Methods for deriving relative permeability from resistivity measurements in the laboratory and from downhole resistivity measurements are described. Further, systems and methods for determining relative permeability from borehole resistivity measurements made during a water flooding event such as drilling with water-based mud, water injection and/or water invasion are described.
Conventional core analysis to determine porosity and absolute permeability.

Steady-state experiment with resistivity measurements at equilibrium.

Plot the RI curve to determine $n$.

Use the equivalence between Equation 1 and Equation 2 to determine $\lambda$.

Calculate $K_{rw}$ and $K_{ro}$ using the below equations and plot $K_r$ on normalized curve.

Un-normalize the $K_r$ curves; curve intervals will be $S_{wi} < S_w < 1$ for the X-axis, $0 < K_{rw} < 1$ and $0 < K_{ro} < K_{ro}(S_{wi})$ for the Y-axis. At the end of the drainage steady-state experiment, $K_o(S_{wi})$ is known.

Fig. 1
Fig. 2-1

Fig. 2-2
In the continuity of the primary drainage, run steady-state experiment with resistivity measurements taken at equilibrium.

Plot the RI curve to determine \( n \).

Use the equivalence between Equation 6 and Equation 7 to determine.

Calculate \( Kr_w \) and \( Ko \) using the below equations and plot \( Kr \) on normalized curve.

Un-normalize the \( Kr \) curves; curve intervals will be \( Sw_i < Sw < Sw_o \) for the X-axis, \( 0 < Kr_0 < 1 \) (\( Ko(Sw_i) \) is used to normalized imbibition \( Kr \)) and \( 0 < Kr_w < Kr_w(Sw_o) \) for the Y-axis. At the end of the imbibition steady-state experiment, \( Kw(Sw_o) \) is known.

Fig. 3
Fig. 4-1

Fig. 4-2

$Y = x^{-1.539}$
Fig. 4-3
Determination of porosity from neutron-density or other logging techniques

Determination of $R_t$ from electrical log during brine invasion or injection

Determination of $m$ and $n$ from core analysis and/or other logging techniques

Determination of $S_w$ from the 2nd Archie’s law

Determination of $\lambda$ using the equivalence between Equation 11 and Equation 12

Calculate $K_{rw}$ and $K_{ro}$ using Equation 16 and Equation 17 and plot $K_r$ on normalized curve

Un-normalization of the $K_r$ curves by determining the $K_r$ end-points using resistivity and formation-tester measurements

Fig. 5
Fig. 7
RELATIVE PERMEABILITY FROM BOREHOLE RESISTIVITY MEASUREMENTS

CROSS-REFERENCE TO RELATED APPLICATIONS


FIELD

[0002] The subject disclosure generally relates to production of oil and gas from subterranean reservoirs. More particularly, the subject disclosure relates to methods for deriving relative permeability from borehole resistivity measurements.

BACKGROUND

[0003] In formation evaluation and reservoir engineering, resistivity index, relative permeability, and capillary pressure are often valuable parameters for estimating oil reserves and planning for production. They can be determined in the laboratory using conventional and Special Core Analysis, or SCAL techniques.

[0004] Several theoretical models have been proposed to infer relative permeability from capillary pressure. A few studies have been initiated to correlate relative permeability and/or capillary pressure with resistivity. For example, Pirson et al., found an empirical relationship between relative permeability and resistivity index (Pirson et al., “Prediction of relative permeability characteristics of intergranular reservoir rocks from electrical measurements,” J. Petrol. Technol., (1964), 561-570). Li et al., (Li, K. and Horne, R. N. “Experimental Verification of Methods to Calculate Relative Permeability Using Capillary Pressure Data,” SPE 76757, Proceedings of the 2002 SPE Western Region Meeting/AAPG Pacific Section Joint Meeting, Anchorage, Ak., May 20-22, 2002; Li, K., “A Semi-analytical Method to Calculate Relative Permeability From Resistivity Well Logs,” SPE 95575, SPE Annual Technical Conference and Exhibition, Dallas, USA, 9-12 Oct. 2005; and Li, K., “A New Method for Calculating Two-Phase Relative Permeability From Resistivity Data in Porous Media,” Transport in Porous Media (2007), DOI 10.1007/s11242-007-9178-4) has developed a semi-analytical model to infer relative permeability from resistivity, and confirmed it using experimental data. All of the above references are incorporated herein by reference in their entirety.

