Geo647 Lab 2

Well logs, reflection coefficients, and synthetic seismograms

Some web-sites (googl'ed):

Sonic logs

http://www.aapg.org/explorer/geophysical_corner/2002/03gpc.html

Gamma ray logs

http://www.ldeo.columbia.edu/BRG/ODP/LOGGING/MANUAL/Pat/text.html

Convolution:

http://mathworld.wolfram.com/Convolution.html

Overview. Calculate a set of reflection coefficients. Create a synthetic seismogram by convolving the reflection coefficients with a wavelet.

1.) Attached are some copies of well logs from a set of shallow well drilled on the UCSD campus (this are essentially the same shallow marine formations exposed at Torrey Pines, for example). Figure 24 shows an electric log and a gamma ray log of the same well, with interpretations. Electric logs measure the resistivity of a formation which is usually controlled by the fluids in the pore spaces. Brine is conductive; hydrocarbons and fresh water are resistive. Gamma ray logs measure the natural radioactivity of the formation. In general, the finer the grain size the more radioactive (although arkosic sandstones, glauconite, and volcanics are important exceptions). Black, organic-rich shales unusually have very high gamma ray signatures, for example. Newer (spectral) gamma ray logs can distinguish between mineralogy in some case.

Figure 25 shows the P wave and S wave interval velocity logs for the same well. We want to generate a set of reflection coefficients from the P wave data. Sonic logs can be inaccurate for a variety of reasons (sometimes other logs such as gamma ray or electric logs can be transformed using various empirical relationships to generate a velocity/depth curve). Because of the scatter in the points we will "block" the P wave log, i.e. group points with similar velocities together to create a layered model. After blocking you should get a velocity model with roughly 7-12 layers. Using the same layer boundaries, estimate the S wave velocities in each of the layers also.

Now, either by hand or with a spreadsheet, calculate the acoustic impedance for each layer and reflection coefficients for the boundaries. Assume the same density of all the rocks to make it simple. Make a table listing the rock type, layer depth (top), thickness, P wave velocity, S wave velocity, acoustic impedance, reflection coefficient, and P travel time (the time needed for a P wave to travel through the layer from top to bottom).

2.) A seismic source (ideally) produces a single wave (or wavelet). The exact shape of the wavelet depends on the source and other factors, but a common shape is the Ricker wavelet. We need to "convolve" a Ricker wavelet with the set of reflection coefficients.

First, we need to produce the proper spacing for the reflection coefficients. Assume that the data is recorded at sample rate of 1000 Hz, i.e. each data sample is spaced 0.001 seconds apart (or 1 milliseconds). Now create a time series representing the reflection coefficients with zeroes representing the time required to travel twice through each layer.

Example (not from this data set):

Rock	Depth	Thickness	Vp	Vs	ρ	Zp	RC	Tp	#0
Sand	0	10	3000	1723	2.8	8400	0.14	0.0067	7
Shale	10	5	4000	2309	2.8	11200	0.06	0.0025	3
Sandstone	15		4500	2589	2.8	12600			

Time series (RC) separated by zeroes representing the travel time through the layer)
[0, 0, 0, 0, 0, 0, 0, **0.14**, 0, 0, **0.6]**

Now we want to convolve this with a Ricker wavelet sampled at the same sample rate. We can use the following time series to represent the Ricker wavelet:
[0, -0.4, 0, 1.0, 0, -0.4, 0]

Convolution is a mathematical operation represented by:

$$h(t) = \int_{-\infty}^{\infty} f(\tau)g(t-\tau)d\tau$$

where f(t) and g(t) are two continuous functions of time and t is a dummy variable. Convolution is often expressed by f(t)*g(t). In the digital world, convolution is:

$$h[k] = \sum_{n=0}^{n+k} f[k]g[k-n]$$

It is possible to perform the discrete version by hand. First, reverse one series, shift, multiply, and add. Convolving [1,2,2] with [4,2,1] would be:

Reverse and shift the second series:

```
    1 2 2
1 2 4
  1 2 4
    1 2 4
      1 2 4
        1 2 4
```

now multiply and sum and we get: [4, 10, 13, 6,2] as the answer.

```
(4)(1)                 = 4
(2)(1) + (2)(4)        = 10
(1)(1) + (2)(2) + (2)(4) = 13
         (1)(2) + (2)(2) = 6
                  (1)(2) = 2
```

If this seems extremely bizarre, it isn't as you have probably done it before. In fact it is the same operation as polynomial multiplication. The equivalent operation is $(z + 2z^2 + 2z^3)(4z + 2z^2 + z^3)$. Obviously, doing long signals by hand is time consuming and subject to error. An easier way is to use Matlab. Start Matlab and type the following command (**in bold**):

>> **a = [1,2,2]**
a = 1 2 1
>> **b = [4,2,1]**
b = 1 2 4
>> **conv(a,b)**
ans = 4 10 13 6 2

conv(a,b) convolves the two series a and b.
Now type in:
>> **ricker = [0,-0.4,0,1,-0.4,0]**
>> **ts = [0,0,0,0,0,0,0,0.14,0,0,0.6]**
>> **seismo = conv(ricker,ts)**
>> **plot(seismo)**

You can save the figure using export (under file) and then import into word. Type in your set of reflection coefficients (with zeros) and convolve with a Ricker wavelet. Plot the result and put in your lab writeup. This is your synthetic seismogram, or what a reflection seismogram should look like if one was shot at the sire of the well.

The lab write-up should contain:

- A copy of your blocked-out logs.
- The table with P velocities, S velocities, depths, thickness, two-way travel, acoustic impedance, and reflection coefficients.
- A copy of your Matlab results (both numbers and plot).
- And answers to 3 of the following questions:

1) Assuming that the lithology is related solely to water depth, create a relative sea level curve for the data in the logs (i.e. water depth versus time). Do you expect to find any erosional unconformities here?

2) After looking at the sonic log web-site, supply several reasons why the sonic log may not yield and accurate representation of the true interval velocities.

3) Demonstrate (using Matlab) how to do convolution using an fft and show that the results are the same as with conv.

4) Using your favorite search engine find an example of a synthetic seismogram using well logs and seismic reflection data (other than web-sites I listed). Be prepared to discuss in class Tuesday if needed.