Topological Closed Plate Polygons

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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

Click here to download the data bundle for this tutorial.

This tutorial dataset includes the following files:

Caltech_Global_20100723.gpml

Caltech_Global_20100723.rot

Caltech_Global_20100723_NO_PLATEPOLYGONS.gpml

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

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

This tutorial dataset is compatible with GPlates 1.5.

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, respectively. 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 topology 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.

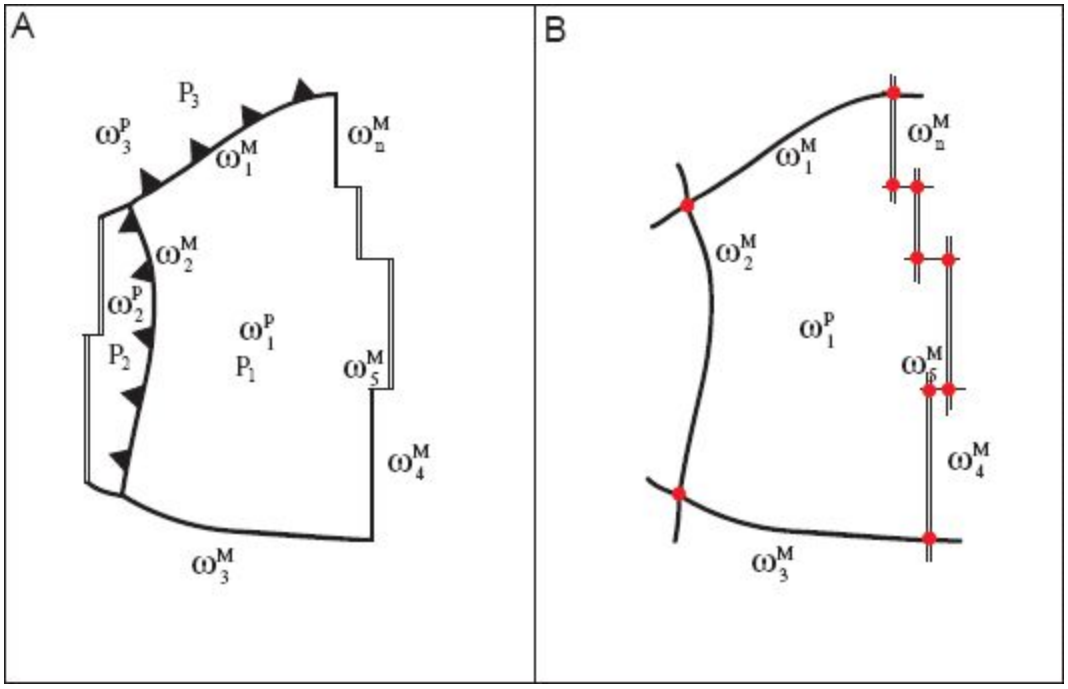


Figure 1: Schematic of the generic features that are incorporated into the Continuously Closed Plate (CCP) algorithm. Red dots represent dynamically computed intersections between plate boundaries.

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

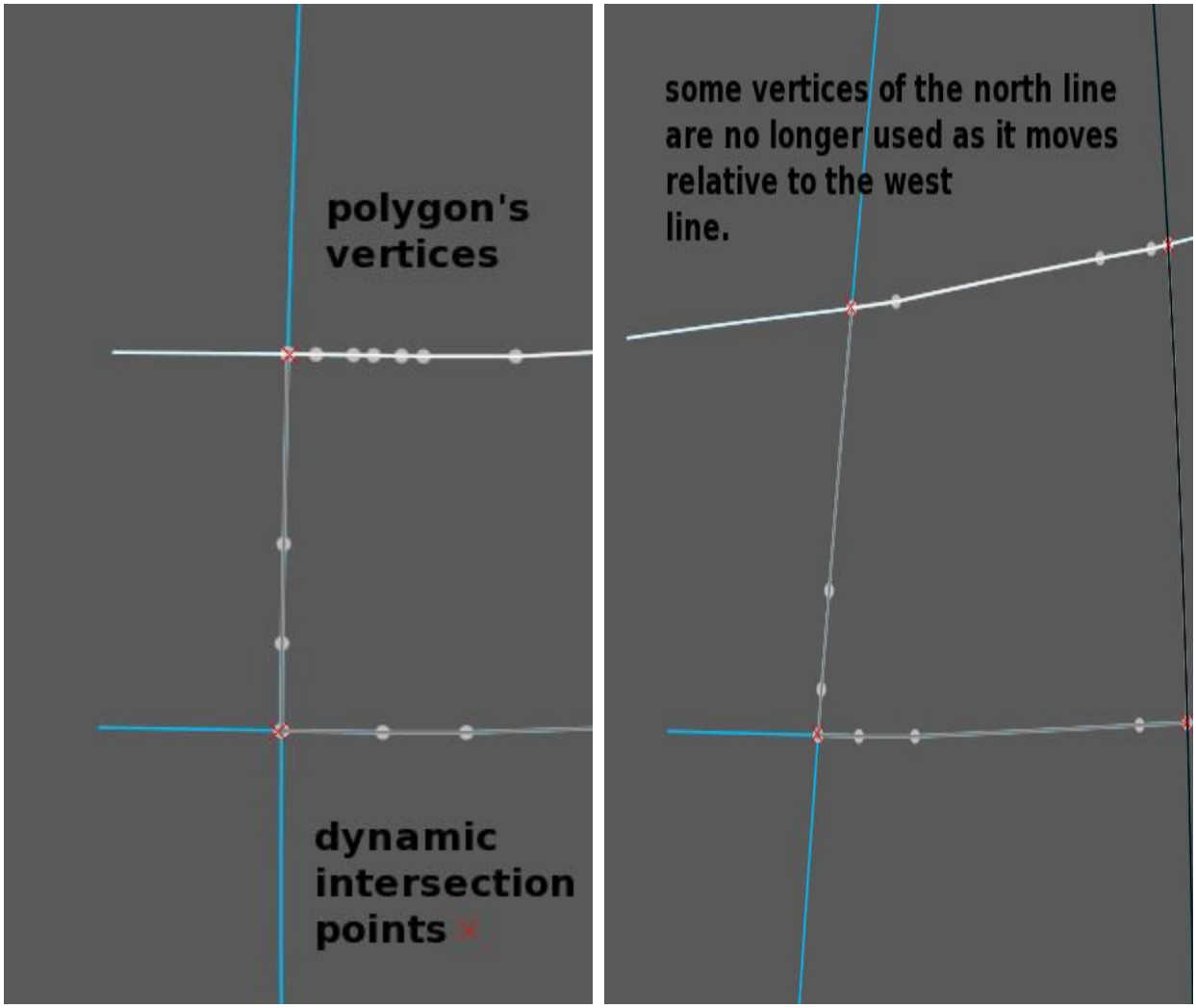


Figure 2: Hypothetical plate polygon from four intersecting lines at two times. Base features are drawn in blue. Plate polygon is outlined in grey, with grey dots showing polygon's vertices. Red crosses have been added in the figures to highlight dynamically computed intersection points, relative to base features' vertices. First line on the boundary list is highlighted white (North Line); last line is highlighted in black (East Line)
A: Reconstruction at 0 Ma, the initial configuration of lines, intersection points, and resolved polygon vertices.
B: Reconstruction at 10 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 (Figure 3). This only becomes visible when you are creating or editing topologies.

- The Topology tab shows a summary of the topology being edited/created. When building a new topology, the Name, Plate Id, and Valid Time displays will be blank (these values will be set when finalising the new topology). When editing an existing topology these will display that the various property values specified when that topology feature was created.
    - 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 Create… button to finalize the creation process (under the Build New Topology Tool).
    - The Apply button appears only when editing topologies and is used to apply all edits to the current topology
- The Section tab shows the basic properties of the focused feature. The 'Add' button will insert the feature into the Topology Sections Table at the current Insertion Point.

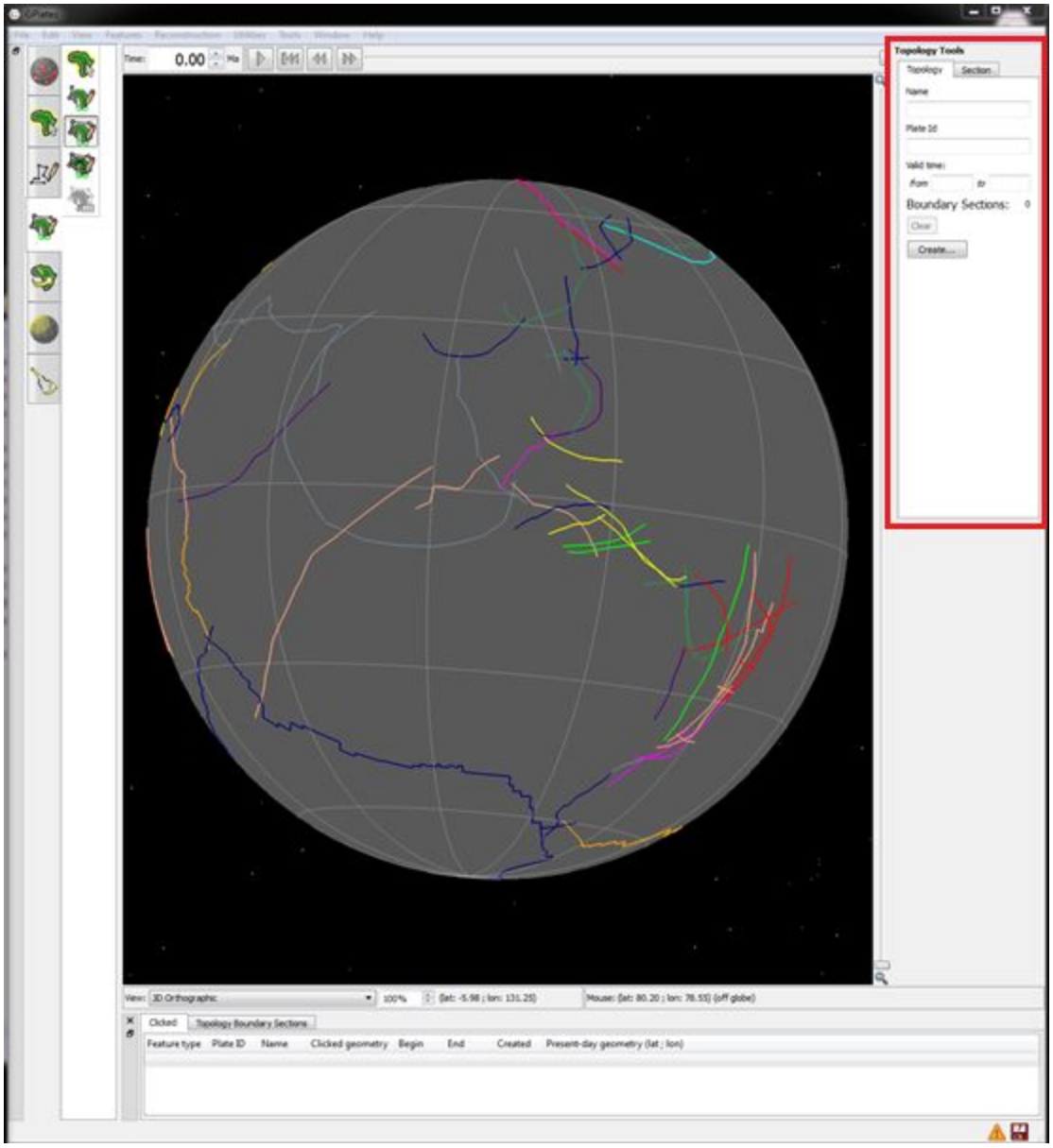


Figure 3: Topology Tools Task Panel

Topology Sections Table

The Topology Sections Table holds an ordered list of boundary features (Figure 4). Upon each reconstruction, it is these features, and their relationships, that will be processed into the resolved polygon geometry for the topology.

