

Introduction to Topologies

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Aim

This tutorial is designed to introduce the user to the concept of topologies, how to create them, how to edit them and how to manipulate mid-ocean ridge topologies.

Included files

[Click here](#) to download the data bundle for this tutorial.

The tutorial dataset (9.3-Topologies_Introduction.zip) includes the following files:

Rotation File 1: Caltech_Global_20100723.rot

Reconstructed Geometries:
Caltech_Global_20100723_NO_PLATEPOLYGONS.gpml

Coastline file: Seton_etal_ESR2012_Coastlines_2012.1_Polygon.gpmlz

Rotation file 2: Seton_etal_ESR2012_2012.1.rot

Plate polygon file: Seton_etal_ESR2012_PP_2012.1.gpmlz

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.

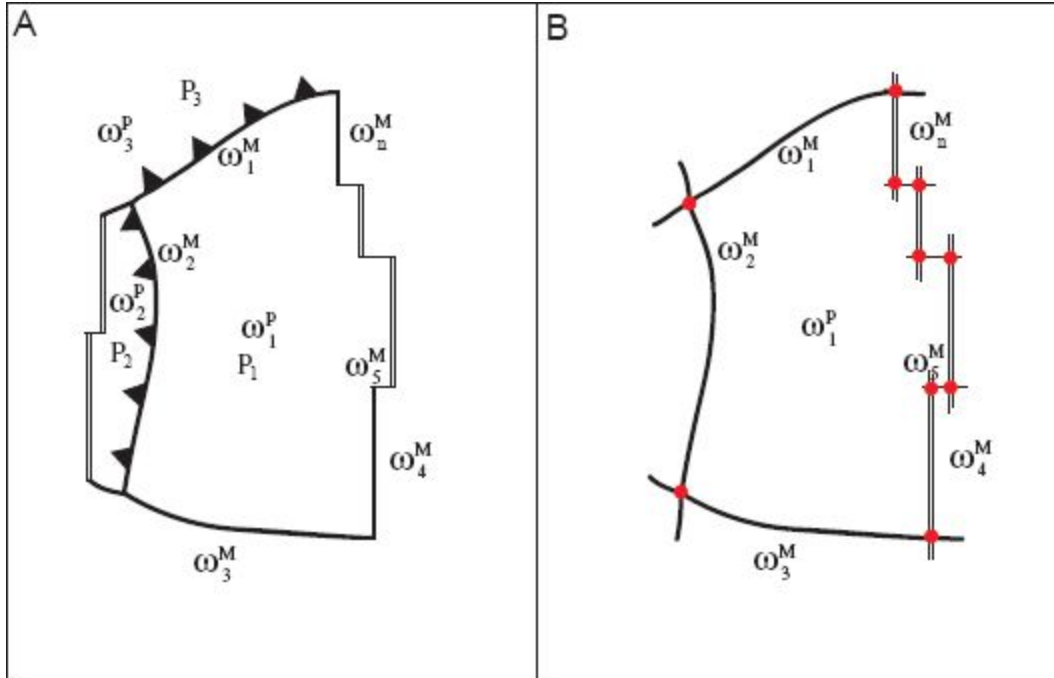


Figure 1: Schematic of the generic features that are incorporated into the Continuously Closed Plate (CCP) algorithm. Red dots represent dynamically computed intersections between plate boundaries.

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

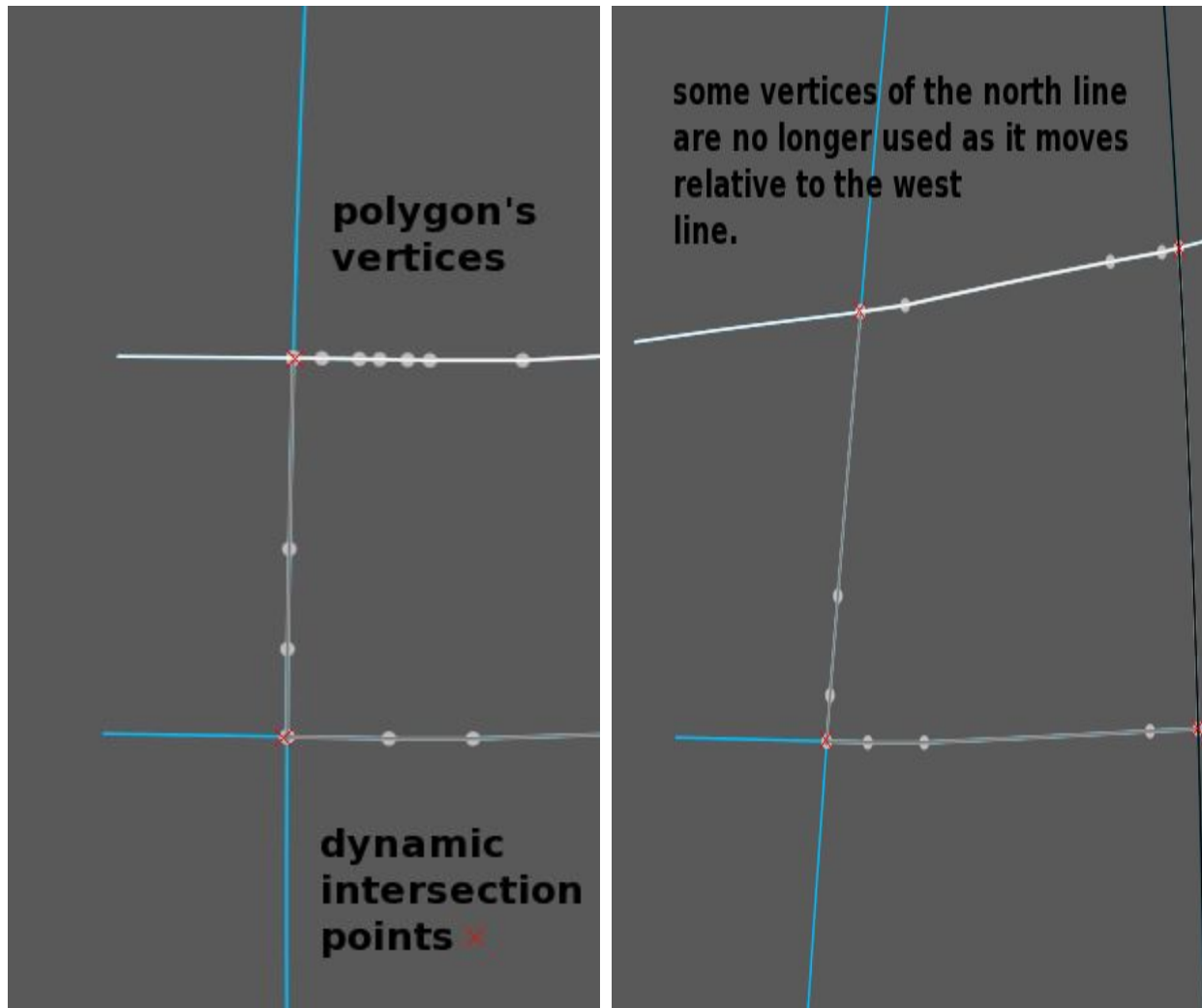


Figure 2: Hypothetical plate polygon from four intersecting lines at two times. Base features are drawn in blue. Plate polygon is outlined in grey, with grey dots showing polygon's vertices. Red crosses have been added in the figures to highlight dynamically computed intersection points, relative to 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).

For more information about the Topology Tools in GPlates, see [Tutorial 5.1](#), or the [GPlates User Manual](#).

Exercise 1 – Creating a Topological Closed Plate Polygon

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 3)

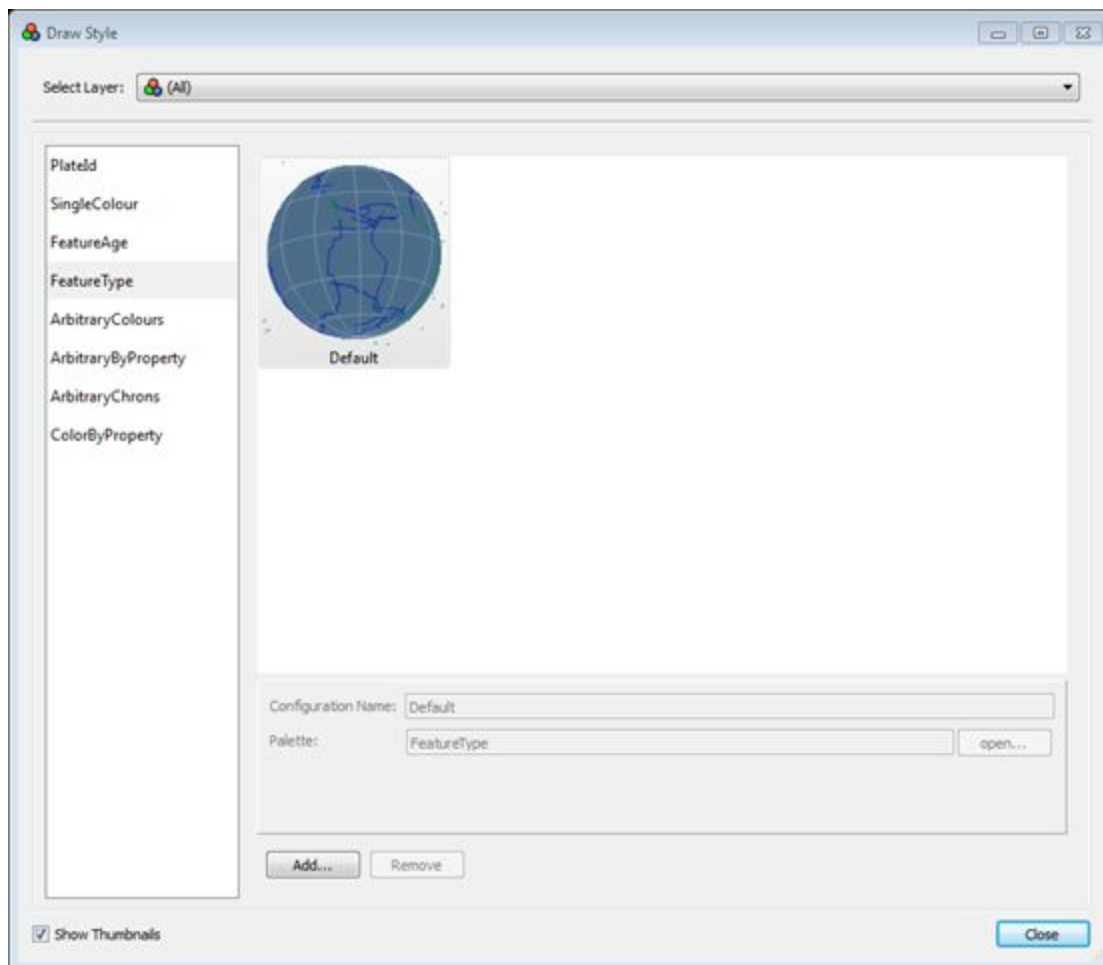


Figure 3: DrawStyle Window, selecting colour by Feature Type

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 4).

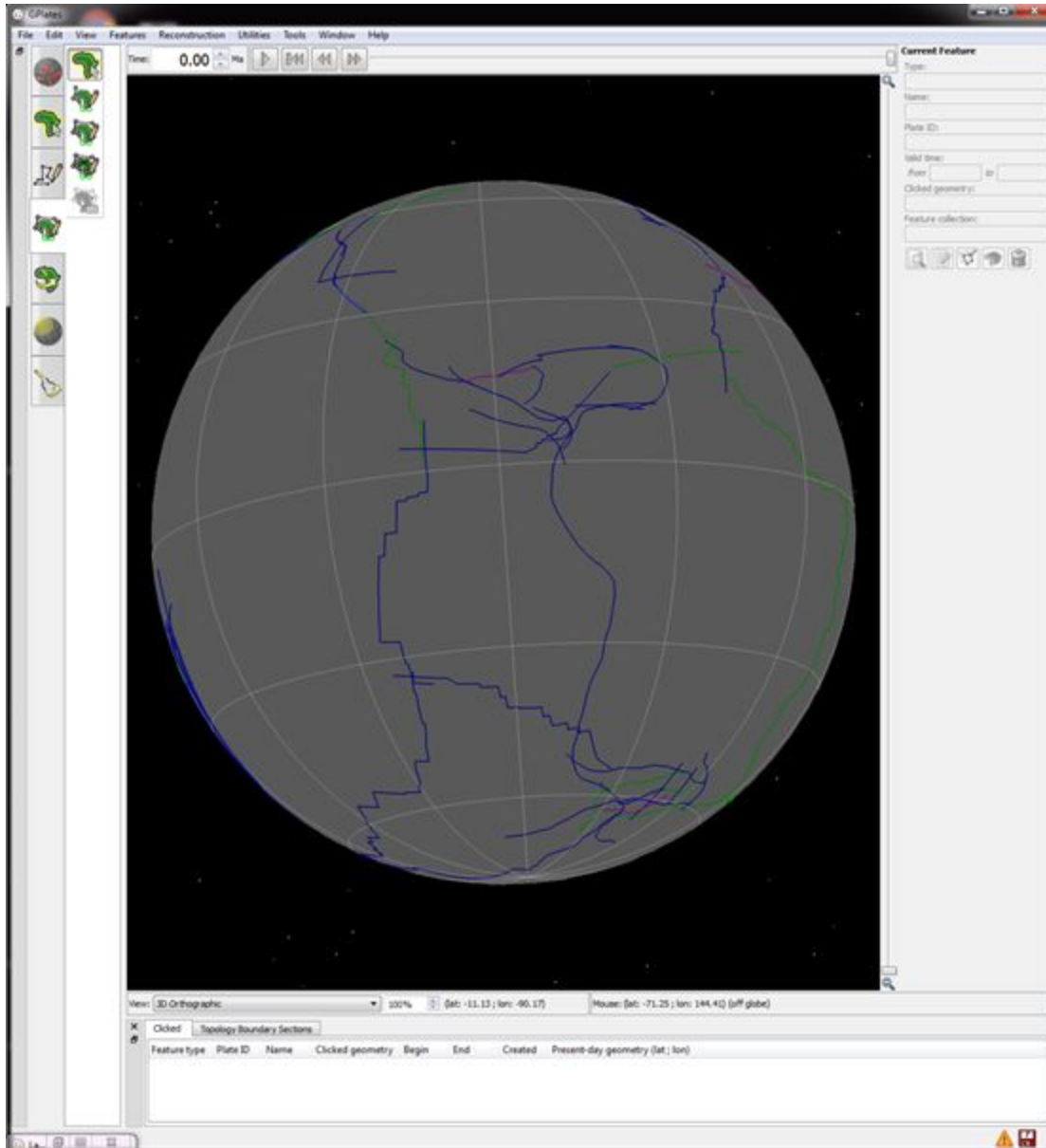




Figure 4: Globe oriented to show the Nazca Plate, features coloured by Feature Type

4. Change the reconstruction time to 3 Ma and play the animation to present day. See how the plate margins move

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)

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 5).

