GY 402: Sedimentary Petrology

Lecture 27: Introduction to Wireline Log Interpretations

Instructor: Dr. Douglas W. Haywick
Last Time

Carbonate Diagenesis
Diagenesis
Paragenesis

Temperate Carbonate Diagenesis

- Marine
- Phreatic
- Meteoric
- Vadose

Deposition
- Type 1
- Type 2
- Type 6 (Matrix)
- Fe-oxides
- Type 3
- Type 4
- Type 5

Cements

Shell Diagenesis
- Mg-calcite
- Aragonite
- Calcite

Siliciclastic Sand Diagenesis (Concretions)
- Marine
- Meteoric (Phreatic)

Deposition
- Ferroan
- Mod. Ferroan
- Non-Ferroan

Compaction
- Fe-oxides

Cement/Alteration Geochemistry
- Ferroan calcite
- Moderately ferroan calcite
- Non-ferroan calcite

Uplift
Today’s Agenda

Electric Logs 1

• Introduction (first electric logs)
• Resistivity Logs
• SP Logs (Spontaneous Potential)
• GR Logs (Gamma Ray)
Electric Logs

Used to gather information about lithology, fluid composition, formation character etc.
Electric Logs

Used to gather information about lithology, fluid composition, formation character etc.

First surface experimentation was done by Conrad and Marcel Schlumberger, French geophysists employed by a Franco-Belgian drilling company in 1912

http://www.spec2000.net/02-history1.htm
Electric Logs

They did the first estimation of formation resistivity too:

Pelchelbronn, France
September 5, 1927

Consisted of a line dropped down the bore hole

Electric Logs

Today electric log analysis uses the highest tech possible. It has to. Modern wells can be drilled in water 1,000’s of m deep and in the harshest conditions imaginable.
Electric Logs

• There are numerous types of logs that provide a wide variety of information.

• We’ll look at the most important

1) Resistivity
2) SP
3) Gamma Ray
4) Neutron
5) Sonic/Density
Electric Logs
Resistivity Logs

Resistivity

- The flow of electricity is governed by Ohm’s Law

\[ E = I r \]

- \( E \) is potential difference in volts
- \( I \) is current in amps
- \( r \) is resistance in ohms
Resistivity Logs

Resistivity

• Resistance is the intrinsic property of all materials to resist a current (ohm-m^2/m \equiv \text{ohm-m}): 

\[ R = \frac{rA}{L} \]

A is the cross-sectional area of the material
L is its length

• Conductivity (another log) is the reciprocal of resistivity
Infiltration Concerns

Infiltration Concerns

Resistivity Logs

Can be used to resolve lithology, but they are most useful for assessing fluid composition.

Shallow versus deep induction
Quartz, calcite and dolomite have resistivities in excess of $1 \times 10^8$ ohm-m. They are insulators.

- Oil: $1 \times 10^8$ ohm-m
- Fresh water: 26 ohm-m
- Sea water: 0.18 ohm-m
- Clays: variable depending upon cation exchange potential
Resistivity Logs

For a clean water saturated rock, the resistivity of a rock \( (R_t) \) is governed by the Archie Equation:

\[
R_t = \frac{R_w}{\Phi^m}
\]

\( R_w \) is the resistivity of the water
\( \Phi \) is fractional porosity
\( m \) is the “cementation factor”
Resistivity Logs

Ultimately resistivity of a rock ($R_t$) is controlled by:

- Salinity of formation pore water
- Volume of pore space
- Geometry of pore space
- Temperature of the logged zone
- Morphology and types of clays
- Phases of pore fluids
Spontaneous potential (self potential).

• The difference of potential (DC voltage) between a movable electrode in the borehole and a distant reference electrode usually at the surface (a copper stake).
Spontaneous potential (self potential).

• The difference of potential (DC voltage) between a movable electrode in the borehole and a distant reference electrode usually at the surface.

• The SP results from the IR drop measurable in the borehole produced by the flow of SP currents in the hole. These currents are generated by the electrochemical and electrokinetic potentials. (e.g., a “battery effect” occurs between the bore hole and the formation water if sufficient permeability is present)
SP Logs

The math expressing spontaneous potential and it’s sign is:

\[ E = -K \log \left( \frac{R_{mf}}{R_w} \right) \]

E: electrochemical potential
K: a “fudge factor” controlled by temperature
\( R_{mf} \): resistivity of mud filtrate
\( R_w \): resistivity of formation water
SP Logs

Spontaneous potential is...