The following options appear when creating and/or editing topologies.

- 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.

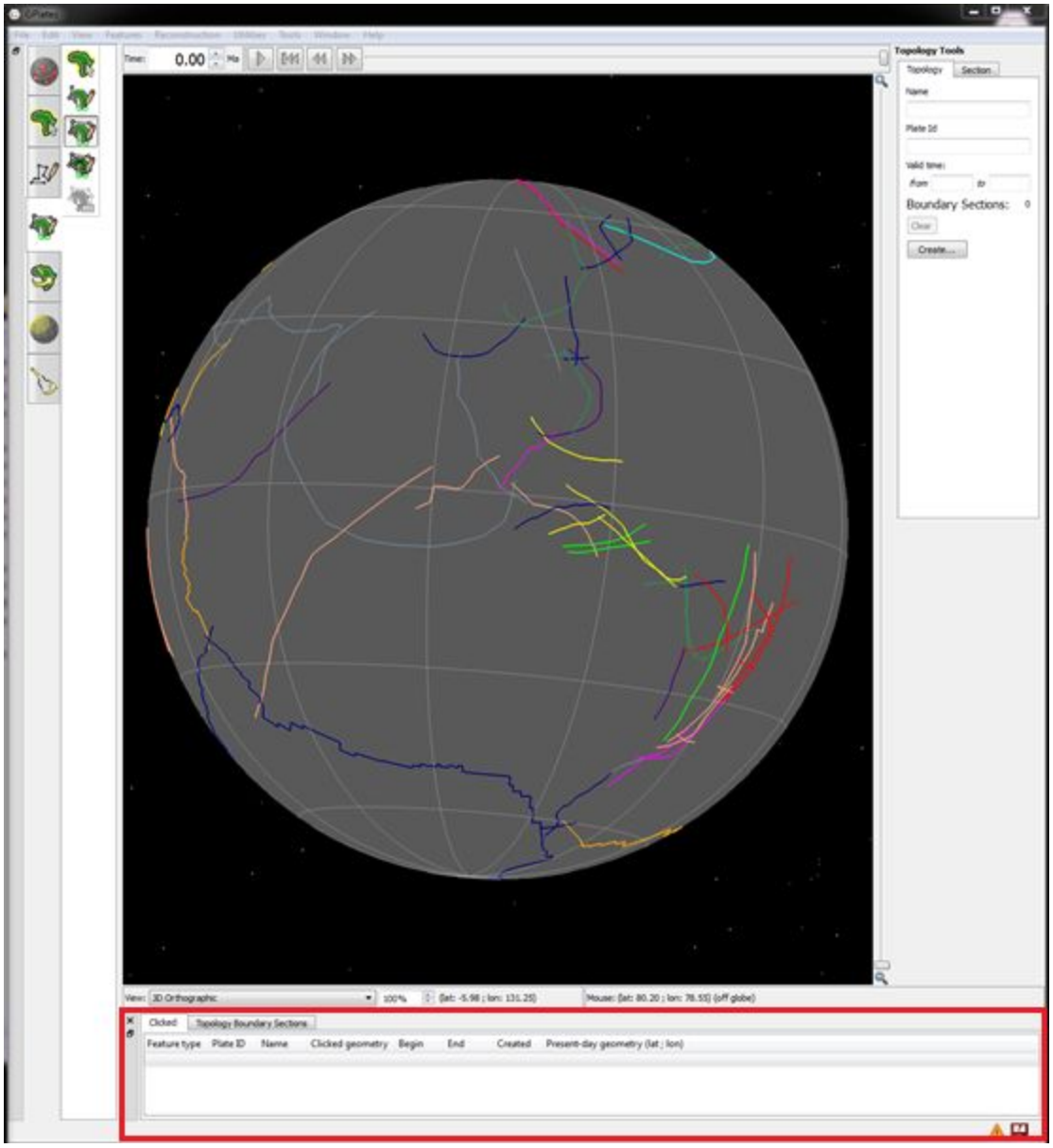


Figure 4: Topology Sections Table

Topology Drawing Conventions

While a topology feature is being edited, GPlates will draw the topology, and its referenced features, with certain highlights and colours.

- 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 grey. All the topology's resolved vertices, both those from the source features, and those computed as intersection points, will be highlighted with grey dots. Note that in some figures we have over-painted with red dots to accentuate the intersections; on-screen these intersections are grey.

- The current insertion point of the Topology Section Table will be highlighted visually on the globe with slightly different colouring 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.

Exercise 1 – 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.

1. Open GPlates and load the following files using File > Open Feature Collection:
    - Caltech_Global_20100723_NO_PLATEPOLYGONS.gpml
    - Caltech_Global_20100723.rot

2. Go to Features > Manage Colouring and on the left hand panel of the Draw Style window, select FeatureType (Figure 5)

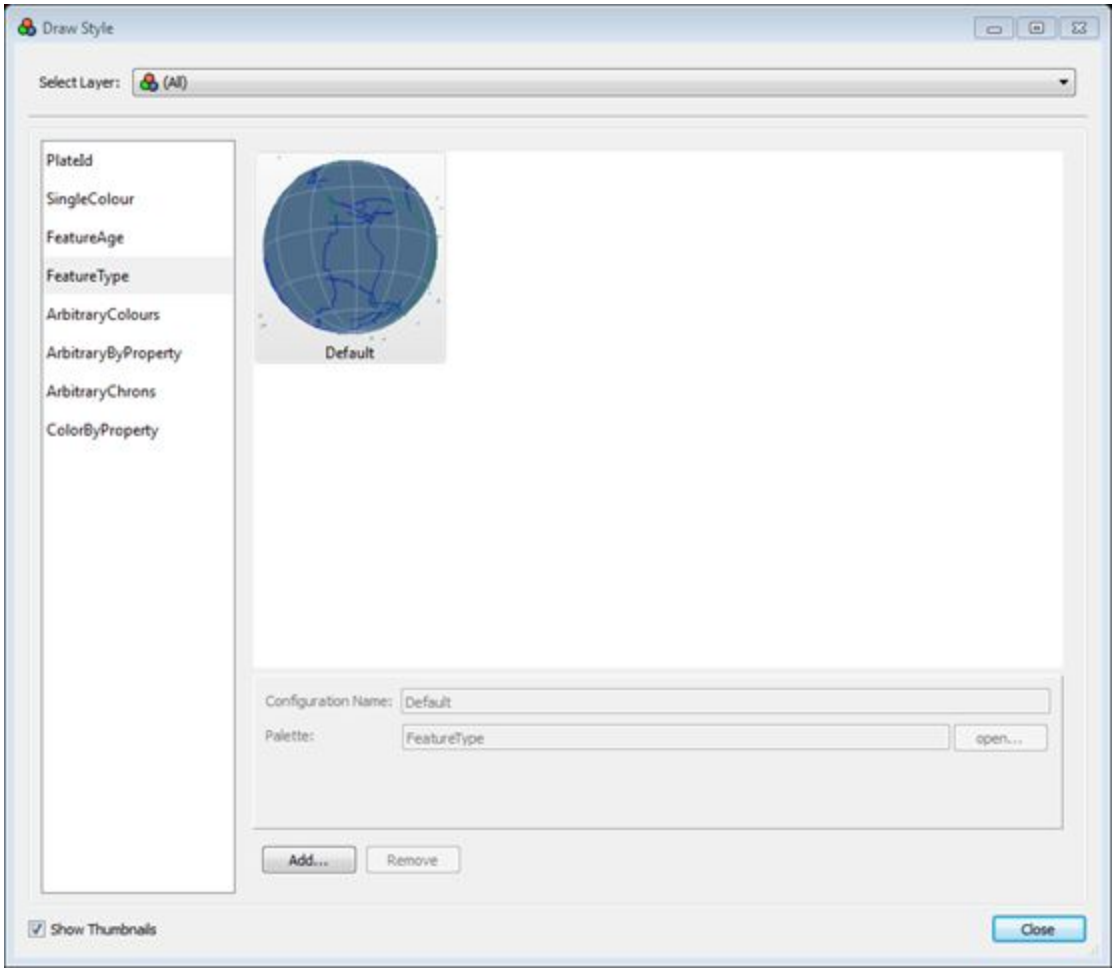


Figure 5: DrawStyle Window, selecting colour by Feature Type

The basic colour scheme is now:

- Green for Mid Ocean Ridges
- Blue for Subduction Zones and isochrons
- Purple for Fracture Zones

(see the GPlates manual for more info on the colour schemes available).

