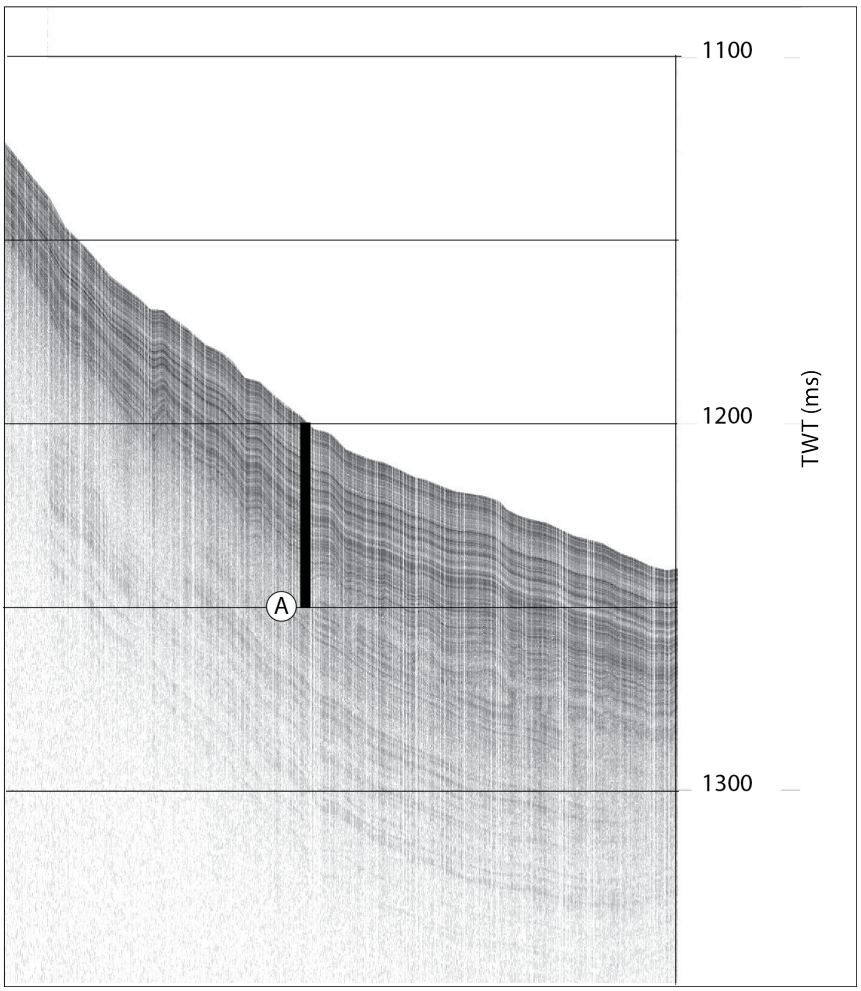
Problem Set, Lecture 2: Subsurface pressure

1. Calculate the effective stress (kPa) 100 m below the seafloor, if the average bulk density of overlying sediments is 2.0 g/cm^3.

2. Calcuate and plot the lithostatic, hydrostatic and effective stress gradients (kPa/m) through a 50 m hemipelgaic clay with an everage bulk density of 1.8 g/cm^3 overlying a 50 m clayey sand with a bulk density of 2.2 g/cm^3?

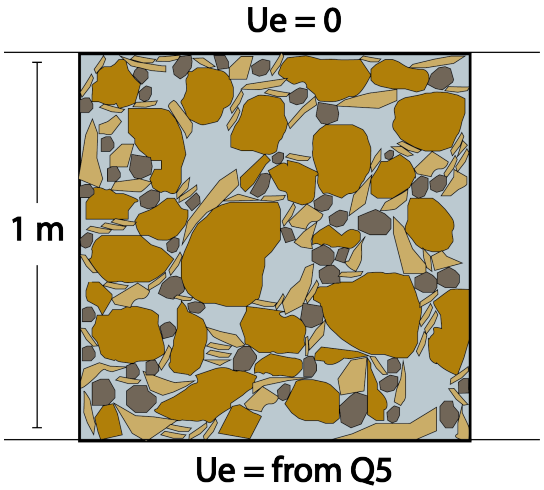
3. Using the subbottom image shown below, calculate the lithostatic and effective pressure at Point A. To asnwer this question you will need to assume reasonable values for the compressional wave velocity and bulk density of the sediments. Assume they are saturated by seawater.



