Topological Closed Plate Polygons

Authors: Mark Turner & Mike Gurnis
Division of Geological and Planetary Sciences, California Institute of Technology
Contact: mturner@gps.caltech.edu

Aim

This tutorial is designed to teach the user how to create and use topological closed plate polygons.

Screen shots have been included to illustrate how to complete new steps within each exercise.

Included Files

The data bundle for this tutorial, **Topologies**, can be located https://sites.google.com/site/gplatestutorials/.

Or here.

Create a folder named Topology, unarchive the datasets into this folder.

See http://www.earthbyte.org/Resources/earthbyte_gplates.html for EarthByte data sets.

Background

GPlates enables the user to create traditional geophysical features like hot spots, mid ocean ridges, and large igneous provinces, with static geometries such as points, lines, and polygons, respectivly. GPlates also has the ability to create specialized topological features with dynamic geometries.

What is a topology? What is it used for?

A topology is specialized feature type whose geometry is determined not by a static list of vertices, but rather from the composition of geometries from other, regular features. A tpology does not contain any vertices itself, but instead contains a list of references to features. During the reconstruction process this *boundary list* is used to gather up the geometry of the boundary features, and form a complete closed polygon for the topology.

Using topology features, we have developed the concept of a "Continuously Closed Plate" (CCP), such that, as each margin moves independently, the plate polygon remains closed geometrically as a function of time. This methodology is a new improvement for combining kinematic plate models with geodynamic models.

Topologies are primarily used to model the large scale tectonic plates. Future versions of GPlates will use these topologies to model deforming regions of the Earth’s crust.

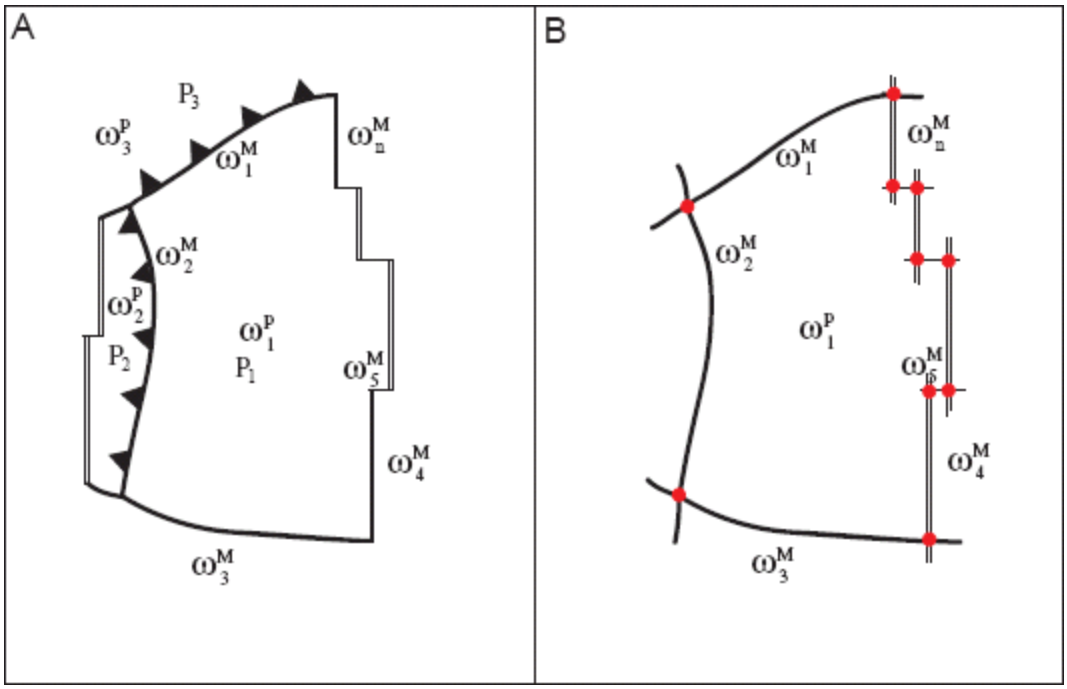

Figure 1: Schematic of the generic features that are incorporated into the Continuously Closed Plate (CCP) algorithm. Red dots represent dyanically computed intersections between plate boundaries.

How does GPlates form a dynamic geometry?

The following diagrams show how GPlates creates a dynamic geometry for a simple hypothetical polygon, for two reconstruction times, 0 Ma, and 10 Ma.

