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(54) Title: METHOD AND SYSTEMS FOR INTEGRATING DOWNHOLE FLUID DATA WITH SURFACE MUD-GAS DATA

(57) Abstract: A method for evaluating a formation fluid includes the steps of drilling a borehole intersecting a formation with a drill string, circulating a drilling fluid in the wellbore, selectively liberating a formation fluid from the formation, injecting the liberated fluid into the drilling fluid returning to the surface, drawing a sample of the returning drilling fluid at the surface, and estimating at least one parameter of the drawn sample at the surface.

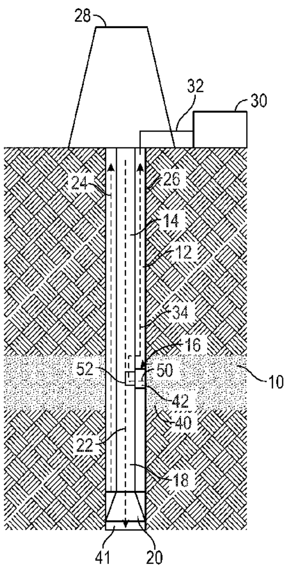

FIG. 1

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[Continued on next page]

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TITLE: **METHOD AND SYSTEMS FOR INTEGRATING DOWNHOLE FLUID DATA WITH SURFACE MUD-GAS DATA**

INVENTOR(S): **ERDMANN, Svenja; RITZMANN, Nicklas; and CARTELLIERI, Ansgar**

BACKGROUND

1. Field of Disclosure

[0001] In aspects, the present disclosure relates to characterizing underground formations and/or features. In further aspects, the present disclosure relates to methods and devices for estimating one or more parameters relating to fluids from a subterranean formation.

2. Description of the Related Art

[0002] Wells, tunnels, and other similar holes formed in the earth may be used to access geothermal sources, water, hydrocarbons, minerals, etc. and may also be used to provide conduits or passages for equipment such as pipelines. Such a hole is commonly referred to as a borehole or wellbore of a well and any point within the borehole is generally referred to as being downhole. Boreholes are commonly used in significant capital commercial developments, such as hydrocarbon fields. Therefore, before field development begins, operators desire to have as much information as possible in order to evaluate the reservoir for commercial viability. Such information may be acquired at the seismic exploration phase, during well construction, prior to well completion and / or any time thereafter. A vast amount of the information used for characterizing reservoirs is based directly or indirectly on measurements made in a borehole traversing a hydrocarbon reservoir of interest.

[0003] In aspects, the present disclosure is directed to devices, systems and method that may be utilized to obtain or improve information that may be used for characterizing a formation or a formation fluid.

SUMMARY

[0004] The present disclosure is directed to a method for evaluating a formation fluid. The method may include the steps of drilling a borehole with a drill string, the borehole intersecting a formation containing the formation fluid, the formation being at a depth uphole of a well bottom; circulating a drilling fluid in the borehole; selectively liberating a fluid from the formation, the liberated fluid including the formation fluid; injecting the liberated fluid into the drilling fluid returning to the surface; drawing a sample of the returning drilling fluid; and estimating at least one parameter of the drawn sample at the surface.

[0005] The above-recited examples of features of the disclosure have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION

[0006] For detailed understanding of the present disclosure, references should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

Fig. 1 illustrates a drilling system that may use methodology in accordance with the present disclosure;

Fig. 2 is a flow chart illustrating one embodiment of a method according to the present disclosure; and

Fig. 3 shows an illustrative plot of gas data generated at the surface according to one embodiment of a method according to the present disclosure.

DETAILED DESCRIPTION

[0007] The present disclosure relates to devices and methods for gas logging and fluid sampling. Disclosed are methods and related systems wherein gas is selectively liberated at one or more desired depth over a specific time, and measuring the liberated gas with a surface system. Thereafter, "cleanup" gas data may be compared to downhole cleanup sensor data and / or gas data, which was recorded when the rock at the corresponding depth was crushed for the first time. They are shown in the drawings, and herein will be described in detail, specific embodiments of the present disclosure with the understanding that the present disclosure is to be considered an exemplification of the principles described herein, and is not intended to limit the disclosure to that illustrated and described herein. Accordingly, the embodiments discussed below are merely illustrative of the applications of the present disclosure.

