met1D_GL3520: a MATLAB program for exploring metamorphic geothermal gradients and PTt paths

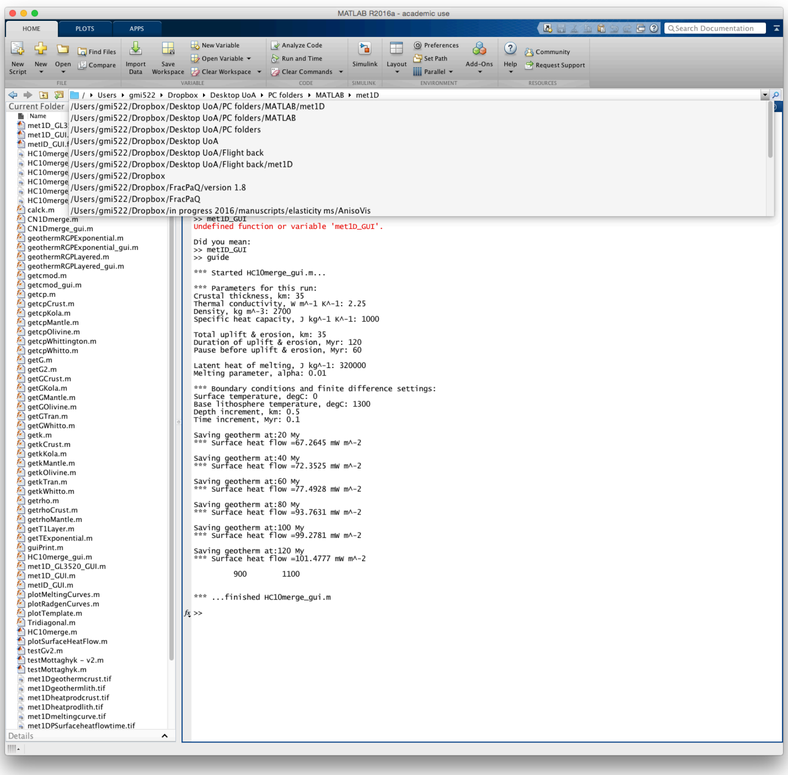
This document is a basic user guide to running met1D_GL3520. The program runs on any computer with a current licence of MATLAB. Standard classroom computers at the University of Aberdeen all have MATLAB installed: on the Desktop, click on the folder shortcut to Physical Sciences and then Geosciences, Geology & Petroleum Geology. Or, you can get your own copy of MATLAB (for free) from the Software Download Service:

https://www.abdn.ac.uk/it/student/pcs/sds.php

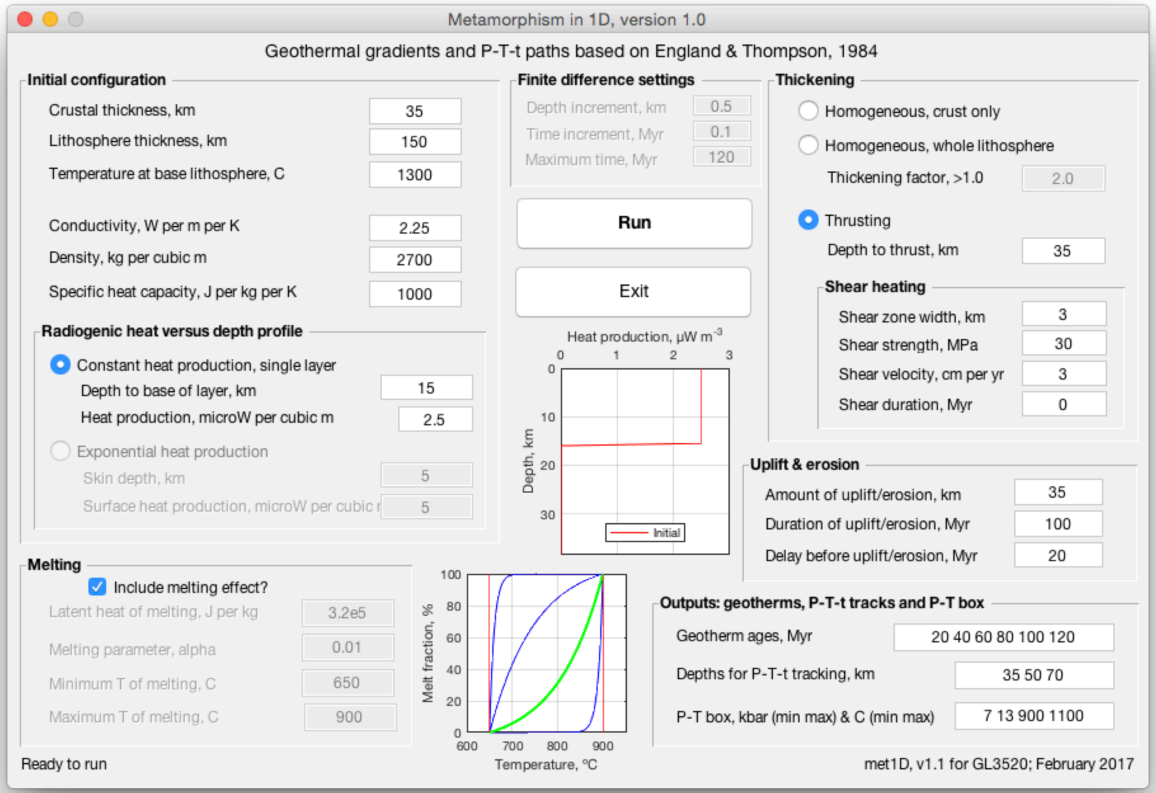
Instructions for installation of met1D_GL3520

