Poro-elastic Properties of Whillan's Ice Stream Till: Implications for Basal Stick-Slip

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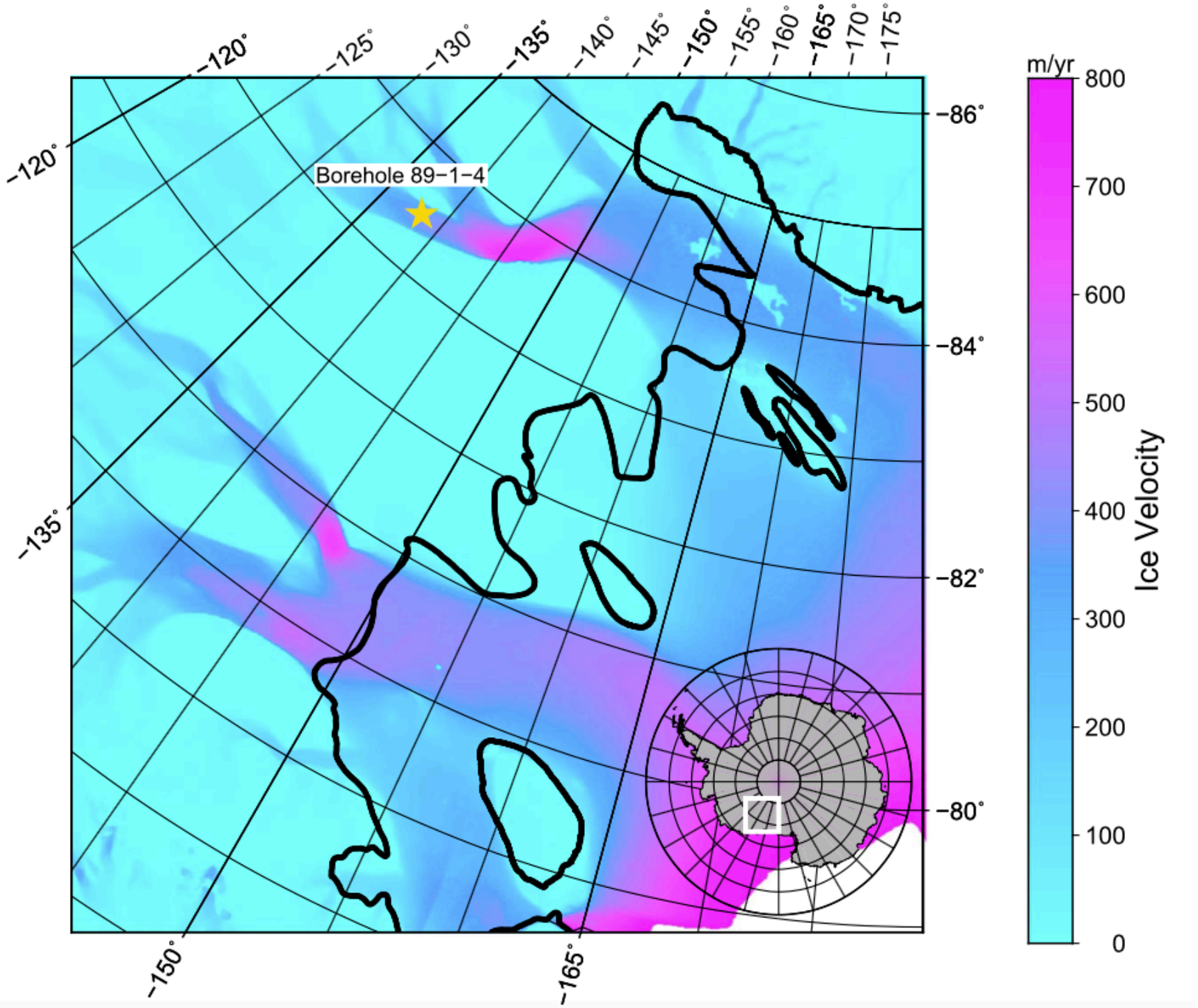
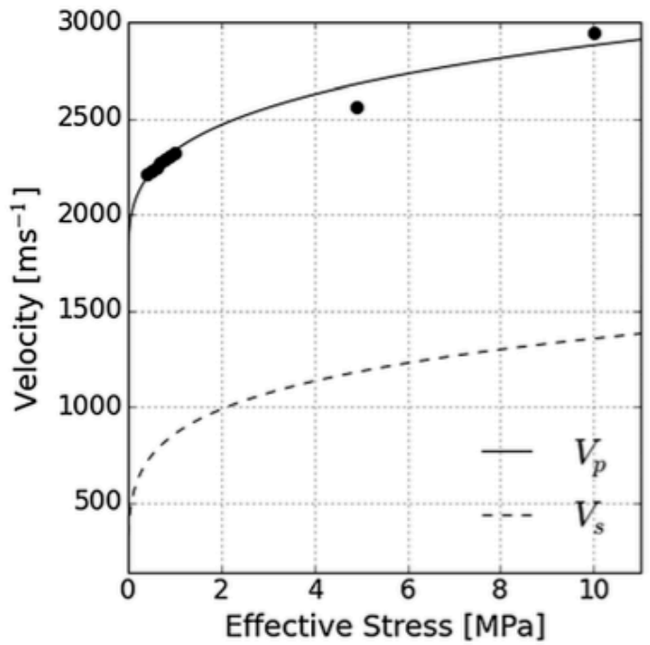


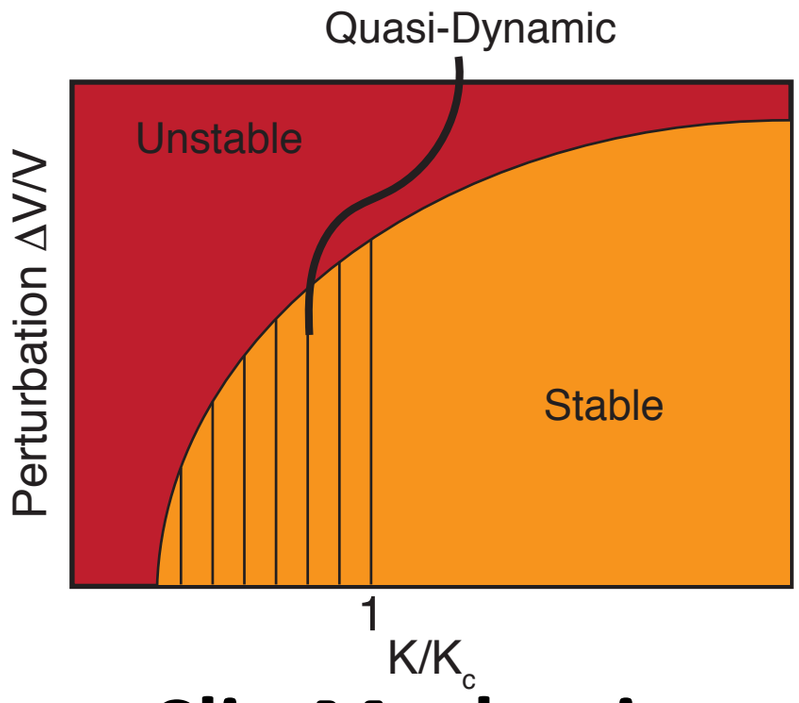
PENN STATE ROCK AND SEDIMENT MECHANICS LABORATORY

We will discuss lab data, numerical models, and propose some slip mechanics arguments

