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(54) DETERMINING WATER SALINITY AND WATER-FILLED POROSITY OF A FORMATION

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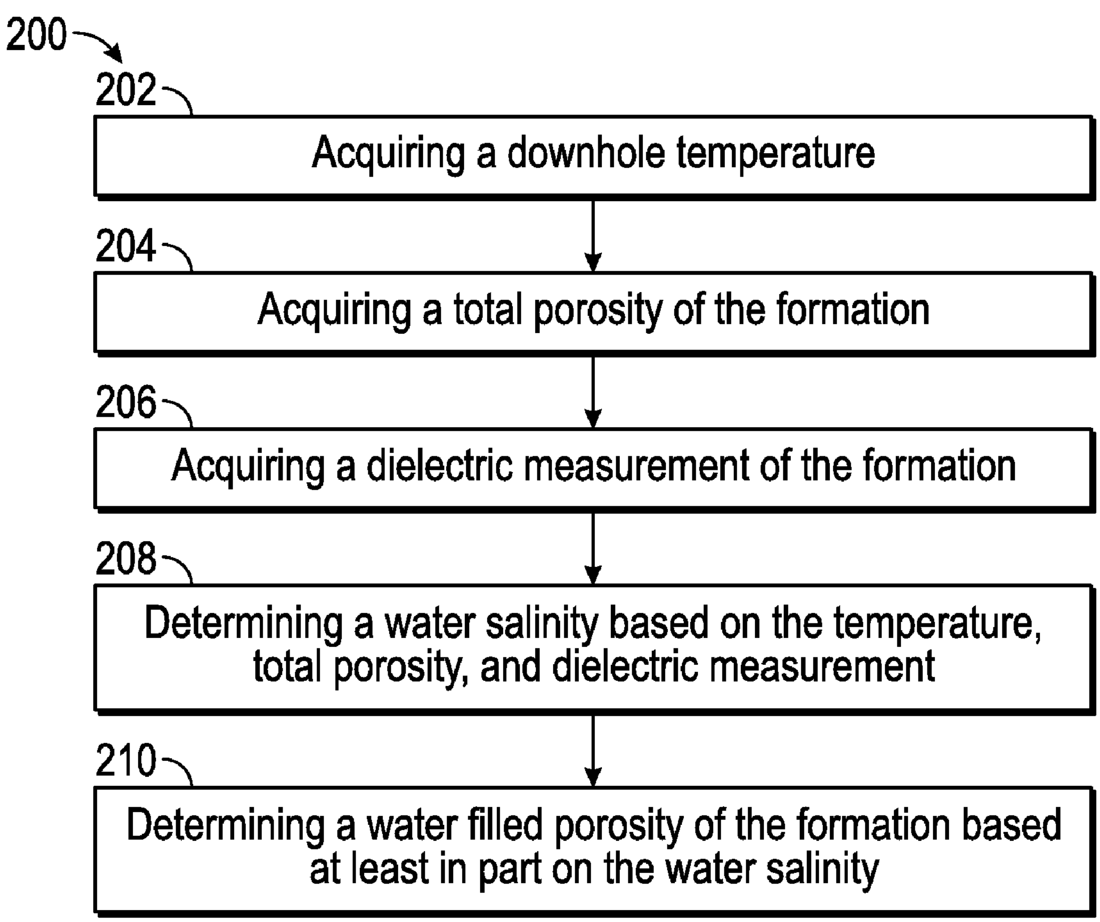
(57) ABSTRACT

An illustrative method of determining water-filled porosity of a formation that includes acquiring a downhole temperature, acquiring a total porosity of the formation, acquiring a dielectric measurement of the formation, determining a water salinity based on the temperature, total porosity, and dielectric measurement. The method further includes determining a water-filled porosity of the formation based at least in part on the water salinity.



