Geo 647- Lab 1
Due Sept. 9, 2004

Measuring elastic properties of rocks with a Schmidt hammer and ultrasonic tester

Related hand-out (read and understand):
Katz, O., Reches, Z., J.C. Roegiers, (2000), Evaluation of mechanical rock properties using a Schmidt Hammer. Int. jour. of rock mechanics and mining science, 723-728.

Background.

Elastic constants. The elastic properties of rocks depend on two basic quantities called the elastin constants (μ and λ) (also called Lamé parameters) and the density (ρ). Another name for μ is the shear modulus and is a measure of resistance to shearing. Liquids have a shear modulus of 0. These constants control what happens when the rock is put under pressure. For example, if you want to know how much a rock will compress if it is squeezed in all directions, the ratio of the pressure to the resulting volume change is: $\lambda + \frac{2}{3}\mu$. For many rocks, μ is roughly equal to λ and the ratio of P wave velocity to S wave velocity is $\sqrt{3}$. More importantly, the elastic properties control P and S wave velocity. S wave velocity is simply $\sqrt{\frac{\mu}{\rho}}$ and P wave velocity is $\sqrt{\frac{\gamma + 2\mu}{\rho}}$.

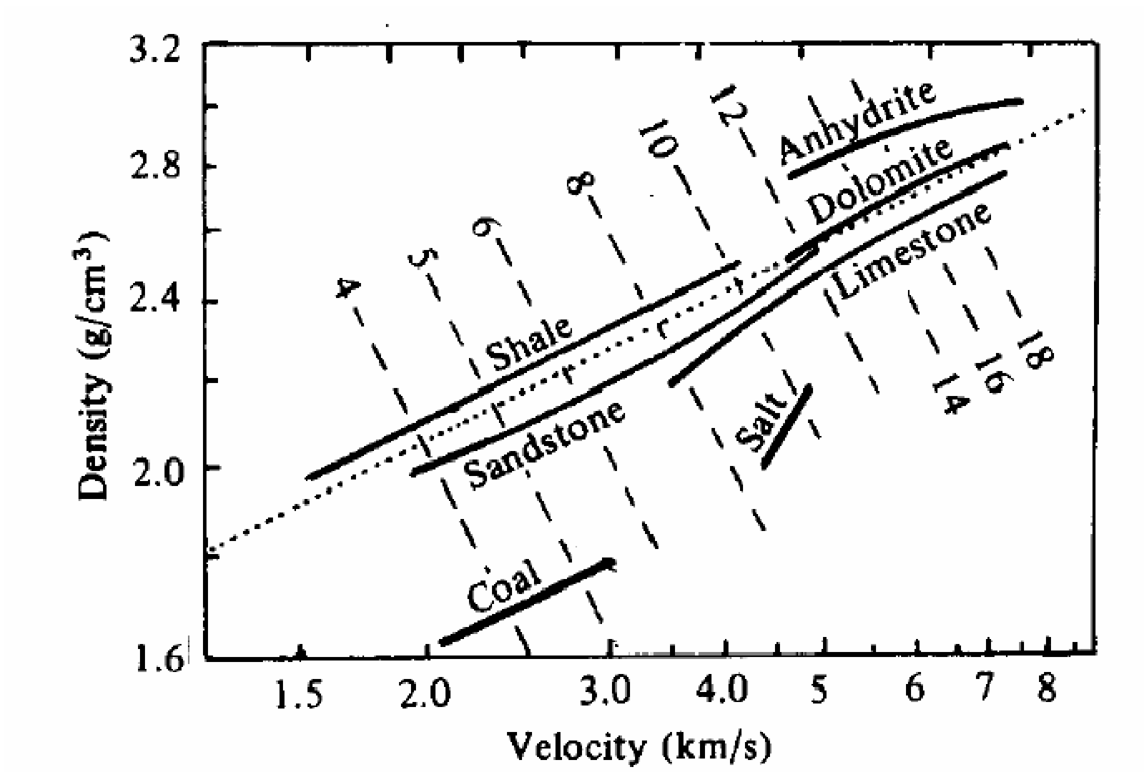
Young's modulus (E). This is defined as stress/strain, or in terms of the Lame parameters, $\frac{\mu(3\lambda + 3\mu)}{\lambda + \mu}$. The Katz et al. paper plots Young's modulus versus hammer rebound units for a variety of rocks.