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.

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).

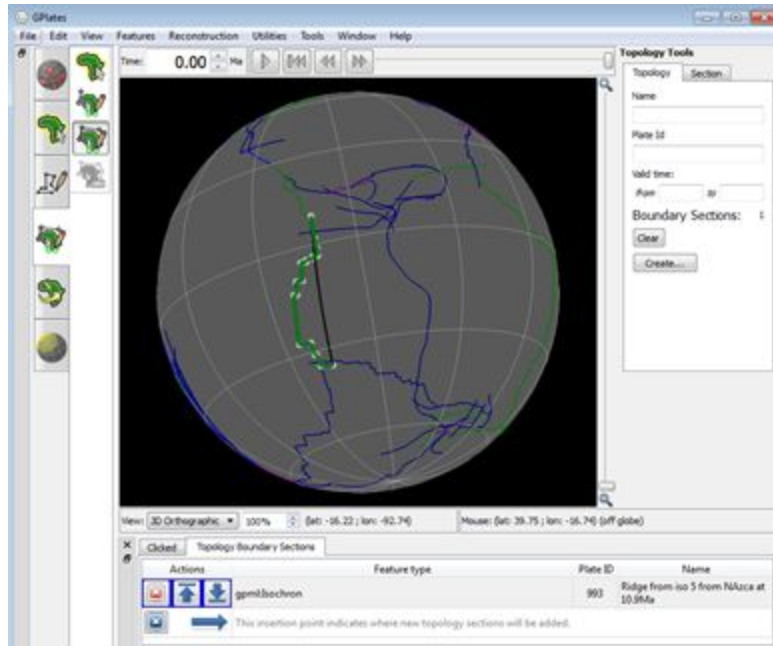


Figure 5: Adding the first section of the Nazca Plate (Step 7)

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 6).

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.

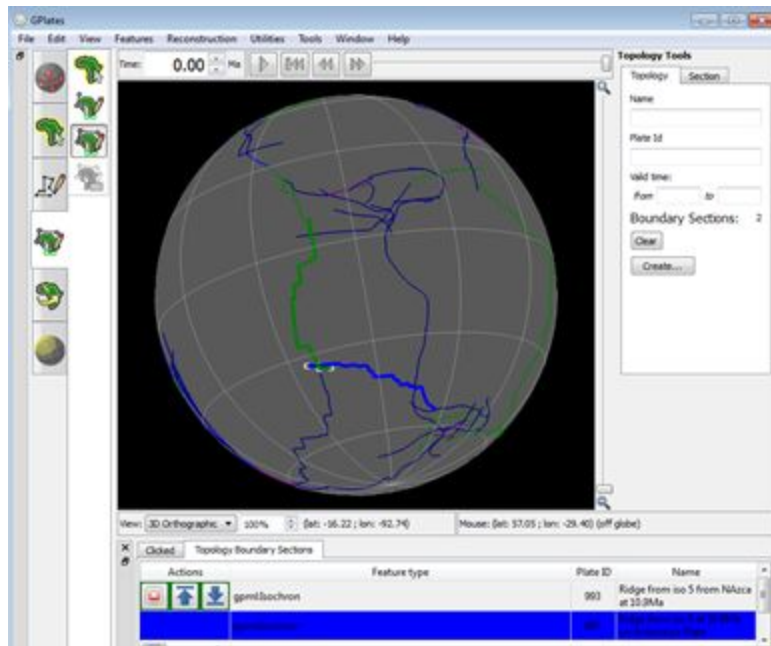


Figure 6: Build the Nazca Plate - Adding the second section results in a green and blue line being highlighted (the start and end of the topology so far); this will be corrected as more sections are added (Step 8)

9. Continue along the eastern Margin, selecting and adding the South American Trench (Figure 7).

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.

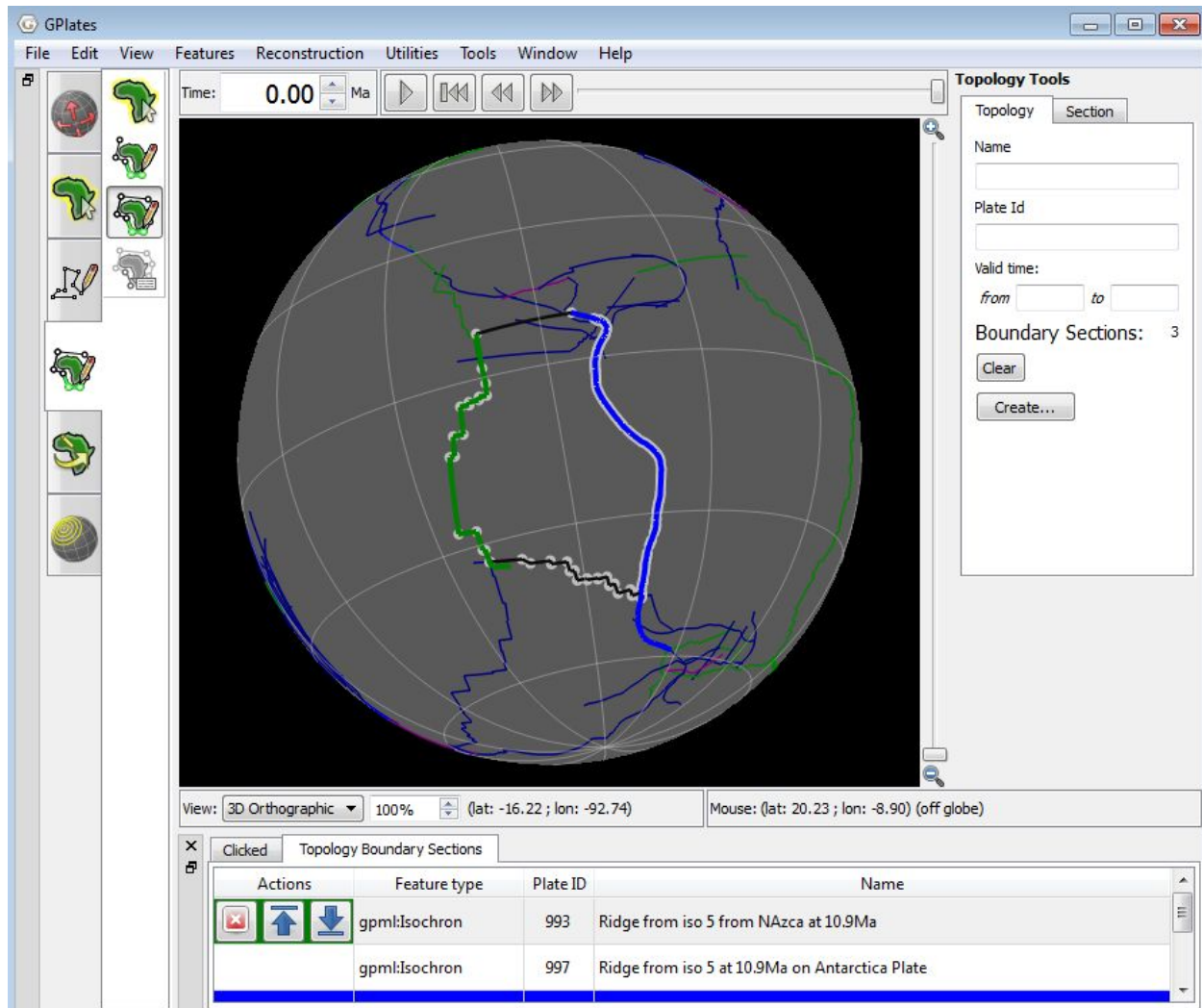


Figure 7: Build the Nazca Plate - Adding the third section results in good intersections in the south, and an automatic closing in the north (Step 9).

10. To complete the plate closure, zoom in to the northern half of the plate area (Figure 8).

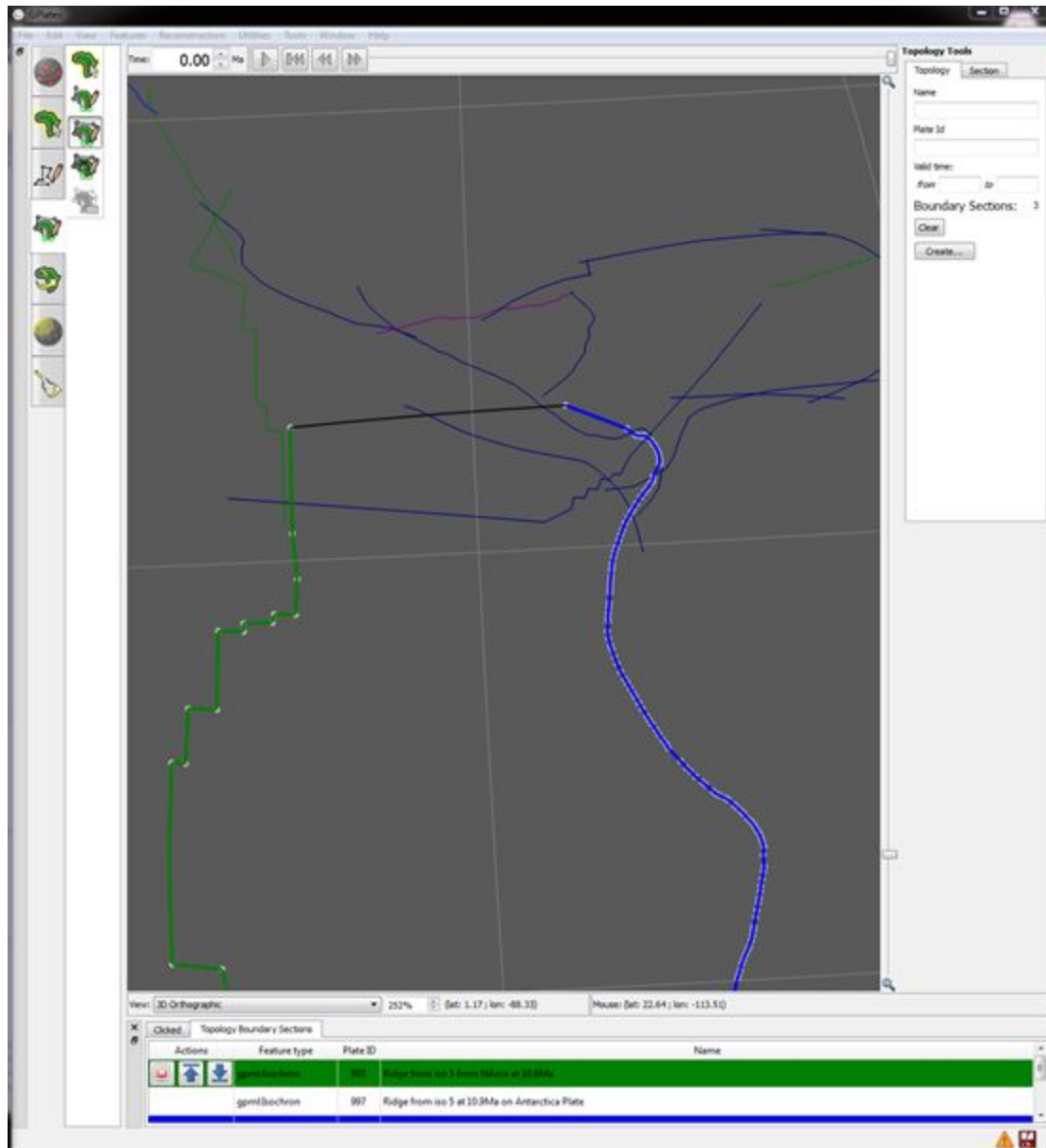


Figure 8: Build the Nazca Plate - zooming into the northern section of the Nazca Plate

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 9).

