Laboratory Investigation of Slip Mode along A Bimaterial (Gabbro/Marble) Fault Interface: Preliminary Results and Implications

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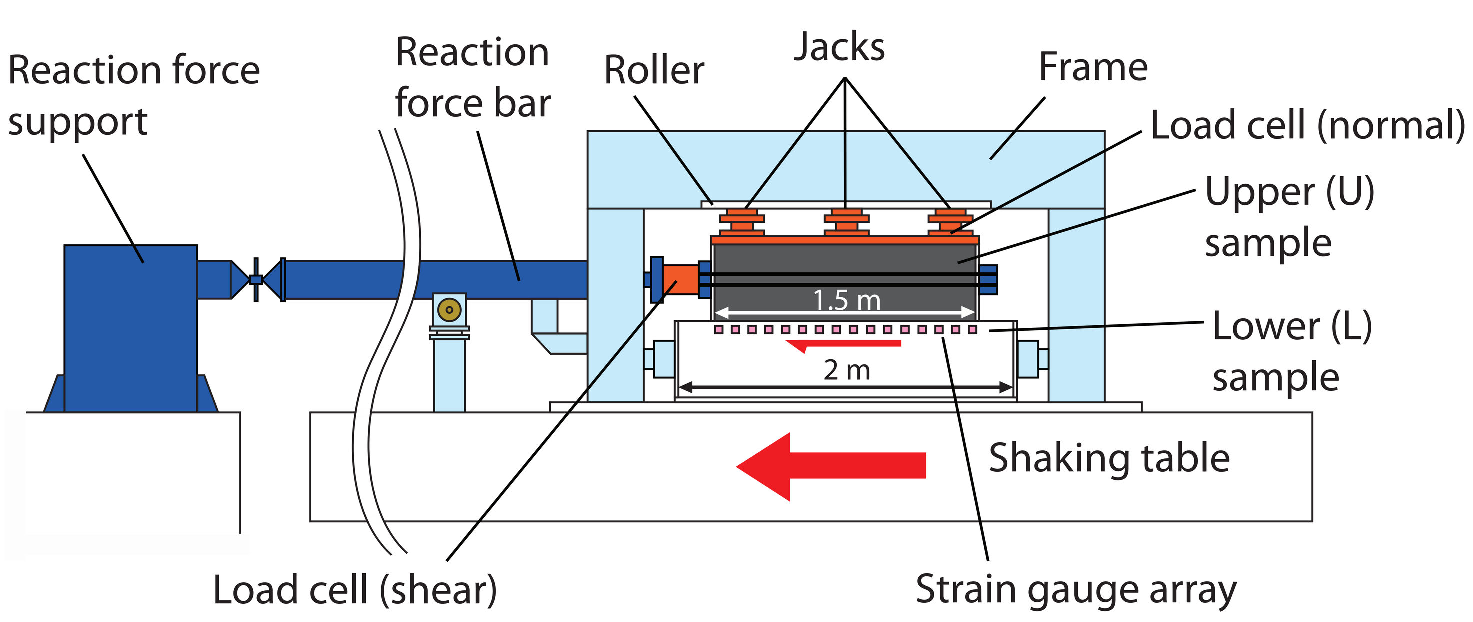
Abstract

We conduct a series of meter-scale direct shear experiments along a gabbro/marble fault interface at NIED. Unlike the transitional behavior from stick-slip to stable sliding along a marble/marble interface under 1.3 MPa normal stress and 0.01 mm/s loading rate, the bimaterial case shows persistent stick-slip behavior under the same loading conditions as well as under 2.6 MPa normal stress in subsequent tests. Visual observations of the damage pattern reveals quite different features between the marble/marble case and bimaterial case. For the marble/marble case, the generated grooves typically show a low aspect ratio between loading-parallel and loading-perpendicular directions, suggesting that some diffusional deformation is effective during slip. In contrast, the corresponding grooves for the gabbro/marble case still show preferred growing direction parallel to loading, similar to what has been observed along a gabbro/gabbro interface. Detailed observation further reveals that gabbro asperities can penetrate into the softer marble sample and can be partially sheared off during ruptures. Supportive strain array data show that the apparent friction before failure at these locations is high or even above 1, confirming the contribution from gabbro asperities. These results highlight the role of discrete brittle asperities in generating stick-slip fault behavior in a surrounding ductile-like environment. An analogous natural example may be found by the role of seamount in generating earthquakes through or underneath sediments in subduction zones (Cloos, 1992). We also analyze the strain array data to understand the detailed rupture process during failure. Because asperity distribution is not likely to be uniform along the surface and there are variations in rupture nucleation site, more work needs to be done before making any conclusion on rupture directivity solely based on the bimaterial effect.