3. Orient the globe to focus on the Nazca plate and zoom in a little (Figure 6).

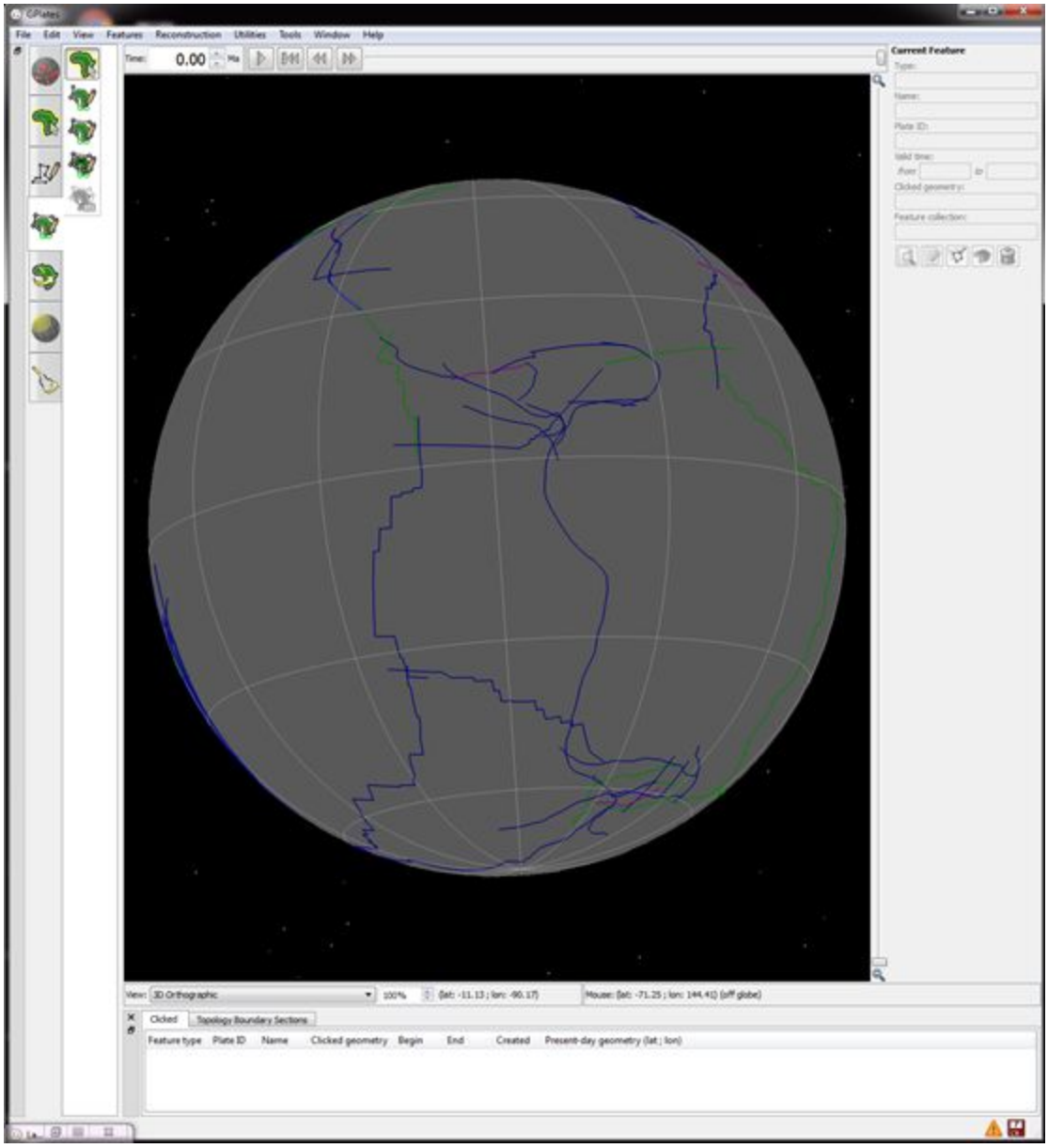


Figure 6: Globe oriented to show the Nazca Plate, features coloured by Feature Type

4. Change the reconstruction time to 3 Ma and play the animation to present day. See how the plate margins move (this is the appropriate life time for this example of the Nazca plate)

5. Select the Topology Tool  , and then the Build New Boundary Topology Tool  . The topology tool is now activated and the new topology will initially have an empty list of sections (as you add sections to the topology, the Topology Sections Table will become populated with the

features)

Select Features to become Topology Sections

Now we will select features by clicking on them on the Globe. Please note that you do not have to switch to the Choose Feature Tool. The Build New Boundary Topology Tool  is a specialized version of choosing features and is located within the Topology submenu or can be selected by pressing 'b' on the keyboard.

6. Select the western margin of the Nazca plate, which is a digitized ridge created from an isochron.

Notice that several features may now 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.

7. Once you have identified the desired feature, click the 'Add' button in Section tab in the right panel (Figure 7).

The feature reference is transferred to the Topology Boundary Sections table in the bottom panel below the globe, 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 (hence we see the black line from joining the ends of the green line).

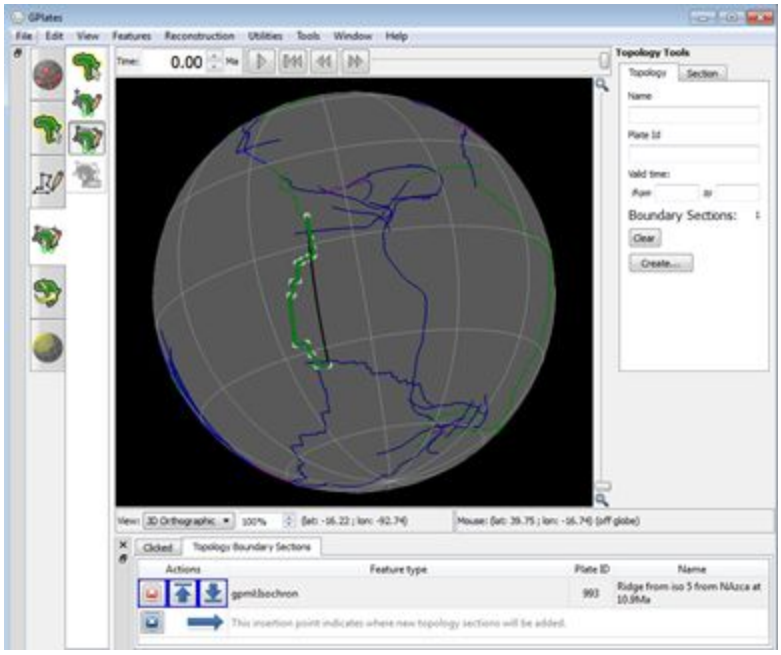


Figure 7: Adding the first section of the Nazca Plate (Step 7)

We will now 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.

8. Choose the southern margin of the plate (another ridge from isochron data) and add it to the list (Figure 8).

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 itself"

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.

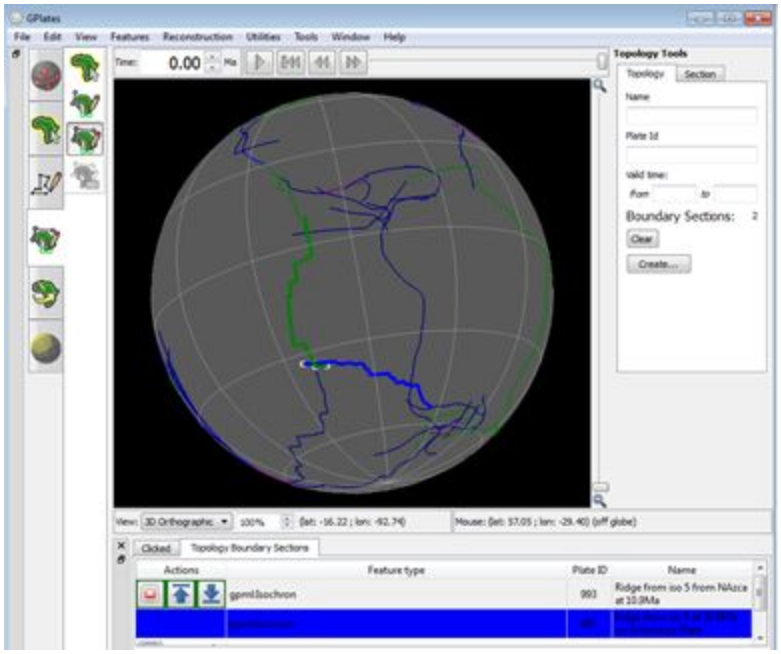


Figure 8: Build the Nazca Plate - Adding the second section results in a green and blue line being highlighted (the start and end of the topology so far); this will be corrected as more sections are added (Step 8)

9. Continue along the eastern Margin, selecting and adding the South American Trench (Figure 9).

Notice how the collection of vertices that form 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.

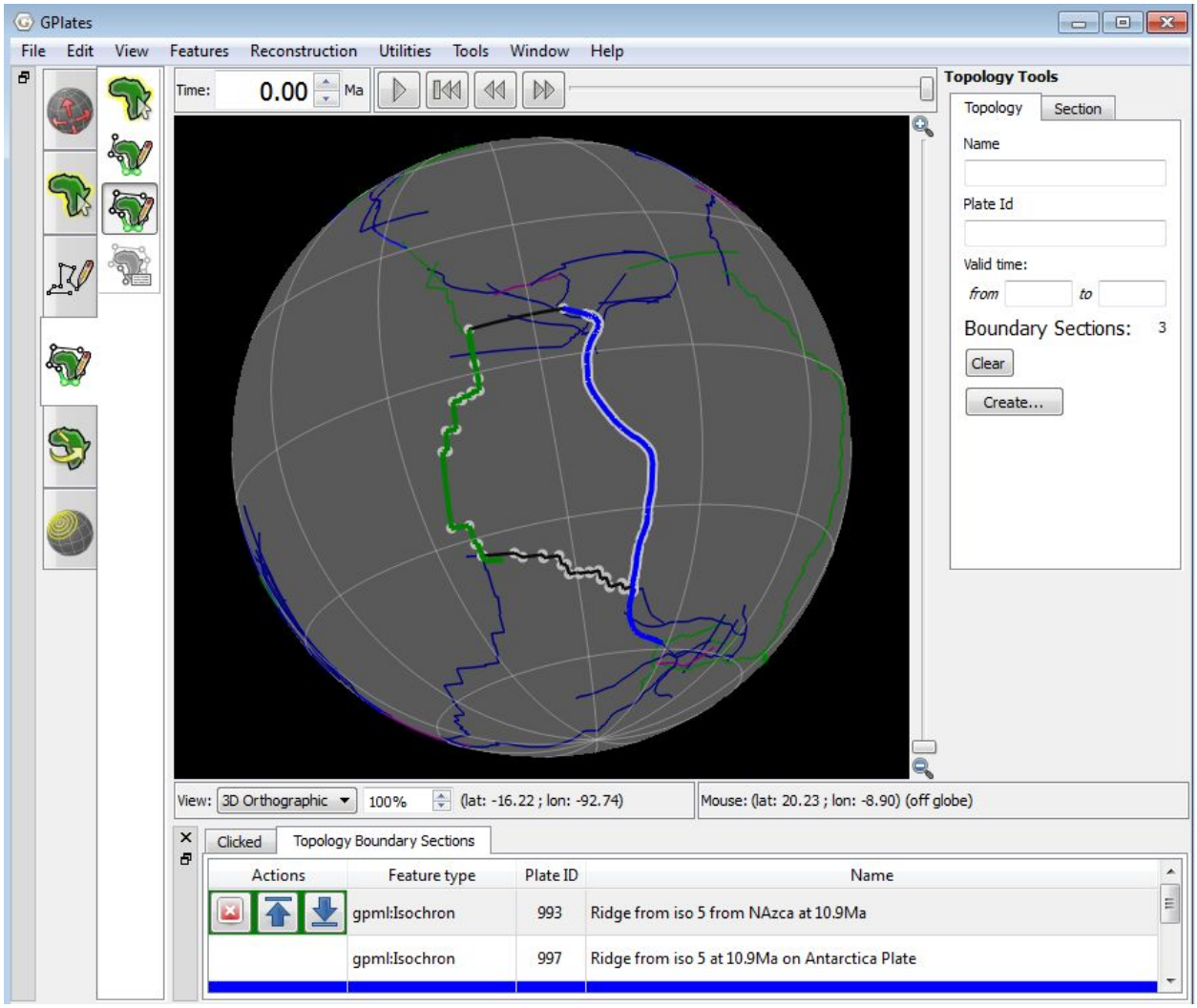


Figure 9: Build the Nazca Plate - Adding the third section results in good intersections in the south, and an automatic closing in the north (Step 9).

