BackStrip v. 5.3

Backstripping of sedimentary strata

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BackStrip is free for academic, non-profit purposes. If you want to use the program for commercial purposes, please contact me at nestor.cardozo@uis.no.

Referencing this program

Please reference the program as: BackStrip by Nestor Cardozo.

Credits

The plots in BackStrip rely on the SM2DGraphView Framework by Snowmint Creative Solutions. Formulas and algorithms are from Allen and Allen (1990) and Watts (2001). A short description is given in the Formulas section.

Introduction

The subsidence of a sedimentary basin can be attributed to three main processes: 1. tectonic subsidence, 2. water and sediment loading, and 3. sediment compaction. Tectonic subsidence is the subsidence of the basement in the absence of water and sediment loads, and it is controlled by tectonic processes responsible for the formation of the basin; water and sediment loading is the subsidence due to the weight of water and sediments; and sediment compaction is the subsidence due to the compaction of the sediments as they are buried.

The shape and magnitude of these three components can be estimated from a stratigraphic column (or a well) using a procedure called *Backstripping* (Allen and Allen, 1990; Watts, 2001). This procedure removes from each layer the effects of sediment compaction and water and sediment loads; thus, extracting from the time-sediment thickness curve, which we construct from the stratigraphic column, a curve that represents tectonic subsidence.

Backstripping assumes that we know how water and sediments load and deform the crust, and how sediments compact as they are buried. There are different types of backstripping depending on the assumptions made to remove water and sediment loads, and to decompact the sediments. The simplest type of backstripping assumes that water and sediment loads are compensated locally by the displaced weight of a column of the weak mantle (the astenosphere), and that the porosity of the sediments decreases exponentially with depth. This type of backstripping is often referred as to *1D Airy backstripping with exponential reduction of porosity*.

Despite its limitations, i.e. loads may not be compensated locally and the porosity of sediments may not decrease exponentially with depth, 1D Airy backstripping is an useful technique to isolate tectonic subsidence and therefore reveal the tectonic processes that created a sedimentary basin. In rift basins, for example, the technique has revealed the typical exponential pattern of tectonic subsidence in post-rift stages. This supports the hypothesis that post-rift subsidence is controlled by thermal cooling and contraction of the lithosphere.

BackStrip is a program to perform *1D Airy backstripping with exponential reduction of porosity*. The program consists of three views: 1. An input view where the data are entered (for a description of the input data and their format see the <u>Conventions</u> section), 2. a backstrip plot where the progressive decompaction of the sediments can be observed, and 3. a tectonic subsidence plot where the total thickness curve, the decompacted curve, the decompacted curve corrected for sediment loads, and the tectonic subsidence curve are shown.

BackStrip makes backstripping easy. The sedimentary units can be easily entered or pasted into a table, backstripping plots can be rapidly produced and edited, and imported into vector drawing programs, or saved for publication. Different sections can be backstripped and compared thanks to the program's document based architecture.

Conventions

Backstripping requires knowledge of the stratigraphy, water depths of deposition, paleo-sea levels, and changes of porosity with depth. These parameters can be entered in the *Input Units* view (Figure 1):

