List of some stratigraphic modelers

The following list was written in 2006 and has been upgraded some and focused on some geological modelers who have made important contributions to stratigraphic modeling and provides some references for each of them. The list not complete list of all who have made contributions to the science, and other modelers and their references are listed in other sections.

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In the late 1980s Tom Aigner worked with Doyle and Lawrence to make a fairly comprehensive model for simulating carbonate stratigraphy. All of the people who worked on it appear to have moved on to other things.

Some References:

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Aigner, T., Doyle, M., Lawrence, D., Epting, M. & van Vliet, A. (1989) Quantitative modeling of carbonate platforms: some examples. In: Controls on Carbonate Platform and Basin Development (Ed. by P. D. Crevello et al.), Society of Economic Paleontologists and Mineralogists Special Publication, 44, 323-338.

AB: A deterministic computer program has been developed to simulate the stratigraphic evolution of two-dimensional transects across sedimentary basins. The history of sea-level fluctuations is reconstructed using the stratigraphy and geometry of carbonate systems as constraints. Our understanding of the controls on carbonate platform architecture is improved by isolating individual processes. In this respect, we investigate the possible significance of isostasy. -from Authors

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Dan is currently the Emeritus Professor of Carbonate Sedimentology, at Royal Holloway, University of London and has a long and distinguished research and teaching history in carbonate sedimentology and processes. Dan Bosence has worked with numerous research scientists modeling carbonate platform stratigraphy incorporating both subaerial and submarine erosion, sediment re-deposition and sea-level changes.

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Bosence, D. W. J., Pomar, L., Waltham, D. A. & Lankester, T. H. G. (1994) Computer modeling a Miocene carbonate platform, Mallorca, Spain. American Association of Petroleum Geologists Bulletin, 78, 247-266.

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Some References:

Bosscher co-designed a model called CARBPLAT that simulates carbonate platform sedimentation. It does not have too much on erosion and redeposition.

Bosscher, H., and Newall, M., 1996, Stratigraphic modelling at Shell - Examples and model comparison , in Watney, W.L., Rankey, E.C., Franseen, E.K., and Goldstein, R.H., convenors, Numerical Experiments in Stratigraphy - An International Workshop, Kansas Geological Survey, Kansas Geological Survey, Open-File Report, 96-27, p. 67.

Bosscher, H., and J. Southam, 1992, CARBPLAT-A computer model to simulate the development of carbonate platforms in: Geology, v.20, p.235-238.

Bosscher, H., and Schlager, W., 1992, Computer simulation of reef growth: Sedimentology, v. 39, p. 503-512.

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Scott Bowman is President and a software developer at Petrodynamics. He is develops and distributes interactive programs that assist the modelling of strata deposition, compaction and erosion processes. He worked extensively with Peter Vail, one of the pioneers of sequence stratigraphy, encapsulating within stratigraphic simulation PHIL much of Vail's ideas and philosophy. This is one of the most comprehensive packages of this kind of software available. It deals equally well with carbonates and siliciclastics and has add-ons for the petroleum industry for inverse modeling and hydrocarbon migration. PHIL has erosional algorithms at the shore-face, in fluvial settings, surface beveling and marine current erosion. PHIL might be the place to start for building any erosion algorithms. PHIL runs as a native application under the Mac/OS, Microsoft Windows, Silicon Graphics, and SunOS 4.1.3, Solaris operating systems.

Some References:

Bowman, S. A., and P. R. Vail, 1999, Interpreting the stratigraphy of the Baltimore canyon Section, offshore New Jersey with PHIL, a stratigraphic simulator in: Harbaugh et al., eds., Numerical Experiments in Stratigraphy: recent advances in stratigraphic and sedimentologic computer simulations, SEPM Special Publication 62, Tulsa, 362 p.

Ye-Qiucheng; Kerans-Charles; Fitchen-W-M; Gardner-M-H; Sonnenfeld-M-D; Bowman-S, 1996, Forward stratigraphic modeling of the Permian of the Delaware Basin in: American Association of Petroleum Geologists 1996 annual convention, p. 156.