A: 0 Ma

B: 10Ma

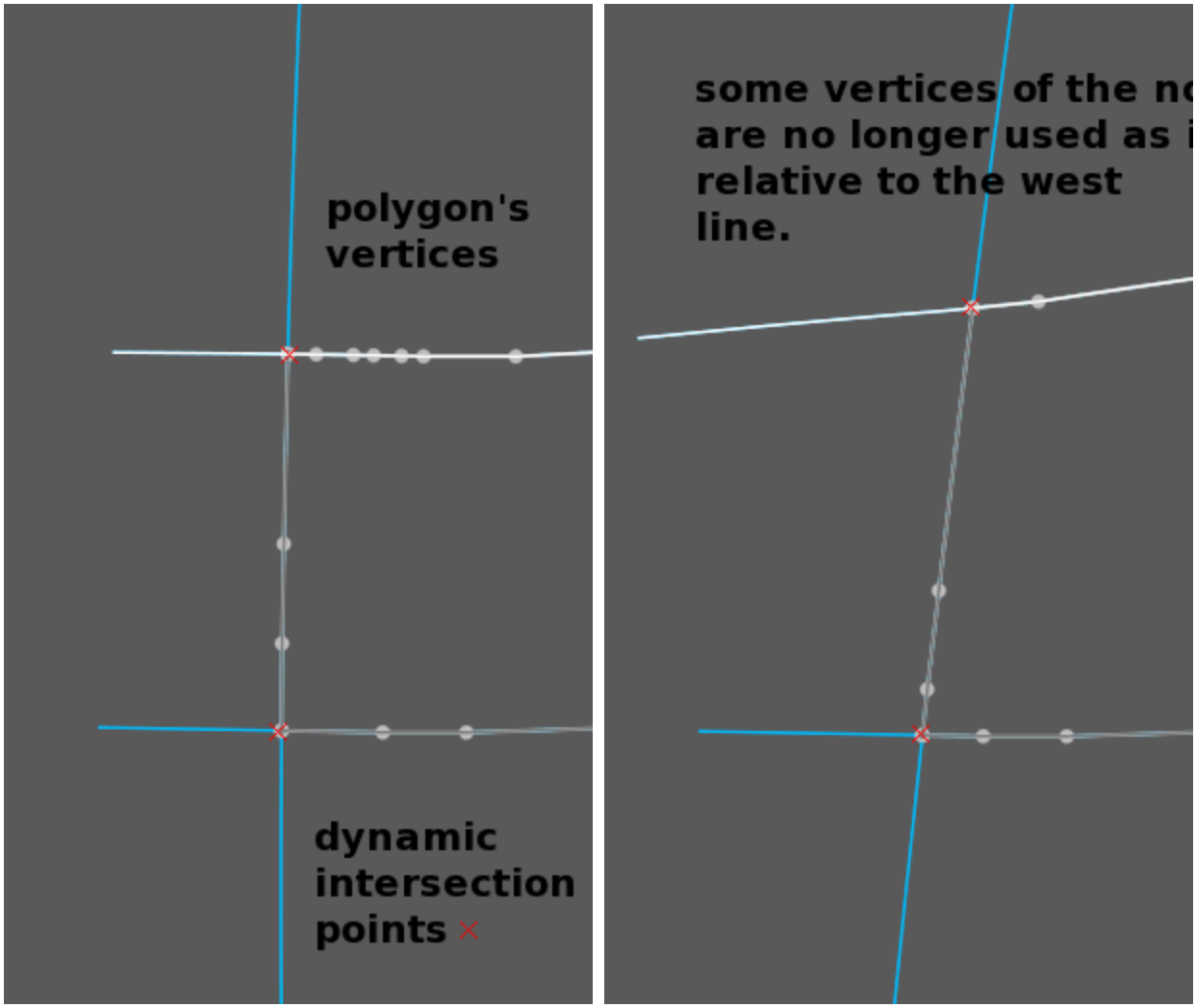

Figure 2: Hypothetical plate polygon from four intersecting lines at two times. Base features are drawn in blue. Plate polygon is outlined in gray, with gray dots showing polygon's vertices. Red crosses have been added in the figures to highlight dynamically computed intersection points, relative to base features' vertices. First line on the boundary list is hightlighted white (North Line); last line is highlighted in black (East Line)

Figure A. Reconstruction at O Ma, the initial configuration of lines, intersection points, and resolved polygon vertices.

Figure B. Reconstruction at 1O Ma, the lines have been reconstructed, new intersection points computed, and the polygon resolved. Some vertices from the North Line are no longer used as it moved relative to the West Line.

In both reconstructions the East Line contributes none of its original vertices, and only the intersection points are used (no vertices exist on the East Line between the intersection points).

The Topology Tools in GPlates

To demonstrate the CCP algorithms in action we present an example of using GPlates and its Topology Tools to create and edit a plate polygon. Using the data bundle we will create an instance of the Nazca Plate.

The following sub-sections first present an overview of the controls, displays, and drawing conventions in GPlates that are used to create plate polygons. Then we give a step by step guide to creating an example instance of the Nazca plate.

In addition to the Globe, the Topology Tools make use of a few other displays and controls on the Main Window. The Topology Tools Task Panel (to the right of the globe) and The Topology Sections Table (below the globe) work together to manipulate the list of features that form a topology's boundary. As you edit the list of boundary features, you will work back and forth between the globe, the Task Panel, and the Sections Table.

Topology Tools Task Panels

The Topology Tools Task Panel has two sub-tabs, one for the topology itself, and the other for a feature intended to become a Section.

- The Topology tab shows a summary of the topology under edit. When building a new topology, the Name, Plate Id, and Valid Time displays will be blank (these values will be set when finalizing the new topology). When editing an existing topology these will display that the various property values of that topology feature.
- The Remove All Section button will delete all entries in Topology Sections Table, and effectively clear the topology. Use with caution: this operation has no undo.
- The Apply/Create… button is used to apply all edits to the current topology (under the Edit Topology Tool), or to finalize the creation process (under the Build New Topology Tool).
- The Section tab shows the basic properties of the focused feature. The Add Focused Feature button will insert the feature into the Topology Sections Table at the current Insertion Point.

Topology Sections Table

The Topology Sections Table holds an ordered list of boundary features. Upon each reconstruction, it is these features, and their relationships, that will be processed into the resolved polygon geometry for the topology.

- Features are added to the Sections Table via the controls in the Task Panel, and via the table itself. The insert location of the Table (and corresponding spot on the ordered list of boundary features) will be highlighted by a special row with a large blue arrow and the message: "This insertion point indicates where the new topology sections will be added". Controls for directly editing the Sections Table appear under the Actions columns.
- Click on a row of the Sections Table to select it, and the following action buttons will appear: Move the Insertion Point to a new row above; Move the Insertion Point to a new row below; Delete the Section from the list.
- The Insertion Point may be reset to the last entry by clicking the blue X box. This causes insert operations to simply append features to the Sections Table.

Topology Drawing Conventions

While a topology feature is under edit GPlates will draw the topology, and its referenced features, with certain highlights and colors.

