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(54) METHOD AND SYSTEM FOR DETERMINING CORE ORIENTATION

VERFAHREN UND SYSTEM ZUR BESTIMMUNG DER KERNAUSRICHTUNG

PROCÉDÉ ET SYSTÈME DE DÉTERMINATION D'ORIENTATION DE CAROTTE

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Description

TECHNICAL FIELD

- 5 **[0001]** A method and system are disclosed for determining core orientation of a core sample cut from the ground by a drill.

BACKGROUND ART

- 10 **[0002]** Core orientation is a well-developed art which is used to enable determination of the in situ orientation of a core sample. This is used by a geologist or other professionals to enable mapping of underground strata.
- [0003]** Electronic, mechanical and electro-mechanical core orientation systems are in current use. Some basic mechanical core orientation systems rely on a mechanical downhole event such as the core drill contacting a toe of the hole to physically mark one end of the core sample with a bottom of hole or top of hole marking.
- 15 **[0004]** Some electronic and electro-mechanical core orientation systems rely on a real time detection of an event which is believed to be indicative of a core breaking operation to trigger measurement and recording or transmission of core orientation data.
- [0005]** Other systems such as in the international publication WO 2016/154677 and publication number US2015/0300162 describe the use of a timer at the surface being triggered to measure an elapsed time which is
- 20 subtracted from a survey time of a downhole measuring device. The subtraction of times is used to locate a nearest (in time) record of orientation acquired by the downhole device.
- [0006]** The patent specification published as US 2015/0136488 (which is a predecessor of the systems in WO 2016/154677 and US2015/0300162) relies on recording orientation data when measurements of vibration being below a predetermined level and before a core sample has been separated from a surrounding body of rock. This system
- 25 makes successive orientation measurements and relies on two successive measurements to be close to each other which are then time-stamped. This system also teaches the use of an above ground communications device having a timer that can be used to mark a user input. The user input can commence a timing period of an internal clock. This may be later used to locate the closest recorded orientation data in a similar manner to that in WO 2016/154677.
- [0007]** The above references to the background art do not constitute an admission that the art forms a part of the common general knowledge of a person of ordinary skill in the art. The above references are also not intended to limit
- 30 the application of the method and system as disclosed herein.

SUMMARY OF THE DISCLOSURE

- 35 **[0008]** In a first aspect there is disclosed method of determining core orientation of a core sample cut from the ground by a drill rig having a drill string and a core drill bit coupled to a downhole end of the drill string, the method comprising:
- continuously acquiring drilling data, while the drill rig is operating to acquire the core sample wherein the drilling data is a combination of core orientation data and rig operational data, wherein the rig operational data is constituted
- 40 by either one or both of: (a) near bit rig data; and, (b) at surface rig data; and
- analysing the drilling data for a specific pattern of rig operational data indicative of the core sample being broken from ground by operation of the drill rig and on detection of the specific pattern determining orientation of the core sample prior to being broken from the ground using the acquired core orientation data.
- 45 **[0009]** In one embodiment acquiring the drilling data comprises acquiring the drilling data at least for a period which includes a continuous period from commencement of operation of the drill rig to cut the core sample to any event occurring after commencement of operating the drill rig to break the core sample from in situ strata.
- [0010]** In one embodiment the event is applying pull-up to the drill string to affect the breaking of the core sample from in situ strata.
- 50 **[0011]** In one embodiment the event is additionally or alternatively retrieval of the core sample through the drill string.
- [0012]** In one embodiment the event is additionally or alternatively extraction of the core sample from the drill string.
- [0013]** In one embodiment acquiring the drilling data includes acquiring, during the operation of the drill rig to break the core sample, rig operational data relating to relative rotational motion between the core sample and an inner core tube supported by the drill string and into which the core sample advances during drilling.
- 55 **[0014]** In one embodiment method comprises compensating the core orientation acquired upon the occurrence of the specific pattern to account for the relative rotational motion and using the compensated core orientation as the core orientation of the core sample cut by the drill rig.
- [0015]** In one embodiment the core orientation data includes dip and azimuth of a known reference datum on or

transferable to the core sample.

[0016] In one embodiment the rig operational data comprises any one, or any combination of any two or more, of: rotational speed of the drill, displacement of the drill in an up hole direction; displacement of the drill in a down hole direction; ambient fluid pressure; the existence of fluid flow in the drill string; rate of fluid flow into the bore hole; vibration in the drill string; mechanical shock; rate of penetration, hole depth; number of drill pipe joints passed when the DAT is transported down the drill string or retrieved from the drill string or both; latent torque in the drill string; weight on bit; torque on bit.

[0017] In one embodiment the specific pattern of drilling parameter data comprises data indicative of: (a) cessation of rotation of the drill string; and subsequently: (b) application of pull-up to the drill string.