SUMMARY

[0005] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

[0006] According to some embodiments a method is described for determining relative permeability for a subterranean rock formation. The method includes: receiving downhole resistivity data representative of resistivity measurements made in a wellbore penetrating the subterranean rock formation during a water flooding event of the subterranean rock formation; and determining one or more relative permeability values for the subterranean rock formation based at least in part on the downhole resistivity data. According to some embodiments, the permeability values include relative permeability for wetting (e.g., water) and non-wetting (e.g., oil) phases during an imbibition mode corresponding to the water flooding event.

[0007] According to some embodiments, the resistivity measurements are made using a logging-while-drilling tool. In such cases the aqueous wetting phase can be a water-based drilling mud and the water flooding event can be the introduction of the water-based drilling mud into the rock formation during a drilling process.

[0008] According to some embodiments, the water flooding event is caused by water being injected from an injection well. The resistivity measurements can be made from an injection well, an observer well and/or a production well. According to some other embodiments, the water flooding event is caused by a brine invasion from a second rock formation.

[0009] According to some embodiments, the relative permeability values are further based on porosity values of the rock formation. The porosity can be derived from, for example borehole measurements such as neutron density measurements, NMR measurements, dielectric measurements, and/or acoustic measurements.

[0010] According to some embodiments, the relative permeability values are further based on one or more derived Archie’s law parameters, such as saturation exponent and/or cementation factor. The Archie’s law parameters can be based on a laboratory core analysis procedure, and/or on borehole measurements.

[0011] According to some embodiments, a system is described for determining relative permeability for a subterranean rock formation. The system includes: a downhole resistivity measurement tool configured to be deployed in a borehole penetrating the rock formation and to take resistivity measurements during a water flooding event of the rock formation; and a processing system configured to determine one or more relative permeability values for the subterranean rock formation, based at least in part on downhole measurements made during the water flooding event made by the resistivity tool.

[0012] As used herein the term “determining” is to be broadly construed and includes like terms such as deriving, calculating, modeling, obtaining, acquiring, estimating and extracting.

[0013] As used herein the term “water” includes aqueous fluids such as brine and water-based drilling mud.

[0014] Further features and advantages of the subject disclosure will become more readily apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The subject disclosure is further described in the detailed description which follows, in reference to the noted plurality of drawings by way of non-limiting examples of the subject disclosure, in which like reference numerals represent similar parts throughout the several views of the drawings, and wherein:
FIG. 1 is a flow chart illustrating aspects of determining relative permeability from drainage-phase laboratory measurements, according to some embodiments; FIGS. 2-1, 2-2 and 2-3 depict the experimental results in primary drainage, according to some embodiments; FIG. 3 is a flow chart illustrating aspects of a method for determining relative permeability for imbibition following a drainage-phase from laboratory measurements, according to some embodiments; FIGS. 4-1, 4-2 and 4-3 depict the experimental results in imbibition, according to some embodiments; FIG. 5 is a flow chart illustrating aspects of a method for determining relative permeability on a log scale based on downhole resistivity measurements, according to some embodiments; FIG. 6 is a diagram illustrating aspects of systems and methods for determining relative permeability from borehole resistivity measurements, according to some embodiments; and FIG. 7 illustrates a wellsite system in which the relative permeability can be determined from resistivity and other measurements taken while drilling with a water-based mud, according to some embodiments.

DETAILED DESCRIPTION

The particulars shown herein are by way of example and for purposes of illustrative discussion of the examples of the subject disclosure only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the subject disclosure. In this regard, no attempt is made to show structural details in more detail than is necessary, the description taken with the drawings making apparent to those skilled in the art how the several forms of the subject disclosure may be embodied in practice. Furthermore, like reference numbers and designations in the various drawings indicate like elements.

According to some embodiments, methods are disclosed for predicting relative permeability from resistivity measured in the lab using a steady-state method and from direct measurements in the well (i.e., downhole resistivity measurements). The steady-state flooding method measures resistivity and steady-state relative permeability at the equilibrium state.

According to some other embodiments, methods are disclosed to modify and improve Li’s model in primary drainage. According to some embodiments, the pore size distribution index λ in Li’s model is substituted by the saturation exponent n in the equation of the relative permeability of the wetting phase. This substitution can be justified by the fact that, when brine is the wetting phase, as is the case in water-wet conditions, the mobility of the wetting brine phase is highly affected by the capillary forces, whereas the mobility of the non-wetting oil phase is more governed by the viscous forces. The saturation exponent n accounts for this in the mobility of the wetting phase. According to some embodiments, for the non-wetting phase which will be less affected by the capillary effects (no capillary suction due to the water wettability of the rock), the factor λ is retained in the model.

