The Oil Game: Problem-based learning exercise in an Environmental Geology lecture-format class.

David H. Voorhees
Waubonsee Community College
dvoorhees@waubonsee.edu

Summary
In a capstone exercise in a unit on energy in an Environmental Geology class of non-science majors, students participate in a ‘field-based’ simulation of oil exploration and exploitation which uses readily available supplies and easily constructed equipment. The class is divided into oil companies of no more than 4 ‘employees’, in which they are asked to explore and model an oil prospect in a ‘field area’ set up in the classroom. Along the way, they are using the scientific method, and are exposed to skills and tools used by professional geologists. They are asked to (1) acquire ‘field data’, (2) construct a geologic model of the field area, (3) ‘drill’ an exploration well, (4) calculate the economics associated with a simulated development plan of the newly discovered oil field using the current price of oil, and (5) discuss and recommend to management (you, the instructor) the economic viability of the prospect by suggesting to proceed with development, or to wait for a particular scenario (i.e., price of oil).

Activity Description and Teaching Materials

Fieldwork

The first part of the assignment is to have the students perform the ‘fieldwork’ and the first part of the fieldwork is to identify samples of sandstone (Millionaire Sandstone Fm), limestone (Texas Tea Fm.), and shale (Trump Chapter 11 Fm.). The students are then asked which of the samples could be a source rock, reservoir rock or seal. These data are entered into their ‘field notebooks’. The remainder of the field work is to measure the strike and dip of 10 outcrops, which consist of 8x10 inch pieces of plywood nailed to a 2x4 with one end cut at the desired dip angle (Figure 1). The dip angles can be the same for all, or they can vary. The set I have are in 3 groups of dip angles (~20°, ~30°, and ~40°), and one without a 2x4 for 0° dip. I made these strike and dip models in about 3 hours using scrap ¼ inch plywood and 2x4, a miter saw, and a circular saw, with most of the time spent painting. In the picture below, note the tape on the table which is used in the pre-class set up marking the strike direction. The tape is also useful to reset the strike-dip model if it is moved during the activity. Strike, dip angle and dip direction data are recorded in their ‘field notebooks’.

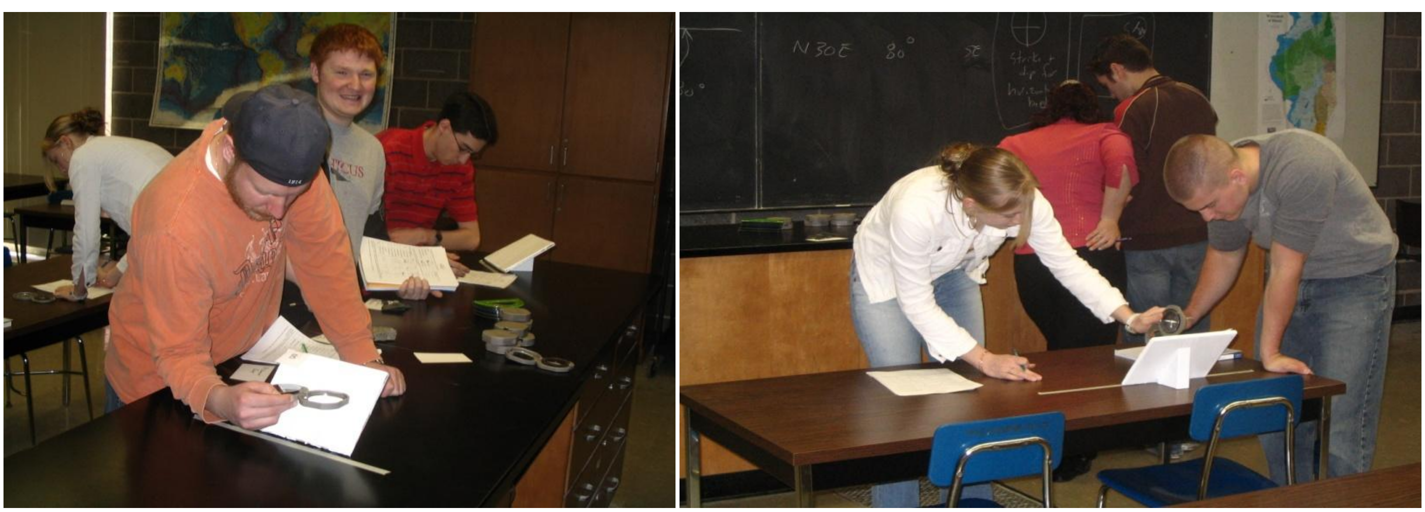

Figure 1. Measuring strike and dip at the ‘outcrop’

