Implications of Cell Size on Modeling of Facies Proportions: A Modern Carbonate Platform Example*

By
Gregory Benson[1] and Steve Bachtel[2]

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[1]Exxon Mobil Upstream Research Company (gregory.s.benson@exxonmobil.com)
[2]ConocoPhillips

Abstract

In shallow carbonate platform interiors, a wide variation in micro-environments and associated depofacies are found in close proximity (example: patch reefs surrounded by skeletal grainstone rings within a background of peloidal packstone). When these depofacies are larger than the geologic model cell size, each cell can reasonably be assigned a discrete rock type, as is done in object-based modeling. However, if the cells need to be made so large that they encompass a mix of depofacies, the modeler has the choice to either assign the cell only its most populous facies (ignoring minority rock types that may contribute significantly to flow) or to characterize the cells as a mixture of depofacies using multiple facies proportions.

This pixel-based satellite image research using LANDSAT 7 data investigates how the stochastic modeling parameters for facies proportions need to change as a function of cell size. Generally, as cells get larger the variance of facies proportions is progressively reduced because cells become less likely to contain only a single facies. In other words, when cells get larger they encompass more diversity, eventually becoming almost homogeneous in their degree of diversity. This is the effect predicted from the Central Limit Theorem.

Consider a simple example in which 50-meter wide patch reefs are sparsely scattered across an area (Figure 1). The odds of a single model cell containing more than one patch reef is a function of the spacing of these relatively small patch reefs over the platform combined with the size of the model cell. One of these 50-meter reefs would account for 100% of four contiguous 25-meter model cells. But since the individual reefs are widely separated, the surrounding model cells would contain 0% of patch reef depofacies. In contrast, when using 100-meter model cells that same 50-meter patch reef can account for no more than 25% of any cell. So, for 25 meter model cells the range of expected patch reef proportions would vary from 0 to 100%, but for 100 meter model cells the range of patch reef proportions would only range from 0 to 25%, since no individual 50-meter reef could ever occupy more than ¼ of any 100m model cell.

In addition to the facies proportion variance reduction observations mentioned above, experimental variogram ranges are observed to become longer as cell dimensions increase. Staying with the patch reef example (Figure 2), consider that the concentration and spacing of these small patch reefs changes across the platform. In some areas the patch reefs cluster more tightly, and in other areas they are relatively rare. At larger cell sizes the short wavelength data (detailed locations of individual patch reefs) are averaged out, but longer wavelength patterns of patch reef clustering begin to emerge. Thus cell size defines the frequency content, and this defines the minimum limit of the variogram range. The insights from this LANDSAT photo analysis are useful whether we are creating depofacies probability models for use as conditioning volumes for small, discrete cell assignments (OBM or SISIM) or as large, common-scale facies proportions for purposes of assigning flow characteristics for input to reservoir simulation (whole-cell effective property estimation).