ABSTRACT: Permian platform-to-basin strata of the Delaware Basin in West Texas and New Mexico represent one of the world's most complete, best studied, and most hydrocarbon productive records of this geologic period in the world. This superb marriage of a refined stratigraphic framework and active exploration provided impetus to develop a forward stratigraphic model of this section to better predict the distribution of reservoir and seal relationships. The approximately 30 m.y. interval modeled is composed of 2 km of platform strata and 3 km of basinal strata divided into 8 composite sequences(average 3 m.y. duration) and 45 high-frequency sequences (400 ky m.y. duration). A 130 km dip section through the basin margin Guadalupe/Delaware Mountain outcrop is inversely modeled to derive local tectonic subsidence and a sea level curve for the Permian. In this process, the highest and lowest shoreline positions of each sequence are interpreted based on facies descriptions, which are assumed to approximate the highest and lowest relative sea level. A eustatic sea level curve is calculated by restoring these shoreline positions and removing local tectonic subsidence using a polynomial fit to the derived relative sea level curve. The quantitatively constrained curve for the Permian contains 2nd,

3rd, and 4th order signals with the 3rd-order amplitudes as great as 180 m. This quantitatively constrained accommodation history (calculated eustatic curve and subsidence history) are input into the PHIL forward modeling program. Model variables of sediment supply and depositional system are adjusted to match known outcrop relations. The resulting model is potentially capable of predicting stratigraphy elsewhere in the basin using only subsidence history data from the inverse model.

Bowman-Scott-A; Vail-Peter-A, 1993, Carbonate sedimentation processes in PHIL in: American Association of Petroleum Geologists 1993 annual convention, p. 78.

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Peter Burgess works on many aspects of the stratigraphic forward modeling of carbonates, carbonate platform dynamics and their associated allocyclic and autocyclic processes and sequence development; multivariate sequence stratigraphy; icehouse world sea-level behavior and relative sea level oscillations and carbonate platforms: numerical forward modeling and outcrop studies, flexural-eustatic numerical models for carbonate ramps; peritidal carbonate parasequence development; interaction between mantle, eustatic and stratigraphic processes; forward modeling of the controls on sequence geometries: and cratonic stratigraphic sequences.with numerous research scientists to model carbonate platform stratigraphy and many other topics. He obviously enjoys an eclectic career.

Some References:

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Burgess, P.M. and Allen, P.A., 1996, A forward modelling analysis of the controls on sequence geometries: The uniqueness problem, in: Hesselbo, S. and Parkinson, N., Sequence stratigraphy and its application to British Geology, Geol. Soc. Lond. Spec. Publ. 103, p.9 - 24.

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Peter J. Cowell has collaborated with numerous others to work on simulating the coastal response to sea-level changes (especially sea-level rises) with a model they call STM (shoreface translation model). They deal with sediment budgets and the response of coastal systems to changing sea level under various sediment input scenarios. This approach could be useful for dealing with both carbonate and siliciclastic erosion and redeposition.

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Cowell, P.J., Roy, P.S., Cleveringa, J., and P. L. De Boer, 1999 Simulating coastal systems using the shoreface translation model in: Harbaugh et al., eds., Numerical Experiments in Stratigraphy: recent advances in stratigraphic and sedimentologic computer simulations, SEPM Special Publication 62, Tulsa, 362 p.

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Tim Cross and his associates Margaret Lessenger and Taizhong Duan pioneered the concept of stratigraphic inversion that uses algorithms that help find a unique set of parameters for a given stratigraphy. This inverse modeling is what JNOC is interested in. It seems to be more useful in an academic sense. If JNOC already knew what the stratigraphy was they would not be bothering with modeling. More recently Taizhong Duan has been working on energy-based algorithms for erosion and deposition on carbonate platforms. This is a good approach and should definitely be investigated when building erosion algorithms.

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Cross, T. A. (Ed.) (1990) Quantitative Dynamic Stratigraphy: Prentice Hall, Englewood Cliffs, New Jersey, 615 pp.

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Bob Demicco has also worked on fuzzy modeling of carbonate strata. He is still actively building his model and may be interested in collaboration.