Reflection coefficients. For near-vertical incidence, the ratio between amplitudes of the reflected wave to the incident wave seismic is: $(\rho_2 V_2 - \rho_1 V_1)/(\rho_2 V_2 + \rho_1 V_1)$ where ρ_1 is the density of layer 1, ρ_2 is the density of layer 2, V_1 is the velocity of layer 1 and V_2 is the velocity of layer 2. ρV (or Z) is also known as the acoustic impedance. Typical values are -0.99 for air above water, 0.5 for water to rock, and 0.2 for shale to sand. At different angles, the reflection coefficients depend on the shear modulus as well and the equations are more complicated. The reflection coefficients control how strong a reflection appears on a seismic section.

Measuring the elastic constants. In this lab, we will try to measure the seismic velocity and infer the elastic constants for several rock samples. We will then calculate the reflection coefficient between pairs of rocks. The instruments we will use are an ultrasonic tester and a Schmidt hammer, which are commonly used to test concrete. An ultrasonic tester has two transducers – one that emits an ultrasonic pulse and one that receives it. It then measures the time interval required for transmission. Once the distance between the transducers is input, it calculates the velocity, which should correspond to P wave velocity. Note that there are several different geometries possible. It requires a smooth surface as well as the application of gel for best results.

The Schmidt hammer hits the rock with a spring-driven pin, and then measures the rebound (in rebound units). Measure the rebound for each rock (do at least 10 trials on each rock). Note that the Schmidt hammer does not work well for small samples and will make marks. While charts are available for concrete, they will differ for rocks. Measure the P wave velocity using the ultrasonic tester and Schmidt Hammer where possible.

Density. For a hand specimen, measuring density is usually straightforward except perhaps for evaporites. For rocks at depth, it is not so straightforward. A common approach is to use an empirical relationship such as Gardner's:



Note that other relationships (such as Nafe-Drake) are necessary for other minerals.

Materials

Water	ultrasound only
Cork	ultrasound only
Hand specimen	ultrasound only
Brick	ultrasound, Schmidt Hammer
Patio bench	ultrasound, Schmidt Hammer
Other?	

Calculate E in two ways: from the values of μ and λ (assume that $\mu = \lambda$ - this is a Poisson solid and use Gardner's for the density) and from the chart in *Katz et al.* Create a chart showing the P and S wave velocity, the values of μ, λ, and E (2 values if available). Next, create a chart showing the reflection coefficient for the following pairs of materials: air/water, water/hand specimen, air/patio bench, patio bench/brick/

I would like a written report on the results (i.e. the charts). The report should include a brief introduction, description of the procedure, results and conclusions. Include any equations that are used. The report should also include sources of error and ways to reduce the error.

Expected results should include 2 charts:

1 showing P, S, Lame parameters, and Youngs' modulus

1 showing reflection coefficients

Questions to consider and answer.

Are the Schmidt hammer results compatible with the ultrasonic tester?

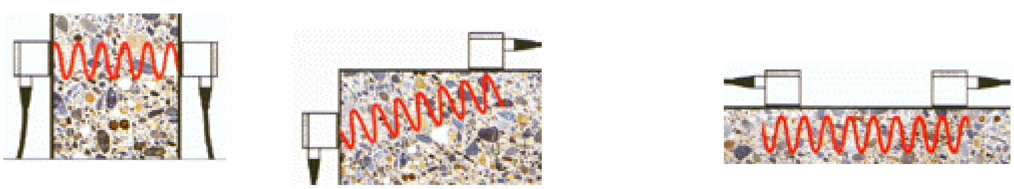
Keeping the equation for P wave velocity in mind, if the Lame parameters are kept constant, how does P velocity vary with density? If we assume that both density and P velocity increases with depth, what does this tell you about the Lame parameters as a function of depth?

Will surface waves affect the results of the ultrasonic tester?

References:
http://www.corvib.com/

Schmidt Hammer

Tico ultrasonic tester



Various modes of use of the ultrasonic tester.