[0018] In one embodiment the specific pattern of rig operational data comprises, subsequent to the occurrence of the application of pull-up, data indicative of (c) vibration arising from impact of an overshot with a head assembly of an inner core barrel assembly containing the core sample cut by the drill rig.

[0019] In one embodiment the method comprises storing the acquired downhole data on a memory device which is disposed near the drill bit while the drill rig is in operation cutting the core sample.

[0020] In one embodiment core orientation data and near bit rig data are electronically communicated to an at surface electronic device or system either (a) while the drill rig is in operation cutting the core sample; or (b) while the core sample is within the drill string; or (c) at the surface after retrieval of the core sample.

[0021] In one embodiment analysing the drilling data occurs: while the drill rig is in operation cutting the core sample; or, while the core sample is within the drill string; or after retrieval of the core sample.

[0022] In one embodiment the method comprises transporting a data acquisition tool (DAT) provided with one or more sensors, devices and systems capable of acquiring the core orientation data and the near bit rig data through the drill string toward the drill bit.

[0023] In one embodiment the method comprises continuously acquiring the core orientation data and rig operational data at a known sample rate.

[0024] In one embodiment the at surface rig data comprises weight on bit.

[0025] In one embodiment the method comprises determining the core orientation involves using one or more of the acquired core orientation data.

[0026] In one embodiment determining the core orientation involves obtaining an average of a plurality of the acquired core orientation data.

[0027] In one embodiment the method comprises determining the core orientation data involves using one or more of the core orientation data acquired within a user selectable time period.

[0028] In one embodiment the user selectable time period comprises a period of time: (a) before the core sample is broken away from the ground; (b) after the core sample has been broken away from the ground; or (c) before and after the core sample has been broken away from the ground.

[0029] In a second aspect there is disclosed a system for determining core orientation of a core sample cut from the ground by a drill rig having a drill string and a drill bit coupled to a downhole end of the drill string comprising:

a data acquisition tool (DAT) wherein the DAT is arranged to continuously acquire core orientation data at least while the drill rig is operating to acquire the core sample; and

one or both of a (a) near bit rig data acquisition system; and , (b) at the surface rig data acquisition system, both arranged to continuously acquire associated data while the drill rig is operating to acquire the core sample.

[0030] In one embodiment the near bit rig data acquisition system is provided in the DAT.

[0031] In one embodiment the system comprises a DAT tripping system capable of transporting the DAT through the drill string toward a toe of a hole drilled by the drill rig and subsequently retrieving the DAT from the drill string.

[0032] In one embodiment the system comprises a releasable locking system arranged to: lock the DAT to the drill string at a location near the drill bit when the tripping system transports the DAT to the location; and release the DAT to enable the tripping system to retrieve the DAT from the location.

[0033] In one embodiment the system comprises one or more core orientation sensors arranged to enable the DAT to acquire one or any two or more of: dip, azimuth, gravitational top or bottom of borehole, Magnetic Tool face or True North measurements of a known reference datum on or transferable to the core sample.

[0034] In one embodiment the DAT comprises one or more near bit rig parameter sensors arranged to enable the DAT to acquire one, or any combination of any two or more, of the following drilling parameter data: rotational speed of the drill, differential rotation between the drill string and the inner core barrel assembly, displacement of the drill in an up hole direction; displacement of the drill in a down hole direction; ambient fluid pressure; the existence of fluid flow through the drill string; rate of fluid flow into the bore hole; vibration; mechanical shock; rate of penetration, hole depth; number of drill pipe joints passed when the DAT is transported to the toe or retrieved from the drill, or both; torque when the drill is drilling; latent torque in the drill string.

[0035] In one embodiment the DAT comprises an on-board memory to enable on-board storage of the downhole data.

[0036] In one embodiment the DAT comprises a processor capable of processing the downhole data to produce processed downhole data.

5 [0037] In one embodiment the system comprises a telemetry system arranged to enable the DAT to communicate the downhole data in real time to an electronic device located at the surface.

[0038] In one embodiment the system comprises a telemetry system arranged to enable the DAT to communicate the processed drilling data to an electronic device located at the surface.

[0039] In one embodiment the system comprises an inner core barrel assembly wherein the DAT is coupled to or housed within the inner core barrel assembly.

10 [0040] In one embodiment the DAT comprises an event sensor arranged to automatically activate the DAT to continuously acquire the downhole data in response to a sensed event pertaining to the lowering or locking of the DAT.

