

Nonstandard fragile geological features

Norman Sleep

Other than precarious rocks

- Persistence of topographic relief
- Shallow ambient rock
- Shallow tectonic stresses

Persistence of topographic relief



Near Cajon Pass

Sackungen: Deep slow landslides

Upper tens of meters moves downhill ~ 1 m during major San Andreas earthquakes.

Horizontal shear traction from Peak Ground Velocity (PGV) brings stiff rock into nonlinearity with horizontal shear tractions on vertical planes.

Dynamic stress scales with PGV.

Failing rock slides downhill. Weight on vibrating ramp.

Slope here is $\sim 19^\circ$.

Yet angle-of-repose $\sim 35^\circ$ slopes persist nearby.

Shallow ambient rock

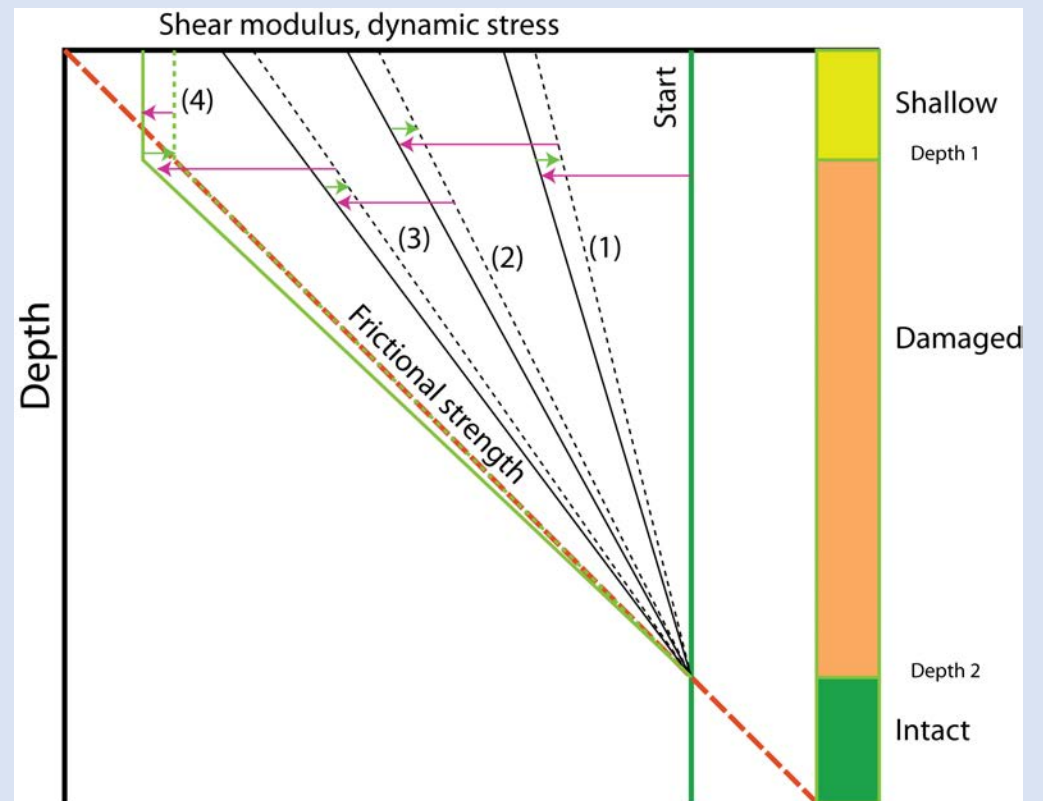
- Long-period Love waves and the near-field velocity pulse bring shallow, stiff rock into nonlinear failure.
- Deep elastic deformation imposes dynamic strain on shallow rocks.
- Strain scales as particle velocity / phase velocity: V/c
- Dynamic stress scales as strain times shear modulus: GV/c
- Failure occurs when dynamic stress exceeds frictional strength
- $GV/c > (\text{effective density}) * \text{gravity} * \text{coefficient of friction} * \text{depth}$
- $GV/c > (\rho - \rho_w) * g * \mu * \text{depth}$
- For constant material properties and water table at the surface