Some References:

Lowenstein, T. K., Hardie, L. A., Timofeeff, M. N., and Demicco, R. V., in press, Secular variation in seawater chemistry and the origin of calcium chloride basinal brines: *Geology*, June, 2003.

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Demicco, R. V., and Klir, G., (eds.), 2003, *Fuzzy Logic in Geology*, Academic Press, San Diego, CA, 365 p.

Spencer, R. J., and Demicco, R. V., 2002, Facies and sequence stratigraphy of two Cambrian Grand Cycles: implications for Cambrian sea level and origin of grand cycles: *Bulletin of Canadian Petroleum Geology*, v. 50, p. 478-491.

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Demicco, R. V. & Spencer, R. J., 1989, MAPS - a BASIC program to model accumulation of platform sediments. Computers & Geosciences, 15, p. 95-105.

Taco den Bezemer

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Taco Den Bezemer used to with others at Vrije University in the Netherlands to model sedimentation associated with fault-bounded folds in non-marine settings.

Some References:

Den Bezemer, T., H. Kooi, and S. Cloetingh, 1999, Numerical modeling of fault-related sedimentation in: Harbaugh et al., eds., Numerical Experiments in Stratigraphy: recent advances in stratigraphic and sedimentologic computer simulations, SEPM Special Publication 62, Tulsa, 362 p.

Den Bezemer, T., H. Kooi, Y. Podladchikov and S. Cloetingh, 1998, Numerical modeling of growth strata and grain-size distributions associated with fault-bend folding in: A. Mascle et al., eds., Cenezoic foreland basins of western Europe (IBS): Geologicl society of London, p. 381-403.

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Peter Flemings has been at the forefront of computer modeling for over fifteen years. He

worked with Theresa Jordan to develop a model for foreland basin stratigraphy and later worked with John Grotzinger to design STRATA, which is a program available as freeware. The foreland basin model is interesting, but models crust like a flexural beam which may not be realistic. STRATA has a siliciclastic and carbonate component. The siliciclastic portion of the model is diffusion based. It is not clear how erosion is handled in the carbonate portion of the model. The results from strata are not very realistic looking.

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Reilly, M., P.B. Flemings, 2010, Deep Pore Pressures and Seafloor Venting in the Auger Basin, Gulf of Mexico, Basin Research, V. 22, p. 380-397, doi:10.1111/j.1365-2117.2010.00481.

Liu X., P. B. Flemings, 2007, Dynamic multiphase flow model of hydrate formation in marine sediments, Journal of Geophysical Research, 112, B03101, doi:10.1029/2005JB004227.

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Dugan, B., Flemings, P.B., 2000, Overpressure and Fluid Flow in the New Jersey Continental Slope: Implications for Slope Failure and Cold Seeps, Science, V. 289, p. 288-29

Flemings and Grotzinger 1997, Flemings, P.B., and Carlson, J., 1996, Transport and deposition of heterogeneous-sized sediment in a non-marine sedimentary basin: : in Watney, W.L., Rankey, E.C., Franseen, E.K., and Goldstein, R.H., convenors, Numerical Experiments in Stratigraphy - An International Workshop, Kansas Geological Survey, Open-File Report, p. 83-86.

Flemings, P. B., and J. P. Grotzinger, 1996, STRATA: Freeware for analyzing classic stratigraphy problems IN: GSA Today, v. 6, n.12, p. 1-7.

AB: We use STRATA, a stratigraphic modeling package were have developed, to describe and illustrate several classic problems in both siliciclastic and carbonate stratigraphy that are still debated. Two simulations of clastic deposition show that, given constant subsidence rate, stratigraphic sequences can be generated by either eustatic sea-level change or variations in sediment supply, and that the resulting stratigraphic architectures are extremely similar. Two examples of carbonate deposition illuminate the development of meter-scale shallowing cycles, and a mechanism for generating 'cycle bundling' that results from the interaction of sea-level change and the intrinsic dynamics of the carbonate system. Ultimately, stratigraphic models are most useful as a way of testing hypotheses of stratigraphic accumulation. We have found STRATA useful in research as well as geological education.

