# Stratigraphic Evolution of Salt-withdrawal Minibasins: Implications from Numerical Models

Hang Deng

April 28, 2016


**Abstract**

Minibasins are an important morphological feature which were formed on many continental slopes (Lamb et al., 2006). Minibasins are formed by vertical subsidence of deepwater sediment onto thick salt on the continental slope and are usually in circular to elliptical forms. Although minibasins are relatively small (1 km to 20km wide), they could hold significant amount of hydrocarbon resources.

Topography of such basins has a significant control on the dynamics and deposition of turbidity currents (Kneller and Buckee, 2000), which affect the resultant stratal patterns of minibasins. Differences in stratigraphic architecture could lead to different hydrocarbon exploration and development strategies because hydrocarbons were trapped at various locations (basinal area v.s. against salt diapirs). Although numerous previous studies have illustrated basin-scale stratigraphic architecture of salt-withdrawal minibasins, no clear understanding of how subsidence and sediment supply interplayed to generate different stratal patterns over regional scale.

This project attempts to employ simplified forward numerical modeling to provide a better understanding of how sediment supply negotiate with subsidence and form different stratigraphic geometries. The model employs sediment diffusion model, parabolic subsidence, and erosion to delineate the evolution of minibasins. The comparison between modeling results and real-world seismic data provides a better prediction of deepwater clastic architecture in minibasins. Such study can be used to reduce risk of hydrocarbon exploration and production.


## Introduction

A complex array of deformed salt bodies and localized depocenters over these salt bodies which are called minibasins dominate the subsurface Gulf of Mexico (Sumner et al., 1991; Figure 1). Slope mini-basins are often almost entirely bounded by bathymetrically-high, shallow-seated salt massifs. The internal structure within slope mini-basins is characteristically simple, relatively unfaulted, and varies from monoclinal and basinward-dipping in more proximal positions to symmetric and synclinal in more distal positions (Sumner et al., 1991).

Large amount of hydrocarbons has been and is being produced from such minibasins. One of the most well-known examples is the Auger field. The first well in this field drilled in 1995 produces over ten thousand barrels of oil per day.

Different stratal patterns have been mapped from extensive seismic data collected within the Gulf of Mexico. Minibasins show stratal patterns of onlapping, drapping, offlapping, and/or complex terminations. The debate of the controls of forming such stratal patterns and how the controls interact with each other has been raised for long time, but few clear understanding of those problems has been derived. This project employs numerical modeling to quantitatively delineate the evolution of minibasins. The purpose of this project is to provide a method of predicting evolution of minibasins and their dominant controls from stratal terminations and depositional patterns.

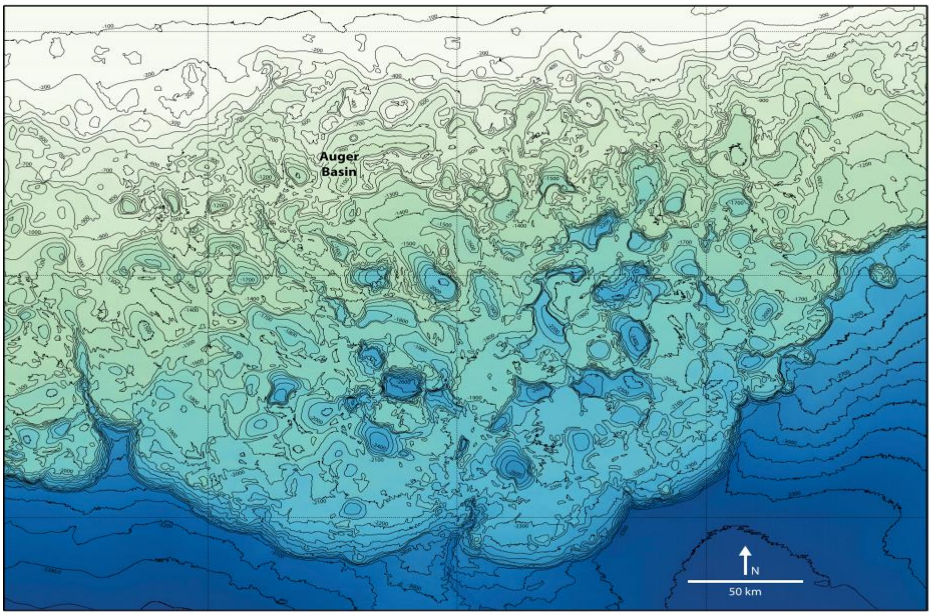


Figure 1. An overview of allochthonous salts in the Gulf of Mexico with mark of locations of the Auger Basin (Sylvester et al., 2015).

