Qazi Ashikin

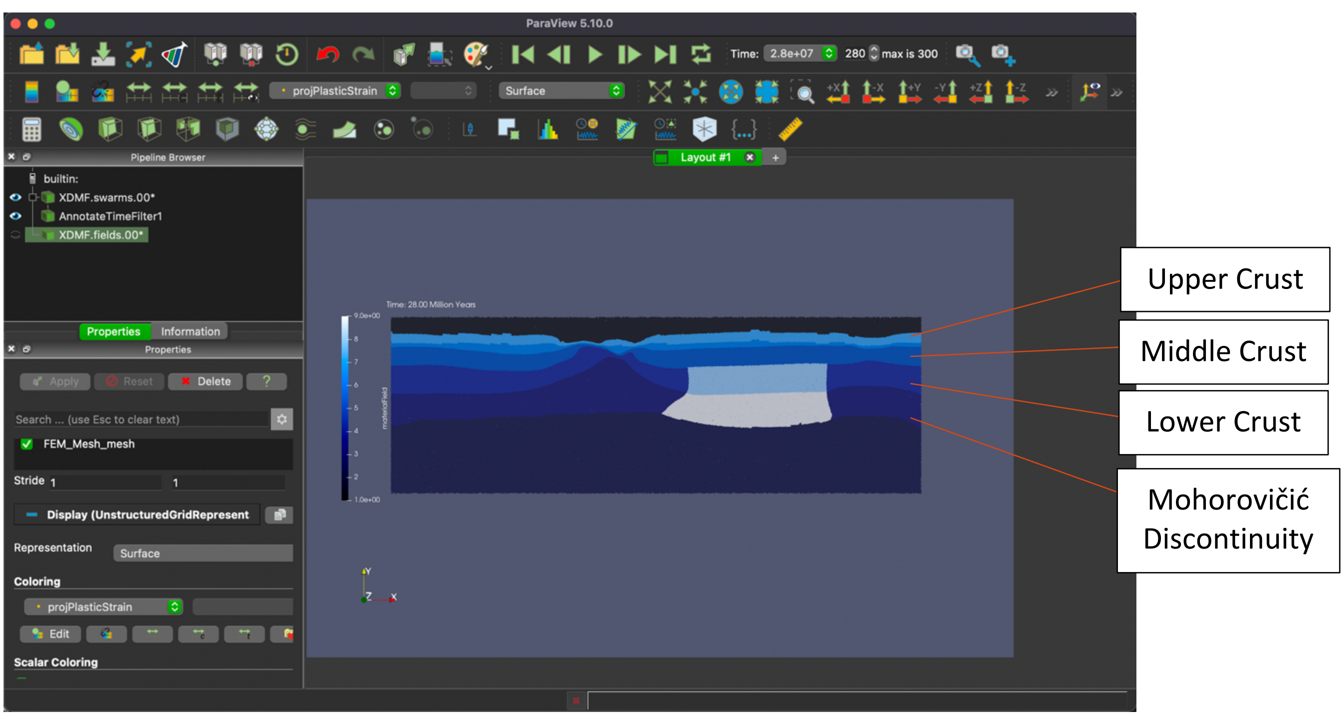
This document further details the research and projects I have been working on with Professor William E. Holt at Stony Brook University. It is not a formal abstract, but I hope you will enjoy learning more about our work.

Professor Holt and I have been working to develop 2D computational models of geologically significant areas. One of our interests lies in the Basin and Range Province of the Western United States. We are particularly fascinated by the metamorphic core complexes that have evolved over recent geologic time in this location due to the movement of the North American, Pacific, and ancient Farallon tectonic plates. Metamorphic core complexes are segments of Earth's crust that have been exhumed, or uplifted, due to the extension factor of tectonic plate movement.

Our models utilize and extend the open-source Python Application Programming Interface called Underworld2, also known as Underworld Geodynamics (UWG). The source code can be found at: https://www.github.com/underworldcode/underworld2.