[0008] In aspects, the teachings of the present disclosure can increase the certainty of the presence of formation fluid types and compositions by implementing a novel gas logging and fluid sampling methodology. Illustrative methods according to the present disclosure involve selectively liberating, for a specified time period, a fluid from a formation, injecting the liberated fluid into a flowing drilling fluid, and monitoring the formation fluid that is pumped to a borehole annulus using surface gas analysis equipment to provide compositional information on the liberated formation fluid in real-time. Optionally, this information may be combined with information on fluid properties from in-situ (downhole) fluid analysis. The gas being analyzed may be a hydrocarbon and / or a non-hydrocarbon (e.*g.*, helium). This information can help inform the decision making early during a well development. Additionally, monitoring the fluid pumped to the annulus may also be used to conduct drilling operations more safely.

[0009] Referring initially to **Fig. 1**, there is schematically represented a cross-section of a subterranean formation **10** in which is drilled a borehole **12**.

The borehole **12** may be used to access geothermal sources, water, hydrocarbons, minerals, etc. and may also be used to provide conduits or passages for equipment such as pipelines. Conveyed along the borehole **12** by a drill string **14** is a formation evaluation tool **16**. At the end of the drill string **14** may be a bottomhole assembly **18**. The bottomhole assembly **18** may be configured to drill the borehole **12** by using a drill bit **20**. An annulus **26** surrounds the drill string **14.** Conventionally, a drilling fluid **22** pumped down the drill string **14** returns as a return fluid **24** via an annulus **26** that surrounds the drill string **14**. In some situations, a reverse circulation scheme may be used. In reverse circulation, the fluid is conveyed into the annulus **26** at the surface. This fluid flows downhole and enters the drill string **14** at the well bottom and returns to the surface via a bore (not shown) of the drill string **14**. Thus, the returning drilling fluid may flow along the annulus **26** or through the bore of the drill string **14**. A rig **28** at the surface may be used to rotate or otherwise handle the drill string **14**.

[0010] In one non-limiting embodiment, a surface logging system **30** may be used in conjunction with the formation evaluation tool **16** to obtain real-time or near real time information about the fluids in the formation **10**. The surface logging system **30** may include a fluid sampling line **32** that is in direct fluid communication with the annulus **26** and one or more instruments configured to analyze one or more components of the return fluid **24**. Illustrative instruments include mass spectrometers, gas chromatographs, and other sensors configured to provide chemical, compositional, and physical information regarding the components of the return fluid **24.** The surface logging system **30** may include an information processor (not shown), a data storage medium (not shown), display devices, and suitable circuitry for storing and implementing computer programs and instructions. The data storage medium may be any standard computer data storage device, such as a USB drive, memory stick, hard disk, removable RAM, or other commonly used memory storage system known to one of ordinary skill in the art including

Internet based storage. The data storage medium may store a program and data collected during the testing process.

[0011] The formation evaluation tool **16** may be configured to selectively liberate a fluid from the formation **10**. The liberated fluid **34** is released into the annulus **26** and flows upward to the surface as it comingles with the other return fluid **24**. If reverse circulation is used, then the liberated fluid **34** is released into the fluid flowing to the surface via a bore of the drill string. The formation evaluation tool **16** may include known devices as a sampling probe **50** and a fluid analysis module **52** that includes one or more pumps, packer(s), and fluid circuitry that can direct pumped fluid into sample tanks and / or the annulus **26**. Thus, the fluid flows into the tool **16** via the probe **50** and then exits the tool **16** via a suitable outlet (not shown). The formation evaluation tool **16** may also include sensors for estimating one or more parameters relating to the fluid before the fluid is injected into the annulus. For estimating properties of downhole fluids (naturally occurring or engineered), the formation evaluation tool **16** may include sensors for estimating aromatic content; asphaltene content; bacterial content; bubble point; chemical composition (this overlaps the parameters with the word "content"); color; density; specific gravity; hydrate (gas hydrate) content; naphthenic content; nitrogen content; odor; oxygen content; radioactivity; salt content; solids content; sulfur content; paraffinic content; pH (acidity/alkalinity); phase (defined as gas or liquid); pressure; temperature; viscosity. Illustrative devices include, but are not limited to, fluorescence spectrometers, mass spectrometers, dielectric sensors, optical analyzers, detectors using gas chromatography, ion selective sensors, resonators (*e.g.*, tuning forks), sound speed sensors, refractometers, nuclear magnetic resonance tools, etc.