0. Download and install MATLAB, if necessary.
1. Download the met1D_GL3520.zip file from:
   http://uk.mathworks.com/matlabcentral/fileexchange/61600-met1d

2. Extract all the program files into your own folder, e.g. met1D
3. Start MATLAB.
4. In MATLAB, change the current folder or directory to the folder you just created for the code (e.g. met1D), using the drop down list box towards the top of the screen, or the folder tree display on the left hand side:



5. Type “met1D_GL3520_GUI” (drop the quotes) at the command prompt (“>>”) and press enter (or return). The following screen should be displayed:



6. If any of the labels or text boxes are truncated or obscured, you can enlarge the window by clicking on the sides and dragging, or maximising it to fill your screen.
7. Some fields are inaccessible and greyed out: this is deliberate, as we won’t be using them in this course.
8. First time around, click on Run and see what happens. You should see plots appearing on your screen (9 in total), messages being printed in the MATLAB command window, and eventually 9 *.tif files in your folder (1 for each plot).
9. If all this works, you have successfully installed met1D ☺ If not, check back through the steps 1-8 above.

Using met1D_GL3520 to explore geothermal gradients and PTt paths

The code solves the partial differential equation described by England & Thompson (1984) for heat flow in a 1-dimensional section of the crust and lithosphere. The solution uses the finite difference method for fixed increments of depth (0.5 km) and time (0.1 million years). In detail, the code solves a modified version of the England & Thompson (1984) equation, as described in Clark et al. (2011) and used by Clark et al. (2015), to include the temperature dependence of thermal conductivity and specific heat capacity, and heat from partial melting in the crust.

The main window in met1D_GL3520 is broken down into sections for ease of use.

Initial configuration

The fields in this area of the screen control the initial settings for the crust and lithosphere template before metamorphism. The default values displayed on start up are all reasonable averages, but you may wish to change these for specific models. Click on the appropriate text box and type in your new value. Pay attention to the units displayed in the labels to the left.

Radiogenic heat versus depth profile

These input fields control the initial distribution of radiogenic heat production. A simple 2-layer model of constant radiogenic heat production down to a certain depth, and then zero radiogenic heat production beyond that is used. More complex models (e.g. exponential decrease in radiogenic heat production with depth) are possible, but we won't explore these in this class. Remember: most of the radiogenic heat producing elements are concentrated in the upper crust, so the depth to the base of this layer should be less than the crustal thickness entered above (Initial configuration).

Thickening, and shear heating

Following England & Thompson (1984), three modes of thickening are available in the model. The first two are: 1) homogeneous thickening of the crust only; 2) homogeneous thickening of the crust + underlying lithospheric mantle. Homogeneous in this case means the thickening strain is distributed evenly with depth. For either of these two choices, simply enter a thickening factor e.g. a value of 2 means an instantaneous doubling of the crust or lithosphere thickness at the start of the model (time $t = 0$). The third alternative is for thickening along a discrete or localised thrust, and here you need to supply the depth of the thrust in km. In this case, you can also specify parameters for shear heating along this thrust. Enter values for shear zone width, shear strength, shear velocity and shear duration. To "switch off" the shear heating contribution to the heat budget in the model, simply enter 0 for the shear duration.