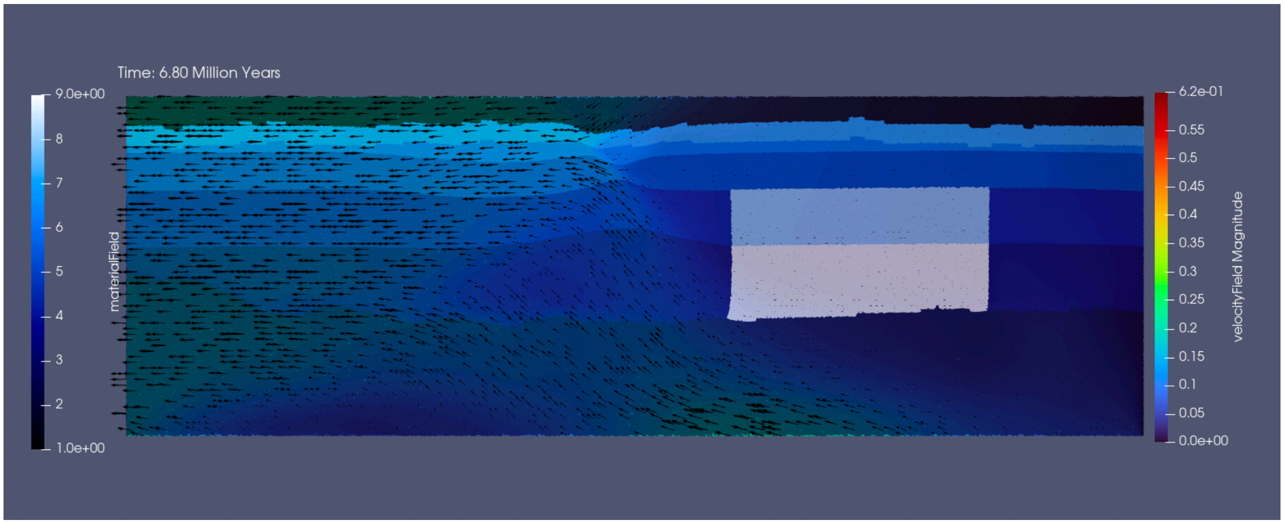
Our code can be viewed here: https://github.com/aizaq1/uwg-animations-and-files.

One model we have developed is for the metamorphic core complexes at latitude 38 North in the Basin and Range Province. By using topological data of the Earth's layers, we were able to create models such as the one below. In this model, UWG iterated over 30 million years of geologic time. Running our models takes nearly 80 hours to complete. It is a very long but rewarding process. The following image is one taken in the Paraview program that Professor Holt and I use to display the thousands of binary files that were produced during the model's run.



I have created several animations for the evolution of this model after learning to use the features available in Paraview. My animations compare the original materialField (layers of the Earth in this region) to other factors, such as velocity and plastic strain. The full playlist containing all my animations can be found here: https://youtube.com/playlist?list=PL_p_Ad629aFb15dF1iLtlCBfJCvPIWuZG. This playlist will constantly be updated throughout the semester. Thus, our most recent accomplishments can be viewed here.

