UNZIP

Magma chamber remobilization

USER MANUAL

Alain Burgisser, CNRS, ISTerre, F-73376 Le Bourget du Lac, France
http://isterre.fr/annuaire/pages-web-du-personnel/alain-burgisser/article/softwares

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1. Introduction

This user manual describes the software Unzip, which calculates how fast a magma chamber filled with crystal-rich magma (mush) that is reheated from below can be remobilized by convection. Theory, use, and limitations of Unzip are described in Burgisser A. and Bergantz G.W. (2011) *A rapid mechanism to remobilize and homogenize highly crystalline magma bodies*, Nature 471:212-215. Unzip is the software used to solve the equation system listed in Burgisser and Bergantz (2011) and it is a scientific code in the sense that the user controls few options, the output format is unique, and no checks are done on the input values.

2. User interface

The user interface (Fig. 1) of Unzip offers one panel (upper left) to calculate specific variables needed in solving the full equation system. It gives access to the inner workings of the model and users interested in calculating physical variables linked to unzipping have probably little use of the options offered by this panel. Such users, however, will find the panel on the right most useful as it lists input values controlling the main button of the software "Graph Mum vs Choice".

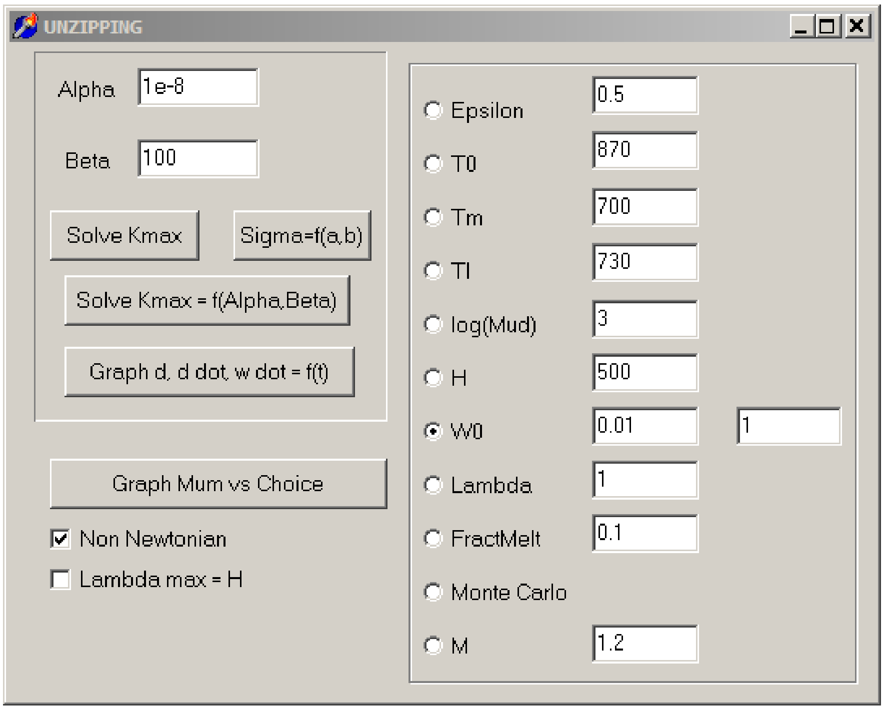

Figure 1: *User interface of Unzip.*

The physical situation of unzipping is depicted in Fig. 2. The main button "Graph Mum vs Choice" solves variables at the onset of unzipping as a function of two free parameters. The first parameter is the mush viscosity Mum, the variation of which is hard-coded from 10^6 to 10^{12}, and the second parameter is user-defined and selected in the list on the right-hand side panel (Table 1). The mush rheology can be selected as being Newtonian or Non Newtonian, in which case the exponent factor M must be specified on the right-hand list. The maximum wavelength of the instability can be clipped to the chamber height by selecting "Lambda max = H". The output data is written in a text file with heading variables as listed in Table 1.

A peculiar behavior is caused by the selection of "Monte Carlo" in the right-hand list. All the parameters are allowed to vary between user-defined bounds for 10000 runs. Three restrictions are enforced to ensure physically viable random situations: T0-Tm>20, (T0+Tm)/2-Tl>2 & Tl-Tm>2, and 10^{-8}<Mud/Mum<0.2.

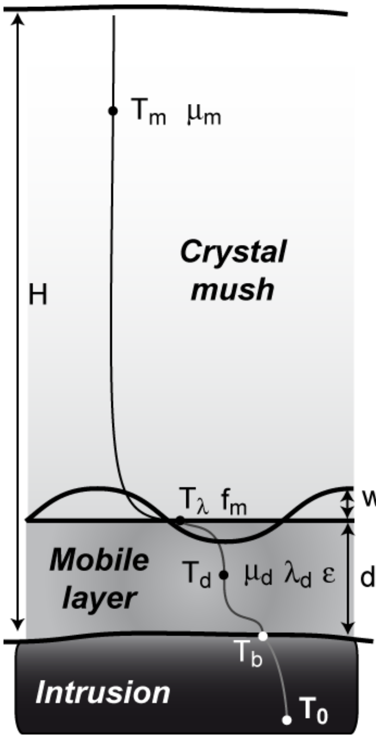

Figure 2: *Schematic representation of a stagnant mid-crustal reservoir being reheated from below by an intrusion. The mush reheats in two stages by creating a convecting mobile layer that grows steadily before eventually becoming unstable and overturning the remaining mush. Symbols are model free parameters and listed in Tables 1 & 2.*