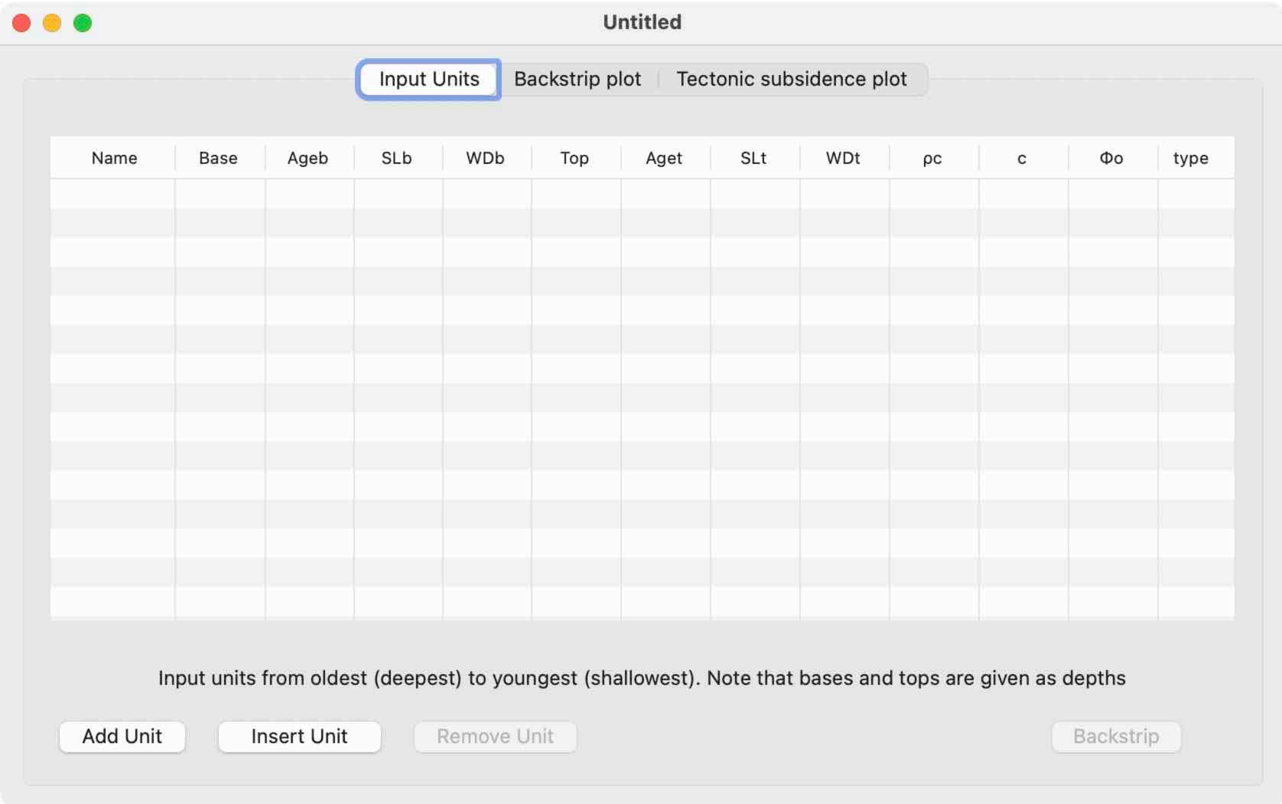


Figure 1. *Input Units* view

The sedimentary units should be entered from the oldest (deepest) to the youngest (shallowest) unit. For each unit, it is necessary to input:

1. The unit base (*Base*) and top (*Top*) as depths in km from a reference level (usually the ground surface).
2. The age of the unit base (*Ageb*) and unit top (*Aget*) in millions of years ago (Ma). Ages should be positive numbers.
3. The sea level at the time of deposition of the unit base (*SLb*) and top (*SLt*) in km. **Please notice that this value should be reported as the difference with respect to the sea level at present.** Positive values indicate sea level above the present level, and vice versa. If the basin is continental (type 1, see item 8 below), *SL* is the paleo-elevation of the top of the basin with respect to the present sea level.

4. The water depth at the time of deposition of the unit base (*WDb*) and top (*WDt*) in km. Water depths should be positive.
5. The *dry* density or grain density (ρ_c) in kg/m^3. The dry density should be a positive number.
6. The porosity coefficient (*c*) in km^{-1}. *c* should be between 0 and 1.
7. The surface porosity (ϕ_0) as percent. ϕ_0 should be between 0 and 100.
8. The type of setting of the basin (*type*). Use 0 to indicate a marine basin, or 1 to indicate a continental basin. If type is 0, any depression is filled with water. If type is 1, any depression is filled with air. The type of setting, marine or continental, affects the correction for sedimentary and water loads (see the Formulas section).

The meaning of each column in the *Input Units* view can be observed by moving the mouse over the column labels. Each label has a "tool tip" associated to it.