- The focused feature will always be drawn in white. Small white dots will be drawn on both ends of the feature's current geometry. These highlights are intended to aid in the selection and ordering of boundary features.
- The topology's resolved boundary polygon will be drawn in light gray. All the topology's resolved vertices, both those from the source features, and those computed as intersection points, will be highlighted with gray dots. Note that in some figures we have over-painted with red dots to accentuate the intersections; on-screen these intersections are gray.
- The current insertion point of the Topology Section Table will be highlighted visually on the globe with slightly different coloring of the features on either side of it: The feature before the insertion point will be drawn in Black, and the feature after the insertion point will be drawn in White. The mnemonic *before black; after white* is a quick way to recall where a new feature will be inserted into the topology sections Table.

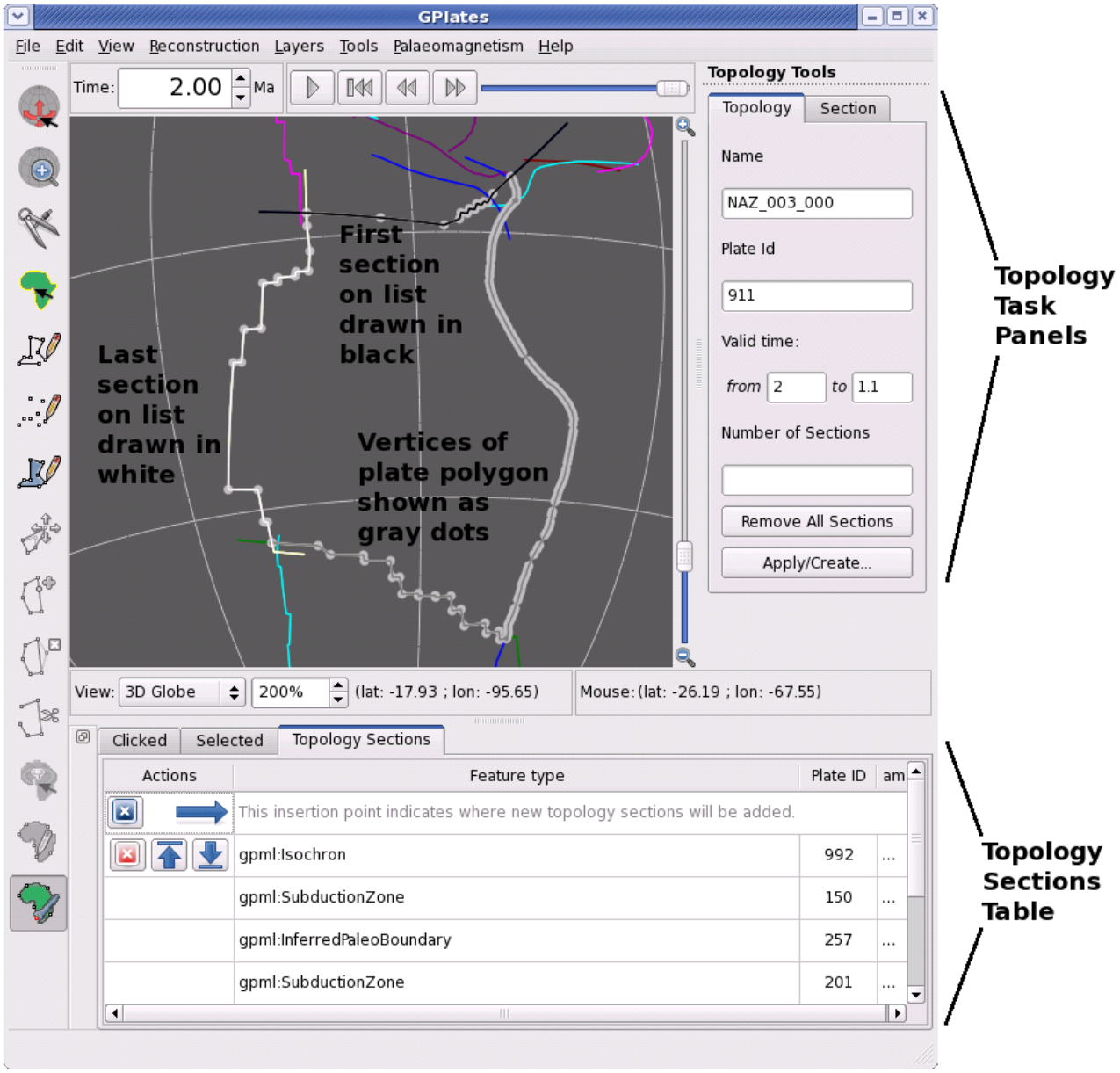

Figure 3: Topology Tools and Drawing Conventions. Topology properties, and Section controls will appear in Task Panels. List of boundary features will appear in Sections Table.

Creating a Topological Closed Plate Polygon

Build Topology Tool

The Build Topology Tool is used to create new topology features from existing regular non-topological features. You will select a series of features, in an ordered fashion, moving around the intended boundary of the topology.

- Using the File → Open Feature Collection menu load the following files:
  - "Caltech_Global_20100723_NO_PLATEPOLYGONS.gpml"
  - "Caltech_Global_20100723.rot"
- Use the Features → Manage Colouring menu to color by Feature Type. The basic color scheme is now: peach/orange for Mid Ocean Ridges and Isochrons; green for Subduction Zones; blue for Fracture Zones; Etc. (Please see the GPlates manual for more info on the color schemes available).
- Orient the globe on the Nazca plate and zoom in a little bit (200% or so).
- Use the reconstruction controls above the globe to see how the margins of the plate move over the period from 0Ma to 3Ma. This is the appropriate life time for this example instance of the Nazca plate.
- Activate the Tool by clicking on the Build New Topology Tools button. Initially the new topology will have an empty list of sections. As you add sections to the topology, the Topology Sections Table will become populated with the features.