Experimental setup

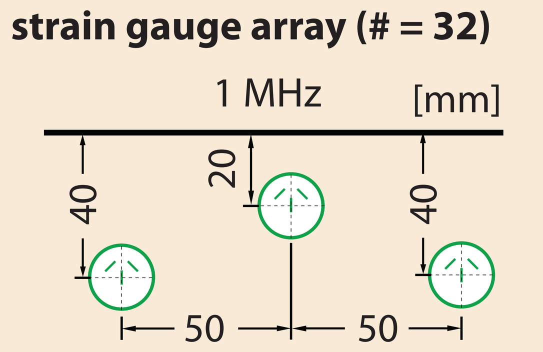


Loading conditions
Rate: 0.01 mm/s
Normal stress: 1.3 - 2.6 MPa

Sample dimension
1.5 x 0.5 x 0.5 m^3 (upper)
2.0 x 0.1 x 0.5 m^3 (lower)

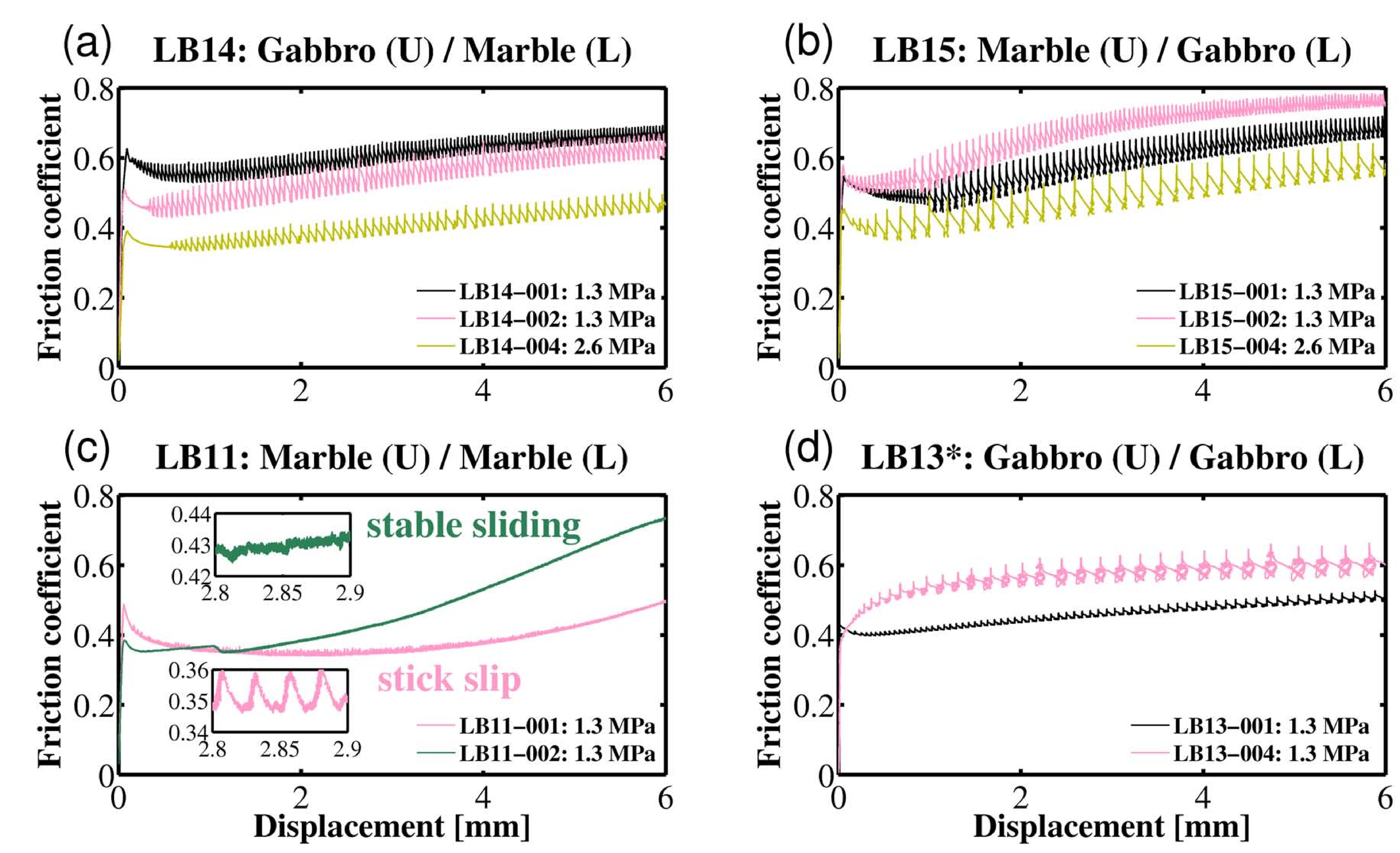
Initially polished surface
Undulation < 10 μm, Grit # 800

