

Plate Deformation - the Andes

Authors: Simon Williams¹, Mike Gurnis², Ting Yang², Samantha Ross¹

¹EarthByte Research Group, School of Geosciences, The University of Sydney, Australia

²Division of Geological and Planetary Sciences, California Institute of Technology

[Plate Deformation - the Andes](#)

[Aim](#)

[Included files](#)

[Background](#)

[Exercise 1 - Deformation of the Andean margin](#)

[Part 1: Defining motions of points along a deforming margin](#)

[Part 2: Building a deforming line feature](#)

[Part 3: Combine deforming margin into global topological model](#)

[Exercise 2 - More detailed Andean Deformation](#)

[Part 1: Load the deformation raster sequence](#)

[Part 2: Create deformation tracker points](#)

[Part 3: Create a Topological Mesh over the Deformation Region](#)

[Additional Exercises](#)

[References](#)

Aim

This tutorial provides the first steps towards modelling plate deformation in GPlates. Traditional plate reconstructions typically consider the Andean margin as a single, rigid boundary through time. However, several studies have shown how the morphology of the Andean margin of South America is likely to have changed significantly during Cenozoic oroclinal bending. The aim of this tutorial is to show how the details of this process can be incorporated into a (global) topological plate model using GPlates.

Exercise 2 allows users to build the deforming network visualised in tutorial 8.1.

Included files

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

The tutorial dataset (8.2-AndesTutorialData.zip) includes the following files:

Seton_etal_ESR2012_Coastlines_2012.1_Polyline.gpmlz

Seton_etal_ESR2012_PP_2012.1.gpmlz

Seton_etal_ESR2012_2012.1.rot

McQuarrie_Geology2002_fig3_rectify_clip.gpml

Arriagada_Images.gpml

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

This tutorial dataset is compatible with GPlates 2.0.

Background

There are various different ways to build a deforming topological network and this tutorial will guide the user through one way of doing so.

Exercise 1 - Deformation of the Andean margin

In the first example, we'll consider how the morphology of the Andean

margin has evolved through the last 70 Ma based on reconstructions presented by McQuarrie (2002). This study used balanced cross-sections to estimate shortening within the Andes and how the magnitude of shortening varied along strike. The results are summarized in a map-view figure that illustrates evolution of the Bolivian orocline (Figure 1).

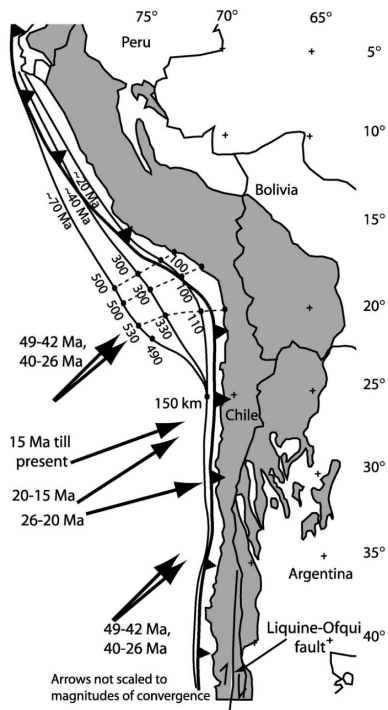


Figure 1: from McQuarrie (2002), 'Initial plate geometry, shortening variations, and evolution of the Bolivian orocline'.

1. Using the File → Open Feature Collection menu load the following files:
 - Seton_et al_ESR2012_2012.1.rot
 - Seton_et al_ESR2012_Coastlines_2012.1.gpmlz
 - Seton_et al_ESR2012_PP_2012.1.gpmlz
 - McQuarrie_Geology2002_fig3_rectify_clip.gpml

A georeferenced version of Figure 1 is provided in the tutorial data set. To make the global plate model geometries move consistently with the raster, we need to make South America (Plate ID 201) the fixed plate.

2. Reconstruction > Specify Anchored Plate ID... and set the value to 201.

(to see what difference this makes, try reconstructing the geometries and raster sequence with the Anchored plate as 000. You'll see an increasing

mismatch between the South America coastlines and rasters as the reconstruction age increases).

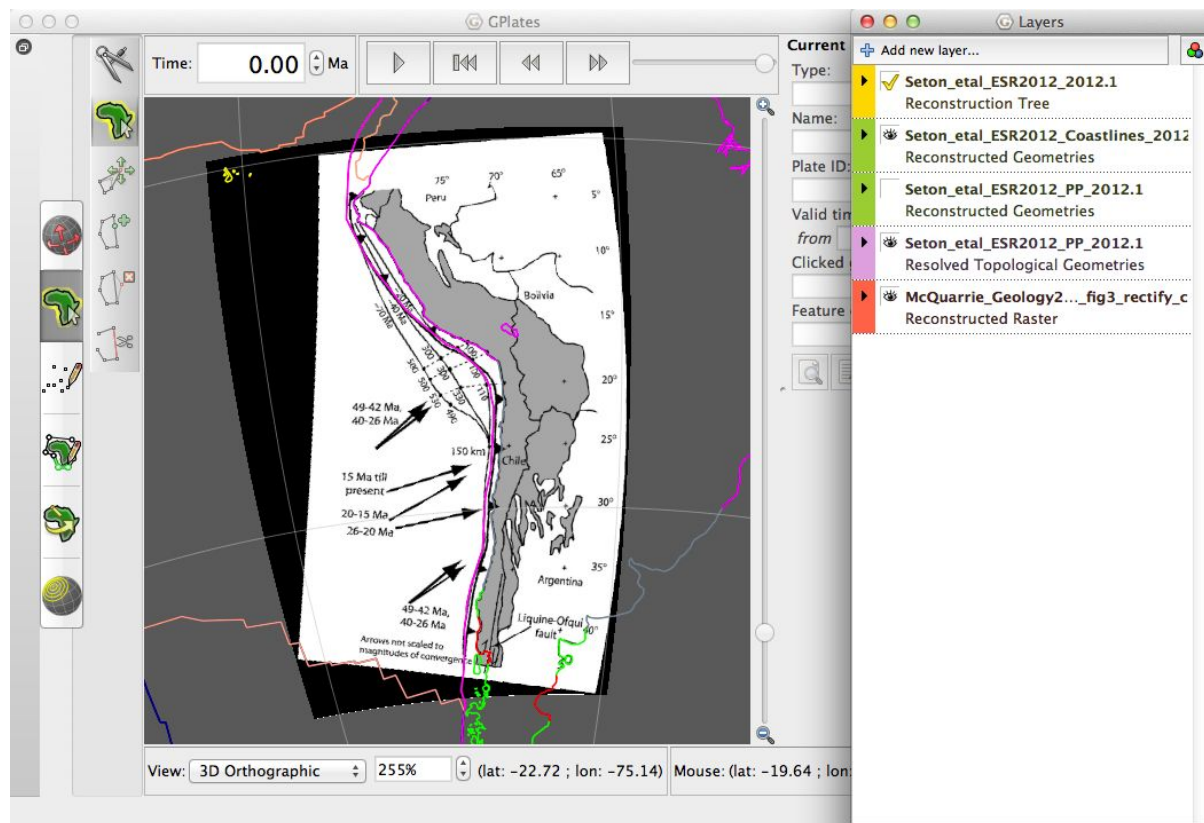


Figure 2: Estimated location of the Andean margin at 70 Ma, 40 Ma and 20 Ma with Plate 201 fixed.

In the area of what is now the Bolivian orocline, the margin moves >500 km west due to crustal shortening. Compare this with the rigid topologies in traditional plate models, where the margin is defined as a rigid line.

Part 1: Defining motions of points along a deforming margin

Before we start worrying about topologies, we will first create a series of points along the Andean margin, each with an individual motion history, that represent this change in morphology through time.

To do this, we will have to create a series of points with unique plate IDs, so

that we can define them with a motion independent from that of one of the 'major' plates like South America. In GPlates, all relative motions are defined by assigning plate IDs and rotation poles, whether this be for a major plate or a single point within a deforming mesh.

To create these points for the Andes, first set the reconstruction time to 0 Ma. Then go to the Digitization menu on the left of the GPlates window, and select 'Digitize new multi-point geometry'. Since each point will end up with a unique plate ID, we will have to create each point separately and define the attributes accordingly. An example of the process for one point would be as follows:

1. Digitize 1 point at a desired location along the present-day Andean margin line (digitize the points along the subduction zone trench location, not the coastline).
2. Select 'Create Feature...'
3. Leave Feature Type as 'Unclassified Feature' (the default), click 'Next'
4. Set the Plate ID to a unique value. In this case, to avoid conflict with existing Plate IDs in use, we will adopt size digit numbers. The numbering system is up to you, in this case we'll start at 201001 (where the 201 is taken from the Plate ID for South America) and increment upwards from there. Also make the begin and end time of the point to 'Distant Past' and 'Distant Future' (Figure 3).
5. Click Next, and Next again, then select the <Create a New Feature Collection> option to save these new points into a new file. Save all subsequent points into this same feature collection.

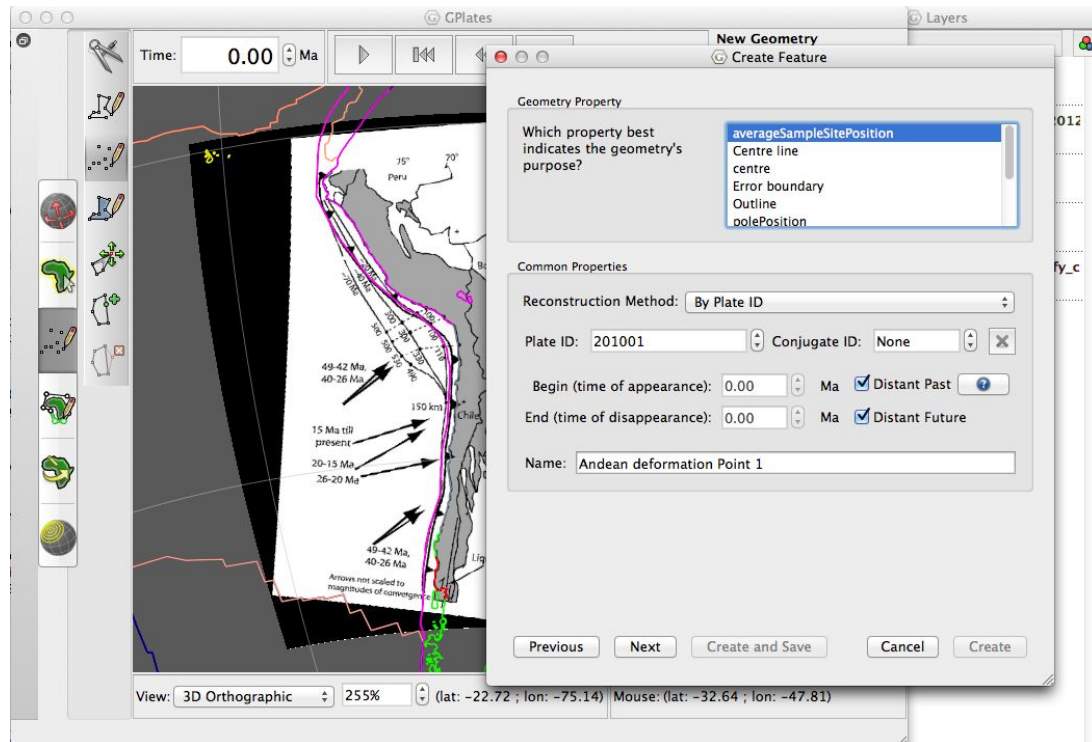


Figure 3: Assigning properties to a feature (Step 3)

6. Repeat this sequence for a series of points along the (present-day) Andean margin (Figure 4) - the position and number of points you decide to digitise is up to you. Make the Plate ID different for each point (e.g. 201002, 201003, etc....).