Uplift & erosion

A fundamental component of the model developed by England & Thompson is the inclusion of the effects of uplift and erosion on the heating within thickened crust and lithosphere. Input fields are provided for the total amount of uplift and erosion (assuming that erosion = uplift, i.e. the crust top surface is always maintained at sea level), the duration of the uplift and an optional delay before the uplift begins.

Outputs: geotherms, P-T-t tracks and P-T box

Here you can enter your choices for the time intervals of the geotherms (geothermal gradients) you wish to see modelled: the default values are for every 20 Myr up to the maximum modelled time of 120 Myr. You can also select a range of specific depth points to be tracked in the form of P-T-t paths. Note that these depths are post-thickening. You can also enter pressure (P) and temperature (T) limits of a rectangular box of interest in P-T space. The default values of "7 13 900 1100" refer to the lower and upper limits of ultra-high temperature metamorphism (P_{min} = 7 kbar, P_{max} = 13 kbar, T_{min} = 900 C, T_{max} = 1100 C) as discussed in Clark et al. (2011 & 2015). You could use a metamorphic facies diagram to define alternative regions of P-T space that may be of interest.

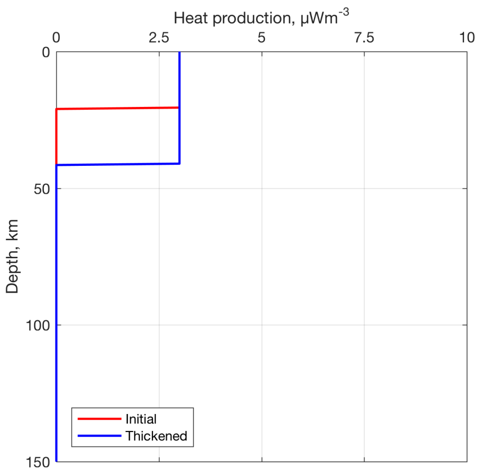
<u>Running models</u>

When you have completed your editing of the various fields, just click the button marked Run to start the calculations. It takes a second or two for plots to appear, as the calculations are not trivial. There should be 8-9 figures in all (8 if you 'switched' melting off, 9 if you left meting on). To finish with met1D, click Exit or close the window using the corner controls.

Examples of the various plots & figures

met1D_GL3520 produces 8 or 9 output plots, and saves each one automatically to a corresponding *.tif file in your working folder. To save these model outputs in between successive runs of the code, you will need to edit the filenames of these *.tif files BEFORE you run another model.

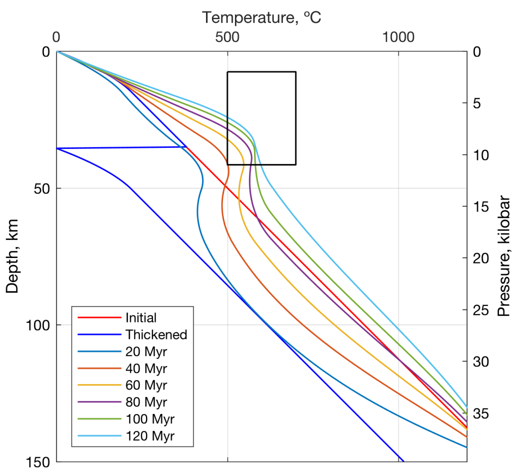
<u>Figure 1 – Heat production profile for the lithosphere</u>



This figure shows the radiogenic heat production profile over the whole depth range of the lithosphere, based on the values entered in the main window. The two-layer model is clearly shown, with an upper layer of radiogenic heat producing elements, and beneath that zero heat production from this source. Separate lines are drawn for the profile before (red) and after (blue) instantaneous thickening at t = 0.

This figure is saved as met1Dheatprodlith.tif in the current working folder.