10. To complete the plate closure, zoom in to the northern half of the plate area (Figure 10).

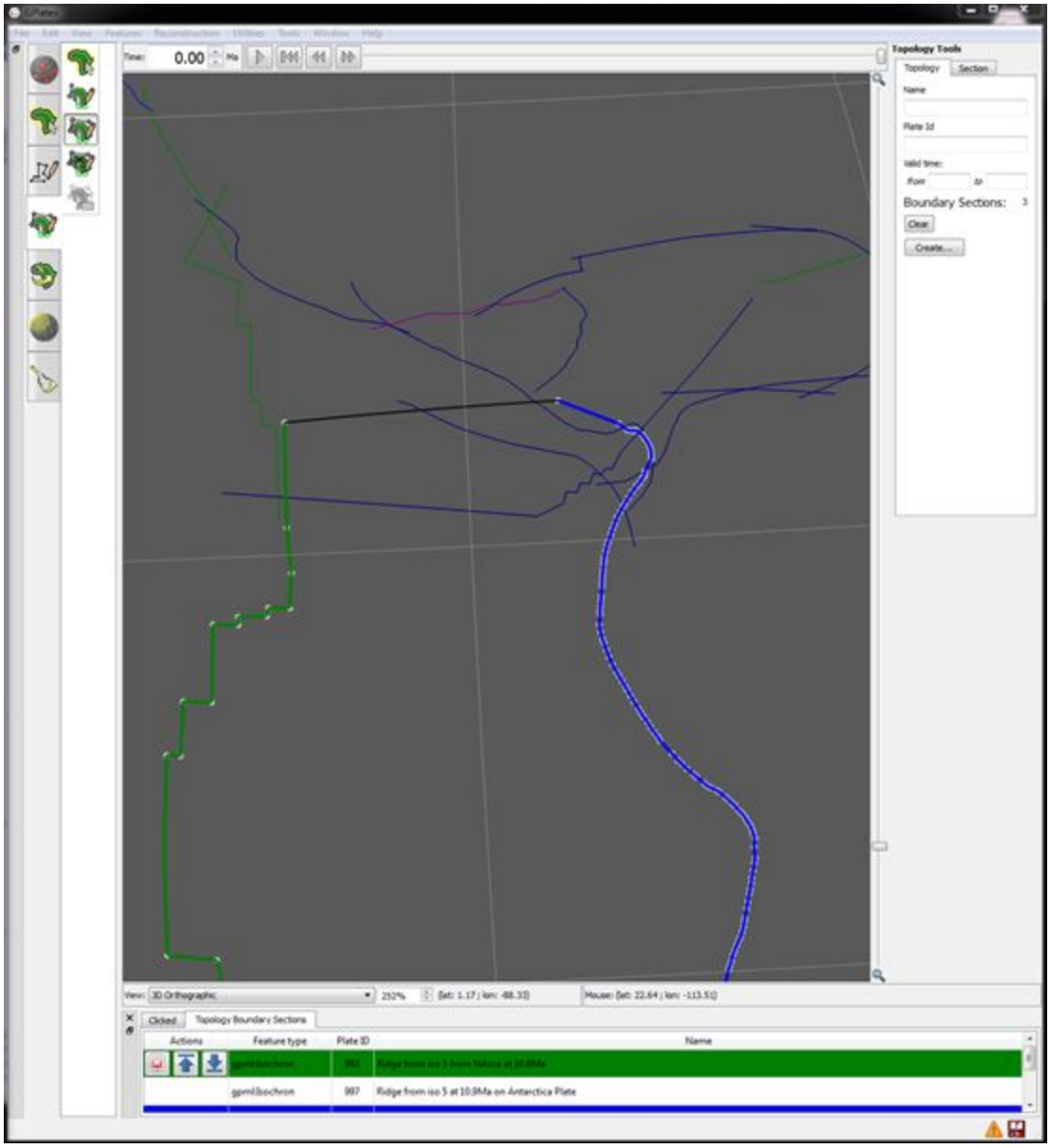


Figure 10: Build the Nazca Plate - zooming into the northern section of the Nazca Plate

We note that the north east region of the plate appears complex, however in this example, we will create a simple topology.

11. Click on the northern margin (a ridge isochron) and add it to the boundary (Figure 11).

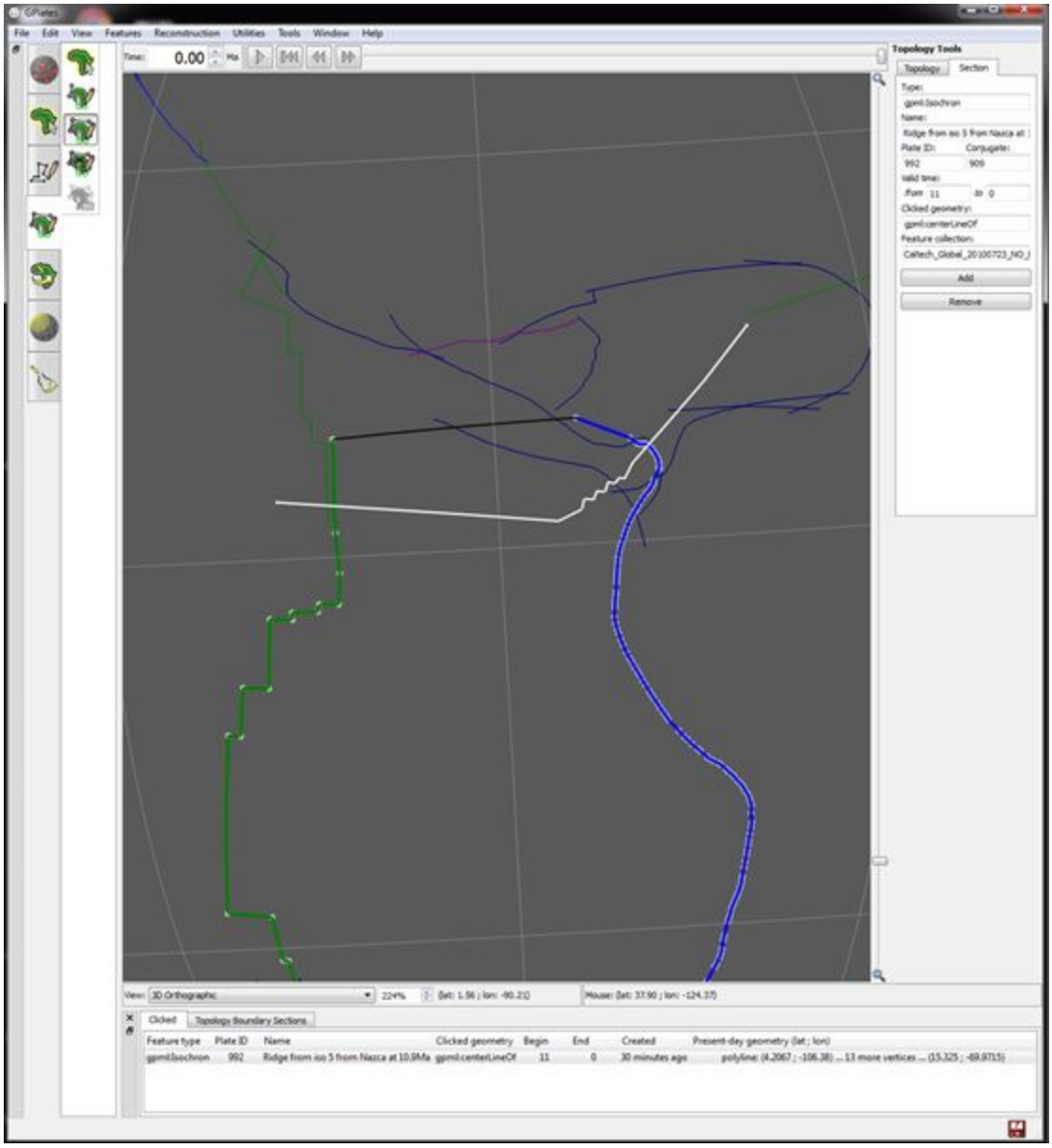


Figure 11: Northern ridge isochron section selected.

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' button. More information about editing topologies follows in Exercise 2.

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, we need to create our new topology.

12. Select the ‘Create…’ button on the Topology Tab of the Topology Tools panel (on the right hand side of the screen).

13. 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.

14. The geometry type is "Boundary" (this value is automatically selected for you)

15. Set the other basic feature properties - Plate ID, Begin Time, End Time, Name (Figure 12).

- 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.

