Benha University | **Time: three hours.**

Faculty of Science | **First Semester 2016-2017**

Dept. Of Geology | **Date: 9/01/2017**

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

جامعة بنها – كلية العلوم – قسم الجيولوجيا

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أستاذ مساعد بقسم الجيولوجيا بكلية العلوم

الاسئله ونموذج الاجابه

ورقه كامله

Benha University

Faculty of Science

Dept. Of Geology

Time: three hours.

First Semester 201٦-201٧

Date: ٩/01/201٧

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

Answer the following questions:

Question1. (30Marks)

Write on three only of the following:

a- Reservoir pore system
b- Drilling Fluids
c- Production logging
d- Normal and abnormal pressures

Question2. (40Marks)

What is the mechanism and purposes of 2 of the following tools?

a- Formation sampling.
b- Drill Stem Test (DST)
c- Repeat Formation Tester (RFT)

Question3. (30Marks)

***Define four only:**

a- Drainage and Imbibation
b- Wettability
c- The Capillary Effect
d- Gas Compressibility
e- Gas Viscosity
f- Liquid Density

Question 4. (20 Marks)

Write on one of the following:

a- Wireline logging
b- Measuring While Drilling(MWD)

BEST WISHES

Benha University | Time: three hours.

Faculty of Science | First Semester 201٦-201٧

Dept. Of Geology | Date: ٩/01/201٧

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

Answer of Question1. (٣٠ Marks)

Write on three only of the following:

a- Reservoir pore system

Three parameters describe the properties of the pore system:

• Porosity fluid storage capacity of the rock

• Permeability flow of a single fluid

• Net Reservoir thickness of reservoir rock

Porosity is defined as the ratio of the amount of pore space present in a volume of rock to the total volume (pore space plus rock matrix) of that rock.

Factors Affecting Porosity

The actual value of the porosity in a particular sample of rock is determined by a number of factors. The porosity can also be reduced by compaction or by the presence of some other material in the pore space, like calcite cement or clay minerals. Porosity is thus dependent on: • grain shape • overburden & compaction• grain packing • cementation • grain sorting • clay content

Types of Porosity

The intergranular porosity of sandstones and the interparticle porosity in carbonates is often referred to as primary porosity. The macroscopic porosity features often encountered in carbonates are called *secondary* porosity. Together these two porosity types make up the total porosity of the rock.

permeability is a measure of the ease with which a fluid can flow through a rock.

"**Net reservoir**" thickness is an important descriptive parameter of the reservoir, as it quantifies the vertical dimension when calculating the volume of hydrocarbons in place.

Net reservoir is defined as the total thickness of rock in a reservoir that contains movable hydrocarbons.

b- Drilling Fluids

Most wells are drilled with clear water for faster penetration rates, until a depth is reached where hole conditions dictate the need for a fluid with special properties. The addition of clay and chemicals to the water permits the adjustment of viscosity, density and other properties to improve hole cleaning and prevent sloughing shale, lost circulation, formation flow and formation damage. In most cases, the circulating fluid used in a rotary drilling operation is a water-based mixture of clays, suspended solids and chemical additives. In some cases, oil is added to the fluid or the entire system may be converted to an oil-based mixture. A small percentage of wells are drilled with air or foam as the circulating fluid for part of the drilling operation.

In any case, the properties of the drilling fluid must be such that it performs the following functions:

- Control subsurface pressures
- Remove cuttings from the hole
- Cool and lubricate the drillstem and bit
- Aid formation evaluation and productivity

c- Production logging

Once a well is on production, there is often a requirement to determine the nature of the flow downhole. This can be carried out by running various production logging tools into the producing (or injecting) well. The principles behind these tools are essentially the same as those for conventional open hole logging tools, in that they are run on electric cable and produce a surface readout.