Experimental

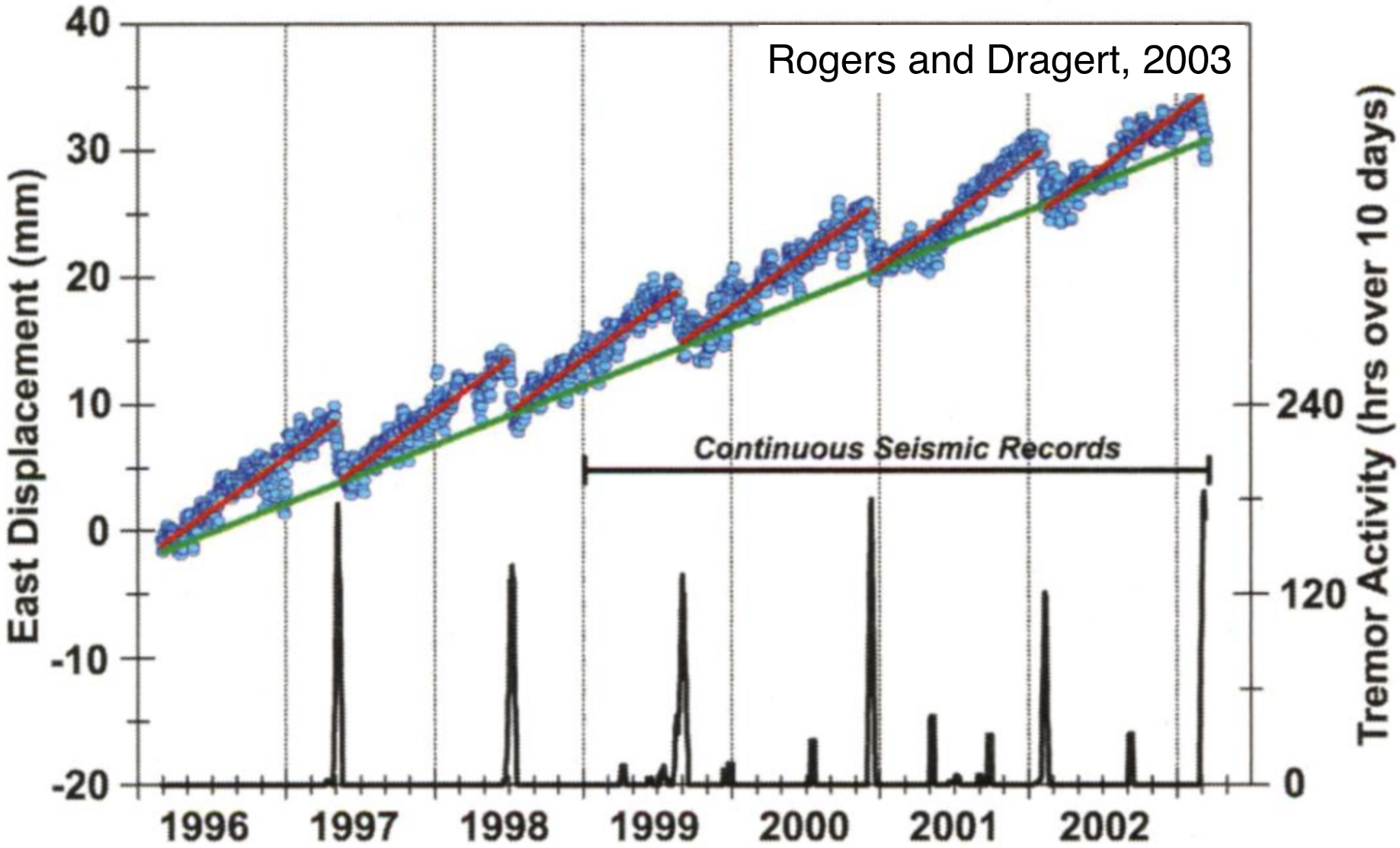


Modeling



Slip Mechanics

Whillans ice stream can be though of as analogous to tectonic slow-slip systems



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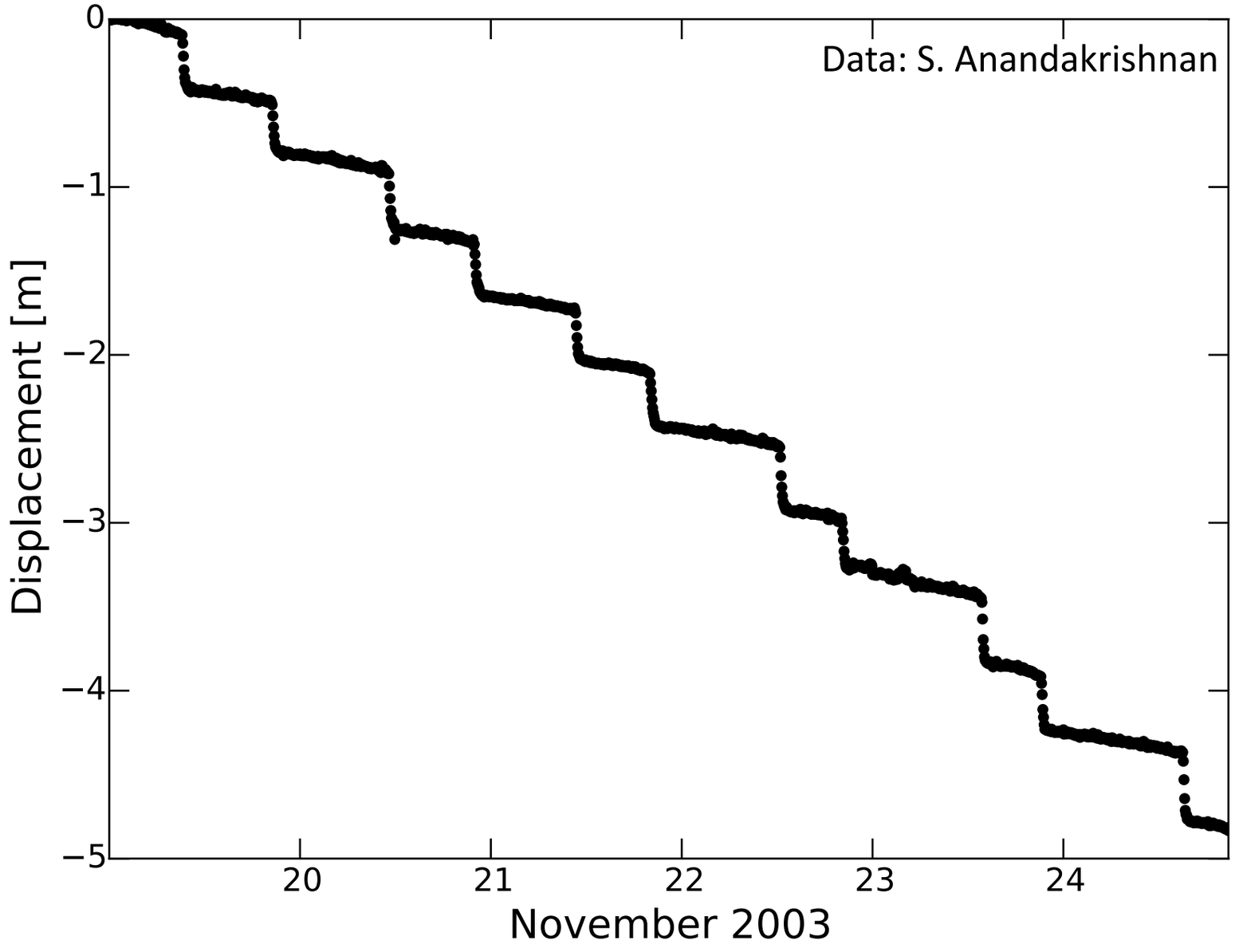
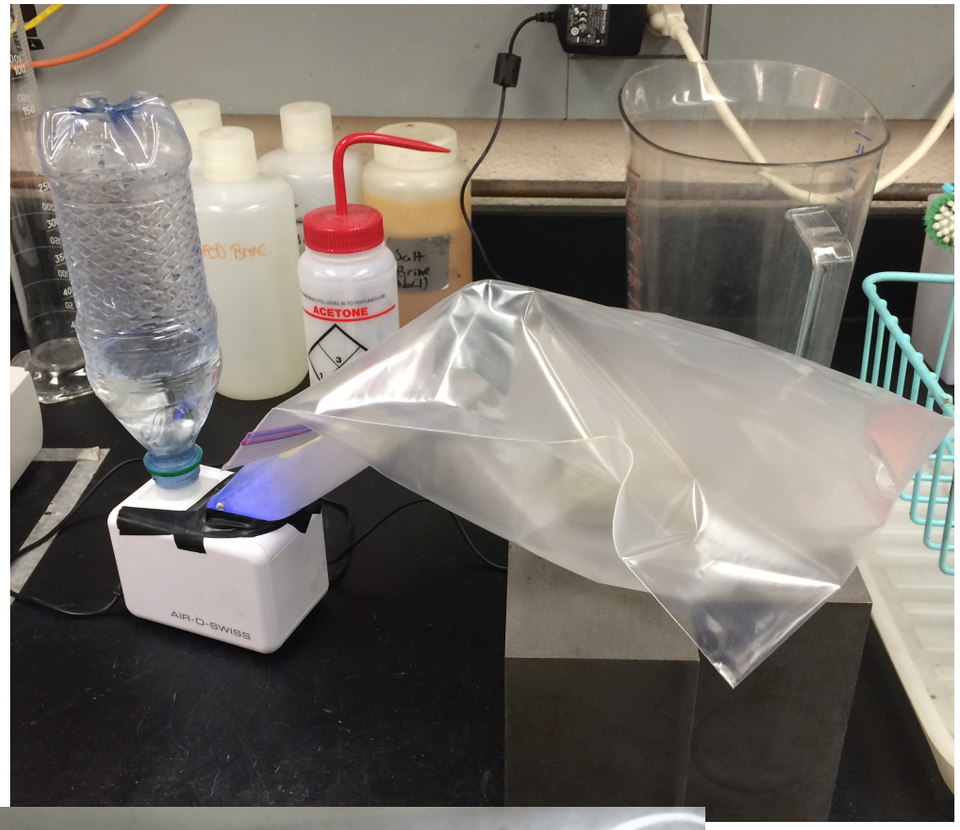
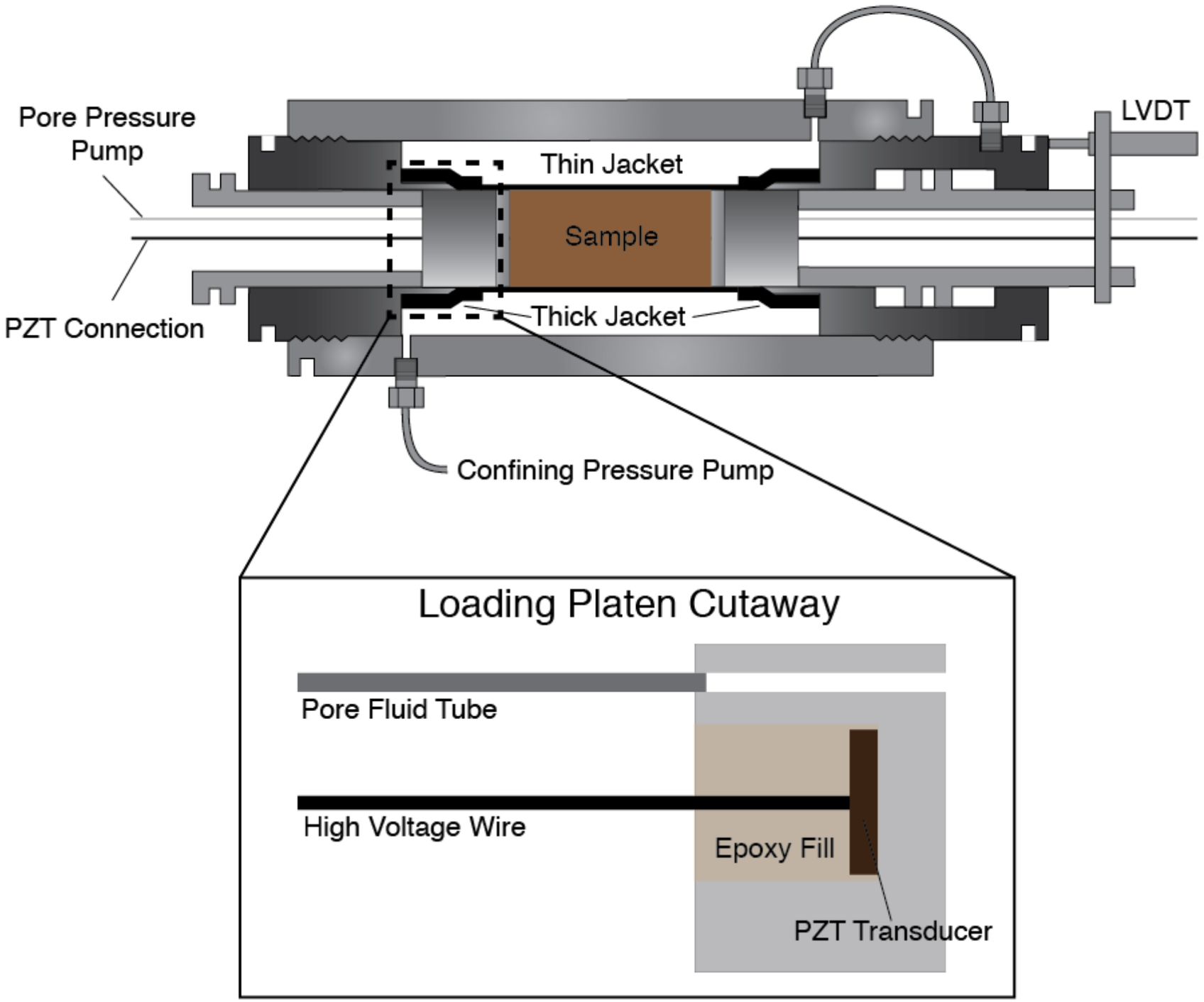


Till samples were collected with a custom designed hot water drill and piston core apparatus