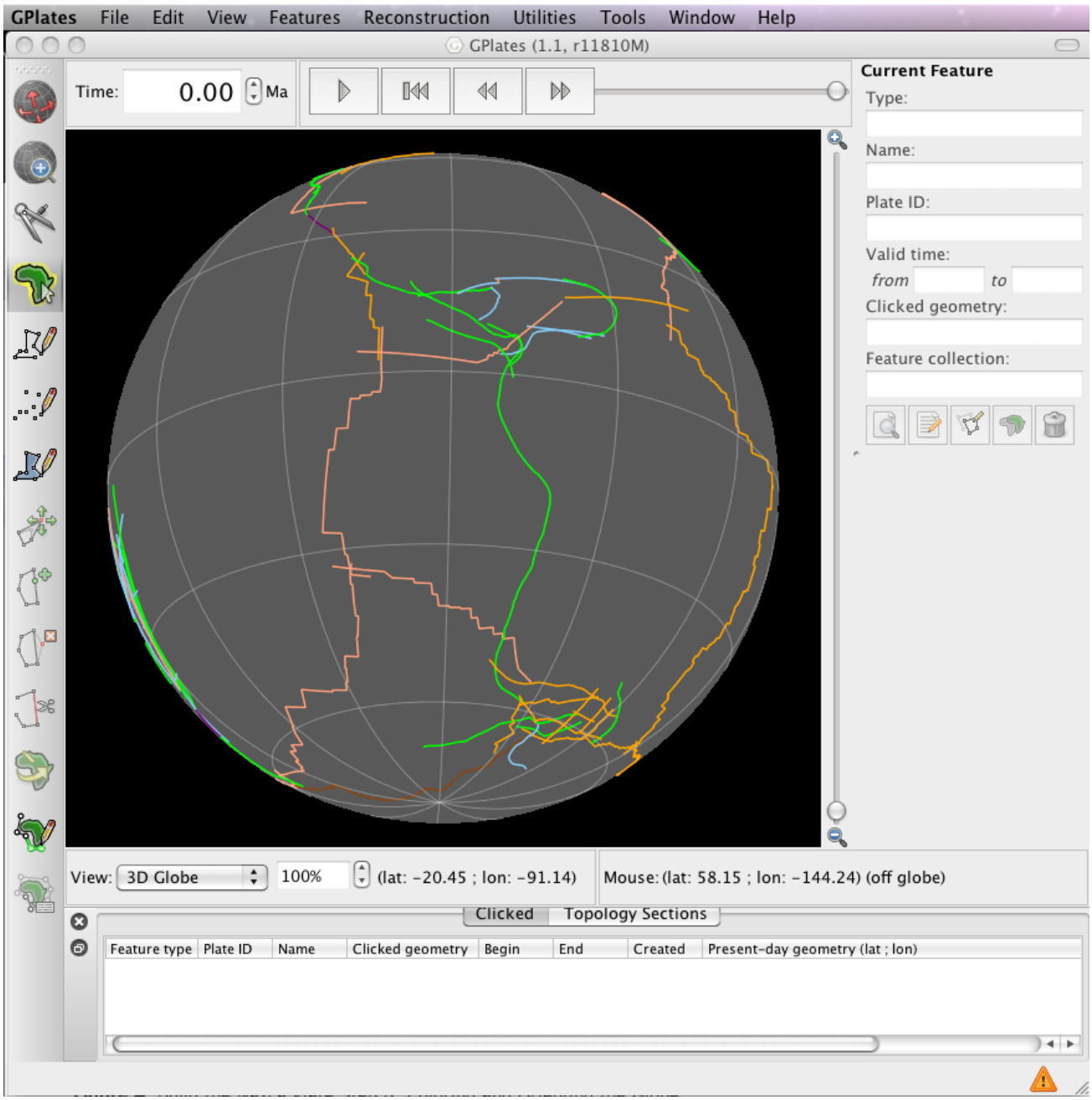

Figure 4: Build the Nazca Plate Step 0: Coloring and Orienting the Globe

Select Features to become Topology Sections

Now we will select features by clicking on them on the Globe. Please Note:

you do not have to switch to the Choose Feature Tool. The Build Topology Tool  is a specialized version of choosing features.

- Select the western margin of the Nazca plate, a digitized ridge created from an isochron. Notice that several features may appear in the Clicked table below the globe. This table lists all the features found under the mouse click point. If more than one feature is under the click point, you can use the Clicked Table to further refine your selection to the proper feature.
- Once you have identified the desired feature, click the Add to Boundary button in the right panel. The feature reference is transferred to the Topology Sections Table in the bottom panel and placed on the working list of boundary features for the new plate polygon. Notice also that the feature and the work-in-process polygon are drawn with special highlighting described above.

At this point there is only one element on the boundary list, so the plate polygon will simply close using only that feature and its vertices.

