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Modeling Flow Barriers and Baffles in Distributary Systems Using a Numerical Analog From Process-Based Model*

Hongmei Li[1], Coralie Genty[1], Tao Sun[1], and James K. Miller[1]

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Abstract

Scour lobes are the fundamental depositional elements in deep-water distributary systems. One common feature of a scour lobe is the fining of grain sizes in both vertical and horizontal directions. The finest grained deposits are potential flow barriers which could compartmentalize the reservoir. On the other hand, erosion (due to scour) of the fine-gained layer during deposition of the overlaying lobes may lead to vertical amalgamation of lobes that enhance the reservoir's connectivity. Therefore, modeling flow barrier and scour distribution is key to predicting reservoir connectivity.

Since barrier distribution is associated with individual lobe geometry, we developed a workflow for extracting lobe-stacking patterns from process-based models. These process-based models simulate the fundamental geologic process and produce realistic 3D numerical representations of the reservoir architecture. Therefore, their results provide ideal reservoir analogs for collecting lobe stacking pattern statistics.

Using the process-based model as a reservoir analog, a hierarchic approach is used for modeling flow barrier distribution. First, the lobe distribution is simulated using a surface-based modeling technique. Individual lobe placement is determined based on the statistics of stacking pattern and topographic constraint. Second, barriers are simulated within each lobe. This is done either by explicitly adding barrier to lobe top surface, or by simulating permeability using vertical and horizontal trends. The resulting simulated models successfully reproduce the pattern features observed in process-based models.

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Objectives

- Quantitatively define flow barrier and baffle distribution in distributary systems (statistics, trends and patterns) using the results from process-based models

- Develop geologic modeling method for more accurately placing flow barriers in models.

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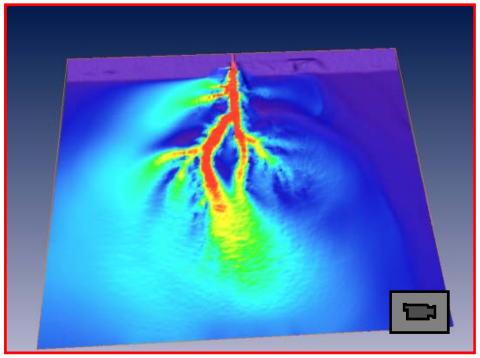
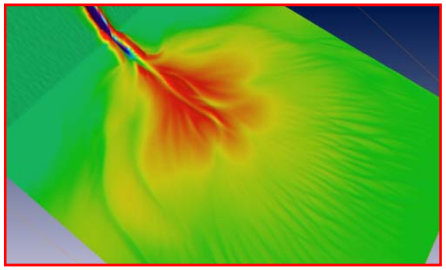
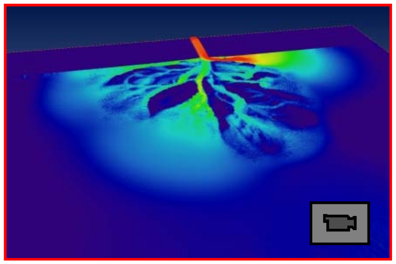
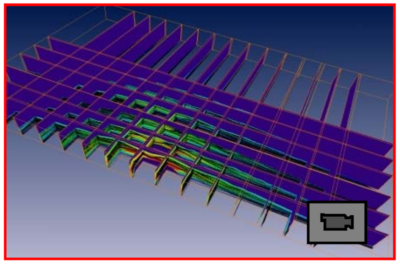
Process Based Models

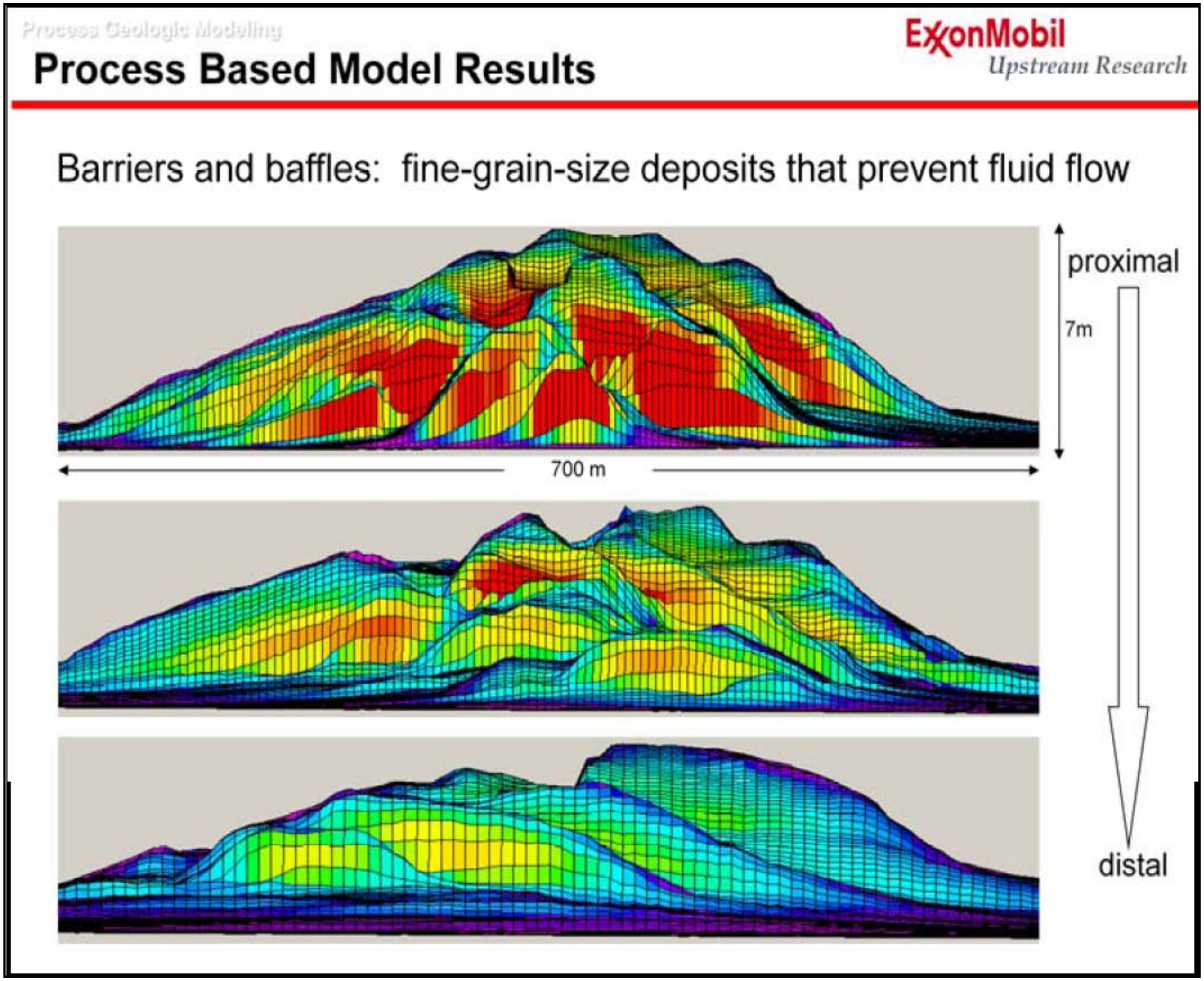
- Physics-based forward computer models simulate fluid flow and sediment erosion, transport, and deposition in fluvial, shallow, and deep water environments.
- Models are fully based on the physics of turbulence, fluid flow and sediment transport.
- Have also been validated and calibrated with tank experiments and field data sets.