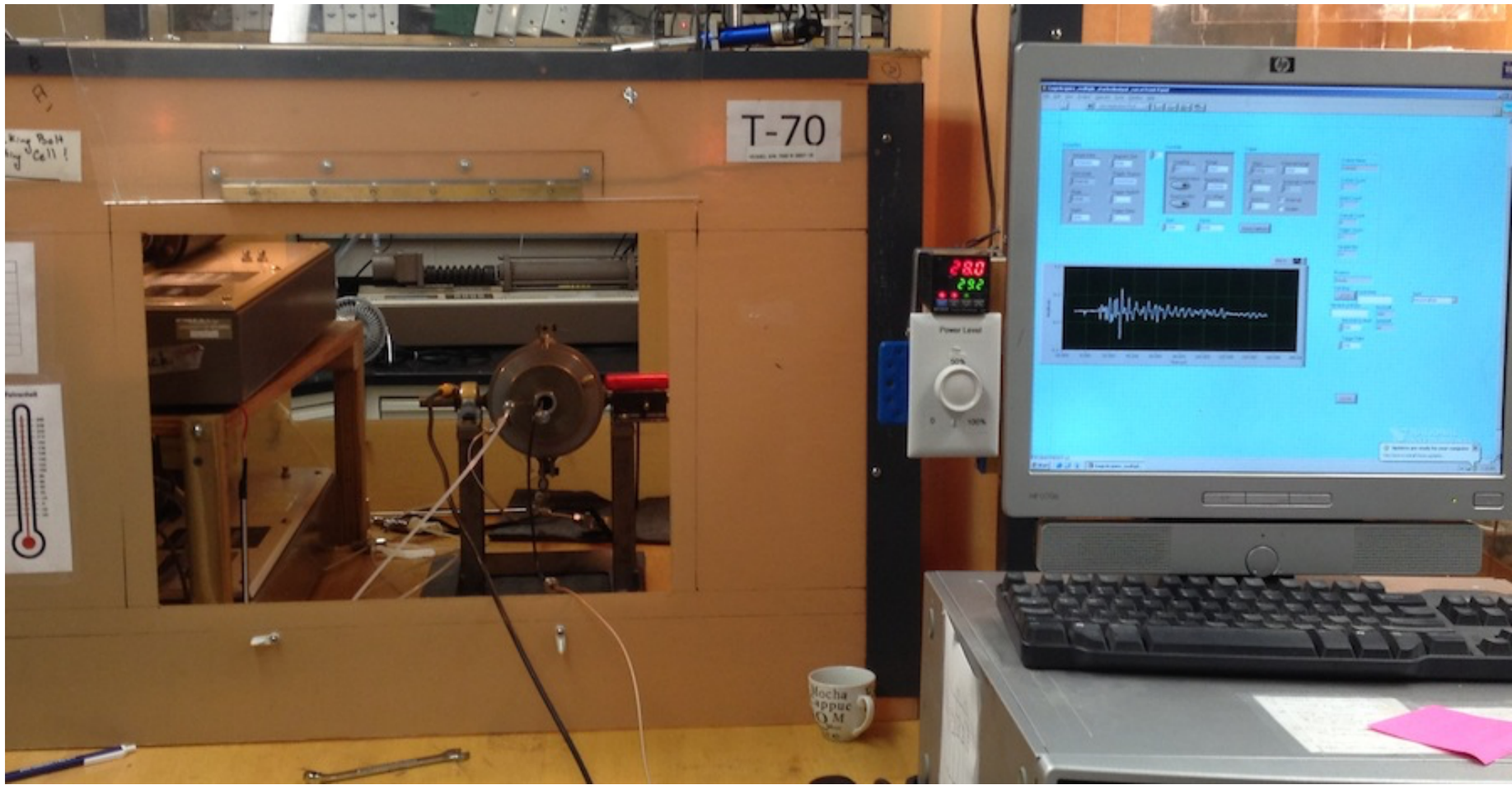
We re-hydrated and prepared the sample



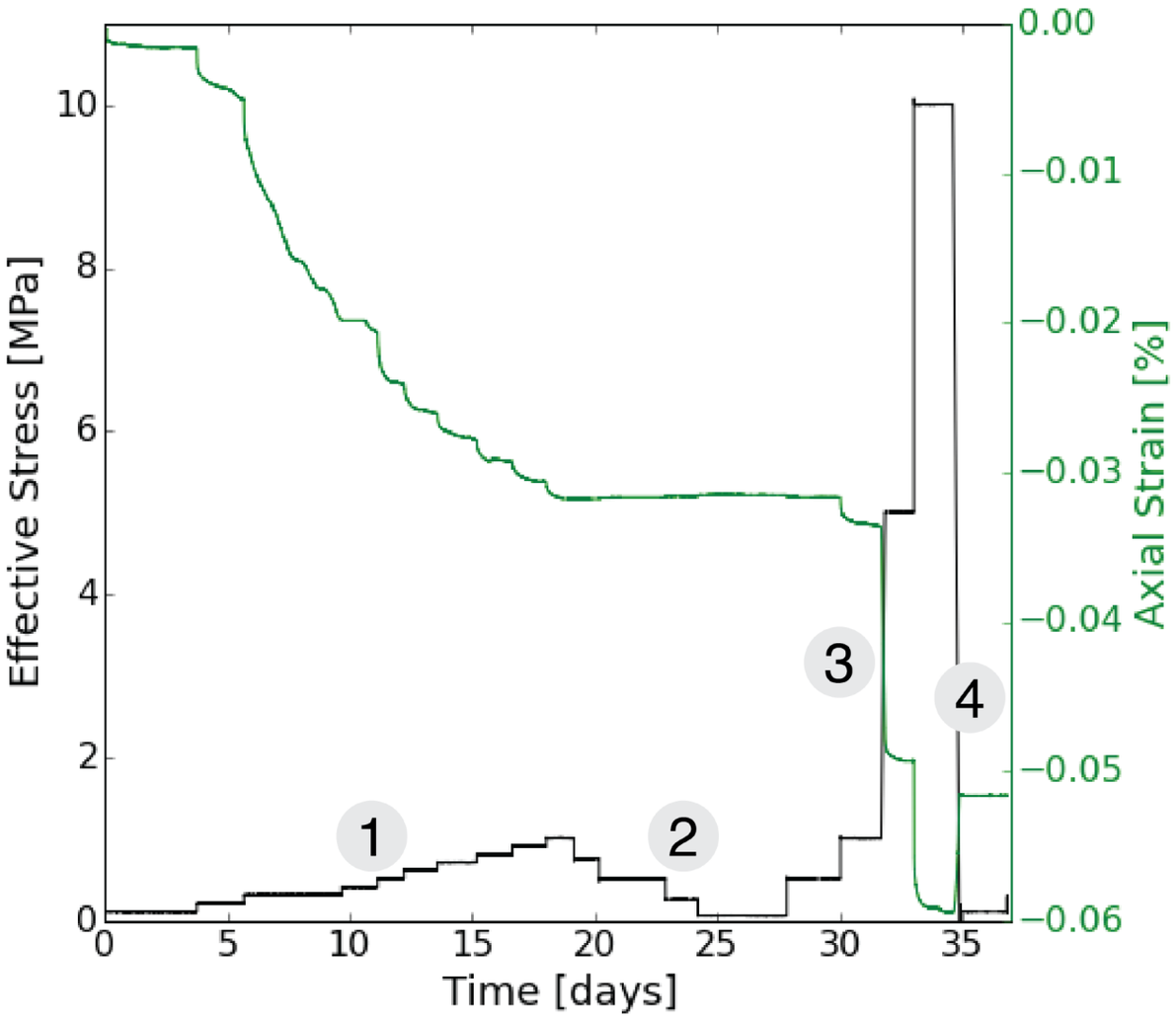
Experiments were conducted in a tri-axial pressure cell with low confining pressure modifications



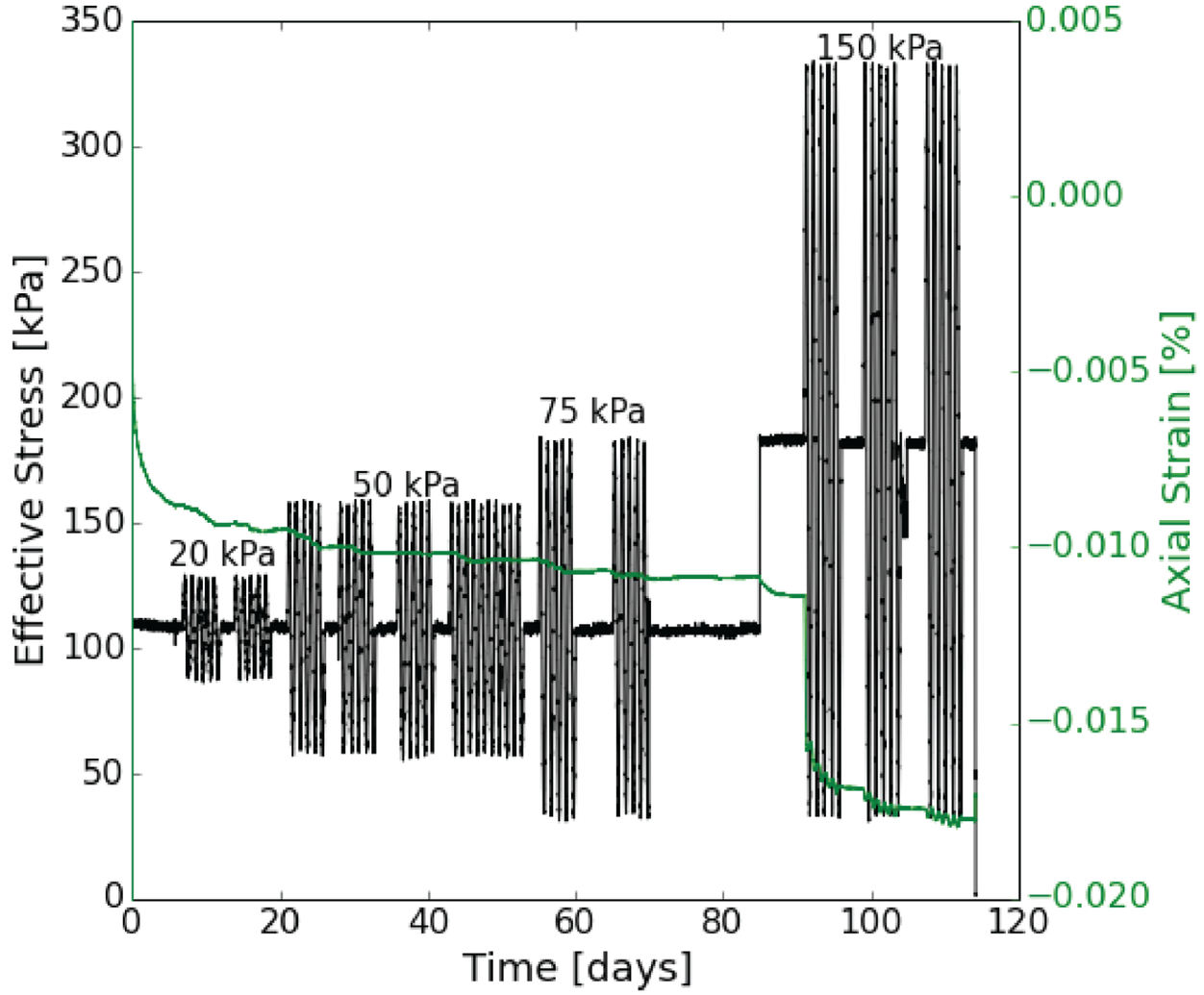
Everything is housed in a temperature controlled box and continuously monitored