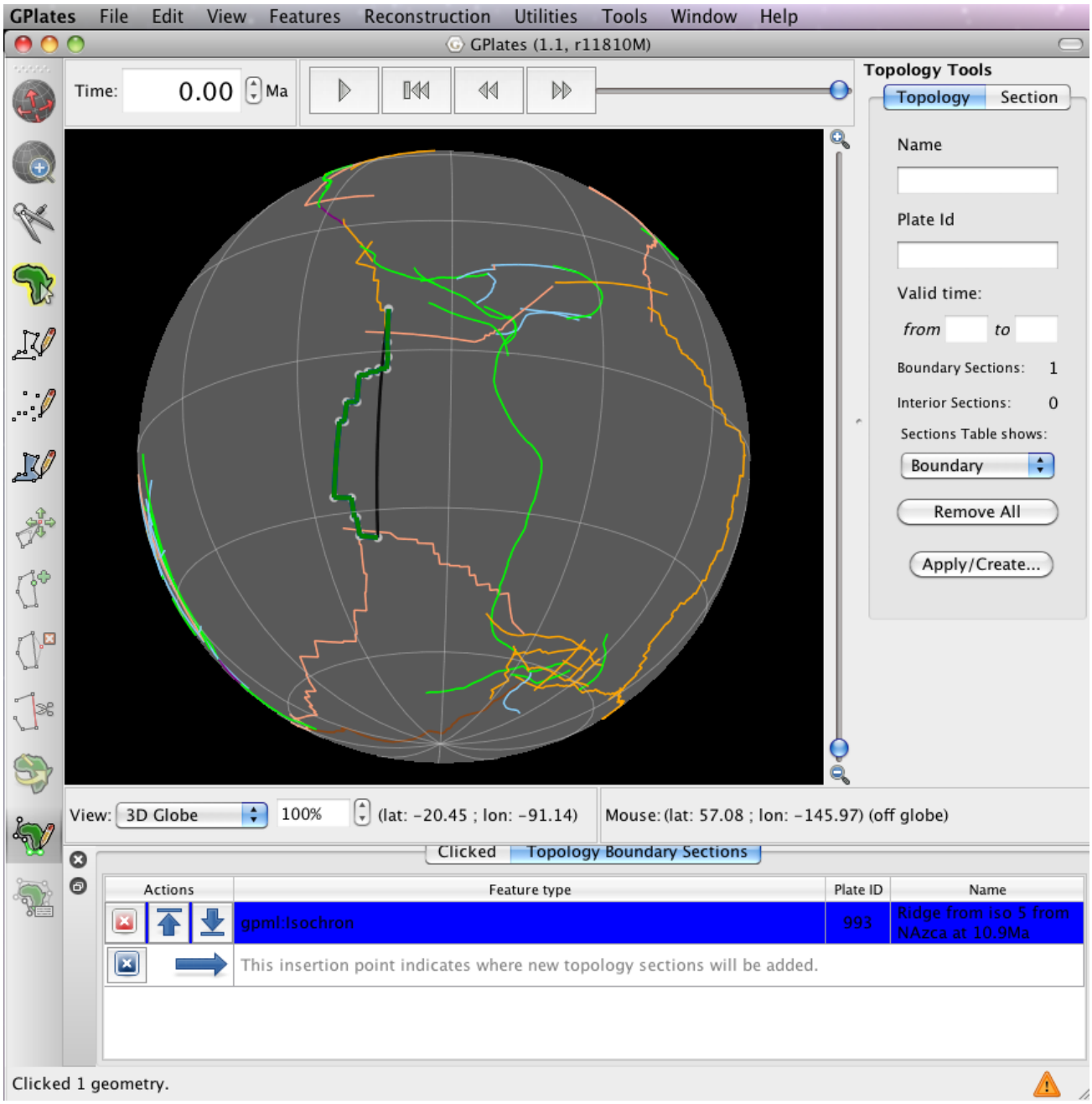

Figure 5: Build the Nazca Plate Step 1: Adding the first section

- Continue creating the intended boundary of the new plate by selecting a feature to focus it, and then clicking Add to Boundary to insert it

into the Topology Section Table.

We recommended creating a new topology by cycling around the boundary systematically (either a clockwise or counter-clockwise) and appending features to the end of the Topology Sections Table. In this example we will close Nazca in the counter clockwise direction.

- Next, choose the southern margin of the plate (another ridge from isochron data) and add it to the list.

Notice how now the south west corner of the plate is formed from the intersection of the two line data features, but it "wraps back upon it self"

With only two features on the list, the internal CCP algorithm chooses the shortest path to close the polygon and it results in a little wedge. This will be corrected as more features are added.