[0012] One non-limiting method **80** using the teachings of the present disclosure is shown in **Fig. 2**. Generally, the method includes circulating a drilling fluid at step **82**, pumping a formation fluid into the annulus (or bore of a drill string) at step **84**, transporting the pumped formation to the surface using the circulating drilling fluid at step **88**, and analyzing the returning drilling fluid at the surface at step **90** and optionally taking a responsive action at step **94**.

[0013] Optionally, the **Fig. 2** method may also include the steps of analyzing the pumped formation fluid *in situ* (*i.e.*, at or close to the location of the pumping) at step **86** and comparing the results of the *in situ* and surface analyses at step **92**.

[0014] The **Fig. 2** method may be used with the **Fig. 1** system. In one implementation, the borehole **12** is drilled using the drill string **14** while the surface gas analysis system **30** generates a log of selected gas parameters by analyzing the returning drilling fluid **24**. It should be noted that the log will include gas-related information obtained as the drill bit **20** is crushing the rock and earth at the formation **10**. Based on formation evaluation data, gas analysis and / or any other information, a depth or multiple depths for further investigation can be established, a sample depth being labeled depth **40**.

[0015] Next, the borehole **12** is drilled using the drill string **14** until the formation evaluating tool **16** is at the depth **40**. The depth **40** is uphole of a wellbore bottom **41**. Drilling is stopped and the probe **50** of the formation evaluation tool **16** is then extended to a borehole wall **42**. Upon being energized, the formation evaluation tool **16** pumps fluid from the formation **10** into the annulus **26** while drilling fluid is circulating. In many situations, the drilling mud in the annulus **26** may be at-balanced or over-balanced (*i.e.*, at the same pressure or a greater pressure than the fluid in the formation **10**). In other situations, this drilling mud may be under-balanced. It should be noted that the fluid being liberated from the formation **10** at depth **40** is not the fluid being liberated at the wellbore bottom **41** (if such fluid is present). At the same time, one or more sensors (not shown) at the formation evaluation tool **16** may estimate one or more parameters of the pumped fluid before it is ejected into the annulus **26**.

[0016] During the drilling and throughout the fluid sampling activity, the surface gas analysis system **30** generates a continuous log of one or more gas properties. The circulating drilling fluid transports the liberated fluid **34** to the surface and a sample is drawn using the fluid sampling line **32**. The drawn fluid is a mix of the liberated fluid **34** and the return fluid **24**. Hydrocarbons and / or non-hydrocarbons from the formation **10** evaporate into gaseous phase at the surface under atmospheric conditions. Depending on the mud, its temperature and hydrocarbon combination, the amount of hydrocarbons in solution may vary and single components may have a different solubility. In one non-limiting arrangement, hydrocarbon extraction is accomplished by feeding the drilling fluid through a vessel with a mechanical agitator and using a vacuum pressure to suck the evaporated hydrocarbons from a headspace of a trap towards the gas logging system **30**. Other arrangements such as a membrane system may be used.

[0017] Next, the drawn fluid is analyzed by the gas logging system **30**. This analysis can be performed by evaluating the released hydrocarbons and non-hydrocarbons using any suitable sensor, such as those described above. Advantageously, the depth at which the liberated fluid **34** enters the annulus **26** is known. Thus, the "lag time," or the time required for the liberated fluid **34** to reach the fluid sampling line **32** can be estimated based on drilling fluid flow rates and other operating parameters. The formation evaluation tool **16** pumps the liberated fluid **34** into the annulus **26** preferably until the readings at the surface stabilize.