A production log may be required to measure:

- Flow rates to locate the precise source of production of oil, gas and water.
- Fluid density to determine the type of fluid being produced from an interval.
- Temperature to determine the flowing and shut-in temperature profile of the well.
- The information from production a log is used to:
- Allocate production or injection to reservoirs or intervals in commingled completions
- Quantify cross flow between intervals
- Identify sources of excess water or gas production
- Quantify the amount of water or gas being produced from a particular interval.
- Identify intervals that require stimulation.
- Analyse the success of a stimulation treatment.
- Locate leaks in the casing, tubing or packers
- Identify flow behind the casing from non-perforated intervals

d- Normal and abnormal pressures

A reservoir is termed *normally*, or *hydrostatically pressured* if there is a continuous column of water extending from surface down to the reservoir, through which the water pressure is being transmitted. One way of checking whether or not a reservoir is normally pressured is to extrapolate the water pressure gradient observed immediately below the oil water contact of a reservoir back up to surface. If there is a continuous column of water the extrapolated pressure will be the atmospheric pressure acting on the top of the water column.

Causes of Abnormal Pressures If overpressures are encountered during drilling the mud overbalance may be lost, and fluids may flow from the over pressured formation, if it is permeable, into the borehole causing a "kick". The density of the fluid influx from the formation will be less than the density of the mud in the borehole, causing a reduction in the weight of the fluid column to the surface. The pressure in the borehole at the point of influx will be reduced, and the under balance will increase. This condition is unstable and may develop into a blowout if it is not quickly controlled by re-establishing an overbalance at the point of influx. If the mud weight is increased to achieve an overbalance against the over pressured formation, the large overbalance which results against the shallower, normally pressured formation may cause unacceptable losses of drilling fluid from the borehole. The shallower formations might therefore have to be sealed off behind casing before drilling into the overpressures.

If under pressures are encountered during drilling, the sudden large overbalance may cause large losses of drilling fluid to the under pressured formation. If these losses cannot be replaced by adding drilling fluid to the wellbore at the surface, the level of the mud in the borehole may drop.

Question2. (40Marks)

What is the mechanism and purposes of 2 of the following tools?

a- Formation sampling.

Dedicated formation sampling can be carried out to obtain quantitative information about the reservoir rock. This may take the form of coring instead of drilling, or sidewall sampling after the hole has been drilled.

Coring cylindrical piece of formation once brought to the surface, the core is transferred to boxes for shipment to the laboratory. At the laboratory the gamma ray attenuation of the core is measured along the length of the core to correlate the core data with wireline logs. Next the core is "slabbed" and photographed. Slabbing involves cutting the core lengthways in two pieces. After slabbing the core is described in terms of environment of deposition, lithology, qualitative rock properties, the presence of fractures or faults, dip of the bedding planes, and indications of hydrocarbons.

Routine measurements taken on the core plugs are:

• porosity
• (horizontal) permeability
• grain density

Special core analyses may be carried out on a selection of core plugs, which should be chosen to cover the
full depth, porosity and permeability ranges of the cored interval. These include:

• vertical air permeability
• relative permeability
• capillary pressure

- cementation factor (m)
- saturation exponent (n)

Core samples may be taken for palaeontological and palynological analyses, animal and plant remains respectively.

Thin sections may be cut from the core to examine the detailed pore structure, and look for evidence of diagenesis. Increasingly cores are being examined by X-ray, scanning electron microscope (SEM), and nuclear magnetic resonance (NMR) tools. Three dimensional pictures of the internal pore structure and its fluid content can be constructed using tomography, which combines the images from a series of slices through a core.

Special coring techniques such as sponge coring and pressure coring are available to recover the fluids in the pore space along with the core as it is cut. These allow the original fluid saturations in the cored material to be inferred from an analysis of the fluids recovered.

Sidewall Sampling

Sidewall samples are taken after the hole is drilled by shooting hollow bullets into the formation The gun can be run with other wireline logging tools to provide good control over the depths at which the samples are taken. Sidewall sampling is a relatively cheap technique for obtaining additional lithological information. It can be used over intervals that were cored, but from which no recovery was obtained. Sidewall samples are also used for identifying the fluid type, in particular for differentiating between oil and gas. In an oil bearing zone, the sidewall samples will be stained with oil, but only very weak shows may be observed in a gas bearing zone.

b- Drill Stem Test (DST)

Drill stem test is essentially the same as a bottom hole pressure survey, but carried out with a temporary completion which uses the drill string itself as a temporary production conduit. This completion may be made in an open hole with the interval to be tested isolated by inflatable packers or in a cased hole with a retrievable packer. The pipe rams in the blow out preventer stack are closed around the drill string to close off the annulus at the surface.