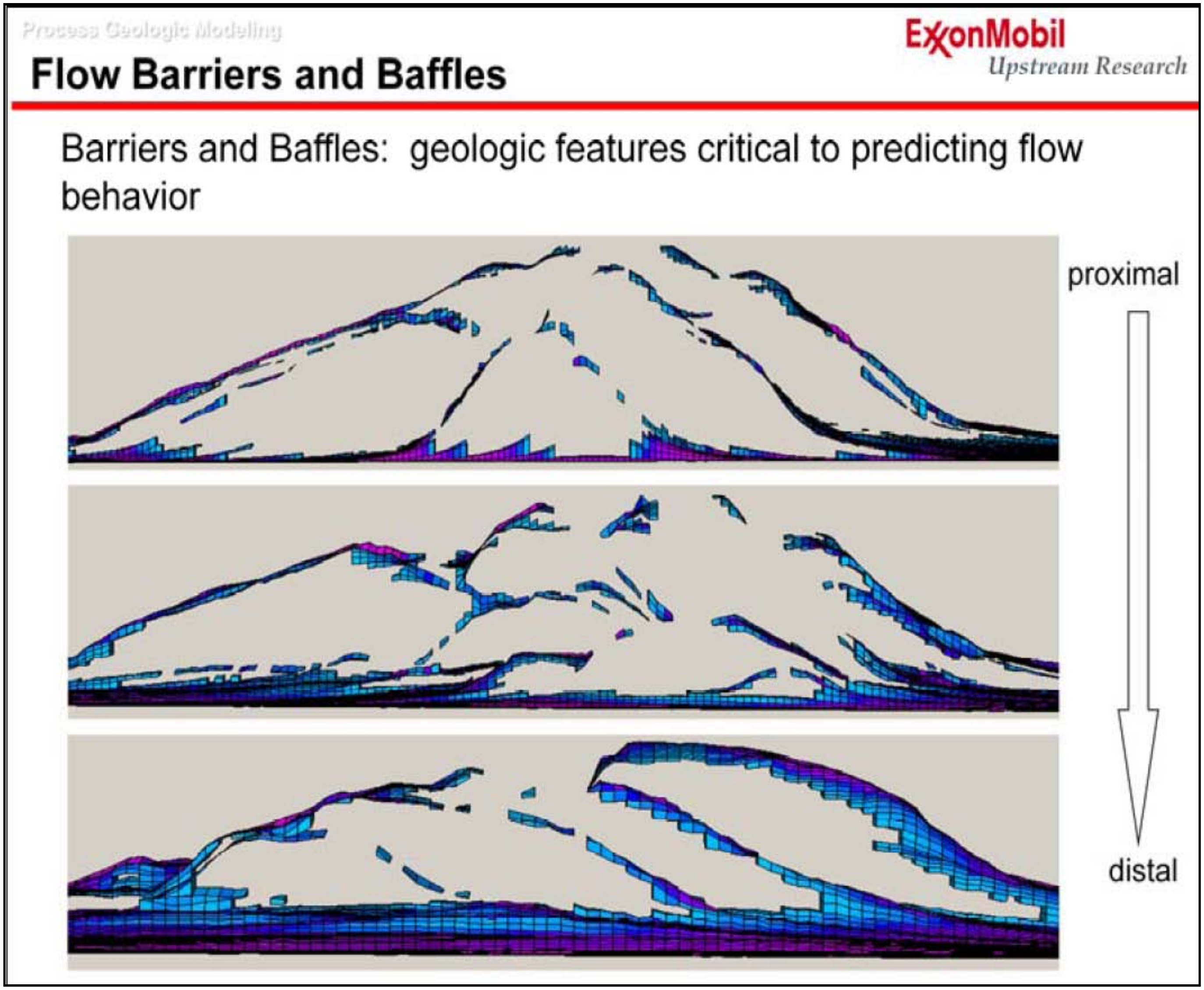








This are three x-sections taken from PBM shown in previous slide. The color is for grain size. From proximal to distal, the lobe stacking pattern changes from vertical aggradation to lateral migration. So the lobes are diverging outwards. Within individual lobes, the deposits are fining upwards. They are also fining laterally from axis to margin. These relatively fine deposits could have very low permeability, and prevent fluid flow. In this case we call them flow barriers.