BRIEF DESCRIPTION OF THE DRAWINGS

15 [0041] Notwithstanding any other forms which may fall within the scope of the method and system as set forth in the Summary, specific embodiments will now be described, by way of example only, with reference to the covering drawings in which:

20 Figure 1 is a schematic representation of a drill rig in relation to which embodiments of the disclosed method and system may be used;

Figure 2a is a side view of an inner core barrel assembly in relation to which embodiments of the disclosed method and system may be used;

25 Figure 2b is a longitudinal section view of the inner core barrel assembly of Figure 2a and showing possible locations of an embodiment of the disclosed system;

Figure 3 is a schematic representation of the drill rig shown in Figure 1 incorporating an embodiment of the disclosed method and system for determining core orientation of a core sample;

30 Figure 4 is a flow chart depicting steps in the disclosed method for determining core orientation of a core sample; and

Figure 5 is a schematic representation of drilling obtained by data use of embodiments of the disclosed method and system and how the acquired data may be used to determine core orientation.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENT

[0042] Referring to Figure 1 is a schematic representation of a drill rig 10 for acquiring core samples 12 of the ground 14. The drill rig 10 comprises a drill string typically made from a number of drill pipes 18 connected end to end. A drill bit 20 (known as a diamond drill bit or core drill bit) is coupled to the end of the drill string 16 to cut the core samples 12. The drill bit 20 is coupled at a downhole end of an outer core barrel assembly 22. The outer core barrel assembly 22 is supported at the downhole end of the drill string 16.

40 [0043] An inner core barrel assembly 24 is releasably latched inside of the outer core barrel assembly 22 and is used to retain and carry a core sample 12 to the ground surface 26. The inner core barrel assembly 24 is tripped through the drill string 16 by a wire line and associated overshot (not shown). The overshot is configured to engage a spear point 28 at an up hole end of the inner core barrel assembly 24.

45 [0044] Figures 2a and 2b generally depict one possible structure of an inner core barrel assembly 24 that may be used in association with the disclosed method and system of acquiring core orientation of a core sample 12. The inner core barrel assembly 24 comprises a head assembly 30 and an inner core tube 32. The spear point 28 is attached to an up hole end of the head assembly 30. The core tube 32 is attached to a downhole end of the head assembly 30. The core tube 32 includes a core lifter assembly 34 which is used to grip the core sample 12 during a core breaking operation and retain the core sample within the inner core barrel assembly 24 when being retrieved from the drill string 16.

50 [0045] The inner core barrel assembly 24 is provided with an upper payload space 36 in the head assembly 30, and a downhole payload space 38 which is in the form of a tube above the inner core tube 32. The downhole payload space 38 is provided below a landing shoulder (not shown) within the drill string 16 on which the inner core barrel assembly 24 lands when travelling through the drill string 16 toward a toe 40 of a borehole 42 drilled by the drill rig 10. As explained below in an embodiment of the disclosed system 50 and method 60 for determining core orientation of a core sample 12 a data acquisition tool (DAT) for determining core orientation may be held within either one of the payload spaces

36 or 38.

[0046] The above description is provided as context only for the describing embodiments of disclosed method and system of determining core orientation. The specific structure of the inner core barrel assembly 24 is not essential to embodiments of the disclosed method and system 50 of acquiring core orientation.

[0047] Figure 3 is a diagrammatic representation of multiple embodiments of the disclosed system 50 for determining core orientation of a core sample 12 in which the same reference numerals as used in Figure 1 are intended to denote the same features.

[0048] The DAT includes at the very least a device or system 52 which continuously acquires core orientation data (hereinafter referred to as the "Core Orientation Data System 52" or more simply "CODS 52"). Conveniently, the CODS 52 is retained in one of the payload spaces 36, 38 of the inner core barrel assembly 24. The CODS 52 acquires core orientation data Cn. The nature of this data is discussed later in this specification.

[0049] The system 50 in addition to the CODS 52C acquires rig operation data. The rig operational data includes either one or both of: (a) a near bit rig data acquisition system 54N and (b) an at surface rig data acquisition system 56S. The near bit rig data acquisition system 54N acquires data Nn relating to the operation of the drill rig 10 measured at or near the drill bit 20. The at surface rig data acquisition system 56S acquires data Sn relating to the operation of the drill rig 10 at the surface.

[0050] The near bit rig data acquisition system 54N may be incorporated in the DAT so that the DAT comprises the combination of both the CODS 50C and the near bit rig data acquisition system 54N. Alternately the near bit rig data acquisition system 54N can be a physically separate device or system to the CODS 50C but nonetheless housed in one of the payload spaces 36 and 38. In this event the near bit rig data acquisition system 54N can be located in the same or different payload space as the CODS 52C.

[0051] The at surface rig data acquisition system 56S may be incorporated as part of the drill rig 10, or alternately formed as a separate device or system that is connected with the drill rig 10 either by physical connection or via a telemetry system.

[0052] The system 50 optional includes at surface data analysis device 58A. The purpose of the at surface data analysis device 58A is to receive data from the CODS 52C, and one or both of the bit rig data acquisition system 54N and the at surface rig data acquisition system 56S and analyse the data for a specific pattern of rig operational data indicative of the core sample being broken from ground by operation of the drill rig 10 and on detection of the specific pattern, determine the orientation of the core sample prior to being broken from the ground using the acquired core orientation data. The at surface data analysis system 58A is optional because in some embodiments the functionality of the system 58A can be incorporated into the DAT and/or the 52C.