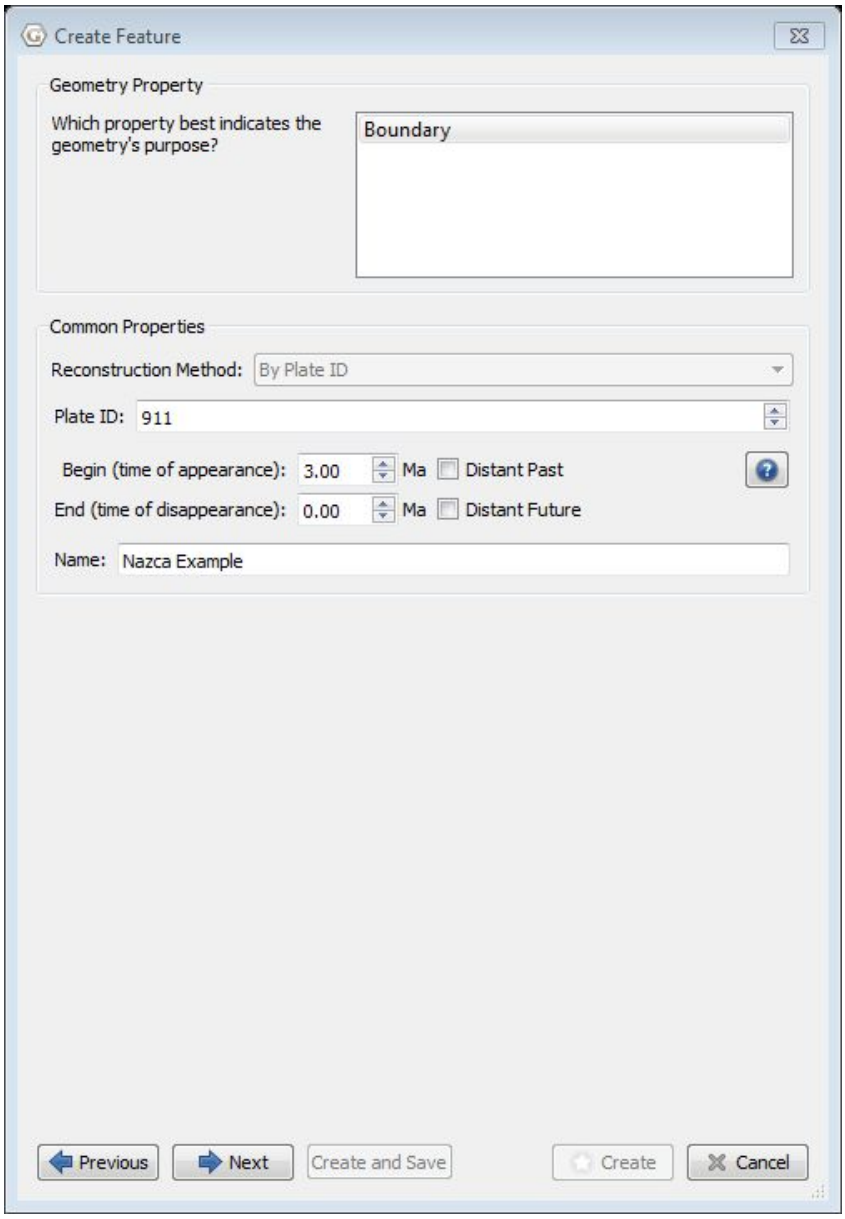


Figure 12: Build the Nazca Plate - Adding basic properties to the Plate Polygon Feature (Step 15).

16. Select Next, Next, and then we have to save the feature 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.

17. We will save this topology into a new feature collection.

You may notice that nothing appears to have changed on screen.

18. Open the Layers Window (Window > Show Layers or Ctrl+L).

Notice that our new layer is pink, and is situated below the green layer that we created the topology from.

19. Make the green layer invisible, and notice that our new topology is now visible (Figure 13).

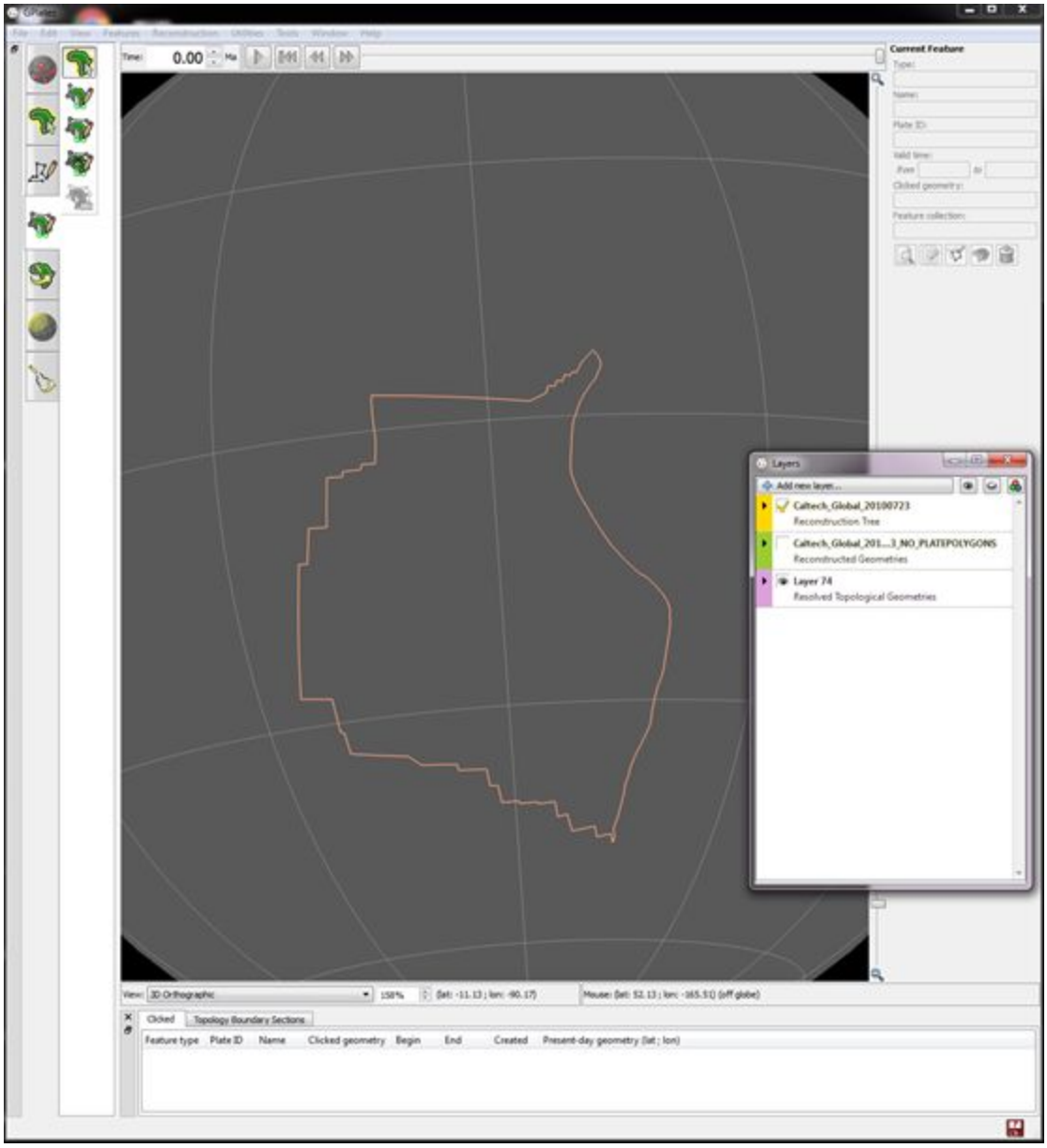


Figure 13: Nazca plate topology visible

Another way to make this visible with the reconstructed geometries, is to change the order of the layers in the Layers window. In GPlates, the layer that is at the top will appear on top of all other layers.

20. Drag the pink layer so that it sits above the green layer in the Layers window and make both layers visible (Figure 14). Note that we can see our new topology as well as the spreading ridges and other reconstructed geometries.

