



# Steering Geodynamics Models with Plate Tectonics Reconstruction Software: GPlates

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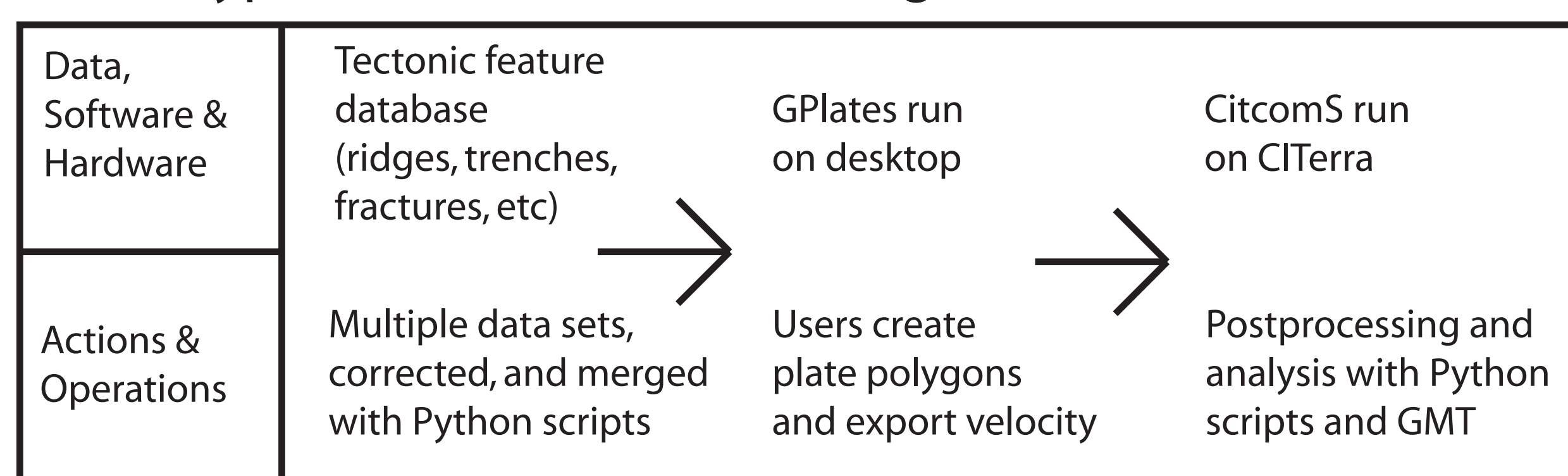
## Introduction

One of our goals is to attempt to place the tectonics of individual boundaries within a global context, and to understand the broader scale forces driving the deformation. There are a host of unsolved questions surrounding the causes for changes in plate motions, including the initiation of new subduction zones. In order to address these questions, the TO has been developing an entirely new generation of tools that are computationally advanced while being consistent with the actual structure and kinematics of plate boundaries. Thus far, we have made considerable progress in this direction.