[0053] The table below summarises different embodiments of the system 50 arising from different possible combinations of the system components.

System Configurations

System 50 Embodiments	Core Ori data system 52C acquiring data Cn	Near bit rig data system 54N acquiring data Nn	At surface rig data system 56S acquiring data Sn	At surface analysis device/system (58A)	Downhole Analysis device/system (52C/ 54N)
50i	✓	✓			✓
50ii	✓	✓		/	
50iii	✓		✓		✓
50iv	/		✓	✓	
50v	✓	✓	✓		/
50vi	✓	✓	✓	✓	

[0054] In embodiment 50i the system 50 comprises the CODS 52C and the near bit rig data acquisition system 54N with an analysis of the data for a specific pattern of rig operational data indicative of the core sample being broken from ground being also performed down the hole. In most instances, and most conveniently the CODS 52C and the near bit rig data acquisition system 54N are integrated into a single downhole DAT which includes a processor for analysing the data for the specific pattern of data indicative of the core sample being broken from the ground. However if the systems 52C and 54N are separate from each other either one may incorporate the processor to enable the data analysis. In this instance the systems 52C, 54N without the processor is arranged to communicate data to the system with the processor so that the analysis can be conducted in relation to all the data acquired by the systems 52C and 54 N.

[0055] In the embodiment 50ii, the system 50 comprises the CODS 52C and the near bit rig data acquisition system 54N with an analysis of the data for a specific pattern of rig operational data indicative of the core sample being broken from ground being performed at the surface by a separate analysis device/system 58A. In this instance the systems 52C and 54N communicate their data Cn and Nn to the system 58A.

[0056] In the embodiment 50iii the system 50 comprises the system 52C which acquires core orientation data down the hole and the system 56S which acquires drill rig 10 data at the surface. In this embodiment analysis of the data is conducted down the hole by the system 52C. This requires communication of the at surface rig data Sn to the CODS 52C.

[0057] In the embodiment 50iv the system 50 again comprises system 52C which acquires core orientation data down the hole and the system 56S which acquires drill rig 10 data at the surface, but in addition the at surface data analysis device/system 58A. In this embodiment the systems 52C and 56S communicate their data Cn and Sn respectively to the system 58A.

[0058] In the embodiment 50v the system 50 comprises all three data acquisition systems 52C, 54N and 56S with analysis of the corresponding data Cn, Nn and Sn being conducted down the hole in the same manner as discussed above in relation to embodiment 50i.

[0059] In the embodiment 50vi the system 50 comprises all three data acquisition systems 52C, 54N and 56S but with analysis of the corresponding data Cn, Nn and Sn been performed by an at surface data analysis device/system 58A. In this embodiment the systems 52C, 54N and 56S communicate their data Cn, Nn and Sn respectively to the system 58A.

Core Orientation Data System (CODS) 52C and core orientation data Cn

[0060] The CODS 52C acquires core orientation data C1, C2,(referred to herein in general as core orientation data Cn).

[0061] Throughout this specification and claims the expression "core orientation" is intended to denote the three-dimensional orientation of a core of strata being cut by a core drill while the core in situ prior to being broken away from parent strata. Similarly throughout this specification and claims expression "core orientation data" is intended to be a reference to data or data sets which quantify the core orientation.

[0062] The core orientation data Cn may include but is not limited to:

- dip (i.e. angle of dip) of the inner core tube 32 and/or a core sample 12 retained within the core tube 32;
- azimuth of a known reference datum on or transferable to the core sample 12;
- gravitational top or bottom of borehole;
- magnetic tool face of a known reference datum on or transferable to the core sample;
- True North measurements of a known reference datum on or transferable to the core sample.

Near Bit Rig Data System 52N and Near Bit Rig Data Nn

[0063] The Near Bit Rig Data System 52N acquires Near Bit Rig Data N1, N2,(referred to herein in general as near bit rig data Nn). The data Nn may include but is not limited to any one or any combination of two or more of the follow data which are acquired at a physical location near to the bit 20:

- N1 rotational speed of the drill 10 and/or the drill string 16;
- N2 displacement of the drill string 16 along its axis, i.e. in either an up hole direction or a down hole direction;
- N3 pull-up applied to the drill string 16 to break the core sample from the parent rock 16;
- N4 ambient fluid pressure within the drill string;
- N5 rate of fluid flow exiting drill string near the bit;
- N6 rate of penetration of the drill 10/drill string 16 into the ground;
- N7 weight on the drill bit;
- N8 vibration of the drill string 16;
- N9 latent axial tension in the drill string
- N10 mechanical shock;
- N11 the existence of fluid flow in the borehole 42;
- N12 relative rotation between a core sample 12 and inner core tube 32 during a core breaking operation;
- N13 relative rotation between the inner core tube and the drill string;
- N14 latent rotational torque in the drill string 16;

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- N15 impact of an overshoot with the spear point 28;
N16 landing of an inner core barrel assembly on a landing ring or landing shoulder of the drill string 16;
N17 unlatching of the inner core barrel assembly from the drill string 16;
N18 number of drill pipe joints passed when the DAT is transported down the drill string or retrieved from the drill
5 string or both; and
N19 torque on bit.