[0018] **Fig. 3** shows a graph of illustrative plots **122** and **124** of surface measurement of gas properties. Here, the "X" axis **126** is time (or volume) and the "Y" axis **128** is concentration and / or any compositional ratio. The measurements in **Fig. 3** may be considered as having five discrete phases. In the first phase **132,** drilling is stopped. In the second and third phases **134**, **136** the tool **16** pumps fluid from the formation. During phase **134**, there is a transition from mud, via mud filtrate to formation fluid (possibly with some impurities like mud filtrate). During phase **136**, there is a stable phase of the cleanup reflecting stable flow from the formation, *i.e.*, the cleanest the pumped fluid can get under the given conditions (formation properties, pump rate, etc.). The pumped fluid may be juvenile formation fluid, and / or a mix of formation fluid and filtrate. During a fourth phase **138**, there is a decoupling of the probe **50** from the formation, and the signals return to background reading. The fifth phase **140** is a "normal" background gas data log.

[0019] Generally, after correction for lag time, a correlation can be observed from the *in situ* measurements and the surface measurements at phases **132** and **134** of **Fig. 3** because the above-described method provides information based on surface and downhole analysis of the same liberated fluid. This information can be related to composition, concentration, properties, or other parameters of gas in the liberated fluid and associated gas ratios. The downhole / *in situ* fluid property information may be integrated with mud gas data; *e.g.*, to determine composition of the formation fluid, and / or calibrate mud gas data or vice versa. Also, the surface gas data can be used to calibrate downhole sensors, whereas downhole sensor data from a specific depth can be used to calibrate and verify results of continuous gas measurements on the surface. Calibration can also be performed on the methods during such analyses. Thus, the calibration may be performed on hardware, software, methodologies, and data / information. Still other responsive action may include selecting a formation from which to produce hydrocarbons, isolating one or more formations, bypassing one or more formation, etc.

[0020] In a next step this "cleanup" gas data can be compared to downhole cleanup sensor data and / or gas data, which was recorded when the rock at the corresponding depth was crushed for the first time. This comparison may contain information related to depth of invasion of the drilling mud filtrate, thus it could be an invasion monitor.

[0021] Another correlation may be made using the gas log data obtained while initially drilling the formation **10** and the information obtained by the formation evaluation tool **16**. For example, the gas logs created while the formation was initially being disintegrated by the drill bit **20** may not be overly affected by filtrate invasion into the formation **10**. The subsequent combined *in situ* and surface analysis described above may be compared with the initial gas logs to gain insight into filtrate invasion into the formation **10**.

[0022] From the above, it should be appreciated that what has been described includes a method for evaluating a formation fluid from a formation. The method may include drilling a borehole with a drill string, the borehole intersecting the formation having the formation fluid, the formation being at a depth uphole of a well bottom; circulating a drilling fluid in the borehole; selectively liberating a fluid from the formation using a fluid sampling tool, the liberated fluid including the formation fluid; injecting the liberated fluid using the fluid sampling tool into the drilling fluid returning to the surface; drawing a sample of the returning drilling fluid at the surface; and estimating at least one parameter of the drawn sample at the surface to generate surface fluid data.

[0023] From the above, it should also be appreciated that what has been described includes a system for evaluating a formation fluid. The system may include a drill string configured to drill a borehole intersecting a formation having the formation fluid; a fluid circulation system circulating a drilling fluid in the borehole; a fluid sampling tool conveyed by the drill string, the fluid sampling tool being configured to selectively liberate a fluid from the formation and inject the liberated fluid into a drilling fluid returning to the surface; and a surface logging system configured to estimating at least one parameter of a sample of the returning drilling fluid returning to the surface, the sample being drawn at the surface.

[0024] The foregoing description is directed to particular embodiments of the present disclosure for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above are possible without departing from the scope of the disclosure. Thus, it is intended that the following claims be interpreted to embrace all such modifications and changes.

THE CLAIMS

We claim:

1. A method for evaluating a formation fluid from a formation (10), comprising: drilling a borehole (12) with a drill string (14), the borehole (12) intersecting the formation (10) having the formation fluid, the formation (10) being at a depth uphole of a well bottom; and circulating (82) a drilling fluid in the borehole (12), the method characterized by:

selectively liberating a fluid from the formation (10) using a formation evaluation tool (16), the liberated fluid including the formation fluid;

injecting (84) the liberated fluid using the formation evaluation tool (16) into the drilling fluid returning to the surface;

drawing a sample of the returning drilling fluid at the surface; and

estimating (90) at least one parameter of the drawn sample at the surface to generate surface fluid data.