These are the same X-sections with coarse deposit filtered out, only shows the barriers. We can see the barriers are pretty thin, but quitecontinuously distributed along lobe top surfaces except where erosion presents. They block the contact between lobe sand bodies. Many studies have shown that if the areal/surface coverage of barriers reaches 40%, they will have impact on reservoir connectivity, hence fluid flow behavior. In distributary systems, it is true in our case. So these flow barriers are geologic features critical to predicting flow behavior. For this reason we need to include them into our geologic model But putting these thin stuff reason, we need to include them into our geologic model. But putting these thin stuff into geologic model is not a easy job? Because we either don't have enough information about this thin, discontinuous barriers information, or we don't have suitable modeling technique to capture their distribution.

Key Learning from PBM

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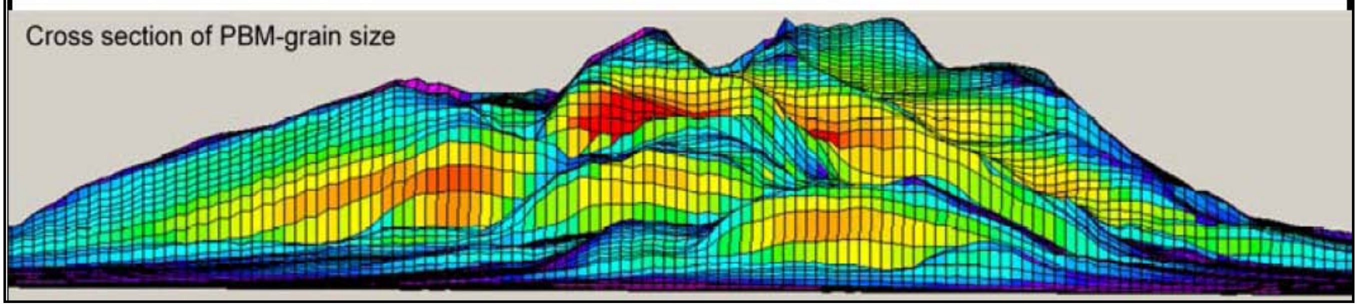
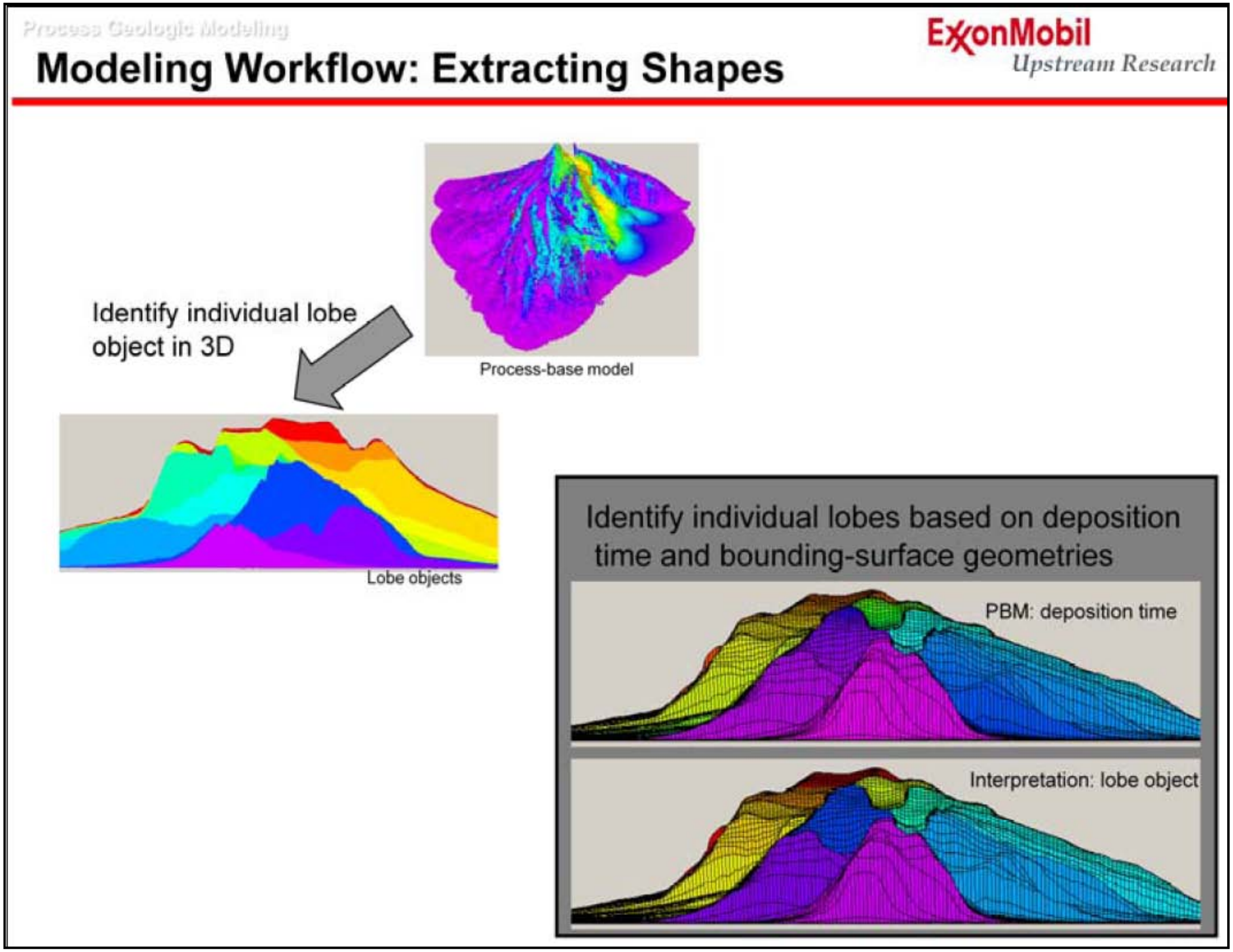
- Flow barriers and baffles are associated with lobe geometry
  - Need to simulate individual lobe distribution first
- Flow barrier and baffle continuity is controlled by erosion
  - Need to reproduce lobe stacking patterns observed from process-based models