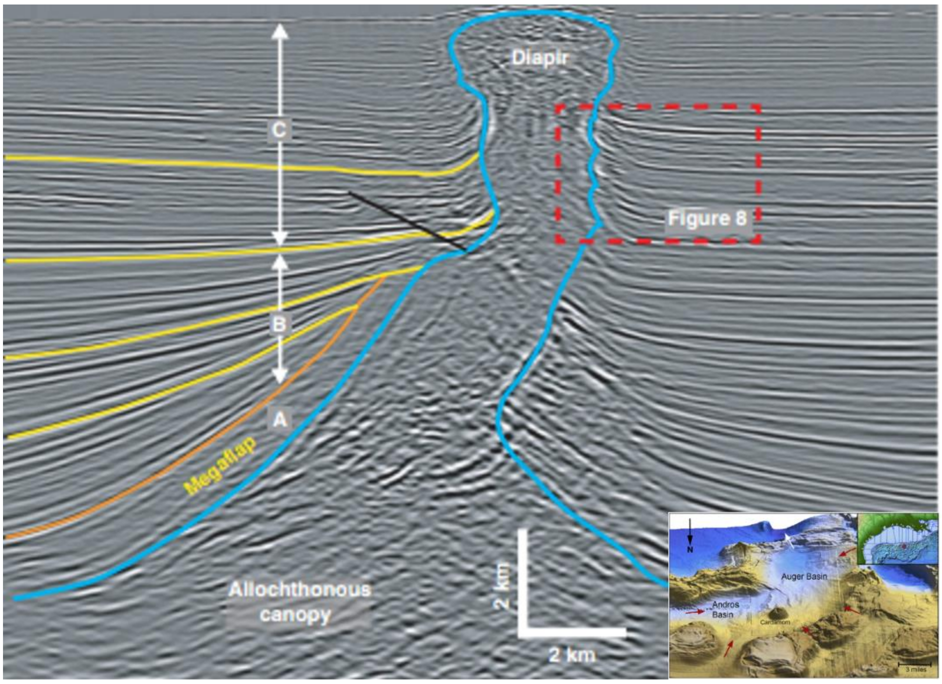


Figure 2. Stratigraphy of the Auger field in Gulf of Mexico with plain view shown at the lower right.

**Methods**

Minibasins with the same width (10 km) were created by subsidence. Parabolic subsidence rates were used to simulate the tectonic evolution of minibasins. The parabolic subsidence rates did not change through time. Therefore, minibasins subsiding through time were created as Figure 2.

Sediment supply were modeled using simple diffusion algorithms with various marine diffusion coefficients. The algorithm is shown below:

$$\frac{dh}{dt} = \mathcal{K}\frac{\partial^2 h}{\partial x^2}$$

Where h is the elevation of the deposits in meters, t is the time in thousands of years, and x is the downstream distance in meters.

In this model, I used constant sediment supply rate and sediment supply rate varying as step function (zero supply in the first half of time, constant supply in the second half of time) to simulate the sedimentation in the minibasins.

Erosion rate was added as well. Parabolic erosion rates with the highest rate at the edge of the minibasins were used for simulating erosion. This assumption might be realistic because erosion of sediments is very high when sediments were entering into the basins in real world.