2. The method of claim 1, further characterized in that the liberated fluid flows into the formation evaluation tool (16) and wherein the liberated fluid is ejected out of the formation evaluation tool (16).

3. The method of claim 1, further characterized in that the estimating step includes a pumping phase and a decoupling phase.

4. The method of claim 1, further characterized by obtaining downhole fluid data (86) by estimating at least one parameter relating to the liberated fluid before the liberated fluid is injected into the returning drilling fluid.

5. The method of claim 4, further characterized by: comparing (92) the downhole fluid data with the surface fluid data.

6. The method of claim 5, further characterized by: revising, based on the comparison, at least one of: (i) the downhole gas data, and (ii) the surface gas data.

7. The method of claim 5, further characterized by: calibrating, based on the comparison, at least one of: (i) a downhole instrument, (ii) a surface instrument, (iii) data, and (iv) methodology used to obtain the data.

8. The method of claim 1, further characterized in that the at least one parameter relating to the drawn sample is at least one of: (i) a fluid property, (ii) a fluid composition; and (iii) a physical property.

9. The method of claim 1, further characterized in that drawing the sample of the returning drilling fluid at the surface and estimating at least one parameter of the drawn sample at the surface is performed continuously during drilling wherein rock is crushed at the well bottom with a drill bit and while the fluid is injected into the returning drilling fluid.

10. The method of claim 1, further characterized by: generating a gas log while drilling the formation (10) and comparing the generated gas log with downhole fluid data obtained by estimating at least one parameter relating to the liberated fluid before the liberated fluid is injected into the returning drilling fluid.

11. The method of claim 1, further characterized in that the liberated fluid is the formation fluid.

12. The method of claim 1, further characterized by evaluating fluid invasion using the estimated at least one parameter.

13. The method of claim 8, further characterized by deriving a flow characteristic of the formation (10).

14. A system for evaluating a formation fluid, characterized by:

- a drill string (14) configured to drill a borehole (12) intersecting a formation (10) having the formation fluid;
- a fluid circulation system circulating a drilling fluid in the borehole (12);
- a formation evaluation tool (16) conveyed by the drill string (14), the formation evaluation tool (16) being configured to selectively liberate a fluid from the formation (10) and inject the liberated fluid into a drilling fluid returning to the surface; and
- a surface logging system (30) configured to estimating at least one parameter of a sample of the returning drilling fluid returning to the surface, the sample being drawn at the surface.

15. The system of claim 14, further characterized in that the formation evaluation tool (16) includes a probe configured to contact the formation (10) and draw the fluid from the formation (10) and an outlet configured to eject the liberated fluid into the returning drilling fluid.

