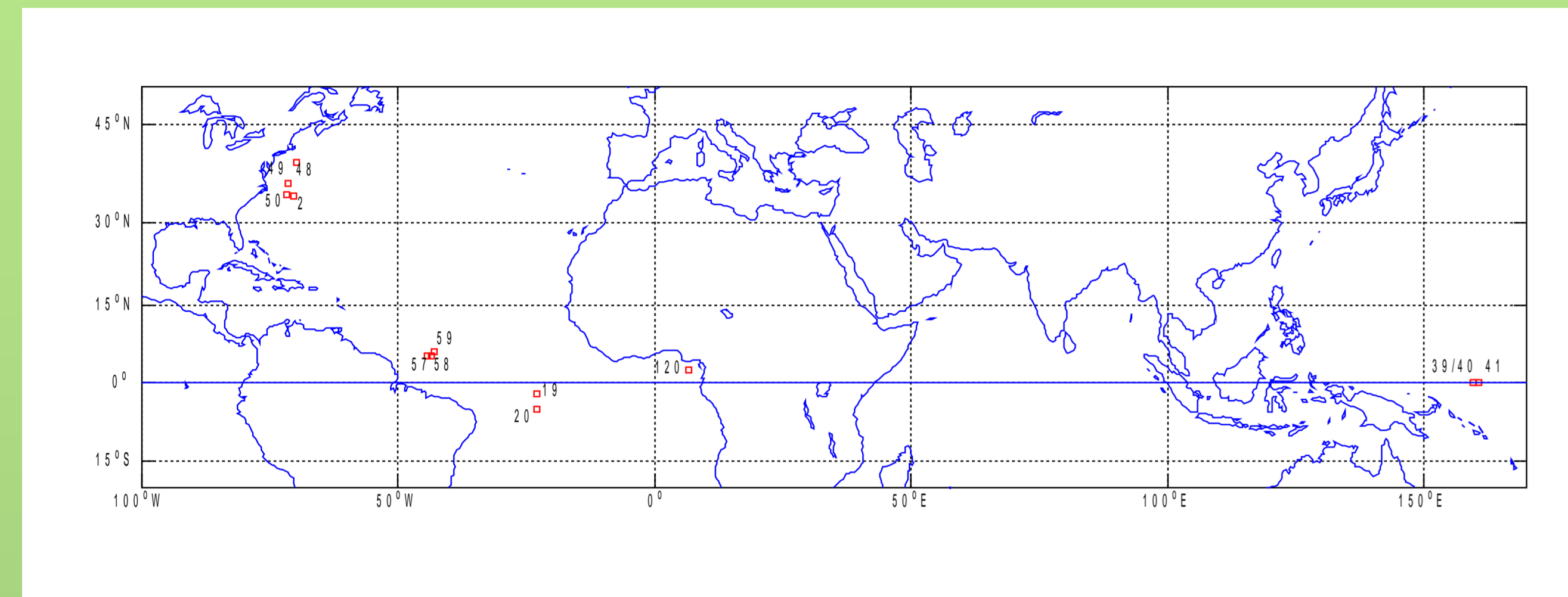
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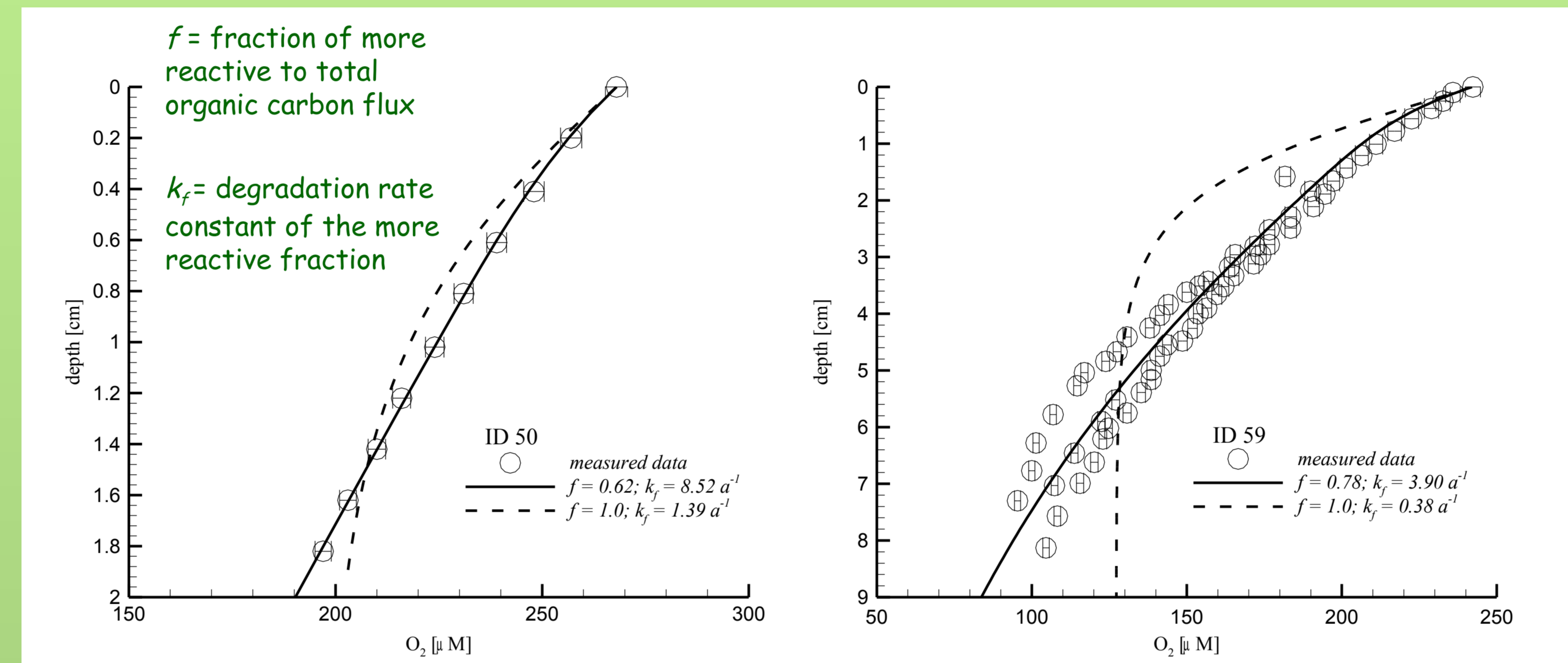
A reaction-transport model is used to interpret 13 data sets of *in situ* O₂ and pH microelectrode profiles measured in deep-sea sediments¹. The model is combined with a parameter estimation approach to quantify organic matter loading, reactivity, as well as the role of calcite dissolution.