We conducted two types of tests

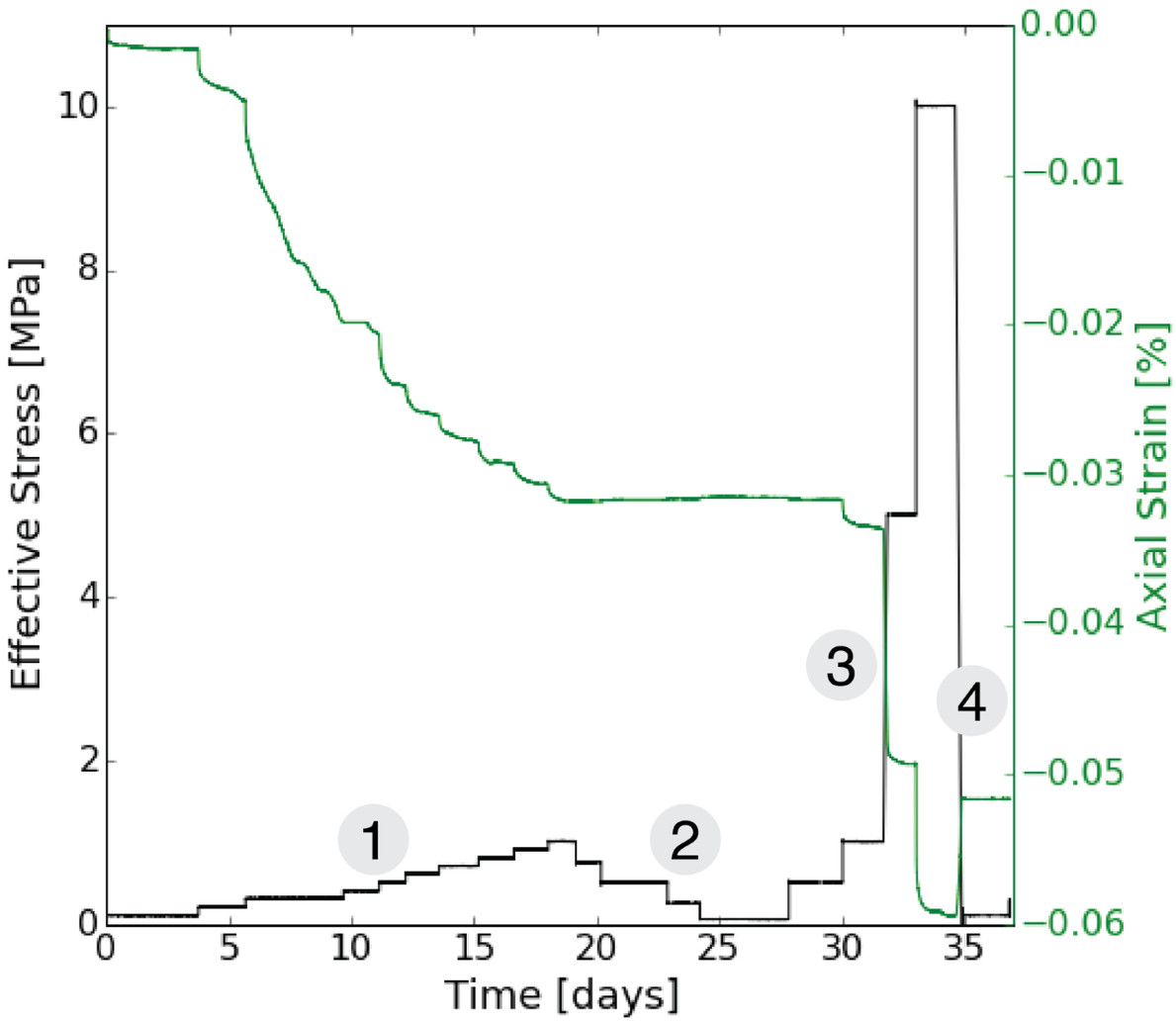


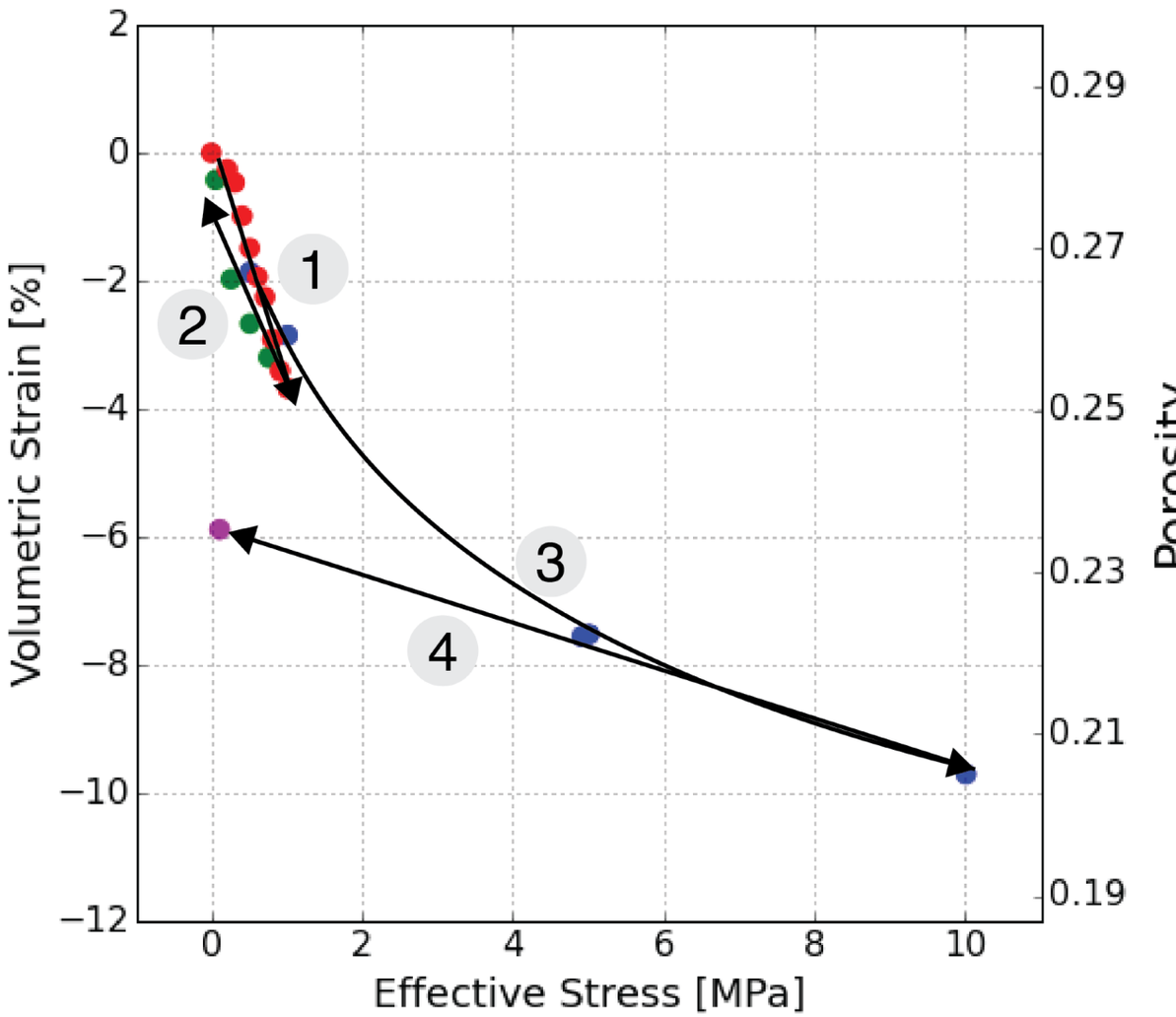
Step Loading



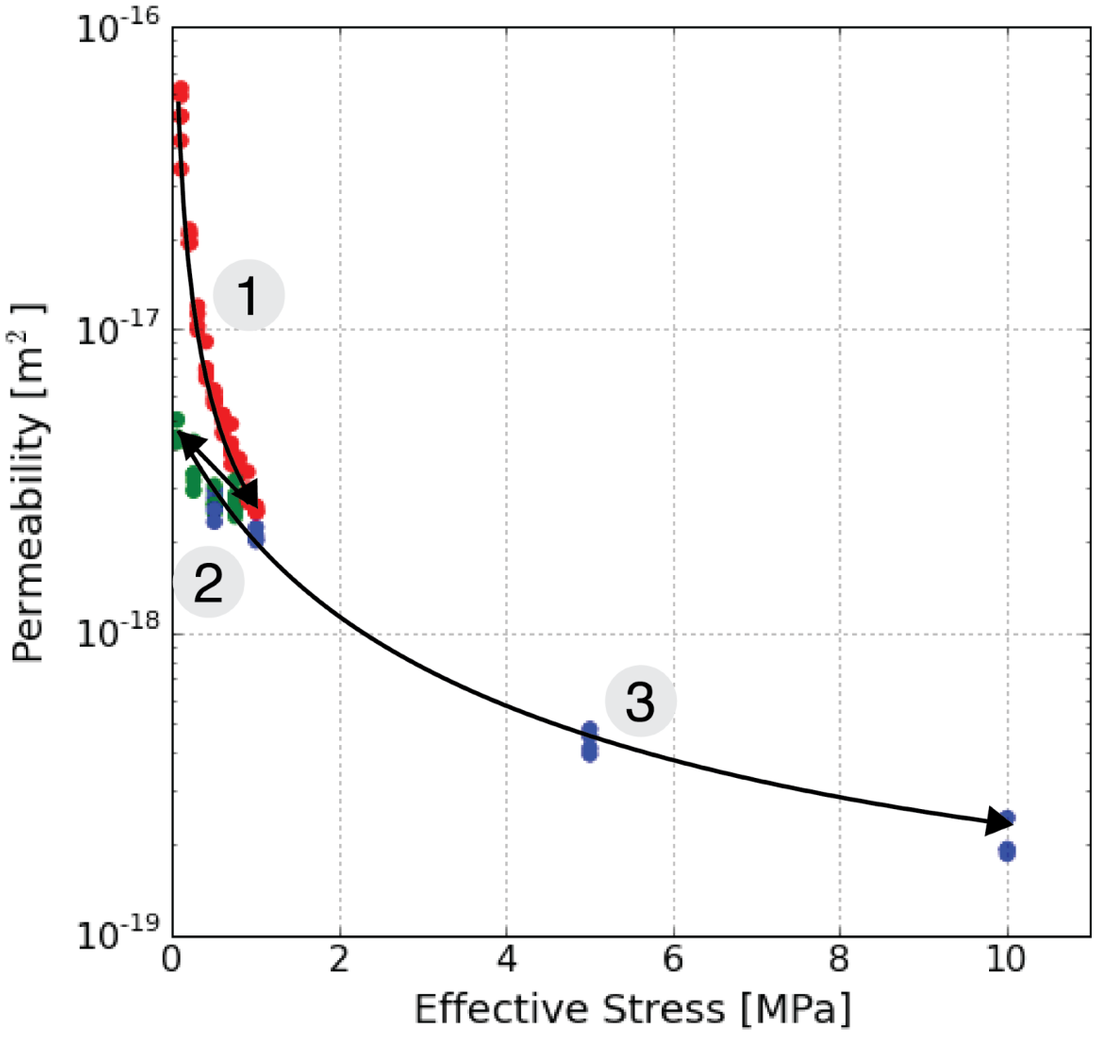
Tidal Loading

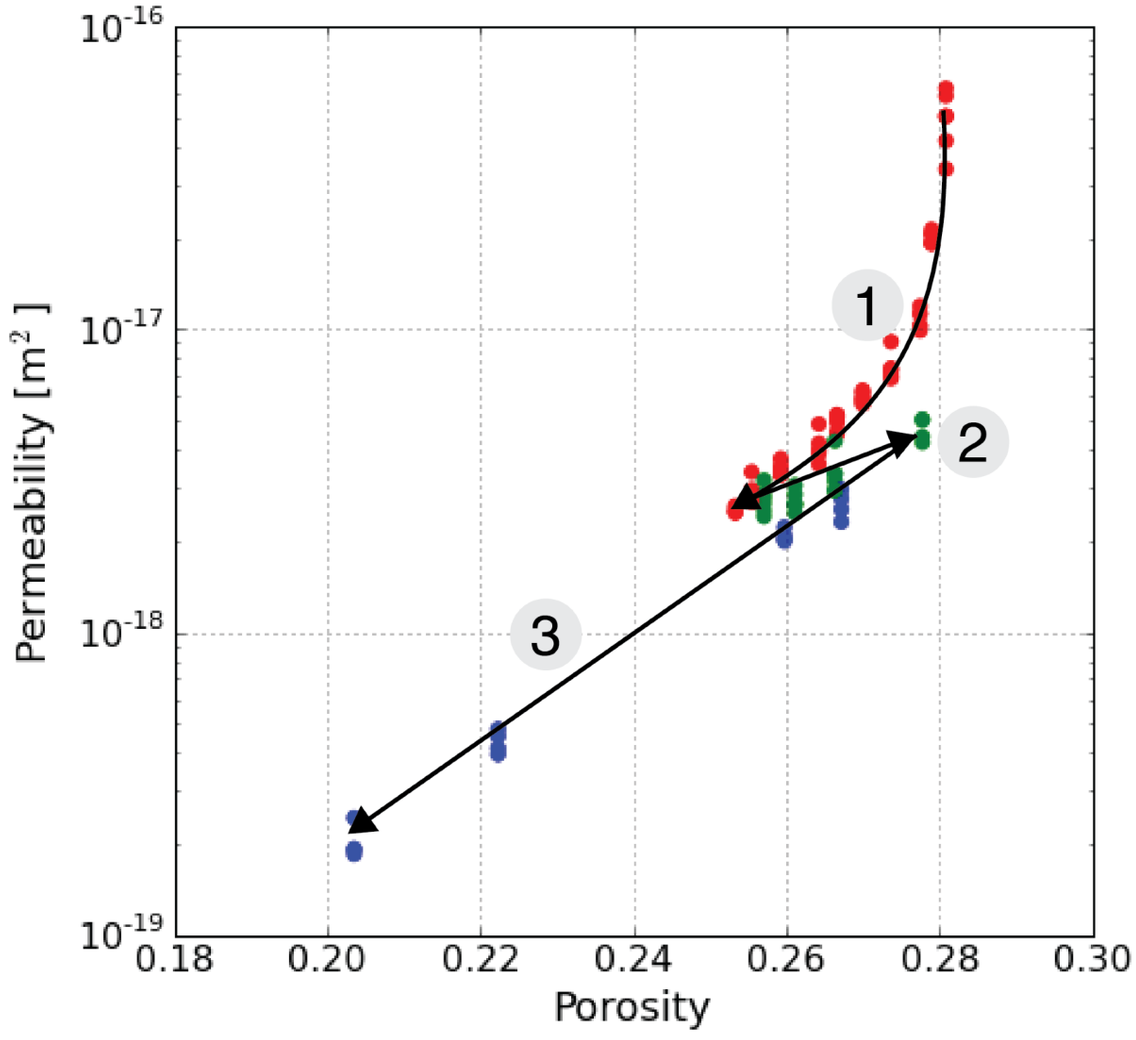
Up to 1 MPa loading was nearly linear elastic, permanently deforming at higher effective stresses