4. Under hydrostatic pore pressure conditions, at what velocity (cm/yr) would we predict saline pore fluid to flow through a clay rich sediment with a permeability of 10^{-15} m^2? Use Darcy's Law and search to find a value for the *dynamic viscosity* of seawater.

5. Hydrofracturing (or hydraulic fracturing) occurs when rocks or sediments are fratcured due to increased pore pressure (or overpressure). How much overpressure is required to hydraulically fracture the base of a 100 m thick silty clay deposit with an average bulk density of 1.8 g/cm^3?

6. Using Darcy's law, predict the maximum pore fluid velocity (cm/yr, m/yr) through the sediments ($\boldsymbol{k}$ = 10^{-5} m^2) in *Q5* before overpressure would cause hydraulic fracturing. We can conceptually simplify this problem – so that the excess pressure only exists at the base of a 1 m thick parcel of sediment, while hydrostatic conditions exist at the top. Use the lecture notes to find a value for the Poisson's ratio.



7. A. The stability of methane hydrates at the seafloor is dependent on temperature and fluid pressure. Dickens and Quinby-Hunt (1994) derived an empirical equation to predict the stability conditions for methane hydrate where,

$$T = \frac{1}{3.79\times10^{-3} - 2.83\times10^{-4}\times\log(P)} - 273$$

Where T = ^{o}C, and P is the fluid pressure in MPa.

A. Assuming a bottom water temperature of 1°C, calculate the ocean depth at which methane hydrates are stable at the seafloor.

B. If the bottom water temperature changes by +1°C, how much deeper does the stability zone migrate? What would happen to methane hydrates that had been stable at shallower depths?

8. Below is a seismic image from IODP expedition 204 to Cascadia Margin, a subduction zone on the Eastern Pacific, south of Vancouver Island. It is a well studied region bearing gas hydrates. In seismic data, the base of the gas hydrate stability zone is often marked by a reflector that mimics the seafloor topography and has a reversed polarity (phase). Yjos is called a vottom-simulating reflector (BSR). The phase reversal occurs because the base of the hdyrate stability zone is marked by a change from frozen methane (high velocity) to free gas (low velcoty) in the pore spaces. It mimics the sahpe of the seafloor, because its depth depends on temperature, which tends to be quasi-linear beneath the seafloor.

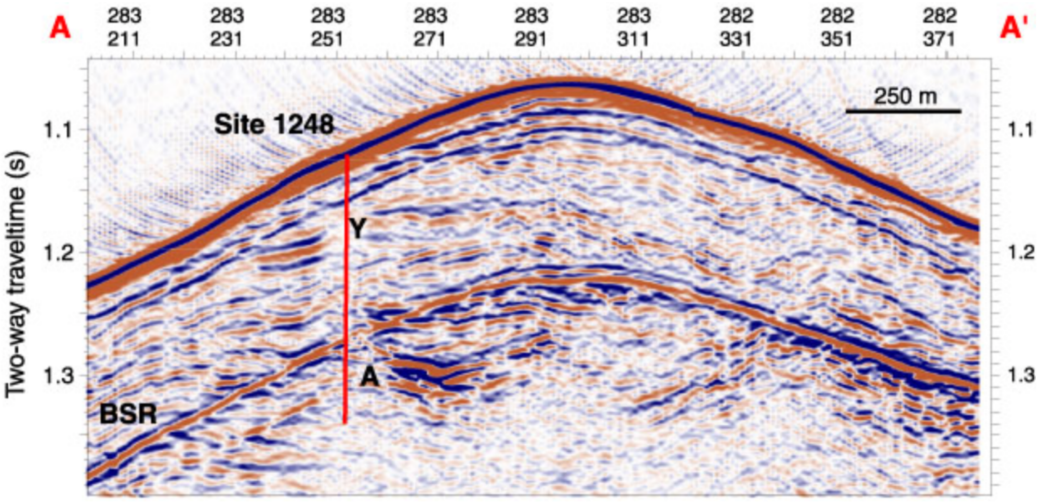


Image from: http://www-odp.tamu.edu/publications/204_IR/chap_01/c1_f7.htm

A. Calcuate the Pressure at the base of the hydrate satbility zone.

B. Using the Quinby-Hunt (1994) relationship from the previous question, calcuate the temperature at this depth.