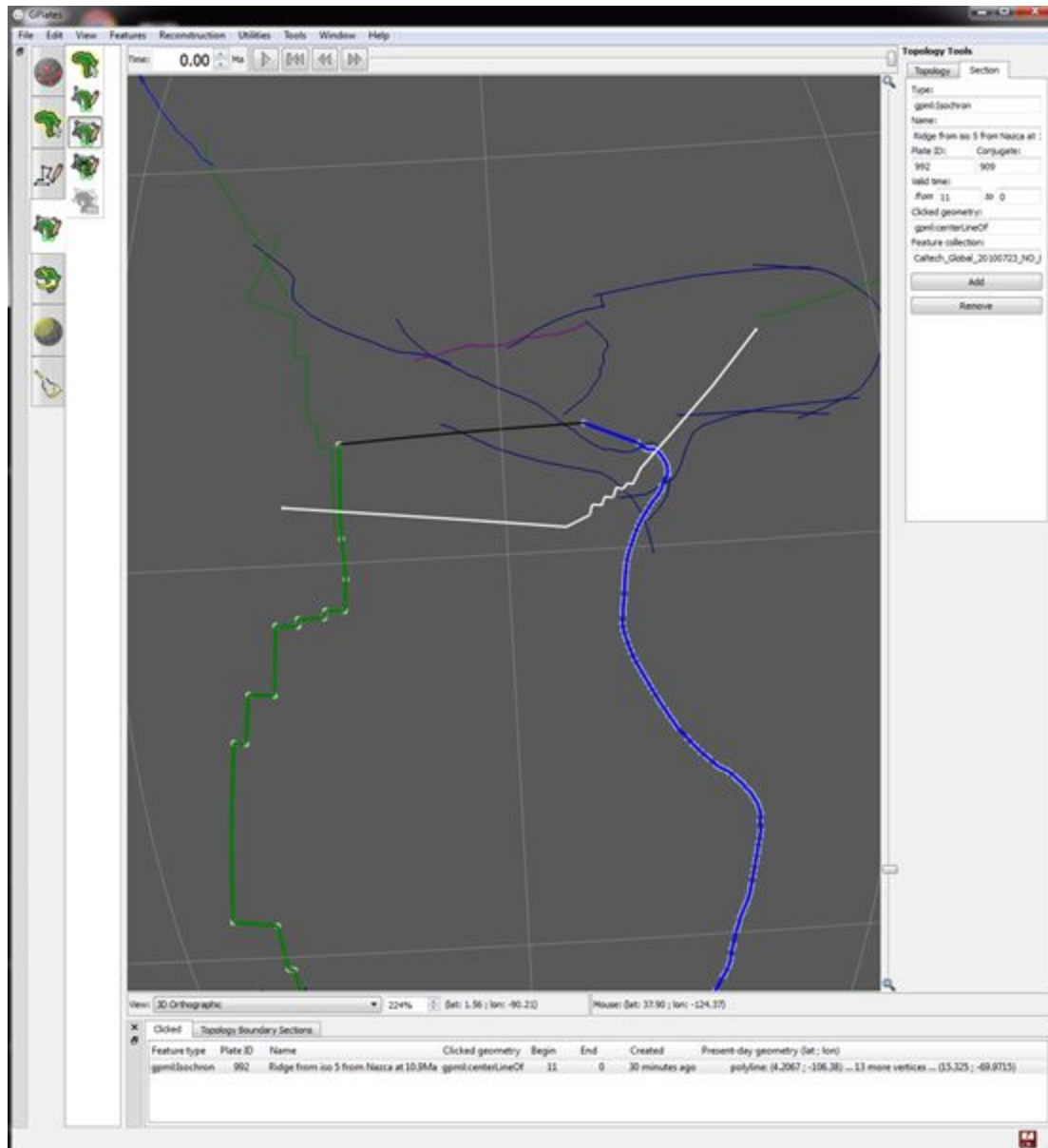


Figure 9: Northern ridge isochron section selected.

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 10).

- 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.

The screenshot shows the 'Create Feature' dialog box. The 'Geometry Property' section has a label 'Which property best indicates the geometry's purpose?' and a list box containing 'Boundary'. The 'Common Properties' section includes a 'Reconstruction Method' dropdown set to 'By Plate ID', a 'Plate ID' text box with '911', 'Begin (time of appearance)' and 'End (time of disappearance)' spinners set to '3.00 Ma' and '0.00 Ma' respectively, with checkboxes for 'Distant Past' and 'Distant Future', and a 'Name' text box with 'Nazca Example'. Navigation buttons at the bottom include 'Previous', 'Next', 'Create and Save', 'Create', and 'Cancel'.

Figure 10: 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.

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 11).

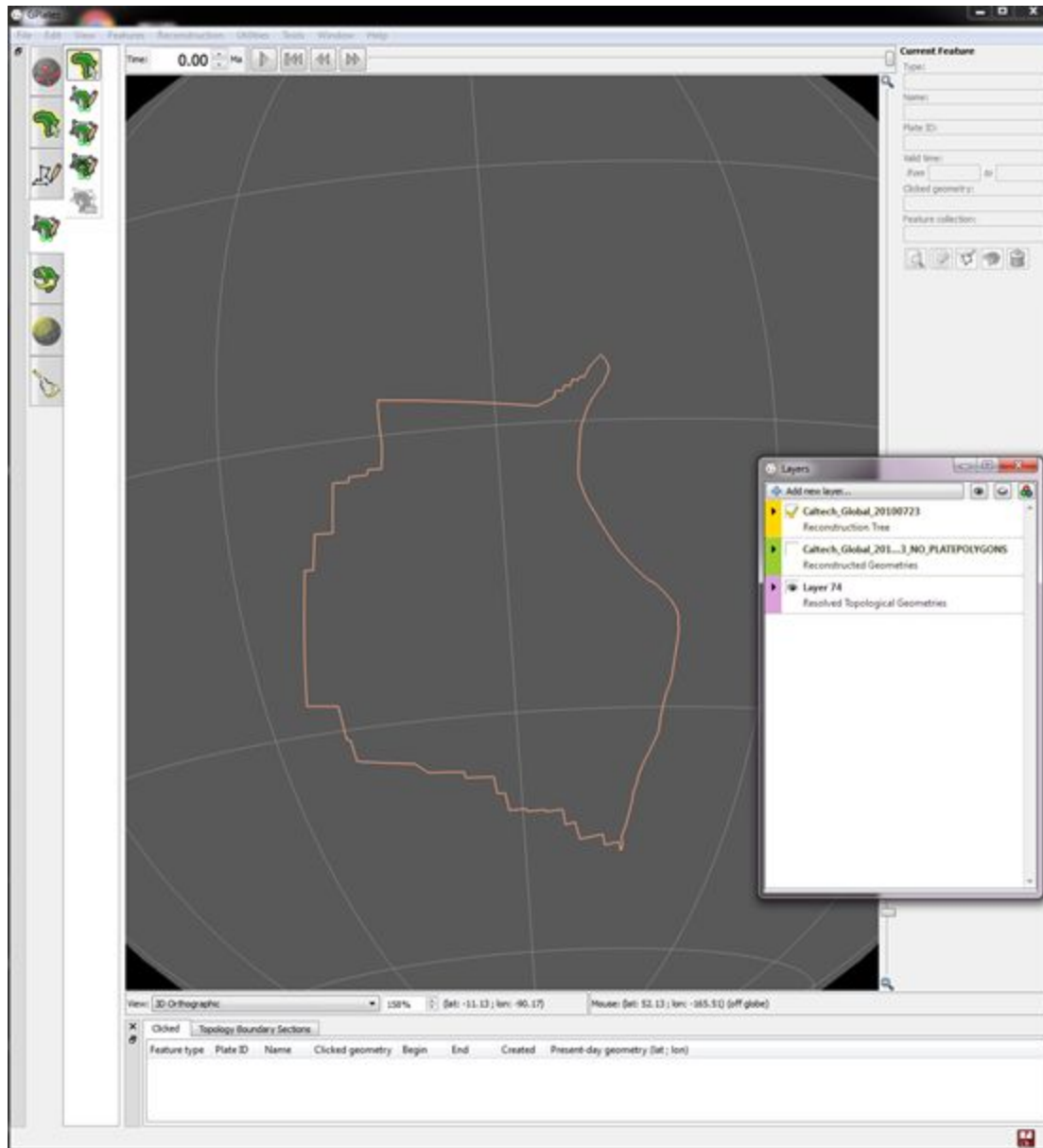


Figure 11: Nazca plate topology visible

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 12). Note that we can see our new topology as well as the spreading ridges and other reconstructed geometries.

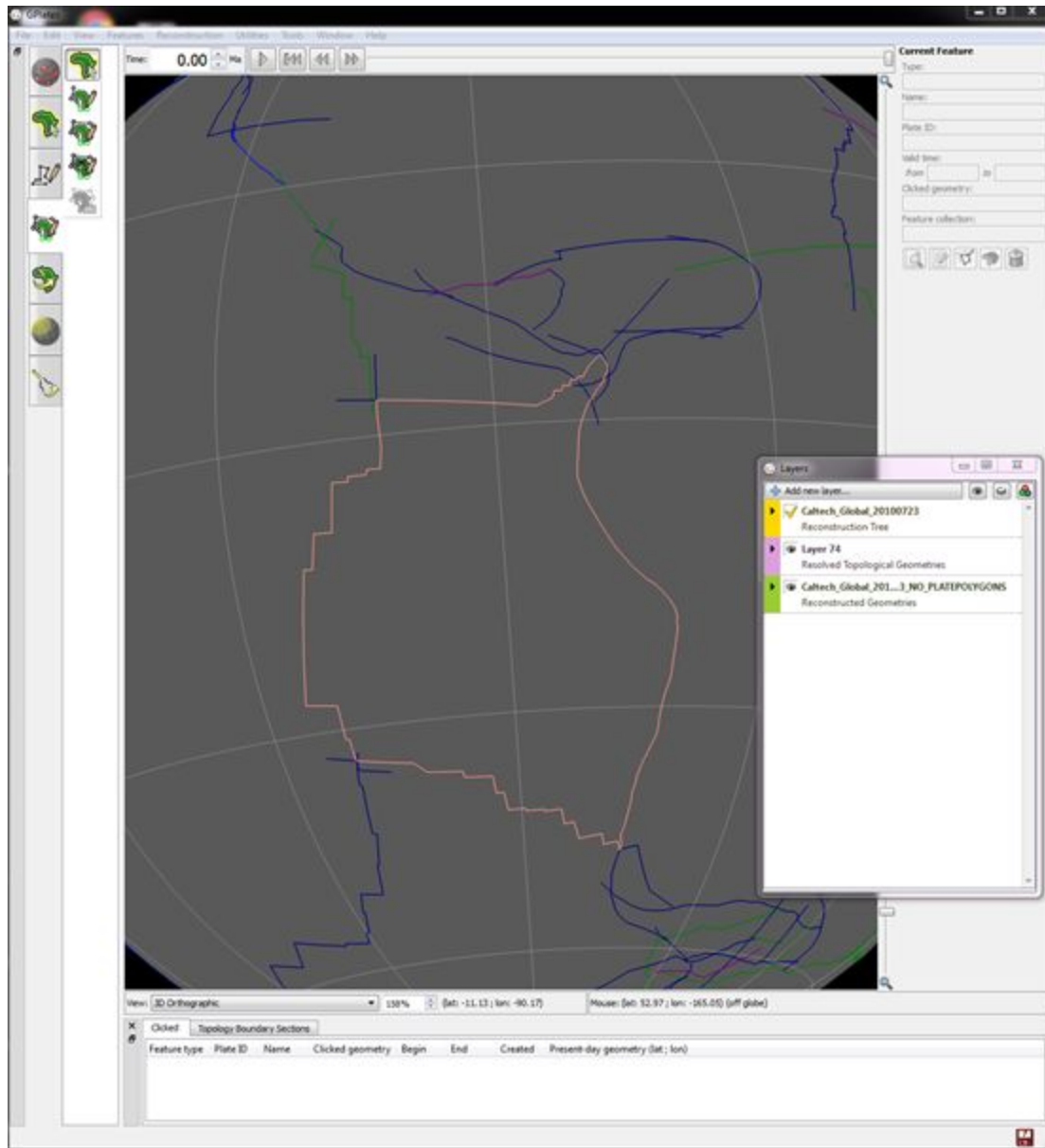



Figure 12: Nazca plate topology on top of existing geometries

For more information about creating new topologies, see [Tutorial 5.1](#), or the [GPlates User Manual](#).

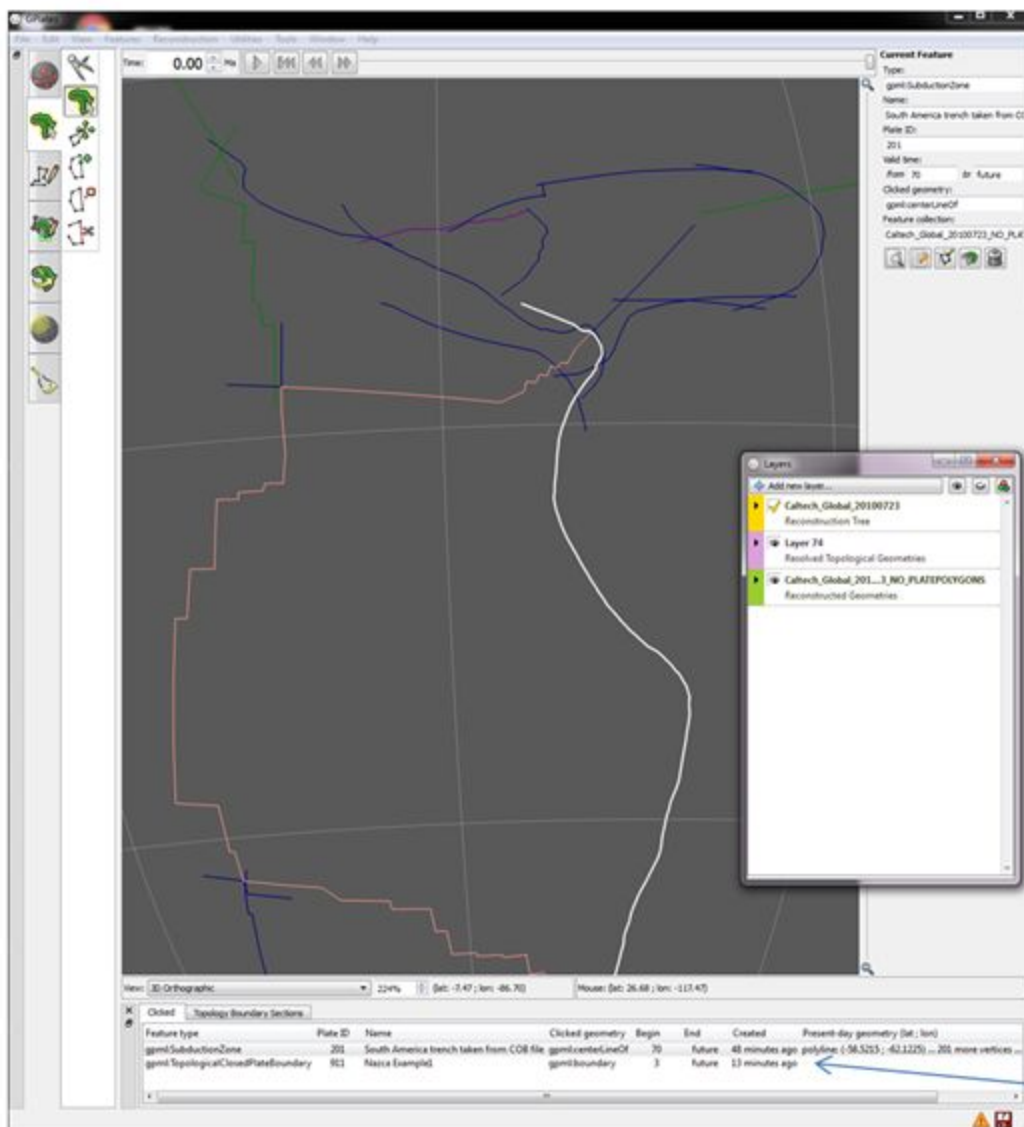
Exercise 2 – Editing an Existing Topology

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 13b). 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 13a). You can select the feature you want to highlight in this table.