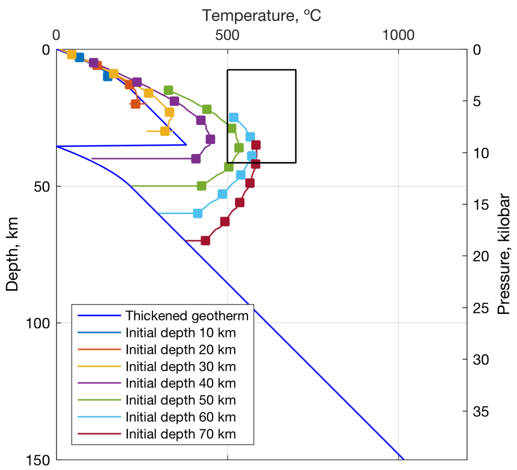
<u>Figure 2 – Geothermal gradients for the lithosphere</u>



This figure shows the evolution of geothermal gradients over the run time of the model (120 Myr), over the whole depth range of the lithosphere. Geotherms are shown for the time intervals selected by the user, and for the initial (pre-thickening, red) and thickened lithosphere (blue at t = 0). The selected P-T box is drawn in black.

This figure is saved as met1Dgeothermlith.tif in the current working folder.

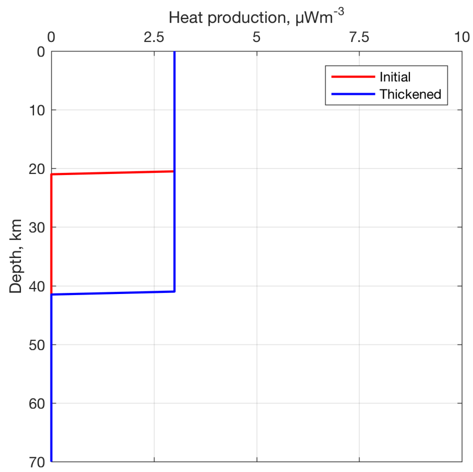
Figure 3 – P-T-t paths for the lithosphere



This figure shows evolution of P-T-t paths over the run time of the model (120 Myr), over the whole depth range of the lithosphere. P-T-t paths are shown for the (post-thickening) depths selected by the user, with symbols at each time interval corresponding to the geothermal gradients displayed in the previous figure. The selected P-T box is drawn in black.

This figure is saved as met1DPTtlith.tif in the current working folder.

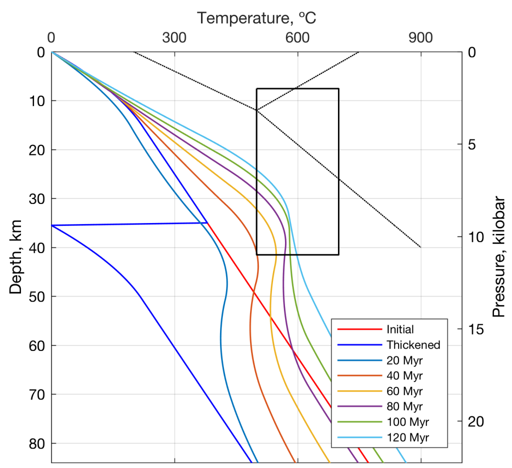
Figure 4 – Heat production profile for the crust



This figure shows the radiogenic heat production profile zoomed in to the depth range of the crust, based on the values entered in the main window. The two-layer model is clearly shown, with an upper layer of radiogenic heat producing elements, and beneath that zero heat production from this source. Separate lines are drawn for the profile before (red) and after (blue) instantaneous thickening at $t = 0$.

This figure is saved as met1Dheatprodcrust.tif in the current working folder.

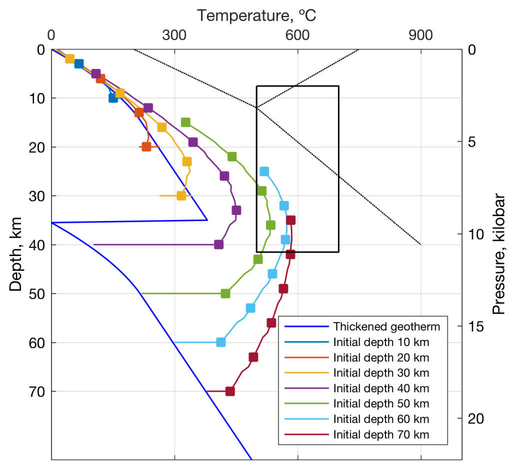
Figure 5 – Geothermal gradients for the crust



This figure shows the evolution of geothermal gradients over the run time of the model (120 Myr), zoomed in to the depth range of the crust. Geotherms are shown for the time intervals selected by the user, and for the initial (pre-thickening, red) and thickened lithosphere (blue at $t = 0$). The selected P-T box is drawn in black.