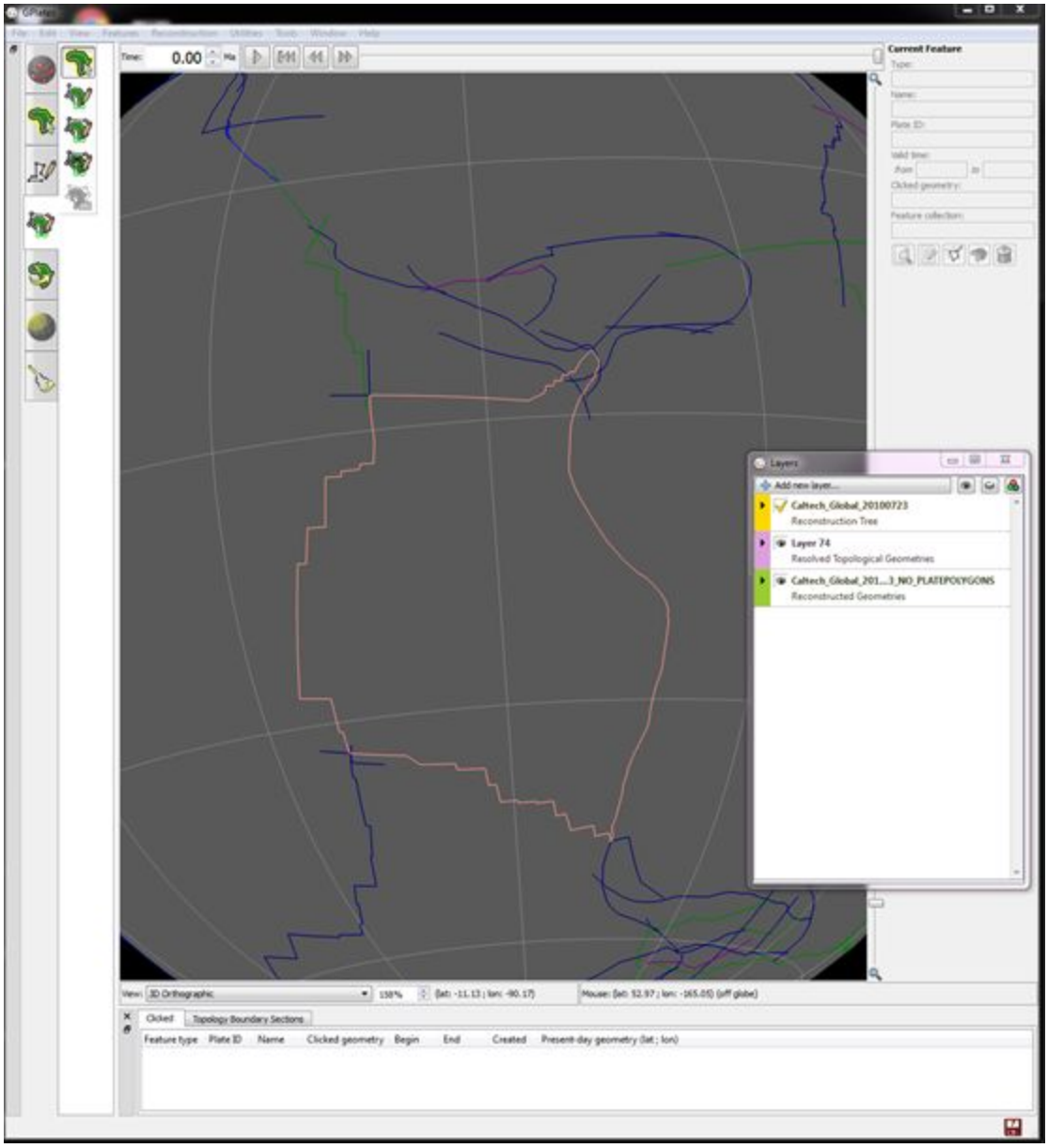


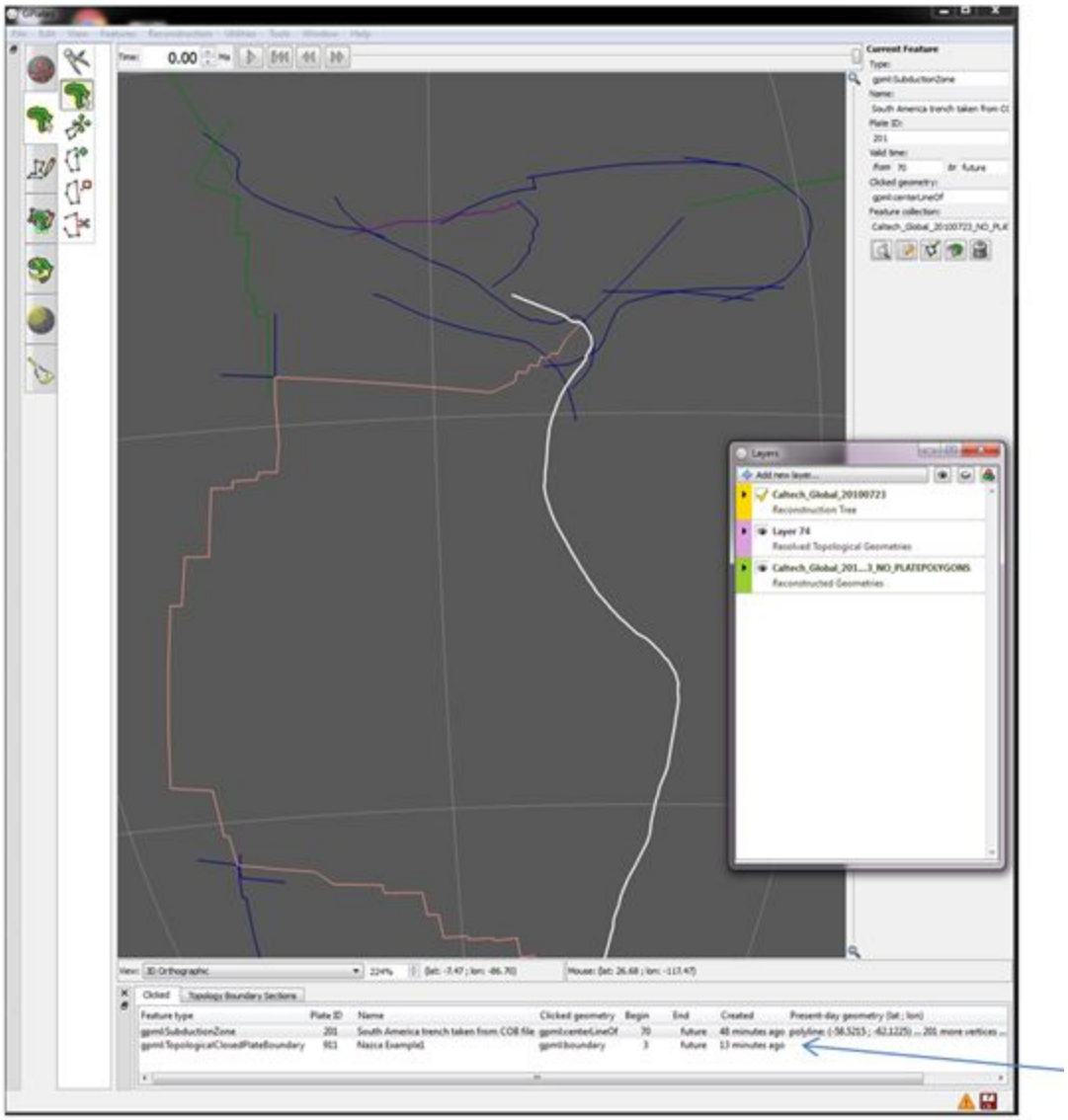
Figure 14: Nazca plate topology on top of existing geometries

Exercise 2 – Editing an Existing Topology

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

We will edit the Nazca plate topology we created in Exercise 1 to incorporate more complexity in the north east corner.

1. Use the Choose Feature Tool to select the existing Nazca Plate topology we created in Exercise 1 (Figure 15b). If you are having trouble with both layers visible, make the green Reconstructed Geometries Layer invisible, select the topology, and then make the green layer visible again. Alternately, when selecting a feature, in the bottom Topology Sections Table, there two features will appear since they sit on top of each other (Figure 15a). You can select the feature you want to highlight in this table.



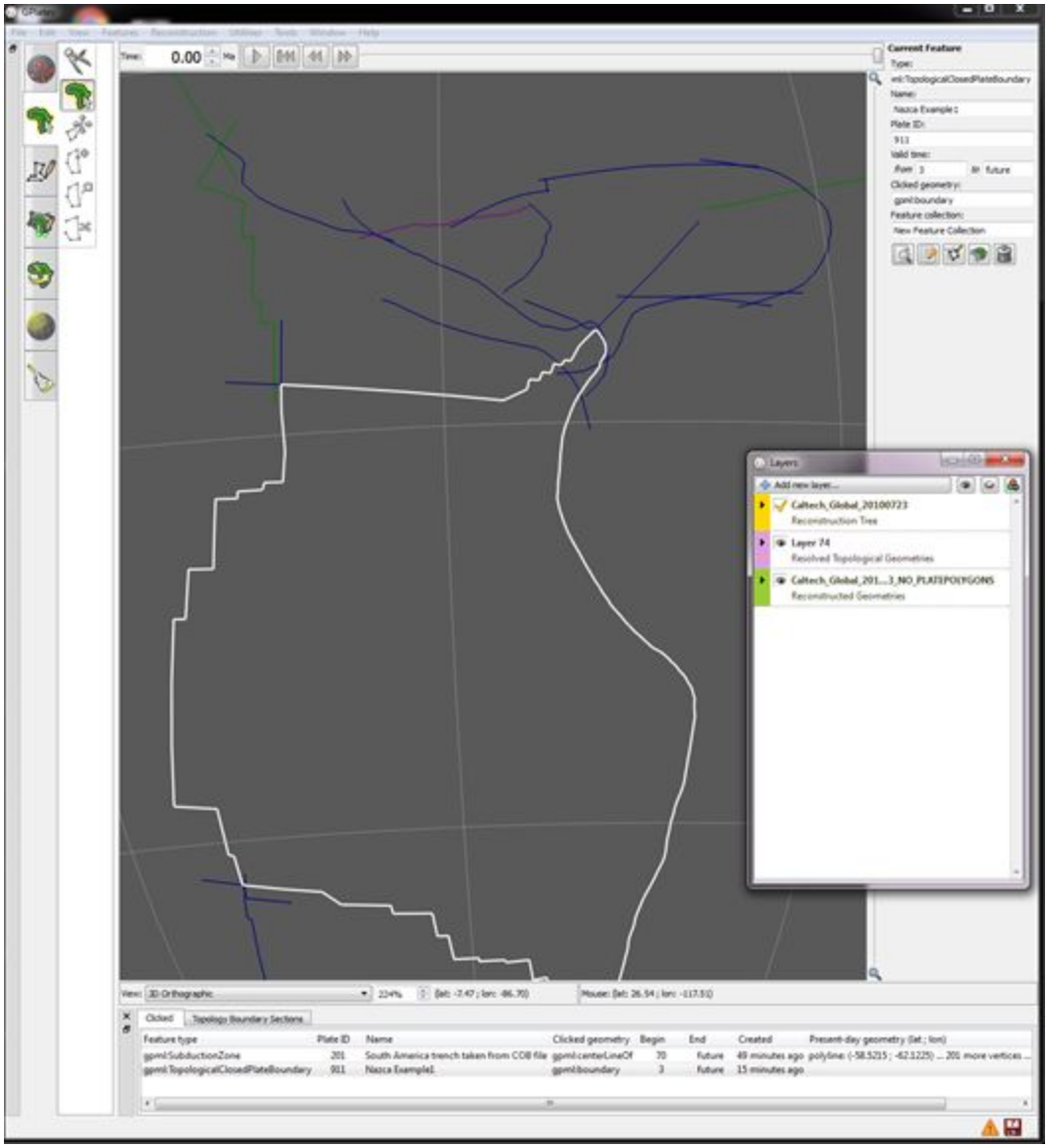


Figure 15: a) Topology selected showing two features sitting on top of each other in the Topology Sections Table **b)** Nazca plate topology selected

2. Click on the Edit Topology Tool button (Figure 16).

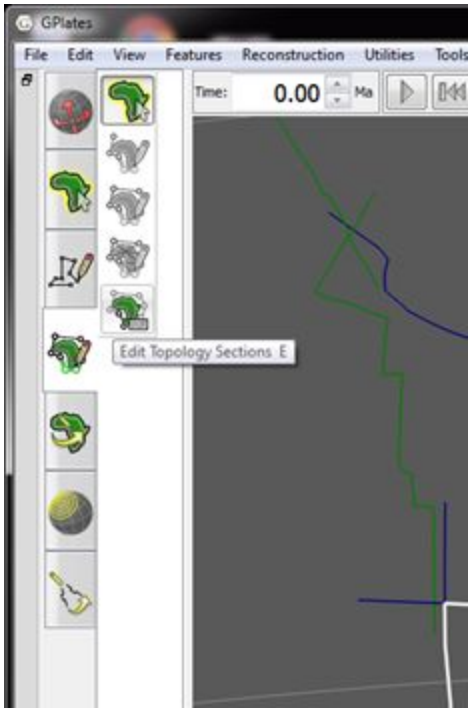


Figure 16: Edit Topology Sections

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 (Figure 17).

A)  B)

Figure 17: a) Topology Sections Table showing the boundaries that are currently making up the topology **b)** Button to expand table into a separate window - useful when many topologies are involved

3. Zoom to the North East Corner of the plate (Figure 18). This is the area where we want to edit the topology to incorporate more complexity.