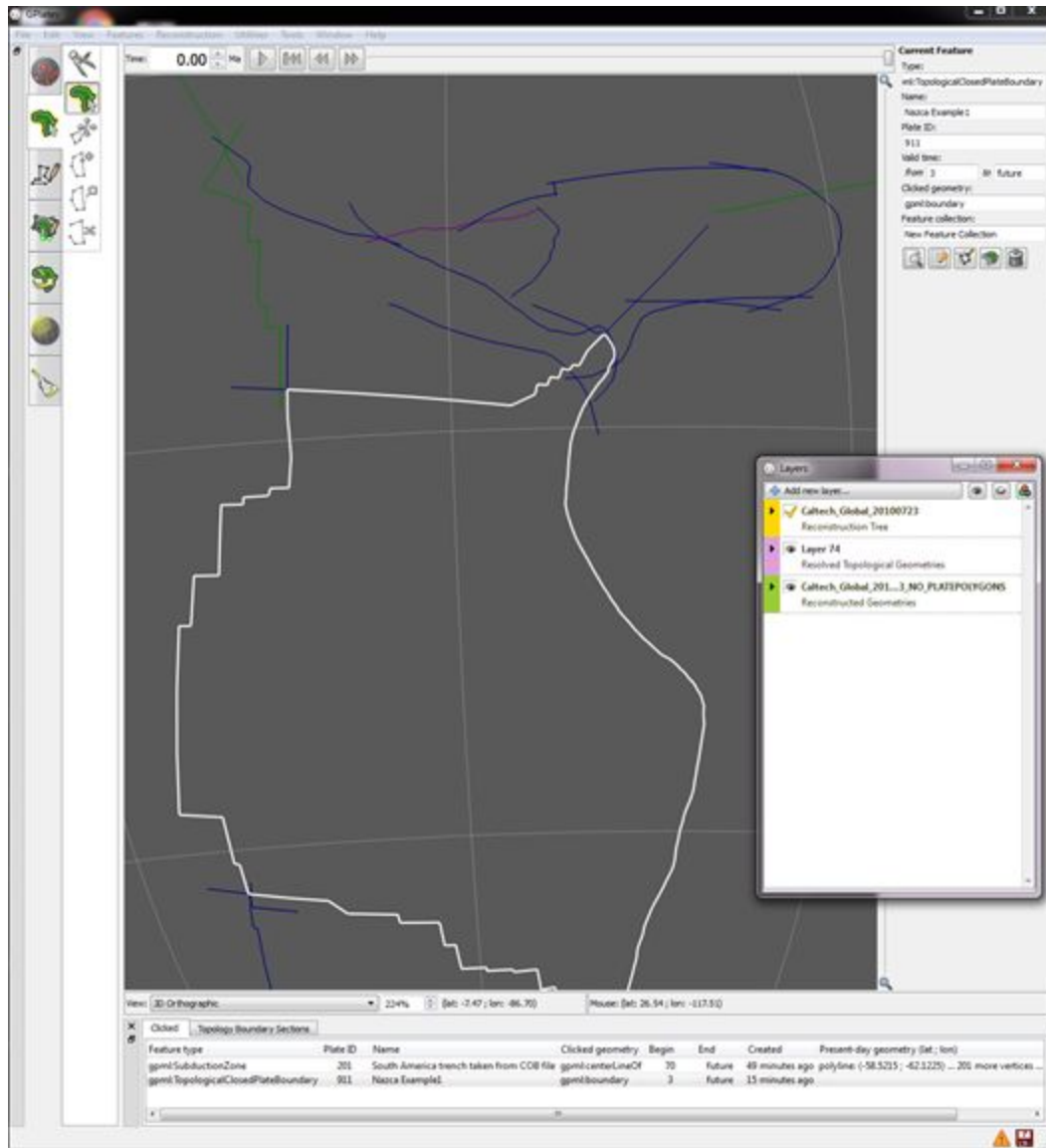


Figure 13: a) Topology selected showing two features sitting on top of each other in the Topology Sections Table **b)** Nazca plate topology selected

2. Click on the Edit Topology Tool button (Figure 14).

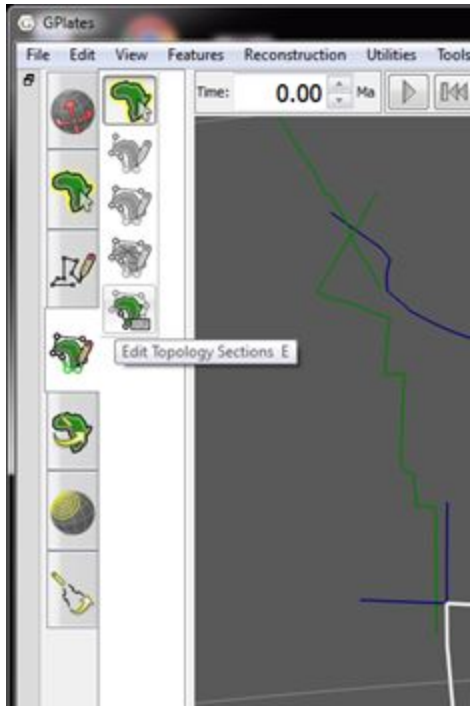


Figure 14: Edit Topology Sections

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 15).

gplates-2

Clicked: Topology Boundary Sections

Actions	Feature type	Plate ID	Name
gpmIsochron		990	Ridge from iso 5 from Nazca at 10.9Ma
gpmIsochron		997	Ridge from iso 5 at 10.9Ma on Antarctica Plate
gpmSubductionZone		201	South America trench taken from COB file
gpmSubductionZone		990	Ridge from iso 5 from Nazca at 10.9Ma

➡ This insertion point indicates where new topology sections will be added.

A)

B)



Figure 15: 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 16). This is the area where we want to edit the topology to incorporate more complexity.

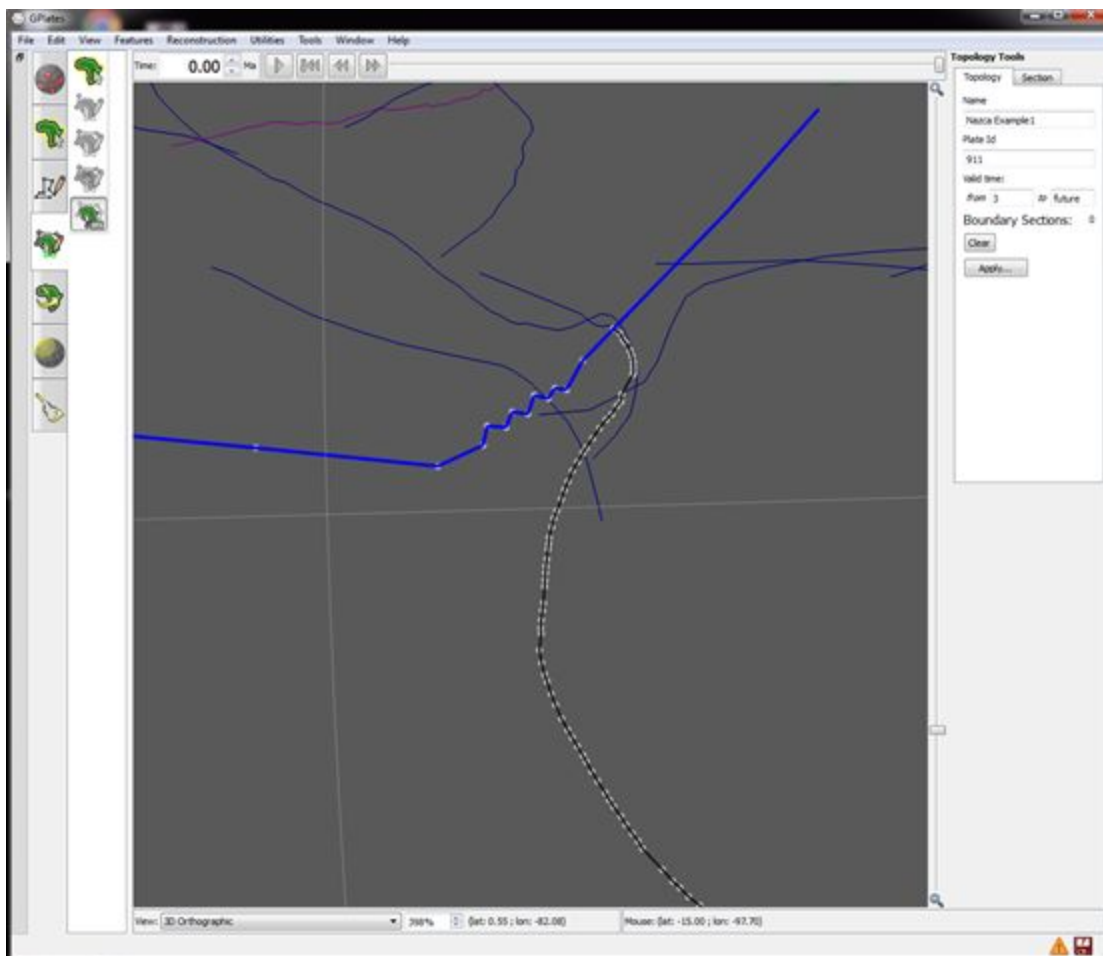


Figure 16: North east corner of Nazca plate

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 17). This means that the new boundary sections that we add will be added after this (and before the green boundary section).

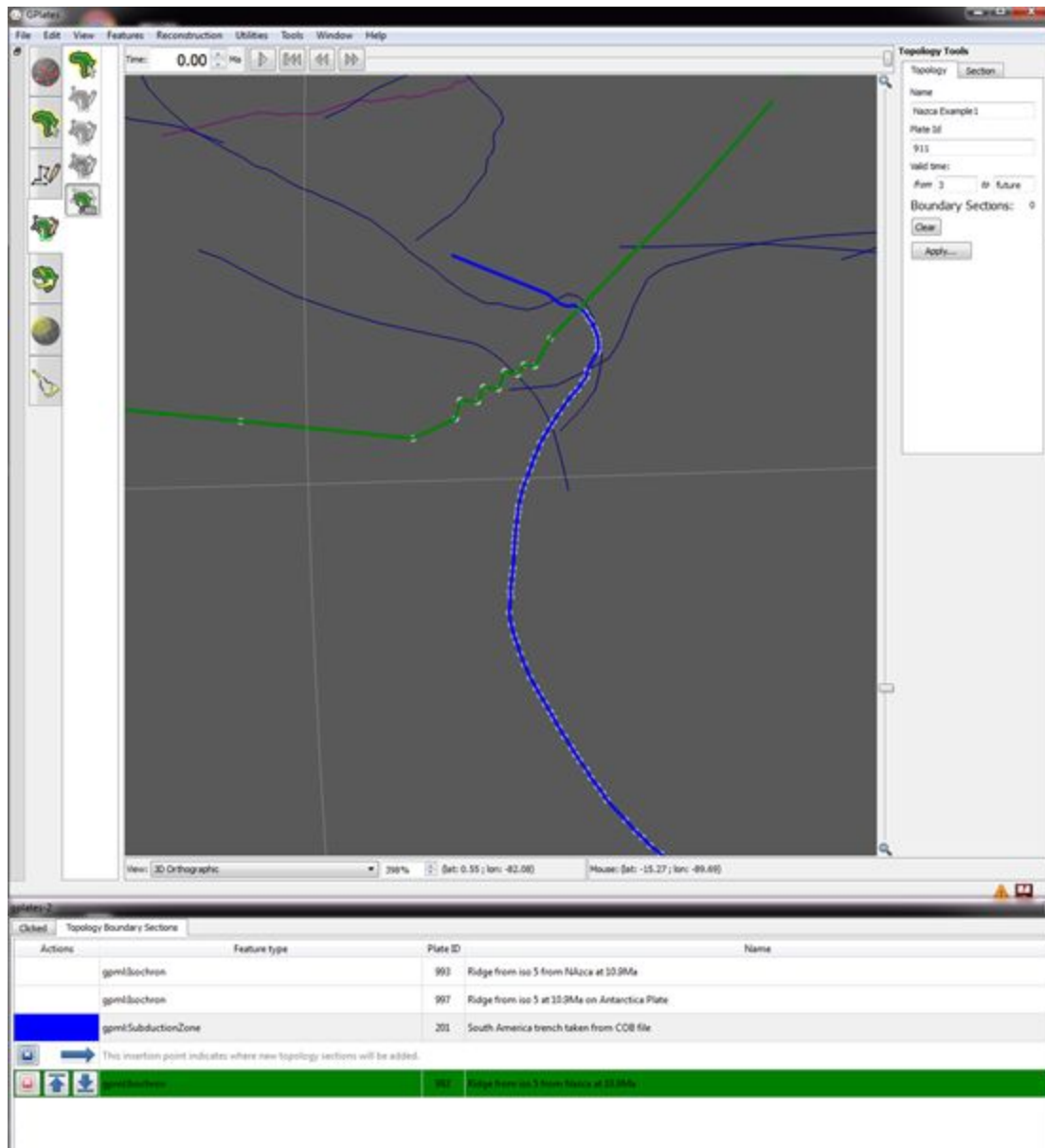


Figure 17: Plate topologies ready to add more complexity after the South American Subduction zone (blue) and before the northern ridge isochron (green).