A major limitation of the technique for both open hole and cased hole tests, is that the drill string is not gas tight. This poses a safety problem with most hydrocarbons, which will separate into gas and liquid phases at some point in the drill string if they are produced to surface. Gas may then escape into the annulus. In some cases a gas tight tubing string, rather than the drill string, may be run with a temporary completion, usually in a cased hole, to overcome this problem. Achieving adequate isolation of the test interval may also be a problem during an open hole drill stem test. Interpreting the results from a drill stem test is identical to interpreting any other bottom hole pressure survey. Correcting pressures to a datum will be less certain, particularly in an open hole, because the depth of the tool and of the test interval are less well defined. Gradient surveys will generally not be possible.

c- Repeat Formation Tester (RFT)

The repeat formation tester (RFT) is the preferred method for measuring reservoir pressure in an open hole. This is a SchIumberger wireline tool which can be set against the borehole wall at selected depths to take a series of spot pressure measurements. An earlier form of the tool, the formation interval tester (FIT) operated in a similar way, but could take only a single measurement. The formation multi-tester (FMT) is the Dresser- Atlas equivalent of the RFT.
A probe is pushed against the borehole wall at the selected depth by back-up shoes. The probe must pass through the mudcake coating the borehole wall and achieve a connection with the formation. A seal around the probe, and the surrounding mud cake, isolates the probe from the mud pressure in the wellbore.
The probe piston and the screen are to try to prevent the probe from becoming blocked by mud particles entering the tool

• Compaction, where permeable rock is isolated by a substantial thickness of clay or other impermeable sediments, and then either buried or uplifted so that the overburden stress is altered.

• Overpressures are created in some relatively impermeable rocks, because of the difficulty with which liquids can escape from the pores as the rock is compacted. These "depopressures" occur particularly in thick clays and shales which undergo rapid burial.

• Thermal effects where water expansion due to changes in temperature is prevented because water cannot escape through the surrounding impermeable sediments.

• Phase changes such as the dewatering of clay minerals and conversion of gypsum ($CaSO_4.2H_2O$) to anhydrite ($CaSO_4$), which contribute additional free water to the pore space.

• Production from a well sealed reservoir may cause under pressures due to "depletion". Removing fluid from such a closed system causes the fluid pressure to be reduced, because no liquid can enter the reservoir to replace the produced volume. The same may apply to a relatively impermeable reservoir, in which any influx of fluid to replace the produced volume takes place very slowly. The reservoir is under pressured during its producing life, but will re-pressure over a longer time period.

• "Inflation" overpressures occur when a normally pressured reservoir becomes connected to an already over pressured zone. This effect may occur over "geological" time, e.g. by leakage of fluid from a deeper over pressured interval into a reservoir, or rapidly during production activities, e.g. by rupturing a fault seal between a normally pressured and an over pressured fault block as the normally pressured block is depleted. Inflation overpressures may also occur as a result of an internal blowout in a well, where fluid flows from a high pressure zone, through the borehole into lower pressure zones.

• Changes in horizontal stress caused by tectonic activity have a similar effect to changes in the vertical overburden stress.
• Osmosis where clays act as semi-permeable membranes separating formation waters with different ionic concentrations, act to pump water molecules into or out of a sealed system.

The Impact of Abnormal Pressures on Drilling Operations

During normal drilling operations there is a column of drilling mud in the borehole. One of the functions of the mud is to generate a fluid pressure in the borehole which is greater than the pressure of the fluids in the formation. This overbalance prevents the formation fluids from flowing into the borehole.

The overbalance is kept small to minimize the loss of drilling mud from the borehole into the more permeable parts of the surrounding formation.

Question3. (30Marks)

***Define four only:**

a- Drainage and Imbibation

The process of oil displacing water in a water wet system, as in the case of a reservoir filling up with oil, is called drainage.