3-component semiconductor strain gauge array (# = 32)



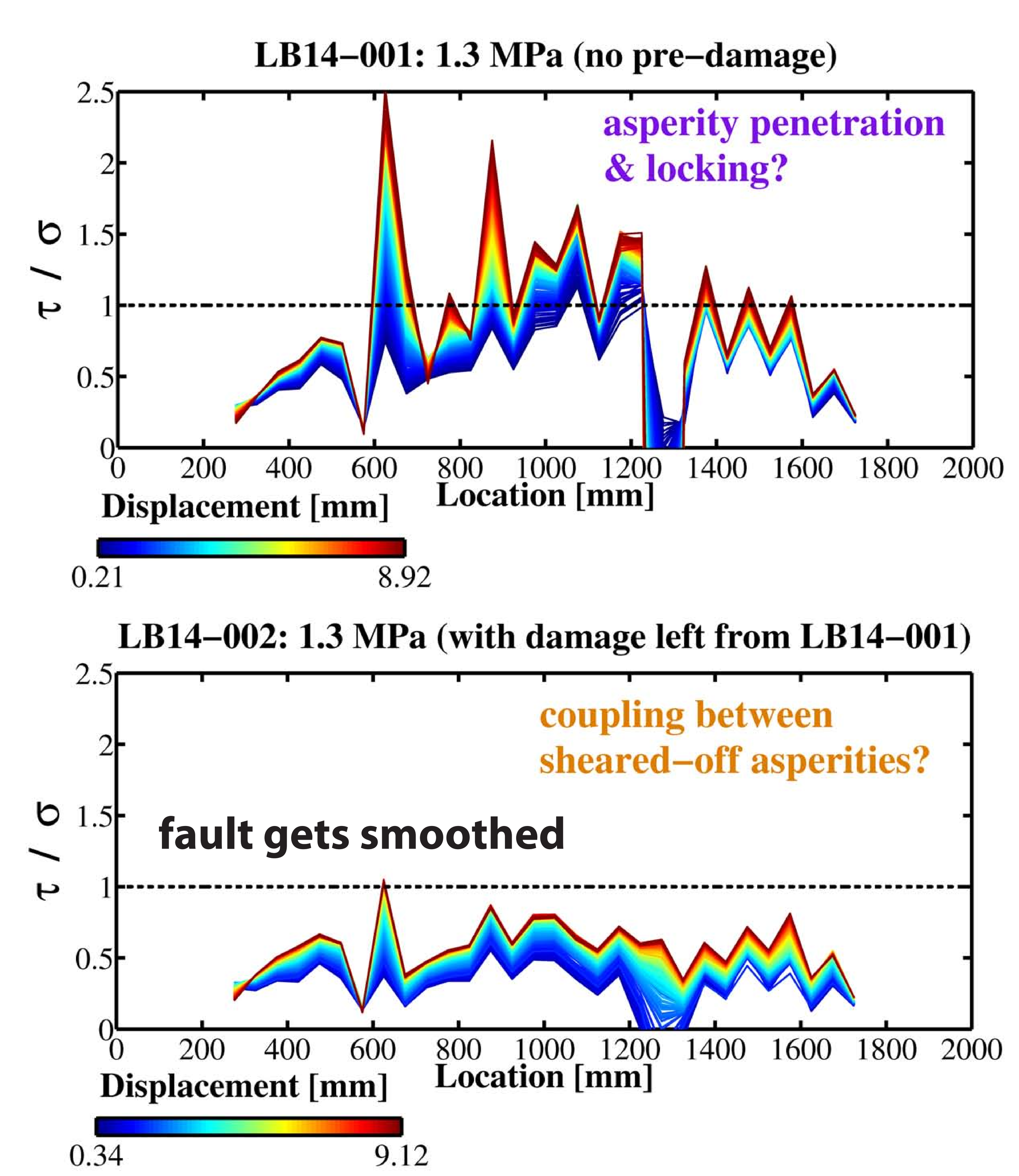
Rock samples
Gabbro (black): Vp = 6.92 km/s, Vs = 3.62 km/s, ρ = 2.98 x 10^3 kg/m^3
Marble (white): Vp = 4.38 km/s, Vs = 2.73 km/s, ρ = 2.68 x 10^3 kg/m^3

Macroscopic friction vs. displacement

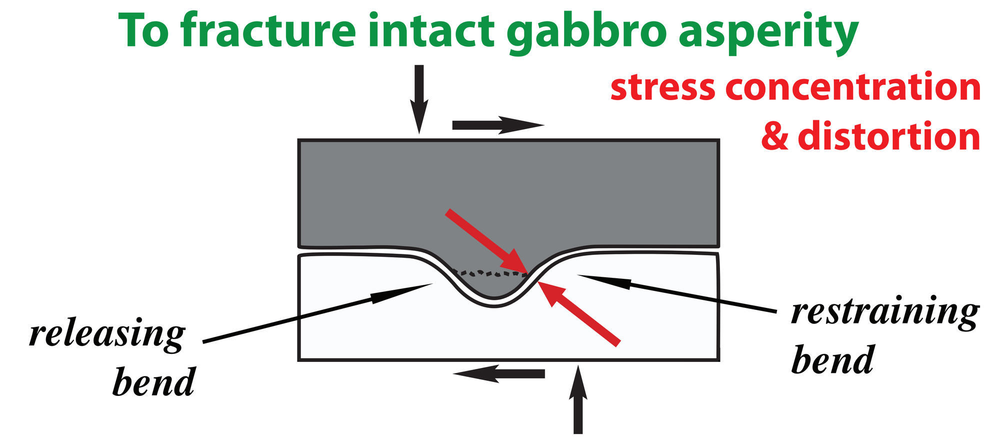


(a), (b) & (d): stick slip. * (d) was performed with 0.5 m wide lower sample
(c): from stick slip to stable sliding, similar to salt (Voisin et al., 2007)

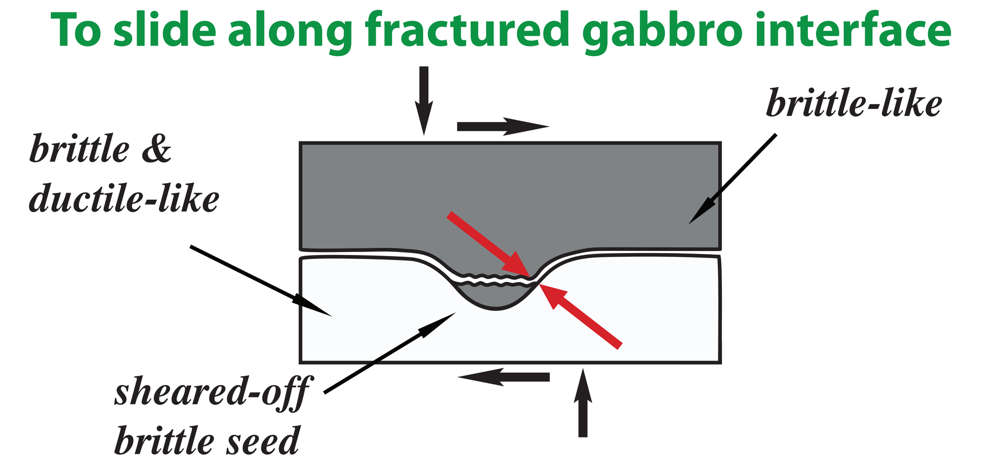
Initial stress profile and possible mechanisms