Geologic model

The oil companies are asked to develop their geologic model which consists of a geologic map and 2 cross sections. Lithologic data are plotted on the outcrops using appropriate lithologic symbols on the geologic map, as well as strike and dip symbols (Figure 2). Note that outcrop H has a 0° dip. Lithologic contacts are interpreted between outcrops using the stratigraphic column (in the handout) as a guide. This is often a difficult task, and typically takes some explanation as how geologists interpret our typically incomplete data set. It is here that it can be mentioned that this is <u>their</u> interpretation, and the position of the contact is where <u>they</u> think it is. It is often (as will be seen shortly) the interpretation of similar data (i.e., where the contacts are drawn) that determine whether a prospect developed by one company will make money, and by another company it will not make money, and ultimately, whether an oil company is profitable and successful or not, even when everyone is using the same data.

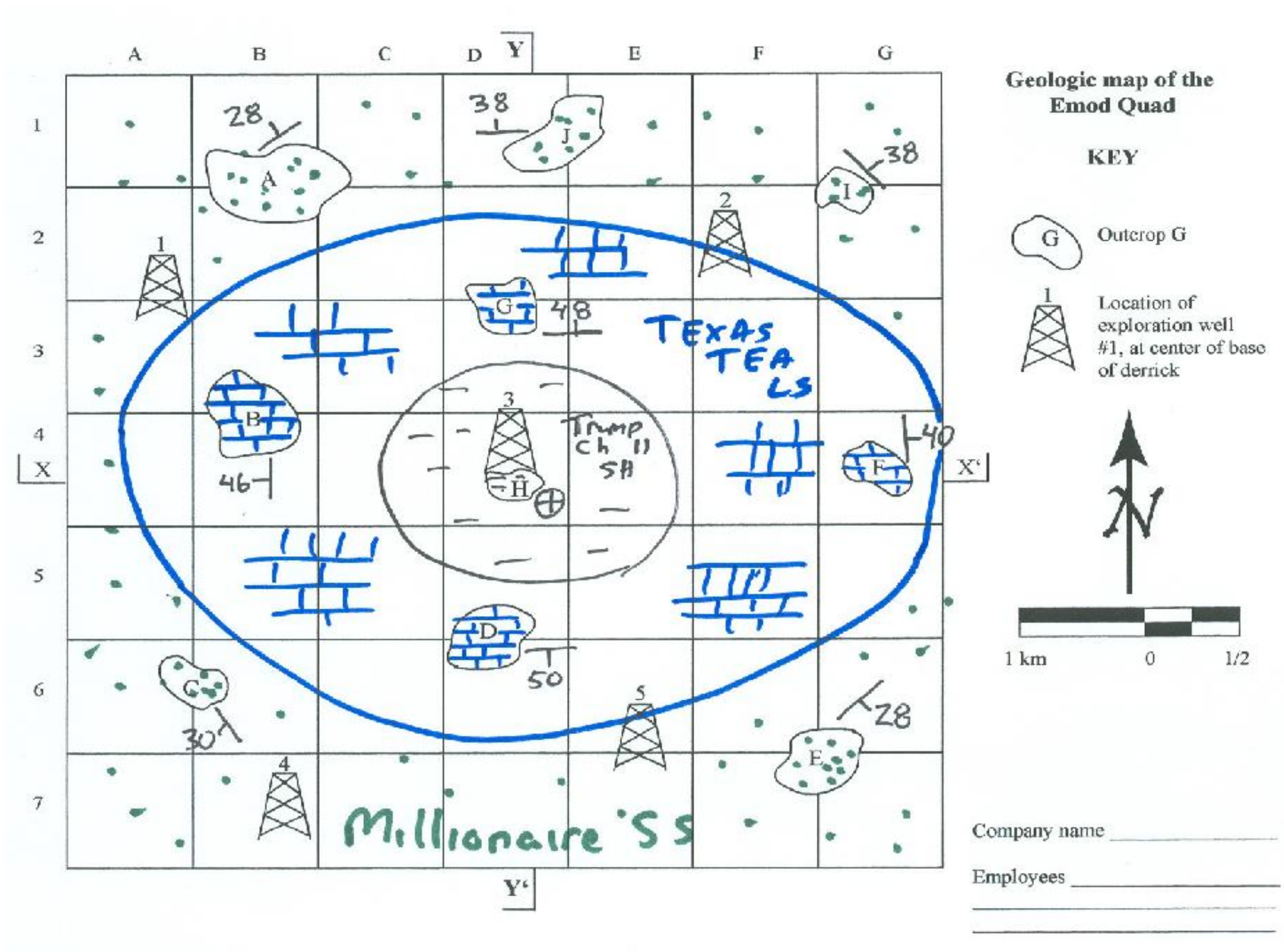

Figure 2: Example of a completed geologic map to be submitted by student Oil Companies

The next step is to draw 2 cross sections, X-X’ and Y-Y’ (Figure 3). The extrapolation from the surface (known) to the subsurface (unknown) is sometimes a difficult task for some students. To complete the cross sections, subsurface data (obtained from their previously completed interpretation of seismic data, discussed in the handout) and the stratigraphic column are used to add the High Roller Sandstone, Kerogen Shale, and Dot Com Limestone. I have reduced the time needed for this assignment by providing a completed X-X’ cross section, which has allowed me to do this activity in 1 (very intense) class session of 1 ¼ hours.