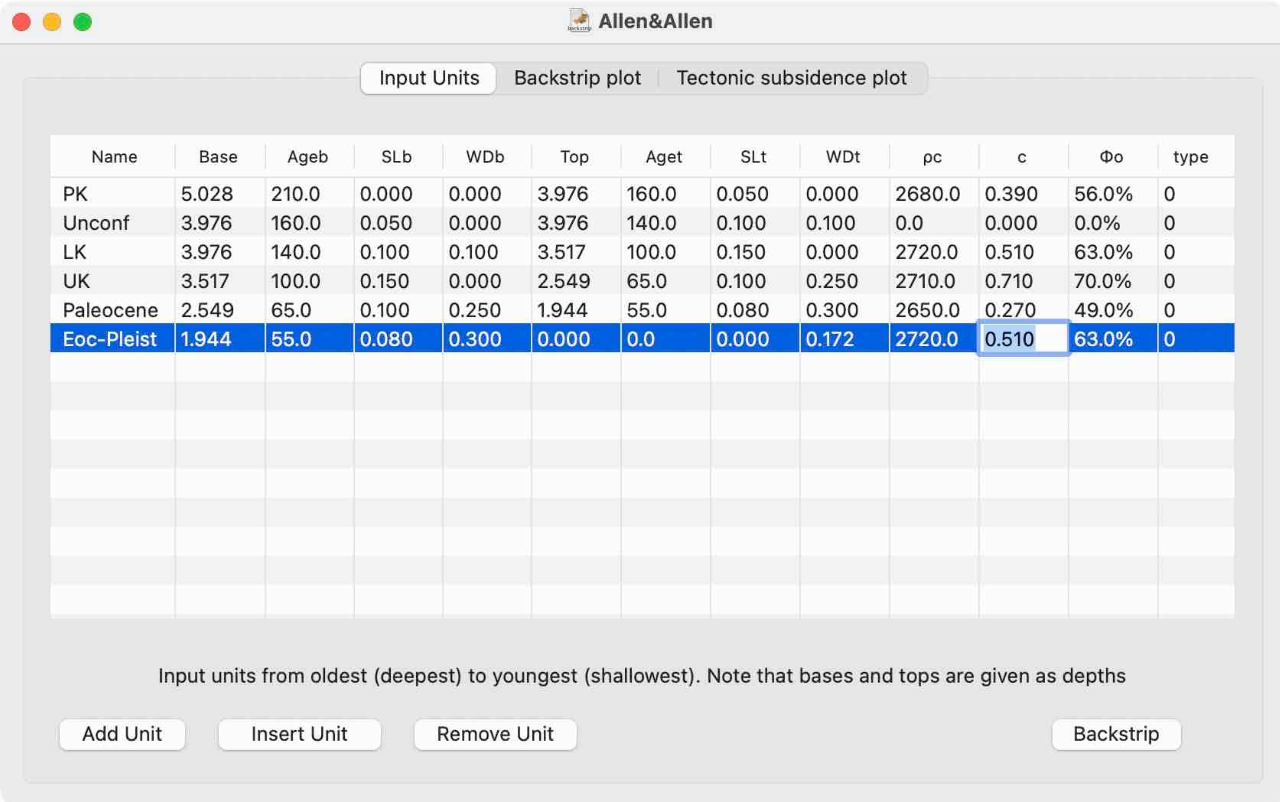
Bases should be deeper and older than tops, and the depth, age, sea level and water depth at the base of a unit should be equal to those at the top of the unit immediately below (**BackStrip** enforces this when adding a new unit). Unconformities represent a gap in the sedimentary record. They should be entered with the same depth for base and top, but with different ages at base and top. See Figure 2 for an example.

Interface

BackStrip consists of three views: 1. An *Input Units* view, 2. A *Backstrip plot* view and 3. A *Tectonic subsidence plot* view. You can choose any of these views by either clicking the tabs on top of the window, using the *Modules* menu, or simply typing ⌘1, ⌘2, or ⌘3, respectively. Backstrip is a *Document based application*. You can open as many documents as you want; each will contain its own analysis.

The *Input Units* view

In the *Input Units* view (Figure 2) you can enter the data. You can add, insert, or remove units by either clicking the *Add Unit*, *Insert Unit*, or *Remove Unit* buttons, choosing the *Add*, *Insert*, or *Remove* submenus in the *Units* menu, or typing ⌘= (add), ⌘I (insert), or ⌘R (remove). You must enter the values in their correct range: Water depths, ages, and densities should be positive, *c* should be between 0 and 1, ϕ_0 should be between 0 and 100, and *type* should be 0 or 1 (see the Conventions section). If not, you will get an error message.