At Surface Rig Data System 56S and At Surface Rig Data Sn

10 **[0064]** The at surface rig data system 56S acquires data S1, S2, (referred to herein in general as at surface data Sn) relating to the operation of the drill rig 10 measured at the surface. As previously mentioned the system 56S can be built into or otherwise incorporated into the drill rig 10 to measure various operational of the drill 10 when operated to obtain a core sample 12.

15 **[0065]** The at surface rig data Sn acquired by the system 56C includes but is not limited to, any one or any combination of two or more of:

- S1 rotational speed of the drill rig 10 and/or the drill string 16;
S2 displacement of the drill string 16 in an up hole direction;
20 S3 pull-up applied to the drill string 16;
S4 ambient fluid pressure within the drill string;
25 S5 rate of fluid flow into the drill string;
S6 rate of penetration of the drill rig 10/drill string 16 into the ground
S7 weight on the drill bit 20;
30 S8 make and break of a head rod from the drill string;
S9 tension in the drill string;
35 S10 tension in the wireline;
S11 activation of a winch on the drill rig used for tripping an overshoot and/or the DAT
S12 drill rig pump pressure; and
40 S13 latent tension in the drill string.

45 **[0066]** It may be recognised with reference to the examples of at surface rig data S1 - S6 mentioned above may be also be acquired as near bit rig data Nn. There is an expectation that data for the same characteristic that can be acquired from both at the surface and near the bit may not be the same. This may be due to non-identical sensors at different location which could be hundreds or thousands of meters apart, the effect of substantially different environmental conditions, and the effect of mechanical forces on the drill string itself as length increases (i.e. stretching in overall length, so that the length is greater than the product of number of drill rods and nominal drill rod length). However it is believed that at surface rig data S7 and S8 above can be acquired at the surface only.

50 **[0067]** In relation to data S7 above, the weight on bit data is data that one would expect to vary in a relatively standard or known manner during a core breaking operation. In particular one would expect weight on bit to vary from a maximum during drilling to 0 Tonnes at core break. Indeed during core breaking the bit may be subjected to negative acceleration with reference to gravity as tension in the drill string is released and thus in effect have a negative weight. Thus incorporating weight on bit data when determining the specific pattern indicative of a core breaking operation may assist in
55 improving accuracy in correlating the orientation data to the core break.

[0068] In the event that at surface data Sn is measured in addition to the near bit data Nn in relation to the same feature or characteristic and a discrepancy greater than a predetermined acceptable error range, for example $\pm 5\%$, is detected an operator may make an informed decision as to whether to disregard a corresponding core orientation.

[0069] Figure 4 depicts in a schematic general and broad sense an embodiment of the method 60 for acquiring core orientation. The method includes a step 62 of continuously and simultaneously acquiring drilling data 64 while the drill rig 10 is being operated to acquire a core sample 12. The drilling data is a combination of the core orientation data Cn and the rig operational data. As previously mentioned the rig operational data comprises either one or both of (a) near bit rig data Nn; and, (b) at surface rig data Sn.

[0070] The step 62 of acquiring the drilling data 64 includes a step 62C of acquiring the core orientation data Cn and a step 62R of acquiring the rig operational data Rn. The step 62R is constituted by one or both of (a) step 62N of acquiring the near bit rig data Nn and (b) step 62S of acquiring the at surface rig data.

[0071] The step 62R of acquiring the rig operational data also includes a step 66 of combining or selecting one or both of the data Nn and Sn. At step 66 of the method 60 an operator is provided with the option of incorporating either one or both of data Nn and Sn in the drilling data 64. This option will be exercised on the base of the availability of the data Nn and Sn. In addition if both data are available but it is considered that one of the sets of data may be inaccurate the operator may at step 66 discard that data. However this option is also be available at the analysis step 68 at which the system 50 and method 60 use the acquired drilling data 64 make a determination of core orientation.

[0072] If the drill rig 10 is not equipped to provide the at surface rig data Sn then the method 60 produces the drilling data 64 comprising only the combination of data Cn and Nn. Barring a malfunction it is expected that the near bit rig data Nn will always be available as the corresponding near bit rig data acquisition system 54N would be provided down the hole with the CDS 52C in an inner core barrel assembly 24 such as, but not limited to, that described above and represented in Fig.2.