The panel on the upper left works as follows. Alpha is the viscosity ratio between mobile layer & mush, λ_m. Beta is the ratio of fluid depths, d/(H-d). The button "Solve Kmax" gives the values of $\bar{\sigma}_{max}$ (Smax) and η_{max} (Kmax), which are respectively the maximum growth rate and wavelength of the instability that are solutions of Eqs (14) and (15). The button "Solve Kmax=f(Alpha,Beta)" saves the log10 values of $\bar{\sigma}_{max}$ (Smax) and η_{max} (Kmax) in a text file for a hard-coded range of λ_m (10^{-6}-1) and d/(H-d) (10^{-5}-1). The button "Sigma=f(a,b)" saves the log10 values of λ_m (Alpha), 4π(H-d)/η (Beta), and $\bar{\sigma}$ (Sigma) in a text file for a hard-coded range of λ_m (10^{-10}-10^{-5}), 4π(H-d)/η (10-10^4) and d/(H-d)=10^{-5}. The button "Graph d, d dot, w dot = f(t)" gives in a text file the evolution in time of the mobile layer thickness according to various assumptions. Free model parameters are here hard-coded to the following values (see Table 1 for symbol correspondence): Epsilon=0.6, T0=1100, Tm=750, Tl=800, Mud=1e4, Mum=1e9, H=2000, W0=0.1, Lambda=5, and FractMelt=0.2. Time varies from $10^{1/200}$ – 10^5 days and the output variables are Time_days (t), d_cond (conductive layer thickness), d_conv (mobile layer thickness without unzipping), d_dot (growth rate of mobile layer without unzipping), w_dot (growth rate instability). The other variables are wX (instability amplitude), where the number X characterize various assumption on mush rheology: Newtonian not clipped (w1), Newtonian clipped (w2), Non Newtonian with M=1.1 (w3), and Non Newtonian with M=1.2 (w4). Outputs eeX and bX are unused.

Table 1: Model parameters and software nomenclature.

Quantities and units	Software symbol	Output file symbol
Free parameters:		
ε = melt volume fraction in mobile layer	Epsilon	Epsilon
f_m = volume fraction of melting during mush reheating	FractMelt	FractMelt
T_0 = temperature of the intrusion (°C)	T0	T0
T_m = initial temperature of mush (°C)	Tm	Tm
T_λ = temperature at mush/mobile transition (°C)	Tl	Tl
λ_d = viscosity ratio within the mobile layer	Lambda	Lambda
μ_d = mobile layer average viscosity (Pa s)	Mud	Mud
μ_m = Newtonian mush viscosity (Pa s)	Mum	Mum
H = total height of the reservoir (m)	H	H
M = Non-Newtonian exponent	M	M
w_0 = initial perturbation of mush interface (m)	W0	W0
Model output:		
τ= shear stress applied on mush at instability tip (Pa)		TauW0
Shear stress applied on mush by the mobile layer buoyancy (Pa)		TauBuoy
λ_m = viscosity ratio between mobile layer & mush		MumMud
average speed of the instability during unzipping		vAvg
Speed of the instability during unzipping		vRT
Nu = Nusselt number in mobile layer at onset of unzipping		Nud
Nu = Nusselt number in mobile layer at onset of convection		Nucp
T_J = total thermal energy transferred by the basalt (J)		TJ
Energy for unzipping/energy for bulk mush reheating		Ratio
Ra = Rayleigh number for permeable convection in mush		RaHoom, RaTS
Re = Reynolds number in mobile layer		Re
Characteristic speed in mobile layer		Ud
$(H\text{-}d_{RT})/\eta_{max}$ = instability aspect ratio		HL
Shear rate applied on mush by the whole instability (s^{-1})		Gamma
Shear stress applied on mush by the whole instability (Pa)		Tau
d_P = distance of penetration of the instability (m)		dPen
η_{max} = maximum wavelength of instabilities (m)		Wavelength
t_P = time for the instability to reach the reservoir roof (days)		tP
t_c = onset time of convection in mobile layer (days)		tC
t_H = time for the mobile layer to reach chamber roof (days)		tH
d_{RT} = thickness of mobile layer at onset of unzipping (m)		dRT
t_{RT} = onset time of unzipping (days)		tRT

Table 2: Hard-coded constants.

Quantities and units	Value
c_p = specific heat capacity of mush & mobile layer (J/kg K)	1000
L_m = specific latent heat of mush & mobile layer (J/kg)	$2.7\ 10^5$
κ = thermal diffusivity of mush & mobile layer (m^2/s)	10^{-6}
α = thermal expansion coefficient (K^{-1})	10^{-4}
g = scalar acceleration of gravity (m/s^2)	9.81
ρ_o = reference density of mush & mobile layer (kg/m^3)	2300
ρ_c = average density of crystal phases melting (kg/m^3)	2700
ρ_c = average density of crystal phases melting (kg/m^3)	2700