Physical Geology
Subsurface Geology and Oil Exploration

Adapted from AGI/NAGT Lab Manual

Name____________________

Period 3-4

Introduction:

Opportunities for direct observation of rocks below the surface of the land are limited to a few mines, tunnels, and caves. Much more information on subsurface geology is obtained from data collected in the drilling of wells for hydrocarbons (oil and gas) and water. Geologists compile information from each well into a *well log*, or well record, of the rocks penetrated by the drill. The log shows each rock unit penetrated, describes its lithology and thickness, and notes any gas, oil, or water encountered. Geologists also use the data from well logs to create maps that show rock thicknesses and attitudes (or directions of dips and strikes) in the subsurface, especially in oil exploration.

Hydrocarbon Traps:

Hydrocarbon traps "trap" oil and gas. They can be geologic structures, porosity/permeability relationships in the rock, or a combination of the two, that cause hydrocarbons to accumulate and remain stored underground. Recall that porosity is the percentage of void space in a rock body (e.g., fractures, holes), and that permeability is a measure of how well fluids can pass through a rock body. (For a rock to be permeable, the pore spaces must be interconnected.) These same principles apply to oil and gas, as well as to water.

Water, oil, and gas can travel through permeable rocks, or be stored in them, but their movement is impeded (or trapped) by impermeable rocks. The permeable rocks of hydrocarbon reservoirs are called *reservoir rocks*. Rocks that impede or trap hydrocarbons are called *confining beds or cap rocks*.

Because oil and gas are less dense than water, they float above the more dense groundwater in rocks. Therefore, in any hydrocarbon trap, one commonly encounters gas in the highest part, oil beneath the gas, and water in the lowest part. For example, Figure 1 shows an idealized structural trap. Water, oil, and gas are trapped in a porous and permeable sandstone (reservoir rock) beneath an impermeable shale (confining bed or cap rock) in an anticlinal structure.

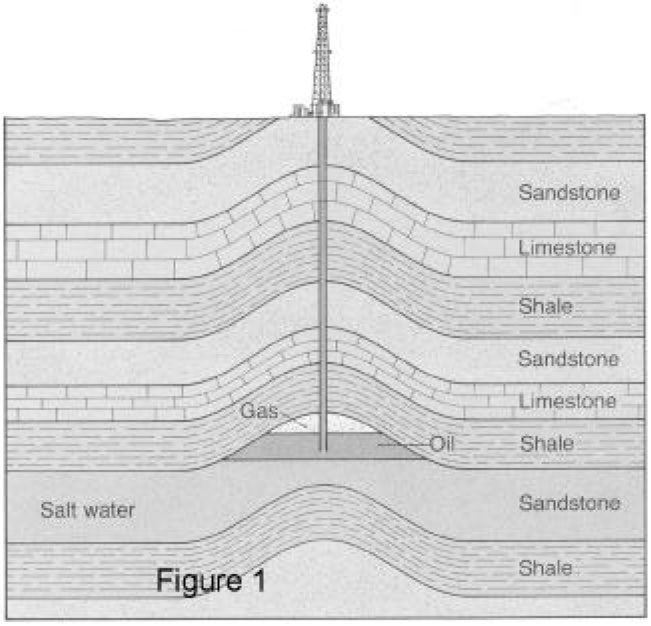
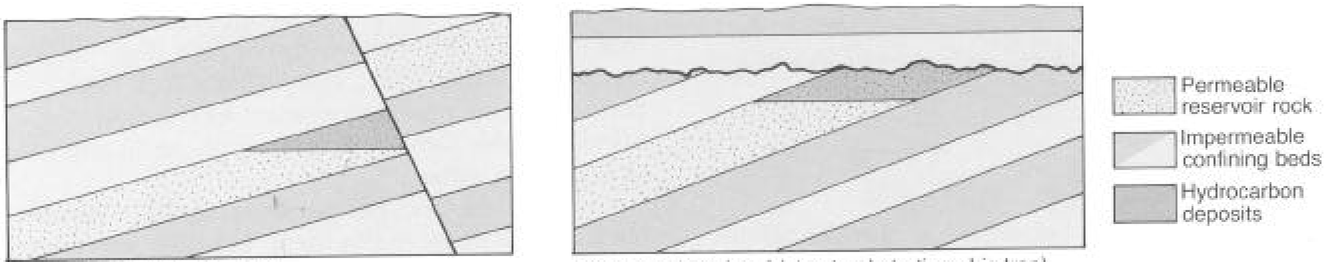


Figure 1

Note that gas is present in the highest portion of the reservoir, salt water is in the lowest portion of the reservoir, and oil is found between the gas and water. The total accumulation of oil and gas trapped in the reservoir is called the *pool*. As shown, the best place to drill a well for hydrocarbons is where the reservoir (and the pool) attains its greatest elevation (in this case, the peak of an anticline).