Shallow ambient rock

- Failure occurs when dynamic stress exceeds frictional strength
- $GV/c > (\text{effective density}) * \text{gravity} * \text{depth} * \text{coefficient of friction}$
- $GV/c > (\rho - \rho_w) * g * z * \mu$
- For constant material properties and water table at the surface
- Damaged zone self-organizes so that rock barely reaches failure for typical dynamic strain
- $G/z = (\rho - \rho_w) * g * (c/V) * \mu$
- Low-cycle fatigue

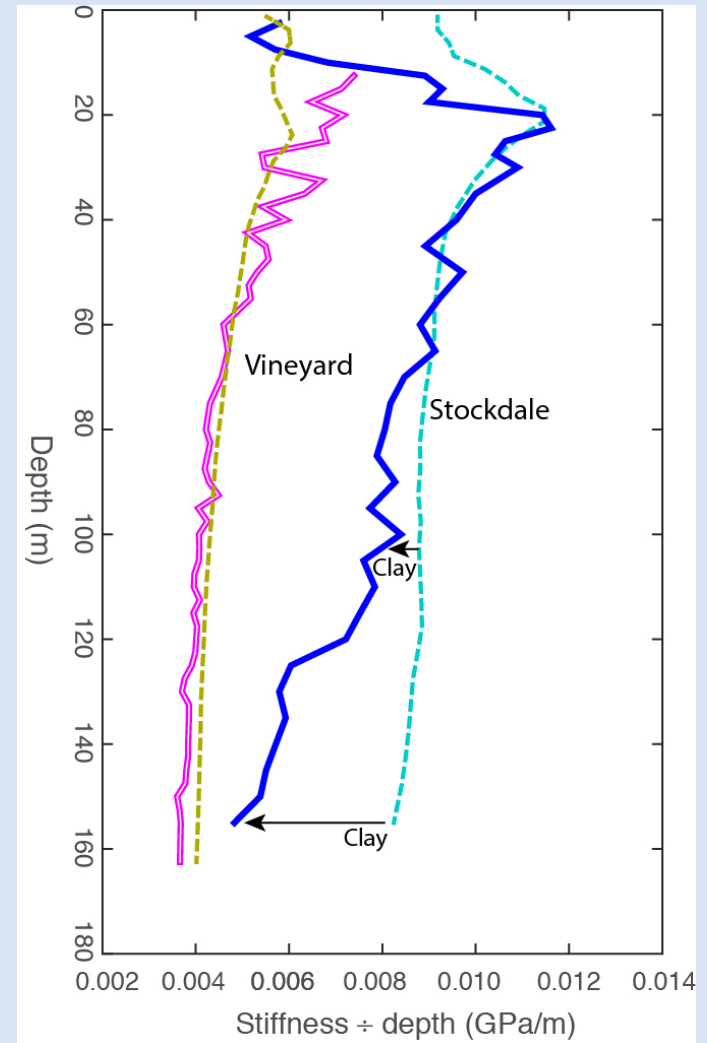
Shallow ambient rock

- Low-cycle fatigue

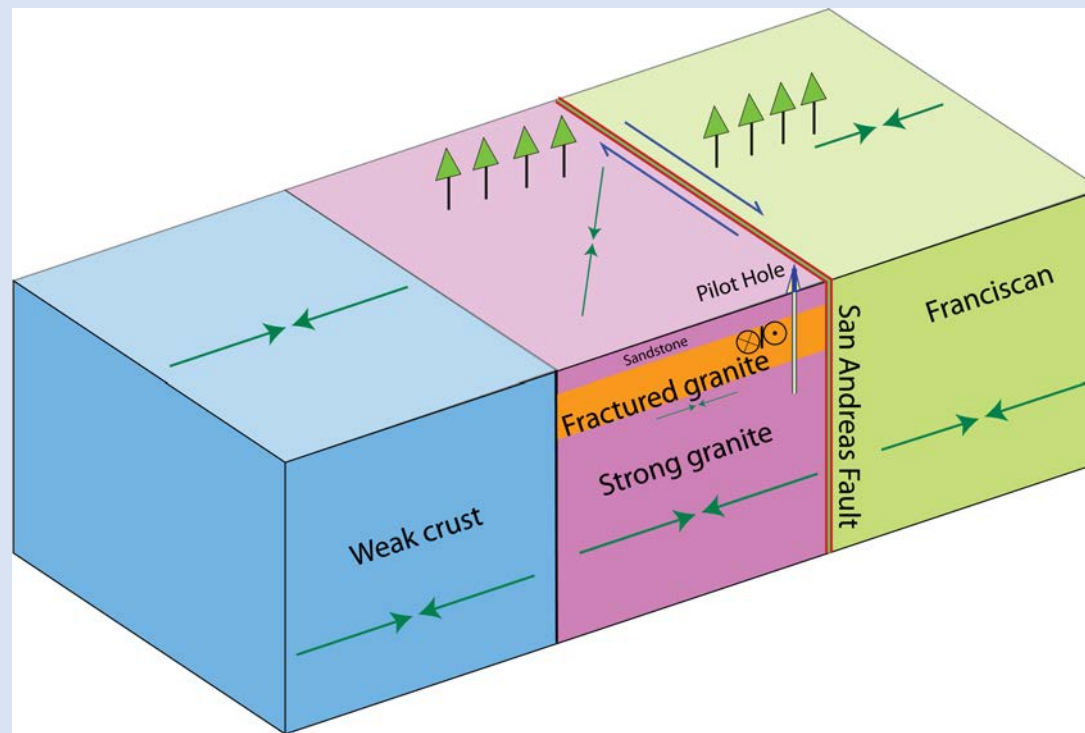


Shallow ambient rock

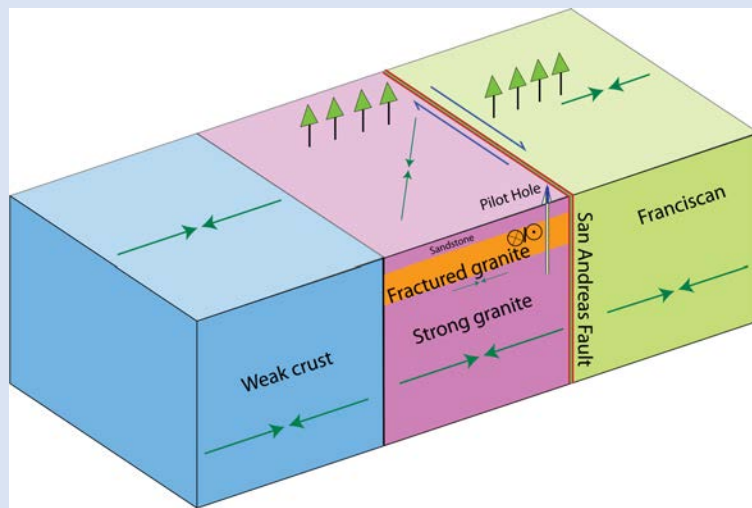
- G/z not constant if coefficient of friction not constant and water table at finite depth
- Near Parkfield: Strong event penetrated fault segment
- Vineyard and Stockdale: past water table not at surface
- Stockdale: low coefficient of friction of clay



Ambient dynamic stress: Parkfield



Ambient dynamic stress: Parkfield



Nonlinear failure from strong shaking preferentially relaxes ambient tectonic stress

Fault-normal compression is relaxed in shallow granite within Parkfield Pilot Hole (Boness et al.)

Oscillating dynamic stresses were too feeble to relax ambient stress in deeper granite.

Relaxation of shallow thrust stresses at Whittier Narrows by strong Love waves from San Andreas Fault causes blind thrusts.

K-Pg Impact

- Magnitude ~11 earthquake
- Triggered small M= 6 earthquake in Colorado
- Where very large intraplate earthquakes triggered?
- **Did global intraplate stress relax?**
- Hard to tell



Bentonite (LB) 40000 years younger than impact.
But there are lots of still younger faults near Jordan Montana