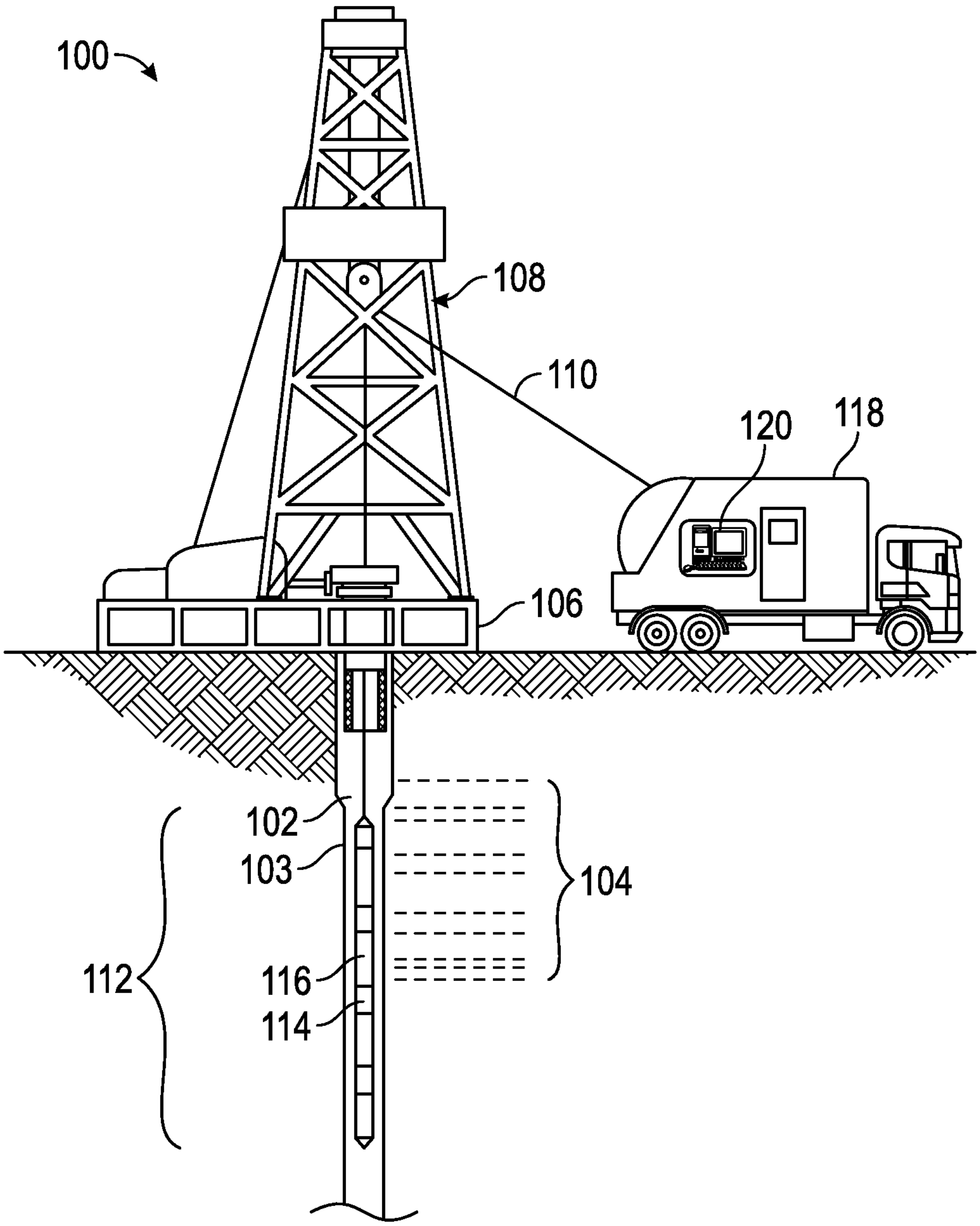


FIG. 1

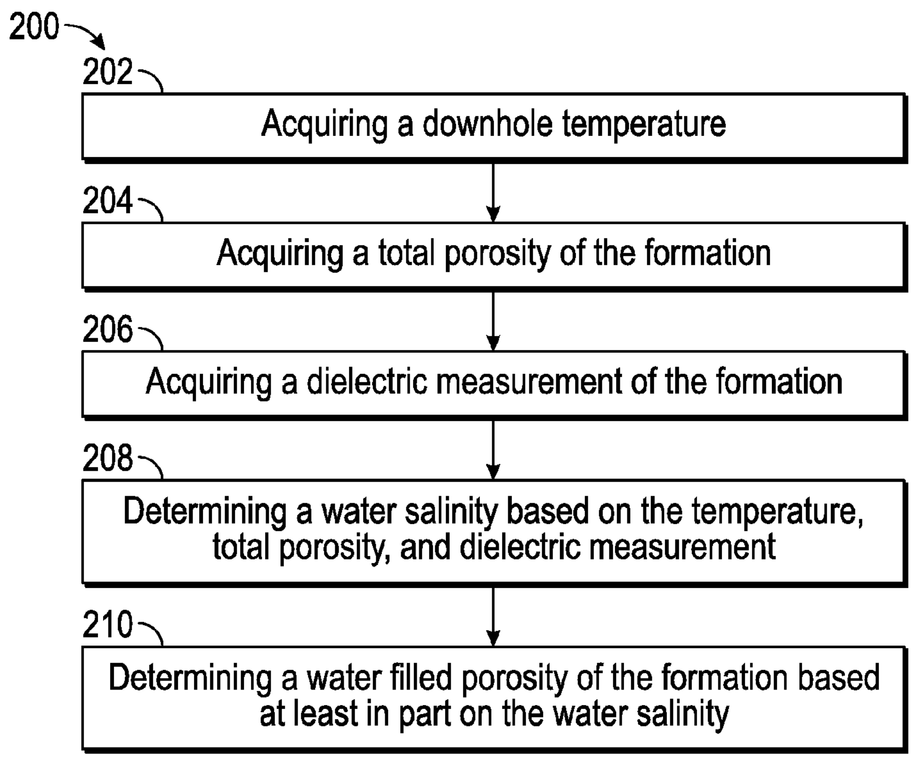

200
202
Acquiring a downhole temperature
204
Acquiring a total porosity of the formation
206
Acquiring a dielectric measurement of the formation
208
Determining a water salinity based on the temperature, total porosity, and dielectric measurement
210
Determining a water filled porosity of the formation based at least in part on the water salinity

FIG. 2

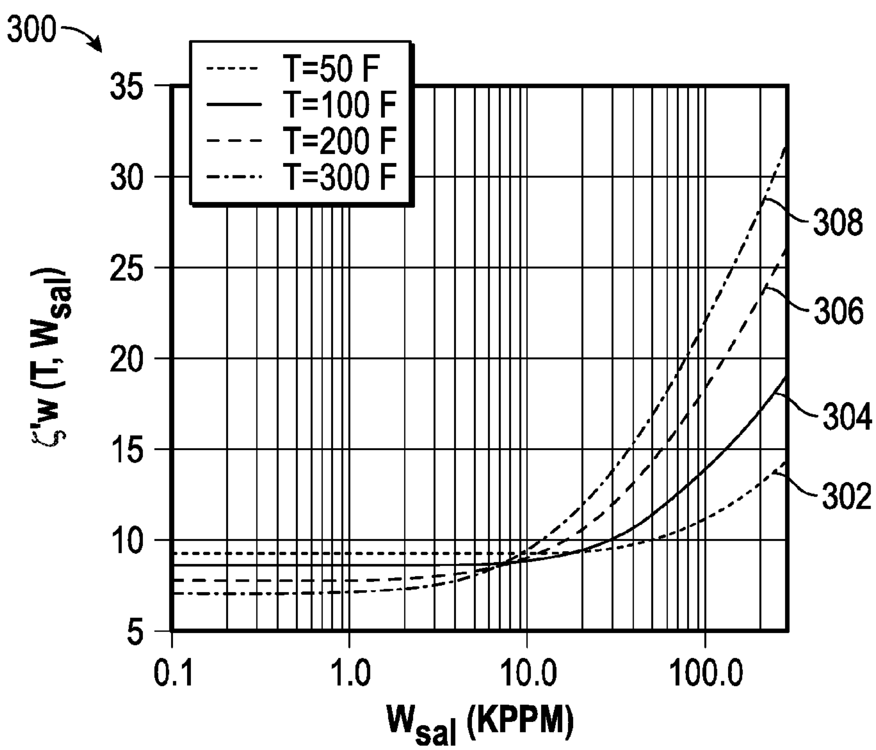

300
T=50 F
T=100 F
T=200 F
T=300 F
308
306
304
302
35
30
25
20
15
10
5
0.1
1.0
10.0
100.0
W_{sal} (KPPM)
$\zeta'w$ (T, W_{sal})