[0073] The drilling data 64 (i.e. the core orientation data Cn; and rig operational data Rn constituted by the near bit rig data Nn and/or the at surface rig data Sn, whichever combination is used), is continuously acquired by the system 50 and the method 60. This is to be contrasted with prior art systems which look or otherwise sense for trigger signals to log a core orientation measurement; or use time stamping to attempt to correlate a core orientation with the occurrence of a core breaking operation.

[0074] The analysis step 68, involves looking for a specific pattern in the rig operational data to signify a core breaking operation and using the core orientation data Cn acquired at the occurrence of the specific pattern as the core orientation of the core sample 12.

[0075] Figure 5 is a schematic representation of the drilling data 64 that may be acquired during operation of the drill rig 10 for the purposes of acquiring a core sample 12.

[0076] In one example looking for the specific pattern may comprise applying respective sliding window filters 70 and/or thresholds to the downhole data 64 to detect:

- (a) the substantially simultaneous occurrence of various near bit rig data Nn at respective predetermined threshold levels; or
- (b) the sequential occurrence of various near bit rig data Nn at respective predetermined threshold levels; or
- (c) a predetermine change or variation in one or more near bit rig data Nn; or
- (d) the substantially simultaneous occurrence of various at surface rig data Sn at respective predetermined threshold levels; or
- (e) the sequential occurrence of various at surface rig data Sn at respective predetermined threshold levels; or
- (f) a predetermine change or variation in one or more at surface rig data Sn; or
- (g) any combination of two or more of (a) to (f).

[0077] For example the specific pattern may comprise:

- i. rotational speed of the drill 10 and/or drill string 16 being 0 RPM, (i.e. one or preferably both of S1 and N1 being 0 RPM);
- ii. vibration of the drill string 16 being substantially zero or no more than natural ground vibration, (i.e. N8 being zero or more likely below a minimum threshold level to account of normal seismic/geological activity and transmission/reflection of on ground induced vibrations from operation of machines);
- iii. a reduction in drill rig pump pressure measured downhole or at the drill rig pump, (S12 dropping below a threshold level); and
- iv. impact of an overshot on the spear point 28 (N15 being above a threshold level).

[0078] In the above example

- A first window W1 is applied to the data Rn to look for or detect silence (-very low measurements or small variations in measurement values such as low S1 and N1 both zero; N8 below a minimum threshold; S12 below its threshold level) followed by a jerk (acceleration in terms of the pull-up applied to the drill string- indicated for example by a

spike in or at least a positive displacement of, S2 and N2), and accompanied by a mechanical shock N10 as the core sample is broken from parent rock.

- A second window W2 is applied to the data Rn to look for or detect the overshoot landing event followed by an axial uphole movement of the overshoot (i.e. a spike in N15 then reading of S11 indicative of the winch being reeling in).
- During a core run Window 1 events may include amongst others a core break or core blockages. Only when Window 2 occurs after a W1 event do we know that the core orientation data Cn that coincided with the most recent Window 1 events recorded the true core orientation.
- Window 1 can be less than 2 minutes and up to 5 minutes or longer.
- Window 2 can be 1 second or longer.

[0079] Upon the above specific pattern of rig operational data Rn occurring the method 60 at step 68 determines orientation of the core sample 12 as it was at or prior to it being broken from the ground by using the acquired core orientation data Cn. The core orientation data Cn used for determining the core orientation will generally be data Cn acquired in the time vicinity of the core breaking operation. The core orientation data Cn used for determining the core orientation data may involve using one or more of the core orientation data acquired within a user selectable time period. The user selectable time period can for example comprises a period of time:

(a) before the core sample is broken away from the ground; (b) after the core sample has been broken away from the ground; or (c) before and after the core sample has been broken away from the ground. In some instances the determined core orientation may be an average of multiple acquired core orientation data Cn.

[0080] The acquisition of the downhole data may occur continuously from when the DAT of the system 50 is first lowered into the drill string 16 to when the DAT is retrieved from the drill string 16. In any event the data acquisition occurs continuously during the operation of the drill 10 to cut the core sample 12 from the ground 14.

[0081] In one embodiment the acquisition of the drilling data can be initiated manually by manipulating a button or communicating a command to the DAT of the system 50 prior to transporting the system 50 through the drill string 16 toward the toe 40 of the borehole 42.

[0082] However in another embodiment the acquisition of the drilling data may commence upon the sensing of an event or combination of events such as landing of the inner core barrel assembly 24 on a landing ring or shoulder within the drill string 16 or landing the core barrel assembly 24 on a landing ring or shoulder within the drill string and the retracted latches or locking balls of the head assembly latching or locking into their normal drilling position within the drill string after the assembly has landed. These events are indicative solely of the DAT being turned ON to continuously acquire data and are not at all indicative of a core breaking operation. Prior to the DAT being turned ON for data acquisition it may be in a sleep or standby mode to preserve battery life. This is to be differentiated from the prior art use of a trigger signal or time stamping to acquire core orientation. The difference being that in the present system 50 and method 60 all of the downhole data 64 is acquired continuously once data sensing has commenced, rather than waiting for some indication of an imminent core break or the passing of a period of time to commence core orientation data collection.