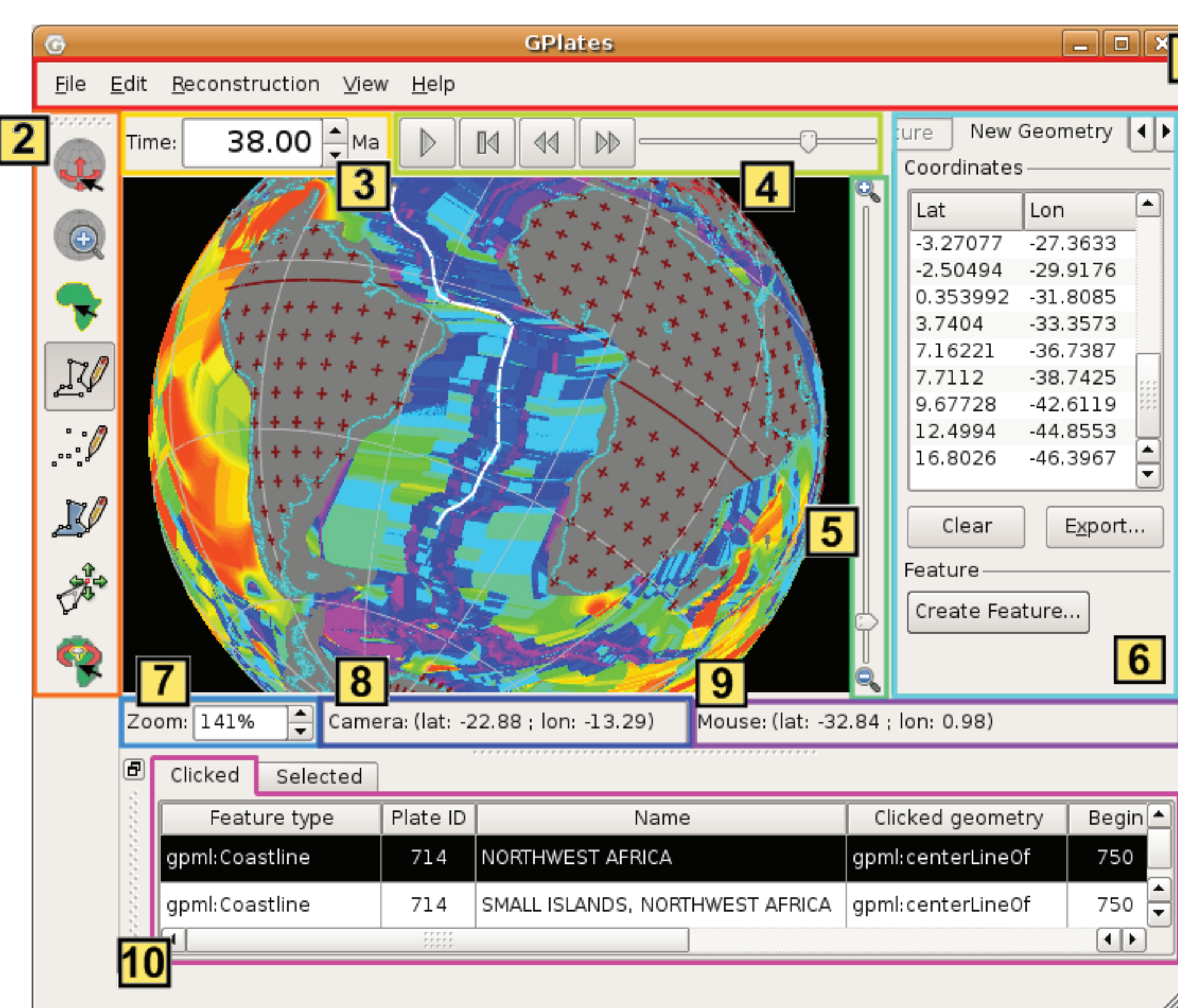
One goal is to assimilate plate tectonic reconstructions into global and regional geodynamic models. With the University of Sydney in Australia and the Geological Survey of Norway, the TO has been a key partner in the development of GPlates, a plate tectonic reconstruction software package. We are using GPlates as the preprocessing front end to global models of mantle convection using the CitcomS finite element code.

Using GPlates, we have developed a method for representing the evolving geometry of tectonic plates. A single plate is represented by all of the margins around the plate, reconstructed according to the euler pole of the margin, and an algorithm for computing the intersections of all of the margins. The end result is a complete evolving description of the surface of the earth without any blank spaces -- an essential prerequisite for merging dynamic models with paleo-reconstructions. We have used this software to build a global set of plates over the last 80 million years, to merge these "dynamic" plate polygons with paleo age grids, and to assimilate this data into global circulation models of the mantle. This work has given the TO a new tool that allows us to explore the dynamics of changes in plate motions and shapes over the next several years. We are now routinely running this software on the CITerra supercomputer.