FIG. 3A

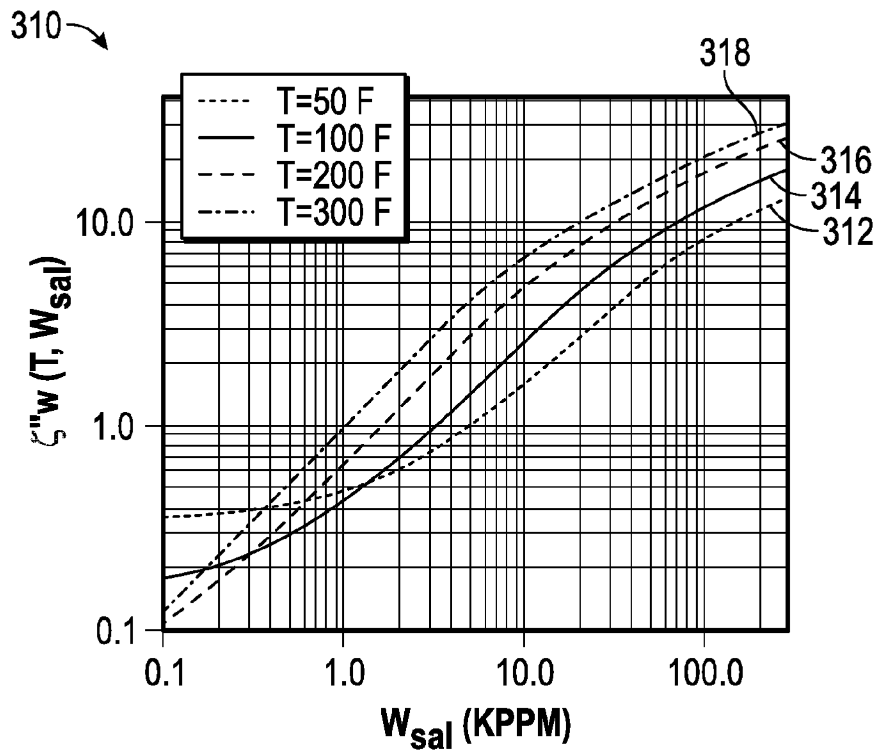

310
318
T=50 F
T=100 F
T=200 F
T=300 F
316
314
312
10.0
1.0
0.1
ζ"w (T, W_sal)
0.1
1.0
10.0
100.0
W_sal (KPPM)

FIG. 3B

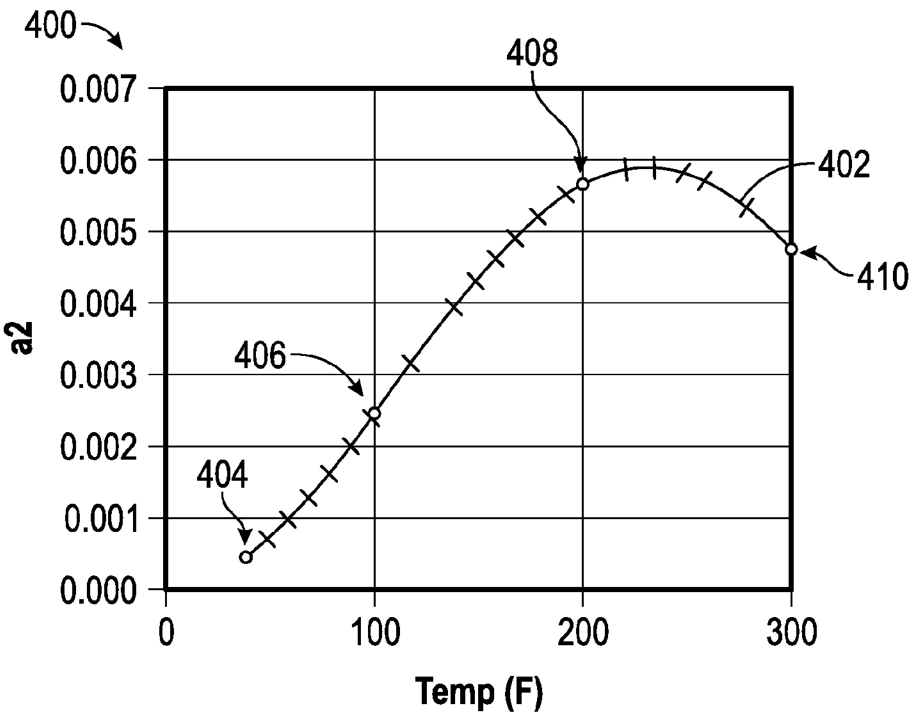

400
408
402
410
406
404
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
a2
0
100
200
300
Temp (F)