Name	Base	Ageb	SLb	WDb	Top	Aget	SLt	WDt	ρc	c	Φo	type
PK	5.028	210.0	0.000	0.000	3.976	160.0	0.050	0.000	2680.0	0.390	56.0%	0
Unconf	3.976	160.0	0.050	0.000	3.976	140.0	0.100	0.100	0.0	0.000	0.0%	0
LK	3.976	140.0	0.100	0.100	3.517	100.0	0.150	0.000	2720.0	0.510	63.0%	0
UK	3.517	100.0	0.150	0.000	2.549	65.0	0.100	0.250	2710.0	0.710	70.0%	0
Paleocene	2.549	65.0	0.100	0.250	1.944	55.0	0.080	0.300	2650.0	0.270	49.0%	0
Eoc-Pleist	1.944	55.0	0.080	0.300	0.000	0.0	0.000	0.172	2720.0	0.510	63.0%	0

Figure 2. Entering data in **BackStrip**

When entering data, you can undo (*Undo* submenu in the *Edit* menu or ⌘Z) or redo (*Redo* submenu in the *Edit* menu or ⇧⌘Z) changes. When adding units you will notice that the program automatically sets the depth, age, sea level and water depth at the base of a new unit equal to those at the top of the unit below. This should always be the case. The program does not do this when inserting or removing units. Thus, you are responsible for keeping the data at the base of a unit equal to the data at the top of the unit below. If not, you will get an error message when trying to backstrip.

Adding units from the pasteboard or a text file

If you find cumbersome entering the units in the program's table, you can enter them in a text editor or in a spreadsheet program. Type the units as in **BackStrip**. If in a text editor, use spaces, commas, or tabs to separate the entries, and use the return key to start a new unit. Make sure to type all (13) entries for a unit, and follow the conventions of the program. You can either copy and paste this information into the *Units* table, or you can save the file as a text file (txt extension). You can then drag and drop the file into the *Units* table. In any case, if there are no errors, the units will be loaded.

If there are errors, for example if the depth, age, sea level and water depth at the base of a unit are not equal to those at the top of the unit below (including the units that may already in the table), the units will not be added. **BackStrip** is very picky when adding units from the pasteboard or a text file. Sorry, you need to be careful. Please notice that dragging and dropping a file in to the *Units* table only works with a text file.

You can save the units data by either choosing the *Save* submenu in the *File* menu, or typing ⌘S. The program will create a file with extension backstrip.

Backstripping

Once the units are entered, you can backstrip them by either clicking the *Backstrip* button, choosing the *Backstrip* submenu in the *Units* menu, or typing ⌘B. If the data contain no errors you will see the *Backstrip plot*. If there are errors, they will be reported sequentially until you correct all. Notice that **BackStrip** does not update automatically the *Backstrip plot* and *Tectonic Subsidence plot* upon changes in the *Input Units*. You will need to click the *Backstrip* button in order to update the plots.

The Backstrip plot view

Before backstripping the units, the *Backstrip plot* view is not very exciting. It shows just a blank graph and a table without data. When you backstrip the data, the program shows the results in the *Backstrip plot* view, in a graph and a table (Figure 3):

The Tectonic subsidence plot view

Before backstripping the units, the *Tectonic Subsidence plot* view is not very exciting. It shows just a blank graph and a table without data. When you backstrip the data, **BackStrip** shows the results in the *Tectonic subsidence plot* view, in a graph and in a table (Figure 4):

