Benha University

Faculty of Science

Dept. Of Geology

Time: two hours.

First Semester 2015-2016

Date: 17/01/2016

Advanced well logging (687G) for Pre-master Students (Applied Geophysics)

جامعة بنـها – كلية العلوم – قسم الجيولوجيا

دراسات عليا(تمهيدى جيوفيزياء تطبيقيه)

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الممتحن: د/ وفاء الشحات عفيفى الشحات

أستاذ مساعد بقسم الجيولوجيا بكلية العلوم

الاسئله ونموذج الاجابه

ورقه كامله

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Answer the following questions:

Question1. (45Marks)

Write on three only of the following:

a- Radioactive Tools

b- Mud Logging

c- Selection of Tools for Resistivity of the Uninvaded Zone and for porosity.

d- Shaly Sand Analysis

Question2. (20Marks)

***Write the uses of:**

a- Neutron Tools

b- Spontaneous potential tools

c- Acaustic tools

d- Cartridge

Question 3. (15 Marks)

What are the potential sources of contamination in cuttings?

BEST WISHES

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<u>Answer of Question1. (45 Marks)</u>

***Write on three only of the following:**

a- Radioactive Tools

Density Tool: Litho-Density Tool (LDT)

These tools have a caesium-137 or cobalt-60 source emitting gamma rays at 0.662 MeV, a short-spaced and a long-spaced detector in the same way as the basic formation density tool. However, the detectors are more efficient, and have the ability to recognize and to count separately gamma rays which have high energies (hard gamma rays: 0.25 to 0.662 MeV) and gamma rays which have low energies (soft gamma rays: 0.04 to 0.0 MeV).

Gamma ray enters the formation, then scattering & looses some of its energy then absorbed by a formation. Then, the detectors detect γ ray which emitted from excited atoms which related to the formation.

• The borehole must be perfectly vertical (no washout) because in this case, the tool will measure air response & causing errors in data.

• Drilling muds with high density will absorb gamma rays efficiently, such as barite filled muds, will affect the detector readings. However, the effect of these muds is compensated for automatically by the spine and ribs correction.

Calibration:

The primary calibrations are made by inserting the tool into a block of pure limestone saturated with fresh water of accurately known density.

Secondary (check) calibrations are made in the wireline tool workshop by inserting the tool into large blocks of aluminum, sulphur and magnesium of known density.

Tool operation:

The tool is physically very similar to the formation density tool. It has enhanced detectors, and the distance between the long spacing and the short spacing detectors has been decreased. This decrease has increased the vertical resolution of the tool and improved its overall counting accuracy. The density measurement has a vertical bed resolution of 50 to 60 cm, which is slightly better than the formation density tool. The enhanced resolution results from the shorter distance between the short and the long spacing detectors.The log is commonly referred to as the photo-electric factor log (PEF).

Neutron Tools: (CNL & SNP)

(**SNP**): Sidewall Neutron Porosity Tool.

(**CNL**): Compensated Neutron Log Tool.

The *neutron* log is sensitive mainly to the amount of hydrogen atoms in a formation. Its main use is in the determination of the porosity of a formation. The tool operates by bombarding the formation with high energy neutrons. These neutrons undergo scattering in the formation, losing energy and producing high energy gamma rays. The scattering reactions occur most efficiently with hydrogen atoms. The resulting low energy neutrons or gamma rays can be detected, and their count rate is related to the amount of hydrogen atoms in the formation.

Calibration:

These tools are calibrated in blocks of limestone, sandstone and dolomite of high purity and accurately known porosity. The tools are calibrated, not to give readings in API neutron porosity units, but to give the porosity directly in percent. The calibration of the CNL tool is checked at the well site before and after each logging run by the use of a neutron source of accurately known activity placed a standard distance from each detector.

Tool Operation:

SNP: This tool is designed for use in open holes only. The tool has a source and a single detector with 16 inch spacing, which are mounted on a skid that is pressed against the borehole wall. Because the tool is pressed against the borehole wall, the drilling mud does not affect the measurement, and the attenuation due to the mud cake is reduced. The detector is sensitive to epithermal neutrons so the SNP tool readings are unaffected by the presence of chlorine in high salinity muds and formation fluids.

CNL: This tool is designed to be sensitive to thermal neutrons, and is therefore affected by the chlorine effect. It has two detectors situated 15 inch and 25 inch from the source.

Gamma Ray Tools:

Total Gamma Ray: (GR)

The *gamma ray* log measures the total natural gamma radiation emanating from a formation. This gamma radiation originates from potassium-40 and the isotopes of the Uranium-Radium and Thorium series. The gamma ray log is commonly given the symbol *GR*. Its main use is the discrimination of shales by their high radioactivity. shales, organic rich shales and volcanic ash show the highest gamma ray values, and halite, anhydrite, coal, clean sandstones, dolomite and limestone have low gamma ray values.