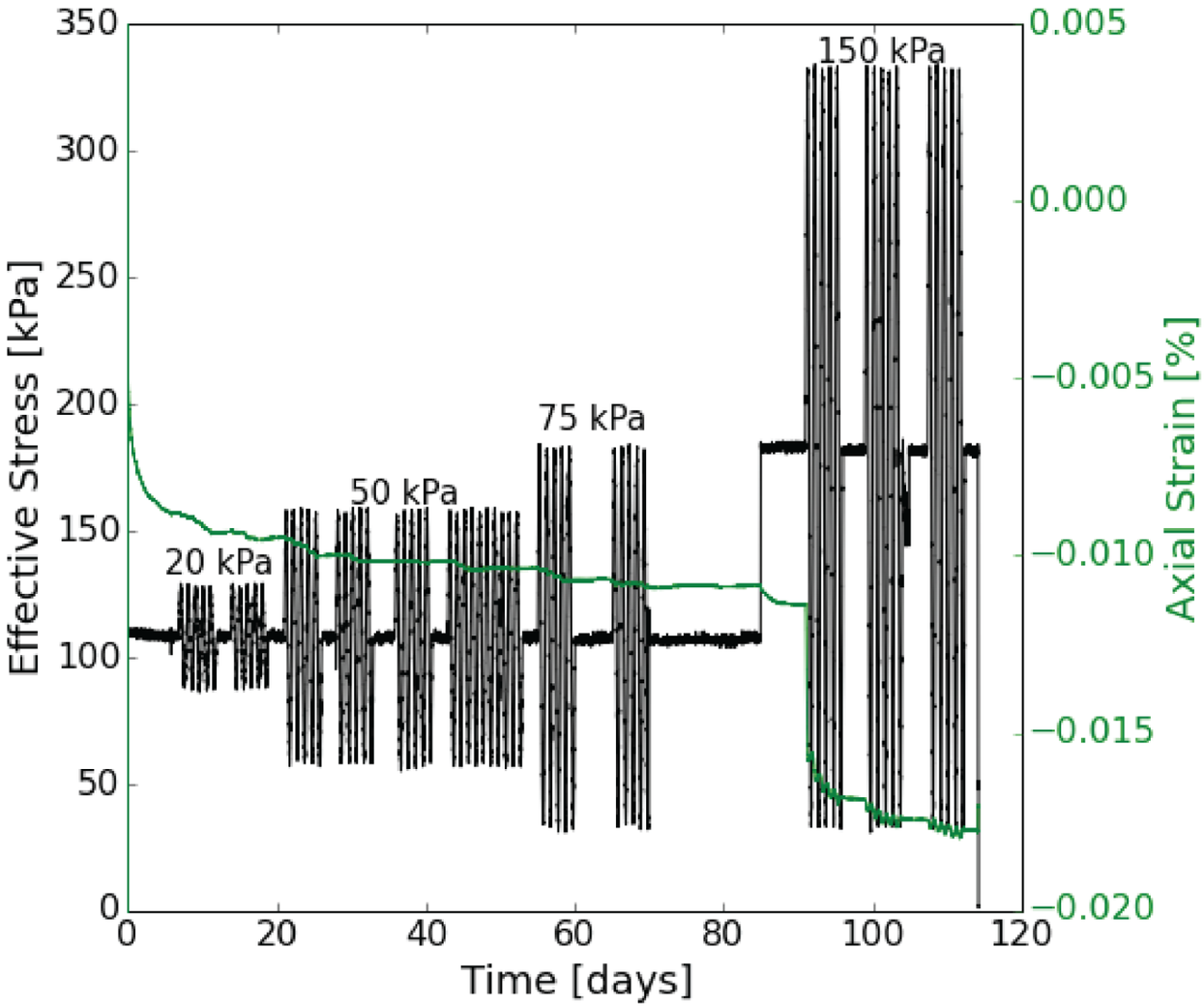


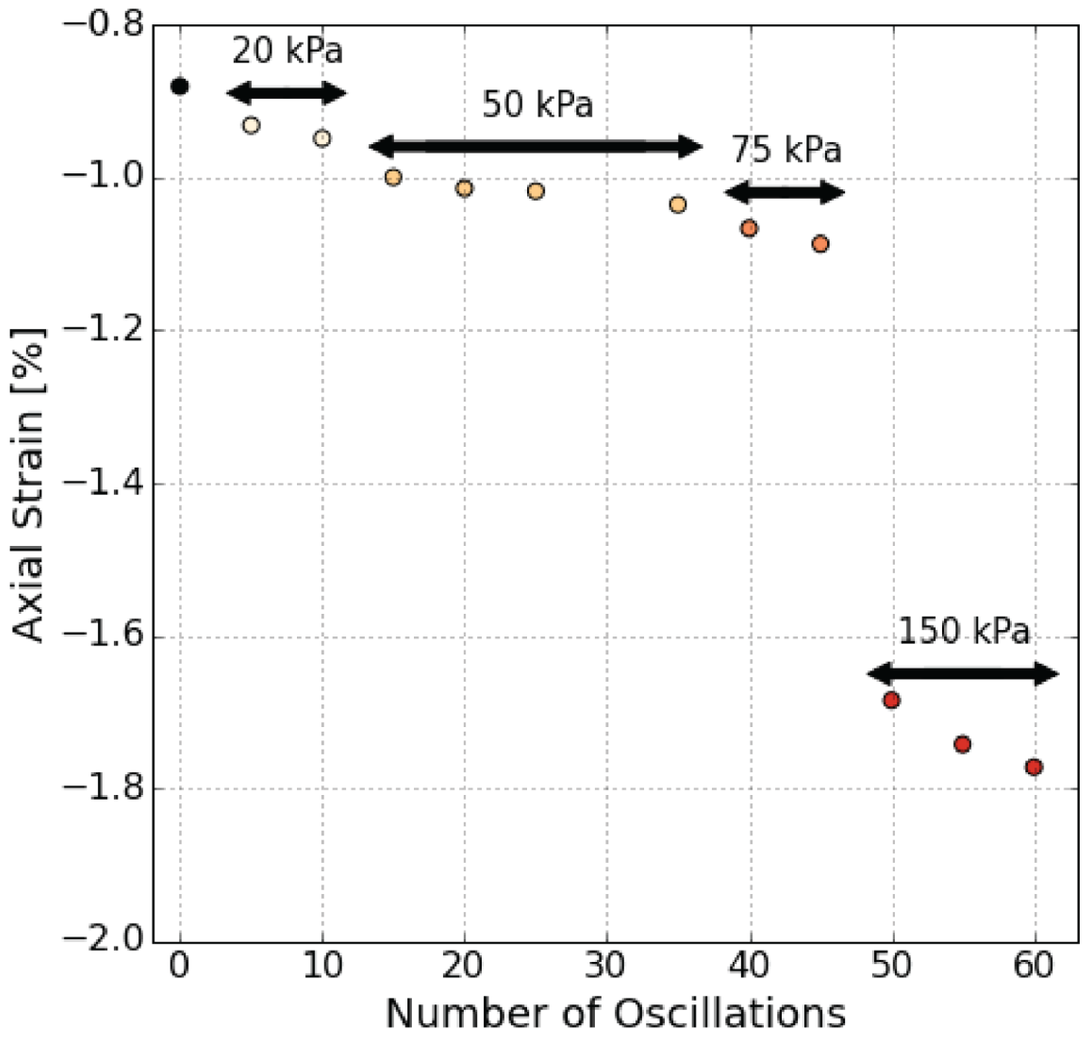
Permeability decreased an order of magnitude on the initial loading with little recovery