According to some embodiments, methods are disclosed for determining Kr during an imbibition cycle. Experiments performed have shown good agreement between Kr determined from resistivity and Kr measured in the lab using the steady-state method during an imbibition cycle. The imbibition methods described are believed to more accurately describe what happens in the wellbore during brine invasion (water-based mud while drilling or brine while injecting). According to some embodiments, the above modeling methods for drainage and imbibition are used to determine relative permeability in a reservoir rock using borehole resistivity measurements made in the reservoir rock.

FIG. 1 is a flow chart illustrating aspects of determining relative permeability from drainage-phase laboratory measurements, according to some embodiments. More particularly, the described method is for determining relative permeability from resistivity measured on water-wet core plugs during a drainage steady-state experiment. In block 110, conventional core analysis is used to determine porosity and absolute permeability. In block 112, steady-state experiments are conducted with resistivity measurements carried out at equilibrium. In block 114, a resistivity index (RI) curve is plotted to determine the saturation exponent (n).

In block 116, the equivalence between Equations 1 and 2 below are used to determine λ.

\[
K_{rw} = Sw^* \cdot \frac{1}{RI} \quad \text{(Equation 1)}
\]

\[
K_{rw} = (Sw^*)^\beta \quad \text{(Equation 2)}
\]

\[
Sw^* = \frac{Sw - Swi}{1 - Swi} \quad \text{(Equation 3)}
\]

In block 118, Krw (relative permeability to the wetting phase or to water) and Kro (relative permeability to oil) are calculated using Equations 4 and 5 below.

\[
K_{rw} = (Sw^*)^{2/\alpha + \beta} \quad \text{(Equation 4)}
\]

\[
K_{rw} = (1 - Sw^*)^{2/\alpha + \beta} \quad \text{(Equation 5)}
\]

In block 120, the Kr curves are un-normalized. The curve intervals will be Swi<Sw<1 for the X-axis, 0<Krw<1 and 0<Kro<Kro(Swi) for the Y-axis. At the end of the drainage steady-state experiment, Kro(Swi) is known.

The model using Equations 4 and 5 was validated in the lab on a water-wet rock. In general, for primary drainage, rocks are assumed to be water-wet because they are cleaned before starting the SCAL experiments at Sw=1 (water saturation).

FIGS. 2-1, 2-2 and 2-3 depict the experimental results in primary drainage, according to some embodiments. FIG. 2-1 depicts the steady-state Kr (relative permeability) with curve 210 showing Krw (water) and curve 212 showing Kro (oil). FIG. 2-2 depicts the RI (resistivity index) curve 220 as plotted according to block 114 in FIG. 1. FIG. 2-3 depicts the comparison between experimental steady state (SS) Kr (curves 230 and 232), Kro from Li’s model (curves 240 and 242), and Kr from the methods in primary drainage shown in FIG. 1 (curve 250), according to some embodiments. As can be seen by comparing curves 230, 240 and 250, a significant improvement over Li’s model is obtained using the model described, according to some embodiments.

FIG. 3 is a flow chart illustrating aspects of a method for determining relative permeability for imbibition following a drainage-phase from laboratory measurements, according to some embodiments. More particularly, the method shown in FIG. 3 is for the imbibition steady-state cycle, following a primary drainage, to determine relative perme-
ability from resistivity. In block 310, in continuity with the primary drainage, a steady-state experiment is run with resistivity measurements taken at equilibrium. In block 312, the RI (resistivity) curve is plotted to determine n (saturation exponent).

[0034] In block 314, the equivalence between Equation 6 and 7 below is used to determine λ.

\[ K_{rw} = \frac{Sw'}{RF} \]  

(Equation 6)

\[ K_{rw} = \frac{(Sw^*)^{2/(1+k)}}{RF} \]  

(Equation 7)

\[ RF = \frac{RI}{RI_{min}} \]  

(Equation 8)

\[ Sw' = \frac{Sw - Sw_i}{1 - Sw - Sor} \]  

(Equation 9)

[0035] In block 316, Krw (relative permeability to the wetting phase or to water) and Kro (relative permeability to oil) are calculated using the equations below, and Kr (relative permeability) is plotted on a normalized curve.