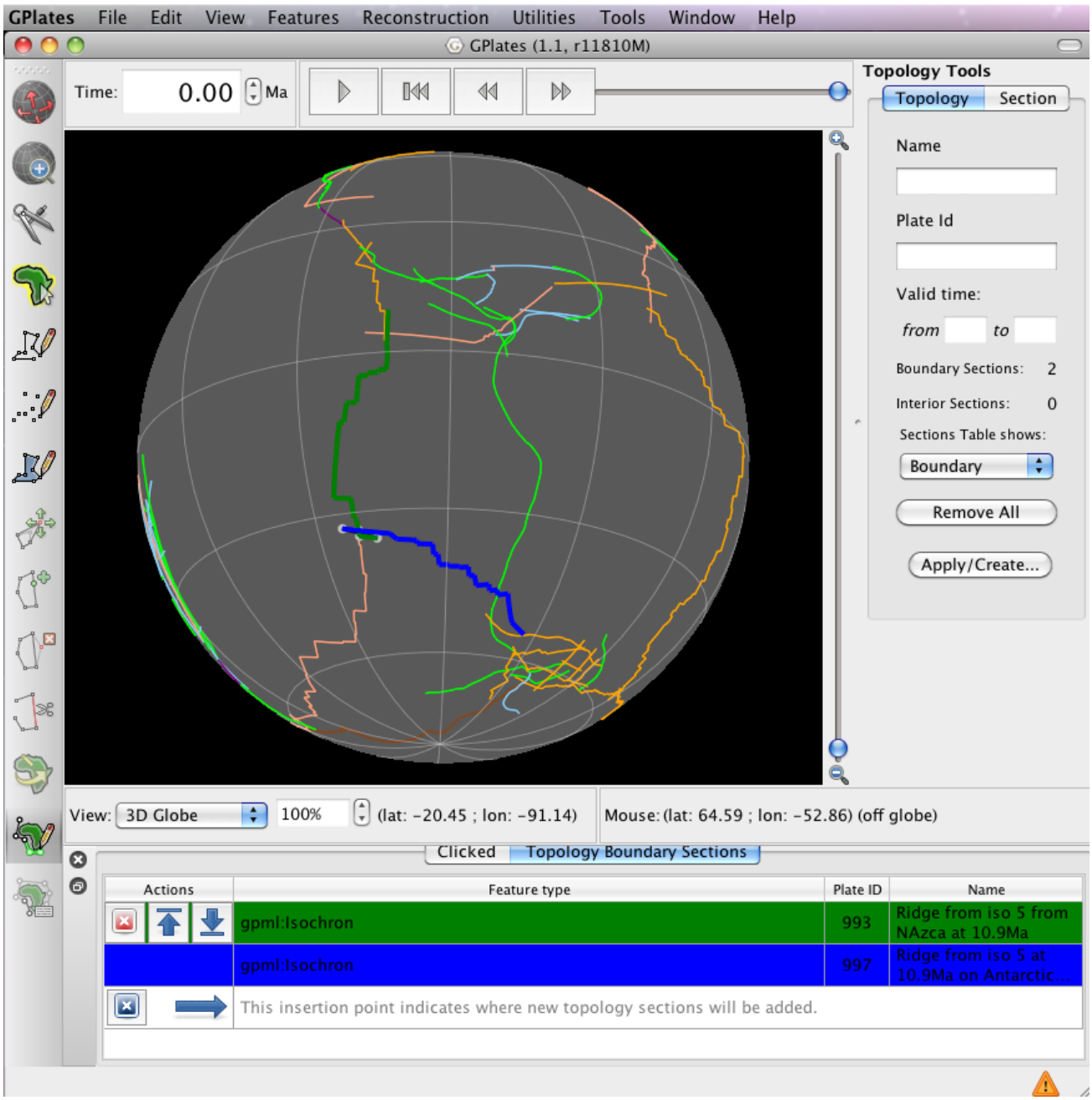

Figure 6: Build the Nazca Plate Step 2: Adding the second section results in a green and blue line being highlighted (the start and end of the topology so far); this will be corrected as more sections are added

- Continue along the eastern Margin, selecting and adding the South

American Trench.

Notice how the collection of vertices forming the work-in-progress plate polygon changes: the polygon uses most of the western margin, an intersection point with the southern margin, the central portion of the southern margin, an intersection point with the trench, and most of the trench.

Notice that the north margin has yet been defined, so the GPlates simply *closes the gap* by connecting the two features.

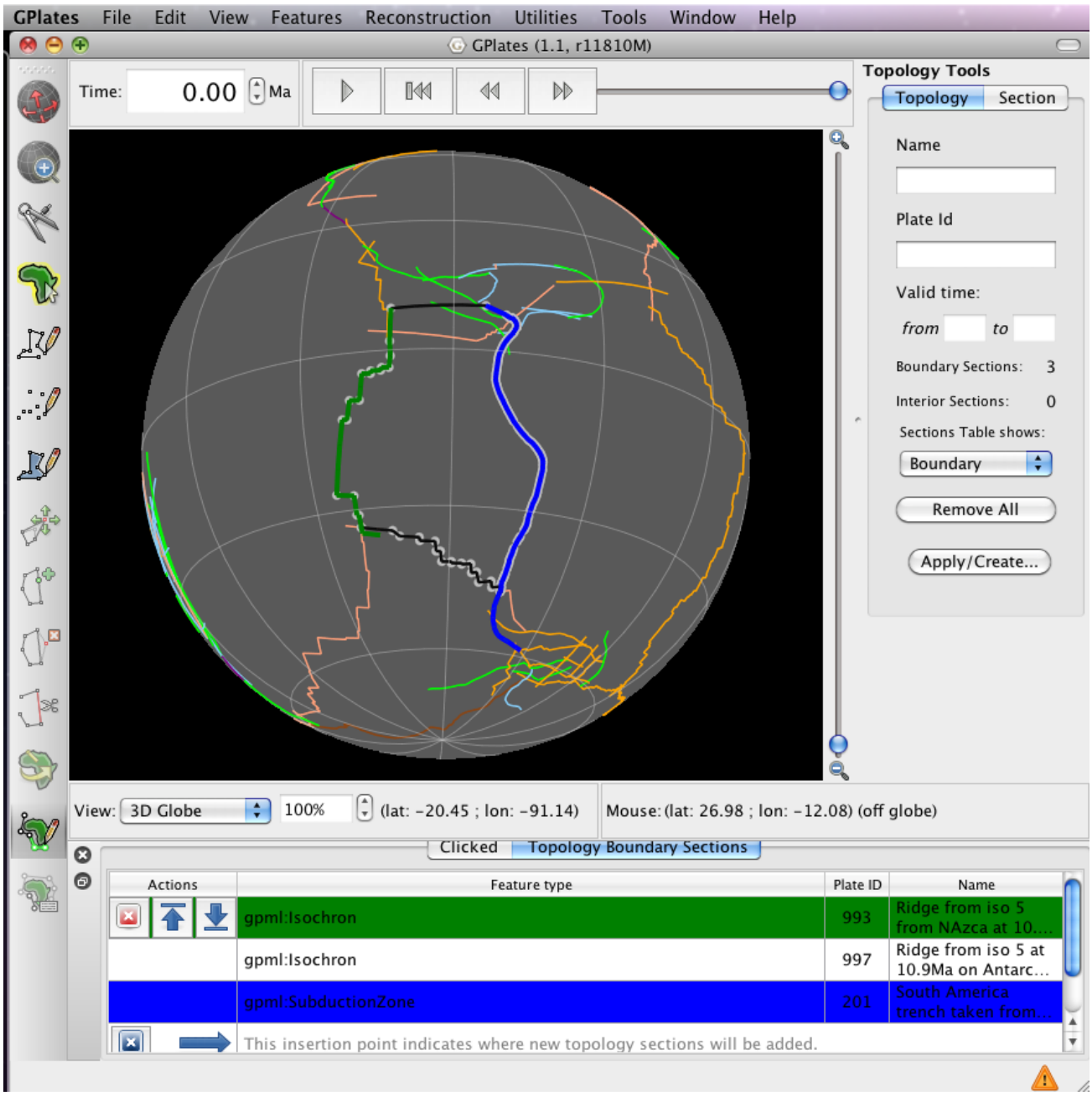

Figure 7: Build the Nazca Plate Step 3: Adding the third section results in good intersections in the south, and an automatic closing in the north.