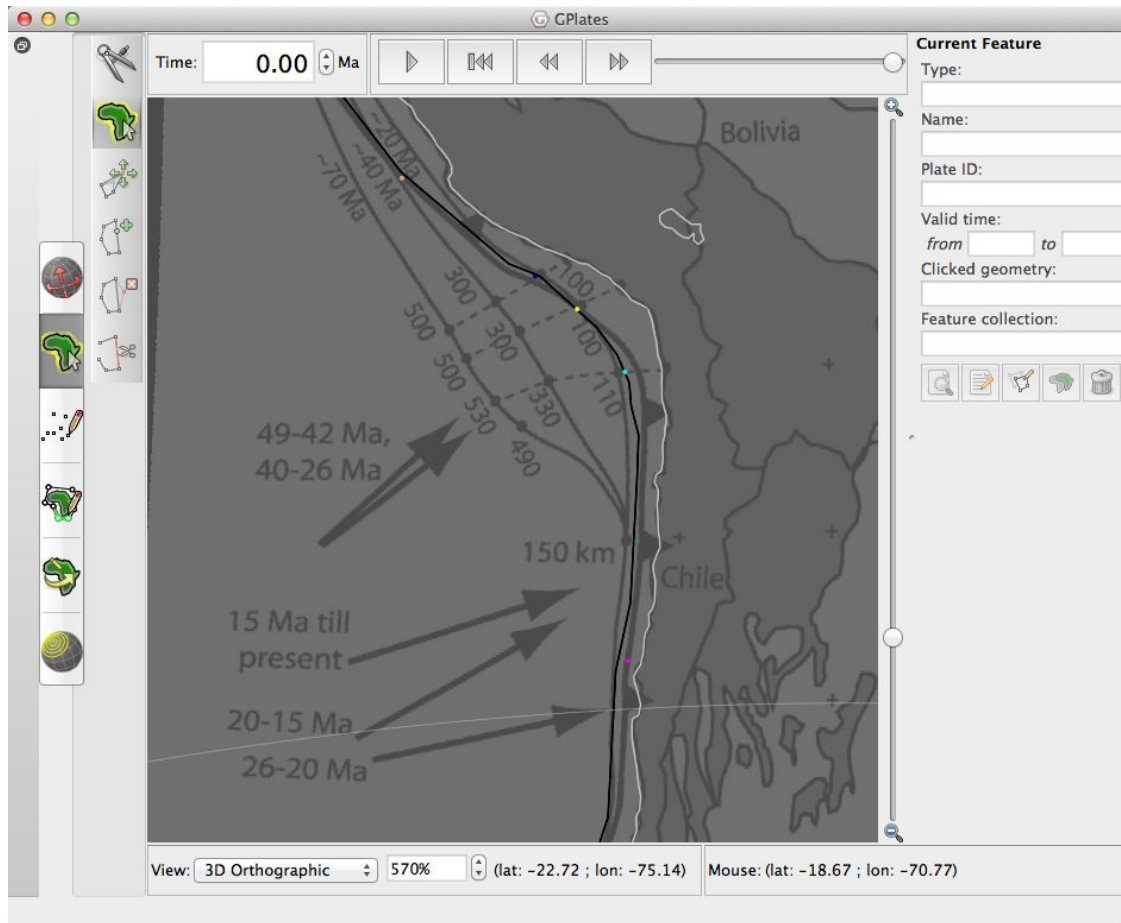


Figure 4: Example of digitised points along the margin (Step 6). Note that the colour of each point is different, denoting their different plate IDs.

Next, we need to implement the motion history of each point. The details of how any feature moves within GPlates is stored within a rotation file, and these points are no different. So first, we need to create a 'blank' set of rotations for each plate. See the 'Changing Rotations' and 'Creating a plate model from scratch' tutorial for a more detailed description.

One additional point to mention here is that rotation tables in GPlates need not all be stored in one file. Instead, we can have motion histories for different rotation files and link them together within GPlates. This has the advantage of keeping motion histories for deforming regions separate from the main global rotation files, rather than creating one large, unwieldy rotation file.

7. Use a text editor (eg Notepad, Textmate) to create a blank rotation file with entries for each of the Plate IDs assigned to the newly digitized points

(Figure 5).

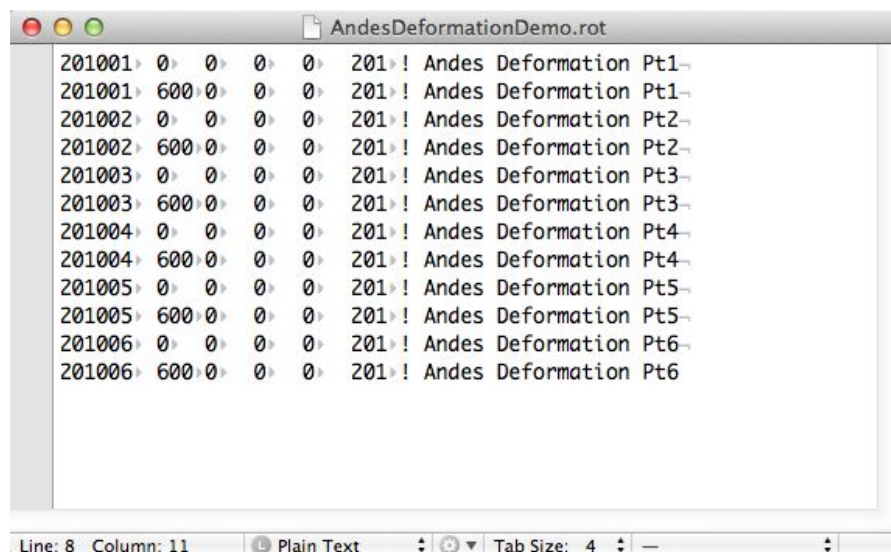


Figure 5: An example of the blank rotation file for the points along the Andean margin (Step 7)

In this example, the motions of each point will be defined relative to South America (201).

[Note that as discussed in the 'Changing Rotations' tutorial, we have to add zero rotations both at present day and at some point in the distant past to begin with. We'll then modify them later].

8. Load this rotation file into GPlates. Make the 'Seton_etal_ESR2012_2012.1' global rotation file the default reconstruction tree by ticking the tickbox, but also expand this layer in the layer manager and click on 'Add a new connection'. Select the Andes rotation file you have just loaded (Figure 6). This layer now treats the contents of both these files as if they were one big table of rotations, combined from the contents of the two individual files.

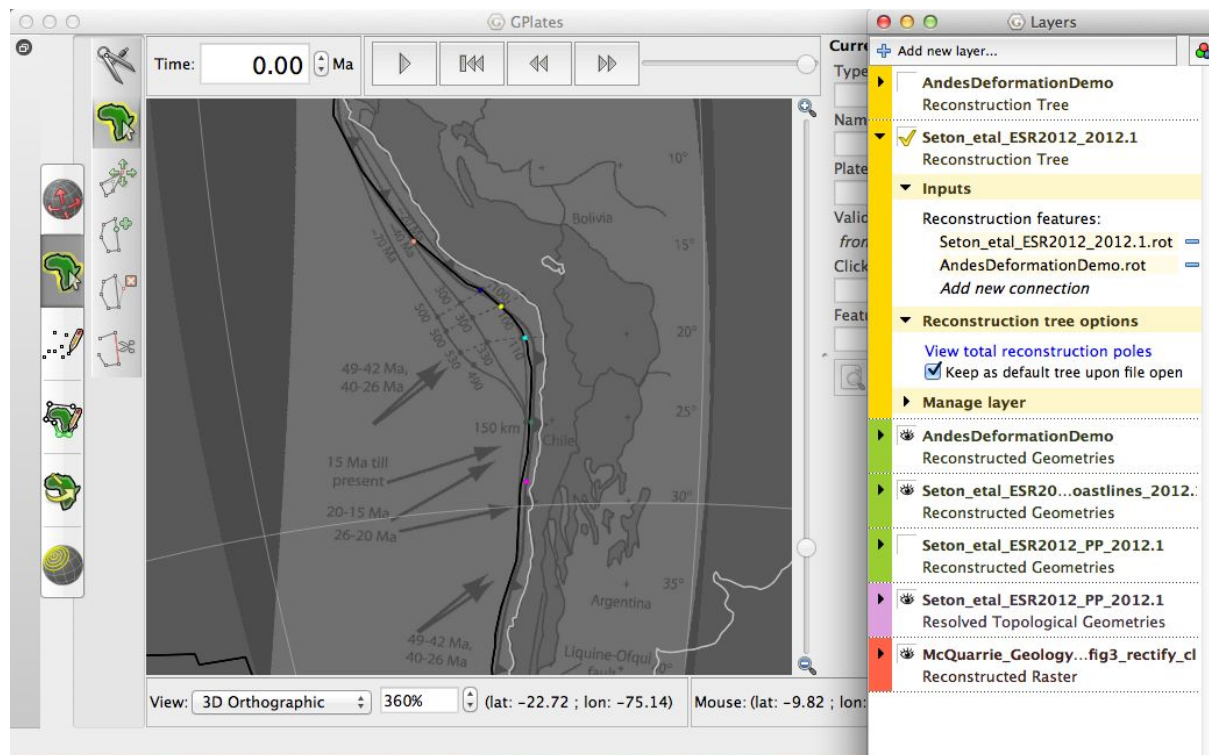


Figure 6: Creating the connection between the global rotation file and the Andes rotation file (Step 8)

For Mac users, if there is an error when loading the rotation file, or the poles of the digitised points are unable to be moved, this may be due to the usage of the wrong line endings by the text editor. To fix this, the line endings must be converted:

Load the rotation file in a text editor such as TextMate or Atom

TextMate:

Save the rotation file and select the "LF" (linefeed) line endings (Figure 6) and reload in GPlates.

Atom:

Download a line ending converter package. Packages -> Convert line endings -> Windows Format. Then reload in GPlates.

This allows GPlates to understand where the line breaks are in the text file

and differentiate between the different rows.