\[ Krw = \frac{(Sw^*)^{2/(1+k)}}{RI} \]  

(Equation 10)

\[ Krw = (1-Sw^*)^{[1/(1-Sw^*)^{2/(1+k)}]} \]  

(Equation 11)

[0036] The Kr curves are un-normalized. Curve intervals will be Swi=Sw<Sor (Sw is the irreducible water saturation, Sw is the water saturation and Sor is oil saturation resistivity) for the X-axis, 0<Kro<1 (Ko(Swi)) is used to normalize imbibition Kr and 0<Krw<Krw(Sor) (Krw is the relative permeability to the wetting phase or to water) for the Y-axis. At the end of the imbibition steady-state experiment, Kw(Sor) is known.

[0037] FIGS. 4-1, 4-2 and 4-3 depict the experimental results in imbibition, according to some embodiments. FIG. 4-1 depicts the steady state Krw (curve 410) and Kro (curve 412) for the imbibition. FIG. 4-2 depicts the RI curve 420, FIG. 4-3 depicts the comparison between experimental steady-state (SS) Krw (curve 430) and Kro (curve 432), and Kr from the model for imbibition mode described in FIG. 3, supra. As can be seen, an acceptable match is obtained for both wetting and non-wetting phase relative permeability values.

[0038] FIG. 5 is a flow chart illustrating aspects of a method for determining relative permeability on a log scale based on downhole resistivity measurements, according to some embodiments. For oil reservoirs, the imbibition model can be used since the reservoir is at Swi (irreducible water saturation). In block 510, porosity is determined from neutron-density or other logging techniques. Examples include NMR or dielectric logging tools. In block 512, Rt (resistivity) is determined from an electrical log during a brine invasion or a water injection process. In block 514, m and n (or other suitable Archie’s law parameters) are determined from core analysis or from other logging techniques. In block 516, Sw (water saturation) is determined from the second Archie’s law. In block 518, λ is determined using the equivalence between Equation 11 above and Equation 12 below:

\[ K_{rw} = \frac{Sw'}{RF} \]  

(Equation 12)

\[ RI = \frac{RI_{min}}{RI} \]  

(Equation 13)

\[ RF = \frac{RI}{RI_{min}} \]  

(Equation 14)

\[ Sw' = \frac{Sw - Sw_i}{1 - Sw - Sor} \]  

(Equation 15)

[0039] RI_{min} is the resistivity index at the end of the water flooding (end of imbibition or Sor) when the resistivity reaches its minimal and constant value.

[0040] In block 520, Krw and Kro are calculated using Equation 16 and 17 below, and Kr is plotted on a normalized curve.

\[ Krw = (Sw^*)^{[1/(1-Sw^*)^{2/(1+k)}]} \]  

(Equation 16)

\[ Krw = (1-Sw^*)^{[1/(1-Sw^*)^{2/(1+k)}]} \]  

(Equation 17)

Note that λ is not substituted by n in Krw since it is an imbibition cycle, and not a drainage cycle.


[0042] FIG. 6 is a diagram illustrating aspects of systems and methods for determining relative permeability from borehole resistivity measurements, according to some embodiments. An injection well 610 is used to inject water into a formation 600, which is for example a hydrocarbon bearing rock formation. On the surface of injection well 610, wellsite 612 includes pumping and monitoring equipment for both injecting water and other fluid which can be stored in tank 614. Also located at wellsites 612, according to some embodiments, is surface data monitoring unit 616 that is in communication with a permanently or semi-permanently installed resistivity measuring unit 624. The water injected is via well 610 at a packer-isolated injection zone 618.

[0043] The fluid produced from reservoir 600 is collected by one or more producer wells, for example well producer well 630. According to some embodiments, the resistivity in producer well 630 is monitored by either a permanent (or semi-permanent) resistivity measuring unit 626 or, according to some embodiments, a downhole resistivity tool 636 is deployed via wireline 634 and wireline track 632. According to some other embodiments, wireline tool 636 is used to retrieve stored data from permanent resistivity measurement unit 628. According to yet other embodiments, resistivity measurements are obtained using a permanent or semi-permanent measurement unit 626 that is positioned in an observer well 620. The data from unit 626 is transmitted to surface station 622. Using an observer well, according to some embodiments, is useful in some applications since it is less likely to be affected by “end effects” and so can provide an improved representation of the resistivity changes during the water injection event.