Calibration:

The gamma ray log is reported in pseudo-units called API units. The API unit is defined empirically by calibration to a reference well at the University of Houston. This reference well is an artificial one that is composed of large blocks of rock of accurately known radioactivity ranging from very low radioactivity to very large radioactivity.

Spectral Gamma Ray: (SGR)

The *spectral gamma ray* log measures the natural gamma radiation emanating from a formation split into contributions from each of the major radio-isotopic sources.

The spectral gamma ray tool uses the same sensor as the total gamma ray tool. The output from the sensor is fed into a multi-channel analyzer that calculates the amount of radiation coming from the energies associated with each of the major peaks.

Calibration:

The spectral gamma ray tool is calibrated using 4 sources of accurately known composition, one each containing only K40, U238, and Th232, and one containing a mixture. Each of the sources is placed next to the detector and the tool is used to make a measurement. The calibration is designed such that the calibrated readings of the tool accurately report difference in the amount of radiation from each of the radiation sources.

b- Mud Logging

Mud logging, also known as hydrocarbon well logging, is the creation of a detailed record (well log) of a borehole by examining the bits of rock or sediment brought to the surface by the circulating drilling medium. This provides well owners and producers with information about the lithology and fluid content of the borehole while drilling.

Functions of drilling Mud:

- Cleaning the hole
- Cooling the drill bit
- Lifting cuttings to the surface
- Control the formation pressure
- Stabilizing the well bore
- Carrying information about formations.
- Helps in the invasion process.

Types of Drilling Fluids:

1-Water-Base Mud:

Water is the liquid phase of water-base Mud.
Water is used may be Fresh water or Saline Water.

2-Oil-Base Mud:

Oil is the liquid phase of oil-base Mud.
Advantages of oil-base Mud:

- Stabilizing formation
- Reduce downhole drilling problems

3-Drilling with air:

Dry air or natural gas is used.
In this case, we use arrangements of air compressors instead of mud pump.
Advantages of this technique:

- Prevent formation damage.
- Allows the bit to drill fast.
- Severe lost circulation problems.

4-Foam drilling:

This technique is used if small amount of water are present in formation is been drilled Drilling foam is water containing air or gas bubbles, much like shaving foam

Mud additives:

- **Bentonite:** which used to increase the Viscosity
- **Barite:** which used to increase the Density

- **Caustic Soda**: which used to increase the Alkalinity
- The drilling mud must be dense & viscous to carry cuttings & keep it from filling
- Drilling mud should have PH of at least 9

Mud Tests:

The tests are done on mud by the Mud Engineer before circulating.

Mud engineer:

- Runs tests on drilling fluid
- Monitors & maintains mud‘s properties
- Recommends changes to improve drilling

Mud Balance:

It is a device is used to determine the mud density.

Density of drilling Mud determines hydrostatic pressure of Mud Column.

Mud Density reads in Pounds/Gallon (PPG), Pounds/Cubic Feet or Millie Gram/Liter.

Marsh Funnel:

It is a device is used to measure the viscosity of Mud.

Funnel Viscosity is 35 sec/quart

- Less viscous if the Funnel viscosity less than 35 sec/quart
- More viscous if Funnel viscosity more than 35 sec/quart

Rotational Viscometer:

It is a device is used to:

- Measure viscosity (Viscosity is measured in Centipoises)
- Measure Yield Point (it is resistance to flow)
- Measure Gel strength (if strength is low, it can’t carry particles)

Filter Press:

Equipment is used to measure the filtration under dynamic conditions. It is considered as simulation for the invasion process in borehole.

There are two commercial dynamic filtration testers:

- The first one, using thick walled Cylinder with rock as a filter medium to simulate the flow into a borehole.
- The other way, using flat porous disks such as paper or fused ceramic plates.

Chloride Test:

It is a test for Salt Chlorides in Mud. It is used to know if the bit reaches a Salt Domes or Salt water.

Mud Logging & Testing:

Drilling Mud carries the cuttings to the surface. It carries also traces about any Hydrocarbons & other substances .The cuttings give great information to geologists about what’s going on in the well. Analyzing the drilling fluid is called Mud Logging.