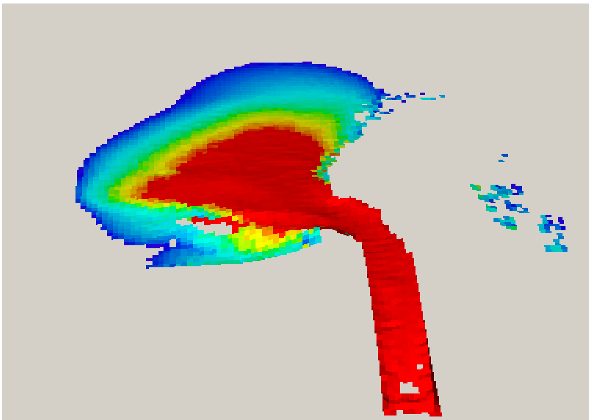


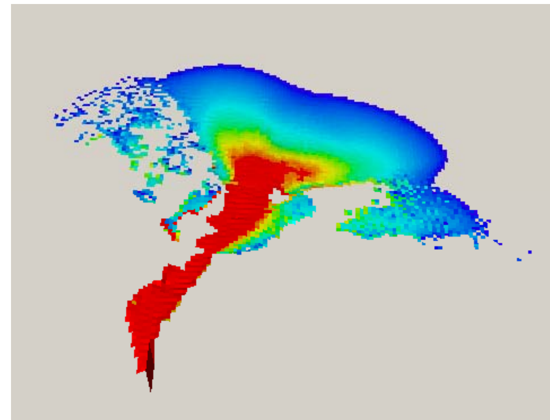
Before talking about the modleing workflow, there are two points needed to emphasize: first, flow barriers are associated with lobe geometry, as we see in PBM. So we need to simulate individual lobe distribution first, then simulate the barriers within lobe framework. Second, the flow barrier continuity is controlled by erosion. The scour lobe is the fundamental architectural element in deep-water distributary systems. The scour erodes the underlying fine deposits. So they break down the continutity of barriers, and increase the connectivity between lobe sand bodies. In order to accurate capture the barrier distribution we need to reproduce lobe stacking order to accurate capture the barrier distribution, we need to reproduce lobe stacking patterns observed from PBM, such as more amalgamated at proximal, and lateral migrated in distal. Generally, it is not an easy job to get quantitative stacking pattern information, and in our case, it is a great benefit that we have process-based model to study these features. Bearing these two points in mind, here is the proposed modeling workflow.

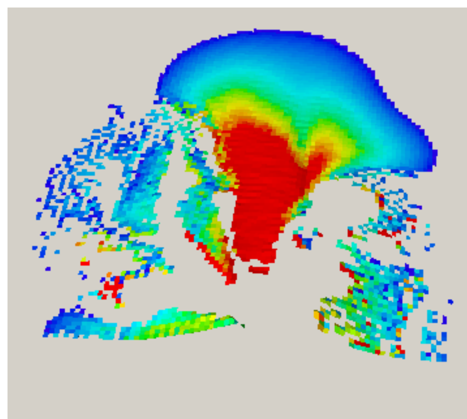


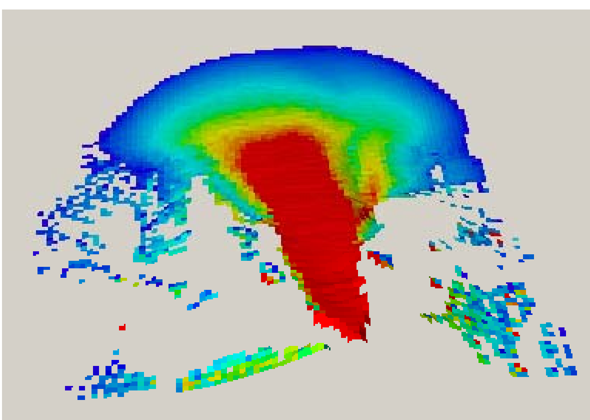
We identify individual lobe objects based on the deposition time and bounding-surface geometries. The reason I use deposition time is only because the same surface has the same time value, but has different grain size values. So it is easy to write script to differentiate the lobes based on deposition time. Of course, to set-up the cut-offs of deposition time for different lobes, we need to consider the bounding-surface geometry. So this is a interpretation process.

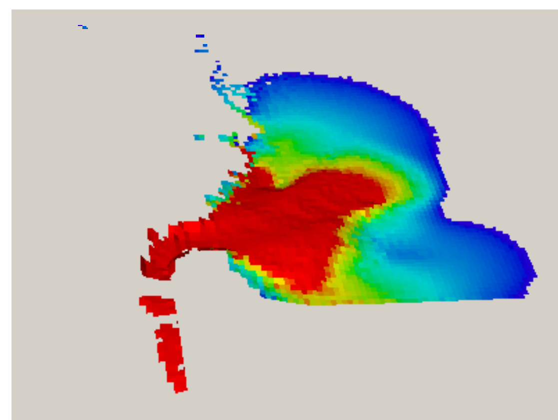
Examples of Extracted Individual Lobes











Sedimentary Body Geometry and Thickness

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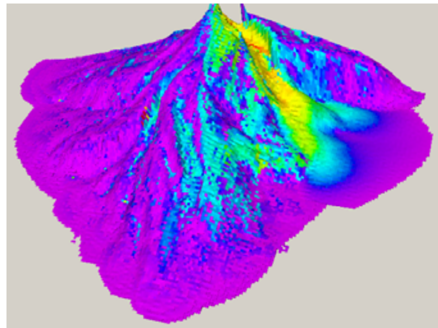
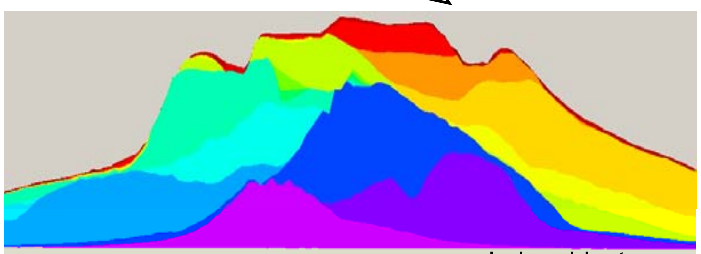


