Mechanical data of simulated basalt-built faults from rotary shear and direct shear experiments

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1. Licence

2. Citation

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The data are supplementary material to:

Citation of article "Frictional properties of basalt experimental faults and implications for volcano-tectonic settings and geo-energy sites" when available at the submitted journal.

Table of contents

1. Licence ... 1
2. Citation ... 1
Table of contents ... 1
3. Data Description ... 2
3.1. Data processing ... 2
4. File description ... 3
4.1. File inventory ... 3
4.2. Description of data tables ... 4
4.2.1. File name sXXXX_d/w_snYYMPa.txt ... 4
4.2.2. File name bXXX.txt ... 4
4.2.3. File name bXXX_dilation_VS.txt ... 4
4.2.4. File name bXXX_model.txt ... 5
4.2.5. File name bXXX_healing.txt ... 5
4.2.6. File name bXXX_dil_comp_SHS.txt ... 5
5. References ... 5

3. Data Description

Here we report the raw data of the friction experiments carried out on basalt-built simulated faults defined by rock-on-rock contacts and powdered gouge. The experiments were specifically designed to investigate the role of fault microstructure on the frictional properties of basalts and the fault slip stability, and were conducted with the rotary-shear apparatus (SHIVA) and the biaxial deformation apparatus (BRAVA), hosted at the National Institute of Geophysics and Volcanology (INGV) in Rome.

Simulated faults were sheared at constant normal stress from 4 to 30 MPa. In SHIVA experiments, we deformed solid samples at constant slip velocity of 10 µm/s up to 56 mm net slip. In BRAVA tests we performed a sequence of velocity steps (0.1 to 300 µm/s), followed by slide-hold-slide tests (30-3000 s holds; V=10 µm/s slides).

Our main results highlight the frictionally strong nature of basalt faults and show opposite friction velocity dependence upon the velocity upsteps: while fault gouges exhibit velocity weakening behavior with increasing normal stress and sliding velocity, bare rock surfaces transition to velocity strengthening behavior as we approach higher slip velocities. The experiments setup and data are further described in the manuscript "Frictional properties of basalt experimental faults and implications for volcano-tectonic settings and geo-energy sites" to which these data are supplementary material.

3.1. Data processing

Rotary – shear experiments:

- SHIVA's data were devoid of the mechanical noise stemming from the unplug of the sprag clutch after the first 2 mm shear run-in phase.

Direct – shear experiments:

- Rate-and-state parameters were retrieved through the XLook software, a program developed by Chris Marone which is available at the following link: https://github.com/PennStateRockandSedimentMechanics/xlook;
- Volumetric strain was calculated after removing the monotonic trend resulting from continuous layer thickness decrease during direct shear tests (see Scott et al. 1994 for details);
- In healing data, we removed from data analysis those points in which a) the difference in the friction coefficient characterizing the slip pre-hold and post-hold period was greater than 1.5% and b) long-term anomalous variations in friction coefficient during the hold phase.

4. File description

Explanation of the folder structure, file list and contents included in data publication of "Mechanical data of simulated basalt-built faults from rotary shear and direct shear experiments".

4.1. File inventory

The file contains folders for rotary shear (i.e, SHIVA) and direct shear (i.e., BRAVA) experiments: 8 for the "*SHIVA*" folder and 13 for the "*BRAVA*" folder.

SHIVA folder contains files in .txt format. Individual files include the main mechanical parameters sampled during a single rotary- shear test conducted on basalt hollow cylinders at constant shear displacement rate (V = 10 μm/s).
BRAVA folder is articulated in 2 subfolders, each encompassing the mechanical data recorded during the tests involving **simulated gouge** (8 in total) and **bare surfaces** (5 in total).
Within the above subfolders, each filename represents a single test. Each experimental folder incorporates the following files, here described separately:

- **bXXX.txt**: mechanical data file in txt format;
- **bXXX_r**: Text file containing a script for processing the raw data via the software XLook.
- **bXXXs05basaltZZ**: Original raw datafile in txt format with 6 columns;
- **bXXXs05basaltZZl** : A "look" file, built from the original datafile using the command "asc2look" of the data processing tool Xlook (see link above in section 3.1);
- **VS** subfolder, which stands for velocity steps tests, contains the files required to model velocity step sequences using the rate and state friction equations and the retrieved friction rate parameters, and the dilation associated with the velocity upsteps.
  Notably, it contains:
  1. a txt format file named *bXXX_model.txt*, containing all the parameters necessary to graphically visualize the inversion model used to retrieve the friction constitutive parameters;
  2. the Excel files "*data_table_XXX.csv*" with the values of the best fits to the Rate-and-State friction model using the Ruina equation (we refer to the EPSL review paper by Marone (1998) for details). In most cases one state variable was sufficient to model our data, although in a few cases two variables were needed;
  3. a txt format file named bXXX_dilation_VS.txt, used to analyze the dilation upon the velocity step increases (data available only for simulated fault gouge experiments).
- **SHS** subfolder, which stands for slide-hold-slide tests, contains all the data required to create Figure 8 of the manuscript to which this data repository is supplementary material.
  In particular, it contains:
  1. a data-file in txt format named *bXXX_healing.txt* used to analyze the healing properties of basalt faults;
  2. a data-file in txt format called *bXXX_dil_comp_SHS.txt*, in which we report the volumetric strain changes following the slide-hold-slide tests. In bare surface tests, in only a few cases it was possible to retrieve such data, because of the high noise and/or anomalous friction variation during the hold phase that accompanied some slide-hold-slides, that affect the quality, hence the data reliability.

With:

- s = SHIVA; b = BRAVA
- d/w = room-dry/ wet
- XXX/XXXX is the 3/4 digits experiment number
- YY is the applied normal stress in MPa

4.2. Description of data tables

4.2.1. File name sXXXX_d/w_snYYMPa.txt

File sXXXX_d/w_snYYMPa.txt contains the main mechanical data recorded during the rotary-shear experiments.

Column header	unit	Description
Time	ms	Elapsed time
Displ	m	Accumulated shear displacement
Normal	MPa	Applied normal stress
Shear	MPa	Shear stress
Mu	\	Friction coefficient
Slip_Vel	m/s	Slip velocity

4.2.2. File name bXXX.txt

File bXXX.txt contains the main mechanical data recorded during the direct shear experiments

Column header	unit	Description
RecNum	\	Record number
lp_disp	µm	Load point displacement
LT	mm	Layer Thickness
Tau	MPa	Shear Stress
SigN	MPa	Applied normal stress
Time	s	Elapsed time
ec_disp	mm	Elastically corrected displacement
mu	\	Friction coefficient
Shear_Strain	\	Shear strain

4.2.3. File name bXXX_dilation_VS.txt

File bXXX_dilation_VS.txt contains data to analyze the average gouge layer dilation upon the velocity upsteps.

Column header	unit	Description
row_s	\	start row number of the selected velocity upstep
row_e	\	end row number of the selected velocity upstep
row_fitS	\	start row number of the linear regression applied to remove the layer thickness trend
row_fitE	\	end row number of the linear regression
Dilation	mm	average gouge layer dilation upon the velocity step
velocity	µm/s	Slip velocity upstep
layer_thickness_start	mm	gouge layer thickness prior to the velocity step increase
strain_start	\	shear strain prior to the velocity step increase
strain_end	\	shear strain after the velocity step increase

4.2.4. File name bXXX_model.txt

File bXXX_model.txt contains the instructions to be copied in the program XLook in order to reproduce the inversion model necessary to retrieve the friction rate parameters.

4.2.5. File name bXXX_healing.txt

Column header	unit	Description
Time	s	Hold time
Dmu	\	Frictional restrengthening
Dmu_c	\	Creep relaxation

4.2.6. File name bXXX_dil_comp_SHS.txt

Column header	unit	Description
Time	s	Hold time
DLT	mm	Dilation following re-shear
COM	mm	Compaction during the hold period

5. References

Marone, C. (1998b), Laboratory-derived friction laws and their application to seismic faulting, *Annual Review of Earth and Planetary Sciences*, *26*(1), 643-696, https://doi.org/10.1146/annurev.earth.26.1.643

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