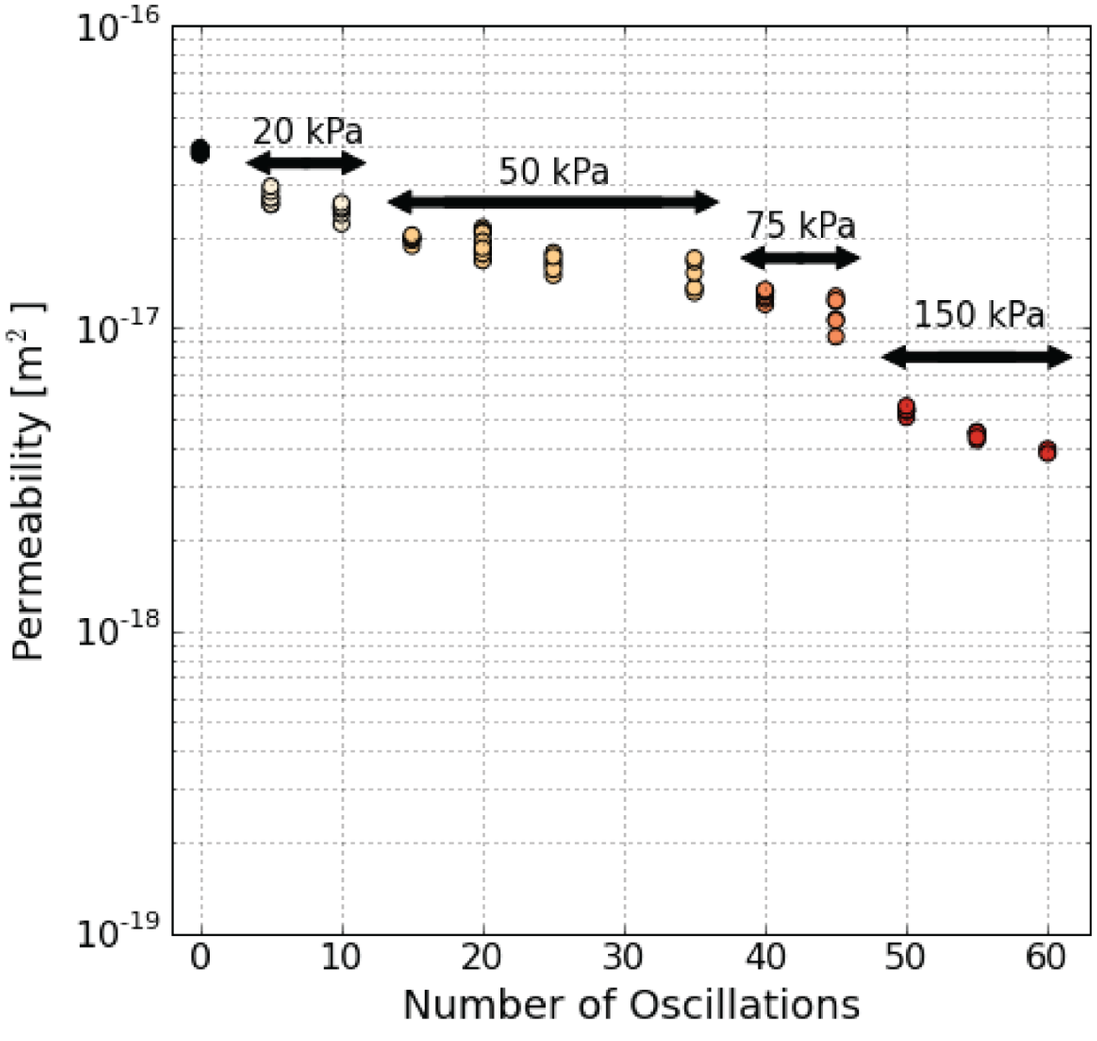


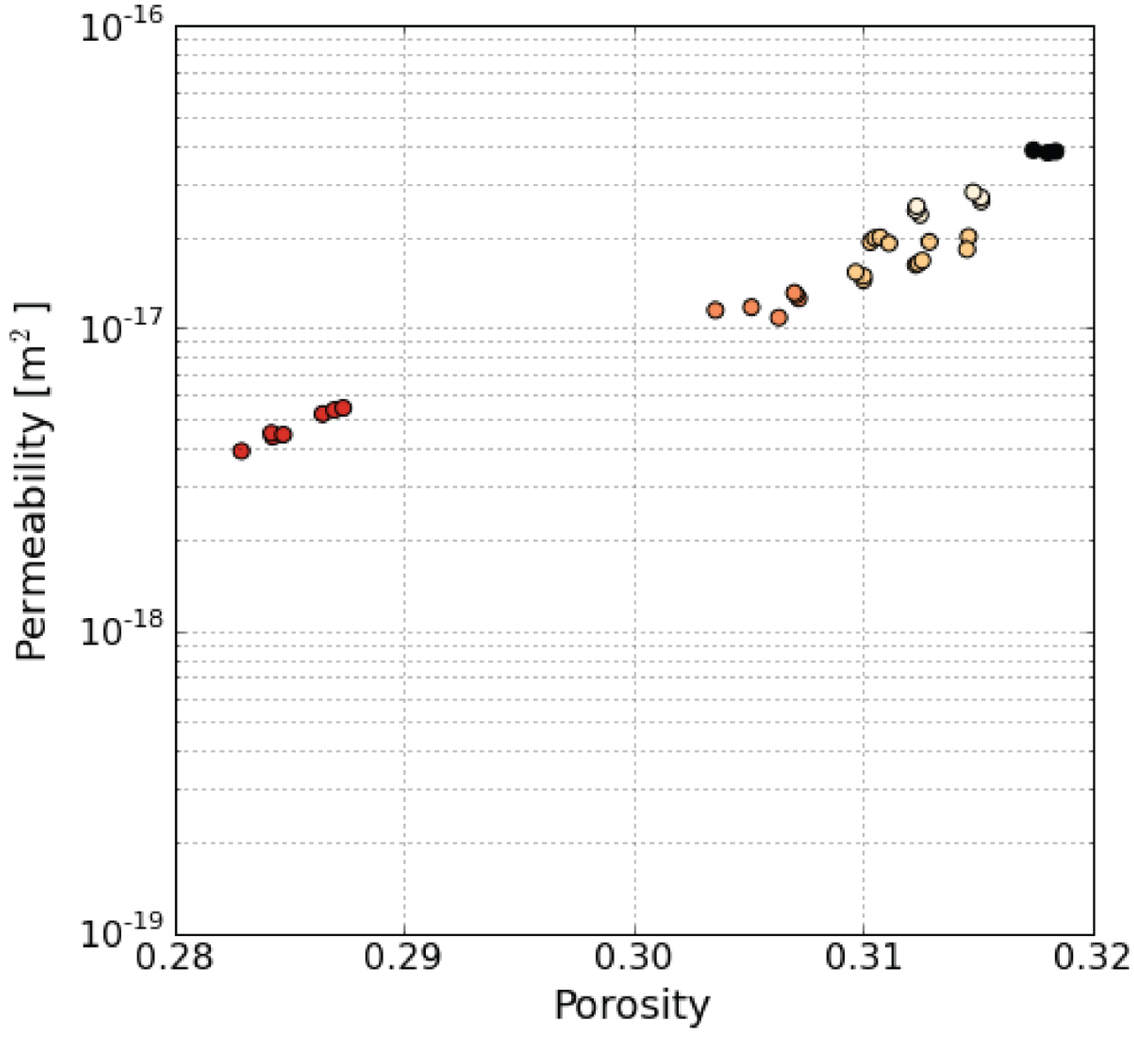
Tidal cycles produced continually increasing strains



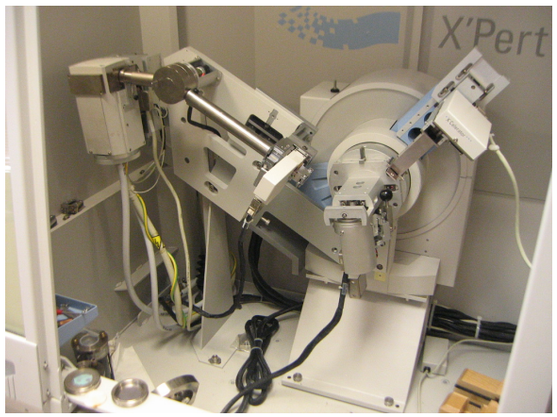


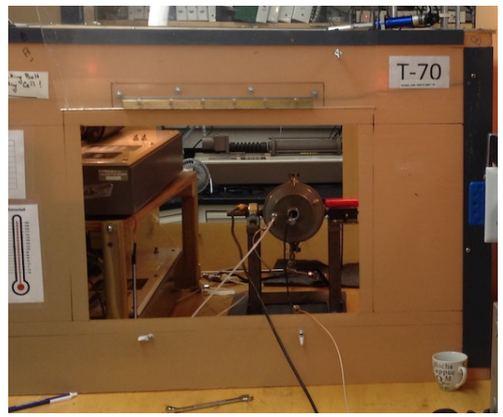
Permeability and porosity were also continually decreased with tidal loading





We can create and verify and effective medium model with our laboratory data

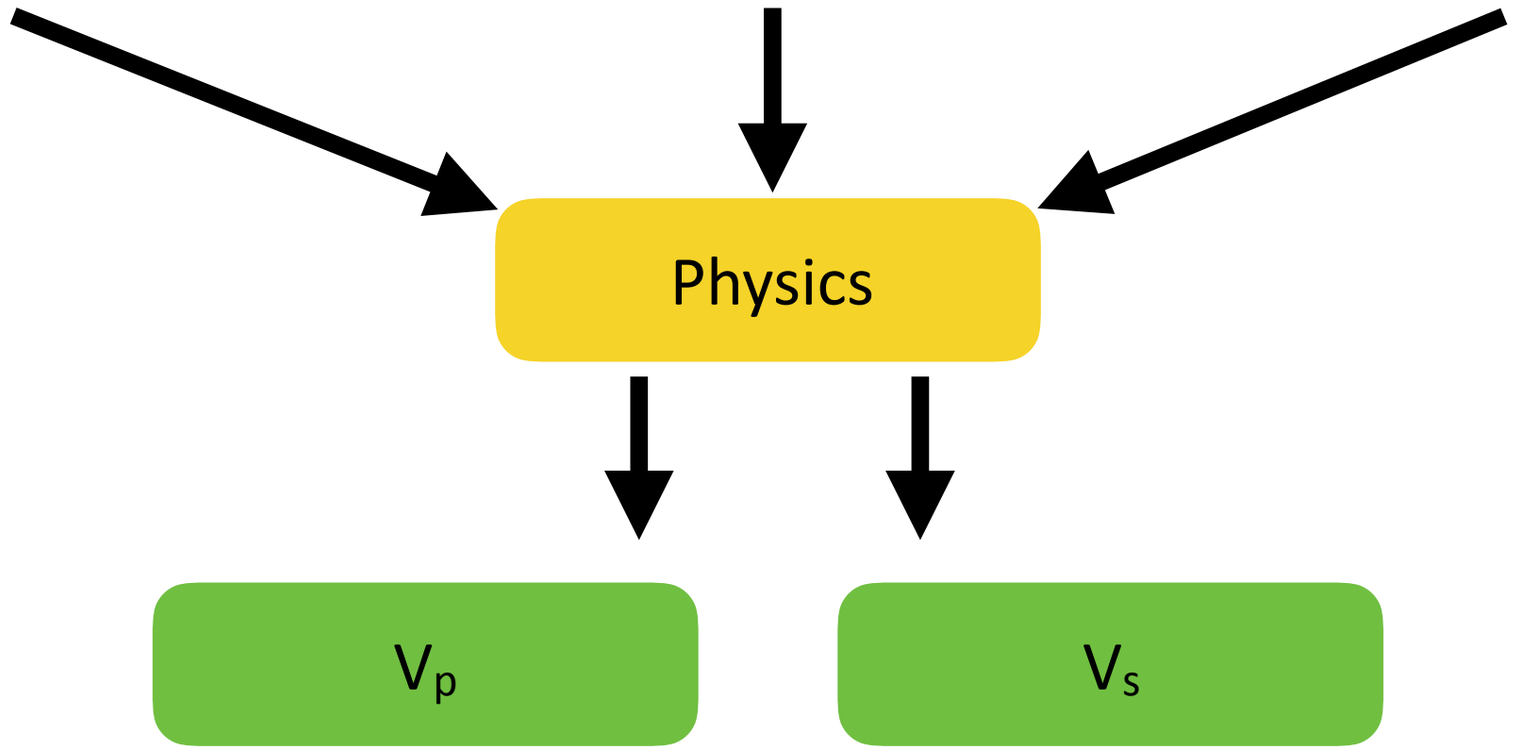




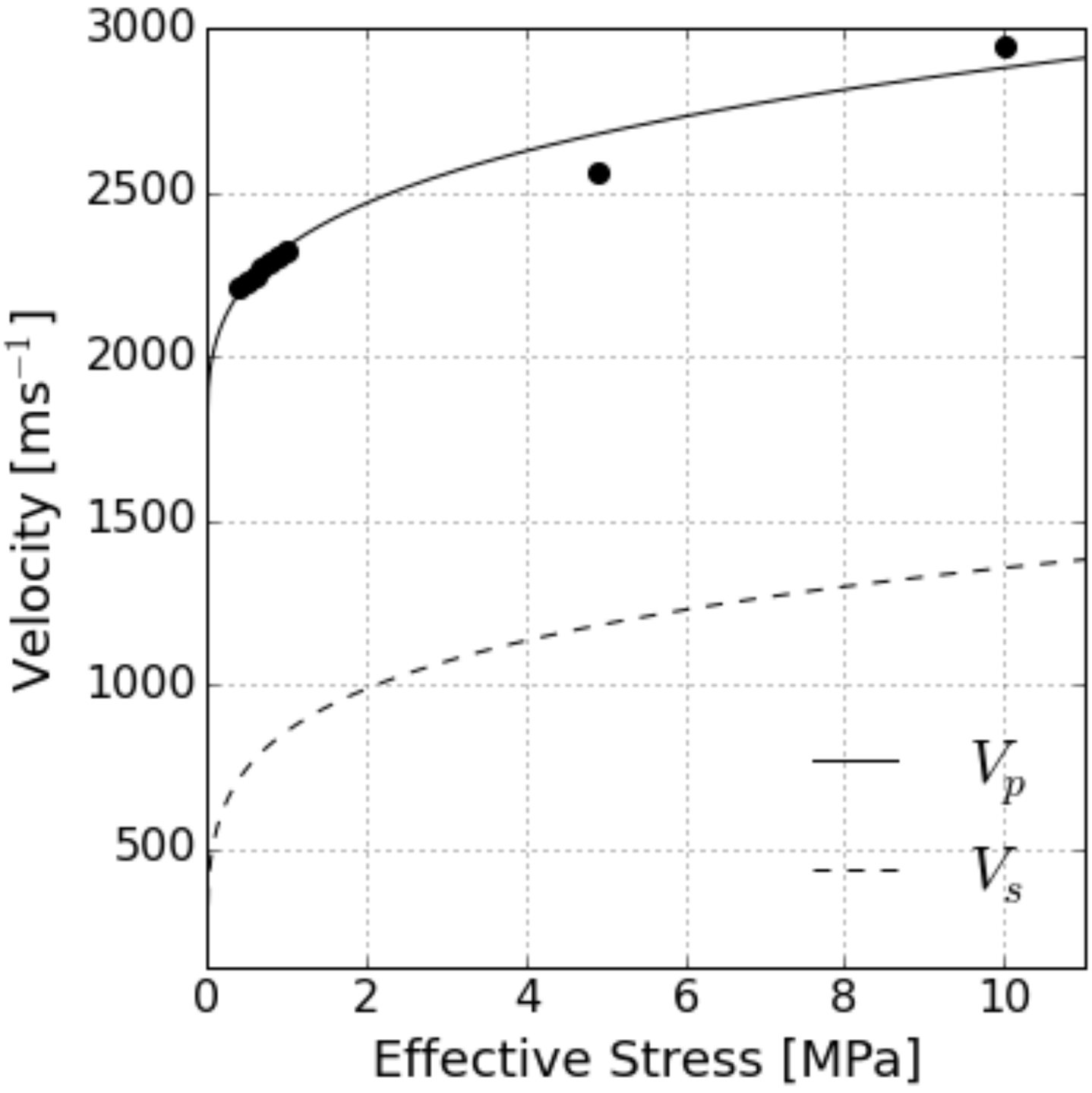
Rock Composition

Rock Properties

Mineral Props.