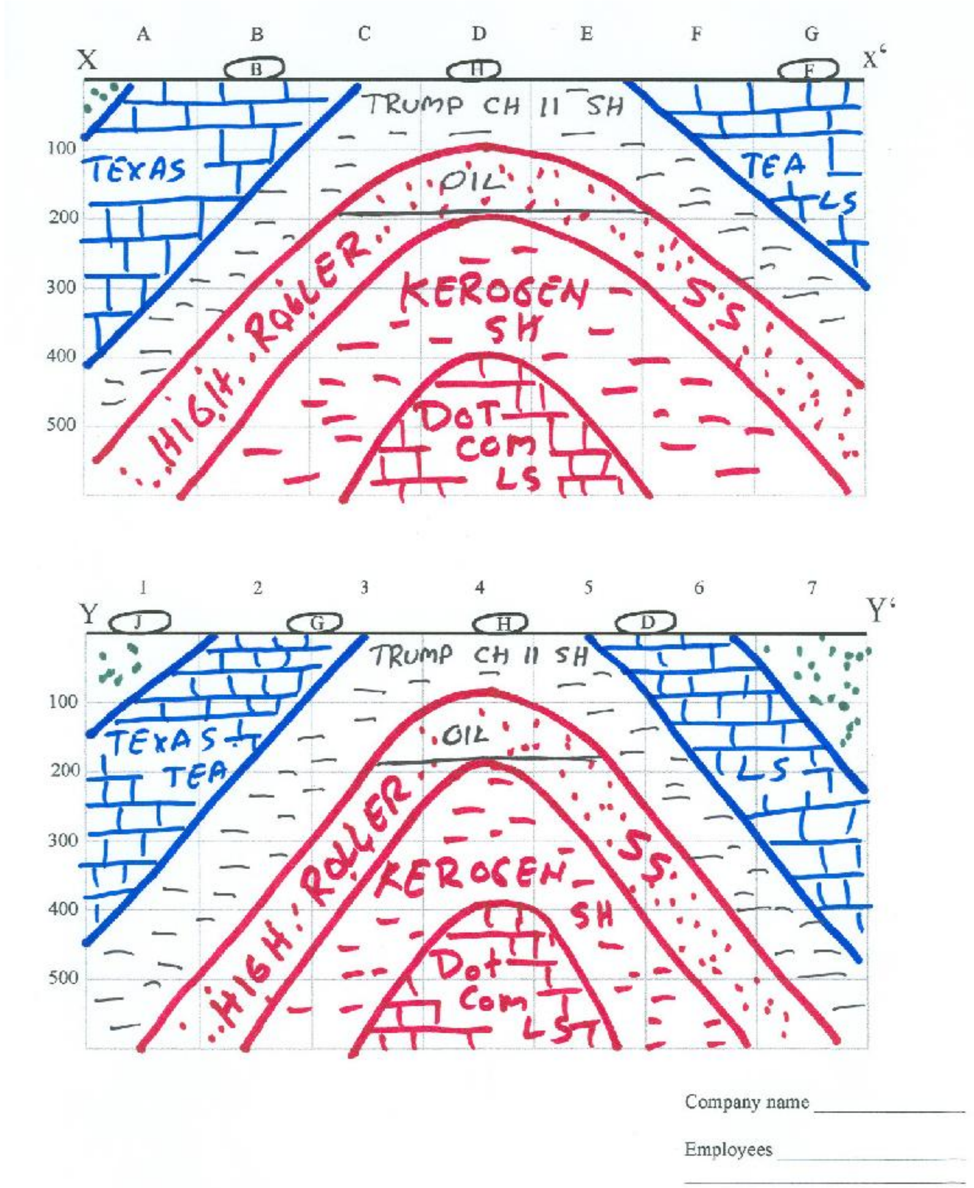

Figure 3: Completed geologic cross sections to be submitted by student Oil Companies

The student oil companies then interpret their model (a hint is in the name of the Quadrangle), and pick an exploration well to drill. The locations the companies have to choose from are given by the numbered derricks. When the oil companies select exploration well #3, you can say 'Congratulations! You have discovered oil!! But, now are you rich?'.

Economics

The first step is to calculate the volume of the reservoir, which is basically the area of the Trump Chapter 11 Shale on their geologic map multiplied by the thickness of the High Roller Sandstone. In Figure 3, note that the lateral extent of the oil cap in the High Roller Sandstone is approximately equal to the surface contact of the Trump Chapter 11 Shale because the dip of the Texas Tea Limestone is roughly 45°. Please also note that the map area will be in km^2, the reservoir thickness is in meters, and the volume needs to be in cubic kilometers (i.e. some students will simply multiply without thinking of units). The next step is to calculate the amount of oil that can be recovered at the surface from this reservoir. This calculation uses a recovery factor of 400,000 bbl/km3, which is based on my personal experience as a Petroleum Geologist in the oil industry. The total income is calculated using the current price of oil from the internet or Wall Street Journal. For the geologic map in Figure 2, the recoverable oil would be

$$(4.5 \text{ km}^2)(0.1 \text{ km})(400{,}000 \text{ bbl/km}^3) = 180{,}000 \text{ barrels oil}$$