[0083] A further difference is that in many of the prior art systems for example as described in the Background Art above, a timer is used to identify the a core orientation recorded close to the time of breaking the core from the in-situ parent rock. In contradistinction in embodiments of the present method and system it is a pattern of events, independent of any time recorded, which is used to indicate the occurrence of a core break and correlate that to the core orientation or orientations recorded during the existence of that pattern of events. With particular reference to Figure 5 when a particular pattern or combination of data Sn and Nn occur then the core orientation data Cn corresponding to the occurrence of that specific pattern is use as the orientation of the corresponding core sample. As previously mentioned this may be an average of two or more core orientation is recorded during the period in which that pattern exists, or the core orientation according made closest to the existence of that specific pattern. A pattern may, though need not necessarily be structured into one or more sliding windows W1, W2Wn applied across the recorded data Cn, Rn as described in the text above.

[0084] When the rig operational data includes the at surface rig data Sn this data is also acquired continuously. The acquisition of this data and can be initiated by the DAT by way of electronic communication with the system 56S.

[0085] During a core breaking operation the drill string 16 is lifted from the toe 40. This causes the core lifter assembly 34 to grip the core sample 12 thereby transferring the tensile load from the drill string 16 to the core sample 12. This has the effect of breaking the core sample 12 from the in situ ground 14 of the toe 40. It is known from time to time that during this process latent rotational torque in the drill string 16 is released which may result in a relative rotation between

the core sample 12 and the inner core tube 32. Embodiments of the present system 50 and method 60 are arranged to enable measurement of any such relative rotational motion between the core sample 12 and the inner core tube 32. Upon detection of a nonzero relative rotational motion measurement, embodiments of the system 50 and method 60 are arranged to modify the core orientation data to compensate for the relative rotational motion.

[0086] The continuous data acquisition may be continuous in an analogue sense, or may be continuous in a digital sense in that data is acquired at a particular known sample rate. In non-limiting examples the sample rate may be (a) at least once per second, or (b) at least once per minute. However the sample rate could be different to this and in any case is selected to enable capture the drilling parameter data and core orientation data with sufficient resolution to enable the correct operation of the system.

[0087] The DAT (i.e. one or both of the CODS 52C and the near bit rig data acquisition system 54N) is provided with an on-board memory device for storing the acquired drilling data. The data is retrieved upon retrieval of the DAT from the drill string 16. At that time the data may be electronically transferred to the at surface analysis device 58A for analysis to locate the specific pattern and provide the corresponding core orientation data. The electronic transfer can be by wireless connection such as but not limited to infrared, Bluetooth™ or Wi-Fi communication, or by plug-in communication using electrical cable or optical cable or direct plug and socket connection between the DAT and another device. In this way the processing and analysis of the data can be performed on the at surface analysis device 58A (e.g. a smart phone, laptop or a PC). Data transfer between the DAT, and the at surface analysis device or system 58A can be performed while the DAT is downhole or after the DAT has been retrieved. Data transfer from the at surface rig data acquisition system 56S can be continuously communicated to the analysis system 58A directly or alternately communicated to the DAT which then relays this data with the data Cn and Nn to the analysis system 58A.

[0088] The system DAT may be arranged to provide a visual and/or audible signal when rotating a retrieved inner core barrel assembly 32 indicative of either the top of hole or bottom of hole relative to the known reference datum.

[0089] Whilst a number of specific method and system embodiments have been described, it should be appreciated that the method and system may be embodied in many other forms; instead, the scope of protection is defined by the appended claims.

[0090] In the claims which follow, and in the preceding description, except where the context requires otherwise due to express language or necessary implication, the word "comprise" and variations such as "comprises" or "comprising" are used in an inclusive sense, i.e. to specify the presence of the stated features but not to preclude the presence or addition of further features in various embodiments of the method and system as disclosed herein.

Claims

1. A method of determining core orientation of a core sample cut from the ground by a drill rig having a drill string and a drill bit coupled to a downhole end of the drill string, the method comprising:

continuously acquiring drilling data, while the drill rig is operating to acquire the core sample wherein the drilling data is a combination of core orientation data and rig operational data, wherein the rig operational data is constituted by either one or both of: (a) near bit rig data; and, (b) at surface rig data; and
analyzing the drilling data for a specific pattern of rig operational data indicative of the core sample being broken from ground by operation of the drill rig and on detection of the specific pattern determining orientation of the core sample prior to being broken from the ground using the acquired core orientation data.

2. The method according to claim 1 wherein acquiring the drilling data comprises acquiring the drilling data at least for a period which includes a continuous period from commencement of operation of the drill rig to cut the core sample to any event occurring after commencement of operating the drill rig to break the core sample from in situ strata.