FIG. 4A

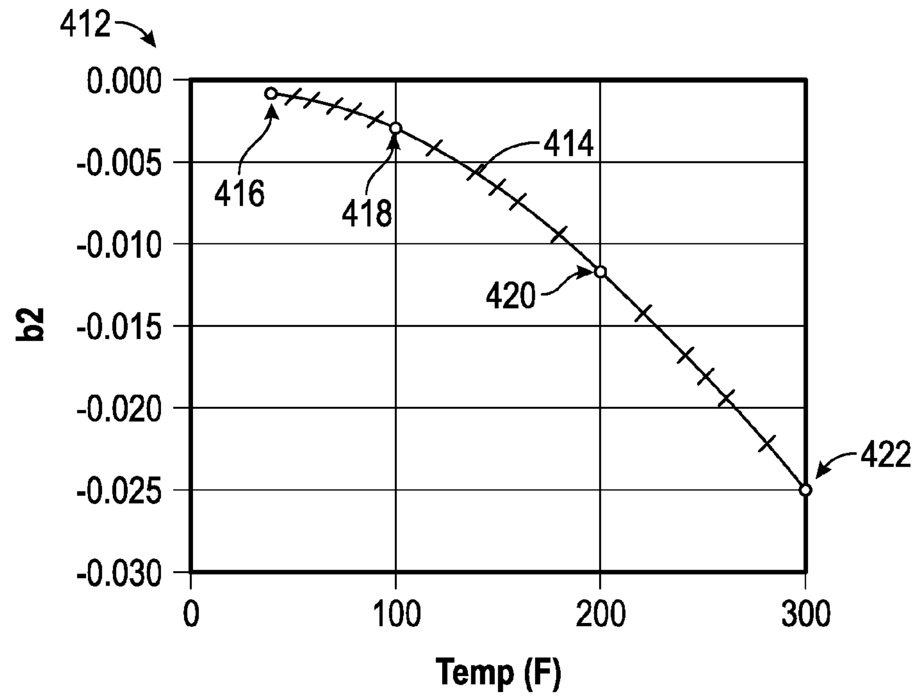

412
0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
b2
416
418
414
420
422
0
100
200
300
Temp (F)

FIG. 4B

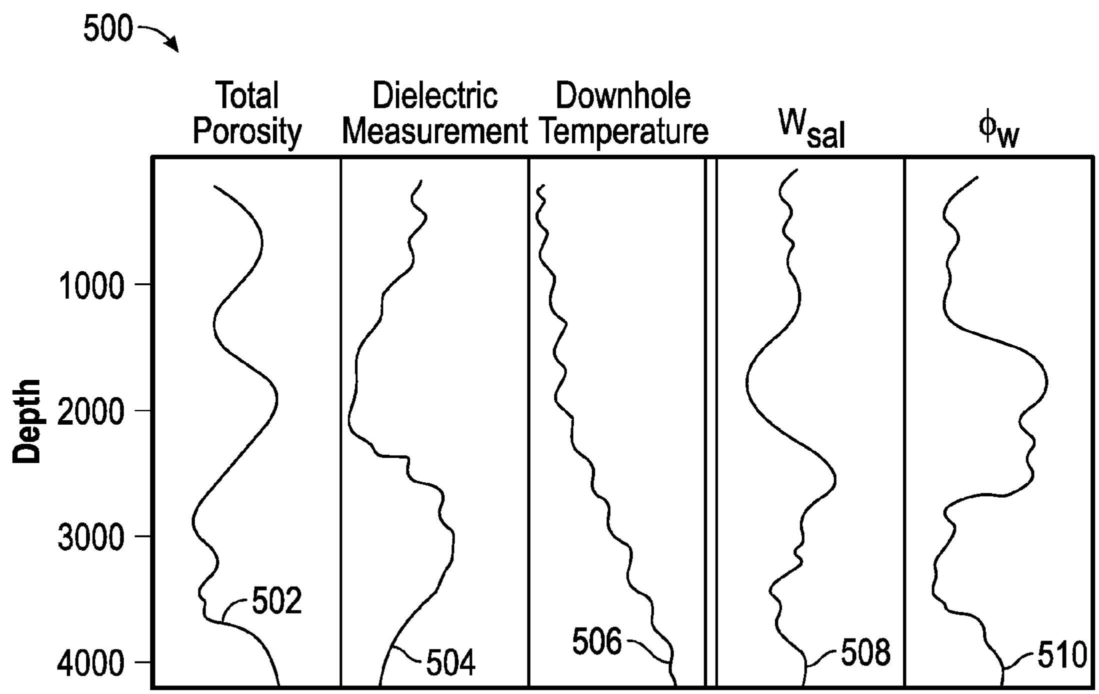

500
Total Porosity
Dielectric Measurement
Downhole Temperature
W_{sal}
ϕ_w
Depth
1000
2000
3000
4000
502
504
506
508
510

FIG. 5

DETERMINING WATER SALINITY AND WATER-FILLED POROSITY OF A FORMATION

BACKGROUND

[0001] Oilfield operators demand access to a great quantity of information regarding the conditions encountered downhole. Such information typically includes characteristics of the earth formations traversed by the borehole and data relating to the size and configuration of the borehole itself. The collection of information relating to conditions downhole, which commonly is referred to as "logging," can be performed by several methods including wireline logging.

[0002] In wireline logging, a probe or "sonde" is lowered into the borehole after some or the entire well has been drilled. The sonde hangs at the end of a long cable ("wireline") that provides mechanical support to the sonde and also provides an electrical connection between the sonde and electrical equipment located at the surface of the well. In accordance with existing logging techniques, various parameters of the earth's formations are measured and correlated with the position of the sonde in the borehole as the sonde is pulled uphole. The direct electrical connection between the surface and the sonde provides power and a relatively large bandwidth for conveying logging information.

[0003] One desirable formation parameter is water-filled porosity of the formation, as it is useful for determining the quantity and producibility of hydrocarbons within the formation. To obtain the water-filled porosity, knowledge regarding water salinity is usually required. The standard techniques for determining water salinity are: (1) take a water sample from the well after it has been drilled, or (2) extrapolate from other wells in the region. Experience has shown these approaches to be unreliable due to significant salinity variation within and between wells, particularly when fluid injection is employed for secondary recovery. In the latter case, the fluid injection causes substantial salinity variation laterally across the reservoir and vertically around the reservoir, making the standard techniques impractical or hopelessly inaccurate. In either case, a determination of water salinity in real time is not feasible, thus requiring additional time and money for analysis. Absent an accurate measure of water salinity, the consequent determinations of water-filled porosity and corresponding implications regarding hydrocarbons are unreliable.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Accordingly, there are disclosed herein method and associated systems for determining water salinity and water-filled porosity. In the drawings:

[0005] FIG. **1** shows an illustrative wireline logging environment.

[0006] FIG. **2** is a flow diagram of an illustrative method for determining water salinity and water-filled porosity of a formation having unknown or mixed salinity.

[0007] FIGS. **3**A and **3**B are illustrative graphs depicting real and imaginary components of water's dielectric constant.

[0008] FIGS. **4**A and **4**B are illustrative graphs depicting temperature-dependent function coefficients.

[0009] FIG. **5** is an illustrative log of water salinity related parameters.