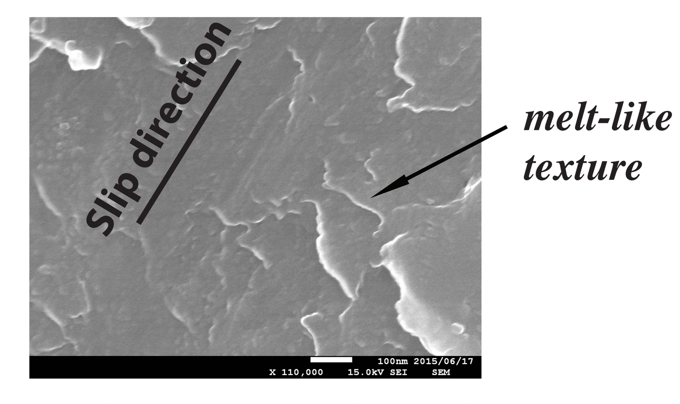
To fracture intact gabbro asperity



To slide along fractured gabbro interface



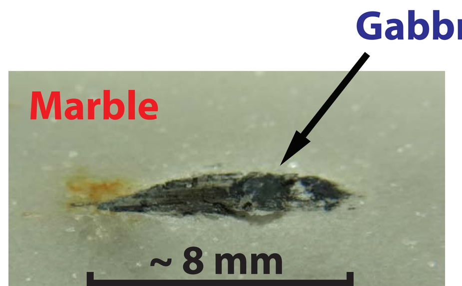
Local melting may occur



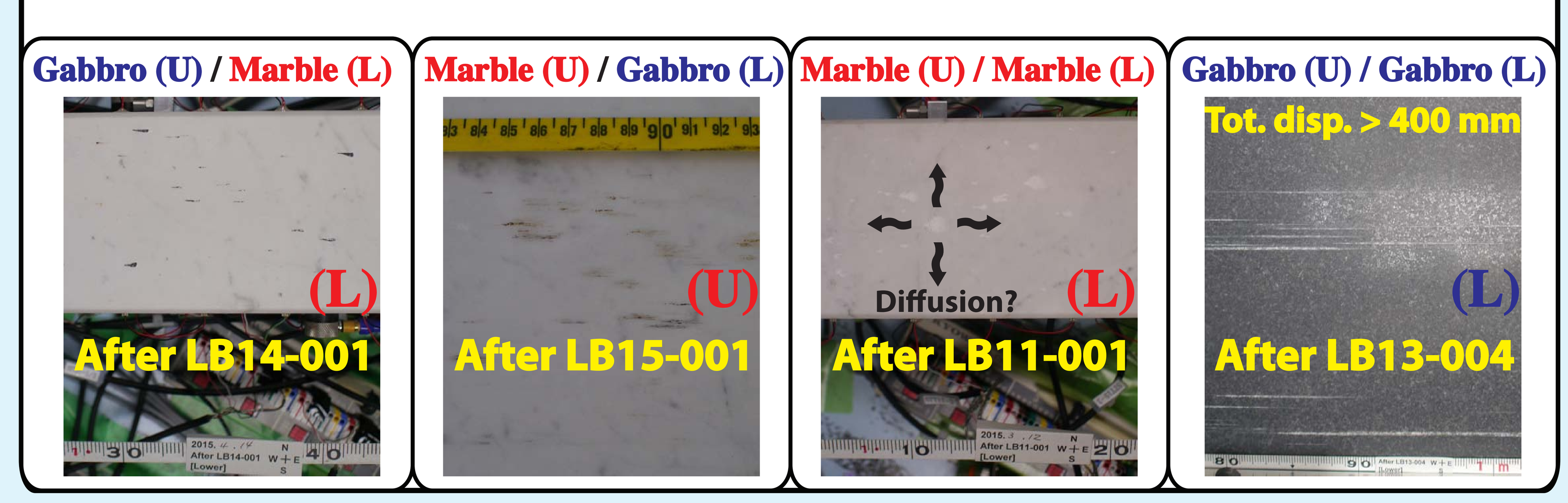
SEM image after LB14-002: from black groove (gabbro) on top of the lower marble sample