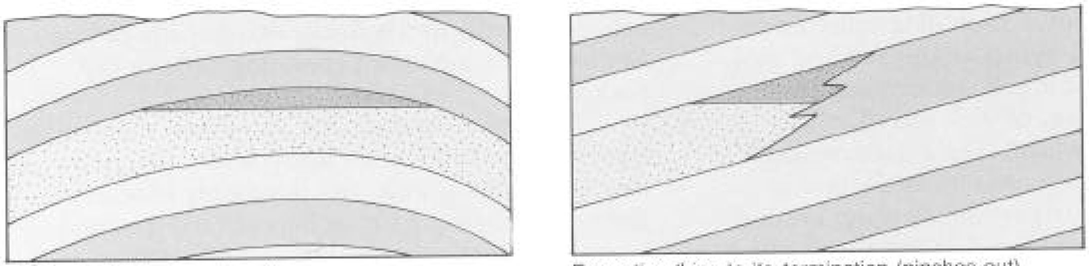
Structural and Stratigraphic Traps:

The two major types of hydrocarbon traps are *structural traps* and *stratigraphic traps* (Figure 2, next page). Structural traps are produced by folding and/ or faulting. Stratigraphic traps are produced by lithologic variations (changes in rock type). Occasionally, structural-stratigraphic traps are also encountered. The unconformity-related trap in Figure 2 was formed by folding, erosion, and sedimentation, which produced horizontal confining beds (probably shale) overlying inclined reservoir rocks.



Fault-related (structural trap)

Unconformity-related (structural-stratigraphic trap)



Fold-related (structural trap)

Formation thins to its termination (pinches-out). Up dip (stratigraphic trap)

Figure 2

Problems and Questions:

In this problem, you are concerned with five wells that have been drilled in an east-west line. They are shown on the cross section (Figure 3, next page) as vertical lines. A well log is given for each well (Figure 4, next page). These logs are a record of the rock units and faults intersected in each well, and the dip angle and direction of each unit or fault is listed as well.

Lithologic descriptions of the rock units are:

Unit 1: Cross-bedded eolian sandstone
Unit 2: Brown-to-gray siltstone with shale zones and some coal seams
Unit 3: Parallel-bedded, poorly sorted sandstone
Unit 4: Conglomerate .
Unit 5: Poorly sorted sandstone with some clay, silt, and pebbles
Unit 6: Black, clayey shale
Unit 7: Parallel-bedded, well-sorted, coarse-grained sandstone
Unit 8: Black shale
Unit 9: Gray limestone

Procedure:

Refer to the cross section (Figure 3) and logs (Figure 4). On each well (vertical line), mark with ticks the elevations of the contacts between units (lightly in pencil). For example, in well A, unit 1 extends from the surface (2400 feet) to 2100 feet, so make tick marks at those points; unit 2 extends from 2100 to 2050 feet, so make ticks at these points; and so on. Label each unit number lightly beside each column, between the ticks.
Pay careful attention to the dip angles indicated-when you make tick marks - It is very helpful to angle them approximately to indicate dip. This is especially true if you encounter any faults in the exercise.

When you have all units plotted in the five wells, connect corresponding points between wells.
(You are "correlating" well logs when you do this, and are preparing a subsurface cross - section of the type actually constructed by petroleum-exploration geologists.) From the lithologic descriptions given above, you can fill in some of the rock units with patterns, e.g.: sandstone (dots), conglomerate (tiny circles), and coal (solid black).

Answer the questions on the last page of this lab.