[0010] It should be understood, however, that the specific embodiments given in the drawings and detailed description thereto do not limit the disclosure. On the contrary, they provide the foundation for one of ordinary skill to discern the alternative forms, equivalents, and modifications that are encompassed together with one or more of the given embodiments in the scope of the appended claims.

DETAILED DESCRIPTION

[0011] Disclosed herein are methods and systems for determining water salinity and water-filled porosity. Certain illustrative method embodiments include acquiring a downhole temperature, along with a total porosity measurement and dielectric measurement of the formation, and determining water salinity from such measurements. Additionally, based at least in part on the water salinity, a dielectric constant of water and a refractive index of the water may be calculated, thereby enabling a calculation of a water-filled porosity. The temperature, porosity, and dielectric measurements may be acquired in log form, i.e., as a function of depth or position along a borehole. Temperature-dependent function coefficients may be used in calculating the water salinity. Moreover, the coefficients may be saved to memory for later recall and/or displayed to the user along with the water-filled porosity.

[0012] FIG. **1** depicts an illustrative wireline logging environment **100**. In FIG. **1**, a borehole **102** (having a borehole wall **103**) has been drilled through various formations **104** in a typical drilling manner. A drilling platform **106** supports a derrick **108** capable of raising and lowering a drill string (not shown) through the borehole **102**. In the figure, the drill string has been removed, enabling a wireline cable **110** to convey a wireline tool string **112** through the borehole **102**. As depicted, the tool string **112** includes various downhole tools **114**, **116** that may help with a determination of formation properties, for example, water salinity and water-filled porosity determinations. Example downhole tools **114**, **116** may include a downhole temperature sensor, a dielectric measurement tool, and/or a porosity measurement tool, such as a density-neutron or nuclear magnetic resonance (NMR) tool. However, it will be appreciated that additional tools may be included on the tool string **112**, such as a control sub for coordinating the operation of the various tools in the tool string and providing telemetry that enables the measurements collected by the various tools to be communicated to the surface.

[0013] Alternatively, or in addition to being communicated to the surface, measurements collected by the tools **114**, **116** may be stored in memory of the tool string **112** and/or processed by a downhole processor within the tool string **112**. A computing or logging facility **118** which includes a computer system **120** having a processor may be arranged at the surface to receive the processed or unprocessed measurements. The computer system **120** may include a memory having software executed by the processor to configure the logging facility **118** to manage tool string **112** operations, acquire and store the measurements, and process the measurements for display to an operator.

[0014] For example, the computer system **120** and processor may be capable of receiving the downhole measurements from the tools **114**, **116**, and responsively calculating water salinity and/or water-filled porosity of the formation. Moreover, such calculations may be a function of the acquired temperature, dielectric, and porosity measurements from the tools **114**, **116**. In particular, the water-filled porosity calculations may be based at least in part on water salinity and down hole temperature. The memory of the computer system **120** may additionally store information for recall later, such as the water salinity and temperature dependent function coefficients used to determine the water salinity. Additionally, the logging facility **118** may present the raw or calculated information to a user via a user interface that includes a monitor or printer.

[0015] While the wireline environment **100** of FIG. **1** is depicted as a land-based environment with a vertical wellbore **16**, it is contemplated herein that the same principles may be applied to a sea-based environment, as well as a deviated or horizontal wellbore, without departing from the scope of the disclosure.

[0016] FIG. **2** is a flow diagram of an illustrative method **200** for determining water salinity W_{sal} and water-filled porosity ϕ_w of a formation having an unknown or mixed water salinity. In general, to determine the water salinity W_{sal}, a downhole temperature T is acquired, as at block **202**. Additionally, the formation porosity ϕ and an overall dielectric measurement c are also typically acquired, as may be accomplished by a porosity measurement tool and a dielectric measurement tool at blocks **204** and **206**, respectively.

[0017] Notably, due to the empirical mixing law known as the Complex Refractive Index Method (CRIM), when the dielectric measurement tool operates at high frequencies (e.g., at approximately 1 Ghz or greater), the measured formation properties can be treated as being independent of the formation or rock texture. The complex dielectric value ϵ^*_{rock} is thus related to only the fluids and minerals that make up the formation.

[0018] At block **208**, a processor determines the water salinity based on the acquired temperature, porosity, and dielectric measurements via the following equations. In general, the following nomenclature is used throughout the equations: variables having an "*" (e.g., (δ^*) are a complex value having real and imaginary components. Variables having a single apostrophe (e.g., δ') are the real component of the complex value and variables having a double apostrophe (e.g., δ'') are the imaginary component of the complex value.

[0019] The dielectric value of the formation ϵ^*_{rock} can be measured in real-time by the high frequency dielectric tool (HFDT) ϵ^*_{HFDT}, and may be expressed in the form of Equation 1:

$$\sqrt{\epsilon^*_{HFDT}}=V_w*\sqrt{\epsilon^*_w}+V_{ma}*\sqrt{\epsilon^*_{ma}}+V_{HC}*\sqrt{\epsilon^*_{HC}} \quad (1)$$

where ϵ^*_{HFDT} represents the dielectric measurement as taken by the HFDT as a function of three rock constituents: matrix (ma), water (w), and hydrocarbons (HC). V represents their relative volumes (which may be expressed as a percentage or dimensionless fraction of unity) and $\sqrt{\epsilon^*}$ is the root of their respective dielectric values (also defined as the refractive index ζ^*). Equation 1 becomes equation 2:

$$\zeta^*_{HFDT}=V_w*\zeta^*_w+V_{ma}*\zeta^*_{ma}+V_{HC}*\zeta^*_{HC} \quad (2)$$