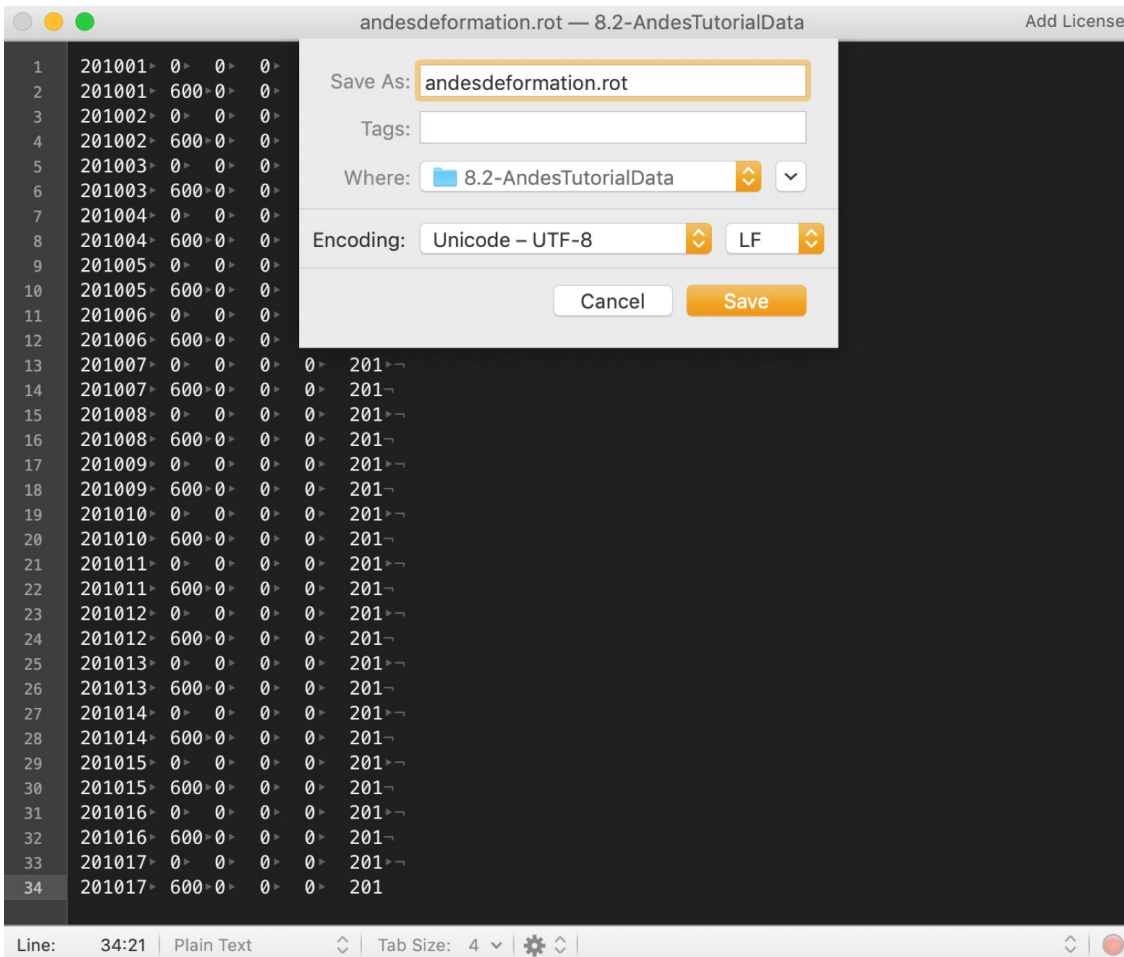


Figure 7: Saving the rotation file with "LF" line endings in TextMate

Now we are ready to define the motion histories for each of the new points on the Andean margin. This will require the use of the 'Pole Manipulation' tool, which was described in 'Changing Rotations' tutorial.

9. Set the reconstruction time to 20 Ma (because this is the youngest time that the McQuarrie study defines an restored margin morphology)

10. Select one of the points, then select the 'Pole Manipulation' tool.

11. Drag the point from it's location at present day to a point that would approximate the location of the equivalent point on the plate boundary at 20

Ma.

Note that this will require some amount of 'eyeballing', because the lines shown on the georeferenced image illustrate the migration of the coastline whereas we are trying to model the migration of the subduction zone trench which lies ~100 km oceanward. In general we can use the shortening estimates (Figure 9) to check that the magnitudes of motion we impose are consistent. (We can use the dashed lines as a guide to the direction of motion that the points should follow).

12. Click on Apply, and a window will pop up showing the new rotation calculated based on how you moved the point. Click on OK, and this rotation will be added to the sequence of rotations in the Andes Deformation table of rotations.

Note that the change won't be saved to file until you manually save your changes in the 'Manage Feature Collections' dialogue. Note also that we are only modifying the Andes rotation file, because this is the file that contains rotations for the plate ID 201001 (or similar) - the global rotation file will not be modified.

13. Repeat this step for the other points, so that all the points are repositioned onto the 20 Ma plate boundary (Figure 8).

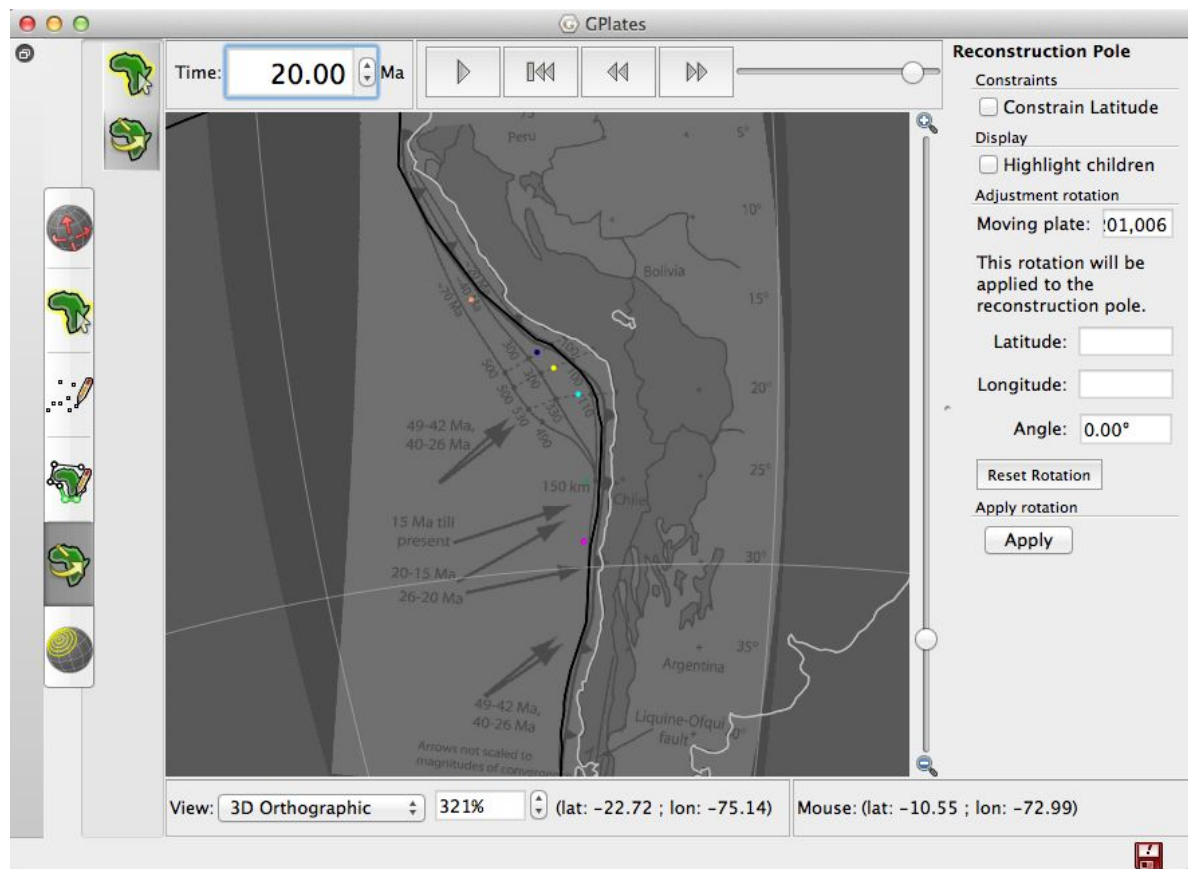


Figure 8: Location of points along Andean margin at 20 Ma (Step 13).

14. Repeat this process (Steps 9-13) for 40 Ma and 70 Ma.

Note that you don't need to modify the rotation if the point hasn't moved relative to the previous time step (e.g. the 2 southernmost points on the image above don't need to move from 70-20 Ma.)

15. Play back the rotation sequence from 70 Ma to present. The points should move progressively eastwards, providing a dynamic representation of the evolution defined by the four timeslices represented in the original image, but with locations interpolated for all times in between.

16. At this point, save changes to unsaved files.

17. Also at this point, it is worth returning to the rotation file in the text editor (make sure to reload the file after you've saved the changes you made in GPlates).

18. Take the rotations for each point at 70 Ma (or the oldest time for which

you defined a new rotation), and cut and paste this over the zero rotations at 600 Ma (Figure 9)

This essentially says 'the points should not move relative to 201 between 600 and 70 Ma. See the 'Changing Rotations' tutorial for more details.

A: Before

```

AndesDeformationDemo.rot
201001 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt1-
201001 20.0 -64.67 43.6 0.61 201 !Calculated interactively by GPlates-
201001 40.0 -65.94 45.7 1.35 201 !Calculated interactively by GPlates-
201001 70.0 -65.49 44.87 2.25 201 !Calculated interactively by GPlates-
201001 600.0 0.0 0.0 0.0 201 ! Andes Deformation Pt1-
201002 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt2-
201002 20.0 -58.24 45.98 0.8 201 !Calculated interactively by GPlates-
201002 40.0 -58.0 45.49 1.95 201 !Calculated interactively by GPlates-
201002 70.0 -58.1 45.66 3.52 201 !Calculated interactively by GPlates-
201002 600.0 0.0 0.0 0.0 201 ! Andes Deformation Pt2-
201003 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt3-
201003 20.0 -65.81 64.24 1.02 201 !Calculated interactively by GPlates-
201003 40.0 -63.9 59.31 2.47 201 !Calculated interactively by GPlates-
201003 70.0 -62.5 56.2 4.14 201 !Calculated interactively by GPlates-
201003 600.0 0.0 0.0 0.0 201 ! Andes Deformation Pt3-
201004 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt4-
201004 20.0 69.72 -62.99 -0.96 201 !Calculated interactively by GPlates-
201004 40.0 69.29 -87.64 -2.87 201 !Calculated interactively by GPlates-
201004 70.0 -67.43 79.15 4.42 201 !Calculated interactively by GPlates-
201004 600.0 0.0 0.0 0.0 201 ! Andes Deformation Pt4-
201005 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt5-
201005 20.0 64.7 -64.65 -0.83 201 !Calculated interactively by GPlates-
201005 600.0 0.0 0.0 0.0 201 ! Andes Deformation Pt5-
201006 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt6-
201006 20.0 60.79 -59.96 -0.72 201 !Calculated interactively by GPlates-
201006 600.0 0.0 0.0 0.0 201 ! Andes Deformation Pt6-

```

B: After

```

AndesDeformationDemo.rot
201001 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt1-
201001 20.0 -64.67 43.6 0.61 201 !Calculated interactively by GPlates-
201001 40.0 -65.94 45.7 1.35 201 !Calculated interactively by GPlates-
201001 70.0 -65.49 44.87 2.25 201 !Calculated interactively by GPlates-
201001 600.0 -65.49 44.87 2.25 201 ! Andes Deformation Pt1-
201002 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt2-
201002 20.0 -58.24 45.98 0.8 201 !Calculated interactively by GPlates-
201002 40.0 -58.0 45.49 1.95 201 !Calculated interactively by GPlates-
201002 70.0 -58.1 45.66 3.52 201 !Calculated interactively by GPlates-
201002 600.0 -58.1 45.66 3.52 201 ! Andes Deformation Pt2-
201003 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt3-
201003 20.0 -65.81 64.24 1.02 201 !Calculated interactively by GPlates-
201003 40.0 -63.9 59.31 2.47 201 !Calculated interactively by GPlates-
201003 70.0 -62.5 56.2 4.14 201 !Calculated interactively by GPlates-
201003 600.0 -62.5 56.2 4.14 201 ! Andes Deformation Pt3-
201004 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt4-
201004 20.0 69.72 -62.99 -0.96 201 !Calculated interactively by GPlates-
201004 40.0 69.29 -87.64 -2.87 201 !Calculated interactively by GPlates-
201004 70.0 -67.43 79.15 4.42 201 !Calculated interactively by GPlates-
201004 600.0 -67.43 79.15 4.42 201 ! Andes Deformation Pt4-
201005 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt5-
201005 20.0 64.7 -64.65 -0.83 201 !Calculated interactively by GPlates-
201005 600.0 64.7 -64.65 -0.83 201 ! Andes Deformation Pt5-
201006 0.0 0.0 0.0 0.0 201 ! Andes Deformation Pt6-
201006 20.0 60.79 -59.96 -0.72 201 !Calculated interactively by GPlates-
201006 600.0 60.79 -59.96 -0.72 201 ! Andes Deformation Pt6-

```

Figure 9: Andes rotation file A: Before rotations are implemented B: After rotations are implemented between 600 and 70 Ma (Step 18).