[0044] According to some embodiments, the resistivity data from units 624, 626, 628 and/or tool 636 are transmitted to a data processing unit 650. The processing unit includes a storage system 642, communications and input/output modules 640, a user display 646 and a user input system 648.
According to some embodiments, the processing unit 650 may be located in the logging truck 632, or at another wellsite location, such as at wellsite 612 or within surface station 622. Data processing unit 650 carries out the calculations that facilitate the determinations of relative permeability, such as described with respect to some or all of FIGS. 1, 3 and 5 described supra.

According to some embodiments, the resistivity measurements from units 624, 626, 628 and/or tool 636 are taken during a water (e.g., brine) invasion event rather than a water injection procedure.

FIG. 7 illustrates a wellsite in which the relative permeability can be determined from resistivity and other measurements taken while drilling with a water-based mud, according to some embodiments. The wellsite can be onshore or offshore. In this system, a borehole 711 is formed in subsurface formations by rotary drilling in a manner that is well known. Embodiments of the invention can also use directional drilling, as will be described hereinafter.

A drill string 712 is suspended within the borehole 711 and has a bottom hole assembly 700 that includes a drill bit 705 at its lower end. The surface system includes platform and derrick assembly 710 positioned over the borehole 711, the assembly 710 including a rotary table 716, Kelly 717, hook 718 and rotary swivel 719. The drill string 712 is rotated by the rotary table 716, energized by means not shown, which engages the Kelly 717 at the upper end of the drill string. The drill string 712 is suspended from a hook 718, attached to a traveling block (also not shown), through the Kelly 717 and a rotary swivel 719, which permits rotation of the drill string relative to the hook. As is well known, a top drive system could also be used.

In the example of this embodiment, the surface system further includes drilling fluid or mud 726, stored in a pit 727 formed at the well site. A pump 729 delivers the drilling fluid 726 to the interior of the drill string 712 via a port in the swivel 719, causing the drilling fluid to flow downwardly through the drill string 712, as indicated by the directional arrow 708. The drilling fluid exits the drill string 712 via ports in the drill bit 705, and then circulates upwardly through the annulus region between the outside of the drill string and the wall of the borehole, as indicated by the directional arrows 709. In this well-known manner, the drilling fluid lubricates the drill bit 705 and carries formation cuttings up to the surface as it is returned to the pit 727 for recirculation.

The bottom hole assembly 700 of the illustrated embodiment contains a logging-while-drilling (LWD) module 720, a measuring-while-drilling (MWD) module 730, a roto-stearable system and motor, and drill bit 705.

The LWD module 720 is housed in a special type of drill collar, as is known in the art, and can contain one or a plurality of known types of logging tools. It will also be understood that more than one LWD and/or MWD module can be employed, e.g., as represented at 720A. (References, throughout, to a module at the position of 720 can alternatively mean a module at the position of 720A as well.) The LWD module includes capabilities for measuring, processing, and storing information, as well as for communicating with the surface equipment. In the present embodiment, the LWD module includes a resistivity measuring device as well as a number of other devices, such as a neutron-density measuring device.

The MWD module 730 is also housed in a special type of drill collar, as is known in the art, and can contain one or more devices for measuring characteristics of the drill string and drill bit. The MWD tool further includes an apparatus (not shown) for generating electrical power to the downhole system. This may typically include a mud turbine generator powered by the flow of the drilling fluid, it being understood that other power and/or battery systems may be employed. In the present embodiment, the MWD module includes one or more of the following types of measuring devices: a weight-on-bit measuring device, a torque measuring device, a vibration measuring device, a shock measuring device, a stick slip measuring device, a direction measuring device, and an inclination measuring device.

According to some embodiments, the resistivity data 760 and other data such as neutron density data, is transmitted to data processing unit 650, which can be located at the wellsite or in some remote location. According to some embodiments, measurements made during the water invasion in the form of water-based mud from the drilling process is used to determine relative permeability as described herein (e.g., with respect to FIG. 5, supra).

In view of the above description it will be appreciated that features of the subject disclosure may be implemented in computer programs stored on a computer readable medium and run by processors, application specific integrated circuits and other hardware. Moreover, the computer programs and hardware may be distributed across devices including but not limited to tooling which is inserted into the borehole and equipment which is located at the surface, whether onsite or elsewhere.