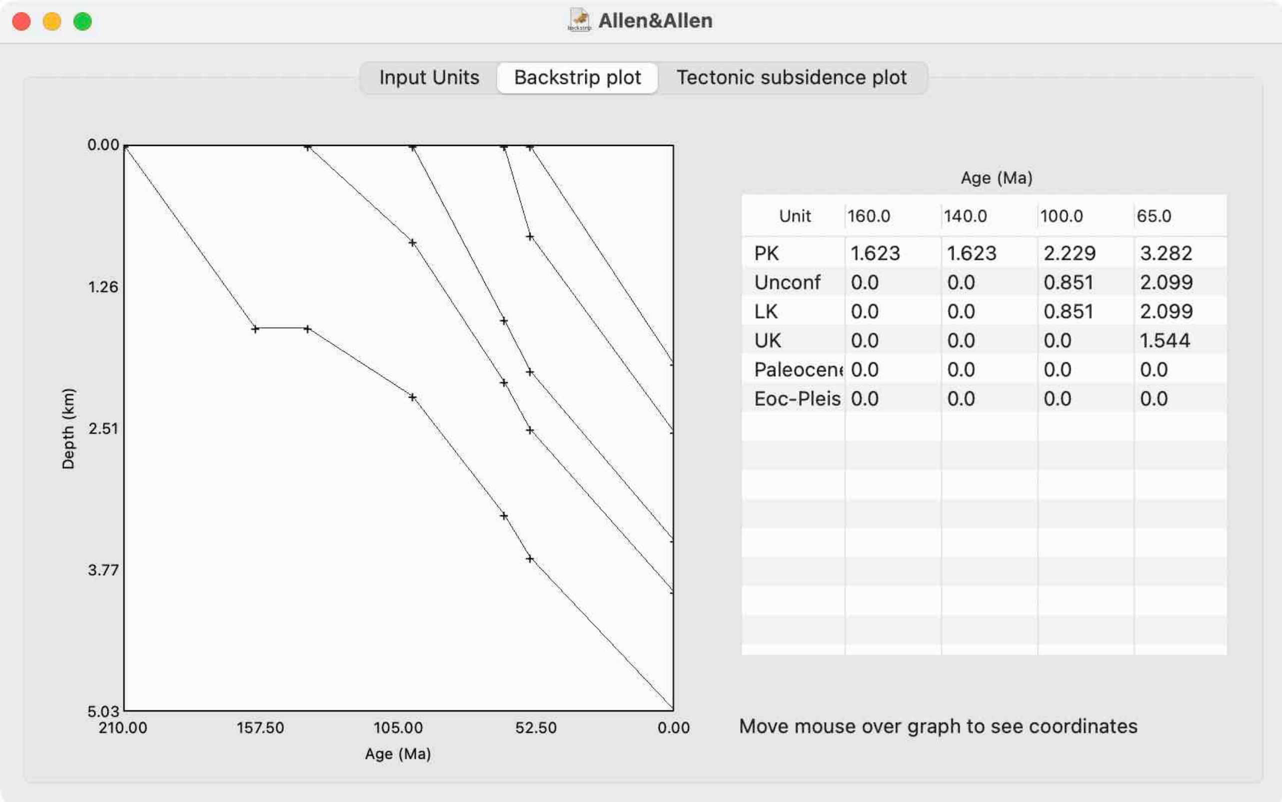


Figure 3. *Backstrip plot* after backstripping

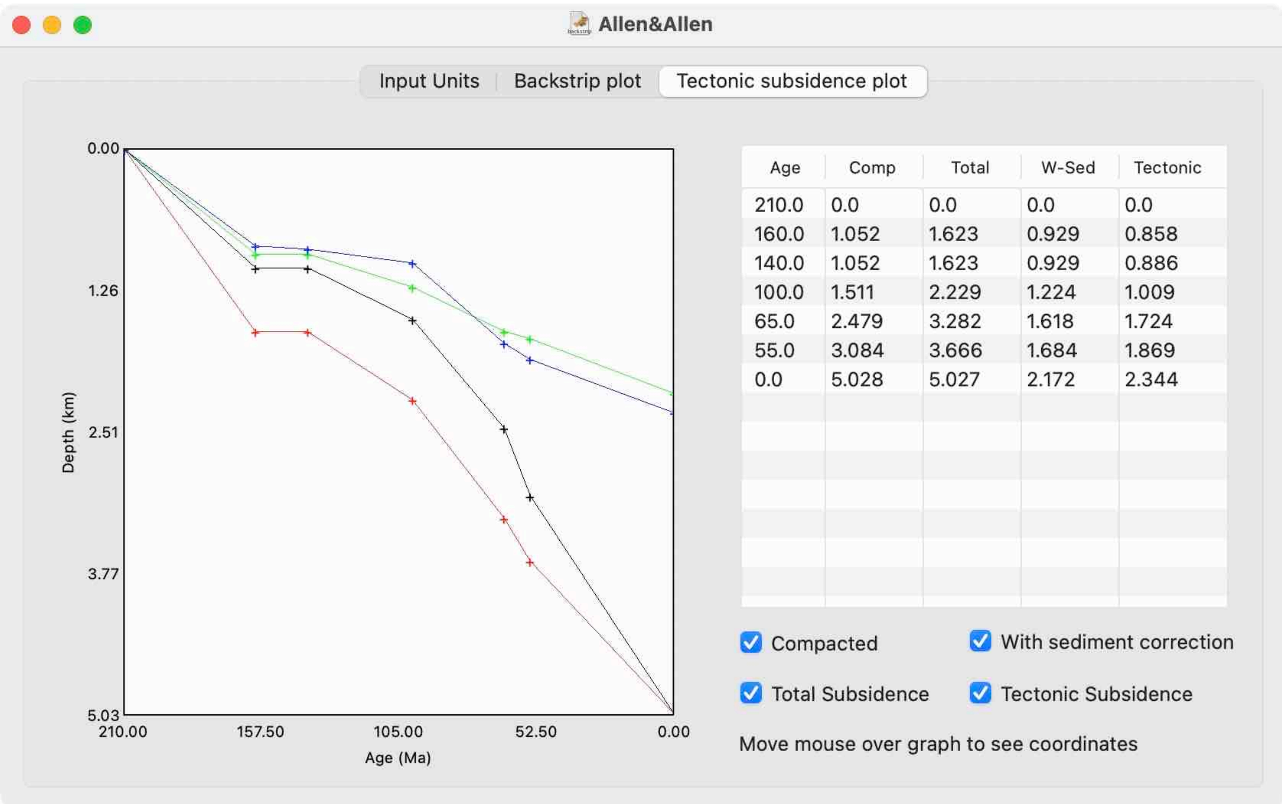


Figure 4. *Tectonic subsidence plot* after backstripping

By default the program plots the compacted (total thickness as of today) curve in black, the total subsidence (decompacted) curve in red, the decompacted curve after sediment loading correction in green, and the tectonic subsidence curve in blue. You can toggle on/off these curves using the buttons below the table. In both, the Backstrip and Tectonic subsidence plots, you can move the mouse over the graph to see the coordinates.