The reverse process, namely that of water displacing oil may also take place in a reservoir, e.g. when oil is being driven out of the reservoir by water from an expanding aquifer below the reservoir. If at any time during drainage the process is reversed by lowering the oil pressure again, an imbibitions process takes place.

The average oil saturation left behind in the sample is termed the **residual oil saturation**.

Water which is trapped in the very small pores and as a film of water coating the grains of rock is the irreducible water saturation is also referred to as **connate water**.

bWettability

Wettability describes the behaviour at the contact between two fluids and a solid, e.g. air, water and glass

c- The Capillary Effect

The capillary effect is a combined result of the influence of surface tension and wettability.

d- Gas Compressibility

Compressibility is an important property of reservoir fluids in terms of describing the performance of the production process.

e- Gas Viscosity

Whenever we need to describe the flow properties of reservoir fluids we need some idea of the fluid *viscosity*, which is a measure of it's internal resistance to flow and is often thought of as a sort of internal "friction"

f- Liquid Density

The density, or mass per unit volume, of hydrocarbon mixtures in the liquid state is easily determined at the surface using hydrometers that measure the API gravity of oil. Determining the density of oil at reservoir conditions can be done in the laboratory or from liquid analyses at both reservoir and surface conditions.

Question 4. (2٠ Marks)

Write on one of the following:

a- Wireline logging

A source of information required to obtain a more complete picture of the formation. This measuring technique is wireline logging, where some physical properties of the formation are measured and interpreted in terms of porosity, hydrocarbon saturation, etc.

Logging Procedure

After the hole has been drilled, a measuring sonde is lowered into the hole at the end of an electrical cable. The sonde is slowly pulled upward and measures some properties of the formation. The measured signal is sent uphole through the cable, recorded and processed by a computer built into the surface logging unit. The data is recorded on a magnetic tape, and on a photographic film from which paper prints can be made.

Log Types

Many logs are available, but they can be classified into three families:

1. Reservoir thickness logs
2. Porosity logs
3. Resistivity logs

Logs from these three families give information about the three parameters required to quantify the amount of hydrocarbons in place in the reservoir:

- Net reservoir thickness
- Porosity
- Hydrocarbon saturation

Another reservoir property of much interest is permeability .There is no log available from which the permeability can be determined quantitatively. Qualitative indications can be obtained from various logs or combinations of logs. Not all logs fit in this simple classification scheme. For example, the dipmeter, which is used to determine the formation dip angle and direction.

Uncertainties and Limitations of Wireline Logs

Wireline logging can supply high quality, quantitative information about the formation provided the measuring conditions are good. Large and irregular boreholes will adversely affect the accuracy of the measurements. Interpretation of the measured data is required to evaluate the formation properties, which are not measured directly.

b- Measurement While Drilling

An alternative to wireline logging is offered by the "measurement while drilling" (MWD) technique. The same type of measurements is carried out as those done by wireline logging, but the measurements are made while the hole is being drilled instead of afterwards. In principle the interpretation of MWD measurements is the same as for wireline logs. The data is the same data, but it is gathered in a different way.

Principle of Measurement

The measurement of physical formation properties is carried out by sensors or sondes that are located immediately above the drilling bit in a dedicated MWD collar. Hole deviation information and drilling parameters, e.g. weight on bit, torque etc., can be recorded continuously, in addition to the formation properties. Information can be transmitted to the surface in various ways. The widely used mudpulse system codes the information in the form of pressure pulses which travel up through the mud column. Alternatively, downhole data recorders can be used, from which the data must be retrieved by wireline at regular intervals while drilling is stopped.

Advantages and Limitations of MWD

The obvious advantage of the MWD technique is that formation data becomes available immediately and continuously. Operational decisions, e.g. to start coring or to set casing, can be taken more easily. The quality of the measured data is limited by design constraints. The equipment must be rugged to withstand the rough down hole conditions. Another limiting factor is the data transmission rate. The transmission rate for mud pulse systems is limited to about 3 bits/s. Down hole data recorders solve this problem, but then the benefit of having continuous and immediate information is lost. Financially, MWD systems are generally comparable to wireline logging, but costs should be checked for each specific case.