5. Select the CAR-SAM boundary feature (Figure 18) 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).

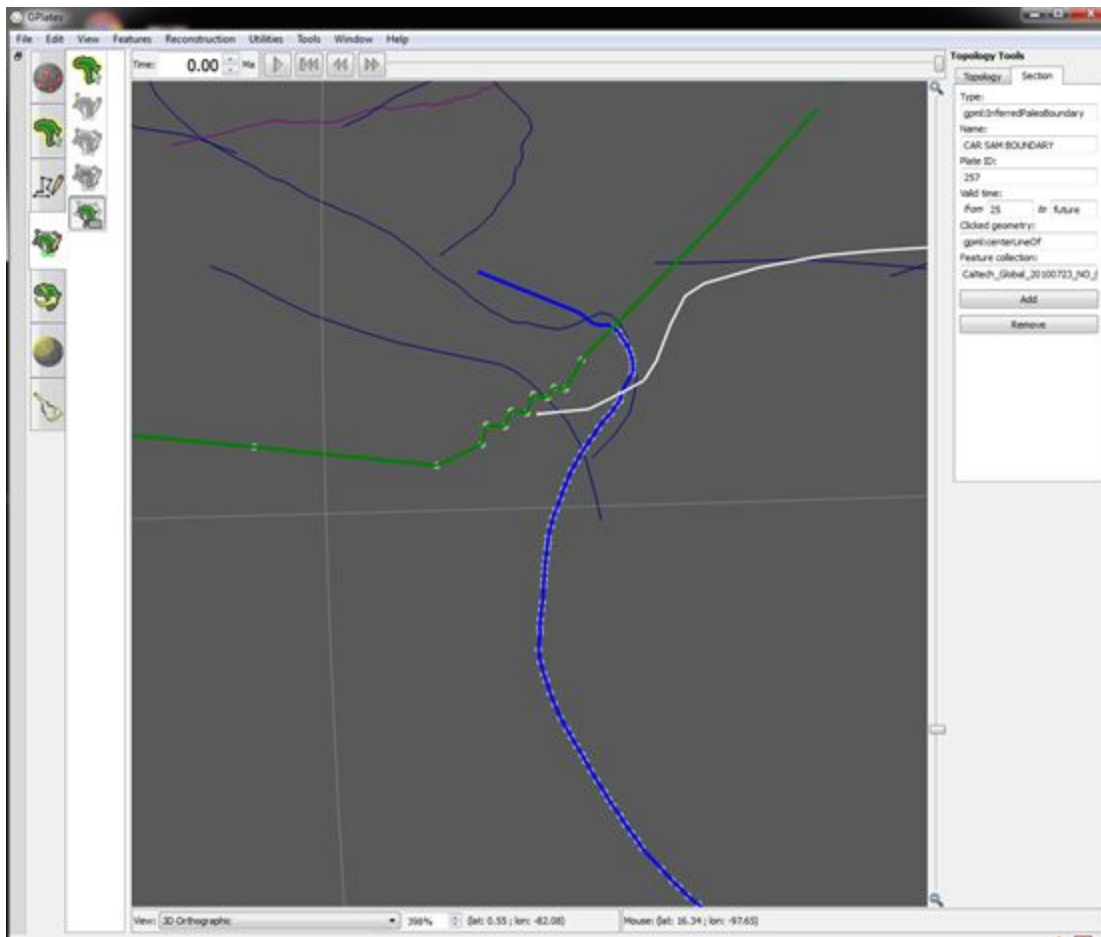


Figure 18: Editing the Nazca plate topology, CAR-SAM boundary feature highlighted before adding it to the boundary.

6. Select the CAR-Cocos Trench (Figure 19) and add it to the boundary.

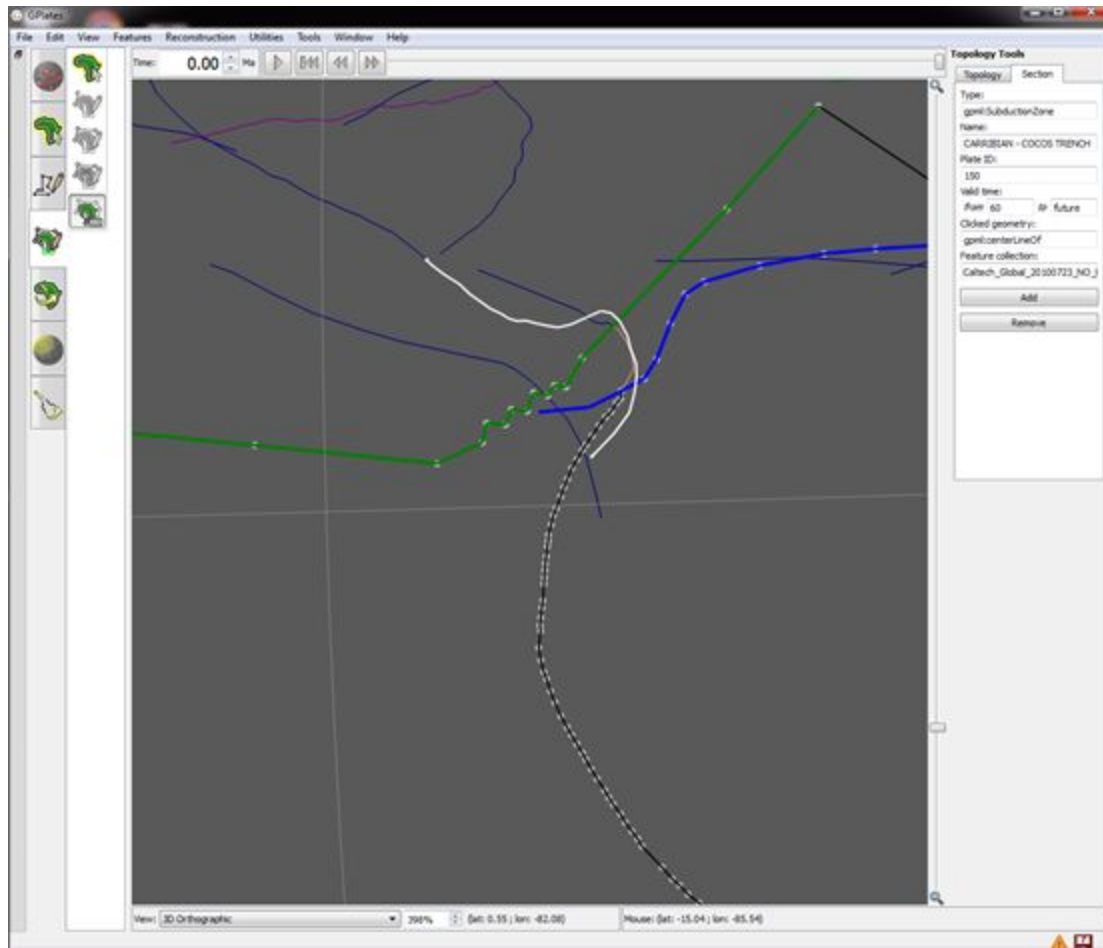


Figure 19: Editing the Nazca Plate - CAR Cocos Trench selected in white

Your final plate topology should look something like Figure 20.

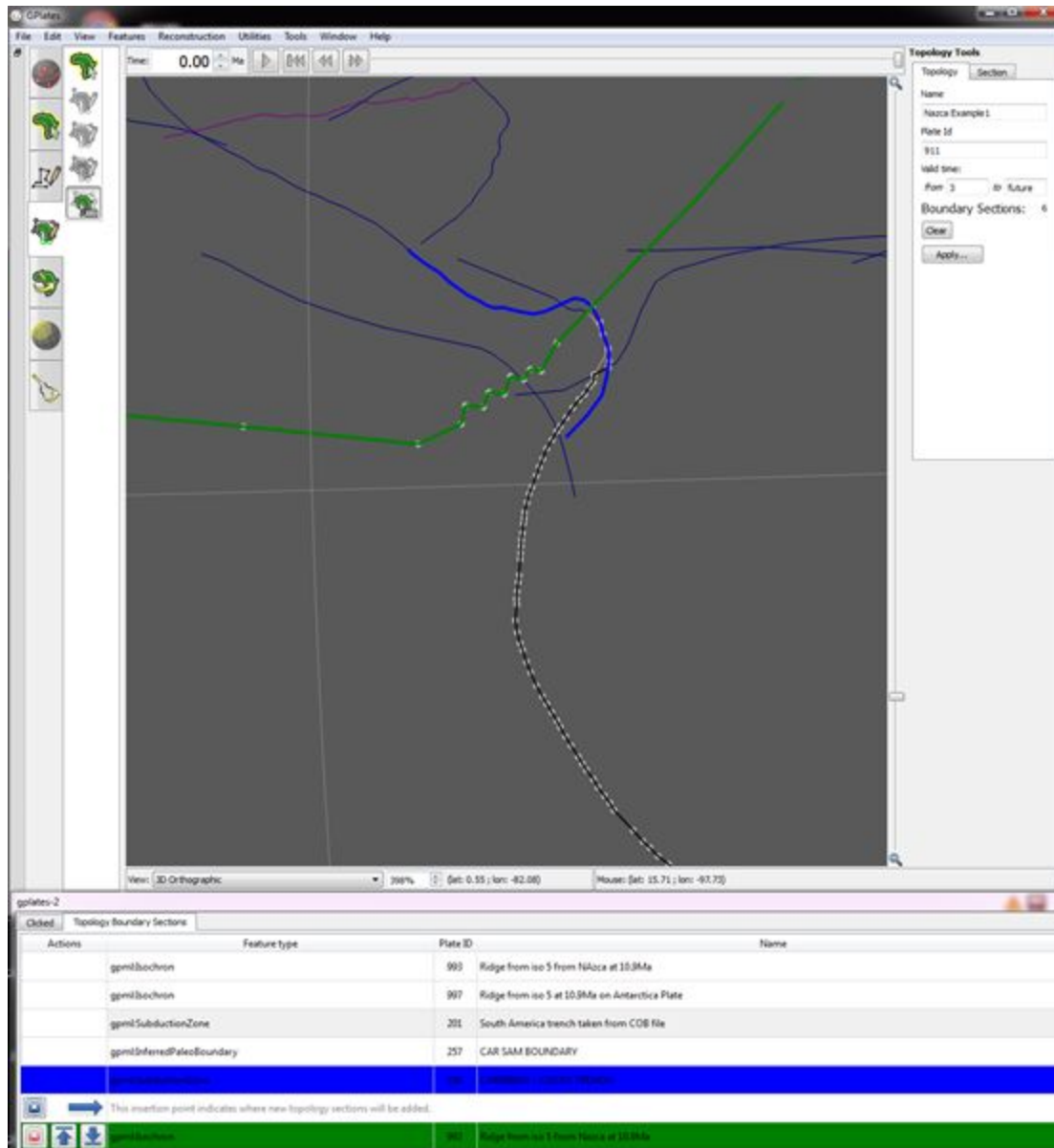


Figure 20: New boundary sections added to the topology

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 21).

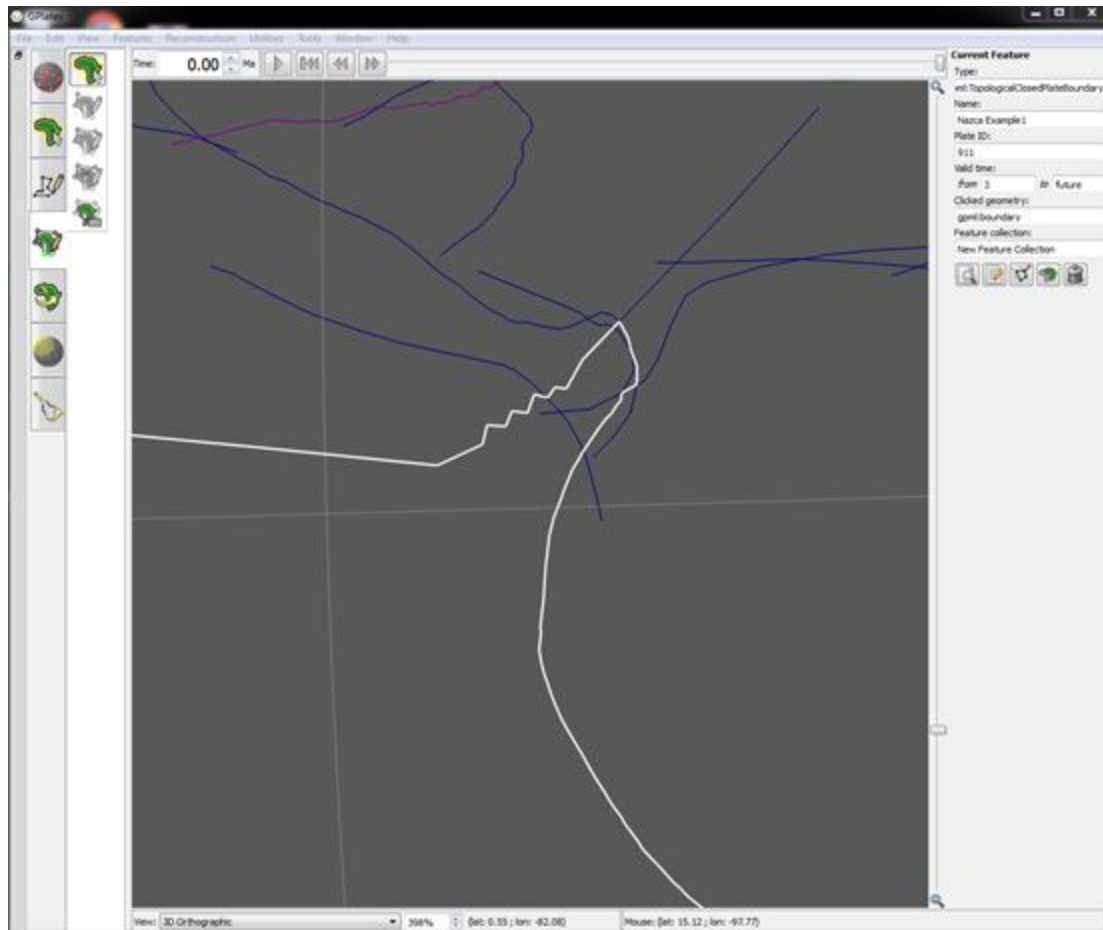


Figure 21: North eastern corner of Nazca plate more complex now that more boundaries are incorporated.