The model matches our V_p observations surprisingly well



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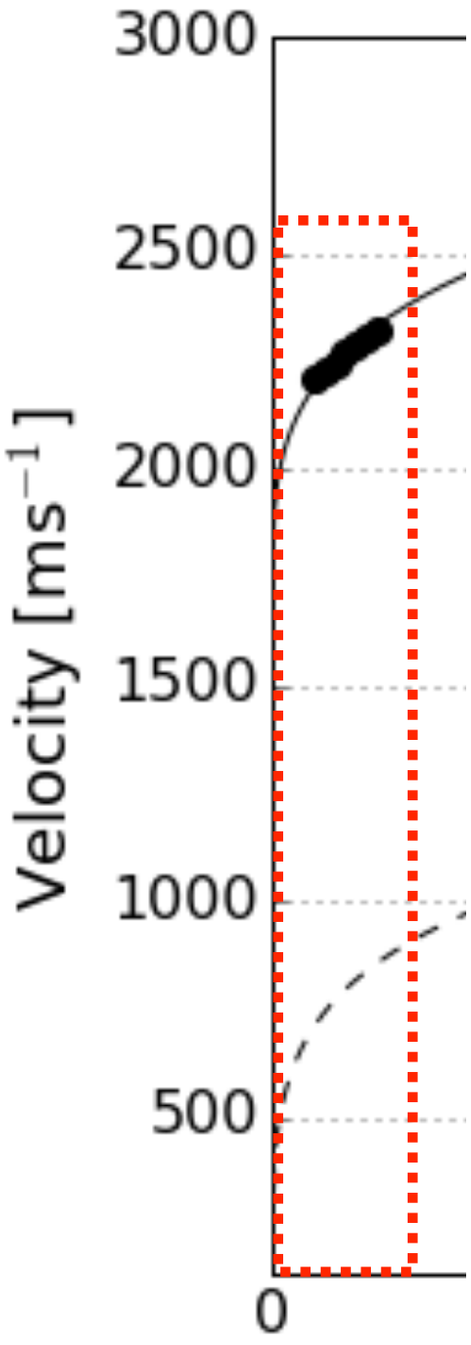
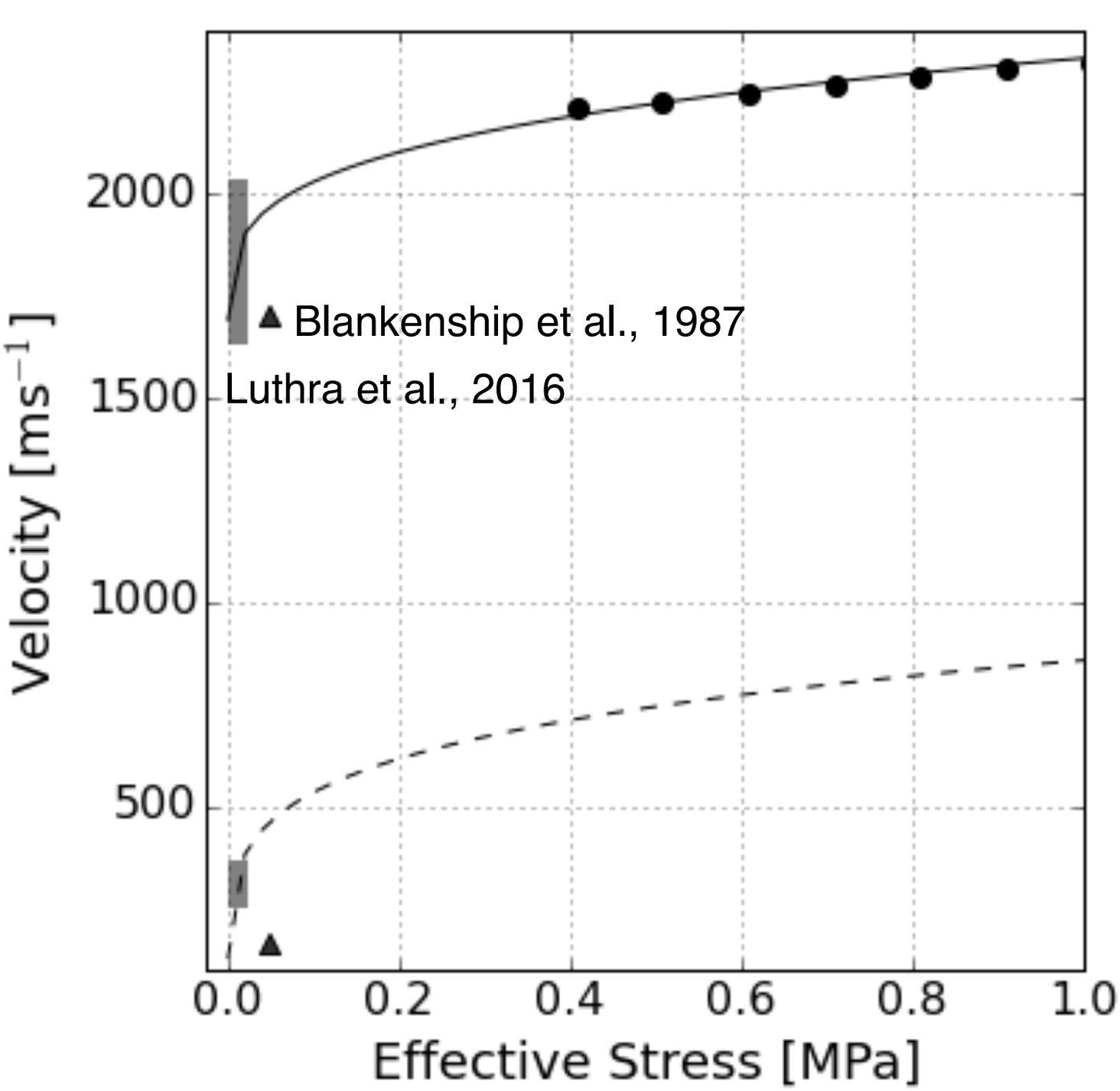
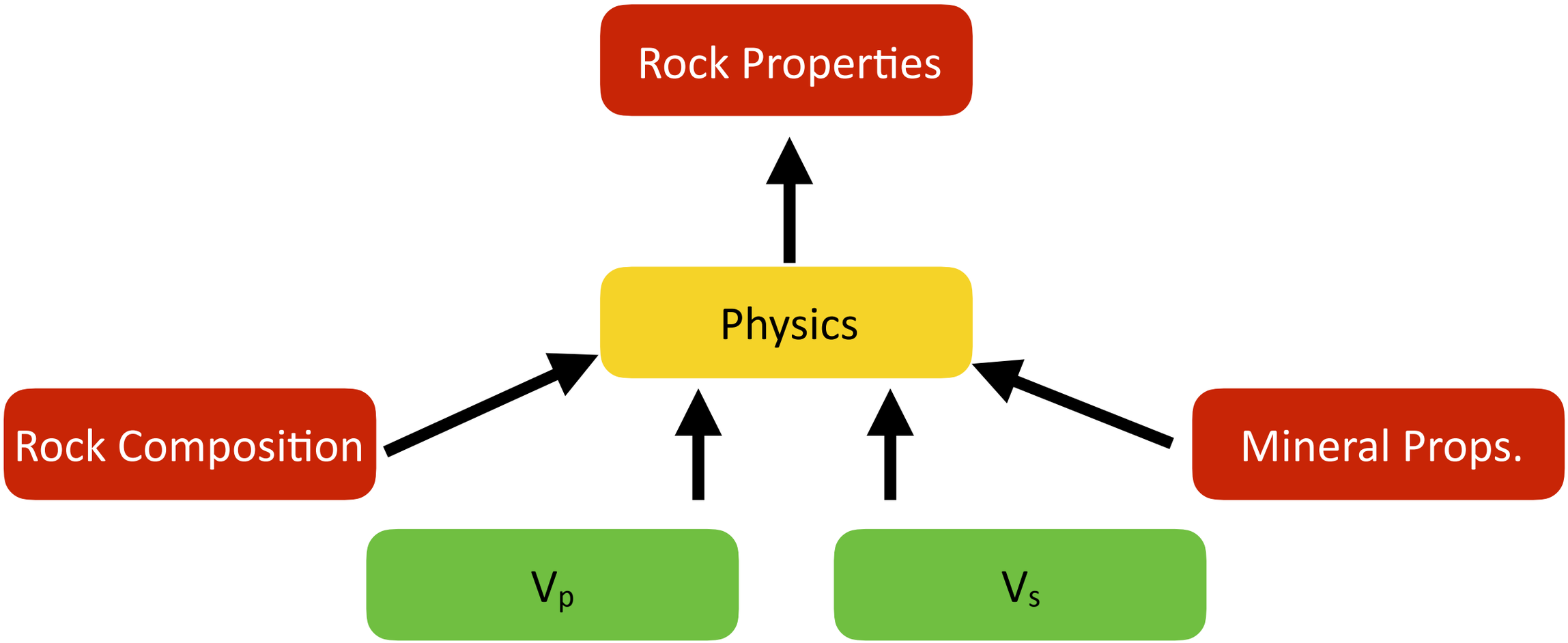
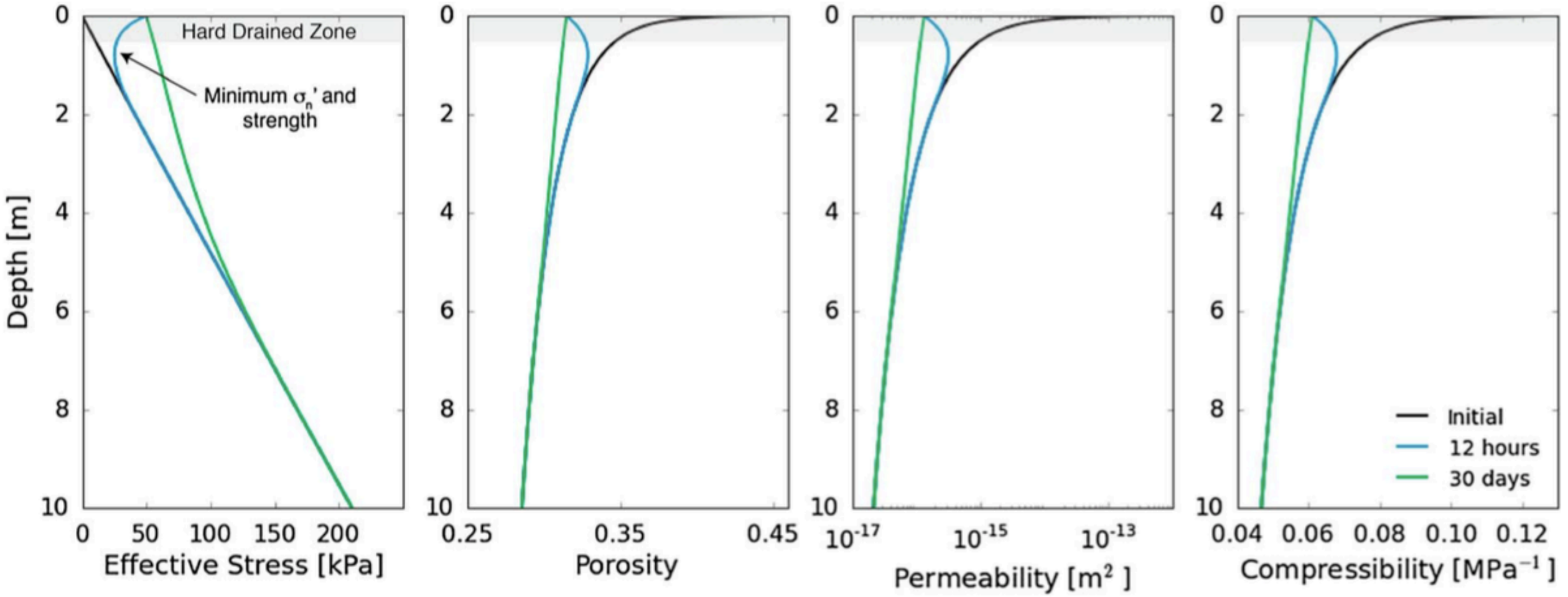