Flemings, P.B., and Jordan, T.E., 1989, A synthetic stratigraphic model of foreland basin development: Journal of Geophysical Research, v. 94, p. 3851-3866.

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Granjeon and Joseph developed a diffusion-based stratigraphic model called Dionisos that operates at a wide range of time scales to simulate geometries and lithologies of coastal settings. Their diffusion equation is based on laws of fluid dynamics and takes into account basin slope, water discharge, lithology fraction and transport efficiency. Again, diffusion may be a useful algorithm for modeling erosion and redistribution of peloids and in the clastics of the North Sea. One interesting thing that IFP did was to use the results of a stratigraphic simulation by Dionisos as a framework for a higher-resolution geostatistical model to model individual rock types. Although it was not carried too far in this paper, this is a good idea and could help solve the problem of scale in computer modeling.

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Granjeon, D. and P. Joseph, 1999, Concepts and applications of a 3-D multiple lithology, diffusive model in stratigraphic modeling in: Harbaugh et al., eds., Numerical Experiments in Stratigraphy: recent advances in stratigraphic and sedimentologic computer simulations, SEPM Special Publication 62, Tulsa, 362 p.

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Granjeon, D., 1997, Modelisation stratigraphique deterministe-conception et applications d'un modele diffusif 3-D multilithologique: Ph. D. Dissertation, Memoires Geosciences, Rennes, v.78, Universite de Rennes, France, 197p.

Joseph-Philippe; Bez-Martine; Eschard-Remi; Rabineau-Marina; Granjeon-Didier; Navarre-Jean-Christophe, 1997, Applications of a 3D multilithological stratigraphic model to the reservoir appraisal in: 1997 AAPG international conference and exhibition; abstracts, AAPG Bulletin. 81; 8, p. 1386

AB: A three dimensional stratigraphic forward model has been developed in IFP to simulate sedimentation processes in continental to marine environments (coastal plain, delta, shoreface and upper offshore). The model is based on an improved diffusion equation which simulates the average fluvial and marine transport of sand, shale and carbonate at a basin scale (tens to hundreds kilometers, hundreds of thousand to tens of million years). The model predicts the geometry of depositional units and their internal facies distribution. It enables to quantify the evolution through time of the water depth, the thickness of the deposited and eroded sediments, and their relative content in basic lithologies (sand, shale and carbonate). In subsurface field studies, a first estimation of the modeling parameters (accommodation i.e. subsidence and eustasy, sediment supply, transport coefficients) is derived from a quantitative analysis of well logs and seismic data. Then an inverse method is used to calibrate precisely these parameters in order to fit the simulation to the available well logs and seismic maps. When this match is achieved, the modeling provides a full 3D distribution of facies between two seismic markers, taking into account the high resolution stratigraphic information coming from the few available wells. In exploration and field appraisal, it helps to validate the geologist's correlation sketch and to predict the extension of reservoir units in areas far away from the wells. The modeling methodology will be demonstrated on different field studies (Niger Delta, Paris and San Juan Basins).

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Website Professional Profile and Contact Information Cedric Griffiths is the Leader of CSIRO Petroleum's Predictive Geoscience Group. His work involves the development of a 3D Forward Stratigraphic Modelling capability at CSIRO and contributing to a variety of quantitative stratigraphic programmes for reservoir characterization and hydrocarbon exploration. Cedges's main area of interest is the quantitative prediction in geology - stratigraphy as the only means of testing geological hypotheses. His previous work has included: NCPGG, University of Adelaide, South Australia, as South Australian Chair of

Petroleum Geology; Stratigraphic Research International (SRi), Trondheim, Norway, Co-founder and Director; BP Exploration, Trondheim, Norway, Principal Research Consultant; University of Trondheim, Norway, Nordic Council Research Professor; Norwegian Continental Shelf Institute, Trondheim, Norway Senior Research Scientist; University of Newcastle-upon-Tyne, Newcastle, England, PhD candidate; Zambian Geological Survey, Lusaka, Zambia, Field Geologist; Exploration Logging Int., England, Wellsite Geologist / Mudlogger; DeBeers (Condiama) Angola, Field Geologist.