### Typical Workflow Assimilating Data into Models



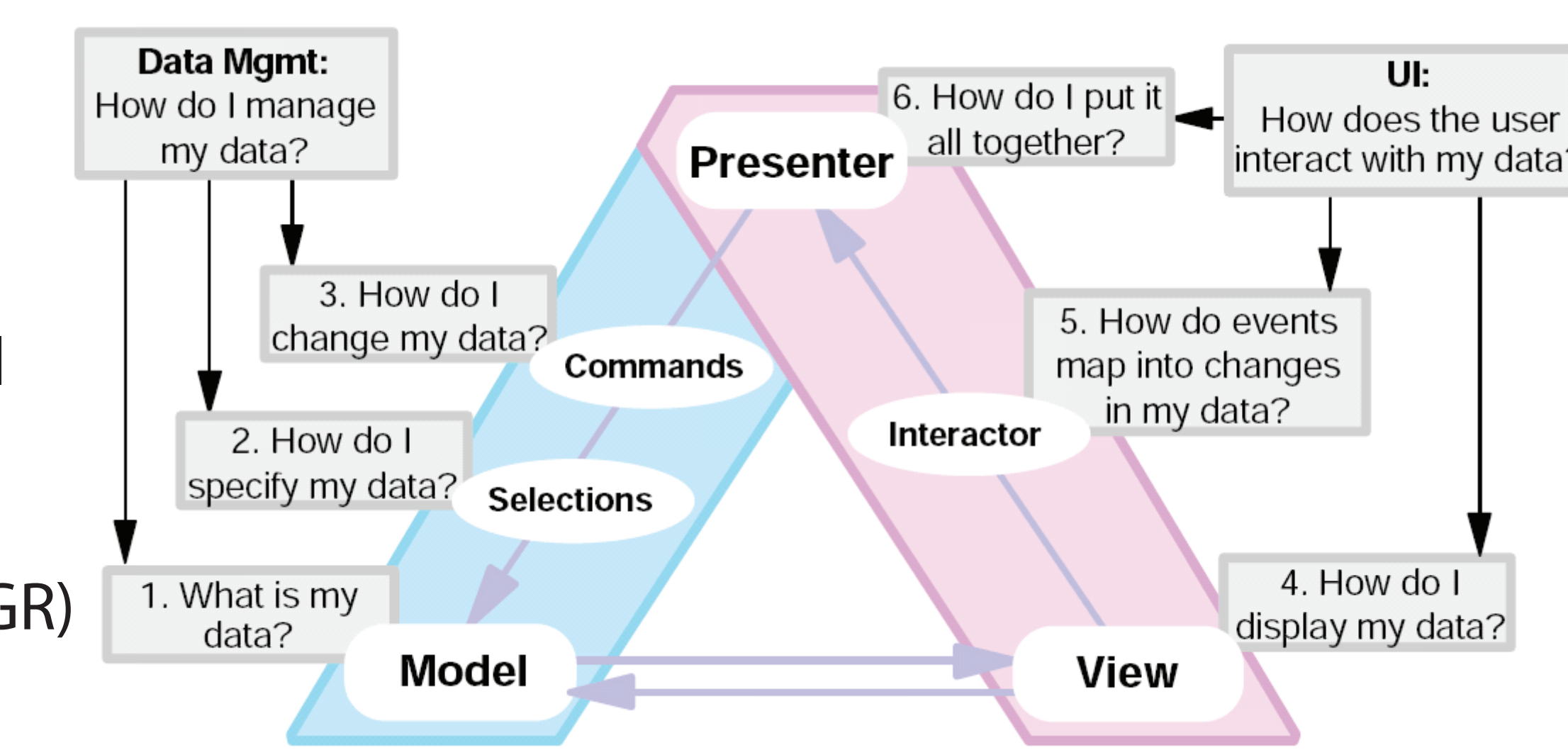
## GPlates: Software for Interactive Plate Tectonics Reconstructions



GPlates main window user interface elements:

- 1 Menu Bar - This region of the Main Window contains the titles of the drop down menus.
- 2 Tool Palette - A collection of tools which are used to interact with the globe and geological features.
- 3 Time Controls - A collection of user-interface controls for precise control of the reconstruction time.
- 4 Animation Controls - A collection of tools to manipulate the animation of reconstructions.
- 5 Zoom Slider - A mouse-controlled slider which controls the zoom level of the Globe View camera.
- 6 Task Panel - Task-specific information and controls which correspond to the currently-activated tool.
- 7 Zoom Control - A user-interface control for precise manipulation of the Globe View camera zoom.
- 8 Camera Coordinate - An information field which indicates the current globe position of the Globe View.
- 9 Mouse Coordinate - An information field which indicates the current globe position of the mouse pointer.
- 10 Clicked Geometry Table - Displays a summary of each geometry or feature touched by mouse click.