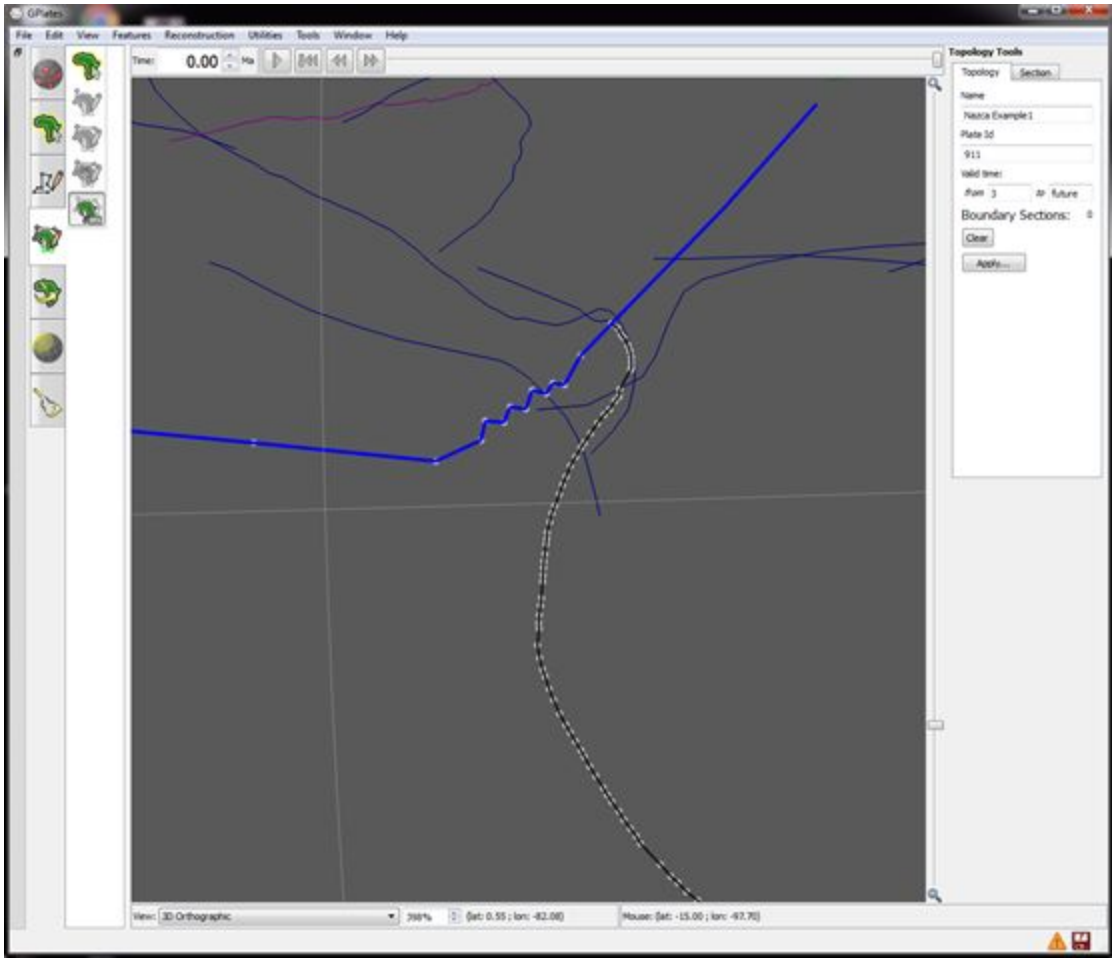


Figure 18: North east corner of Nazca plate

4. In the Topology Boundary Sections Table, select the Subduction zone (Plate ID = 201) and move it to the bottom by clicking the down arrow on the left hand side of the row. The eastern boundary should now appear blue (Figure 19). This means that the new boundary sections that we add will be added after this (and before the green boundary section).

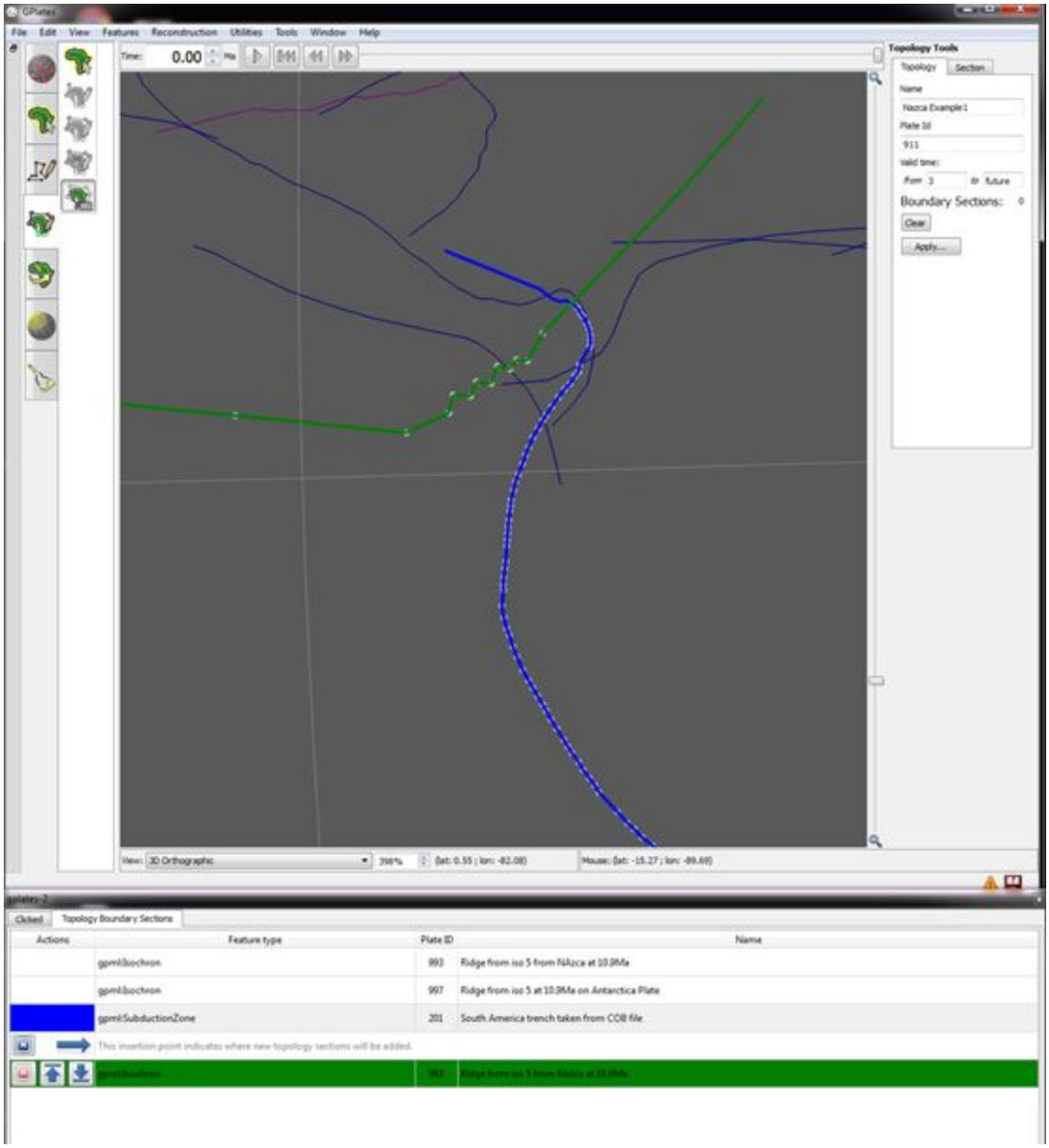


Figure 19: Plate topologies ready to add more complexity after the South American Subduction zone (blue) and before the northern ridge isochron (green).

5. Select the CAR-SAM boundary feature (Figure 20) and add it to the boundary. You should now notice that it appears blue (this means that the next boundary section we add will come after this).

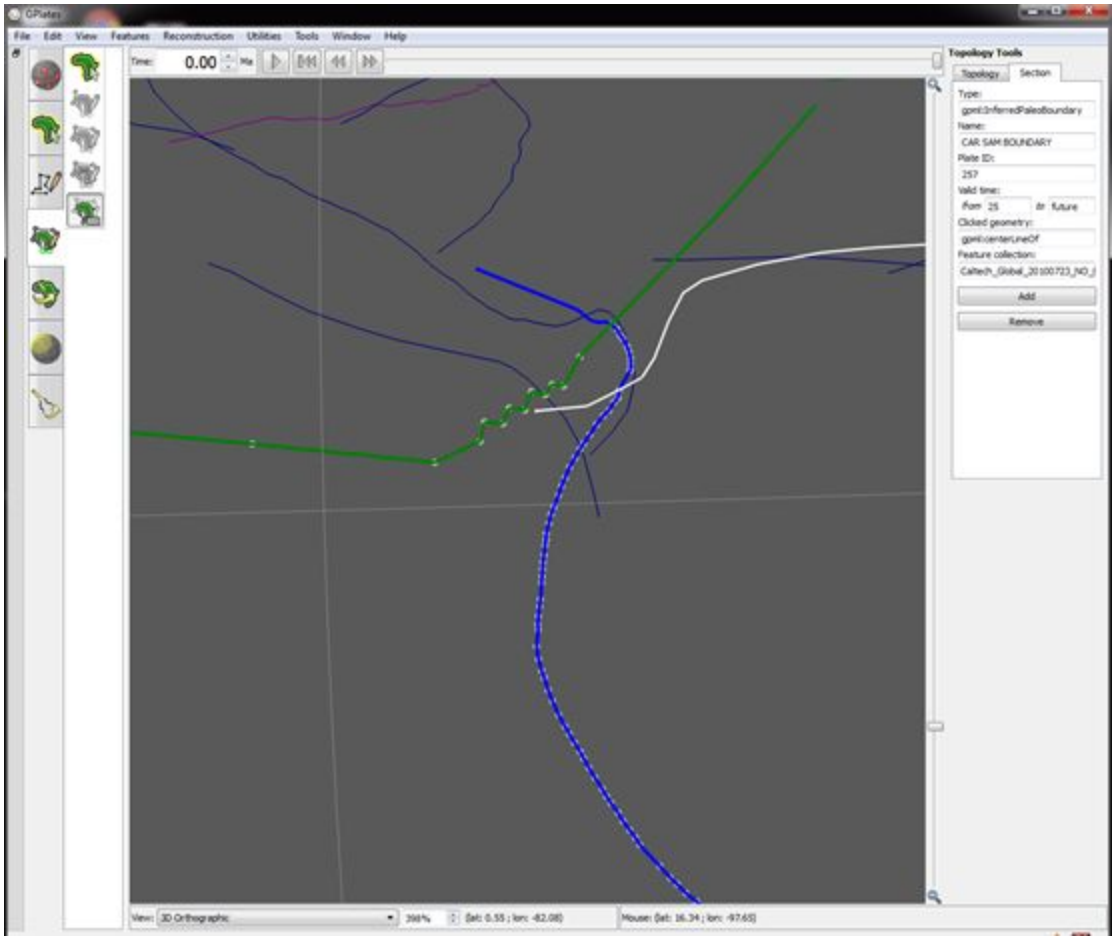


Figure 20: Editing the Nazca plate topology, CAR-SAM boundary feature highlighted before adding it to the boundary.