…most useful as a basic tool to distinguish lithology...
(although indirectly via “permeability)
SP Logs

Spontaneous potential is...

...most useful as a basic tool to distinguish lithology

...especially sandstone versus shale because shale, even if wet, will NOT usually allow ion transfer. Water is trapped to clay surface
SP Logs

Sand line versus Shale Line

http://www.petrolog.net/webhelp/Logging_Tools/sp/sp07.gif
SP Logs

Sand line versus Shale Line

Beware of signal drift
SP Logs

SP logs can also allow you to resolve broad stratigraphic and sedimentological transitions (e.g., transgressions, regressions).

<table>
<thead>
<tr>
<th>Facies System</th>
<th>Character</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrogradational</td>
<td>Thin upward coarsening sands; upward fining sands packages; backstepping</td>
</tr>
<tr>
<td>Aggradational</td>
<td>Thick, blocky, stacked sands</td>
</tr>
<tr>
<td>Progradational</td>
<td>Thin to thick upward coarsening sands; upward coarsening sand packages</td>
</tr>
<tr>
<td>Deep-Sea Fan</td>
<td>Thin to thick upward fining sands, blocky at base; singular or stacked; thick shale at top</td>
</tr>
</tbody>
</table>
Gamma Ray Emissions

- The energy of gamma rays can tell you about the nature of the radioactive isotope(s)

\[ E = h \nu \]

- \( E \) = energy in Joules
- \( \nu \) = frequency (hertz)
- \( H \) = Planck’s Constant

http://207.10.97.102
Gamma Ray Emissions

Each isotope has a specific emission energy...

- Potassium: 1460 KeV
- Thorium series: 2620 KeV
- Uranium-Radium: 1760 KeV
Gamma Ray Emissions

• ... so it is possible to resolve the percentage of each radioactive isotope in surface and subsurface analyses.

• This is a useful technique for surface analysis and remote sensing.

• Requires a simple Geiger counter.
Gamma Ray Emissions

- It is rare to see spectral gamma ray logs in the oil industry. They are most interested in total gamma ray emissions.

www.spec2000.net
www.odp.tamu.edu
Gamma Ray Emissions

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• Why? Shales tend to have the highest concentrations of K\textsuperscript{40} (clay minerals) and clays also tend to absorb U/Th isotopes.
Gamma Ray Emissions

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- Why? Shales tend to have the highest concentrations of K$^{40}$ (clay minerals) and clays also tend to absorb U/Th isotopes.

- But beware ringer rocks:
  - Arkose sandstone (K$^{40}$)
  - Evaporites (K$^{40}$)
  - Clay cemented sandstone
  - Coals and rare dolostones absorb U
Gamma Ray Logs (sub-surface)

- This is a more typical Gamma Ray log as used in the oil industry.
Gamma Ray Logs (sub-surface)

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• Deflections to the right mean higher counts

  = Shale

www.geomore.com
Gamma Ray Logs (sub-surface)

- This is a more typical Gamma Ray log as used in the oil industry.

- Deflections to the right mean higher counts

  = Shale

- Similar to the SP log in that you can distinguish a shale line
Like SP logs, Gamma Ray log responses can be used to identify depositional conditions.
But like so much in geology, one type of information is seldom sufficient to completely characterize lithology.

Gamma ray logs are commonly paired with Resistivity or Neutron Logs

Gamma Ray Logs (sub-surface)

[Diagram showing the relationship between Gamma Ray logs and Neutron/Density logs, with different rock types represented and porosity levels indicated.]
Upcoming Stuff

Homework
1) Moscow Landing research due next Tuesday (last day of classes OK)
2) Prep for final lab exam (Next Thursday)

Lab this Week
Diagenesis due Thursday (last day of classes OK)

Next Tuesday
Lecture: Sequence Startigraphy
Lab: nothing
GY 402: Sedimentary Petrography

Lectures 23: New Zealand temperate carbonate shelves

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