### Software Engineering and Code Development: the Model View Presenter pattern



GPlates is open source, cross platform (Linux, Mac, Windows) Written in C++ with Standard Template Library (STL). We use Qt for GUI and OpenGL for low level drawing (fast!) Strong use of Design Patterns for object interfaces. MVP pattern for overall organization of program:

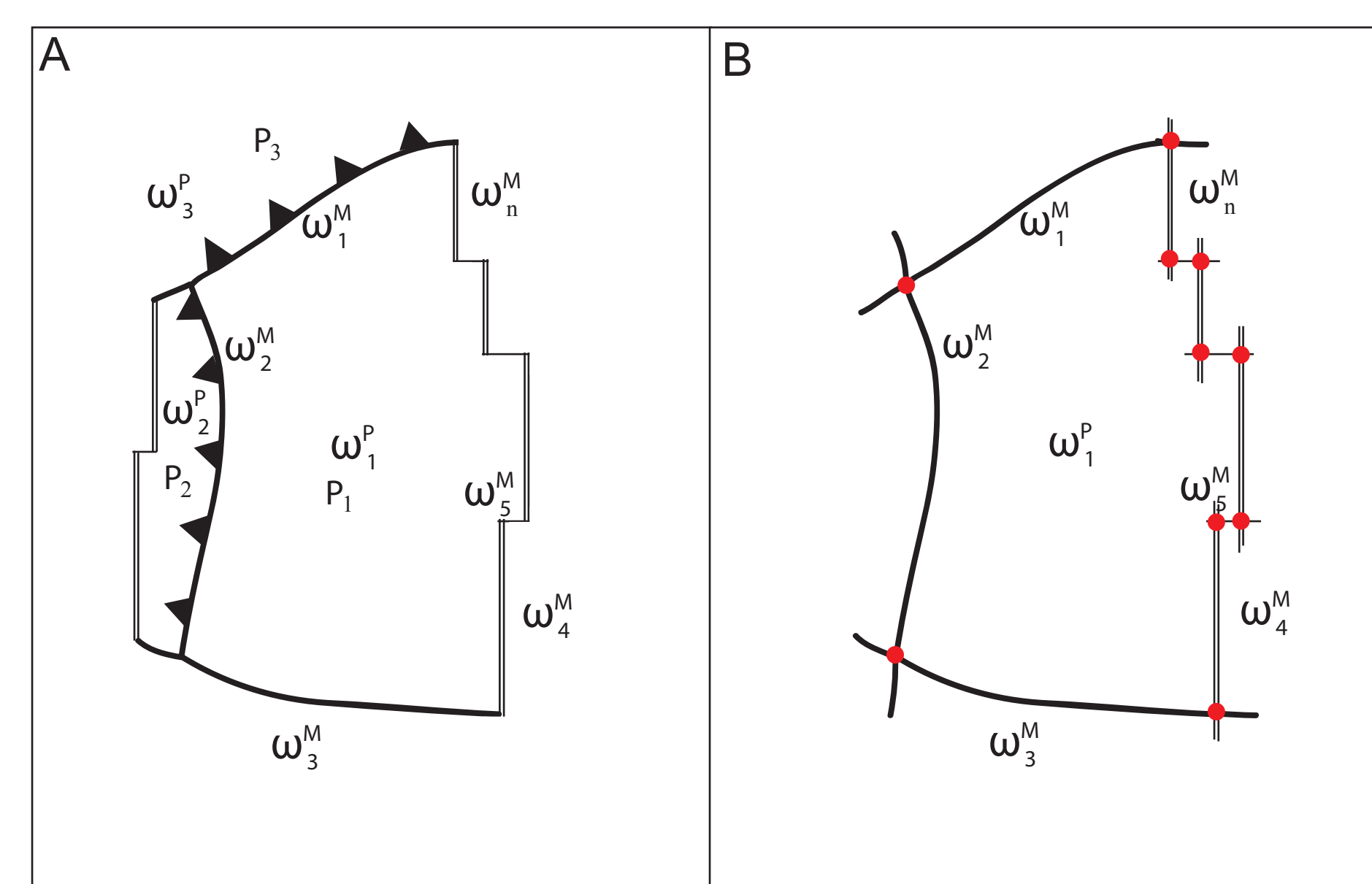
- Model: Geological Features and Properties
- View: Drawing of feature geometry, decorations,
- Presenter: Layout updated upon each reconstruction