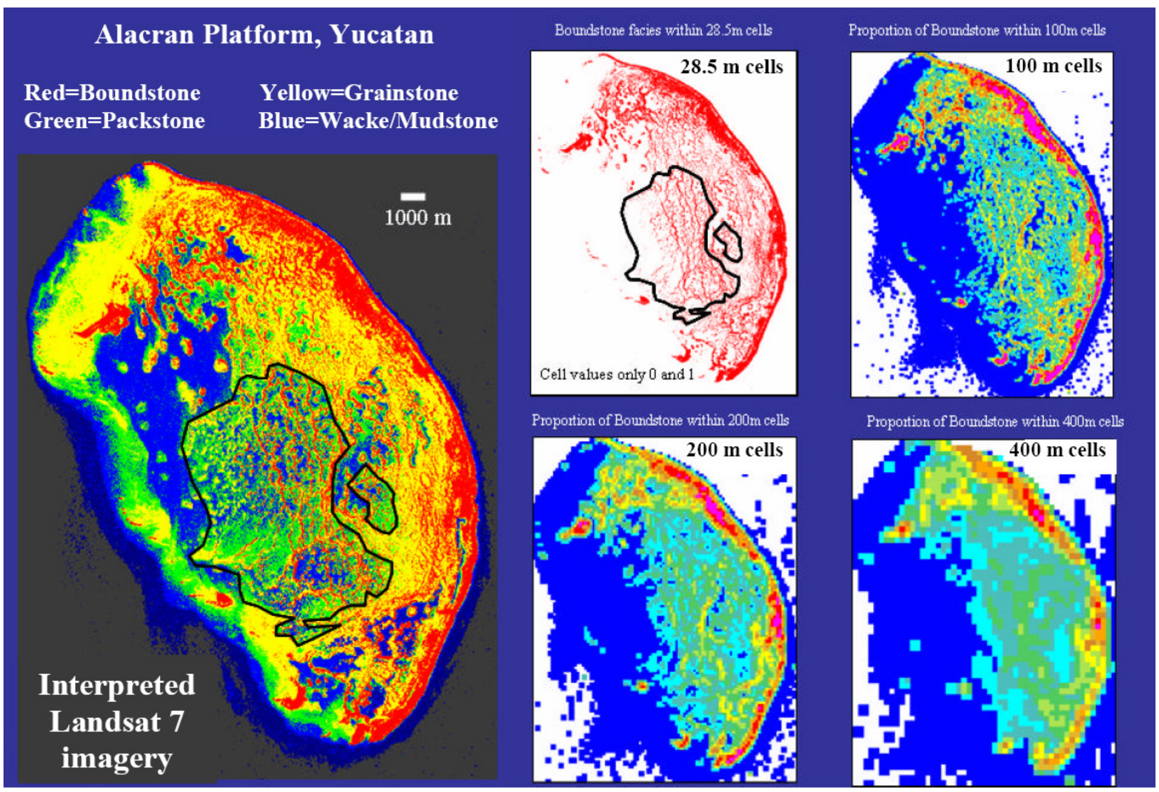

Figure 1. Alacran platform, Yucatan (interpreted Landstate 7 imagery). Red=boundstone; yellow=grainstone; green=packstone; blue=wacke/mudstone. The left image is the interpreted Landsat image. The colors represent the various depofacies. The four images on the right are proportion maps for the reef facies at four different cell size groupings. Note that at larger cell sizes the extreme proportion values tend to be averaged away. As different as these images are, bear in mind that each of these proportion maps is exactly correct for the model cell size being used.

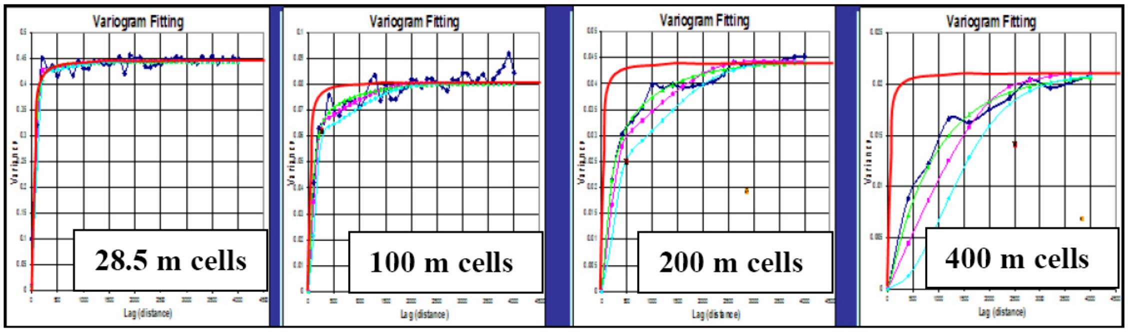

Figure 2. Semivariograms of the four cell groupings. The dark blue line is the experimental variogram, and the green, pink, and light blue curves are the Exponential, Spherical, and Gaussian variogram regressions. The red curve is the 28.5 m variogram, repeated for each cell grouping as a reference. The Exponential regression fits the experimental data best for all cell grouping sizes for this depofacies. Note that the variogram range (X axis coordinate where the variogram goes flat) increases as cell size increases. The variogram range used to model depofacies proportions should take into account the model cell size and the dimensions and spacing of the depofacies elements.