[0020] Advantageously, eliminating the square root terms from equation 1 enables simplified calculations when solving equation 2. The refractive index is also a complex value, having real and imaginary parts, $\zeta^*=\zeta'+i*\zeta''$, thus equations representing the real and imaginary components may be represented as equation 3 (the real components) and 4 (the imaginary components):

$$\zeta'_{HFDT}=V_w*\zeta'_w+V_{ma}*\zeta'_{ma}+V_{HC}*'_{HC} \quad (3)$$

$$\zeta''_{HFDT}=V_w*\zeta''_w+V_{ma}*\zeta''_{ma}+V_{HC}*''_{HC} \quad (4)$$

Assuming the conductivity of both the hydrocarbons and the rock matrix is close to zero, the corresponding imaginary portion of the complex dielectric constants (ϵ''_{ma}) and (ϵ''_{HC}) are zero, thus their corresponding refractive index (ζ''_{ma}) and (ζ''_{HC}) are zero, and equation 4 becomes:

$$\zeta''_{HFDT}=V_w*\zeta''_w \quad (5)$$

With ϕ representing the total porosity, the relative volumes may be represented as $V_w=\phi_w$, $V_{HC}=(\phi-\phi_w)$, and $V_{ma}=(1-\phi)$. Therefore, equations 3 and 5 become:

$$\zeta'_{HFDT}=\phi_w*\zeta'_w+(\phi-\phi_w)*\zeta'_{HC}+(1-\phi)*\zeta'_{ma} \quad (6)$$

$$\zeta''_{HFDT}=\phi_w*\zeta''_w \quad (7)$$

[0021] Solving for water-filled porosity ϕ_w in equation 7, we obtain equation 8:

$$\varphi_w=\frac{\zeta''_{HFDT}}{\zeta''_w} \quad (8)$$

Expanding equation 6, isolating ϕ_w, and then substituting equation 8 for ϕ_w in equation 6 and solving for ϕ_w results in equation 9:

$$\frac{\zeta'_w-\zeta'_{HC}}{\zeta''_w}=\frac{\zeta'_{HFDT}-[\varphi*\zeta'_{HC}+(1-\varphi)*\zeta'_{ma}]}{\zeta''_{HFDT}} \quad (9)$$

All the terms on the right hand side of equation are either measured or known. For example, the refractive index ζ'_{HFDt} and ζ''_{HFDt} are measurements from the HFDT tool. Similarly, the total porosity ϕ is known (i.e., from one of the downhole tools **114**, **116**, such as the density-neutron or NMR tool). The difference in porosity $(1-\phi)$ can be calculated, and the hydrocarbon refractive index ζ'_{HC} and matrix refractive index ζ'_{ma} are known or estimatable from previously obtained or calculated data. Specifically, the type of hydrocarbons may be determined by monitoring drilling fluids, acquiring formation fluid samples, or extrapolating from what is known from seismic data and/or nearby wells. The refractive index of the rock matrix can be determined in a similar fashion, and advantageously, such values are expected to be more readily determinable than water salinity.

[0022] On the left side of the equation, the hydrocarbon refractive index ζ'_{HC} is also known from previously obtained or calculated data, such as $\sqrt{\epsilon'_{HC}}=\zeta'_{HC}\approx\sqrt{2}\approx1.414$. Thus, the real and imaginary refractive index components of water ζ'_w and ζ''_w are the only unknown variables in equation 9.

[0023] Both ζ'_w and ζ''_w are a function of pressure, temperature T, and water salinity W_{sal}. Assuming the pressure effects are negligible, ζ'_w and ζ''_w may be represented by corresponding functions, f**1** and f**2**, dependent on only temperature (T) and water salinity (W_{sal}) as measured by the tools **114**, **116** of the tool string **112** (FIG. **1**), thus equation 9 becomes:

$$\frac{f1-c1}{f2}=c2 \tag{10}$$

where c**1** and c**2** are calculated from the HFDT measurements, the porosity measurements, and the refractive indices of the formation matrix and hydrocarbons. When rearranged, equation 10 can be represented as:

$$f1-c1=c2*f2 \tag{11}$$

It can be shown that the following polynomial equations are representative of f**1** and f**2**:

$$f1=a_0(T)+a_1(T)*W_{sal}+a_2(T)*W_{sal}^2 \tag{12}$$

$$f2=b_0(T)+b_1(T)*W_{sal}+b_2(T)*W_{sal}^2 \tag{13}$$

The coefficients a**0**, a**1**, a**2**, b**0**, b**1**, b**2** can be determined by fitting quadratic curves to laboratory measurements of saline water. Applying equations 12 and 13 to equation 11 results in equation 14:

$$a_0(T)+a_1(T)*W_{sal}+a_2(T)*W_{sal}^2-c1=c2*(b_0(T)+b_1(T)*W_{sal}+b_2(T)*W_{sal}^2) \tag{14}$$

Equation 14 can also be represented as equation 15 by subtracting the right side of the equation and isolating W_{sal} and W_{sal}^2.

$$[a_0(T)-c2*b_0(T)-c1]+[a_1(T)-c2*b_1(T)]*W_{sal}+[a_2(T)-c2*b_2(T)]*W_{sal}^2=0 \tag{15}$$

As discussed above, c**1** and c**2**, along with the temperature T are known. In some embodiments, the temperature-dependent coefficients (a**0**, a**1**, a**2**, b**0**, b**1**, and b**2**) may also be known from prior calculations, thus allowing a determination of water salinity W_{sal}.

[0024] In other embodiments, the coefficients (a**0**, a**1**, a**2**, b**0**, b**1**, and b**2**) may be unknown and need to be solved for at block **208**. To determine the coefficients, Stroud, Milton & De (Physical Review B Vol. 34, No. 8, Oct. 15, 1986) shows that at 1 GHz, the water's dielectric ϵ'_w and ϵ''_w can be approximated by the empirical relationship shown in equations 16 and 17.

$$\varepsilon'_w=\frac{1}{\frac{1}{94.88-0.2137*(T)+217*10^{-6}*(T^2)}+\frac{2.4372*W_{sal}}{58.443*(1000-W_{sal})}} \tag{16}$$

$$\varepsilon''_w=\frac{(17.9753*(T+7))/82}{0.0123+\frac{3647.5}{(1000*W_{sal})^{0.955}}}+ED(T,1\text{ Ghz}). \tag{17}$$

Stroud et. al. do not include the water diffusion loss term ED(T, 1 Ghz) as depicted in equation 17, however addition of this term helps to better describe the asymptotic behavior of ϵ''_w at low salinities and temperatures.