### GPlates data format: GPML / GML / XML

The native file format is GPML, an open source data interchange format that builds upon the Open Geospatial Consortium's primitive data types defined in GML. GPML / XML is (mostly) human readable plain text. We use the Geospatial Data Abstraction Library (GDAL/OGR) reader for other formats (Shapefiles, raster images, etc.)

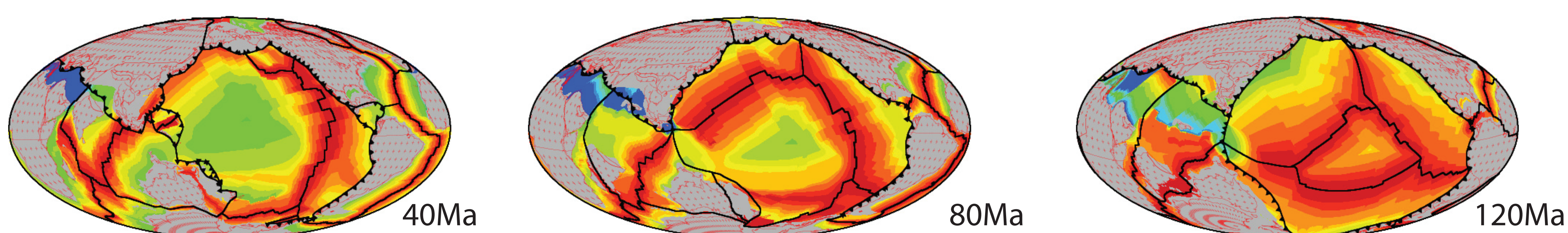
## Continuously Closing Plate Polygons

An idealized tectonic plate showing component margin line data features. Each line feature has its own euler pole and rotates according to the rules of plate tectonics (A). The user selects line features to create a plate polygon. GPlates automatically calculates the intersection points (red dots in B) to form the complete plate boundary. Upon each reconstruction all data rotates independently, and GPlates automatically recomputes the new closed plate boundary.



