Well Logging

Cap-17 Geophysical & Chemostratigraphic Correlation
Well Logging

- One of the oldest and most used methods that depends on the geophysical properties of rocks is subsurface **well logging**.

- These methods are particularly good when surface outcrops are not available. For examples in central US rocks are covered by meters of glacial deposits.

- Seismic can be used to determine the subsurface structure but a direct sample of the rock is needed to be sure of the lithology.
Well Logging

- The most practical way is to drill a well and record all the useful information possible from a core.
Well Logging

• Continuous core recovery is far too expensive and is not done except when great detail is needed.
Modern drilling use a lubricating mud that is pumped down through the drill pipe to cool and lubricate the drilling area. The drilling mud is usually a mixture of bentonitic clay and oil or water, plus barite to regulate density. It is forced up the well to the surface so that mud constantly flows toward the mud tanks, carrying the cuttings, or chips, away from the drilled formation to prevent the well from clogging.
This chips are a primary source of information about the subsurface unit. The site geologist usually keeps a continuous log and sample of the chips as they come up and are screened out of the drilling mud. The chips are the only record of the lithology. If the density of one unit greatly differs from the next the chips may rise to the surface at different rates and give an erroneous impression of the sequence.
Engines drive the drawworks and the rotary table, which rotates the kelly.
Crown block
Dead line
Fast line
Drilling line (wire rope)
Travelling block
Dead line anchor
Supply reel
Drawworks
Drilling line

Courtesy of the Petroleum Communication Foundation
Well Logging

• The second and more important source of stratigraphic information comes after the well has been drilled and the drill pipe removed. A caliper lowered down the holes measures the hole diameter. This will help to indicate the presence of shales that tend to cave.

• A sonde is lowered down the hole and as is raised it calculates the response of the logging tool to various electrical; other properties of the hole are measured.
The electric logging sonde and the configuration of electrodes for recording short normal, long normal, and laterlog resistivity curves. The short normal curve measures the resistivity difference between the current electrode A and point M1, about 40 cm away. The long normal curve measures the resistivity between A and M2, about 160 cm apart. The laterlog measures the resistivity difference between A and O.
Spontaneous Potential

• SP log measures the difference in electrical potential between two widely spaced electrodes, a grounded electrode at the top of the well and an electrode on the sonde.

• Drilling mud invades the pore space of the rock adjacent to the well. When drilling mud and the natural pore fluid come into contact, they set up an electrical potential.
Spontaneous Potential

- The movement of ions from the drilled formation to the borehole accounts for 85% of the measured voltage difference, and invasion of drilling mud from the borehole into the formation accounts for 15%.

- For this reason, the SP log is a measure of permeability.

Figure 17.3 Idealized spontaneous potential and resistivity curves for various combinations of rock types and contained fluids. (After Krumbein and Sloss, 1963: 78.)
Spontaneous Potential

Limestones are low in permeability unless they are porous or fractured. Sandstone usually show a large deflection toward the negative pole because of their permeability.

If the sonde encounters a fluid that is a better conductor than the drilling mud (such as salt water), the curve will deflect to the left; if the fluid is a poor conductor (such as fresh water or oil), it will deflect to the right.

Figure 17.3 Idealized spontaneous potential and resistivity curves for various combinations of rock types and contained fluids. (After Krumbein and Sloss, 1963: 78.)
Resistivity (R) log

- R-log measures the resistivity of the fluids contained in the surrounding rock to an applied electrical current.
- The R indicates the amount of fluid in the rock and therefore the pore space.
- Because the drilling mud invades the pores rock from the borehole, this log actually measures the difference in resistivity between the invaded zone (mud has a high resistivity) and the uninvaded zone (natural pore fluids have a lower resistivity).
Resistivity ( \( R \) ) log

- Resistivity increases with decreasing pore space; 10% porosity is about 10 times more resistive than 30% porosity.
- Dense rock with no pore space have very high resistivity, so they usually deflect the record to the right, event off the scale.
- Sandstone filled with a nonconductive fluid such as oil or fresh water also deflect to the right.
- Shales have low resistivity and deflect to the left.
Common oil and gas traps

In a typical trap, gas accumulates on top of the reservoir as a “gas cap” over the “oil leg” which in turn overflows the water-saturated zone in the reservoir. This occurs because natural gas is lighter than oil which is lighter than water. However, all three fluids are often intermingled in parts of the reservoir. Porosity is the ability of rock to hold oil and gas like water in a sponge. Permeability indicates how easily fluids can flow through the rock.

A trap requires three elements:
- a porous reservoir rock to accumulate the oil and gas – typically sandstones, limestones and dolomites
- an overlying impermeable rock to prevent the oil and gas from escaping
- a source for the oil and gas, typically black waxy shales

1. THRUST FAULT
   In the foothills of Western Canada, east of the Rockies, the original limestone layer was first folded and then thrust-faulted over itself. An overlying seal of impermeable rock completes the structural trap. Examples include the Turner Valley oil and gas field and Jolting Round gas field, both in southwestern Alberta.

2. NORMAL FAULT
   Faults drop one side down and push the other side up to close the reservoir rock against impermeable sealing rocks, forming a structural trap. An example is the Dunvegan gas field in northwestern Alberta.

3. STRATIGRAPHIC PINCH-OUT
   This occurs where the porous limestone reservoir loses its porosity and becomes impermeable. Limestones, or the porous sandstone reservoir simply thin and pinch out. Overlying impermeable rocks act as seals. Examples include the D-1 Crossfield sour gas field and many oil and gas fields in Saskatchewan.

4. REEF
   Porous ancient coral reefs grew in the warm seas that once covered much of Western Canada. They now provide prolific oil and gas reservoirs. Often overlying porous rock layers are “dipped” or folded over the reefs and form separate traps. Overlying impermeable shales act as seals to the reservoir. An example is the Ledah oil and gas field in Alberta.

5. ANTICLINES
   Where rock layers are folded into anticlines and synclines, the oil and gas migrate to the crests of the anticlines within the reservoir rock, and are trapped if overlain by an impermeable layer. If fractures occur, oil and gas may seep to the surface. Examples include the Bubbles and Jeddore gas fields in northeastern British Columbia.

6. SALT DOME
   Under the weight of overlying rock layers, layers of salt will push their way toward the surface in salt domes and diapirs. Oil and gas are trapped in folds and along faults above the dome and within uplifted porous sandstones along the flanks of the dome. Examples are found off Canada’s East Coast.

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