Zoom in on the north east corner of the plate area and we will show some of the subtleties and detail work involved with plate closure. This region

has a few different options available to us.

- Click on the small section of the CAR SAM Boundary feature that lies between the South American Trench and the Cocos Caribbean Trench. This small sub-segment will become part of the Nazca boundary.
- Continue with the CAR Cocos Trench, and the northern Margin, another Ridge from isochron data.

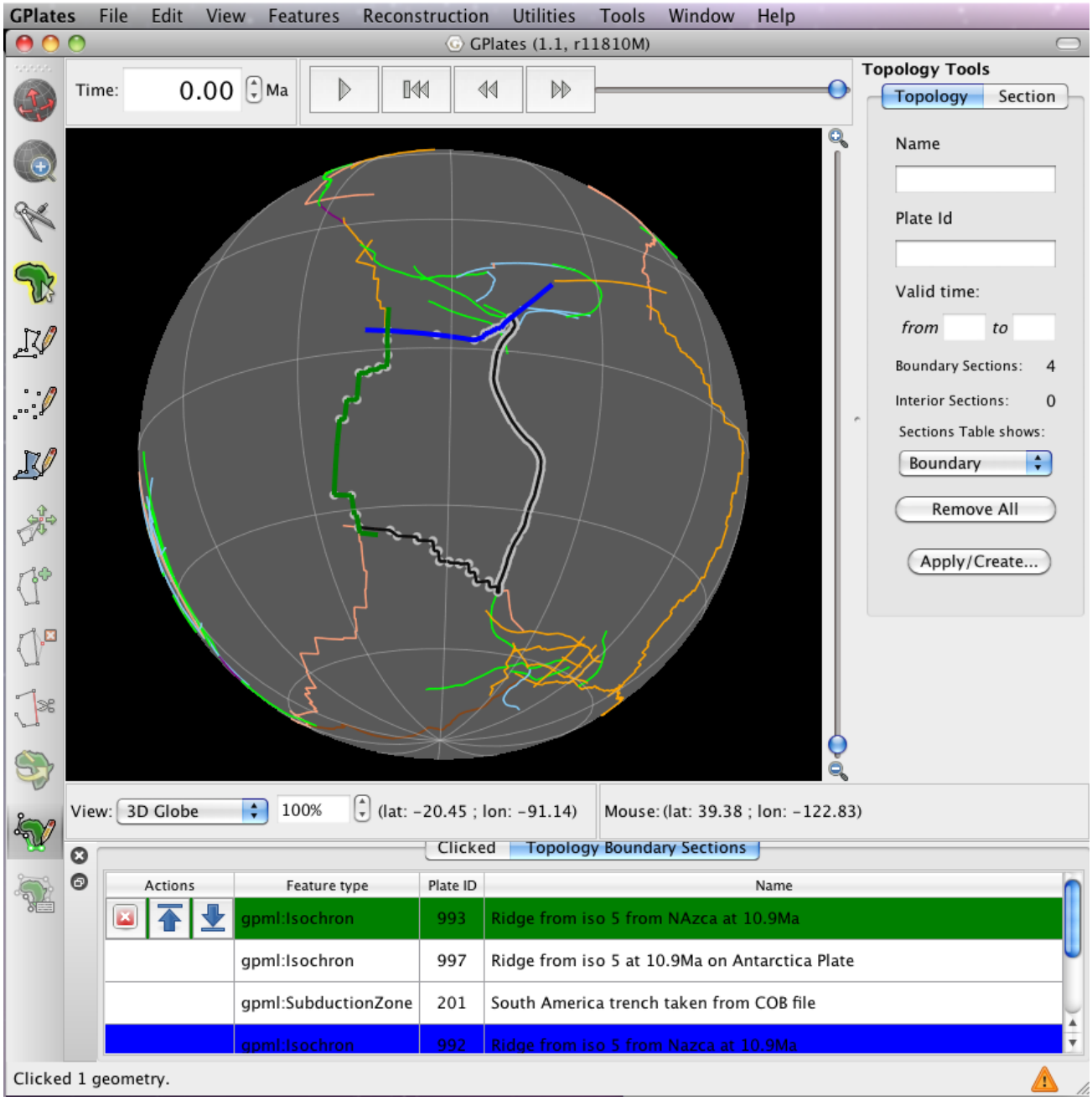

Figure 8: Build the Nazca Plate Steps 4, 5 & 6: Adding the fourth section gives the desired detailed topology in the north east.

You can check the outline of the final topology by turning off all line features that are loaded.
View > Geometry visibility > and untick the Show Line Geometries option.

Editing the Sections Table

If you have discovered that you forgot a feature in the middle of the boundary list list, or realize you want to modify the ordering of the Sections in the Table, then you may change the insert point via the Actions column of the table in the bottom panel, and continue with the same steps as above: Focus a feature on the Globe, then click the Add Focused Feature button.

Adding a feature does not change the insertion point, so be aware if you perform an Insert operation out of sequence.

Creating the new feature

Once you are satisfied with the entries in the Topology Sections Table, and the resulting geometry of the Closed Plate Polygon, then you may create the new Topology via the "Apply/Create …" button on the right Topology Tab of the Topology Tools Panel. This action will lead you through a series of dialogs to finalize the creation process.

- In the first step you will choose the Feature Type of the new Topology. Select: gpml:TopologicalClosedPlateBoundary.
- The next step is to assign other basic property values to the Topology. The geometry type is "Boundary", and this value is automatically selected for you.

The other basic feature properties must be set as well: Plate ID, Begin Time, End Time, Name.

