Measuring stress and strain

Lecture 4.2 - How is stress measured?

Lecturer: David Whipp
david.whipp@helsinki.fi
Goals of this lecture

- Introduce several methods for measuring stress
- Distinguish between rock strength measurements and in situ stress measurements in the crust
Measuring stress

- Rock *yield stress* (or strength) can be measured in a laboratory, providing insight into stresses rock can support before failure.

- An alternative is to measure stress in the lithosphere *in situ*, where the focus is the stress field at the sample site, rather than the yield stress of the sample.
Laboratory rock stress measurement

- Laboratory rock strength measurements are common example of **direct stress measurement**
- A rock sample is loaded in a press and **squeezed** until it fails
- This measures **rock strength**

When the sample transitions from elastic to brittle or plastic deformation, the **yield strength** (stress) has been reached.

*Fig. 5.2 in Stüwe, 2007*
In situ stress measurement: Overcoring

- **Overcoring** is an *in situ* stress measurement made at the bottom of a drill hole.

- The hole is drilled and strain gauges are installed on the base and sides in 3 orthogonal positions.

Fig. 2.17, Turcotte and Schubert, 2014
**In situ stress measurement: Overcoring**

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  - The hole is drilled and *strain gauges* are installed on the base and sides in 3 orthogonal positions.
  - An outer annular hole is drilled around the original hole.
  - This is thought to completely relieve the stress in the original hole, allowing stress to be calculated from the relaxation measured by the strain gauges.

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- **Limitation**: Max hole length: ~1 m (!)
In situ stress measurement: Hydrofracturing

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In situ stress measurement: Hydrofracturing

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- Fluid is pumped into the isolated segment, continually monitoring the pressure.
- Pressure is increased until fracturing occurs.

Zhao et al., 2013
In situ stress measurement: Hydrofracturing

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- Fluid is pumped into the isolated segment, continually monitoring the pressure.
- Pressure is increased until fracturing occurs.
- The pressure when fracturing occurs is the **breakdown pressure**, $p_b$.
- If the pump is immediately turned off after fracture and the circuit is kept closed, the **instantaneous shut-in pressure (ISIP)** is recorded.
**In situ stress measurement: Hydrofracturing**

- The ISIP value is the **minimum pressure** required to keep the fractures open.
- If we assume vertical fracture orientations and fracture in pure tension, then:
  - The **minimum horizontal principal stress** is equal to the ISIP value.
  - The maximum horizontal principal stress can be deduced from $p_b$ and ISIP, but less accurately.

![Hydrofracturing pressure log](image)

Fig. 2.18, Turcotte and Schubert, 2014
The hydrofracturing (fracking) controversy

- Hydrofracturing to measure stress is a bit different from the ‘controversial’ hydrofracturing used in the oil and gas industry.

- The general concept is the same, with injected fluids being used to fracture rock, but the extraction of oil or gas requires a much larger network of fractures to liberate trapped deposits.

- Some of the potential risks in this process are shown on the left.
Let’s see what you’ve learned…

• If you’re watching this lecture in Moodle, you will now be automatically directed to the quiz!

• References:
