Recommendations for construction of carbonate stratigraphic simulator

Modeling of carbonate build-ups from the prospective of reservoir characterization requires a complex 3-dimensional stratigraphic simulator. The following are recommendations are essential to achieving the goal of reservoir simulation and prediction:

Robust sedimentologic/stratigraphic and structural model: It is essential to have a good understanding of the stratigraphic architecture and depositional environment when constructing the model. One clearly needs to study of the build up and its facies, but the sedimentological model should not be too simple. The geometries might best be understood after a 3-D seismic or well log survey has been interpreted. A good outcrop analog for this type of system might be in the Miocene of Turkey (Janson and Eberli, 1999). The Miocene section there is composed of numerous isolated platforms where grainstones were produced on the tops of the platforms and then deposited on the edges of the platforms as they prograded into the lows. There are no blankets of grainstone at the bases of the inter-platform lows or channels. A thorough understanding of the controlling parameters on this type of system is essential to construction of a good model.

It is also important to understand what controls the isolated platform development. Are they mounds? Are they fault controlled? If they are fault controlled and the faults are active during deposition, the modeling of the subsidence history and fill of the inter-platform areas will be quite different than if they are mounds.

3-Dimensional model: If a reservoir simulation is the ultimate goal of the project, a 3-D model is essential. There are only a few existing 3-D stratigraphic models (Cross and Duan, 1999; Nordlund, 1996, 1999; Granjeon and Joseph, 1999). Granjeon and Joseph's (1999) model is interesting and they took the next step and performed a reservoir simulation within the modeled stratigraphy (Dolgiez et al., 1999). It cannot be modeled as a simple ramp or rimmed shelf because there is no consistent depositional strike and dip. The model should be able to handle multiple platforms and progradation in several directions.

Modelling of waves, wind-driven currents and tidal currents: Filling of the channels could be symmetric or asymmetric depending on strength and consistency of the prevailing wind-driven currents, waves and tidal currents (see Eberli et al., 1994 filling of Andros Channel). If the platforms are tide-dominated, a more symmetrical progradation might occur. If they are wind-dominated a more asymmetrical progradation will occur. In

an asymmetric progradation pattern, the clinoforms are steep on the windward side of the platforms and gentle on the leeward side. This is important because the lateral extent of the reservoir facies may be quite different depending on which side of the platform they occur. (Also see the series of three books on Computer modeling of seas and coastal regions).

Erosion: Erosion can be modeled several different ways. Again, it is important to understand what sort of currents are moving the sediment (tides, wind-generated, waves, or storms) and input current velocities accordingly. Many modelers of siliciclastic systems, have chosen to model erosion as part of an overall diffusion algorithm (Rivenaes, 1992; Kaufman et al., 1991; Flemings and Grotzinger, 1996). Another approach which looks promising is the energy-based algorithm used in Cross and Duan (1999). Most models have erosion algorithms that range from simple linear relationships to water depth to more complicated modeling of specific processes. Others that are worth reading are Bosence et al. (1994) and Bowman and Vail (1999).

One of the difficult things to model in carbonates is early marine diagenesis. It is difficult to model the effects of hardgrounds and other early marine cement on erosion. In my experience with Cretaceous carbonates, there is not much early marine cement, so this may bot be an issue here.

Fuzzy or crisp model? Ulf Nordlund (1996, 1999) and Bob Demicco have pioneered the use of fuzzy modeling in carbonates and it may be the best way to go. Fuzzy modeling is where there are not crisp boundaries between facies and processes but continuums. A platform need not be only affected by tides or waves but a combination of both. A rock type need not only be sand or mud but may be a combination of the two. Nordlund has developed a 3-D fuzzy model that may be a good starting point for a more complex model.

Deterministic, stochastic or inverse model? It is important to decide early on what type of model should you want. Most models are stochastic vs, deterministic, because it is possible to see how different parameters might interact to produce an unexpected result with a stochastic model. Inverse models (Lessenger and Cross, 1999) are useful for defining what parameters are necessary to produce a given stratigraphy. It might be best to build a stochastic model that has an inverse component to it. If stratigraphy is well understood in one area and not in another, the controlling parameters (subsidence history, sea-level change, accumulation and erosion rates, etc.) could be determined through an inverse model in the well understood area and applied in the poorly understood area.

Problem of scale: One of the biggest problems with stratigraphic modeling is including processes that occur at vastly different time scales. Trying to model the effects of daily - yearly tides or storms in the same model as sea-level changes and tectonic activity which occur at the 0.01-1 million-year scale is very difficult. With increased computing power that may be available now or in the near future, it may soon be possible to run models that have millions or billions of time slices in them where daily processes can be modeled with million year scale tectonic and sea-level changes in a reasonable amount of time.

Another possible approach is that being done at IFP (Institute Francais du Petrole) where they first do a stratigraphic simulation at the kilo-year scale and then so a more complex geostatistical reservoir simulation within the predicted stratigraphy (Dolgiez et al., 1999). This approach has a long way to go but may looks promising. It might be good to contact IFP concerning this approach and see if they are interested in collaboration.