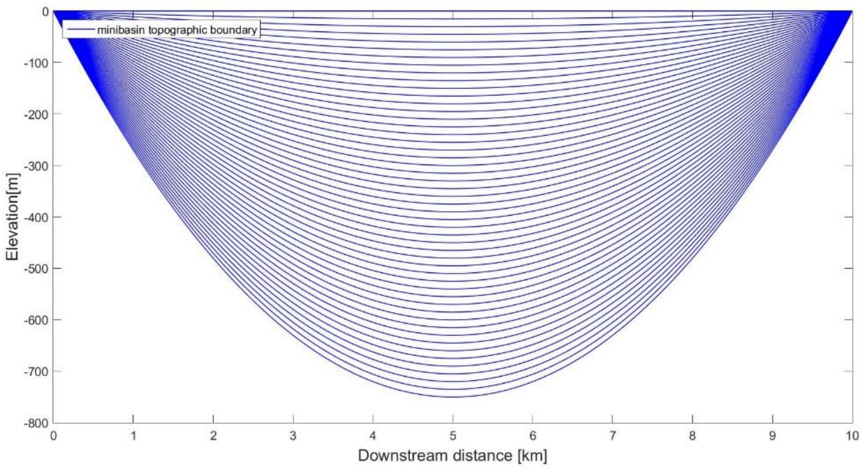


Figure 3. minibasin subsidence through time with maximum subsidence rate of 1.5 meters per thousand years.

**Modeling results**

The figures below are some representative results of this modeling project.

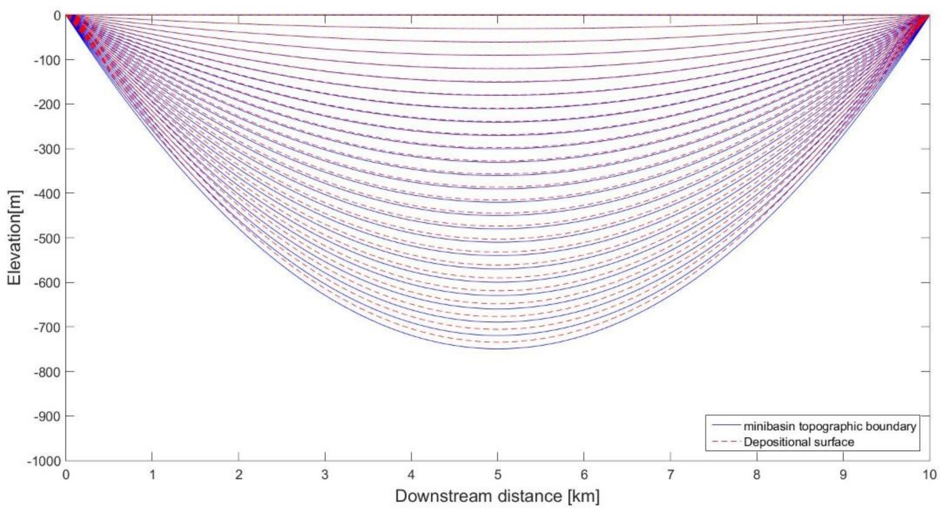


Figure 4. single minibasin stratigraphic evolution. Red dash lines represent depositional

surfaces and blue lines represent minibasin topographic surface.