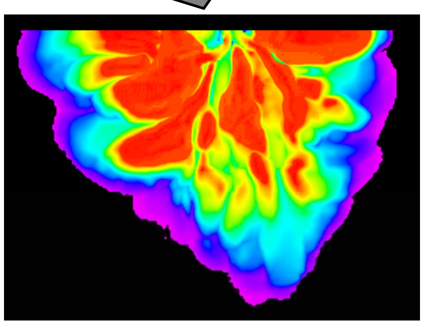
Process-base model

Identify individual lobe object in 3D



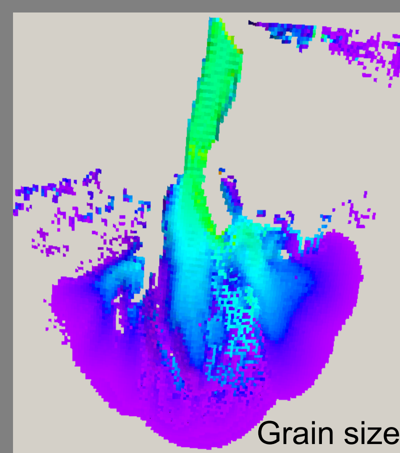
Lobe objects

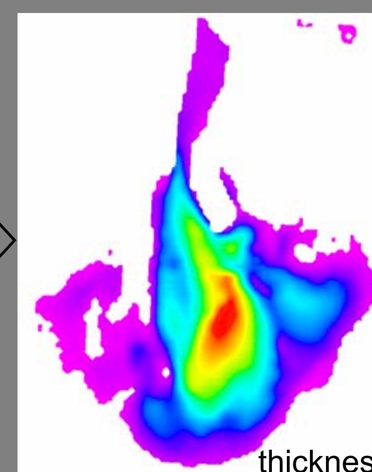
Generate thickness map for each lobe



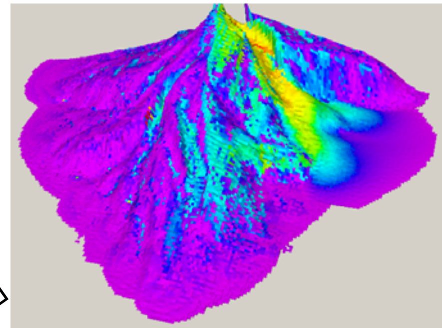
Thickness map

From 3D geometry to 2D thickness map



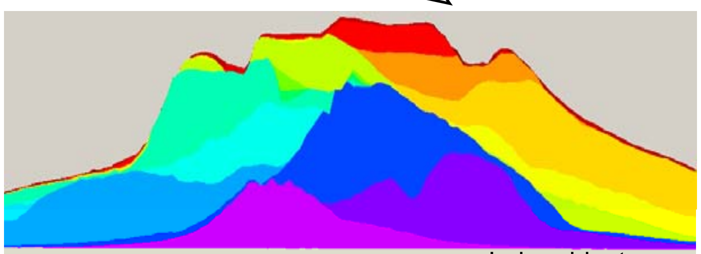


Spatial placement and correlations



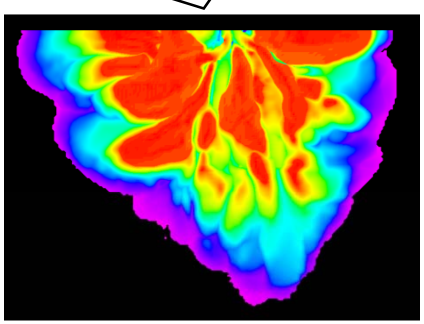
Process-base model

Identify individual lobe object in 3D



