Mechanical data of rotary shear experiments in bituminous dolostones (https://doi.org/10.5880/fidgeo.2025.037)

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1. Licence

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3. Data description

Mirror-like Surfaces (MSs) are ultra-polished fault surfaces widespread in carbonate seismic terrains, but their formation process is still debated. We have conducted five successful experiments (out of nine) which data are reported in this repository. We deformed gouge samples from exposed fault surfaces hosted in bituminous dolostone rocks in a rotary shear apparatus (SHIVA) at seismic slip rates (1 m/s). By changing the water availability (water-pressurised and room-humidity conditions) and the organic matter/dolomite content (> 35%, dark gouge DG; < 30% bright gouge BG) we investigated the mechanical behaviour leading to MSs formation in fault gouges. We run tests at 15 MPa effective normal stress, 2 MPa confinement and 1 MPa pore pressure for the water-pressurised experiments and a total displacement of 0.13 m. Mirror-like fault surfaces were obtained in all successful experiments; mirrors were more developed under room-humidity conditions. Bituminous dolostones under room-humidity conditions had a slip neutral behaviour with a low friction (0.3). Bituminous dolostones under water-pressurised conditions showed a slip weakening behaviour with an initial peak effective friction $\mu_p = 0.65$, followed by a drop to effective friction μ_{ss} DG than in BG (i.e., μ_{ss} of 0.25 vs 0.28). Future work will focus on the microstructural analysis of the experimental products and the investigation of the slip behaviour of bituminous dolostones at sub-seismic slip rates for a complete study of the slip behaviour spectra. This publication results from work conducted under the national open access action at SHIVA (Slow to High Velocity Apparatus) - HP-HT laboratory of experimental Volcanology and Geophysics (INGV, Roma 1 section) supported by WP3 ILGE - MEET project, PNRR - EU Next Generation Europe program, MUR grant number D53C22001400005.

3.1. Starting material and sample preparation

Experiments were carried out on samples of bituminous dolostones collected in the Monte Camicia fault zone (Fornaca Valley, Italian Central Apennines) that were ground and sieved to obtain gouges with grain size <250 µm. Two types of gouges were used, "dark gouge" (DG) with organic matter contents of 40-45%, and "bright gouge" (BG) with 20-25% of organic matter. One experiment was carried out with 100% Carrara dolomite gouge (CG; grain size <250 µm) as an end-member comparison. Layers with different amount of organic matter were separated manually using a hammer and chisel to obtain dark and bright gouges. The organic matter vs. dolomite content was estimated by image analysis on BSE-SEM images.

3.2. Analytical procedure: rotary-shear friction experiments

Laboratory: HP-HT Laboratory of Experimental Volcanolgy and Geophysics (INGV, Rome, Italy)

The rotary-shear experiments were performed using the Slow to HIgh Velocity Apparatus (SHIVA) installed at the HP-HT laboratory of the Istituto Nazionale di Geofisica e Vulcanologia (INGV) in Rome (Di Toro et al., 2010). Gouges were deformed using seismic (v=1 m/s) slip rate under room-humidity (RH) or fluid-pressurised (FP) deformation conditions at 15 MPa of effective normal stress (σ_{eff}), for a total displacement of 0.13 m. The FP experiments were performed at 1 MPa of pore fluid pressure (P_f) and 2 MPa of confining pressure (P_c). For the experiments performed under RH deformation conditions we sheared 5 g of gouge using a steel ring-shaped sample holder (internal diameter=0.035 m, external diameter=0.055 m; Smith et al., 2013); the initial thickness of the gouge was ≈2.5 mm. For the FP conditions we used a steel sample holder consisting of two cylinders connected to the pore fluid pressure line (diameter=0.0511 m) with porous steel plates at the bases (Aretusini et al., 2021). The gouge (12 g; initial thickness ≈3 mm) in the sample holder is separated from the confinement fluid thanks to a PVC shrink jacket fixed to the static sample holder with stainless steel wire and lubricated with MoS2-based solid lubricant. The confinement was obtained with a fluid-filled vessel; deionised water was used as pore and confinement fluids, pressurised by two syringe pumps. The rotary shear experimental procedure involved a gradual increase of the normal stress and, for fluid-pressurized conditions, of *Pc* and *Pf*; loading of the remaining normal stress (2-4 kN/min ramp; for FP conditions) followed by 15 min of static compaction; 0.01 m of pre-shear at 0.000015 m/s and the main event. A velocity ramp was imposed to simulate the seismic deformation conditions, with acceleration of 7.12 m/s^2 and deceleration of 14.2 m/s^2, to maintain the target speed for a longer time. During the experiments the axial displacement was measured with an LVDT (0.03 µm resolution, 3 mm stroke) installed in the stationary side of the sample holder; increase in temperature was measured with a K-type thermocouple at ≤0.5 mm from the static boundary of the gouge layer in both configurations. P_f was measured downstream on the rotary side with a pressure transducer while the upstream P_f and the P_c were controlled by the two syringe pumps. The acquisition rate was set to 20 kHz during the main event and to 4 Hz during the rest of the experiment.