- Enter 911 for the Plate ID corresponding to the Nazca plate.
- Enter a Begin Time of 3 Ma; an End Time of 0 Ma;
- Enter something like "Nazca Example" for the name of the new plate polygon.

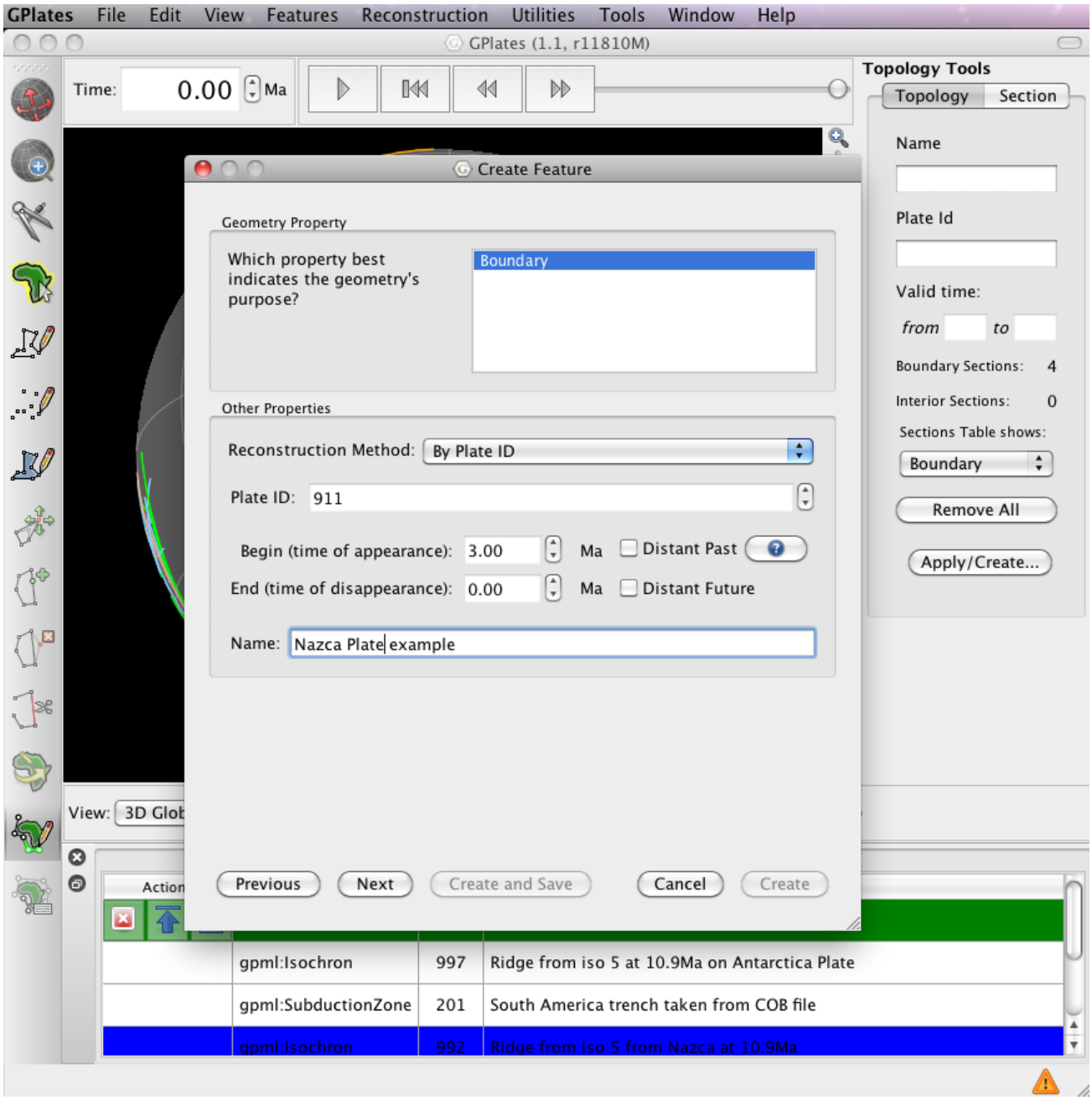

Figure 9: Build the Nazca Plate Steps 7: Adding basic propeties to the Plate Polygon Feature.

In the final step of feature creation, the feature is assigned to a feature collection. All data files that are currently loaded in GPlates will be listed here, as well as the < New Feature Collection > option. Choosing any one of the existing feature collections and clicking Create will add the newly

created topology feature to that collection and return the user to the GPlates main window.

If the < New Feature Collection > option is selected, a new feature collection will be created to hold the new feature. This feature collection will not yet have a name, and is not associated with a file on disk. Like all other feature collections, the new one will be found in the Manage Feature Collections dialog.

The convenience button "Create and Save" adds the feature to the selected feature collection, and opens the Manage Feature Collections dialog, so that you may immediately save or rename the collection.

Editing an Existing Topology

Edit Topology Tool

The Edit Topology Tool  is the tool used to edit existing topology features. Under this tool you will load an exiting topology into the Topology Sections Table, and make edits to that ordered list of features.

- Use the Choose Feature Tool to select an existing topology.
- Click on the Edit Topology Tool button.

Notice that the topology will be drawn with the highlighting described above. The feature's basic data is placed into the Topology tab of the Task Panel, and the Topology Sections Table will be filled with the list of boundary features.

- Now you may use the same basic editing steps described above to change the boundary sections.

Once you are satisfied with the changes, then click on the Apply/Create button and the Topology's boundary list will be changed to the current contents of the Topology Section Table.

References

Gurnis, M., Turner, M., Zahirovic, S., DiCaprio, L., Spasojevic, S., Müller, R., Boyden, J., Seton, M., Manea, V., and Bower, D., 2012, Plate Tectonic Reconstructions with Continuously Closing Plates, Computers & Geosciences, 38(1): 35-42, doi:10.1016/j.cageo.2011.04.014.