Changing parameters and editing plots

You can change some model parameters and edit the plots by either choosing the *Inspector* submenu in the *Tools* menu, or typing ⇧⌘I. This will open the *Inspector* panel (Figure 5):

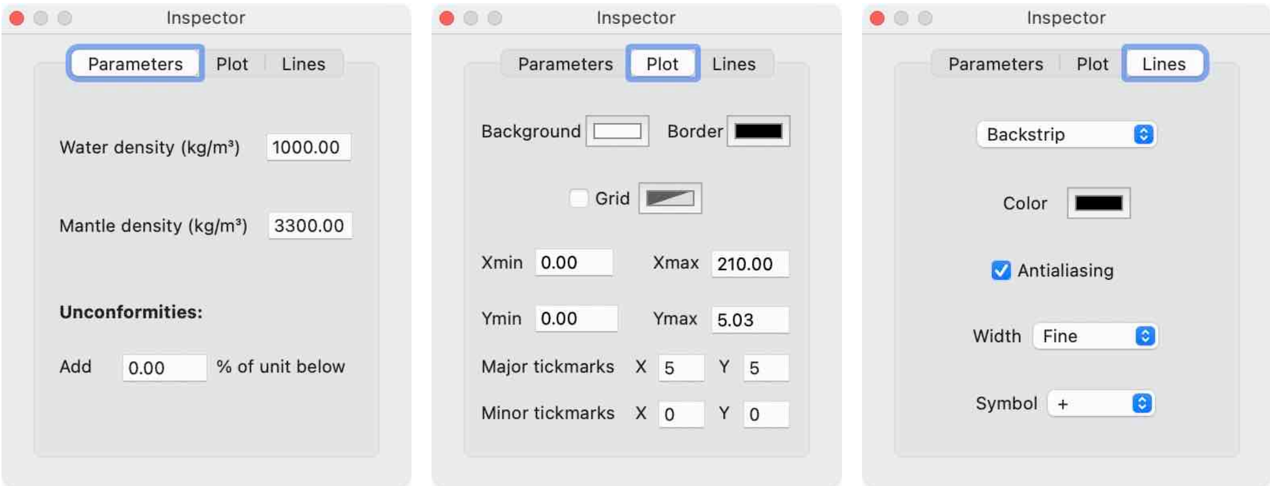


Figure 5. *Inspector* panel. Parameters (left), Plot (middle), and Lines (right) views

The *Inspector* panel has three views: The *Parameters* view for setting water and mantle densities and adding sediment material below unconformities, the *Plot* view for setting general plot parameters, and the *Lines* view for setting line properties.