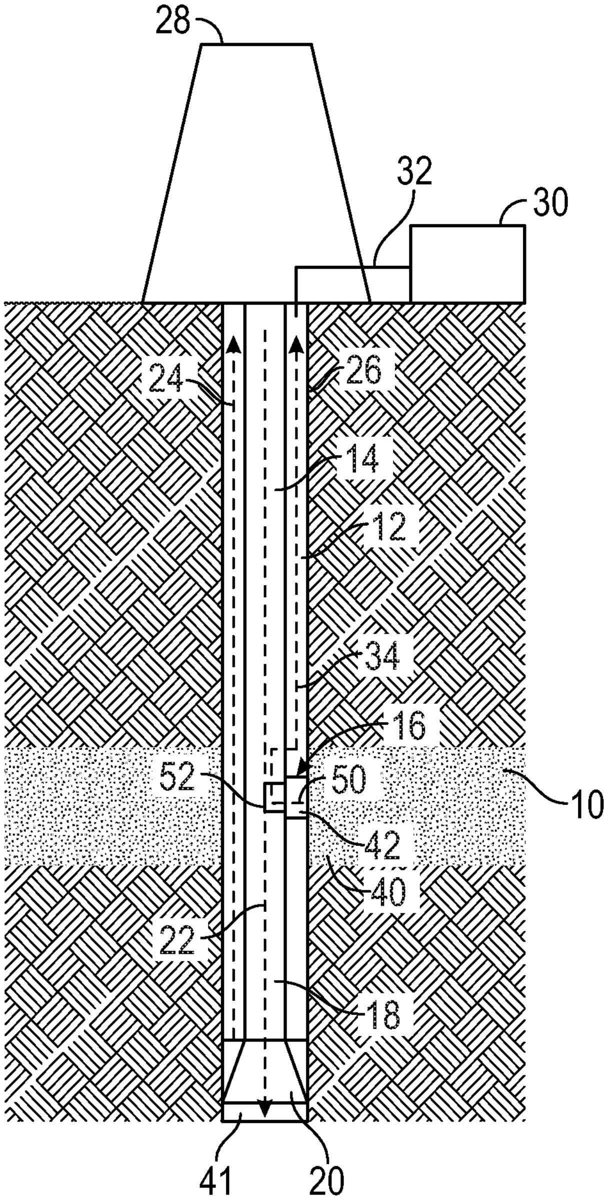

FIG. 1

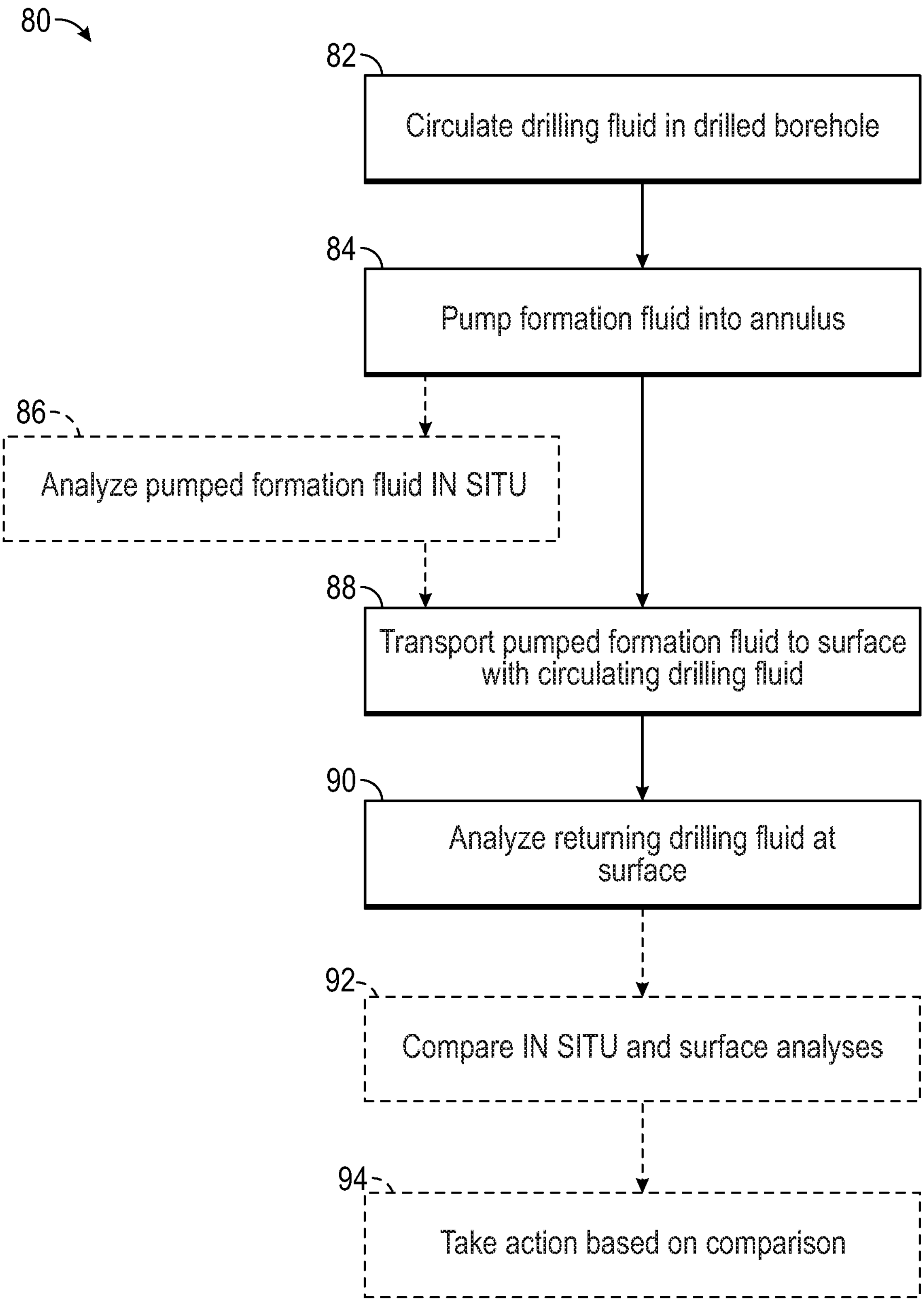
80
82
Circulate drilling fluid in drilled borehole
84
Pump formation fluid into annulus
86
Analyze pumped formation fluid IN SITU
88
Transport pumped formation fluid to surface with circulating drilling fluid
90
Analyze returning drilling fluid at surface
92
Compare IN SITU and surface analyses
94
Take action based on comparison