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Griffiths, Cedric M., Felix Gradstein, (1996) Essentials of Quantitative Stratigraphy, Published by Kluwer Academic Publishers Group ISBN 0412434601

Griffiths C. M., Dyt, C., Paraschivoiu, E., Liu, K., (2001), Sedsim in hydrocarbon exploration, in Merriam, D., Davis, J. C. (Eds.) Geologic Modeling and Simulation, Kluwer Academic, New York, p. 71- 97.

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John Harbaugh has worked on simulation of basin stratigraphy for 30 years. He co-wrote several books on the subject. The most recent book by Martinez and Harbaugh has a section on simulating erosion, transport and deposition. He has helped to design numerous programs including DYNASED, SEDSIM, DEPOSIM and WAVE. The erosion and sediment transport are primarily done in WAVE which is a 3-D or 4-D program. The book simulation nearshore environments is worth buying. It has nice figures and lots of equations. DYNASED is a stochastic model designed to examine the complex interplay of nearshore depositional processes.

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Chris Kendall is a pioneer of stratigraphic modeling. He has worked with numerous collaborators and developed numerous models, the most recent being the empirical simulation SEDPAK. SEDPAK constructs empirical models of sedimentary geometry. These sedimentary geometries are created by the infilling of a two dimensional basin from both sides with a combination of clastic sediment and in situ carbonate growth. The simulation is designed for an engineering workstation environment. Data entry is accomplished by using a graphical user interface. Values are entered for the initial basin configuration and, as a function of time, the following variables may be specified: local tectonic behavior, sea level behavior, amount and direction of clastic deposition, accumulation rates of carbonates both as a function of water depth and pelagic accumulation. The model traces the evolving geometries of clastic and carbonate sediments through time, responding to the depositional processes previously itemized. Sediment geometries are plotted as they are computed, so the results are viewed immediately.

Based upon these observations, parameters can be changed interactively and the program rerun until the resultant geometries are satisfactory. SEDPAK is a powerful tool which can be used to interpret sequence stratigraphy from seismic and well cross sections. It allows the interactive testing of all the basin fill variables (including subsidence and uplift, sea level, and rates of sedimentation) against interpreted seismic or stratigraphic sections, magnification of a segment of simulation geometries by zooming in on the output, and comparison with interpreted seismic and stratigraphic data.

SEDPAK requires user-specified information about various minor parameters (e.g., repose angle) which affect the major process variables in the model. In return, SEDPAK provides the graphic and tabular outputs which describe the accumulated sediments deposited by the model over a specified geologic time period. These outputs may have several uses. In particular, SEDPAK enables explorationists and production geoscientists to extend and "complete" observed data, specifically seismic and/or well based cross sections, and compare model outputs with this data in an attempt to substantiate and verify inferences drawn about the hydrocarbon entrapment potential of a basin. Similarly SEDPAK offers the researcher an opportunity to investigate the sensitivity of a particular lithofacies model to such parameters as sea level behavior, tectonics, and sedimentary processes. In this way, a catalog of simulations that represent both promising and implausible zones for hydrocarbon entrapment can be acquired.

SEDPAK was used to model Tertiary sediments of the Great Bahama Bank, the Permian of West Texas, the Sichuan Basin and numerous other hypothetical and real examples with a good deal of accuracy. The erosion algorithm in SEDPAK is based on exposure. Sediment also moves off of the platform when too much is produced at the reef or shelf edge. Building algorithms with which sediment is continuously produced at the shelf edge and then transported down-slope when overproduction occurs could be a useful approach for modeling the Cretaceous of the Middle East.

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Margaret Lessenger has been a leader in stratigraphic inverse modeling. She did her Ph. D. at the Colorado School of Mines on modeling. She has continued to refine her model and play an important role in stratigraphic modeling.

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Ulf Nordlund pioneered the application of fuzzy logic in stratigraphic modeling. The methods of fuzzy logic allow for quantification of qualitative data and modeling of complex nonlinear relationships and systems involving non-random uncertainty. A fuzzy system is a set of logic rules using fuzzy sets with imprecise boundaries instead of conventional sets with precise boundaries in premises and conclusions. This approach seems appropriate for stratigraphic modeling because it is hard to quantify some sedimentologic processes. It might be possible to take the qualitative idea that "peloids are eroded off of shoals and re-deposited in tidal channels during sea-level fall" and incorporate it into the model.