[0025] Illustrative results of equations 16 and 17 are depicted in FIGS. **3**A and **3**B which graph the real and imaginary components of water's dielectric constant as measured at various temperatures. FIG. **3**A depicts a graph **300** illustrating the real portion of the refractive index of water for the temperature 50°, 100°, 200°, and 300° as plots **302**, **304**, **306**, and **308**, respectively. The X-axis is a log-based scale representing water salinity W_{sal} (thousands of parts per million) and the Y-axis represents the refractive of the water ζ'_{HFDT}.

[0026] A second order polynomial can be fit to each of the temperature curves **302**, **304**, **306**, **308**. Alternatively, for increased accuracy, a piecewise polynomial fit may be performed on each curve. For example, generating a first polynomial fit for a salinity W_{sal} of 0 to 10, a second polynomial fit from 10 to 100, and a third polynomial fit from 100 upwards, resulting in the following equations:

$$a_0(T)=k*a_{00}+k*a_{01}*(T)+k*a_{02}*(T^2)+k*a_{03}*(T^3) \tag{18}$$

$$a_1(T)=k*a_{10}+k*a_{11}*(T)+k*a_{12}*(T^2)+k*a_{13}*(T^3) \tag{19}$$

$$a_2(T)=k*a_{20}+k*a_{21}*(T)+k*a_{22}*(T^2)+k*a_{23}*(T^3) \tag{20}$$

[0027] FIG. **3**B is similar to FIG. **3**A, however the graph **310** plots the imaginary dielectric component of the water as a function of temperature and water salinity W_{sal}. Again, a single polynomial equation may be derived for each temperature, or alternatively multiple piecewise polynomials may be derived, resulting in the illustrative equations 21-23:

$$b_0(T)=k*b_{00}+k*b_{01}*(T)+k*b_{02}*(T^2)+k*b_{03}*(T^3) \tag{21}$$

$$b_1(T)=k*b_{10}+k*b_{11}*(T)+k*b_{12}*(T^2)+k*b_{13}*(T^3) \tag{22}$$

$$b_2(T)=k*b_{20}+k*b_{21}*(T)+k*b_{22}*(T^2)+k*b_{23}*(T^3) \tag{23}$$

[0028] Upon determining the coefficients (a**0**, a**1**, a**2**, b**0**, b**1**, and b**2**), they may be graphed as depicted in FIGS. **4**A and **4**B. In particular, the graph **4**A illustrates the coefficient a**2** depicted as plot **402**. The X-axis represents temperature and the Y-axis represents the coefficient value. The coefficient value associated with the temperatures plotted in FIGS. **3**A and **3**B, 50°, 100°, 200°, and 300°, are marked as points **404**, **406**, **408**, and **410**, accordingly, and the third order polynomial equation 20 results in the curve fitting plot **402** and equation 24:

$$a_2(T)=k*a_{20}+k*a_{21}*(T)+k*a_{22}*(T^2)+k*a_{23}*(T^3) \tag{24}$$

FIG. **4**B similarly represents a graph **412** for the coefficient b**2**, as does equation 25.

$$b_2(T)=k*b_{20}+k*b_{21}*(T)+k*b_{22}*(T^2)+k*b_{23}*(T^3) \tag{25}$$

In one example, the following numbers may be derived: $ka_{20}=5.20*10^{-4}$, $ka_{21}=1.40*10^{-5}$, $ka_{22}=2.27*10^{-7}$, $ka_{23}=7.21*10^{-10}$, $kb_{20}=8.09*10^{-5}$, $kb_{21}=2.71*10^{-6}$, $kb_{22}=2.27*10^{-7}$, and $kb_{23}=0$.

[0029] Upon determining the coefficients (a**0**, a**1**, a**2**, b**0**, b**1**, and b**2**), they may be employed in equation 15, thereby enabling the determination of water salinity W_{sal}. It is likely that the coefficients can be extrapolated for use in additional or future calculations for unmeasured temperatures.

[0030] With the determination of water salinity in hand, and referring back to FIG. **2**, water-filled porosity ϕ_w may be found, as at block **210**. In some embodiments, the water's dielectric constants ϵ'_w and ϵ''_w may be calculated using equations 16 and 17. As discussed above, $\sqrt{\epsilon^*}$ is also defined as the refractive index ζ'. The magnitude and angle of the refractive index may be calculated by equations 26 and 27:

$$|\zeta^*|=\sqrt[4]{\varepsilon'^2+\varepsilon''^2} \tag{26}$$

-continued

$$\angle\zeta^* = \left(\frac{1}{2}\right) * \tan^{-1}\left(\frac{\varepsilon''}{\varepsilon'}\right) \quad (27)$$

Therefore:

[0031]

$$\zeta' = \sqrt[4]{\varepsilon'^2 + \varepsilon''^2} * \cos\left(\left(\frac{1}{2}\right) \tan^{-1}\left(\frac{\varepsilon''}{\varepsilon'}\right)\right) \quad (28)$$

$$\zeta'' = \sqrt[4]{\varepsilon'^2 + \varepsilon''^2} * \sin\left(\left(\frac{1}{2}\right) \tan^{-1}\left(\frac{\varepsilon''}{\varepsilon'}\right)\right) \quad (29)$$

Having calculated the water's dielectric constants ϵ'_w and ϵ''_w, equations 28 and 29 may now be solved to find the water's refractive index components. Resulting therefrom, equation 7 ($\zeta''_{HFDT}=\phi_w*\zeta''_w$) may be used to find the water-filled porosity ϕ_w as the refractive index of the formation ζ''_{HFDT} is known from measurements of the HFDT and the water's refractive index ζ'' is also known.

[0032] Advantageously, by no longer relying on ex-situ measurements or an iterative process, these calculations can now be performed in near real-time, for example, by the processor of the computer system **120** (FIG. **1**). Additionally, the hydrocarbon porosity may be determined based on the water-filled porosity from the previously mentioned formula $V_{HC}=(\phi-\phi_w)$. One or a multiple of the aforementioned measurements and determinations may be logged and/or presented to the user with the computer system **120**. It should be understood that the method **200** may vary and may, for example, include more or less blocks, and the blocks may be performed in parallel or in a different order.

