

TopoChronia: A QGIS Plugin to Create Topographic and Geographic Maps of the Earth Geological Past from the PANALESIS Plate Tectonic Model

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Summary

Reconstructing the palaeogeography and palaeotopography of the Earth has been a challenge since the advent of the plate tectonics theory in the 1960s. With the development of geographic information systems (GIS), many plate tectonics models have been created and allowed researchers to reconstruct the movements of plates back in time (up to 1 billion years for some models), based on geological evidence found in the present-day Earth.

We present TopoChronia, a QGIS plugin that converts input data from plate tectonic models into quantified and synthetic topography. This plugin is optimized to work with the PANALESIS model, because it is the only one currently providing sufficient information in terms of geological features to reconstruct a fully quantified topography.

Statement of need

Most of the plate tectonic models and reconstructions use the standalone GPlates software [GurnisPlateTectonicReconstructions2012], which allows users to move plates in time steps and export geospatial data layers. These layers can later be used in GIS software, such as the QGIS plugin TerraAntiqua [aminovPaleogeographicReconstructionsUsing2023], to reconstruct palaeotopography. Other models, such as PANALESIS [verardPanalesisGlobalSynthetic2019], are created and have processing functionalities that use commercial GIS software (ArcGIS). A preliminary version of the code to generate topography of the Earth based on PANALESIS past was developed as an ArcGIS extension, written in Visual Basic .NET but never published. It is now fully updated as a QGIS plugin in Python.

Constraining the palaeotopography is critical in fields such as climate and mantle dynamics modelling, as the elevation of land and bathymetry of oceans are used to set the initial conditions of models [belloAssessingRoleSlab2015; ragonAlternativeClimaticSteady2023]. Quantifying the Earth's topography and its evolution also allows to estimate the volume of rocks being eroded, for instance through sediment discharge [lysterPredictingSedimentDischarges2020], as weathering or silicate rocks is a key controlling factor of CO₂ concentration in the atmosphere over geological time scales [molnarLateCenozoicUplift1990; macdonaldArccontinentCollisionsTropics2019].

The traditional method to create palaeotopographic maps [scoteseAtlasPhanerozoicPaleogeographic2019] is to use present-day geological evidence, rotate them back to their past location and derive semi-quantitative elevation typical of the environment the depict. Another method is to take the present-day Earth topography of an area of interest as it is, and rotate it back in time to its past location [aminovPaleogeographicReconstructionsUsing2023]. These methods have limitations, including that present-day features are the result of millions of years of

42 plate movements and cannot be “copy-pasted” as such, and that one time step might not be
43 coherent with the previous and next ones.

44 We provide here an open-source plugin to reconstruct palaeotopography and palaeogeography
45 “from scratch” using the PANALESIS model, which is based on present-day geological evidence
46 and uses a dual-control approach, meaning that one reconstruction is based on the state
47 of the Earth in the previous time-step, and influences the next step. Synthetic values for
48 elevations are generated in nodes (points) related to geological settings and based on their
49 present-day counterparts [verardStatisticsEarthsTopography2017]. The output maps of
50 TopoChronia can be used for modelling purposes and to reconstruct sea-level curves, over the
51 Phanerozoic and beyond [verard3DPalaeogeographicReconstructions2015]

52 **Functionalities**

53 TopoChronia is divided into three main parts:

- 54 1. Check Configuration → Assesses the input data files (geometry, fields, values) and allow
55 manual corrections if necessary.
- 56 2. Create Node Grid → Converts input data (lines and polygons) into points containing
57 elevation values, based on the age of various types of geological settings, including
58 mid-oceanic ridges, isochrons, abandoned arcs, continents, cratons, lower subduction,
59 upper subduction, passive margin wedges and continents sides, hot-spots, other margins,
60 rifts and collision zones. Once processed, all nodes are merged and cleaned to avoid
61 clashing between features.
- 62 3. Interpolate to Raster → Creates a raster layer by interpolating the elevation values from
63 the nodes, including post-processing steps such as correcting for water load added to
64 match the reference volume.

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72 **References**