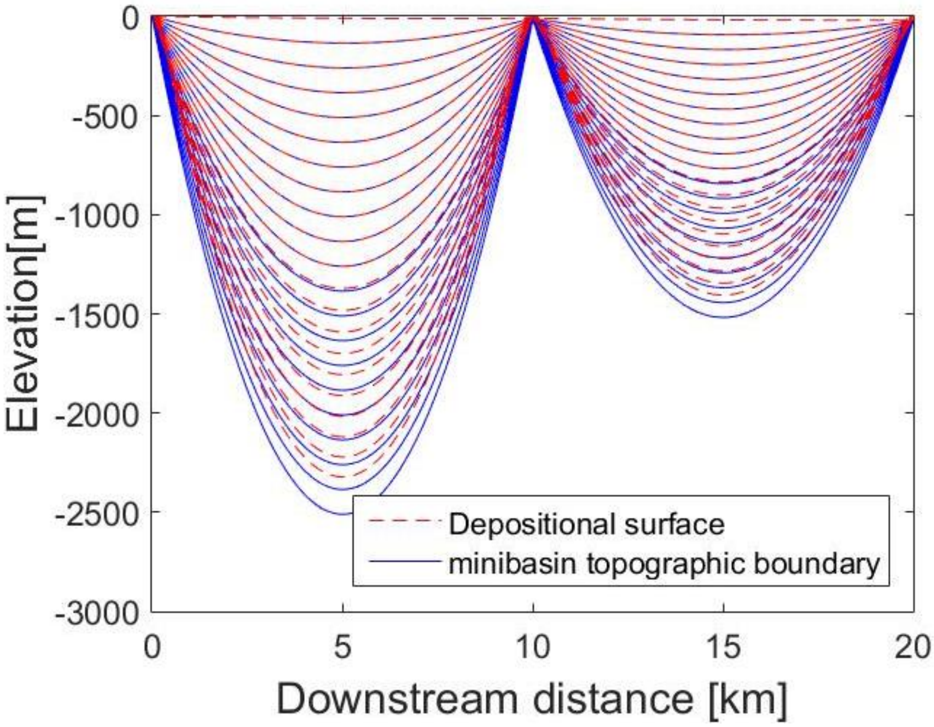


Figure 5. Stratigraphic evolution of two adjacent minibasins with different subsidence rates.

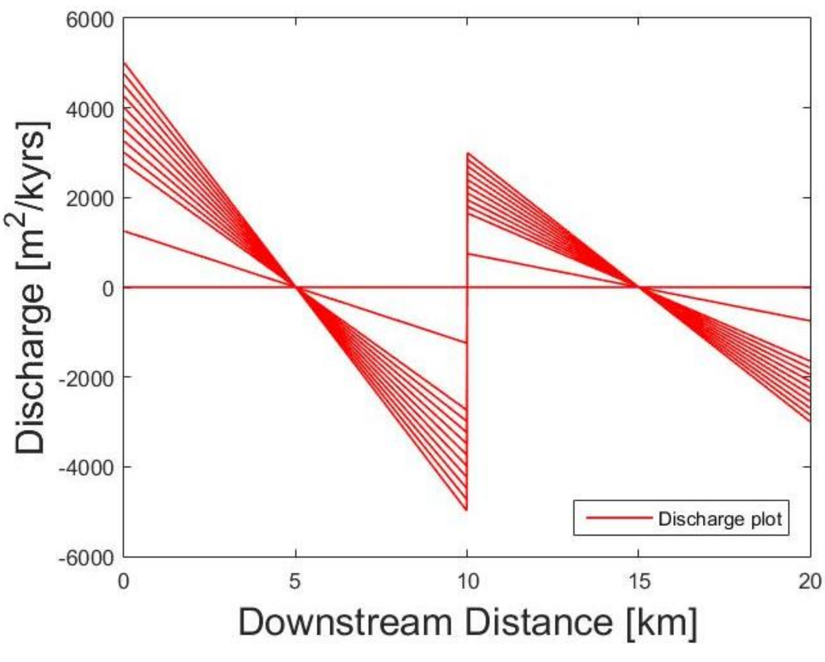


Figure 6. Sediment discharge plots through time and downstream distance.

**Discussions**

The initial modeling results show various depositional surfaces that can be used to compare with seismic reflections in Figure 7. The formation of drape fills might be dominantly controlled by minibasin subsidence. The high subsidence with moderate to low sediment supply might result in drape fills. The formation of the axial fills might be dominantly controlled by sediment supply rates. The high sediment supply rates with moderate to low minibasin subsidence might result in axial fills.

As the modeling results indicate, it would be possible to predict the stratigraphic patterns of minibasins through estimating paleodischarge and subsidence of continental slopes.

Additionally, we can infer from the modeling results that there is higher mismatch of topographic surfaces and depositional surfaces in the older strata than younger strata and at basin edges than basin central area.