Rig Monitors:

It shows:

- Rate of Penetration (ROP)
- Weight on Bit (WOB)
- Total Hook Load (the total force pulling down on the Hook)
- Rotary Speed or RPM
- Rotary Torque (the twisting force on drill string)
- Pit Volume PVT (the level of Mud tank)
- Mud Weight (in & out the hole)
- Mud temperature & Pump Strokes
- Casing & Stand Pipe Pressure

Mud logger can combine Rig information with other information from Drillers & Wireline Operator

Chromatograph:

It displays the percentage of Hydrocarbon gases in Mud returns to the surface.

It consists of sensors integrated in Mud Return Line to detect gases.

Core Plugging Apparatus:

It is apparatus takes a small plug out from the Core Sample.

Mud logger can analyze the plug to give idea what a large Core Sample contains.

Fluoroscope:

It is a device contains Ultraviolet lamp.

When mud logger or geologist puts cuttings or Plug in the Fluoroscope, it will glow or flours when contain hydrocarbons.

Microscope:

It helps the mud logger or geologists to identify formations, & know very small characteristics & fossils also.

Vacuum Oven:

It is used to dry up formation samples

Analytical Balance:

It is a device used to calculate the rock density & porosity for a fixed weight.

Porosimeter:

It measures the porosity of the rock (more pore space is more space for oil).

Gas Analyzer:

It analyzes hydrocarbon gases in mud & detects Hydrogen Sulphide & Carbon Dioxide (Non hydrocarbon Gases).

- **Sour Gas**: Gas that contains Hydrogen Sulphide
- **Sweet Gas**: Gas that contains little or no Hydrogen Sulphide

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c- Selection of Tools for Resistivity of the Uninvited Zone and for porosity.

The induction log usually gives the best value for Rt. In some cases these other logs may be as good or better.
• In thick uniform formation a standard IES may be best Rt tool.
• The responses of the 6FF40 and LL7 indicates the LL7 reads closer to Rt only when invasion is greater than 0" and Ri/Rt is less than 1/5.
• In very thin formations with shallow invasion a Laterolog or Guard Log may be used to give bed definition and Rt.

For Porosity

1. If cores are available, a plot of core porosity versus log porosity will aid in selecting the best tools in future wells in a field.
2. If information related to lithology is desired, more than one porosity tool should be run.
3. If two porosity tools are to be run, the density and the neutron may be the best combination in most wells, but local experience is the best guide.
a. The neutron along with the density or sonic can be used to detect gas.
b. The neutron log and sonic log are influenced by shale and give porosities that are too high when shale is present. The density is normally influenced less by shale than the sonic or neutron.
4. In areas where the Movable Oil Plot is useful, a Microlaterolog may be run along with the density, neutron or sonic. This may be the only logging technique available in deeply invaded formations where Rt cannot be obtained.
5. In low porosity, regular formations, the neutron is probably the best, the density second and the sonic third. The Microlaterolog is not recommended for porosities less than 5%.

d- Shaly Sand Analysis

The presence of shale (i.e., clay minerals) in a reservoir can cause erroneous water saturation and porosity values derived from logs. These erroneous values are not limited to sandstones, but also occur in limestones and dolomites.
Whenever shale is present in a formation, all porosity tools (Sonic, Neutron, Density) will record a porosity which will be too high. Two extraordinary exceptions to this rule are density, if the density of the shale is equal to or greater than the matrix, and the neutron through a gas-bearing shaly sand, depending on the volume of shale present.
As well as affecting porosity, the presence of shale in a formation will cause the resistivity log to read a resistivity that is too low. This has the effect of reducing the contrast between oil or gas and water; hence, if shale is present in a reservoir, Sw may be difficult to calculate. It is usually accepted that for shale to significantly affect log derived water saturations, the shale content must exceed 10% to 15%.

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The first step in shaly sand analysis is to determine the volume of shale (Vcl or Vsh). There are a number of ways to do this and some are summarized below. If more than one method is used and all values are reasonably close, the lowest value should be taken to represent shale volume (Vcl).

Vcl may be calculated from single curves or from crossplots using the following logs:

- Gamma Ray
- Spectra Log
- Spontaneous Potential
- Resistivity
- Neutron

- Neutron - Density Crossplot
- Neutron - Sonic Crossplot
- Density - Sonic Crossplot

Gamma Ray

The Gamma Ray responds to the natural radioactivity of the formation. In erivation of shale content, the assumption is made that the only radioactive component is shale, hence the presence of other radioactive minerals will cause Vsh to be too high. There are two methods used to calculate clay volume from the Gamma Ray; one assumes a linear response and the other a curved response.

The basic equation common to both linear & curved response is the Gamma Ray Index:

where: GR min = GR minimum (in clean sand)

GR max = GR maximum (shale zone)

linear response: VclGR = IGR

Spectra Log

The Spectra Log (Western Atlas term) may be used in one of three ways to calculate Vcl.

