補足資料

Table S1: The change in the ESR intensity thorough various fracturing tests simulating the fracture of rock and minerals by faulting.

Methods	Starting material and its properties	Grain size diameter (ϕ[a])
Fracture		
Fracturing[63,64] Fracturing[63,64] Fracturing[66]	Pegmatite Pegmatite Quartz sand	N/A 840-2000 μm *M*[a]: 30 g 75-250 μm *M*: 3 g
Low-speed friction[19]	Quartz sand Quartz sand and kaolinite clay (Volume ratio 1:1)	420-840 μm
Low-speed friction[66]	Quartz grains in quartz sand	75-250 μm
Low-speed friction[66]	Quartz grains in quartz sand	75-250 μm
Low-speed friction[65]	Quartz sand (830-1700 μm) crushed by a ball mill and irradiated to 40±5 Gy using a ^{60}Co γ ray source	90-250 μm
Low-speed friction[67]	Quartz sand	Component: Quartz 95 wt% 45-300 μm
Stress		
Low-speed friction[61]	Quartz sand	Component: Quartz 100% >250 μm
Creep[70]	Quartz grains in mylonite	N/A
Uniaxial compression[59,60] Uniaxial compression[20,69]	Quartz grains in granite Quartz grains in fault gouge annealed at 550°C for 24 hours and irradiated to 500 Gy using a ^{60}Co γ ray source ($\dot{D}$[a]: 5.028 Gy/min)	250-840 μm 60-300 μm
Triaxial compression[63]	Granite	Shape: Cylinder ϕ_{out}[a]: 100 mm *H*[a]: 50 mm

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Experimental conditions	ESR signals	ESR intensity	Machine
N_c[a]: 10-40	E_1' center	Decrease	Iron bowl
R[a]: 20 rpm	E_1' center	Decrease	Agate mortar and agate pestle
t_f[a]: 1-7 min			(M: 12 kg, diameter: 70 mm)
t_f[a]: 1-5 min	E_1' center	No change	Agate mortar and agate pestle
	Al center	No change	(M: 15 kg)
	Ti center (g=1.913)	Increase	
	Ti center (g=1.931)	Increase	
	Ti center (g=1.979)	Increase	
V[a]: 28.3-125 mm/s	E_1' center	Zero-setting	Stainless steel cylindrical forcing block
σ[a]: 0.98-2.9 MPa			
τ[a]: 0.38-1.9 MPa			
D[a]: 0.28-1.4 m			
d[a]: 1 mm	E_1' center	Just after friction: Zero-setting	Stainless steel cylindrical forcing block
V[a]: 28.3 mm/s		Water washing: Decrease	
σ[a]: 0.98 MPa		Ultrasonic cleaning: No change	
D: 1.7 m		HCl treatment: Increase	
d: 1 mm	E_1' center	Just after friction: Slight increase	Ceramics cylindrical forcing block
V: 28.3 mm/s		Water washing: Slight increase	
σ: 0.98 MPa		Ultrasonic cleaning: Slight increase	
D: 1.7 m		HCl treatment: Slight increase	
d: 1 mm	E_1' center	Decrease	Titanium alloy columnar forcing block
V_e[a]: 0.54-2.00 mm/s	Al center	Zero-setting	
σ: 0.5 MPa			
D_e: 0.54-2.00 m			
d: 1.5 mm	E_1' center	Increase	Brass cylindrical forcing block
V: 0.76 mm/s	Peroxy center	No change	
σ: 1.0-15 MPa	OH center	No change	
D_e: 0.28-1.4 m			
Stress			
V: 0.05 and 0.5 mm/s	E_1' center	Decrease	Westerly granite forcing block
σ: 5 and 10 MPa	Al center	No change	(Shape: N/A)
D: 0.004-0.04 m	Ti center	Increase	
σ: 100 MPa	OH center	Decrease	N/A
t_c[a]: 925-15000 s	Ge center	Decrease	
	Al center	Decrease	
σ: 14-250 MPa	E_1' center	Decrease	Stainless steel (SUS304) bowl
σ: 29 and 60 MPa	OH center	Decrease	Metal piston and metal bowl
t_c: 30 s	Ge center	No change	
	Al center	No change	
	Ti center	No change	
P_c[a]: 10-50 MPa	E_1' center	Decrease	Cylindrical granite covered
P_d[a]: 310-580 MPa	OH center	Decrease	with a thin copper jacket

[a] ϕ: grain size diameter, N_c: number of crushes, R: rotational speed, M: weight, t_f: crushing times, V: velocity, σ: normal stress, τ: shear stress, D: shear displacement, d: thickness of gouge layer, V_e: equivalent slip rate, D_e: equivalent displacement, t_c: compression time, $\dot{D}$: dose rate, P_c: confining pressure, ϕ_{out}: outer diameter, P_d: differential stress, H: height.

Table S2: The change in the ESR intensity thorough various heating tests simulating frictional heating by seismic faulting.