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Chris Paola's major research focus has been the development of techniques for experimental stratigraphy, the centerpiece of which is the Experimental EarthScape system (XES or "Jurassic Tank"), a large experimental basin equipped with a subsiding floor.

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ABSTRACT: The Lower Mississippian Lodgepole/lower Madison Formations (20-225m thick) developed along a broad (>700km), storm-dominated pericratonic ramp. Three types of fifth-order upward-shallowing cycles are recognized across the ramp-to-basin transition. Peritidal cycles consist of very shallow subtidal facies overlain by algal-laminated tidal flat deposits, which are rarely capped by paleosol/breccia layers. Shallow subtidal cycles consist of stacked ooid grainstone shoal deposits, or deeper subtidal facies overlain by ooid-skeletal grainstone caps. Deep subtidal cycles located along the outer ramp consist of basal sub-storm wave base limestone-argillite, overlain by storm-deposited limestone, which are capped by hummocky stratified to massive skeletal-ooid grainstone. -from Authors

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Rivanaes, along with Kaufman et al. from MIT, was one of the first to develop depth-dependent diffusion models for modeling erosion, transport and sedimentation. Again, diffusion is a possible approach for dealing with the peloidal grainstones and clastics. He now works for a hydrologic company and is working on a model called DEMOSTRAT that is a siliciclastic model. His approach could be useful for modeling sediment transport.

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Rivenaes, J.C., 1997, Impact of sediment transport efficiency on large-scale sequence architecture: results from stratigraphic computer simulation in: Basin Research, v9/2, p. 91-105.

ABSTRACT: The computer simulation model DEMOSTRAT, is a powerful tool in investigating the sequence development scenarios in a 2-D dip section. The model includes tectonic subsidence, eustasy, two- component (sand and mud) nonlinear diffusional sediment transport, compaction and isostasy. The transport coefficients in the diffusion equations express the system's ability to transport sand and mud, and are mainly dependent on climate and subaquatic processes. Keeping other model input parameters constant, the magnitude of transport coefficients seems to have an important impact on sequence development. With high transport coefficients, extensive erosion during sea-level fall and lack of sediment buildup above sea-level during rise may reduce the preservation potential for nonmarine sediments. In addition, the former slope break will be eroded during transgression, forming sand-rich slope or basin floor sediments that may be misinterpreted as lowstand fans. Moreover, the magnitude of transport coefficients has an impact on unconformity timing and development (shown in Wheeler plots).

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Rudy Slingerland has worked on modeling of siliciclastics and siliciclastic depositional environments for many years. The book that he wrote with Harbaugh and Furlong is excellent and could have a lot of useful information. He has also worked on modeling different types of currents and this is critical for his Cretaceous study.

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Michael Steckler has worked on computer modeling of basin scale stratigraphy until recently when he worked on high-resolution sequence stratigraphy and the interplay of eustasy, tectonics, erosion and sedimentary processes. His most recent model is discussed in the SEPM Special Publication 62 volume and there is a good deal on erosion. He works on the rate of erosion and includes an algorithm that erodes more during long-term exposure than during short-term exposure.

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James P. Syvitski currently director of CSDMS, the diverse community of experts promoting modeling of earth surface processes by developing, supporting, and disseminating integrated software modules that predict the erosion, transport, and deposition of sediment and solutes in landscapes and their sedimentary basins. He has developed numerous computer sedimentary simulations for modeling siliciclastic depositional settings and processes. Many of the models are linked together and described in his publication in the SEPM Special Publication 62 volume. The model he developed also can make synthetic seismic profiles and logs from any portion of the model. This integrated approach is a good one for any new modeler

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Lyn Watney, Gene Rankey and others have worked for several years to compare various stratigraphic models. Their summary in the SEPM 62 volume is an excellent summary of the history and state of the art. He has also worked with others to produce 1-D and 2-D models.

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