The figure and table below show the location and characteristics of sites with available pH and O₂ data sets. These data are from *in situ* benthic landers deployed in deep-sea sediments deposited in oxygenated bottom waters at water depths > 2000m.

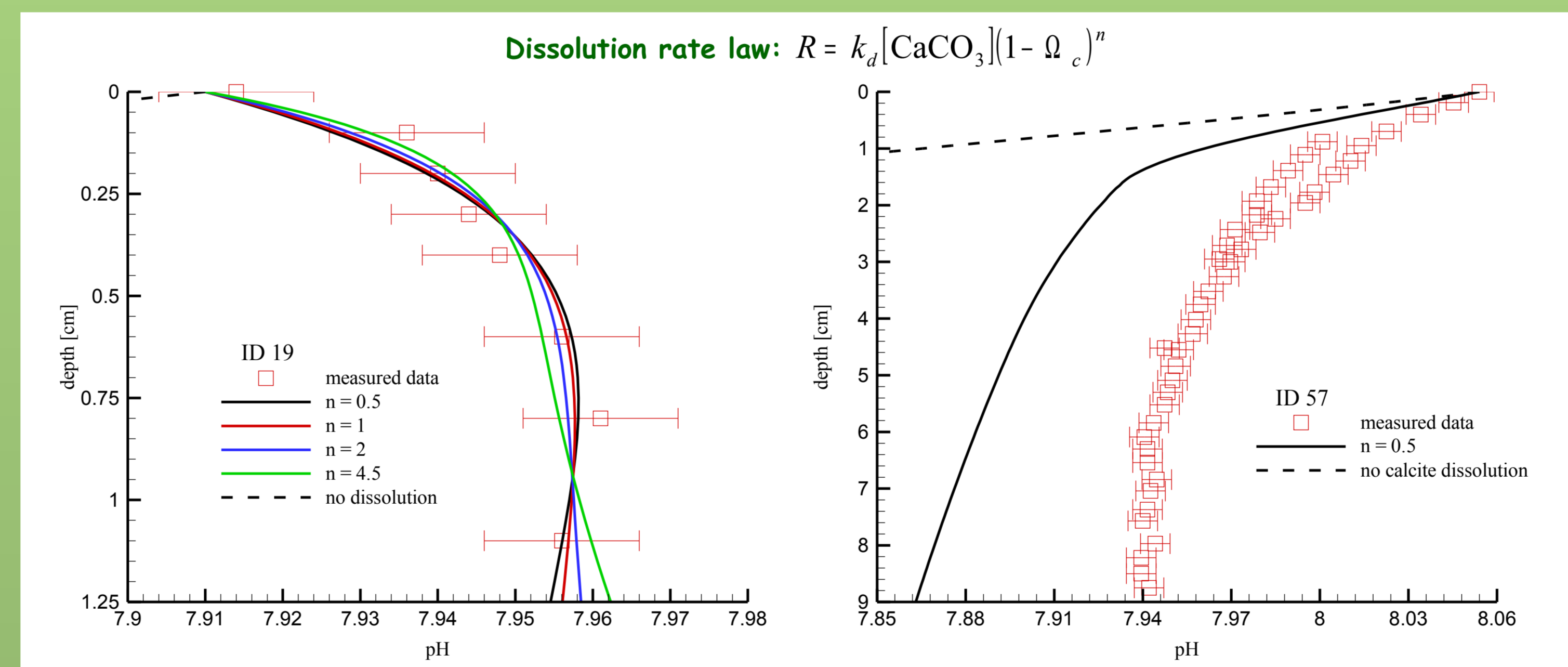


Bottom water characteristics					Sediment
Site	Depth [m]	Ω_c [CO ₃ ²⁻] [Ca ²⁺] / κ_{sp}	O ₂ [μM]	pH	Average [CaCO ₃] weight %
2 ⁽²⁾	5210	0.87	266	8.015	22
19 ⁽³⁾	4950	0.65	216	7.91	10
20 ⁽³⁾	5075	0.63	211	7.902	10
39 ⁽⁴⁾	2322	0.87	130	7.82	90
40 ⁽⁴⁾	2335	0.87	131	7.825	90
41 ⁽⁴⁾	2966	0.72	145	7.78	87
48 ⁽²⁾	2159	1.68	268	8.112	21
49 ⁽²⁾	4236	1.06	271	8.048	26
50 ⁽²⁾	4501	1.01	268	8.042	31
57 ⁽⁵⁾	3279	1.23	262	8.054	66
58 ⁽⁵⁾	3990	1.02	270	8.016	64
59 ⁽⁵⁾	4675	0.78	242	7.94	43
120 ⁽⁶⁾	2185	1.31	233	7.97	3.2

The model successfully reproduces the measured O₂ profiles at all 13 sites. The best-fit pH profiles capture the general features at 9 of the sites, where the variations in pore water pH are reproduced within 10%. The figures below show the simulation results for sites with the lowest data-model misfit (left) and the highest misfit (right).