Photo image after LB14-001

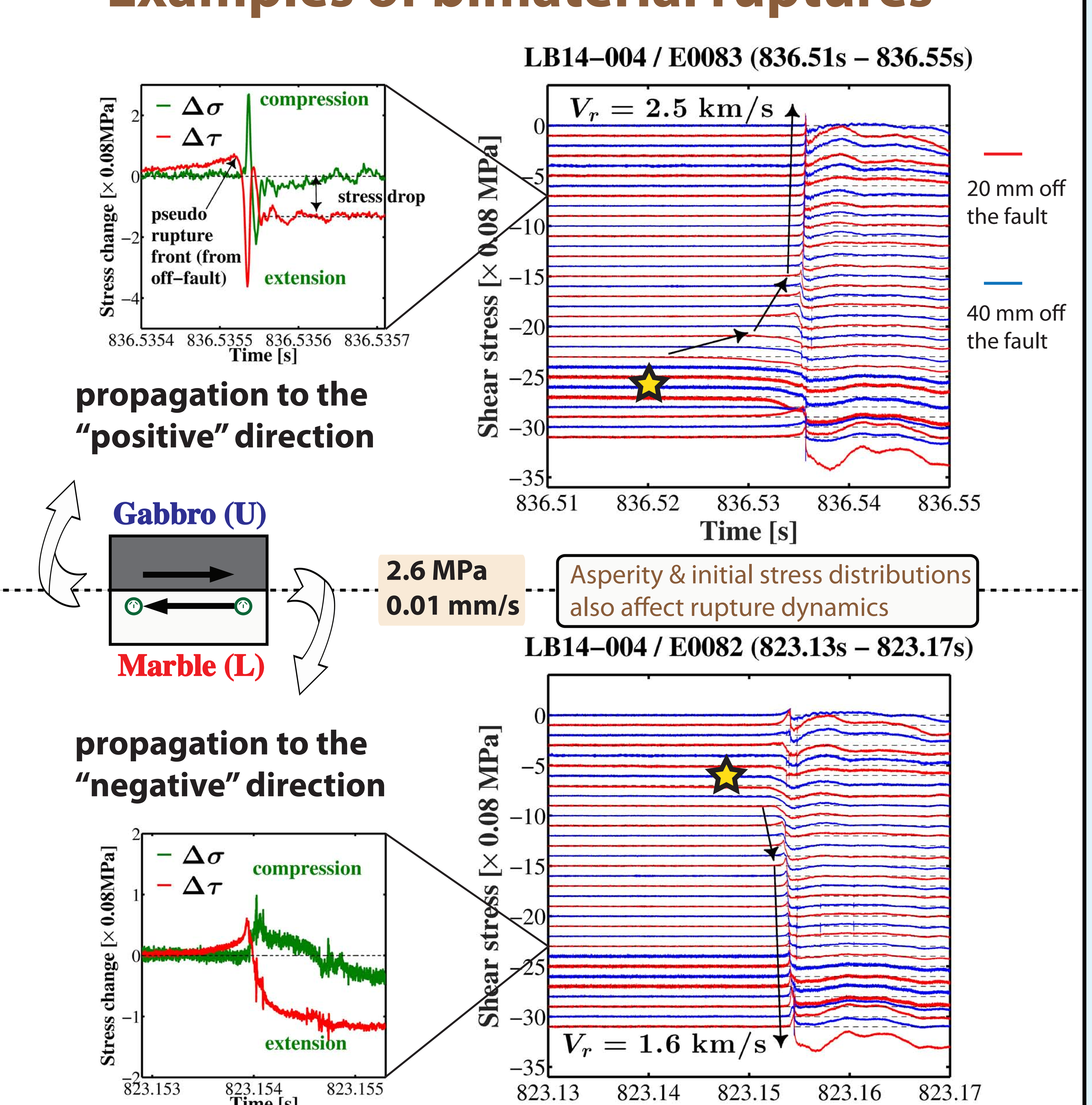
Stress profile correlates with the damage distribution



Surface damage pattern



Examples of bimaterial ruptures



Conclusions

1. Stick-slip behavior is observed along gabbro/marble interface, in contrast to the transitional behavior from stick-slip to stable-sliding along marble/marble interface.
2. Penetrated and sheared-off gabbro asperities play a key role in causing the above stick-slip behavior along gabbro/marble interface, which may resemble the role of seamounts in generating earthquakes in sediment-rich environment (Cloos, 1992).
3. More work needs to be done before making any conclusion on rupture directivity.