1. *Spectralog Total Counts*: The total counts curve on a Spectralog is a sensitive gamma ray measurement and may be used subject to the same constraints as mentioned for the Gamma Ray. It is a linear response:

2. *Spectralog Potassium*: The spectralog-derived determination of potassium may be used to calculate Vcl because, with the exception of potassium deficient shale, potassium content can be correlated directly to the formation shale content.

The presence of other potassium rich minerals will cause too high a value of Vsh; however, with the exception of potash deposits, feldspar rich granite washes and zones rich in mica, the clean formation contribution to potassium content is generally small. The greatest advantage of this method is that it is not
affected by uranium salts.

3. *Spectralog Thorium*: Thorium can also be correlated to the amount of shale in the formation. Unlike the GR or K40 curve, the Thorium curve may be used for Vsh calculations in a granite wash. The presence of thorium in formation other than shale is rare in sedimentary environments.

Spontaneous Potential

The SP curve may be used to calculate Vsh; however, factors such as SP noise, lack of Rw to Rmf contrast, and hydrocarbon content can complicate the derivation of Vcl from the SP. The use of high salinity drilling fluids restricts the development of a good SP and a valid Vcl.

where: SP min = SP in clean water sand

SP max = SP in shale

Another way of calculating Vcl from the SP is as follows:

where: PSP = SP of shaly formation

SSP = SP of thick, clean sand or carbonate

SSP can also be calculated rather than read from the SP curve:

Resistivity

The use of a resistivity device as a clay indicator is dependent on the contrast of the resistivity response in shale and a clean pay zone. The basic equation is:

where: Rlimit is the maximum resistivity where clay volume is zero.

The resistivity method for Vcl calculations is not always accurate and should be used with discretion.

Neutron

The Neutron response in a formation is primarily a function of the formation hydrogen content. Since shale contains various amounts of water, the neutron porosity in a shaly interval is a function of both shale content and liquid filled effective porosity. Vcl calculations in low porosity zones will be accurate while calculations in higher porosity zones will cause Vcl to be too high. Zones which contain light hydrocarbons will show a volume of shale which is too low.

where: φNmin = Neutron value where clay volume is zero

Neutron-Density Crossplot

This crossplot relies on the neutron and density response in shale to calculate a Vcl. Calculated shale volumes will be too low in gas-bearing intervals. The clean matrix characteristics (neutron and density values in sand) must be known or assumed. Typically, the density of clean matrix is taken as 2.65 gm/cc and the neutron is about 4% when recorded in limestone porosity units, or 0% when recorded in sandstone units.

Neutron-Sonic Crossplot

This is not widely used to calculate porosity or clay content in shaly sands because both the sonic and neutron tools are highly affected by clay. When cross plotted, there is very little resolution for either porosity or clay content.

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While this crossplot has little use in determining porosity or clay content, it can be used effectively in selecting potential gas zones. Since the sand fluid and clay-fluid lines are very close points those which are gas bearing will normally fall to the left of the matrix-fluid triangle.

Density-Sonic Crossplot

The density-sonic crossplot has the advantage that the lithology lines are close together and a changing lithology will only slightly change calculated shale volumes. Caution should be used in applying this technique to

<u>Answer of Question 2. (20Marks)</u>

***Write the uses of:**

a- Neutron Tools

The *neutron* log is sensitive mainly to the amount of hydrogen atoms in a formation. Its main use is in the determination of the porosity of a formation

b- Spontaneous potential tools

Uses of SP:

- The detection of permeable beds
- The determination of Rw
- The indication of the shaliness of a formation
- Correlation

c- Acaustic tools

The sonic log is used to evaluate porosity in liquid filled pores

d- Cartridge

Cartridge: Surrounding the sensor in the modern tools and do three functions: 1.Powering the sensor to be ON/OFF. 2. Processing the acquired data (First step of processing). 3. Data transmission along cables to the up-hole instruments.

<u>Answer of Question 3. (15Marks)</u>

What are the potential sources of contamination in cuttings?

There are many potential sources of contamination when under taken estimates of Lithology percentage. Some examples are:

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*Cavings: cuttings from previously drilled intervals rather than from the bottom of the hole.
*Recycled cuttings: are recognized as being small, abraded, rounded rocks fragments in the sample.
*Mud chemicals: such as L.C.M. "Lost Circulation Material" & Bentonite.
*Cement: may be mistaken for Siltstone, but is readily identified by testing with Phenolphthalein solution, its high PH will give a purple color.
*Metal: originates from wearing the inside of the casing by the drill string, so we use rubber drill pipe protectors. Other sources of metal fragments are bits.