This figure is saved as met1Dgeothermcrust.tif in the current working folder.

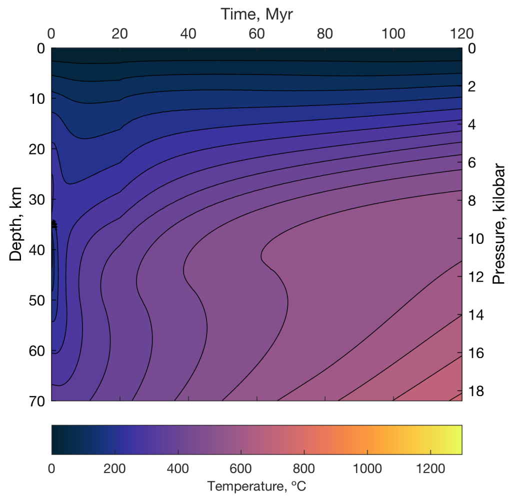
Figure 6 – P-T-t paths for the crust



This figure shows evolution of P-T-t paths over the run time of the model (120 Myr), zoomed in to the depth range of the crust. P-T-t paths are shown for the (post-thickening) depths selected by the user, with symbols at each time interval corresponding to the geothermal gradients displayed in the previous figure. The selected P-T box is drawn in black.

This figure is saved as met1DPTtcrust.tif in the current working folder.

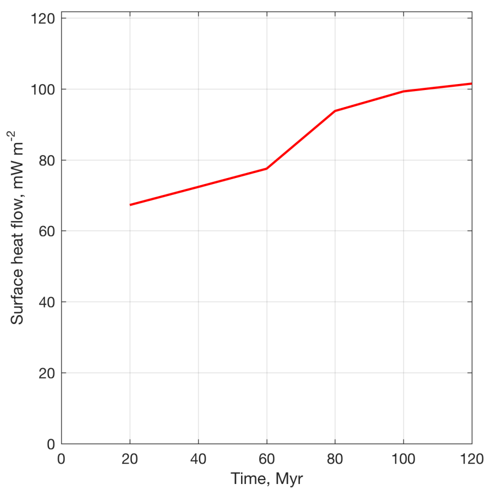
Figure 7 – Temperature variation across time and depth



This figure shows the variation of temperature with depth and time over the run time of the model (120 Myr), zoomed in to the depth range of the crust.

This figure is saved as met1DTempdepthtimecrust.tif in the current working folder.

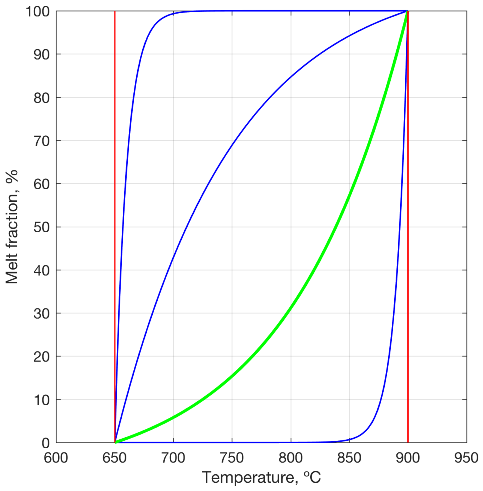
Figure 8 – Surface heat flow against time



This figure shows the variation of surface heat flow with time over the run time of the model (120 Myr.

This figure is saved as met1DSurfaceheatflowtime.tif in the current working folder.

Figure 9 – Melting profile



This figure shows the melting model used (green line) in the calculations to determine how much heat is produced or consumed by partial melting. NB: this only affects the calculations for those regions of the crust that enter the melting window defined by the red lines. If you switched melting off, you won't see this figure.

This figure is saved as met1Dmeltingcurve.tif in the current working folder.

Errors & bugs

The programs that make up met1D_GL3520 contain over 2,000 lines code: there will be bugs! If you do encounter an error, don't panic. Take a note of any messages, and take a screen shot if possible. E-mail d.healy@abdn.ac.uk with the details. In most cases, a simple restart of MATLAB and met1D_GL3520 will fix things.

Bibliography

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