The next step is to calculate the costs to recover the oil, which are described in the handout. The ultimate profitability of the prospect depends upon the size of the Trump Chapter 11 Shale on the geologic map, the current cost of oil, and the number of employees. Note that for most oil companies, they only need to account for the cost of 1 exploration well. For the geologic map in Figure 2 and an oil company with 2 employees, the total costs are $8,530,000, which gives a breakeven point of $47.39 per barrel of oil. This breakeven point will vary from company to company depending upon their geologic map and the number of employees.

Recommendation

The last step is for the oil companies to make a recommendation to management (i.e. you), whether the prospect should be drilled, should be ignored, and what is the breakeven point of the prospect. The breakeven point is important given the volatility of oil prices.

Teaching materials needed

- Samples of sandstone, limestone, shale
- 10 strike dip models for those with a dip, the 10th is just a piece of plywood for flat dip.
- Compasses to measure strike and dip.
- Protractors and ruler to plot strike and dip symbols on the geologic map
- Colored pencils for the geologic map
- Calculators for economic evaluation
- Copies of the handout, ‘field notebook’, geologic map, cross sections and balance sheet for each student.

Suggestions for changes (which will increase depth of engagement as well as time needed for activity)

- Increase the number of lithologies to include those not seen at surface
- Increase the number of outcrops
- Do not provide pre-selected exploration well locations, and have students select on their own
- Set up each company with an initial bank account, and only release information after the oil companies have purchased them from you. This information could be outcrop data, seismic data, stratigraphic information, etc.