3.3. Data processing

After the experiments, the shear stress *(τ)*, normal stress (σ_n), displacement, and equivalent velocity (*v*) were determined using the method described in Shimamoto and Tsutsumi (1994) or Di Toro et al. (2010). The effective friction coefficient (μ) is obtained by dividing τ by σ_{eff}, with $\sigma_{eff} = \sigma_n - P_f$ (P_f=0 under RH conditions). Thickness evolution of the gouge layer was obtained by the axial displacement subtracting the initial touch point thickness and then zeroed at the first increment of slip to monitor shortening/dilation variations. Effective friction coefficient curves of the experiments showing a slip weakening behaviour were fitted with an exponential decay function as proposed by Mizoguchi et al. (2007) to obtain the steady-state effective friction coefficient (μ_{ss}) and the slip weakening distance (D_c). The goodness of fit to the experimental data was quantified by the coefficient of determination R^2. For further details on data processing see Di Toro et al. (2010), Niemeijer et al. (2011) and Aretusini et al. (2021).

4. File description

The provided files are:

- One ***.csv* file** (tab separated values), named "Experiments" describing the deformation conditions of the performed successful experiments;
- Five ***.csv* files** (tab separated values), one for each successful experiment (s2023, s2024, s2026, s2027, s2028), named according to experiment number.

4.1. "Experiments.csv" file

For every experiment ("Exp" = number of the experiment) the following data are reported:

Column header	**Unit**	**Description**
Gouge	-	type of gouge (BG=bright gouge; DG= dark gouge; CG= Carrara Dolomite gouge)
Exp. cond.	-	experimental condition (FP= fluid pressurized; RH= room humidity)
Slip rate	m/s	slip rate at which the experiment was performed
Slip	m	slip displacement of the experiment
σn	MPa	normal stress
Pc	MPa	confining pressure
Pf	MPa	pore fluid pressure
σeff	MPa	effective normal stress
Acc	m/s^2	acceleration rate
Dec	m/s^2	deceleration rate
Sample holder	-	sample holder described in *Smith et al.* (2013) or in *Aretusini et al.* (2021)
µeff-peak	-	peak value of the effective friction coefficient
µss	-	steady-state value of the effective friction coefficient
Dc	m	slip weakening distance
R^2	-	coefficient of determination

4.2.“s202X.csv” files

Each *.csv* file contains a subset of the following variables that were monitored during the experiments:

Column header	**Unit**	**Description**
Normal	MPa	imposed normal stress
Shear1	MPa	shear stress
Pc	MPa	confinement fluid pressure (downstream)
Pf	MPa	pore fluid pressure (downstream)
EffPressure	MPa	effective normal stress, calculated as: *Normal - Pf*
PumpPressure	MPa	pressure of the pore fluid pump (upstream)
PumpVolume	ml	volume of the pore fluid pump
Slip	m	slip (tangential displacement)
Vel	m/s	slip velocity or slip rate
Rate	-	incremental record number
Time	ms	incremental time
InternalTemperature	°C	temperature measured by the thermocouple
Mu1	-	friction coefficient calculated as: *shear1/Normal*
Thickness_high	mm	thickness variations of the sample during the experiments, relative to the thickness measured before the main event
LVDT_high	mm	high resolution shortening measurement

5. Acknowledgement

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