Don't forget to save your new layer if you need the changes you made! (File > Manage Feature Collections...)

For more information about editing existing topologies, see [Tutorial 5.1](#), or the [GPlates User Manual](#).

Exercise 3 – Incorporating a new MOR into an existing plate polygon dataset

We will now interactively construct a MOR feature with the intention of replacing an existing MOR. This requires the user to ensure the new MOR geometry intersects with pre-existing plate boundaries so that it can replace an old MOR. The user then has to delete the old MOR, and manually edit existing topologies to insert the new plate boundary. When deleting a MOR, the user must fix at least two polygons at any one time. That is because the old MOR formed the mutual boundary between two polygons.

Users must also take care to correct any other polygon artefacts they may have introduced by deleting the old redundant MOR. GPlates does not automatically detect polygon artefacts, so a careful interactive reconstruction in GPlates through time is required to ensure polygon closure without gaps, overlaps or “rubber-banding” artefacts.

For this example, we will create a new MOR in the Atlantic Ocean adjacent to the existing South America-Africa MOR, which exists between 60 and 20 Ma.

1. If you are coming from Exercise 1 or 2, File > Clear Session (if beginning at this Exercise, open GPlates and go to Step 2)

2. File > Open Feature Collection... > Open the following files from the tutorial data bundle:

Coastlines: Seton_etal_ESR2012_Coastlines_2012.1.gpmlz

Plate Polygons: Seton_etal_ESR2012_PP_2012.1.gpmlz

Rotation File: Seton_etal_ESR2012_2012.1.rot

3. Change the colour of the Plate Polygon Layer ONLY to colour by single colour - black (Features > Manage Colouring)

4. In the Layers window (Window > Show Layers...), drag the pink reconstructed geometries layer to the top (Figure 22).

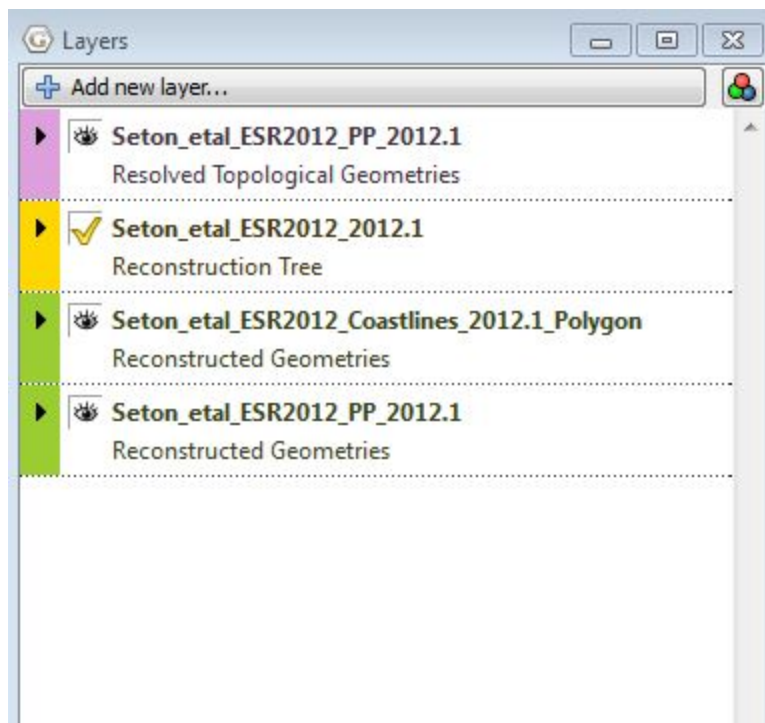


Figure 22: Layers window showing the pink (resolved topological geometries) at the top.

5. Reconstruct to 60 Ma and focus on the black MOR between at the junction of the South American (SAM) Plate and the African Plate (Figure 23). Note that the navy blue MOR which runs almost parallel to the black MOR is actually the isochron, and is not involved in the plate boundaries of the SAM Plate and the African Plate.

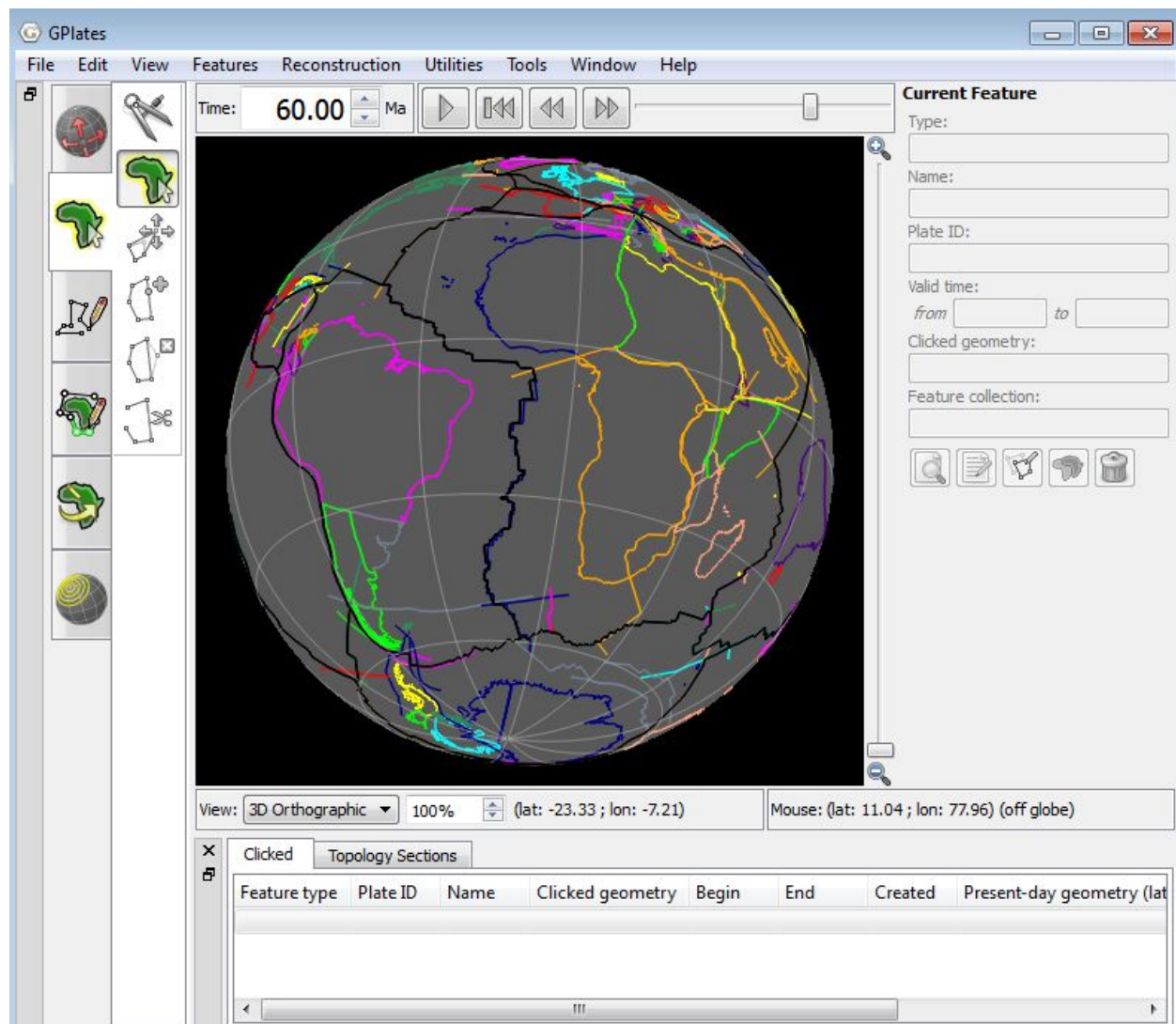


Figure 23: The Atlantic Ocean, Africa and South America reconstructed at 60 Ma, centred on the South America-Africa MOR.

6. Under the 'Digitisation' icon on the left, select 'Digitise new polyline geometry'.

7. Plot a series of points which span the length of the existing South

America-Africa MOR (Figure 24). Note that your new MOR geometry must intersect the pre-existing plate boundaries of the two conjugate plates (SAM and Africa). Again if you plot an incorrect point, use the keyboard command Ctrl-Z to undo the action. The Appendix will detail how to extend a new MOR to intersect with existing boundaries if it doesn't already.

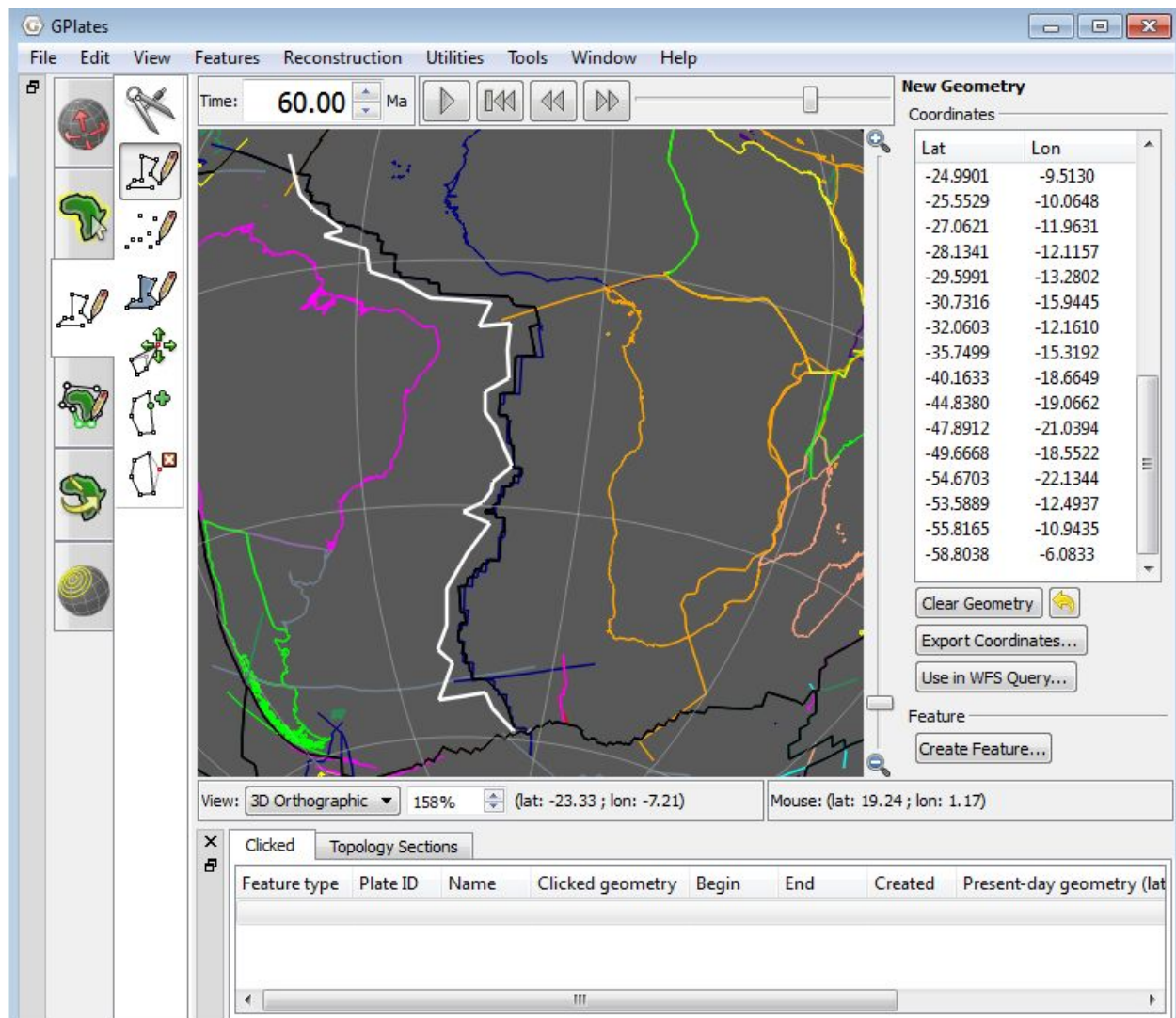


Figure 24: Digitise the new MOR to intersect the plate boundaries of the SAM and African plate.