Methods	Starting material and its properties	Grain size diameter (ϕ^b)
friction		
Intermediate-speed friction[75]	Quartz grains and kaolinite clay with sprayed water (Volume ratio 1:1)	74-250 μm
High-speed friction[18]	Fault gouge	8-20 μm
High-speed friction[57]	Fault gouge crushed by a mortar	N/A
High-speed friction[65]	Quartz grains in quartz sand (ϕ: 830-1700 μm) crushed using a ball mill and irradiated to 40±5 Gy using a ^{60}Co γ ray source	
Isothermal heating		
[77]	Quartz grains in granite	N/A
[78]	Quartz grains in volcanic ash	N/A
[66]	Quartz grains in quartz sand	75-250 μm
[79]	Quartz grains in sandstone	N/A
[80]	Quartz grains in loess	63-100 μm
Isochronal heating		
[81]	Quartz grains in fault gouge	105-250 μm
[82]	Quartz grains in tuff	125-250 μm
[77]	Quartz grains in granite	90-250 μm
[83]	Quartz grains in rhyolite	75-250 μm
	Quartz grains in pumice	
[84]	Quartz grains in quartzose sandstone	75-250 μm
[85]	Quartz grains in fault gouge	75-250 μm
[79]	Quartz grains in sandstone	N/A
[86]	Quartz grains in flint	80-200 μm
[88]	Quartz grains in dune sand	N/A
	Quartz grains in dune sand irradiated to 2200 Gy using a ^{60}Co γ ray source	
	Quartz grains in dune sand exposed light for 120 h using the solar simulator	
[87]	Quartz grains in marine sediment	100-200 μm
	Quartz grains in fluvial sediment	100-200 μm

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Experimental conditions	ESR signals	ESR intensity	Machine
d^{b}: 0.5 mm V^{b}: 0.1 m/s D^{b}: 0-1 m σ^{b}: 0-2.5 MPa	E_1' center Ge center	Zero-setting Zero-setting	N/A
d: 0.75 mm $V_e{}^{b}$: 0.37-1.74 m/s σ: 0.61 MPa $D_e{}^{b}$: 3.5-16.6 m	E_1' center	No change	Quartz glass columnar forcing block
M^{b}: 0.5 g V_e: 0.47-1.6 m/s σ: 2.0 MPa D: 11-38 m Atmosphere: dry (room temperature) wet (Injected ~0.5 mL of distilled water)	E_1' center	Decrease (dry) Slight decrease (wet)	Gabbro columnar forcing block
d: 1 mm D: 0.54-2.00 m/s σ: 0.5 MPa D: 8.1-30 m	E_1' center Al center	Zero-setting Zero-setting	Titanium alloy columnar forcing block
M: 100-200 g T^{b}: ① 345・370・400・420°C ② 300・345・370・400°C ③ 185・220・240・260°C $t_h{}^{b}$: 0-420 min	E_1' center Al center Ti center	E_1' center: decrease at T① Al center: decrease at T② Ti center: decrease at T③ ※ Greater decrease at higher temperature	N/A
M: 100-200 g T: 320・350・370・400°C t_h: 0-290 min	E_1' center	Decrease ※ Greater decrease at higher temperature	N/A
M: 300 g T: 300・400・500°C t_h: 0-10 min	E_1' center Al center Ti center	300°C：E_1' center: increase Al center, Ti center: decrease 400°C：E_1' center: decrease after increase Al center, Ti center: decrease 500°C：E_1' center: decrease after increase Al center, Ti center: decrease	Machine: thermal annealing furnace Bowl: columnar copper bowl (Diameter: 20 mm, height: 5 mm, thickness: 0.25 mm)
T: 250°C t_h: 0-300 min	E_1' center	Decrease after increase	N/A
T: 160・180・200・220°C t_h: 4-128 min	Al center Ti center	Decrease ※ Greater decrease at higher temperature	N/A
Isochronal heating			
T: 120-350°C t_h: 15 min	E_1' center OH center Ge center Al center	Decrease	N/A
T: 19-350°C t_h: 15 min	OH center Ge center Al center	Decrease	N/A
M: 100-200 g T: 34-440°C t_h: 15 min	E_1' center Al center Ti center	E_1' center: decrease after increase Al center, Ti center: decrease	N/A
T: 24-420°C t_h: 15 min	Al center Ti center	Decrease	N/A
T: 22-500°C t_h: 15 min	E_1' center	E_1' center: decrease after increase	N/A
T: 30-500°C t_h: 15 min	E_1' center Al center Ti center	E_1' center: decrease after increase Al center, Ti center: decrease	N/A
T: 20-420°C t_h: 60 min	E_1' center	E_1' center: decrease after increase	N/A
T: 0-500°C t_h: 15 min	E_1' center Peroxy center OH center Al center	E_1' center, Peroxy center and OH center Decrease after increase Al center: decrease	Electric oven Bowl: ceramics crucible
T: 24-400°C t_h: 15 min	Al center Ti center	Decrease	N/A
T: 0-390°C t_h: 15 min	Al center Ti center(g=1.913) Ti center(g=1.931) Ti center(g=1.979)	Decrease	N/A

[b] ϕ: grain size diameter, M: weight, V: velocity, σ: normal stress, D: shear displacement, d: thickness of gouge layer, v_e: equivalent slip rate, D_e: equivalent displacement, T: heating temperature, t_h: heating time.

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