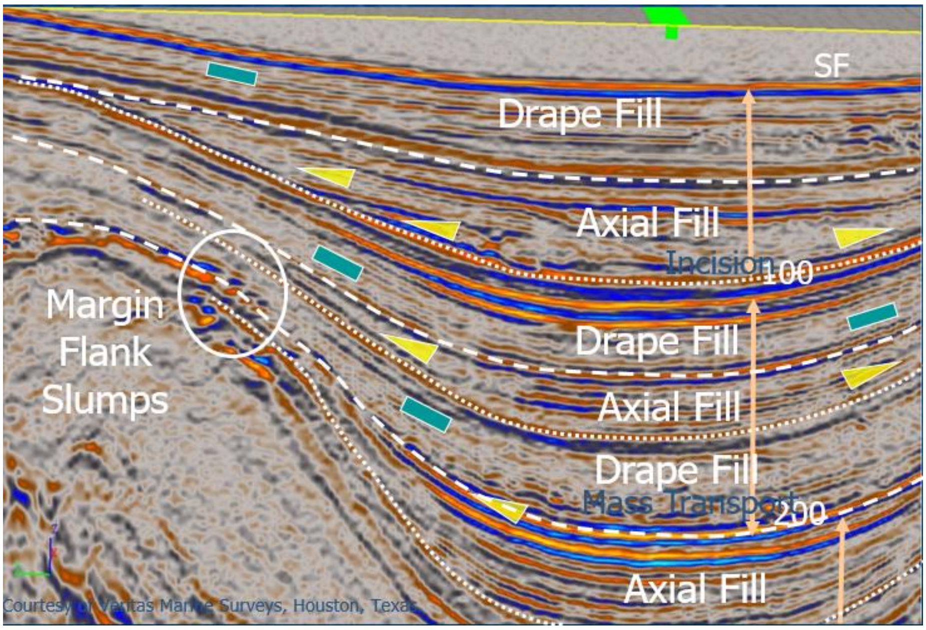


Figure 7. Cross section of minibasin in the Gulf of Mexico showing different stratal patterns (Figure courtesy of Vishal Maharaj, now in Marathon Oil).

**Future work**

Sylvester et al., 2015 illustrates another modeling method to study the stratigraphic evolution of intraslope minibasins. The authors assume all sediments were dumped in the center of the minibasins without consideration of erosion and compaction. It does not take physical laws (e.g. diffusion) into consideration either. In the future work, I will employ similar method by calculating the volume of accommodation created by minibasin subsidence, comparing accommodation with sediment input, and updating surface elevations of deposits through time if accommodation matches volumes of sediment input. To further this research, I will add rules of erosion and compaction into my model. It will allow for a better prediction of stratigraphic evolution of intraslope minibasins.

Modeling turbidity currents over the minibasin topography will be another focus in future project. Methods are introduced in Pratson et al., 2000. Original work is from Jiang and Leblond, 1993 and Parker et al., 1986.

**References**

Hearon, T. E., Rowan, M. G., Giles, K. A., and Hart, W. H., 2014, Halokinetic deformation adjacent to the deepwater Auger diapir, Garden Banks 470, northern Gulf of Mexico:

Testing the applicability of an outcrop-based model using subsurface data: Interpretation, v. 4.

Jiang, L., and Leblond, P. H., 1993, Numerical modeling of an underwater bingham plastic mudslide and the waves which it generates: Journal of Geophysical Research, v. 98, pp. 10,303-10,317.

Kneller, B. and Buckee, C., 2000, The structure and fluid mechanics of turbidity currents: a review of some recent studies and their geologic implications: Sedimentology, 47(Suppl. 1), 62–94.

Lamb, M. P., Toniolo, H., and Parker, G., 2006, Trapping of sustained turbidity currents by intraslope minibasins: Sedimentology, v. 53, pp. 147-160.

Parker, G., Fukushima, Y., Pantin, H. M., 1986, Self-accelerating turbidity currents: Journal of Fluid Mechanics, v. 171, pp. 145-181.

Pratson, L. F., Imran, J., Parker, G., Syvitski, J. P. M., and Hutton, E., 2000, Debris flows vs. turbidity currents: a modeling comparison of their dynamics and deposits: AAPG Memoir 72, p. 57-72.

Sylvester, Z., Cantelli, A., and Pirmez, C., 2015, Stratigrpahic evolution of intraslope minibasins: Insights from surface-based model: AAPG Bulletin, v. 99, pp. 1099-1129.

Sumner, H. S., Robison, B. A., Dirks, W. K., and Holliday, J. C., 1991, Structural style of salt/mini-basin systems: lower shelf and upper slope, central offshore Louisiana: GCSSEPM Transactions, v. 41, pp. 582-582.