FIG. 2

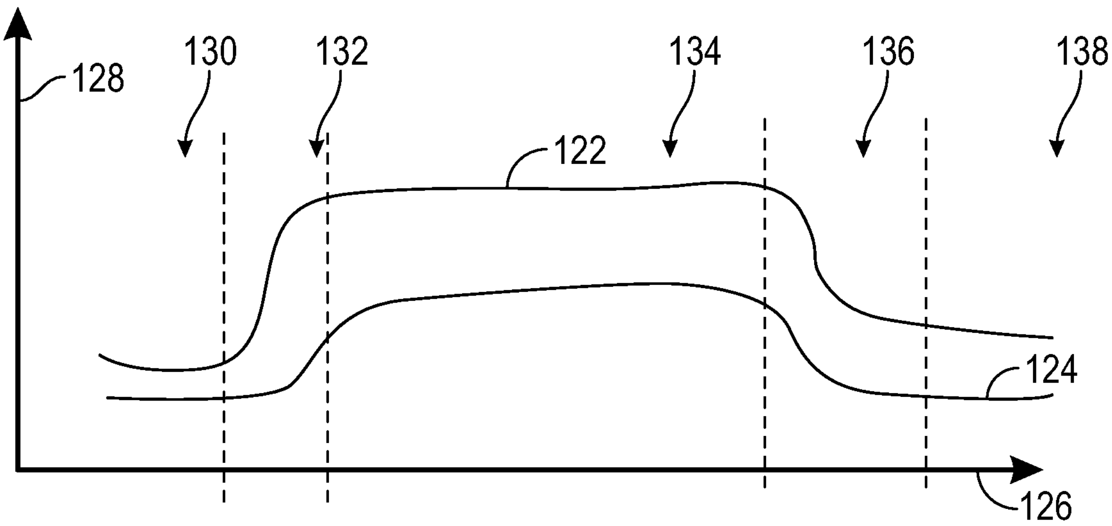

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/030021

A. CLASSIFICATION OF SUBJECT MATTER

E21B 49/08(2006.01)i, E21B 21/06(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B 49/08; E21B 47/00; E21B 49/00; E21B 25/00; G01N 1/00; E21B 21/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: drilling fluid, formation fluid, probe, surface, analyze, estimate, compare, log

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	US 2014-0238670 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 28 August 2014 See paragraphs [0033]-[0034]; claim 1; and figure 1B.	1-15
Y	US 5277263 A (AMEN, RANDALL M.) 11 January 1994 See column 5, lines 4-32; and figures 1-2.	10
A	WO 2009-009409 A1 (SCHLUMBERGER CANADA LIMITED et al.) 15 January 2009 See paragraphs [0035]-[0046], [0053]-[0066]; and figures 2-3, 10.	1-15
A	US 2005-0194134 A1 (MCGREGOR et al.) 08 September 2005 See paragraphs [0016]-[0044]; and figures 1-5.	1-15

☐ Further documents are listed in the continuation of Box C.　　☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 August 2017 (28.08.2017)	**05 September 2017 (05.09.2017)**

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