Part 2: Building a deforming line feature

A topological line feature can be constructed from a series of points or lines, each with individual plate IDs (and therefore independent motion histories). This enables us to construct lines whose geometry evolves through time, but to also use these line features as boundaries within a topological polygon in the same way as rigid lines. See the Topology tutorials for more detailed instructions on how to build topological features.

1. To do this, go to the 'Topology' menu, then select 'Build New Line Topology'.
2. Click on one of the points for which we've just defined rotations, starting at one end of the sequence of points. Then click on 'Add' on the righthand menu. Repeat this for each point in order (e.g. from north to south) (Figure

10).

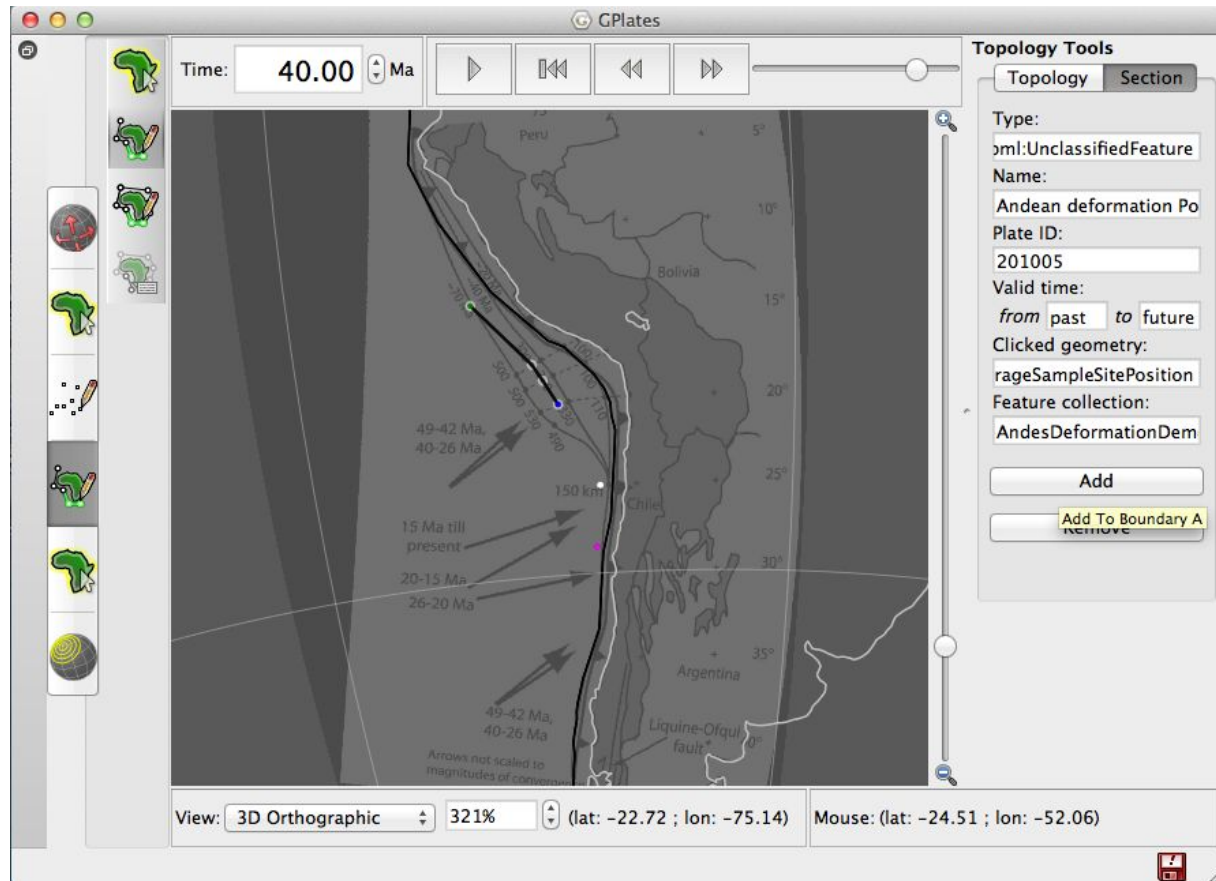


Figure 10: New line topology after four points have been added (Step 2)

3. Once all the points have been added, click on Create and specify all the attributes as required (make sure to change the Begin and End time from 0, for example to 'Distant Past' and 'Distant Future'). Save this new feature to a new feature collection.

Once created, you should be able to see a line feature, with 6 vertices, where each vertex moves independently based on the previously defined motion history (Figure 11)

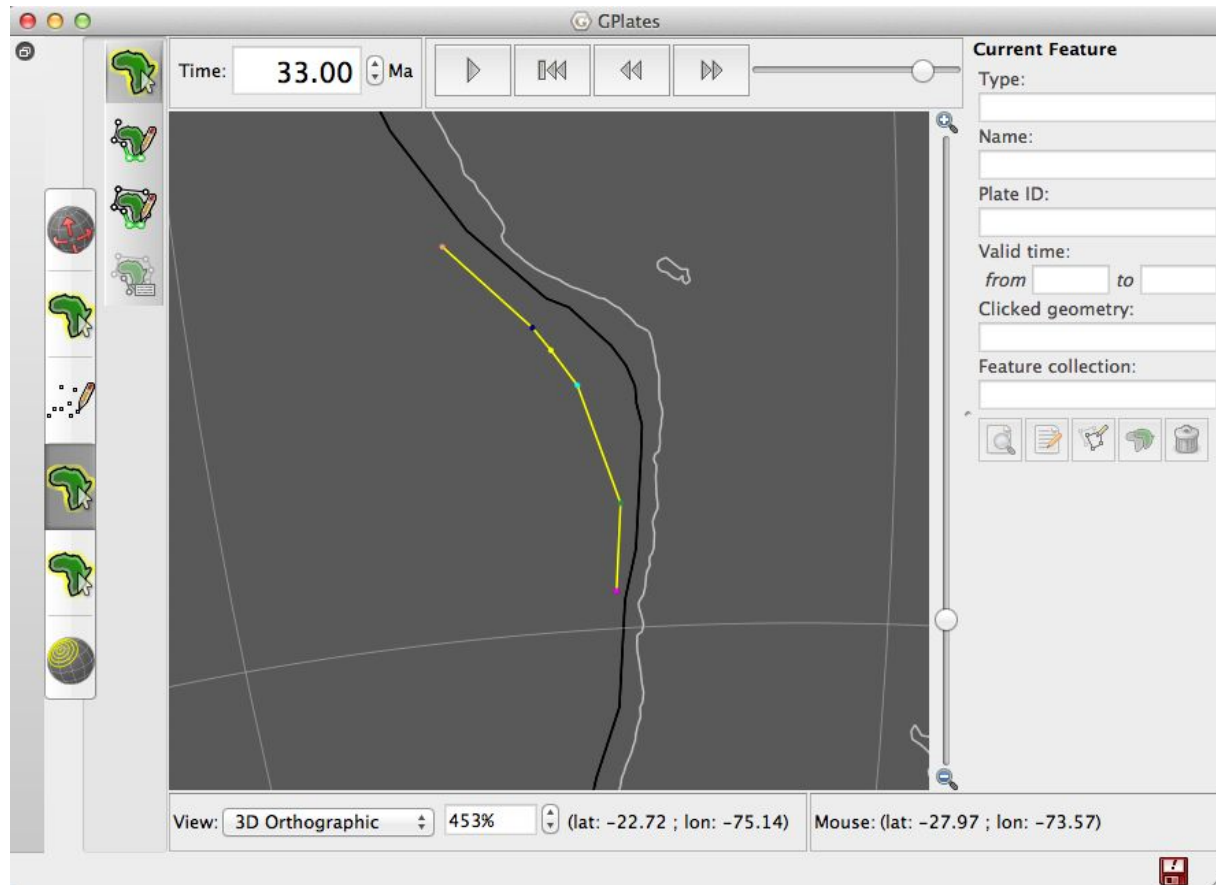


Figure 11: New line feature with 6 vertices

This line feature can now be treated like any other line in GPlates - we can add subduction zone properties, and use it as one of the boundaries within a topological plate boundary polygon.

Part 3: Combine deforming margin into global topological model

To use this boundary as part of the topological polygons for South America and the adjacent Farallon plate, we first need to chop out the existing rigid section.

1. Start by selecting the 'South American Trench' line feature from the Seton_etal_ESR_PP_2012.1' reconstructed geometries layer.
2. Select the 'Feature Inspection' toolbar and use the 'Split Feature' tool to cut this single line into three, with one cut to the north of the new topological line and one cut to the south.

You'll notice that straight away the topologies 'break', as evidenced by the long, straight lines going annoyingly across the display (Figure 12).

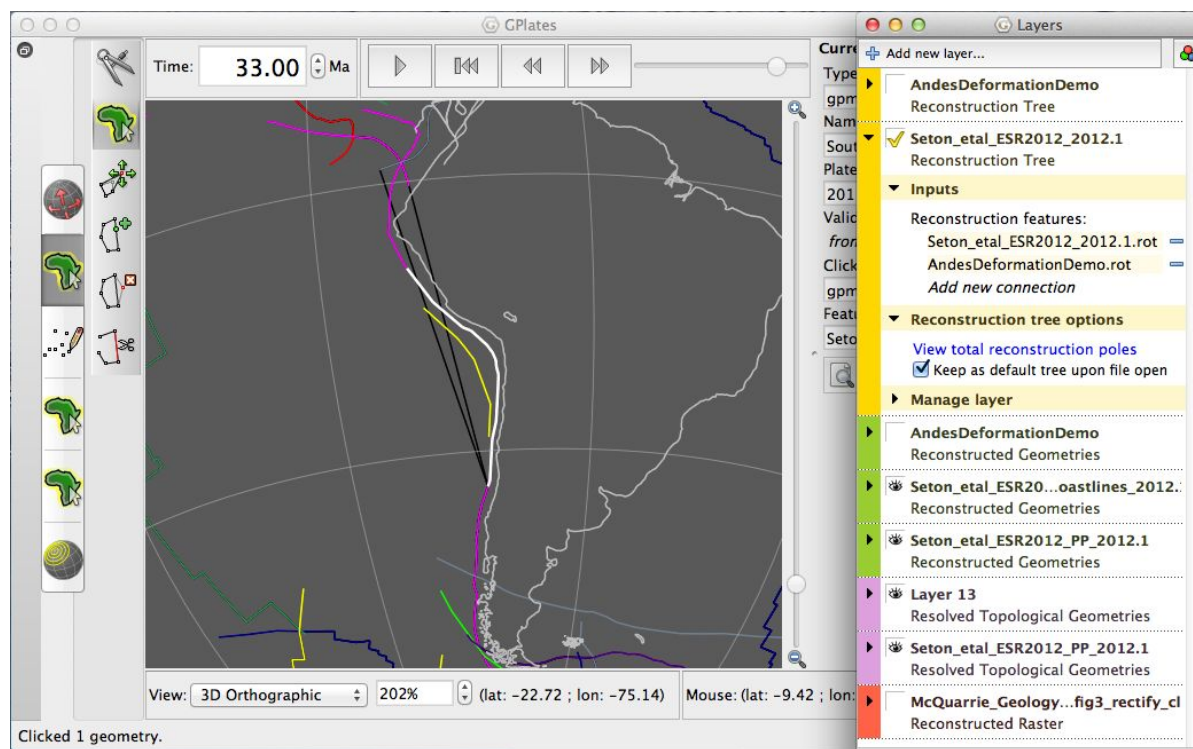


Figure 12: Broken topologies when the South American Trench is 'split' (Step 2).