[0033] FIG. **5** is an illustrative log **500** of water salinity related parameters. The Y-axis represents depth, which may be true vertical depth of the tool string or may be overall well depth. As shown, the log **500** includes measurements used to determine water salinity and water-filled porosity of a formation, such as a porosity (ϕ) log **502**, a dielectric measurement log **504**, and a downhole temperature log **506**. The log **500** may further include the resulting calculated water salinity **508** and water-filled porosity **510**. By depicting such measurements and resulting calculations, the user may be capable of quickly determining which portions of the formation contain hydrocarbons, and in what quantity. It will be appreciated that the log **500** is merely for illustrative purposes and is not to scale or accuracy.

[0034] Numerous other modifications, equivalents, and alternatives, will become apparent to those skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such modifications, equivalents, and alternatives where applicable.

[0035] Embodiments disclosed herein include:

[0036] A: A method of determining water-filled porosity of a formation that includes acquiring a downhole temperature, acquiring a total porosity of the formation, acquiring a dielectric measurement of the formation, determining a water salinity based on the temperature, total porosity, and dielectric measurement, and determining a water-filled porosity of the formation based at least in part on the water salinity.

[0037] B: A system for determining and logging water-filled porosity having a downhole tool assembly that acquires downhole temperature measurements, the tool assembly including a dielectric measurement tool that acquires dielectric measurements of formations surrounding a borehole, and a porosity measurement tool that acquires total porosity measurements of the formations. The system further having a processor that determines and logs water-filled porosity of the formation as a function of the temperature, dielectric, and porosity measurements.

[0038] Each of embodiments A and B may have one or more of the following additional elements in any combination: Element 1: presenting a log of the water-filled porosity to a user. Element 2: where the temperature, total porosity, and dielectric measurements are acquired as a function of depth or position along a borehole, and the determining a water-filled porosity includes creating a log of the water-filled porosity as a function of depth or position along a borehole. Element 3: where determining a water salinity includes relating the real and imaginary components of water's dielectric constant. Element 4: where determining the water salinity and determining the water-filled porosity are performed by a processor in real-time. Element 5: determining a hydrocarbon porosity of the formation based on the water-filled porosity. Element 6: where determining a water salinity includes obtaining temperature-dependent function coefficients expressing a dependence of real and imaginary components of water's dielectric constant on salinity. Element 7: where determining the function coefficients includes implementing a piecewise polynomial fit. Element 8: further including determining real and imaginary components of a refractive index of the formation from the dielectric measurement. Element 9: calculating a constant based on the refractive index, the porosity, a dielectric constant of hydrocarbons, and a dielectric constant of the matrix. Element 10: calculating a dielectric constant of water based at least in part on the water salinity. Element 11: calculating a refractive index of water based at least in part on the water salinity. Element 12: storing the coefficients in a memory.

[0039] Element 13: a user interface coupled to the processor, where the user interface displays the log of water-filled porosity. Element 14: where the processor further determines a water salinity of the formation as a function of the temperature, dielectric, and porosity measurements. Element 15: where the processor further determines the water-filled porosity based at least in part on salinity and temperature. Element 16: a memory that stores temperature dependent function coefficients expressing dependence of water's dielectric constant on salinity. Element 17: where the dielectric measurement tool is a high frequency dielectric measurement tool (HFDT) operating at a frequency of 1 GHz or greater.

1. A method of determining water-filled porosity of a formation, comprising:

acquiring a downhole temperature;

acquiring a total porosity of the formation;

acquiring a dielectric measurement of the formation;

determining a water salinity based on the temperature, total porosity, and dielectric measurement; and

determining a water-filled porosity of the formation based at least in part on the water salinity.

2. The method of claim **1**, further comprising presenting a log of the water-filled porosity to a user.

3. The method of claim **1**, wherein said temperature, total porosity, and dielectric measurements are acquired as a function of depth or position along a borehole, and wherein said determining a water-filled porosity includes creating a log of said water-filled porosity as a function of depth or position along a borehole.

4. The method of claim **1**, wherein said determining a water salinity further comprises relating the real and imaginary components of water's dielectric constant.

5. The method of claim **1**, wherein determining the water salinity and determining the water-filled porosity are performed by a processor in real-time.

6. The method of claim **1**, further comprising determining a hydrocarbon porosity of the formation based on the water-filled porosity.

7. The method of claim **1**, wherein said determining a water salinity includes obtaining temperature-dependent function coefficients expressing a dependence of real and imaginary components of water's dielectric constant on salinity.

8. The method of claim **7**, wherein determining the function coefficients comprises implementing a piecewise polynomial fit.

9. The method of claim **1**, further comprising determining real and imaginary components of a refractive index of the formation from the dielectric measurement.

10. The method of claim **9**, further comprising calculating a constant based on the refractive index, the porosity, a dielectric constant of hydrocarbons, and a dielectric constant of the matrix.

11. The method of claim **1**, further comprising calculating a dielectric constant of water based at least in part on the water salinity calculating a refractive index of water

12. The method of claim **11**, further comprising calculating a refractive index of water based at least in part on the water salinity.

13. The method of claim **7**, further comprising storing the coefficients in a memory.

14. A system for determining and logging water-filled porosity, comprising:

a downhole tool assembly that acquires downhole temperature measurements, wherein the tool assembly includes:

a dielectric measurement tool that acquires dielectric measurements of formations surrounding a borehole;

a porosity measurement tool that acquires total porosity measurements of said formations; and

a processor that determines and logs water-filled porosity of the formation as a function of the temperature, dielectric, and porosity measurements.

15. The system of claim **14**, further comprising a user interface coupled to the processor, wherein said user interface displays said log of water-filled porosity.

16. The system of claim **14**, wherein the processor further determines a water salinity of the formation as a function of the temperature, dielectric, and porosity measurements.

17. The system of claim **14**, wherein the processor further determines said water-filled porosity based at least in part on salinity and temperature.

18. The system of claim **14**, further comprising a memory that stores temperature dependent function coefficients expressing dependence of water's dielectric constant on salinity.

19. The system of claim **14**, wherein the dielectric measurement tool is a high frequency dielectric measurement tool (HFDT) operating at a frequency of 1 GHz or greater.

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