In the *Parameters* view, the text field in the Unconformities section, allows adding sediments below the unconformities. These represent the sediments eroded during the unconformity events. The sediments to be added below unconformities should be specified as the percentage of the present/compacted thickness of the units below the unconformities.

The use of the *Inspector* is straightforward. Try changing the water or mantle density, you will see that the program automatically updates the tectonic subsidence plot. The inspector is a great way to edit the plots for publications and presentations. In the *Lines* view, you can choose the line to edit (backstrip, compacted, total subsidence, etc.) using the first pop up button.

Changes in the *Inspector* affect the document currently selected. Also, the *Inspector* contents update according to the document selected. The settings in the *Inspector* are saved to backstrip files. These files, however, contain only the *Input Units* and the *Inspector* settings. After opening a backstrip file, you will need to press the *Backstrip* button to get the results.

Saving plots

You can save the plots produced by **BackStrip** as pdf. Just choose the *Save Plot as PDF* submenu in the *File* menu.

Copy and paste

You can drag plots to vector programs, and the content of the tables to text editors and spreadsheet programs. You can also drag these elements to the Finder to make a pdf of a plot, or a text clipping of the selected data. You can also copy and paste table data using the *Copy* (⌘C) and *Paste* (⌘V) submenus.

Preferences panel

You can choose whether or not to open new documents when starting the program, through the *Preferences* panel (⌘, Figure 6).

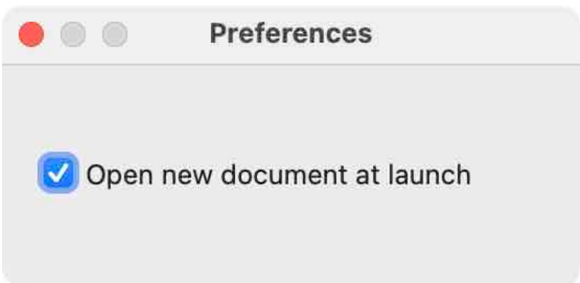


Figure 6. The *Preferences* panel

Formulas

BackStrip formulas are based on Allen and Allen (1990) and Watts (2001):

Exponential decrease of porosity with depth:

$$\phi = \phi_0 \exp(-cy) \quad (1)$$

where c is the porosity coefficient, ϕ_0 is the surface porosity, and ϕ is the porosity at depth y.

General decompaction equation:

$$y_2' - y_1' = y_2 - y_1 - \frac{\phi_0}{c}[\exp(-cy_1) - \exp(-cy_2)] + \frac{\phi_0}{c}[\exp(-cy_1') - \exp(-cy_2')] \quad (2)$$

where y_1' and y_2' are the base and top a unit before compaction, and y_1 and y_2 are the present base and top of the unit after compaction.

Sediment loads correction:

Marine basin (type 0):

$$Y = S\frac{(\rho_m - \rho_s)}{(\rho_m - \rho_w)} \quad (3)$$

Continental basin (type 1):

$$Y = S\frac{(\rho_m - \rho_s)}{\rho_m} \quad (4)$$

where Y is the depth to the basement corrected for sediment load, S is the total thickness of the sedimentary column corrected for compaction, and ρ_m, ρ_s, and ρ_w are the mantle, mean sediment and water densities, respectively. Note that in a marine basin (type 0), any depression is filled with water. Therefore the restoring force is proportional to $(\rho_m - \rho_w)$.

In a continental basin (type 1), any depression is filled with air which has a density near zero. Therefore the restoring force is proportional to ρ_m.

Water loads correction:

Marine basin (type 0):

$$Y_t = Y - SL\frac{\rho_w}{(\rho_m - \rho_w)} + (W_D - SL) \quad (5)$$

Continental basin (type 1):

$$Y_t = Y - SL \quad (6)$$

In a marine basin (type 0), SL is the **difference** in sea level with respect to the present sea level, and W_D is water depth. In a continental basin (type 1), SL is the paleo-elevation of the top of the basin with respect to the present sea level. Note that in a continental basin, it does not make sense to talk about water depth, since there is no water filling the basin.

References

Allen, P.A. and Allen, J.R. 1990. Basin Analysis, Principles and Applications. Blackwell Scientific Publications.

Watts, A.B. 2001. Isostasy and Flexure of the Lithosphere. Cambridge University Press.