5. Click 'Create Feature' to open up the Create Feature window. Select 'gpm1:MidOceanRidge' as the feature type and specify all properties as before (i.e. Left and Right plate IDs of 201 and 701 respectively, the Begin and End time to 60 and 20 Ma respectively, and a new filename) and click Next (Figure 25).

Create Feature

Geometry Property

Which property best indicates the geometry's purpose?

- Centre line
- Outline
- Unclassified / miscellaneous

Common Properties

Reconstruction Method: Half Stage Rotation

Left Plate ID: 201 Right Plate ID: 701

Begin (time of appearance): 60.00 Ma ☐ Distant Past

End (time of disappearance): 20.00 Ma ☐ Distant Future

Name: Atlantic_MOR_1

☐ Create conjugate feature

Previous Next Create and Save Create Cancel

Figure 25: Specify all the properties of the new MOR feature in the 'Create Feature' window.

6. Select the Plate Polygon (PP) dataset to save your new MOR to, and click Create. You will then be taken back to the main GPlates window where you can reconstruct back to 20 Ma to check whether your MOR is reconstructing correctly.

Ideally, the endpoints of your MOR should continue to intersect the adjacent plate boundaries but in the situation in which they do not (Figure 26), refer to the Appendix before continuing.

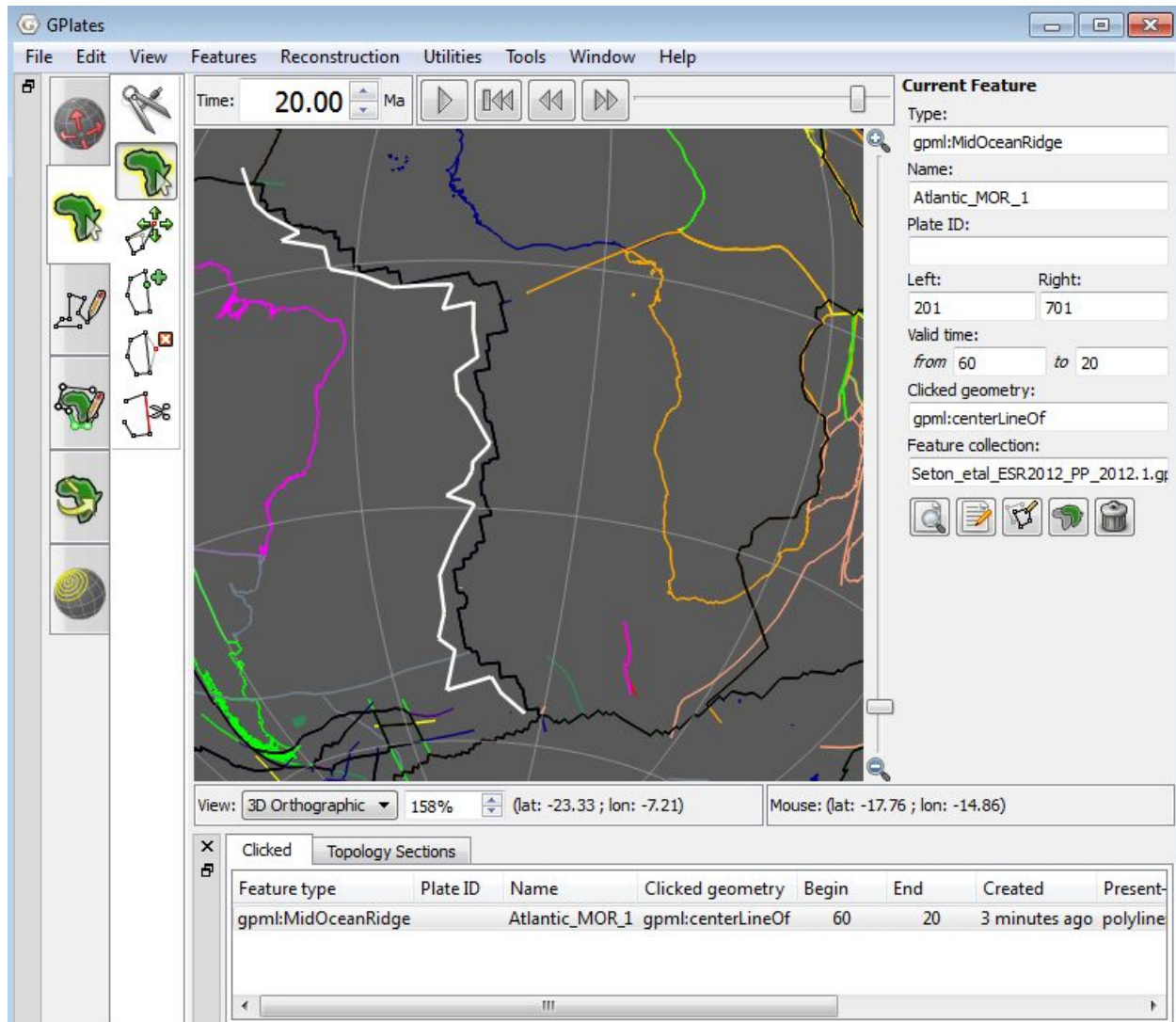


Figure 26: The southern end of the new MOR feature reconstructed at 20 Ma (circled) does not intersect with the pre-existing plate boundaries, and therefore must be modified.

7. Select the first plate polygon to be edited (we will choose the SAM Plate), and then select 'Edit Topology Sections' under the 'Topology' icon (Figure 27).

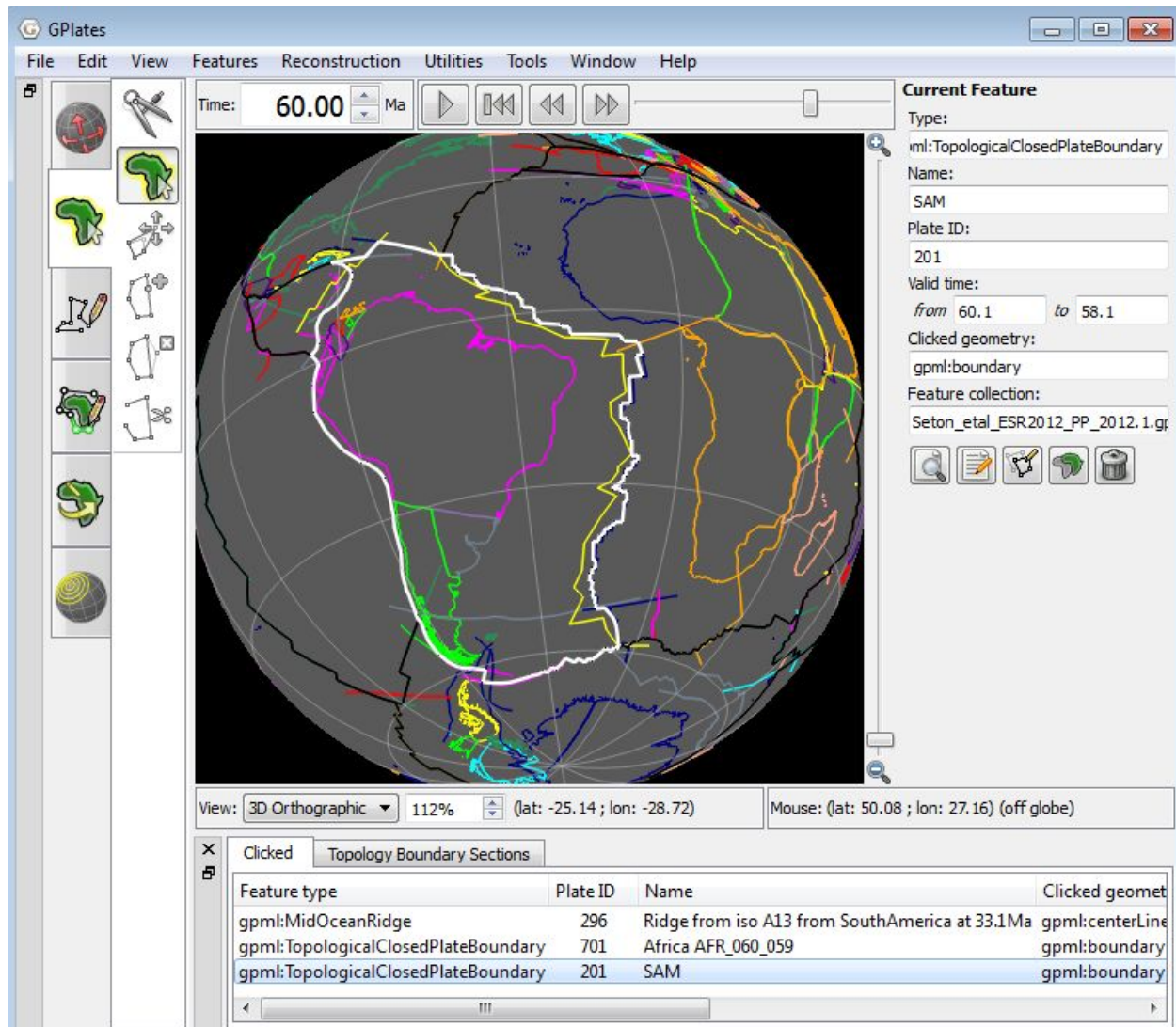


Figure 27: Under the 'Topology' icon, select the SAM Plate using the 'Choose Feature' tool and then select the 'Edit Topology Sections' tool.

8. Click the problematic boundary that needs to be replaced. In this example, there are two, both with Plate ID 296. It will be highlighted in the Topology Sections list at the bottom of the GPlates window.

9. Click the down or up arrow next to the problematic boundary to specify the new insertion point for the newly created MOR – note that this can be done after deleting the old topology, but you may lose track of where the new MOR is supposed to be once you delete the old one.

10. Click the "X" button to the left of both problematic MOR features to delete the old boundary from the topology (Figure 28).

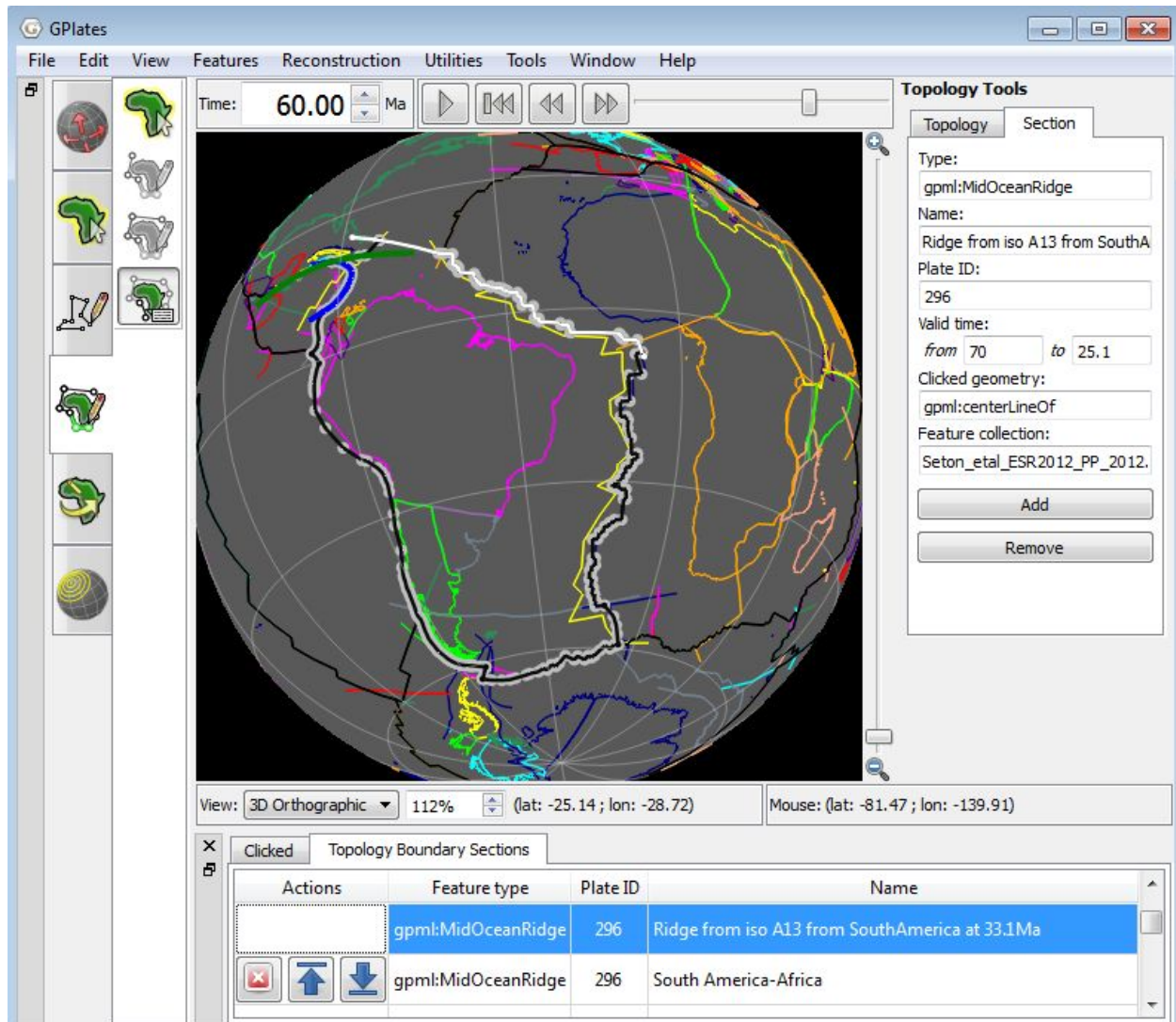


Figure 28: Select the two problematic MOR features and click the X button to remove them.

Notice that a “rubber-banding” artefact will appear until you insert the new MOR boundary.