6. Select the CAR-Cocos Trench (Figure 21) and add it to the boundary.

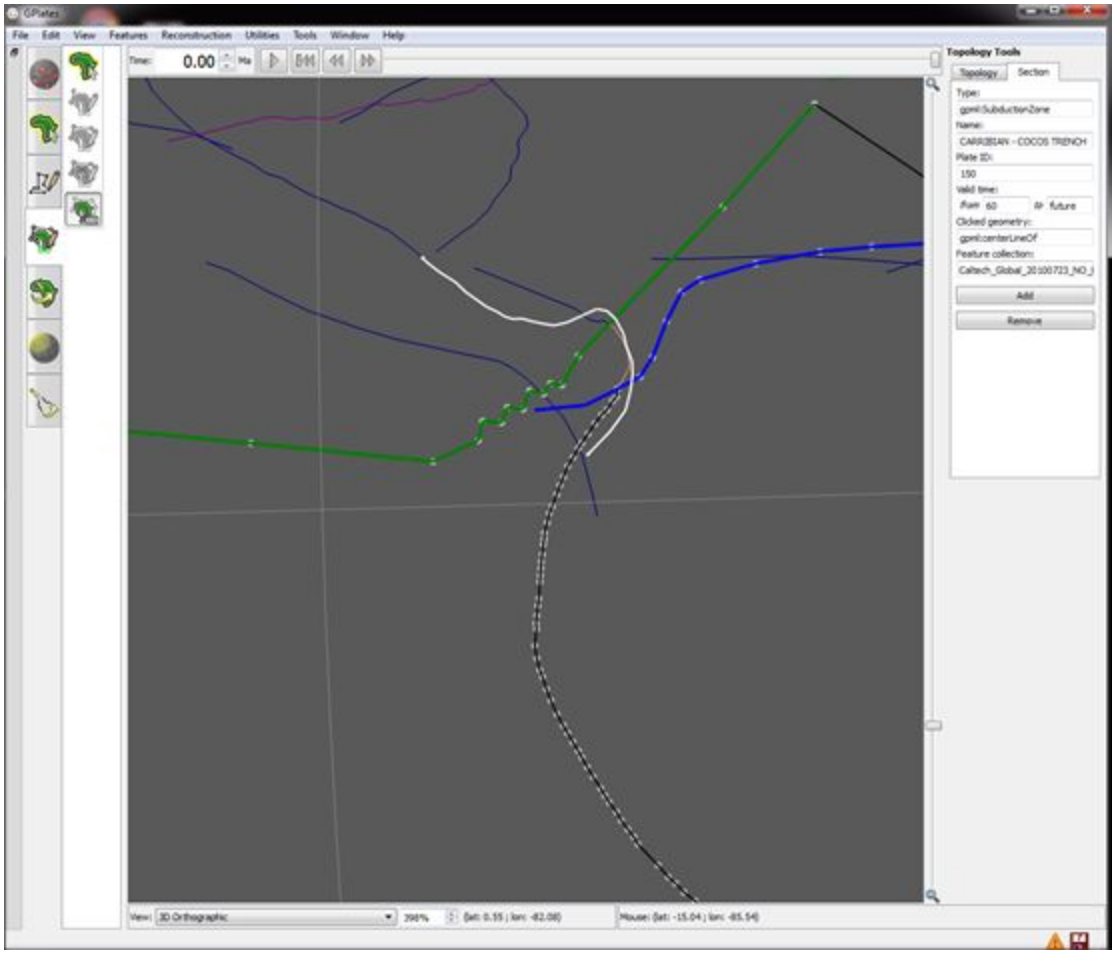


Figure 21: Editing the Nazca Plate - CAR Cocos Trench selected in white

Your final plate topology should look something like Figure 22

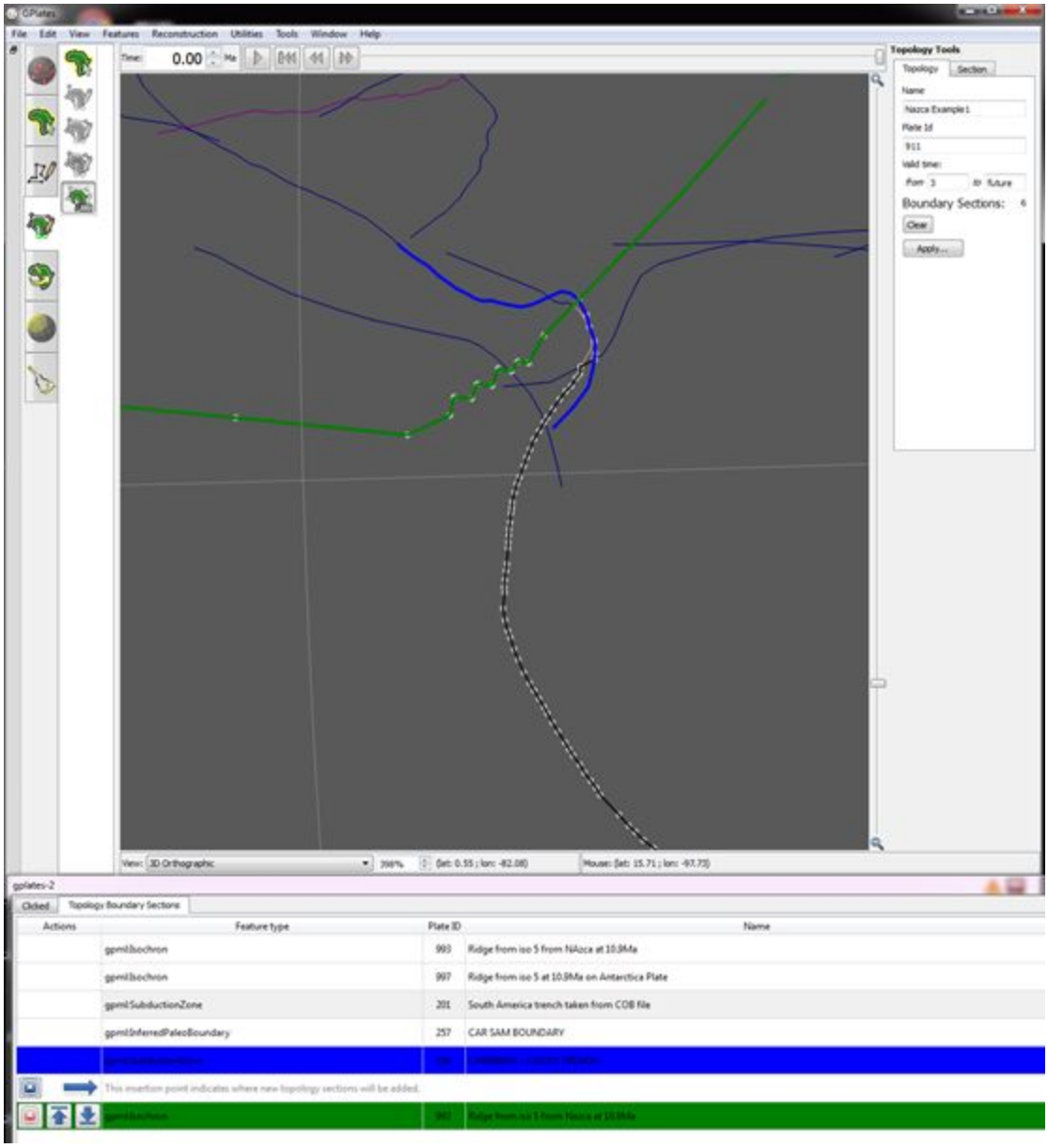


Figure 22: New boundary sections added to the topology

7. Now that we are happy with our modifications to the plate topology, click Apply… on the Topology Tools section (right hand side of the screen).

The north eastern corner of the Nazca plate should now appear slightly different and more complex to before (Figure 23).

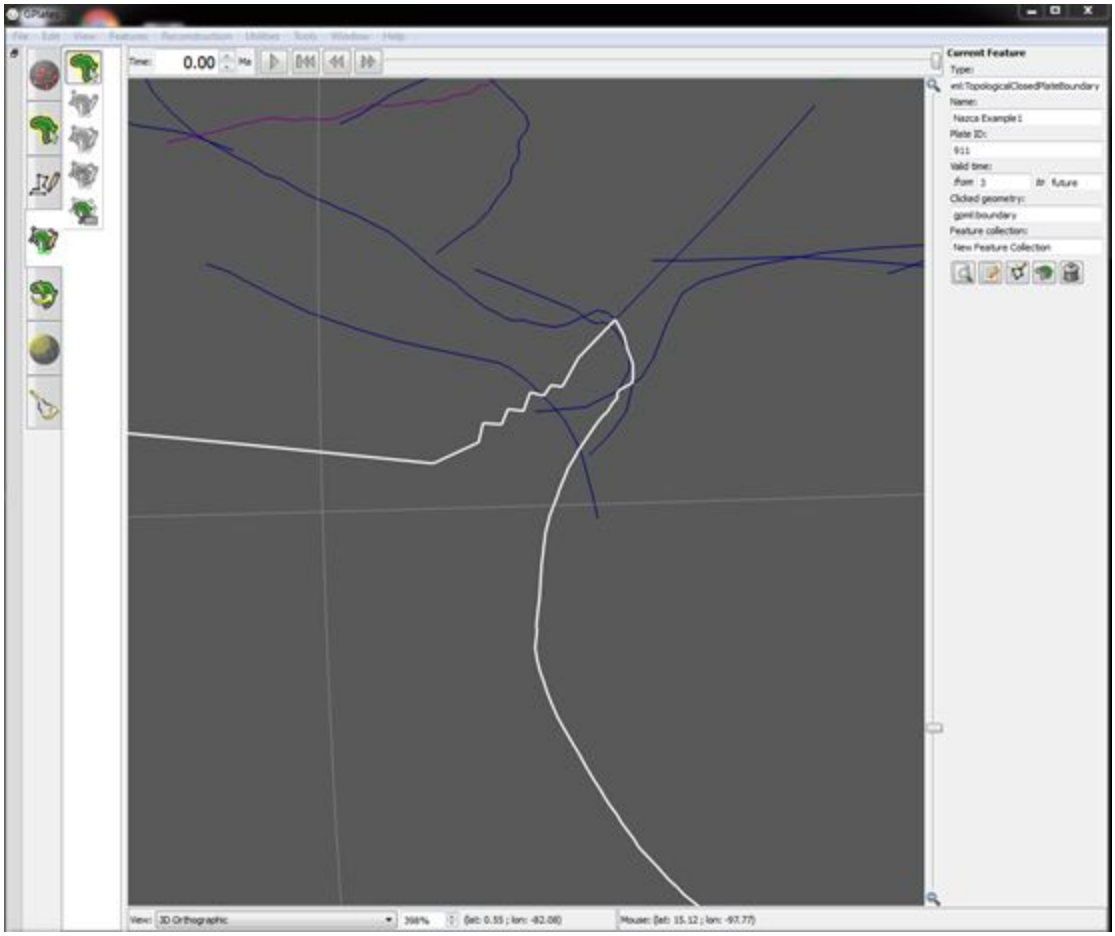


Figure 23: North eastern corner of Nazca plate more complex now that more boundaries are incorporated.

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.