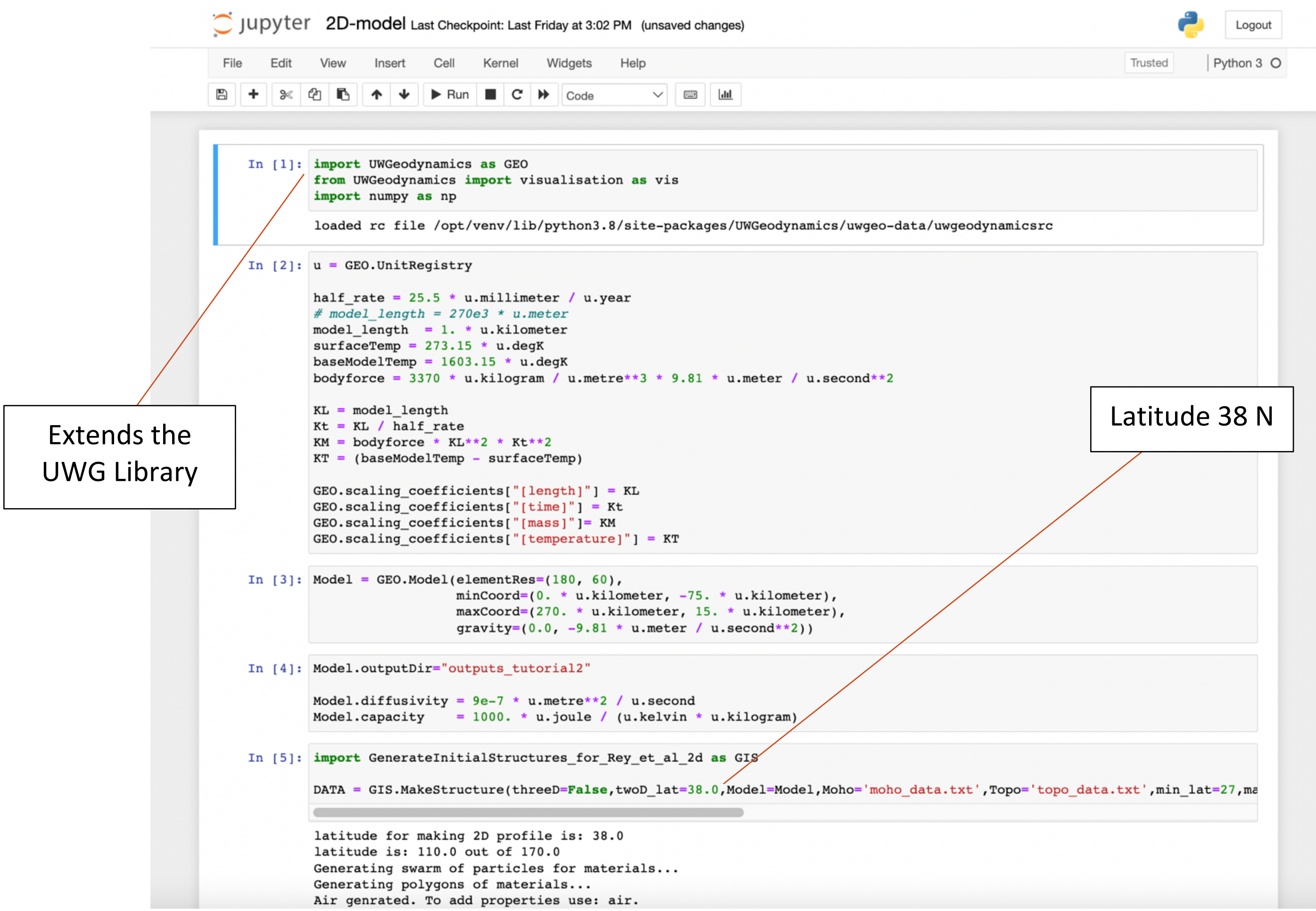
The image above simply plots the materialField. Here is a snapshot of the same model with vectors indicating the velocity field:



And here is an animation of it: https://youtu.be/3vVJIBWflzo.

Another fascinating animation I created shows how the plastic strain in the layers evolves with the core complex. In the following animation, we can see a damage zone developing in the region as well as a conjugate zone that meets it, creating a flattened "V" shape: https://youtu.be/x1HaU3X18zA. There is also evidence of another zone of damage to the right, indicated by a light green hue.

This is a snippet of our code, written with the help of postdoctoral research scientist Alireza Bahadori from Columbia University, that produced the binary files necessary to make the model:



Our code was written in Python using Project Jupyter and run with the Docker and Kitematic software.

Professor Holt and I were interested in how we could manipulate this model to consider other situations for the metamorphic core complexes. For example, what would happen if we applied a velocity boundary condition to both sides of the model, rather than on just one, as is currently?