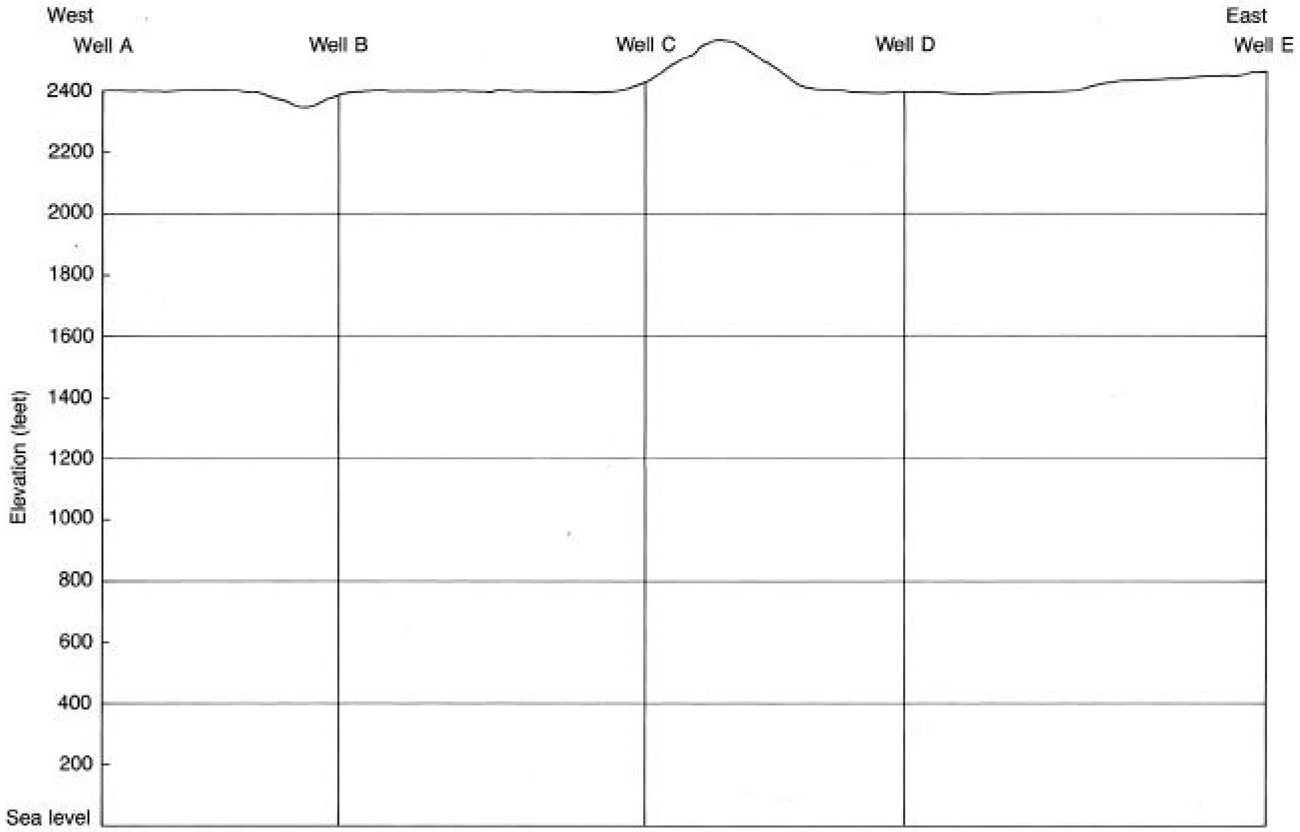


FIGURE 3 Cross section showing well locations.

Well A

2400–2100	Unit 1, horizontal
2100–2050	Unit 2, horizontal
2050–1700	Unit 3, dips westward 15°
1700–1150	Unit 4, dips westward 15°
1150– 800	Unit 5, dips westward 15°
800– 550	Unit 6, dips westward 15°
550– 200	Unit 7, dips westward 15°
Bottom of well	

Well B

2300–2100	Unit 1, horizontal
2100–1980	Unit 2, horizontal
1980–1650	Unit 3, dips westward 15°
1650	Fault; dips eastward 60°
1650–1350	Unit 4, dips westward 15°
1350–1000	Unit 5, dips westward 15°
1000– 750	Unit 6, dips westward 15°
750– 200	Unit 7, dips westward 15°
200–sea level	Unit 8, dips westward 15°
Bottom of well	

Well C

2350–2100	Unit 1, horizontal
2100–1900	Unit 2, horizontal; coal seam at 1950
1900–1700	Unit 3, dips westward 15°
1700–1150	Unit 4, dips westward 15°
1150– 800	Unit 5, dips westward 15°
800– 550	Unit 6, dips westward 15°
550– 200	Unit 7, dips westward 15°
200	Fault; dips eastward 60°
200– 100	Unit 9, dips westward 15°
Bottom of well	

Well D

2300–2100	Unit 1, horizontal
2100–1800	Unit 2, horizontal; coal seam at 1950
1800–1350	Unit 4, horizontal
1350–1000	Unit 5, horizontal
1000– 750	Unit 6, horizontal
750– 200	Unit 7, horizontal
200– 100	Unit 8, horizontal
Bottom of well	

Well E

2400–2100	Unit 1, horizontal
2100–1650	Unit 2, horizontal; coal seams at 1950 and 1850
1650–1450	Unit 3, dips eastward 21°
1450– 900	Unit 4, dips eastward 21°
900– 550	Unit 5, dips eastward 21°
550– 300	Unit 6, dips eastward 21°
300– 200	Unit 7, dips eastward 21°
Bottom of well	

FIGURE 4 Logs for wells shown in Figure 3.

Name____________________

Period 3-4

Questions:

1. What is the nature of the bottom contact of Unit 2?____________________How was that contact formed? ____

____

____

2. Why is coal not found in wells A and B, while two coal seams are found in well E?________________________

____

____

3. Wells A and E are dry holes (i.e., they contained no hydrocarbons), but the others produce petroleum. An oil pool is penetrated in well B from 750 feet to 650 feet, in well C from 550 down to 500 feet, and in well D from 750 down to 500 feet. Sketch the oil pools on the cross section and explain why the oil was trapped in each pool.

____

____

____

____

____

4. Why is there no oil in either well A or well E?

____

5. Using the principles of original horizontality, superposition, and cross cutting relationships, describe the sequence of events that developed this geologic situation.

____

____

____

____

____

____

____