Essentially, the previous topological polygons referenced a line that has been modified (cut in two), and anyway, we don't want to use all of that line anymore. Instead, the topological polygons need to be rebuilt to incorporate the new 'deforming line' segment, and the two rigid line segments either side of the new deforming line segment.

To fix this problem, we will merge the northern and southern sections of the Andean margin line that we want to keep with the topological line we just created, to create a topological line that extends along the whole Andean margin. We will then rebuild the polygons, replacing the previous Andean line section with the new, deforming version.

3. Select the topological line we already created. Go to the 'Edit Topology Sections' tool, then add the lines defining the northern and southern parts of the Andean margin, adding one at the beginning of the pre-existing list and the other at the end (Figure 13).

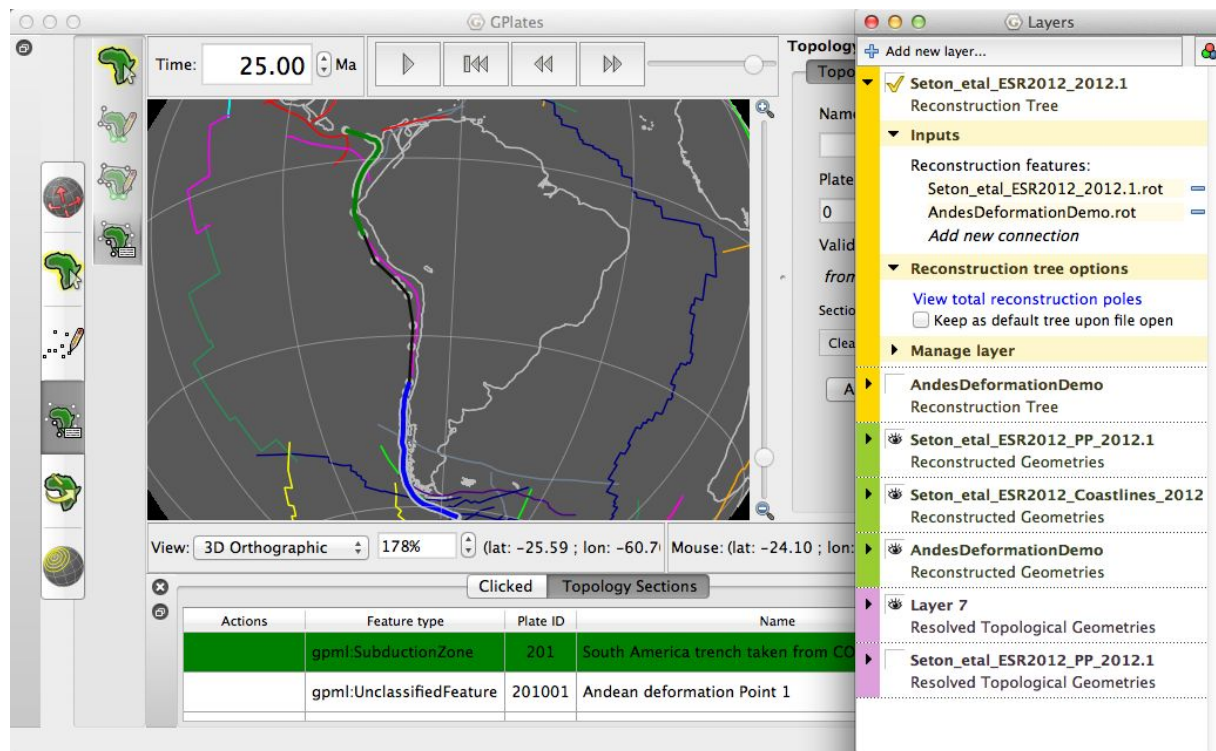


Figure 13: Northern part of the Andean margin highlighted in green, southern part of the Andean margin highlighted in blue, the rest of the topological line highlighted in black (Step 3).

The process of (re)building polygons is similar, and is described in detail in the 'Topological Closed Plate Polygons' tutorial. This is done by selecting the topological polygons we want to update, then clicking on 'Edit Topology Sections'

4. Remove the existing 'South American Trench' segments from the topology list, and add the new topological line in its place. Then click 'Apply...' (Figure 14)

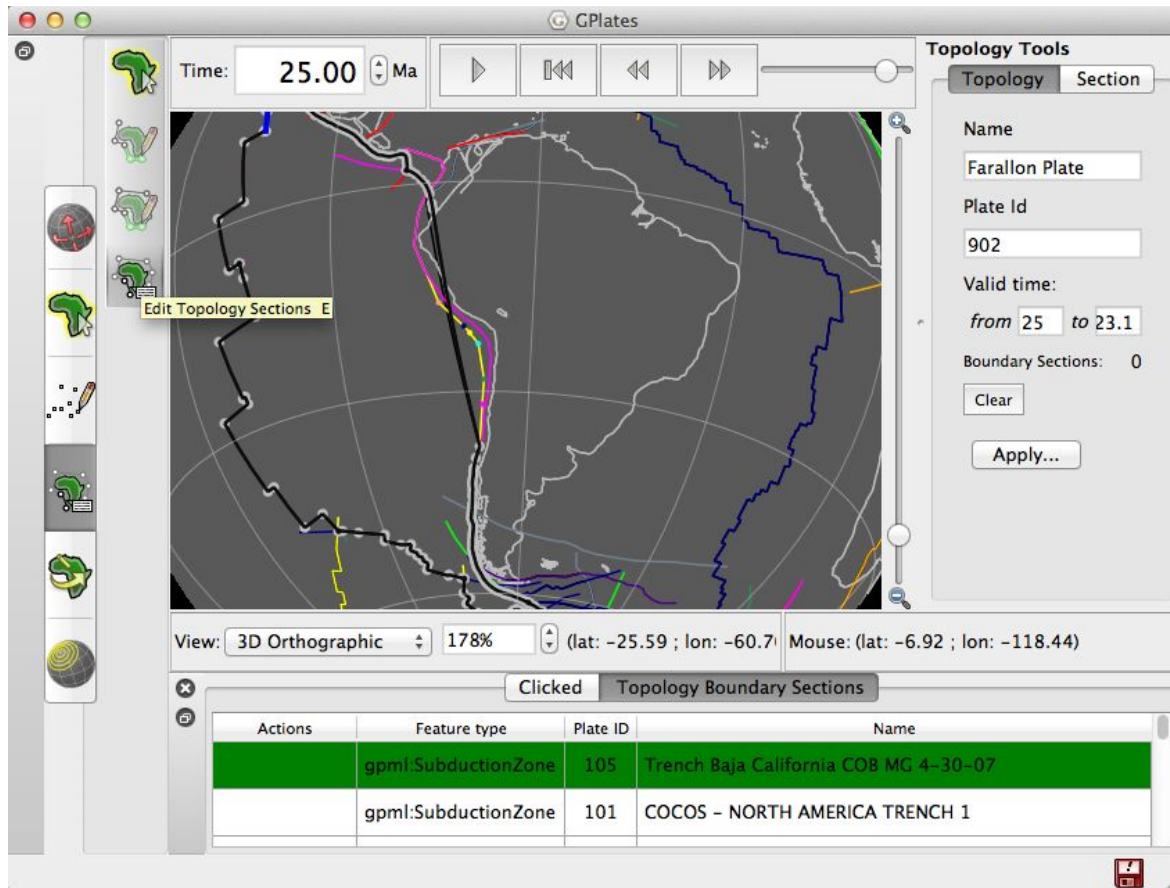


Figure 14: Edit topology boundary sections (Step 4)

5. Repeat this for both plates (South America and Farallon), and the plate polygons should be back to normal, but now incorporating the deforming margin (Figures 15 & 16). Note that the name of the oceanic plate(s) bordering the western margin of South America changes through time, for more recent times you'll be modifying the Nazca plate.

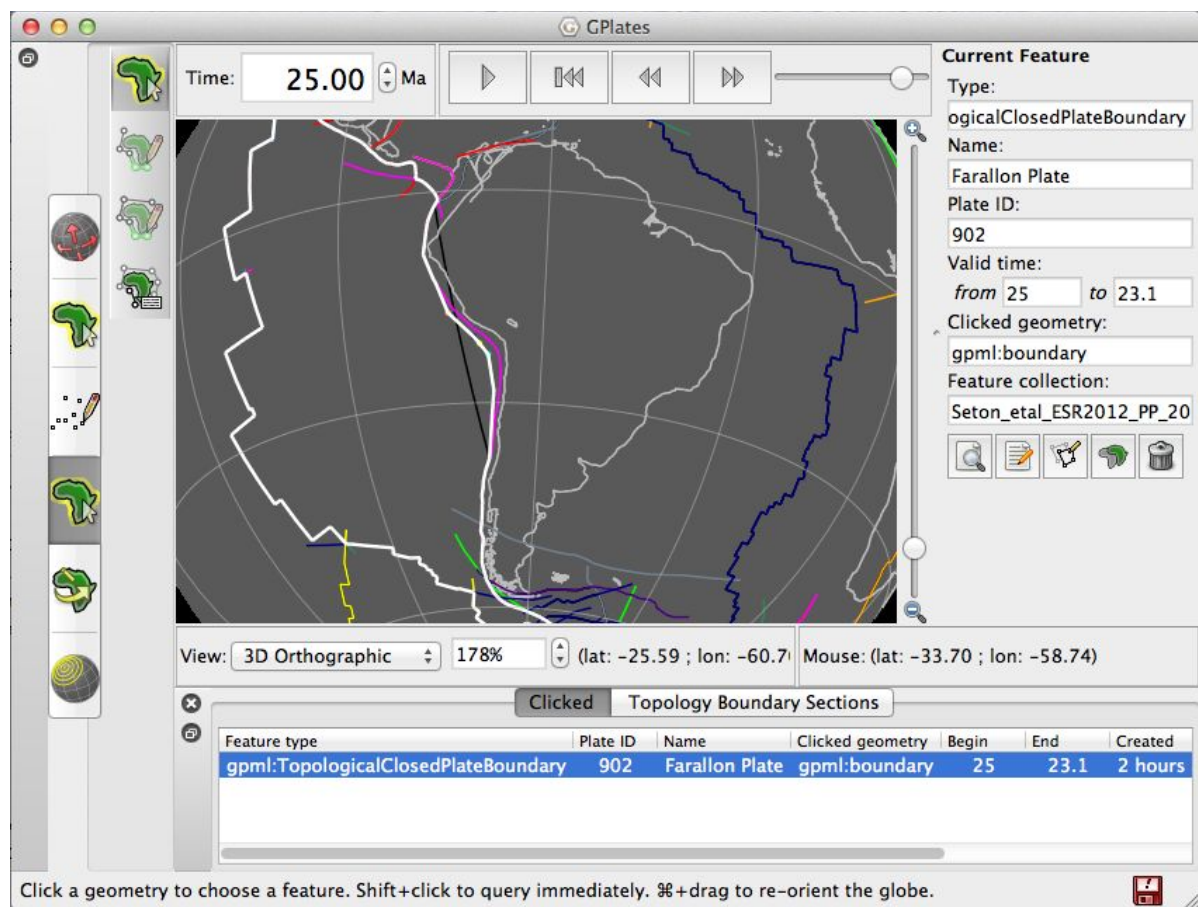


Figure 15: Modifying the Farallon Plate boundary (Step 5)