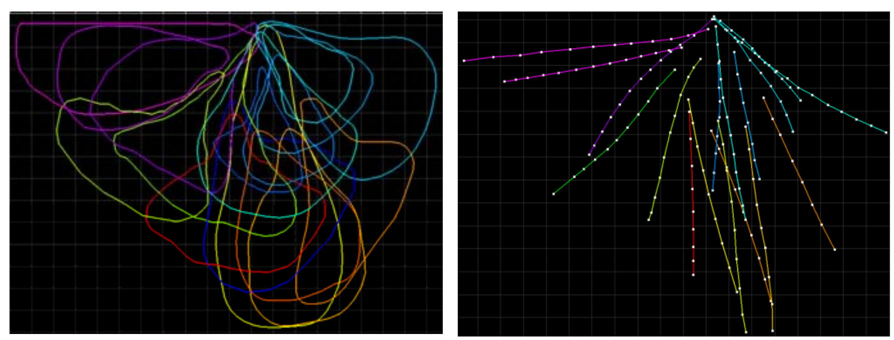
Lobe objects

Calculate thickness map for each lobe

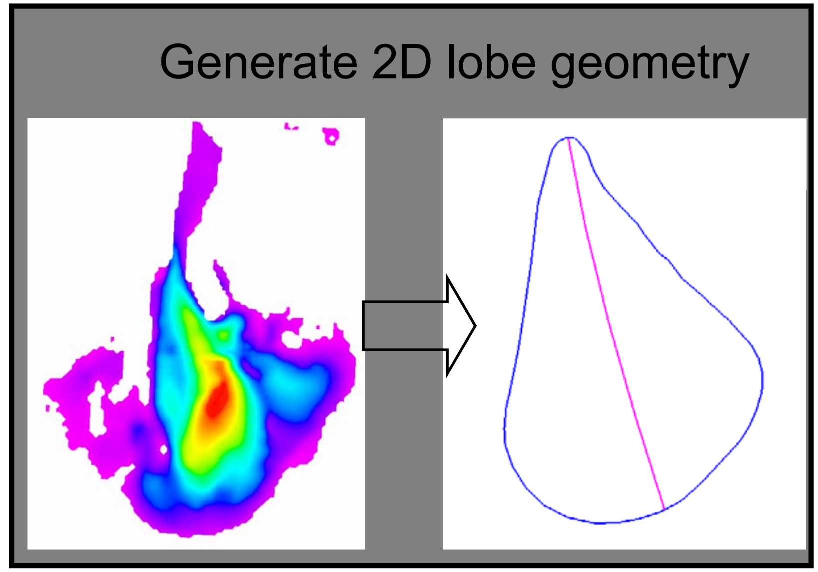


Process-base model

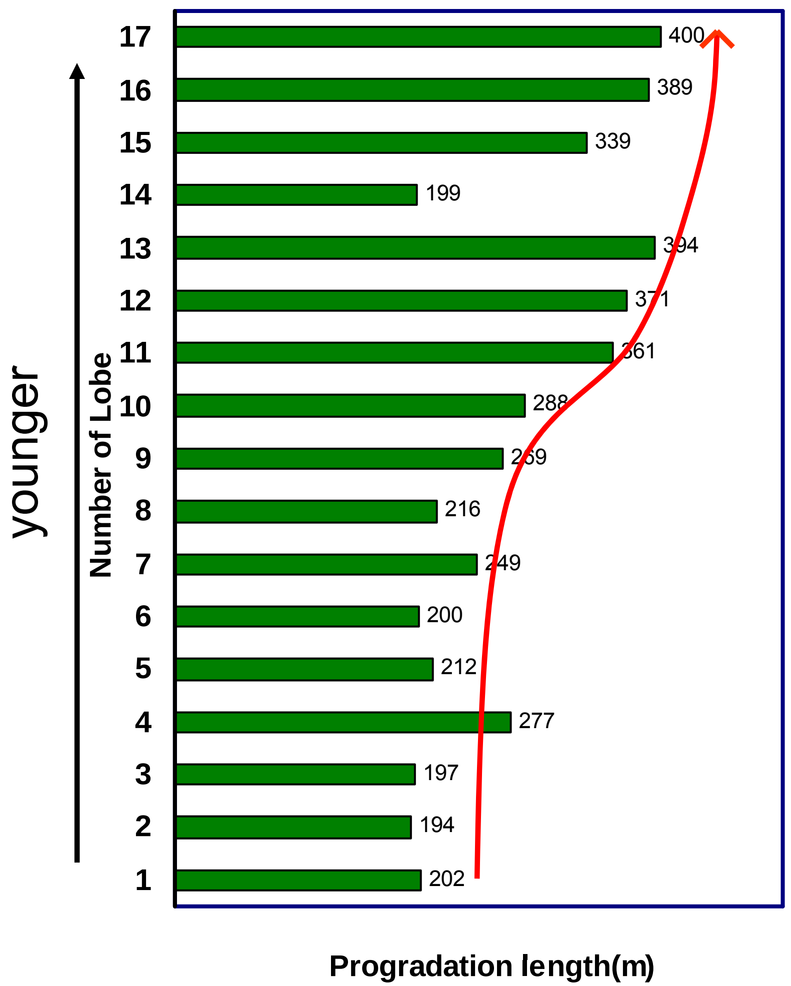
Generate polygons

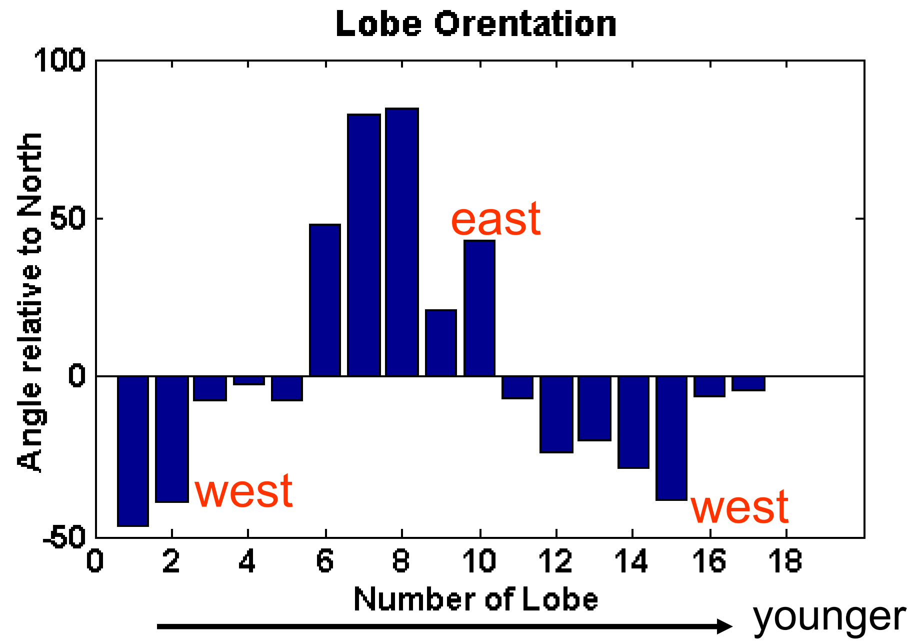


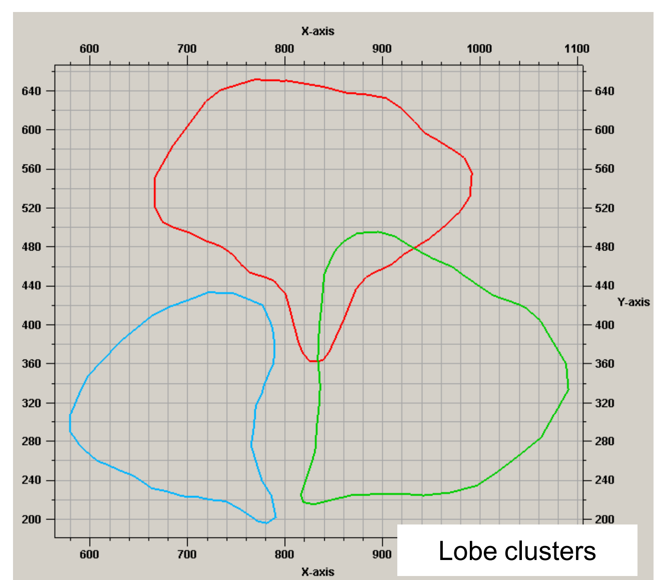
Lobe geometry



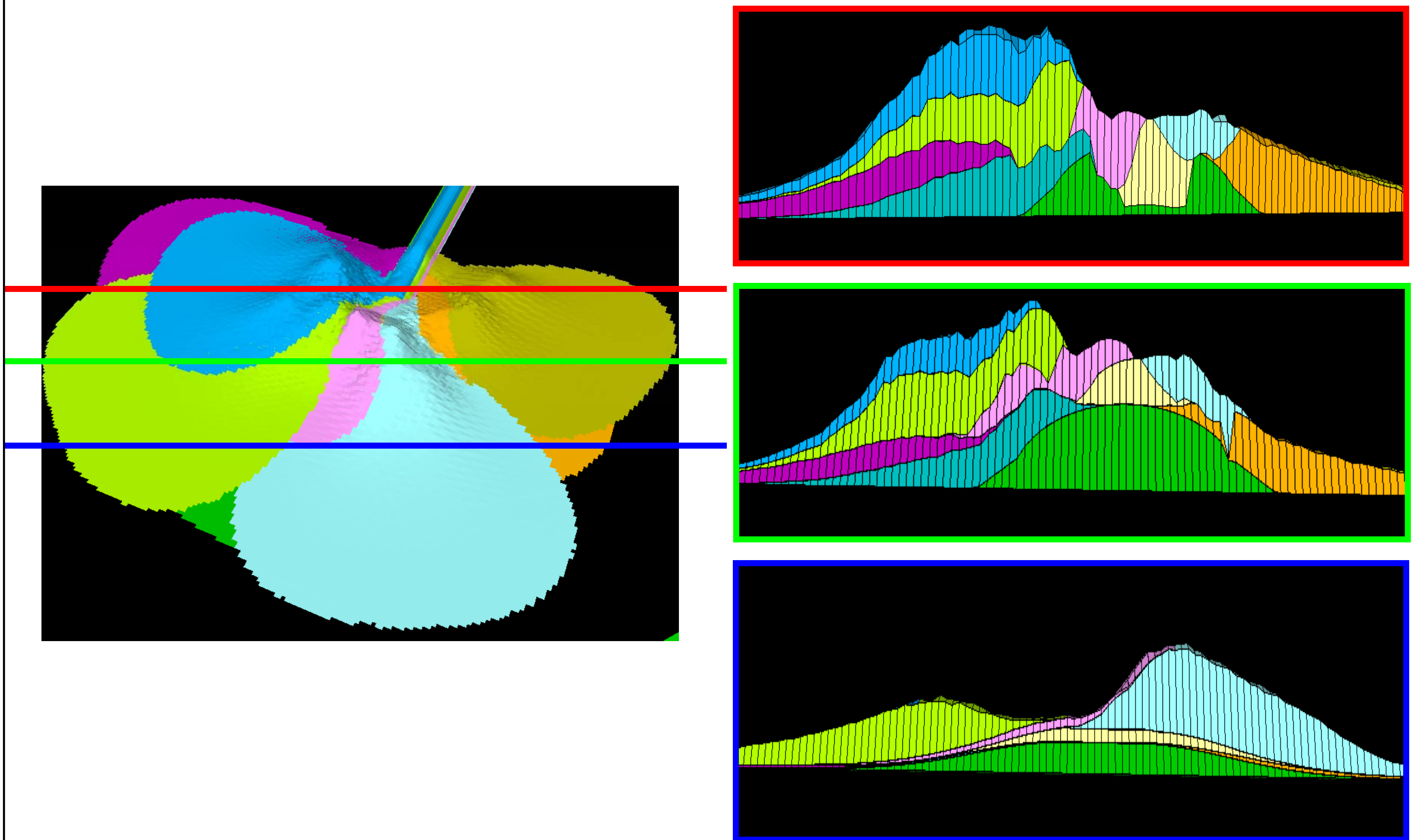
Lobe pattern trends







Model Realization



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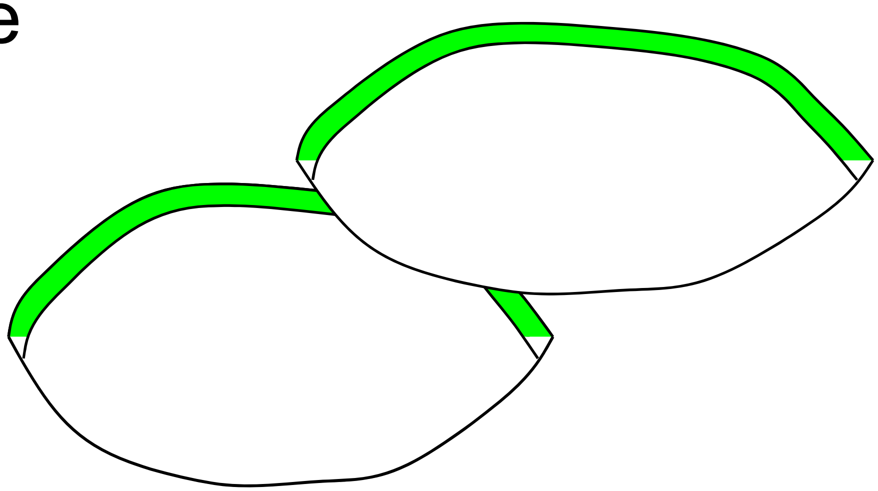