11. Select the new MOR feature by clicking on it, and then click the ‘Add’ button on the right hand side of the main window (Figure 29).

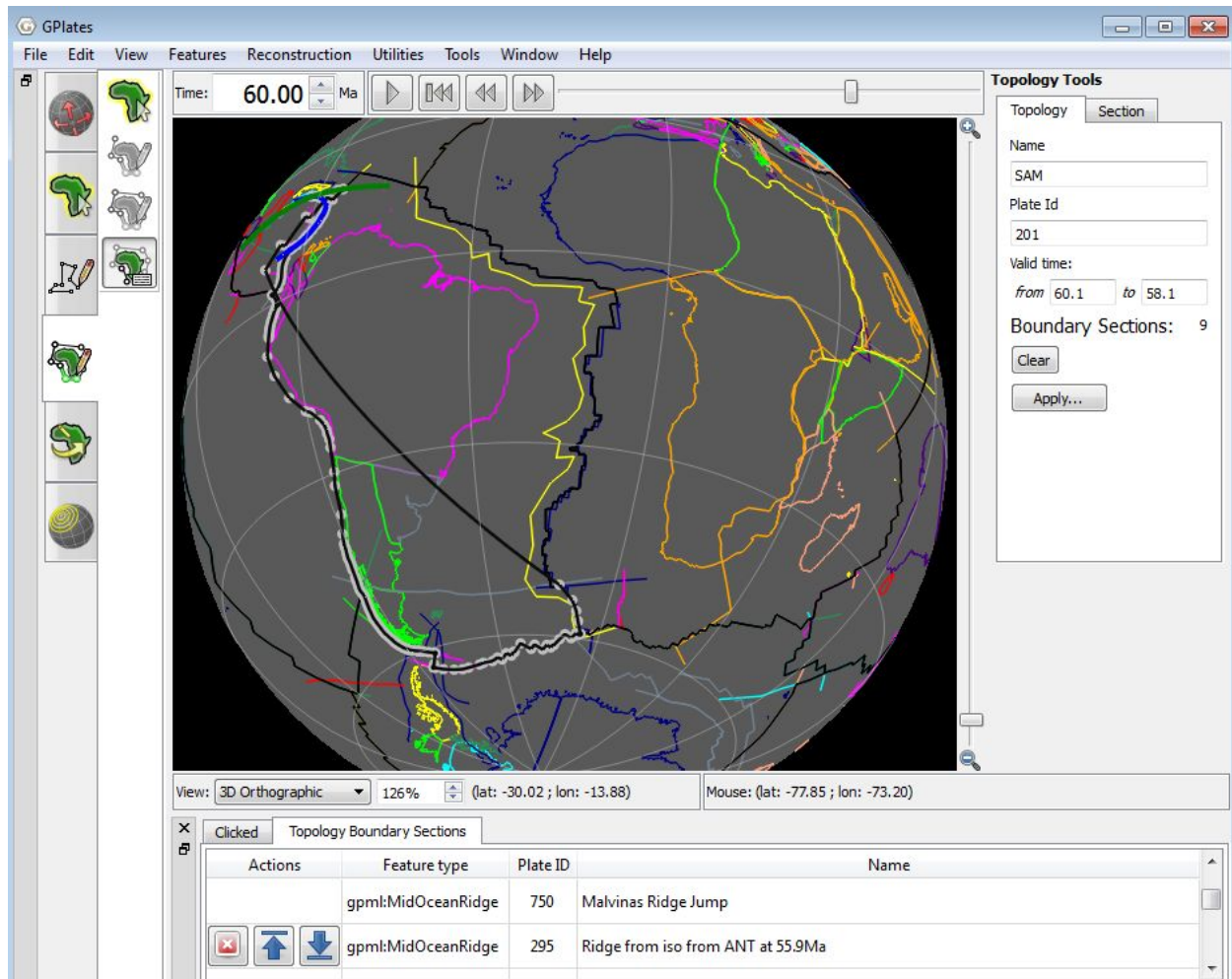


Figure 29: Select the new MOR feature and click the 'Add' button to add it to the existing topology.

In the next window, notice that the 'Valid time' for which the topology can exist for is limited from 60.1 to 58.1 (Figure 30). This is because the plate polygon you are modifying will cease at 58.1 Ma (and transform into a 'new' one). The new MOR topology you have just incorporated into the polygon will similarly cease to exist at this point in time. If you select any feature, you will notice that the right-hand-side window will display the Valid time for which the feature will exist.

12. Click Apply.

Topology Tools

Topology **Section**

Name

Plate Id

Valid time:
from *to*

Boundary Sections:

Figure 30: The 'Valid time' for which the newly edited topology can exist for is limited by the existing 'Valid time' of the old topology.

You have now successfully fixed one polygon.

13. You must repeat this process on the other polygon (the Africa plate in this example) that shared the old MOR boundary.

Once you have done this you will want to make sure that you have not created any artefacts or discontinuities. The best way to see gaps, overlaps and rubber-banding artefacts is by turning off the lines and just displaying the resolved topologies.

14. In the Layers list, disable the Plate Polygon (PP) Reconstructed Geometries layer in the 'Layers' window.

You can avoid these problems by carefully extending the new MORs to intersect at the same place as the old boundary (see Appendix). However, there is likely to be a lot of manual work to introduce new MORs into existing plate polygon datasets.

For more information about editing MOR topologies, see [Tutorial 5.2](#), or the [GPlates User Manual](#).

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](#).

Appendix

Extending a new MOR to intersect with existing plate boundaries

If intending to replace an existing MOR with a new MOR feature, it is crucial that the new MOR geometry intersects with pre-existing plate boundaries in order for the user to edit the new topology in. If the MOR fails to intersect these plate boundaries, which may be the case after reconstructing back through time, it is possible to interactively extend the MOR to intersect with the required plate boundaries.

Using the 'Choose Feature' tool, select the problematic MOR and click the 'Insert Vertex' tool (Figure 31).

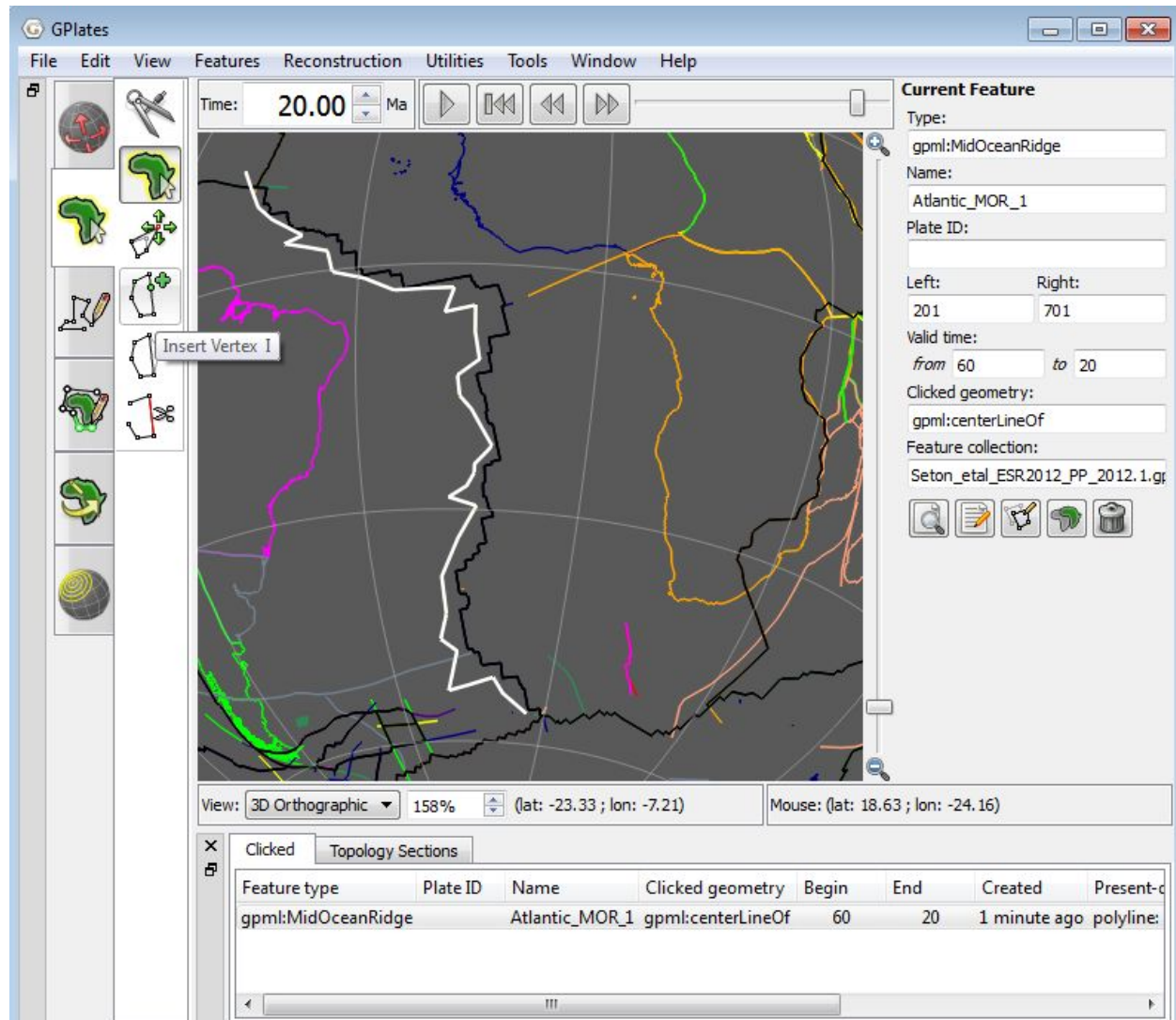


Figure 31: Select the MOR feature and click the 'Insert Vertex' tool.

Add points to make the sure MOR intersects with neighbouring boundaries (Figure 32).

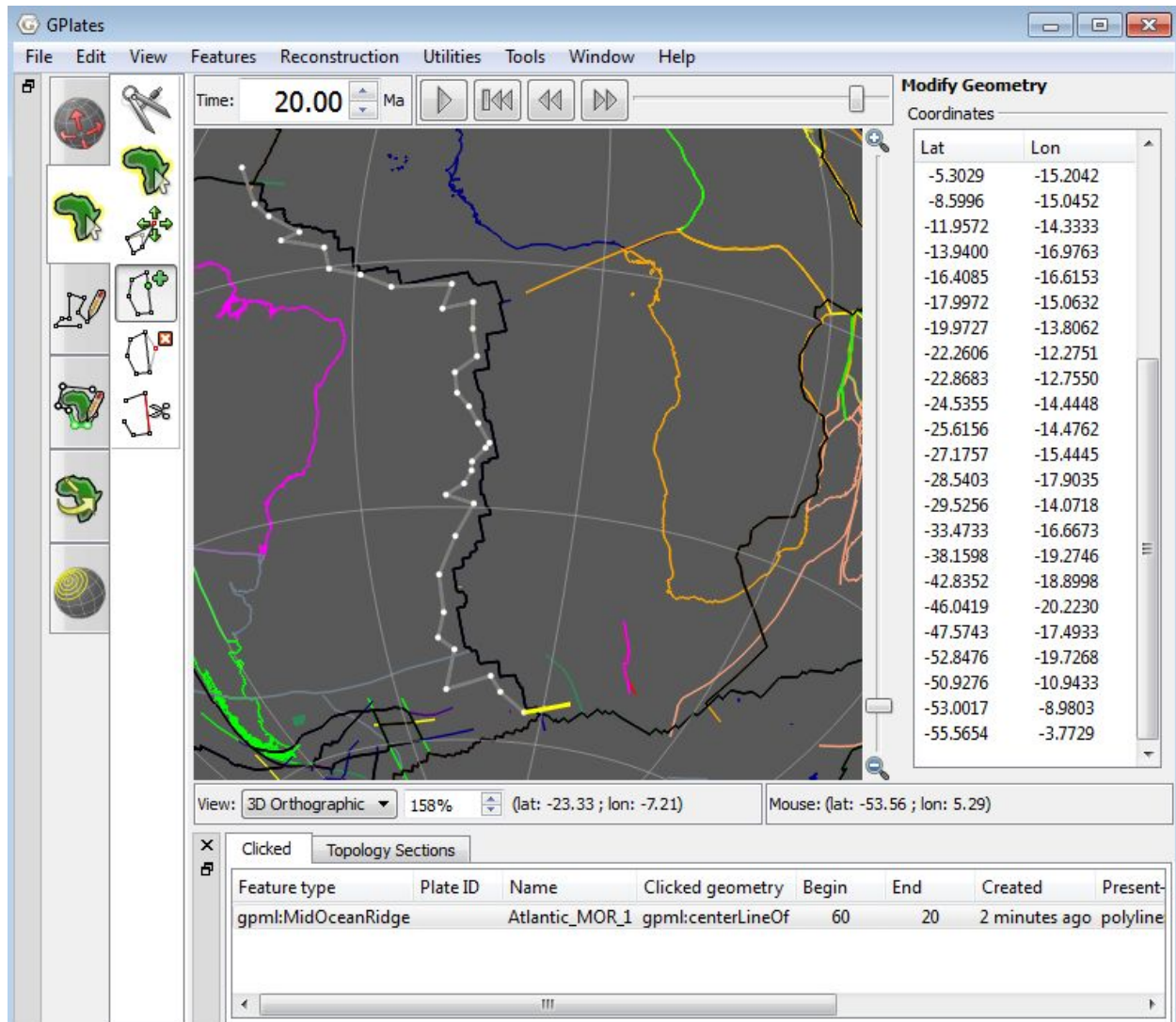


Figure 32: Plot points interactively to extend the MOR until it intersects with adjacent plate boundaries.

Once you are satisfied, select any other tool on the main interface (such as the 'Choose Feature' tool) to halt the process. You have now successfully extended your MOR feature!