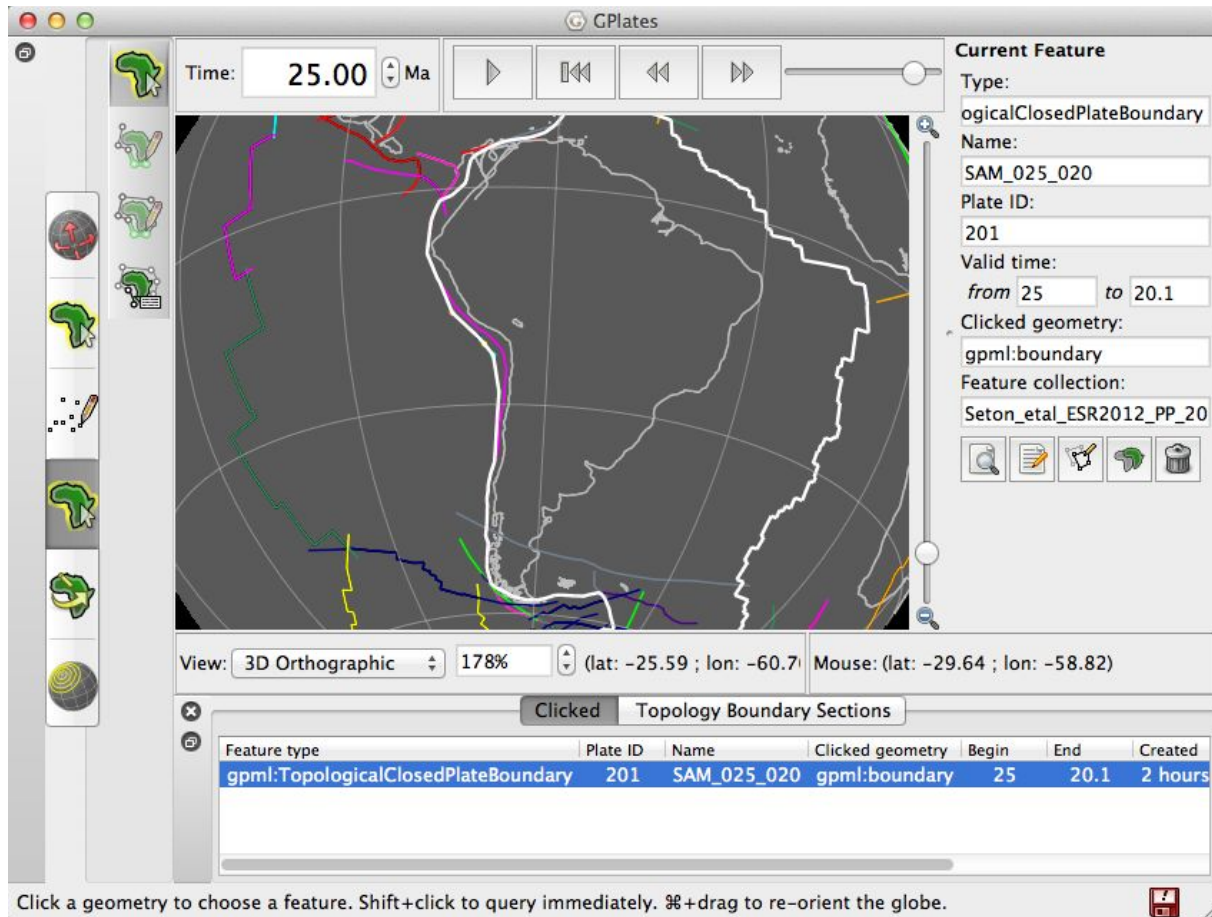


Figure 16: Modifying the South American Plate boundary (Step 5)

As is the way with topological polygons, you will likely need to repeat the rebuilding process for many different time steps due to the limited lifespan of each polygon.

Exercise 2 - More detailed Andean Deformation

In this second exercise we will go through the process of capturing the more detailed model of Andean evolution contained within the study of Arriagada et al (2008). This study generated a series of map-view restorations of deformation within the central Andes from 45 Ma to present day using available information on the magnitude and age of tectonic shortening, combined with paleomagnetic data to constrain local block rotations. The

restorations are presented in a series of intuitive figures and animations that we can capture as a time dependent raster sequence, georeference and load into GPlates. From there, we can generate a set of points with individual motion histories that represent the same deformation histories. Then, we combine the motion histories for each point into a single topological deforming region that describes the overall kinematics consistent with the original study.

Part 1: Load the deformation raster sequence

The first step is to capture the deformation model from the original study of Arriagada et al (2008).

[We are not going to go through that in detail here - however, bear in mind that if you wanted to do this, the steps involve georeferencing a series of images (the georeferencing would be done in ArcGIS) corresponding to different reconstruction times, then loading the series of georeferenced images files into GPlates using the 'Import time-dependent raster' option. See the 'Changing Rotations' and 'Time-dependent rasters' tutorials for further details]

As a short-cut for this tutorial, the tutorial data set includes a time-dependent raster sequence derived from the animation made available as supplementary material as part of the Arriagada et al (2008) study. The movie file was converted to a series of images, then loaded into GPlates (the original movie contains images at 0.5 Ma intervals, but in the interests of file size we only include 5 Ma intervals here).

1. To load this raster sequence, load the associated gpml file from the tutorial data folder under ArriagadaAndesRasterSequence > GPML > "Arriagada_Images.gpml".

2. Also load in the global rotation file and topologies (from Seton et al, 2012) into GPlates:

- Seton_etal_ESR2012_2012.1.rot
- Seton_etal_ESR2012_Coastlines_2012.1.gpmlz
- Seton_etal_ESR2012_PP_2012.1.gpmlz

You should see the present day image appear within South America (Figure

17).

As with the previous example, it is important to set the Anchored Plate ID to 201 (South America).

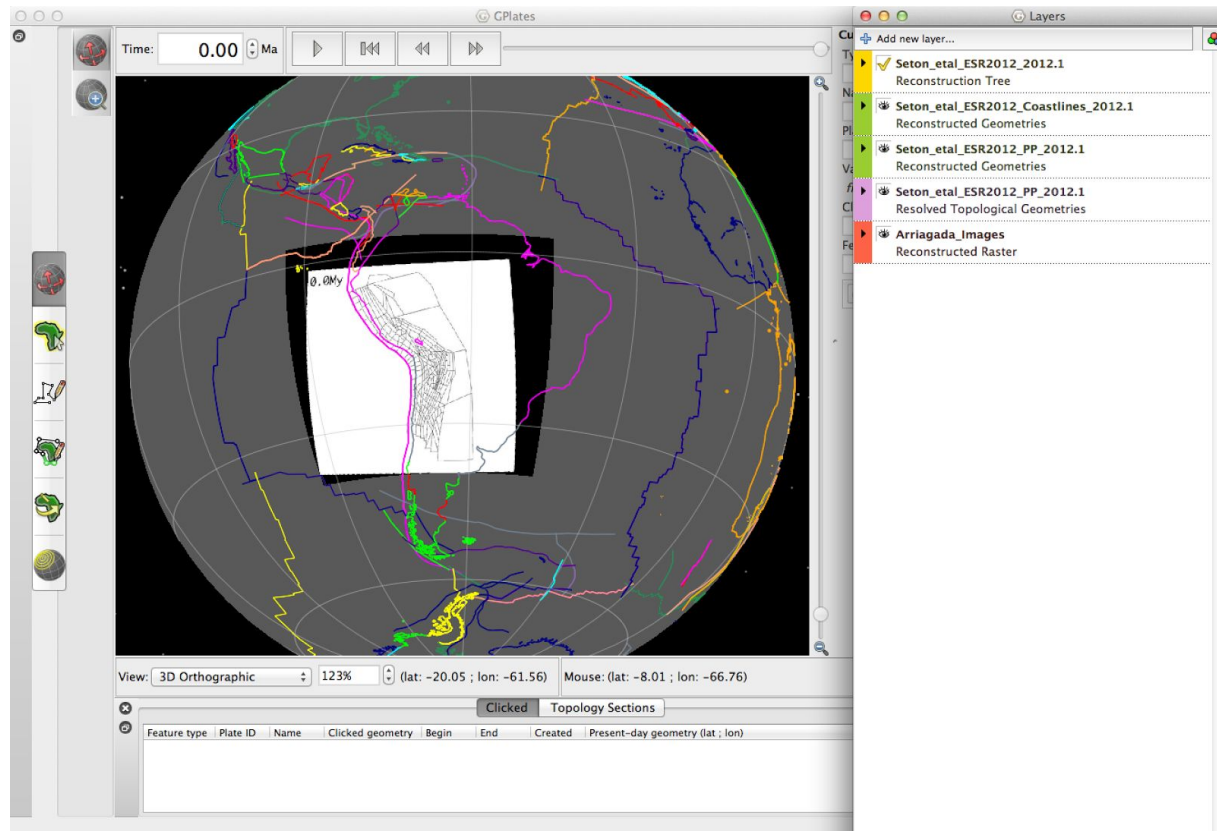


Figure 17: Present day reconstruction image over South America

3. Zoom in on South America, then change the reconstruction time to 45 Ma. You should see the Andean margin based on the Arriagada et al (2008) time dependent raster sequence, lying >400 km to the west of the Andean margin represented in the rigid plate geometries (Figure 18).

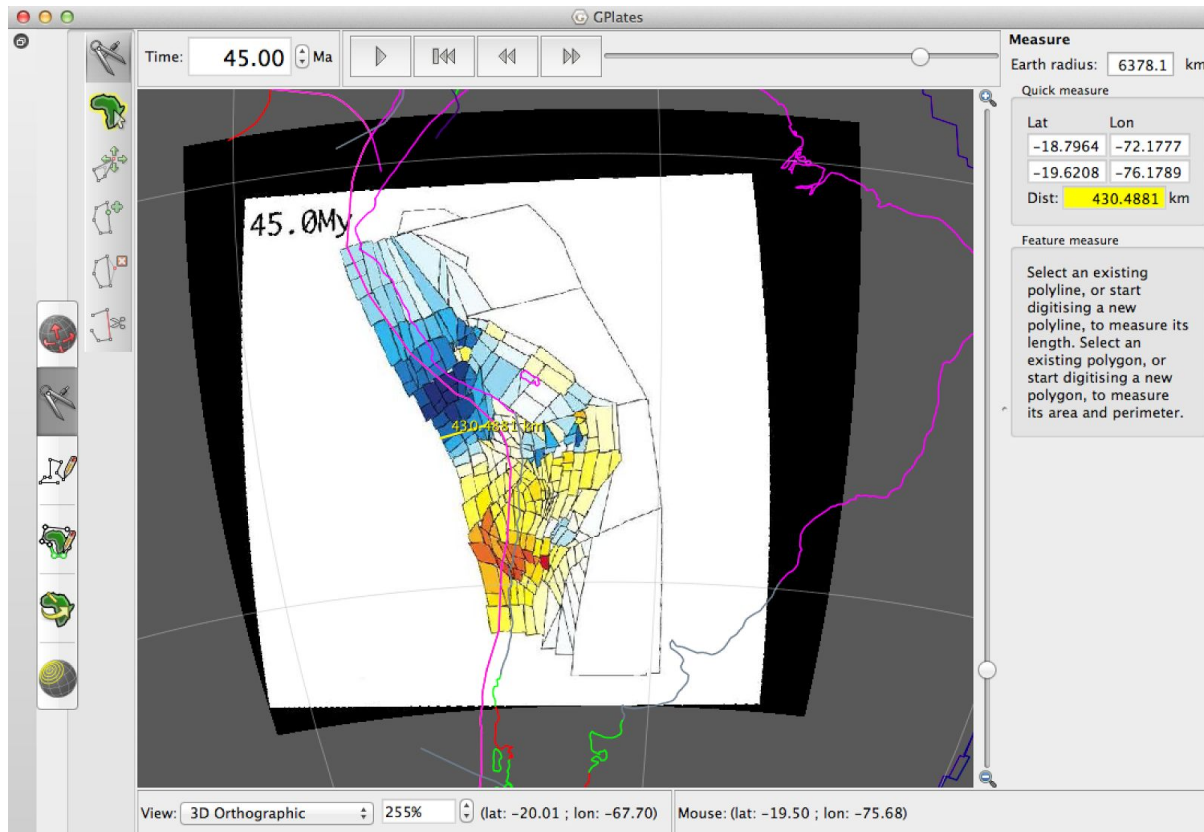


Figure 18: Andean margin at 45 Ma based on the Arriagada et al (2008) raster sequence (Step 3).