Well, to find out, we needed to make a slight change to the original code. In the following, we specify an extension force of 1 mm/year to both sides of the model.

Original Code

No specified velocity on the right side

```
In [16]: Model.set_velocityBCs(left=[(-2.0) * u.millimeter / u.year, 0.0 * u.millimeter / u.year],
                               right=[0.0 * u.millimeter / u.year, 0.0 * u.millimeter / u.year],
         #                      right=[(25.5/1) * u.millimeter / u.year, None],
                               bottom=GEO.LecodeIsostasy(reference_mat=ml, average=True))

Out[16]: <underworld.conditions._conditions.DirichletCondition at 0x414bbd6c10>
```

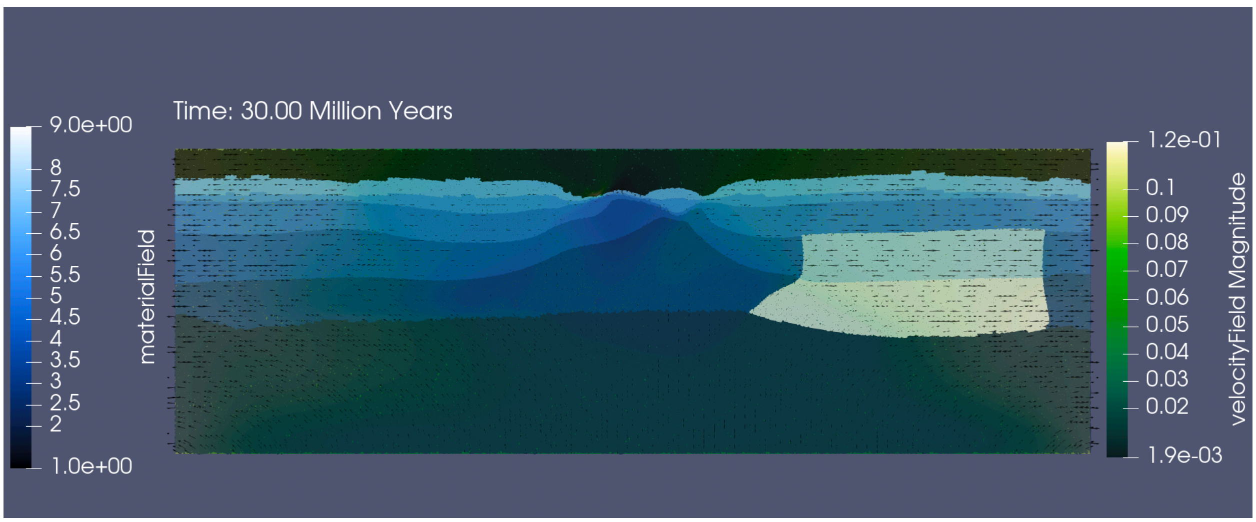
A velocity of 1 millimeter per year applied to both sides of the model

Modified Code

```
In [16]: Model.set_velocityBCs(left=[(-1.0) * u.millimeter / u.year, 0.0 * u.millimeter / u.year],
                               right=[1.0 * u.millimeter / u.year, 0.0 * u.millimeter / u.year],
         #                      right=[(25.5/1) * u.millimeter / u.year, None],
                               bottom=GEO.LecodeIsostasy(reference_mat=ml, average=True))

Out[16]: <underworld.conditions._conditions.DirichletCondition at 0x408f77eaf0>
```