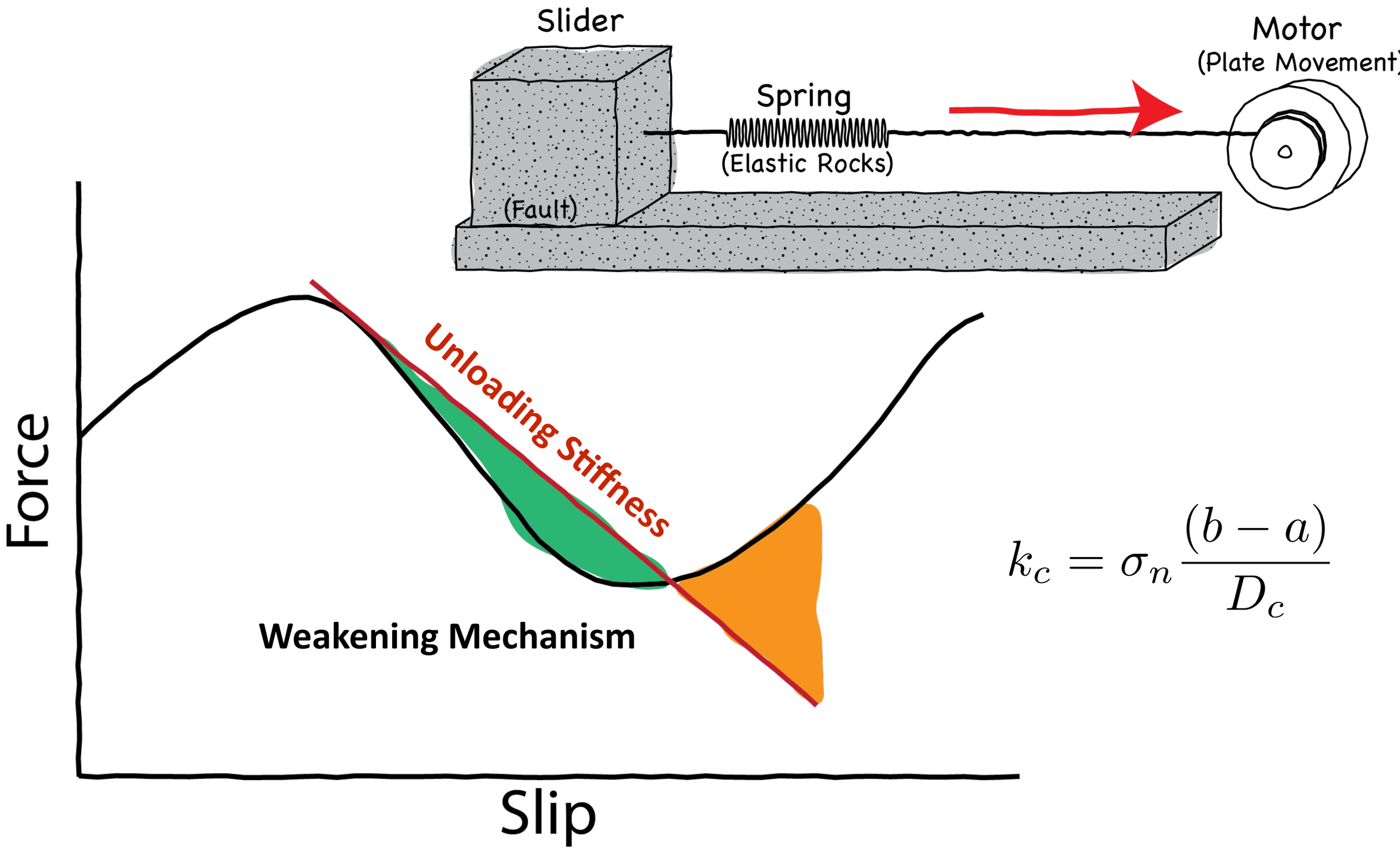
An effective medium model can help interpret seismic data in terms of physical properties



The models shows the development of a hard layer 10's of cm deep over 12 hours, meters deep over a month

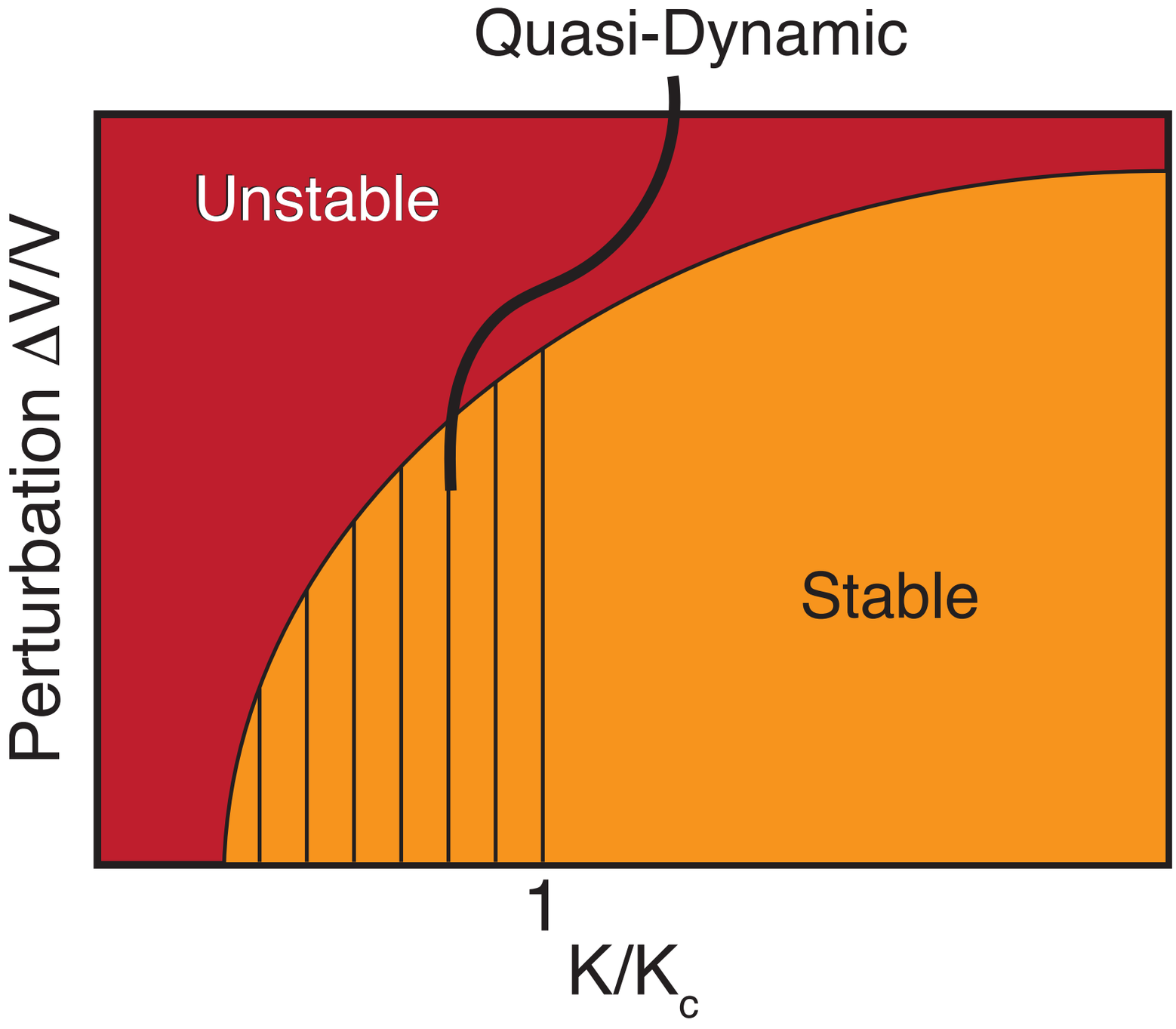


Stiffness of the system determines how the system will fail

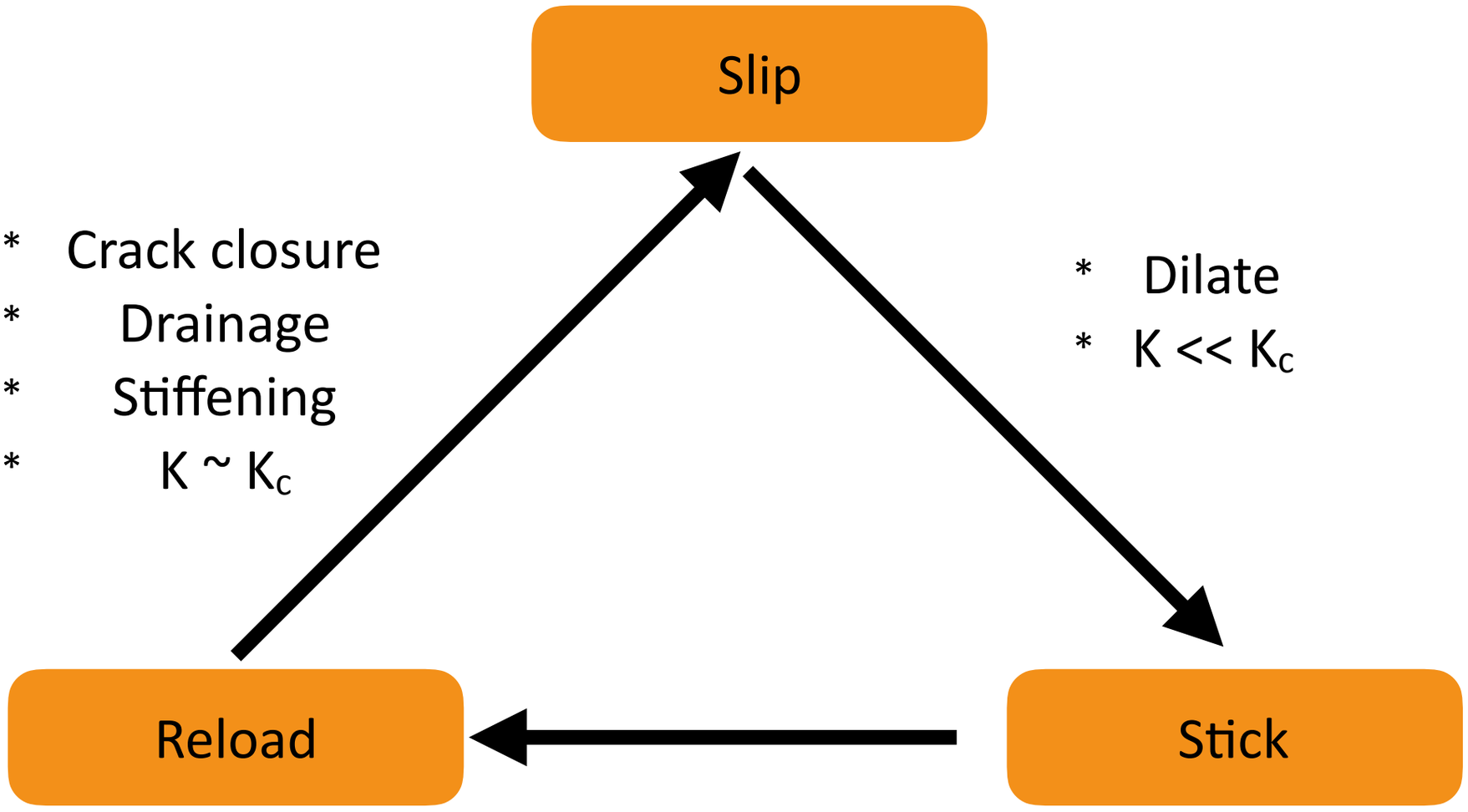


$$k_c = \sigma_n \frac{(b-a)}{D_c}$$

The stability bifurcation is more complex than a simple stable/ unstable boundary



A feedback loop could keep the system in the slow-slip regime for an extended period of time



* Elastic energy depleted
* Movement stops

Conclusions

- **Slow slip on the ice stream in maintained by the system's stiffness and critical stiffness**

- **Cyclic loading due to tides should lead to overconsolidation, embrittlement, and stick-slip motion**

- **Sonic velocity measurements are consistent with low effective stress at the base of ice streams**

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