Part 2: Create deformation tracker points

In actuality, deformation tracker points are just points with their own Plate IDs - so that we can define them with a motion independent from that of one of the 'major' plates like South America. In GPlates, all relative motions are defined by assigning plate IDs and rotation poles, whether this be for a major plate or a single point within a deforming mesh.

1. To create these points for the Andes, first set the reconstruction time to 0 Ma.

Next, you need to decide what level of detail you want to incorporate into your model. The level of detail you employ is entirely up to you, and depends on how much time you want to spend on the task and the purpose of your model. For example, if you were only interested in how the shape of the Andean margin has evolved you could ignore the interior mesh points

entirely. Alternatively you could define mesh points at each vertex of the 257 blocks within the original model. This tutorial illustrates the process with 6 points along the Andean margin and 10 points in the interior zone of crustal deformation.

You then need to decide which points to digitize. For the purposes of this tutorial we will just do ten points (Figure 19).

2. Digitise the desired number of points and assign individual plate IDs sequentially (eg. from 201101 to 201110 if you are digitising 10 points)

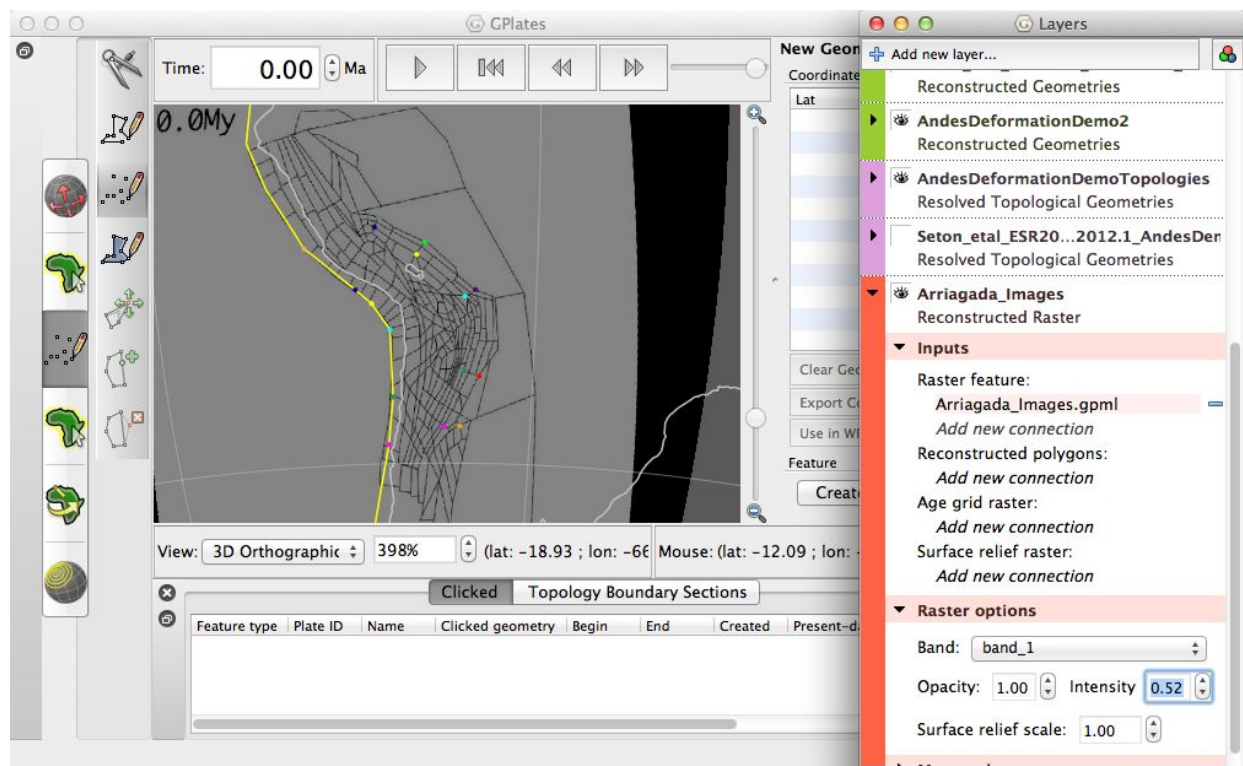


Figure 19: Digitised points in the interior zone of crustal deformation (Step 2)

One further element we need to create is a boundary line that will divide the deforming region from the stable/rigid part of South America.

3. Create this line using the line digitization tool, assigning the feature a Plate ID of 201 - we want the boundary of the deforming region to move with the existing rotations for South America (Figure 20).

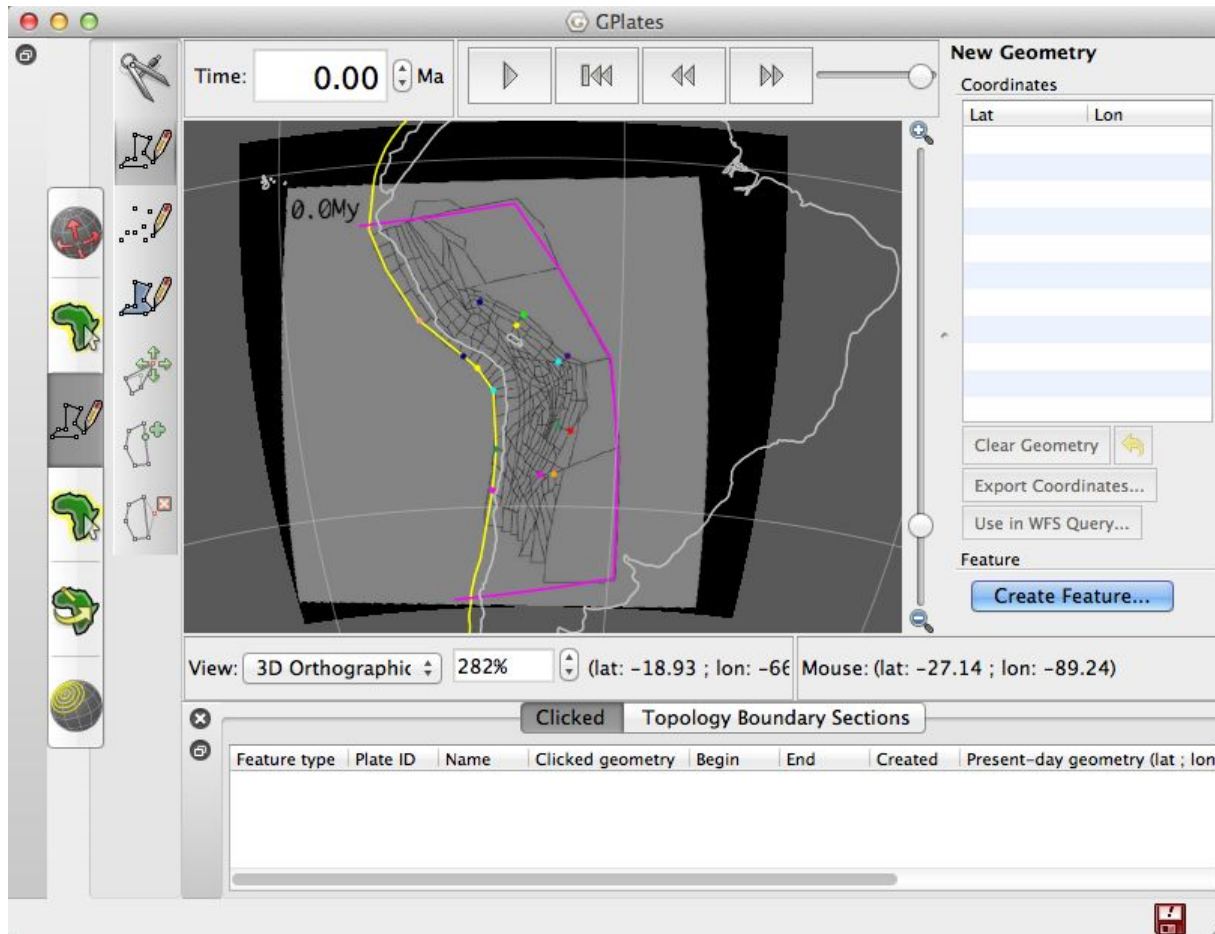


Figure 20: Digitised boundary line that divides the deforming region from the stable/rigid part of South America (Step 3)

Before we start modifying the deformation points we need to repeat the process carried out above (Exercise 1, Part 1, Step 7) to create 'blank' rotations for these points in the local rotation file (the rotation file we just created which contains only rotations for our deforming points).

4. In the text editor, create rotations corresponding to each point and PlateID that you have newly created. Save the edits in the text editor, then 'reload' the rotation file using the button on the 'Manage Feature Collections' window.

5. Set the reconstruction time to some time in the past that corresponds to the most recent time in the past you want to create point displacements for, and which corresponds to a timeslice in the underlying time-dependent rasters. (in the example below we skip the 5 Ma and 10 Ma snapshots and use 15 Ma - it is up to you whether you want to capture more timeslices).

6. Use the change rotations tool as before, to create motion histories for each point, dragging each point to the polygon intersection in the 15 Ma image that corresponds to the same polygon intersection at 0 Ma (Figure 21), but shifted by the deformation model.