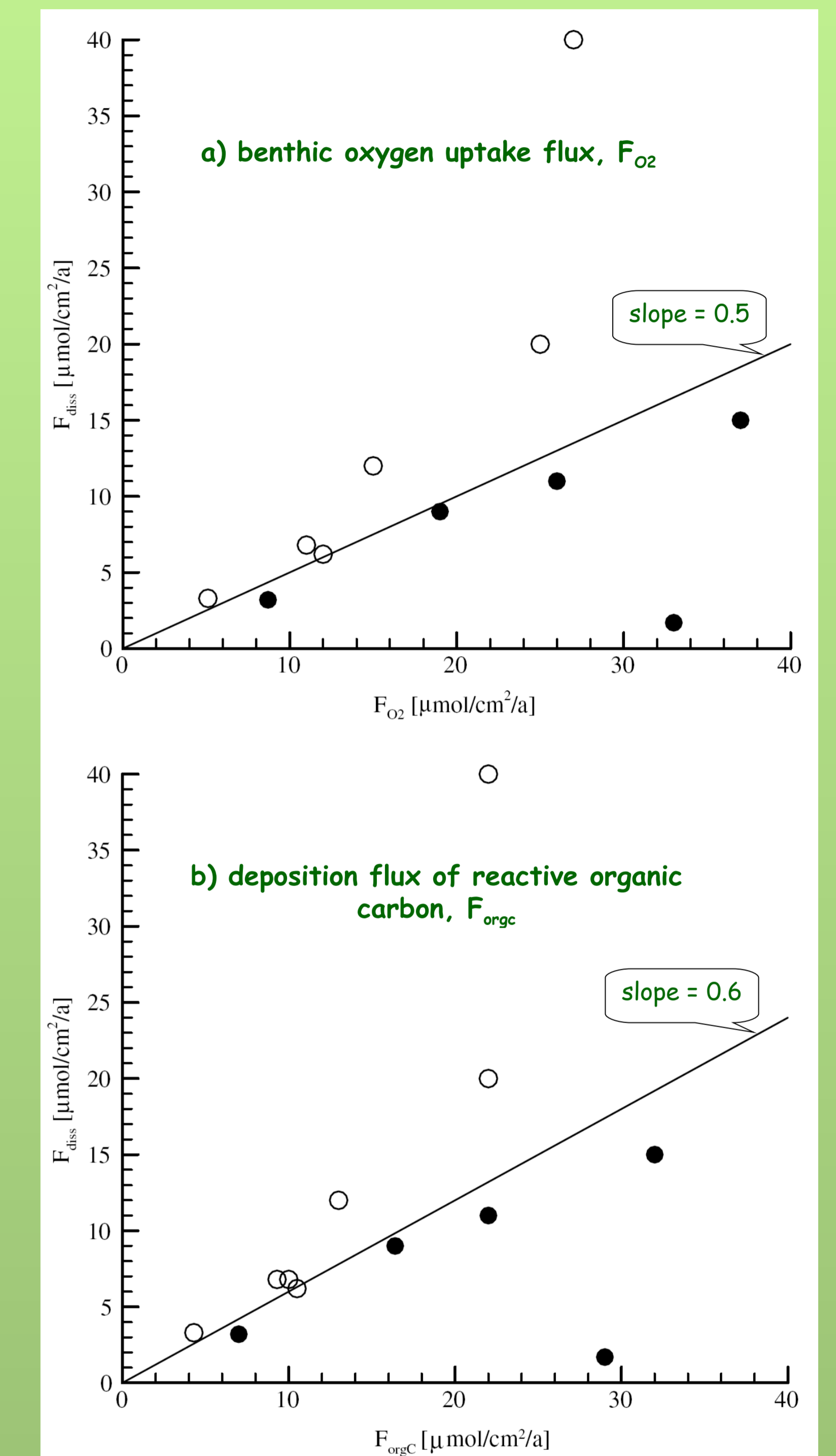


- Consideration of two pools of reactive organic carbon is sufficient to reproduce the oxygen data.
- The more reactive pool dominates the organic carbon deposition flux.
- Suboxic degradation pathways play a non-negligible role at the majority of sites.



The dissolution rate expressions with the higher rate orders tested ($n = 2$ and 4.5) are generally more successful in reproducing the *in situ* pH profiles. While the pore water pH profiles cannot constrain the calcite deposition flux, robust estimates of the depth-integrated calcite dissolution rates can be obtained.

depth-integrated calcite dissolution rates (F_{diss}) correlate positively with:



The trends vary for sites overlain by supersaturated (○) and undersaturated (●) bottom waters.

References:

- Jourabchi P., Meile C., Pasion L. R., and Van Cappellen, P. (2008) Quantitative interpretation of pore water O₂ and pH distributions in deep-sea sediments. *Geochimica et Cosmochimica Acta* **72**, 1350-1364.
- Hales B., Emerson S., and Archer D. (1994) Respiration and dissolution in the sediments of the western North Atlantic: estimates from models of in situ microelectrode measurements of porewater oxygen and pH. *Deep-Sea Research II* **41**, 695-719.
- Archer D., Emerson S., and Reimers C. (1989) Dissolution of calcite in deep-sea sediments: pH and O₂ microelectrode results. *Geochimica et Cosmochimica Acta* **53**, 2831-2845.
- Hales B. and Emerson S. (1996) Calcite dissolution in sediments of the Ontong-Java Plateau: in situ measurements of pore water O₂ and pH. *Global Biogeochemical Cycles* **10**, 527-541.
- Hales B. and Emerson S. (1997) Calcite dissolution in sediments of the Ceara Rise: In situ measurements of porewater O₂, pH, and CO_{2(aq)}. *Geochimica et Cosmochimica Acta* **61**, 501-514.
- Wenzhöfer F., Adler M., Kohls O., Hensen C., Strotmann B., Boehme S., and Schulz H. D. (2001) Calcite dissolution driven by benthic mineralization in the deep-sea: In situ measurements of Ca²⁺, pH, pCO₂, and O₂. *Geochimica et Cosmochimica Acta* **65**, 2677-2690.