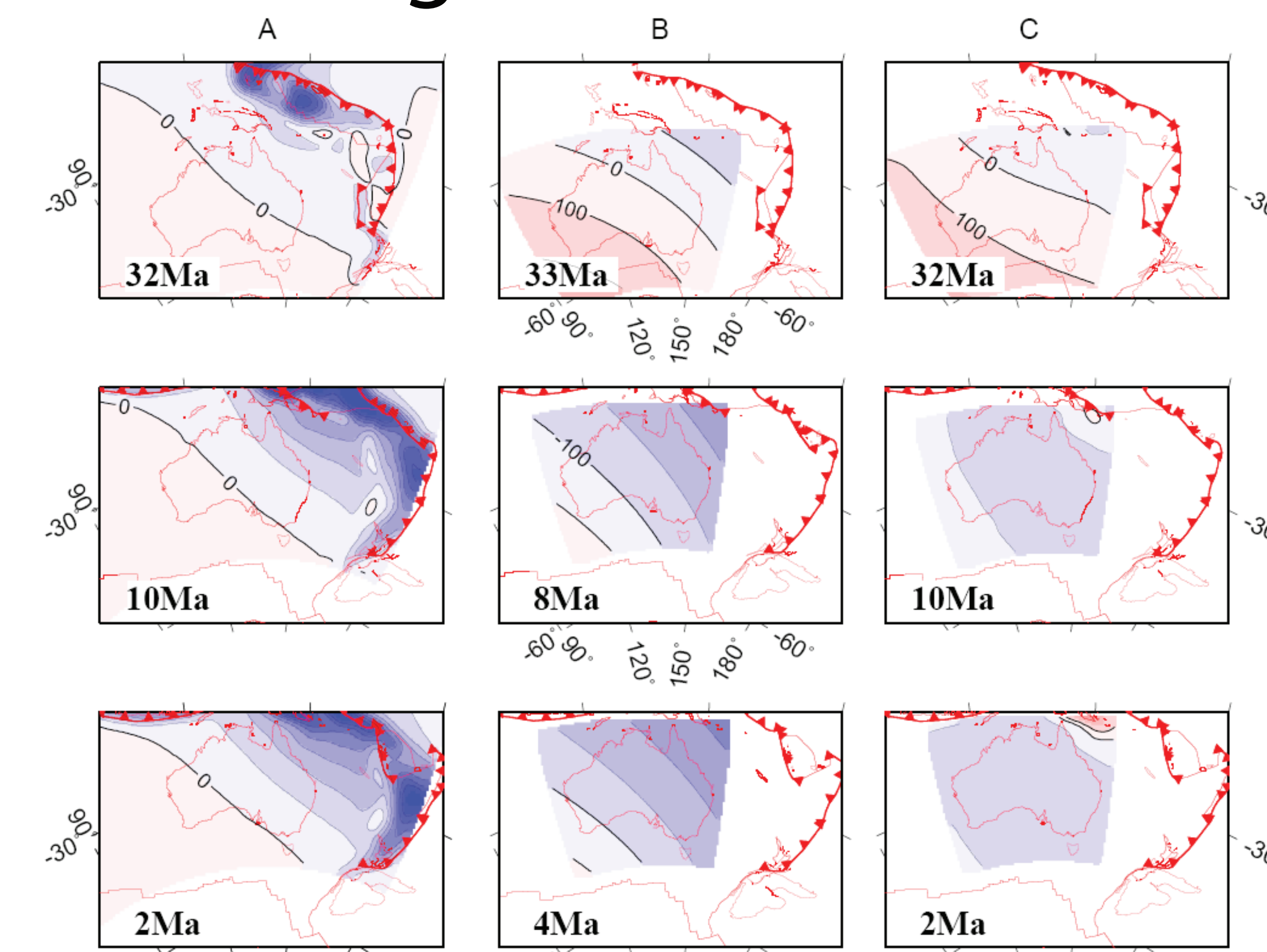
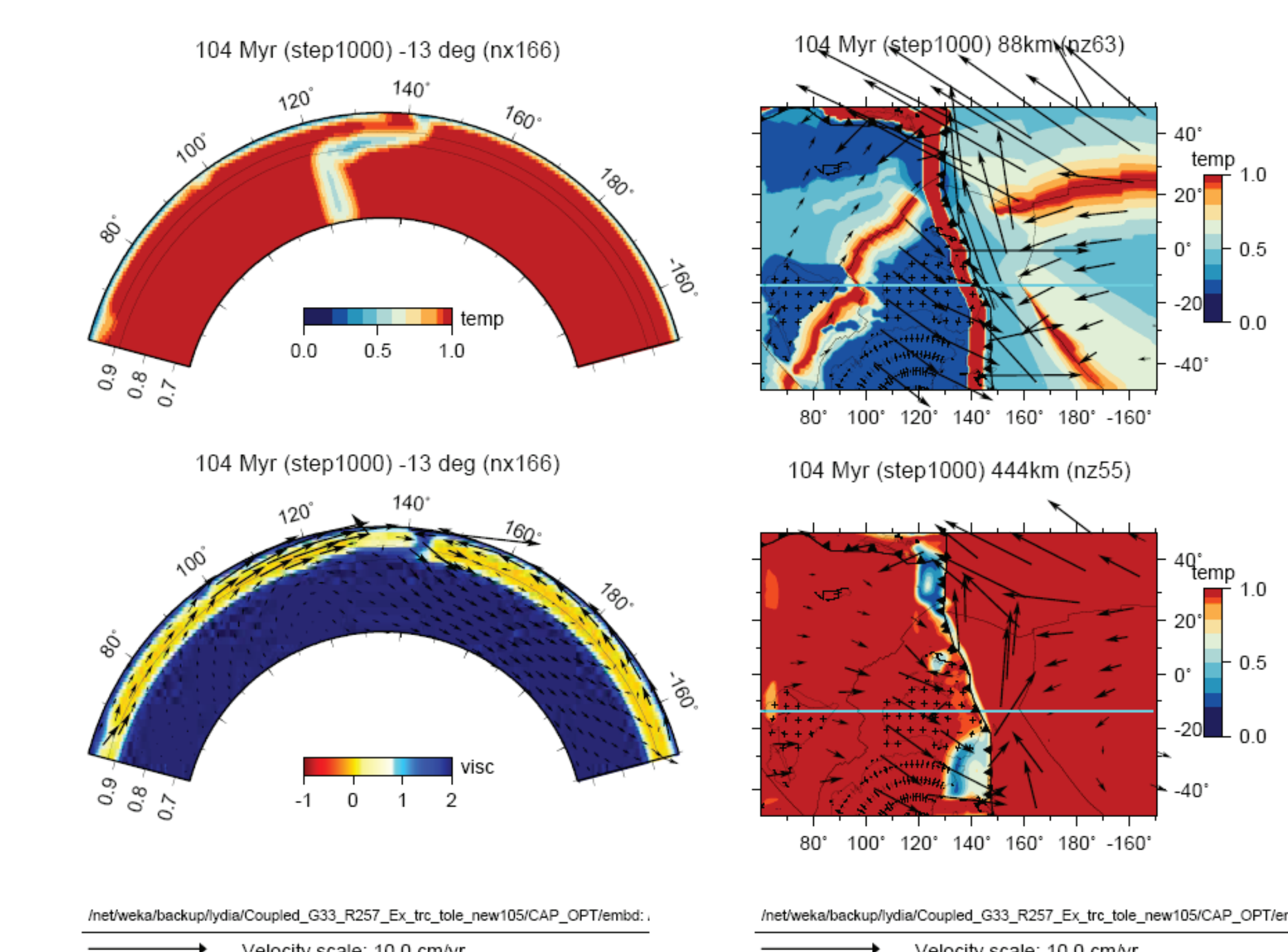
### Global Closed Plate Polygon Model:

Using the CCP algorithms, we created global reconstructions with continuously closing plates from 140 Ma to the present. There are 45 'plates' but with 485 'logical plate polygons'. These polygons are closures that were manually created with GPlates and embody the rules of continuous closure. The life span of a polygon is between 1 Myr and ~40 Myr. The Australian and Pacific plates are the most complex with 53 and 49 closures, respectively, and with polygons lasting on average ~3 Myr. The global average lifetime of a CCP is >5Myr. The reconstruction is available dynamically as a GPML file, which can be read in, manipulated, and output in other formats with GPlates. The data are also available as 140 sets of static polygons.



## Topographic History of the Australian Region Since the Cretaceous

Within CitComS the entire tectonic system has been rotated North to the Equator. A detailed nested-mesh (red) sits inside the global CitComS mesh (grey).



A. Differential subsidence since 50 Ma predicted by the model.  
B. Differential subsidence inferred from detailed analysis of Australian stratigraphy since ~44 Ma.  
C. Residual between the predicted and inferred subsidence is mostly flat over the Australian continent indicating the continent the titld is very well predicted by the model. However, there is still a residual indicating that the continent has undergone at least 100 m of subsidence in addition to the tilting. Shaded contours are at 100m intervals for all plots.