Although only a few examples have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the examples without materially departing from this subject disclosure. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Thus, although a nail and a screw may not be structural equivalents in that a nail employs a cylindrical surface to secure wooden parts together, whereas a screw employs a helical surface, in the environment of fastening wooden parts, a nail and a screw may be equivalent structures. It is the express intention of the applicant not to invoke 35 U.S.C. §112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words 'means for' together with an associated function.

What is claimed is:

1. A method for determining relative permeability for a subterranean rock formation comprising:
   receiving downhole resistivity data representative of resistivity measurements made in a wellbore penetrating the subterranean rock formation during a water flooding event of the subterranean rock formation, and determining one or more relative permeability values for the subterranean rock formation based at least in part on the downhole resistivity data.

2. A method according to claim 1, wherein the one or more permeability values include relative permeability for wetting and non-wetting phases during an imbibition mode corresponding to the water flooding event.
3. A method according to claim 2, wherein the wetting phase is an aqueous fluid and the non-wetting phase is an oil fluid.

4. A method according to claim 3, wherein said resistivity measurements are made by a logging-while-drilling tool, the aqueous wetting phase is a water-based drilling mud and said water flooding event is introduction of said water-based drilling mud into the rock formation during a drilling process.

5. A method according to claim 1, wherein the water flooding event is caused by water being injected from an injection well.

6. A method according to claim 5, wherein said resistivity measurements are made from said injection well.

7. A method according to claim 1, wherein the water flooding event is caused by a brine invasion from a second rock formation.

8. A method according to claim 1, wherein said resistivity measurements are made from a production well configured to produce fluid from the rock formation.

9. A method according to claim 1, wherein said resistivity measurements are made from an observer well.

10. A method according to claim 1, wherein said determining one or more relative permeability values are further based on one or more values for porosity of the rock formation.

11. A method according to claim 10, wherein said one or more values for porosity are based at least in part on borehole measurements.

12. A method according to claim 11, wherein the borehole measurements upon which the one or more values for porosity are based are selected from a group consisting of: neutron density measurements, NMR measurements, dielectric measurements, and acoustic measurements.

13. A method according to claim 1, wherein said determining one or more relative permeability values are further based on one or more derived Archie’s law parameters.

14. A method according to claim 13, wherein said one or more derived Archie’s law parameters are selected from a group consisting of: saturation exponent and cementation factor.

15. A method according to claim 13, wherein said one or more derived Archie’s law parameters are based at least in part on a laboratory core analysis procedure.

16. A method according to claim 13, wherein said one or more derived Archie’s law parameters are based at least in part on borehole measurements.

17. A method according to claim 16, wherein said borehole measurements on which said one or more Archie’s law parameters is based at least in part are made using a borehole dielectric measurement tool.

18. A system for determining relative permeability for a subterranean rock formation comprising:
   - a downhole resistivity measurement tool configured to be deployed in a borehole penetrating the rock formation and take resistivity measurements during a water flooding event of the rock formation; and
   - a processing system configured to determine one or more relative permeability values for the subterranean rock formation based at least in part on downhole measurements made during the water flooding event made by said resistivity tool.

19. A system according to claim 18, wherein the one or more permeability values include relative permeability for a wetting aqueous fluid phase and a non-wetting oil fluid phase during an imbibition mode corresponding to the water flooding event.

20. A system according to claim 19, wherein said downhole resistivity tool is a logging-while-drilling tool, the aqueous wetting phase is a water-based drilling mud and said water flooding event is an introduction of said water-based drilling mud into the rock formation during a drilling process.

21. A system according to claim 19, wherein the water flooding event is due to a cause selected from a group consisting of: water being injected from an injection well, and a brine invasion from a second rock formation.

22. A system according to claim 21, wherein said downhole resistivity tool is permanently or semi permanently resistivity sensor mounted in a well type selected from a group consisting of: injection well, observer well and production well.

23. A system according to claim 18, wherein said one or more relative permeability values determined by said processing system are further based on one or more values for porosity of the rock formation.

24. A system according to claim 23, wherein said one or more values for porosity are based at least in part on borehole measurements selected from a group consisting of: neutron density measurements, NMR measurements, dielectric measurements, and acoustic measurements.

25. A system according to claim 18, wherein said one or more relative permeability values determined by said processing system are further based on one or more derived Archie’s law parameters.

26. A system according to claim 25, wherein said one or more derived Archie’s law parameters are based at least in part on a laboratory core analysis procedure.

27. A system according to claim 25, wherein said one or more derived Archie’s law parameters are based at least in part on borehole measurements.

* * * * *