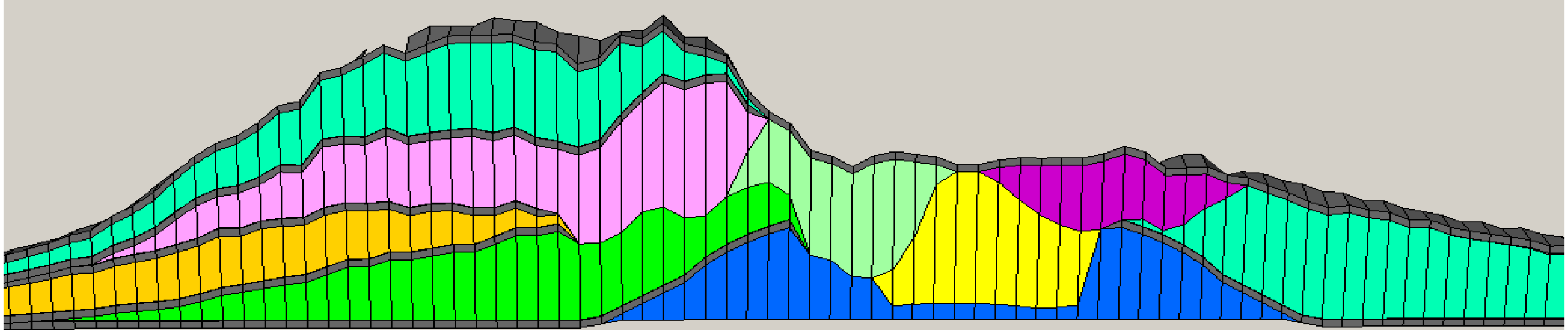
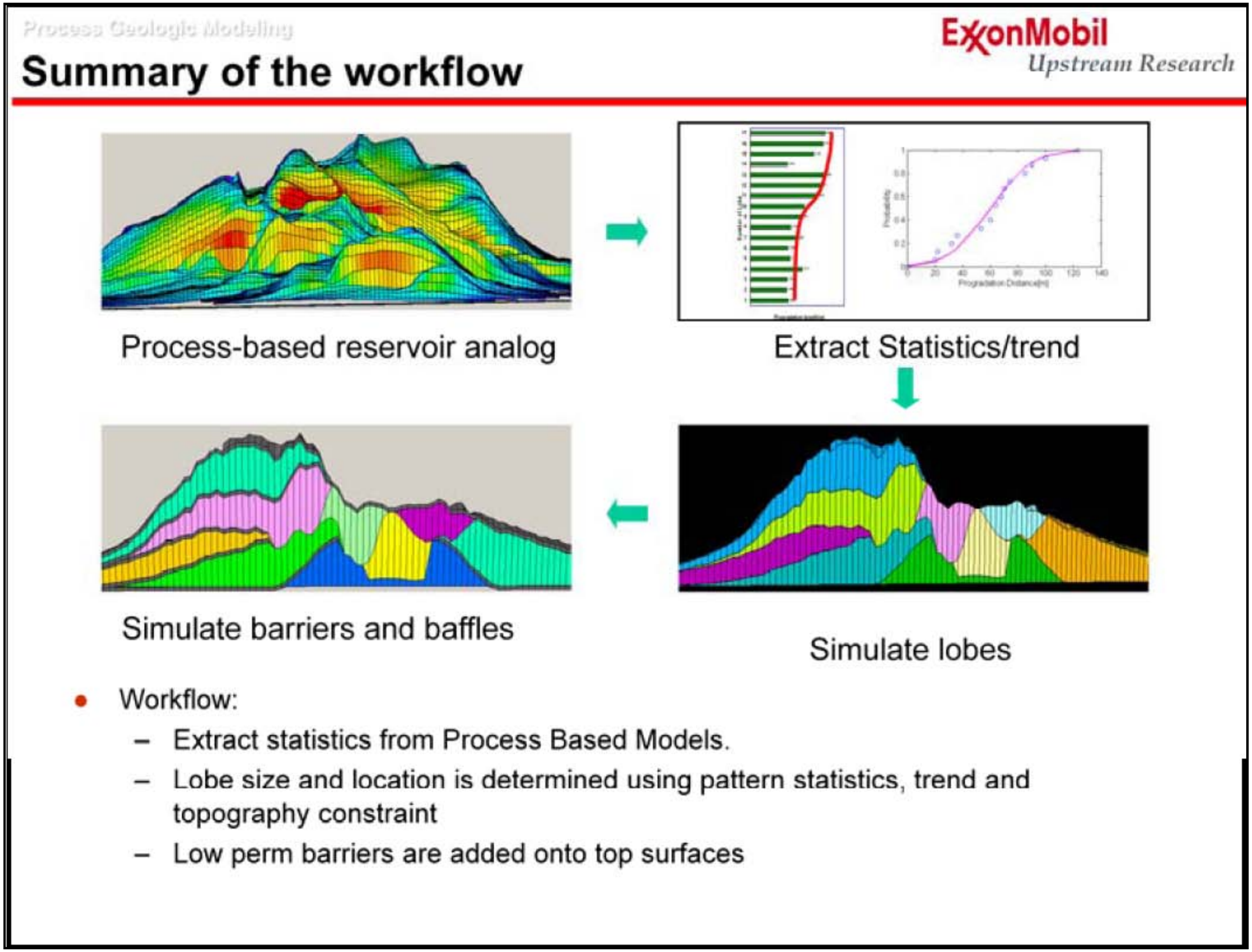
Modeling Flow Barriers and Baffles

- Add barriers and baffles explicitly along the lobe top surface





Flow barrier distributed along lobe top surfaces



This is the workflow for flow barrier modeling. First, we extract statistics and trends from process-based model, then we use this information to simulate lobe distribution. Once we have the lobe distribution, we can simulate barriers within each lobe.

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Summary

- Process-based models are an informative tool for deriving analog reservoir architectural-element statistics
- Integrating statistics and topographic constraints into a reservoir model is critical if we are to generate more realistic realizations
- Combining process based models and rule and object-based methods provides an effective avenue for
  - ✓ Accurate reproduction of channel-lobe stacking pattern
  - ✓ Flow barrier modeling
  - ✓ Data conditioning