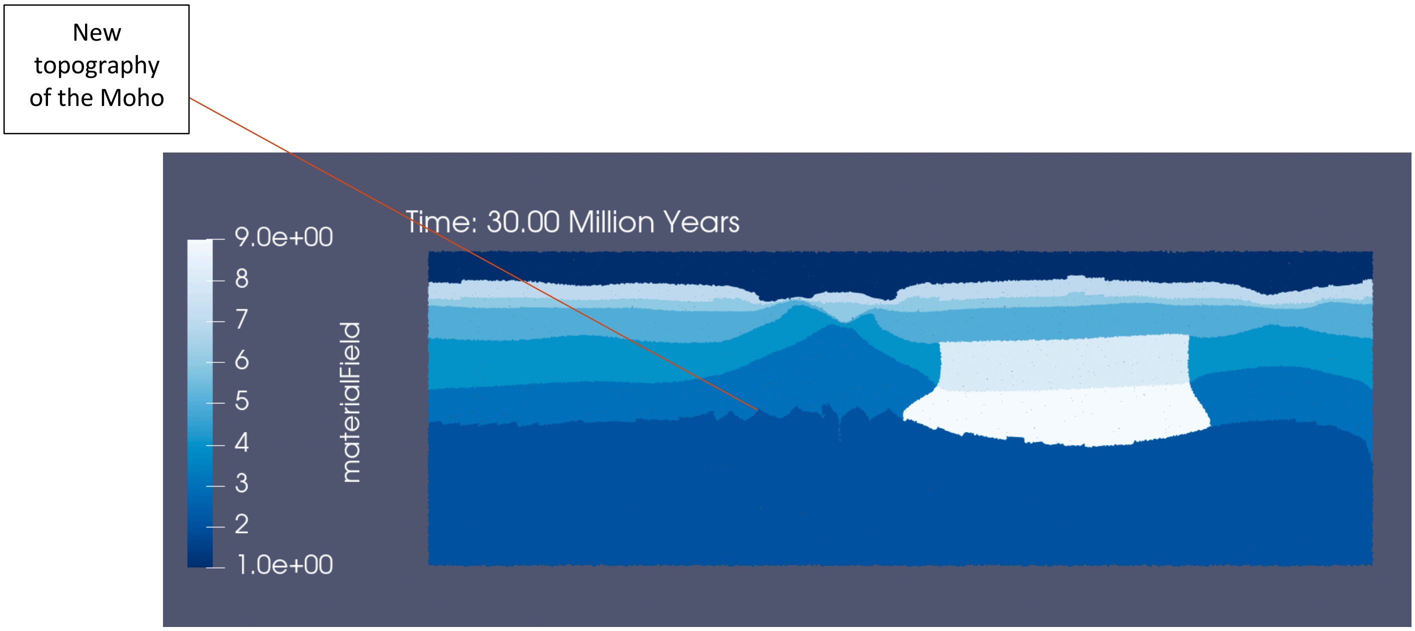
We then ran the notebook for another 80 hours to produce a whole new set of binary files, which, with some work in Paraview, created this new model:



Notice how the topography has changed from the first model! By just applying a velocity of 1 mm/year to the right-hand side of the model, we have altered the relative location of the core complex's evolution over the 30 million years. Here is an animation for the new model's velocity field: https://youtu.be/XWCkQceUxes. Many other animations for this new "Symmetric" model can be found in the playlist.

It looks like the relative topography of the new symmetric model is similar to the first one, only shifted to the right (of course!). But then how can we uncover the cause for the zone of damage and its respective inclination? Well, we might find clues by analyzing a completely different latitude and comparing cross-sections!

The following image is of the materialField for Latitude 39 N. Animations I have made for this new location may be found in the master playlist as well as ones that compare our different models.



Wow! The surface topography is similar yet different. The shape of the layers is also strikingly unique. This most likely plays a role in the evolution of the core complex…

Here is another image of the new latitude 39 with velocity vectors. Notice the green hue indicating the velocity field. It is mainly on the left because this model is not symmetric.

Professor Holt and I continue to work on developing our models. We continue to question how we can manipulate and interpret our simulations: How would the core complex evolve if we change the material type for the definitions of viscosity in our code, to something other than wet quartz, as it is now? What if we define extension forces of greater caliber? How could producing models that pull the region from the right-side instead of the left change the results?

After delving deeper into those questions, our next course of action would be to produce models that cover other latitudes in the Basin and Range Province to see how they are both similar and different from the locations we have already analyzed.