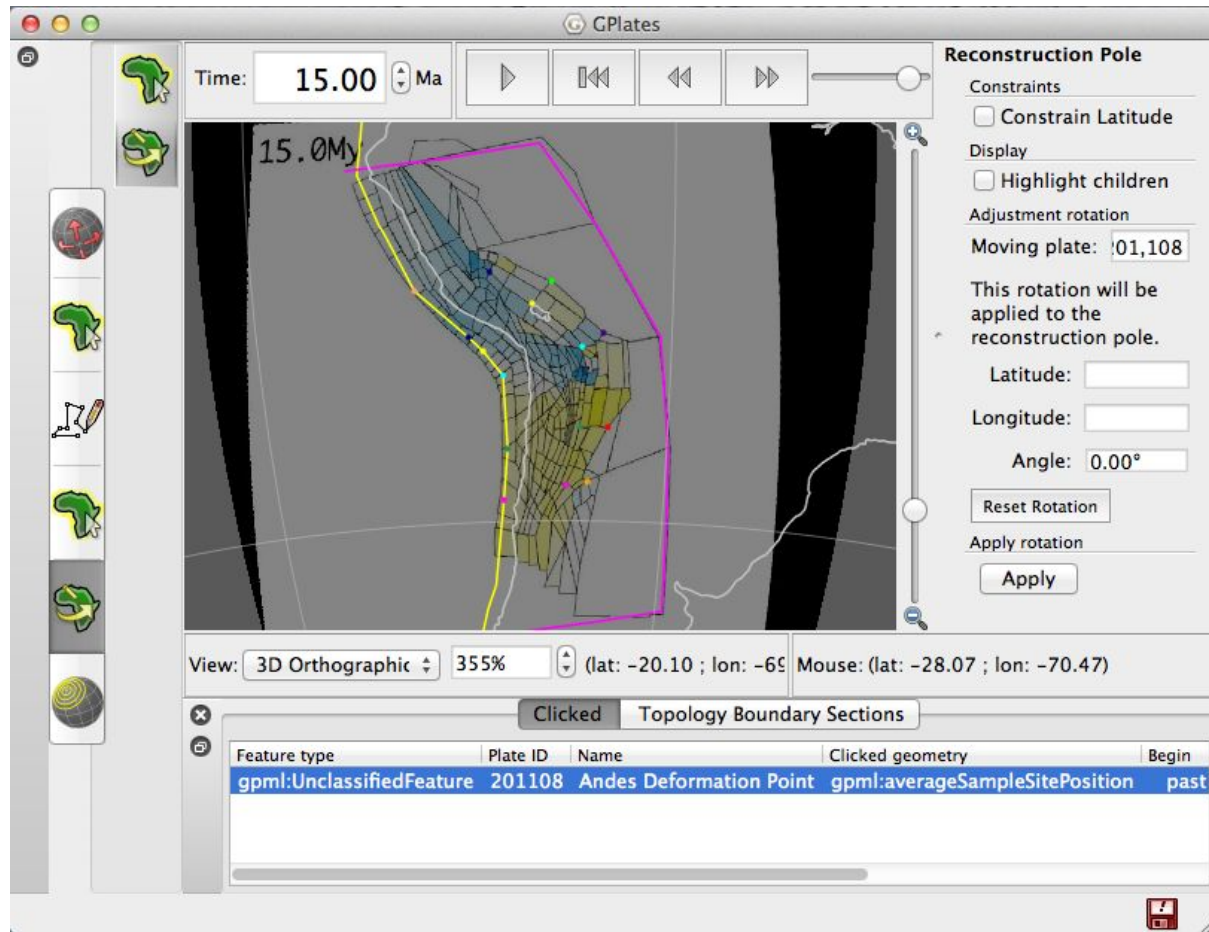


Figure 21: Modifying rotations to create motion histories for each point at 15 Ma (Step 6).

7. Repeat this process (Step 6) for each of the ten points at 15 Ma.

8. Repeat Steps 5-7 for 30 Ma and 45 Ma

Part 3: Create a Topological Mesh over the Deformation Region

1. To create a deforming network topology, select the Topology tools menu on the left, then select the 'Build New Network Topology' tool (Figure 22).

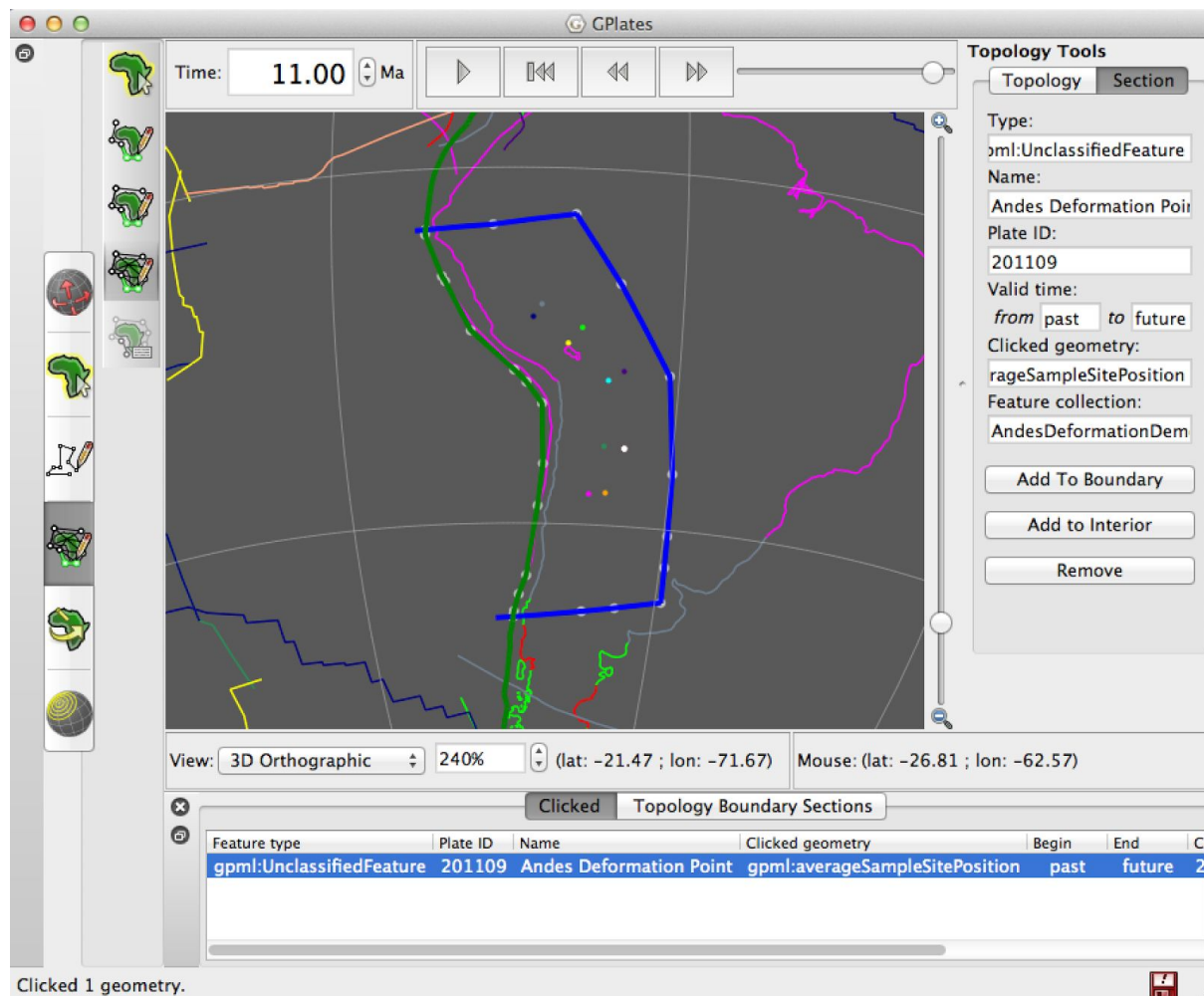


Figure 23: Blue and green lines have been added to the boundary of the new topological network

2. Add the appropriate points to the boundary (blue and green lines in Figure 23) .
3. We then add all the deformation points within the Andes as interior points, then select 'Create', select 'TopologicalNetwork'.

The result should look something like Figure 24 (if your network does not appear, expand the options in the Layer window and select the Triangulation Colour Mode as 'Dilatation strain rate' the colouring here has been modified - this can be done in the layer manager, however you must 'update' before colouring is applied).

As you reconstruct back and forward through time the mesh should evolve

according to the motion of the various geometries involved in the topology.

Note that topological Network layers appear in the layer manager in gold.

4. At this point, save the newly featured topological network to a feature collection (gpml format).

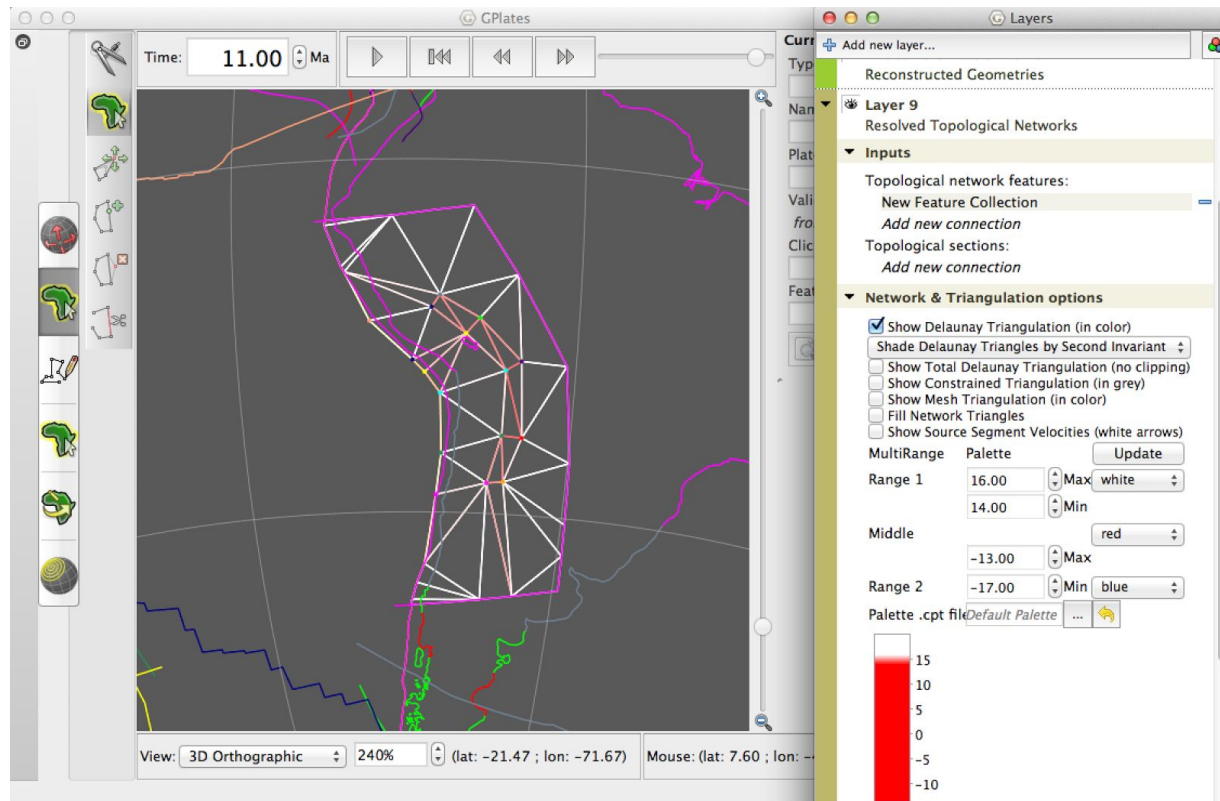


Figure 24: Final topological mesh

Additional Exercises

Firstly, note that what we just did was not completely self-consistent. We ended up with a deforming plate boundary based on the McQuarrie (2002) shortening estimates, but the interior points based on the block reconstruction of Arriagada et al (2008). Since they are two different

approaches to the same restoration, you may want to compare the two (both the end result in GPlates, and the different methodologies and observations used by reading the original papers). Other similar reconstructions have also been proposed (e.g. Kley, 1999, see reference list).

At this point, you may want to explore some of the ways we can visualise the deformation implied by the mesh you have created. For example:

1. Loading velocity features such as mesh caps - see the 'Velocity Fields' Tutorial
2. Expand the Network layer in the Layer Manager and explore the options under 'Network and Triangulation Options'. This provides options to colour each triangular element of the mesh based on the instantaneous deformation implied.
3. Following on from Exercise 2, think about how the deforming mesh can be incorporated as a deforming region into the global plate set of topological plate polygons.

References

- Arriagada, C., Roperch, P., Mpodozis, C., & Cobbold, P. R. (2008). Paleogene building of the Bolivian Orocline: Tectonic restoration of the central Andes in 2-D map view. *Tectonics*, 27(6), doi:10.1029/2008TC002269
- Kley, J. (1999). Geologic and geometric constraints on a kinematic model of the Bolivian orocline, 12, 221–235.
- McQuarrie, N. (2002). Initial plate geometry, shortening variations, and evolution of the Bolivian orocline. *Geology*, 30(10), 867.
- Seton, M., Müller, R. D., Zahirovic, S., Gaina, C., Torsvik, T., Shephard, G., Talsma, A. & Chandler, M. (2012). Global continental and ocean basin reconstructions since 200Ma. *Earth-Science Reviews*, 113(3), 212-270.