3. The method according to claim 2 wherein the event is applying pull-up to the drill string to affect the breaking of the core sample from in situ strata.

4. The method according to claim 2 wherein the event is retrieval of the core sample through the drill string.

5. The method according to any of claims 2-4 comprising compensating the core orientation acquired upon the occurrence of the specific pattern to account for the relative rotational motion and using the compensated core orientation as the core orientation of the core sample cut by the drill rig.

6. The method according to any one of claims 1-5 wherein the core orientation data includes dip and azimuth of a

known reference datum on or transferable to the core sample.

7. The method according to any one of claims 1-6 wherein the rig operational data comprises any one, or any combination of any two or more, of: rotational speed of the drill, displacement of the drill in an up hole direction; displacement of the drill in a down hole direction; ambient fluid pressure; the existence of fluid flow in the drill string; rate of fluid flow into the bore hole; vibration in the drill string; mechanical shock; rate of penetration, hole depth; number of drill pipe joints passed when the DAT is transported down the drill string or retrieved from the drill string or both; latent torque in the drill string; weight on bit; torque on bit.
8. The method according to any one of claims 1-7 wherein the specific pattern of drilling parameter data comprises data indicative of: (a) cessation of rotation of the drill string; and subsequently: (b) application of pull-up to the drill string.
9. The method according to any one of claims 1-8 wherein determining the core orientation data involves using one or more of the core orientation data acquired within a user selectable time period.
10. A system for determining core orientation of a core sample cut from the ground by a drill having a drill string and a drill bit coupled to a downhole end of the drill string comprising:
 - a data acquisition tool (DAT) wherein the DAT is arranged to continuously acquire core orientation data at least while the drill rig is operating to acquire the core sample;
 - and one or both of a (a) near bit rig data acquisition system; and , (b) at the surface rig data acquisition system, both arranged to continuously acquire associated data while the drill rig is operating to acquire the core sample.
11. The system for acquiring drilling data according to claim 10 wherein the DAT comprises one or more core orientation sensors arranged to enable the DAT to acquire one or any two or more of: dip, azimuth, gravitational top or bottom of borehole, Magnetic Tool face or True North measurements of a known reference datum on or transferable to the core sample.
12. The system for acquiring drilling data according to any one of claims 10-11 wherein the DAT comprises one or more near bit rig parameter sensors arranged to enable the DAT to acquire one, or any combination of any two or more, of the following drilling parameter data:
 - rotational speed of the drill, differential rotation between the drill string and the inner core barrel assembly, displacement of the drill in an up hole direction; displacement of the drill in a down hole direction; ambient fluid pressure; the existence of fluid flow through the drill string; rate of fluid flow into the bore hole; vibration; mechanical shock; rate of penetration, hole depth; number of drill pipe joints passed when the DAT is transported to the toe or retrieved from the drill, or both; torque when the drill is drilling; latent torque in the drill string.
13. The system for acquiring drilling data according to any one of claims 10-12 comprising a telemetry system arranged to enable the DAT to communicate the downhole data in real time to an electronic device located at the surface.
14. The system for acquiring drilling data according to claim 13 comprising a telemetry system arranged to enable the DAT to communicate the processed drilling data to an electronic device located at the surface.
15. The system for acquiring drilling data according to any one of claims 10-14 comprising an inner core barrel assembly wherein the DAT is coupled to or housed within the inner core barrel assembly.

Patentansprüche

1. Verfahren zum Bestimmen der Kernausrichtung einer Kernprobe, die von einem Bohrturm aus dem Boden geschnitten wird, der einen Bohrstrang und eine Bohrkrone aufweist, die mit einem unterirdischen Ende des Bohrstrangs gekoppelt ist, wobei das Verfahren umfasst: kontinuierliches Erfassen von Bohrdaten, während der Bohrturm in Betrieb ist, um die Kernprobe zu erfassen, wobei die Bohrdaten eine Kombination von Kernorientierungsdaten und Bohrturmbetriebsdaten sind, wobei die Bohrturmbetriebsdaten durch entweder eines oder beide von Folgendem gebildet werden: (a) Bohrturmdaten in der Nähe der Bohrkrone; und (b) Bohrturmdaten an der Oberfläche; und Analysieren der Bohrdaten auf ein spezifisches Muster von Bohrturmbetriebsdaten, das darauf hinweist, dass die Kernprobe durch den Betrieb des Bohrturms aus dem Boden gebrochen wird, und bei Erkennung des spezifischen

Musters Bestimmen der Orientierung der Kernprobe, bevor sie aus dem Boden gebrochen wird, unter Verwendung der erfassten Kernorientierungsdaten.

2. Verfahren nach Anspruch 1, wobei das Erfassen der Bohrdaten das Erfassen der Bohrdaten mindestens für einen Zeitraum umfasst, der einen kontinuierlichen Zeitraum vom Beginn des Betriebs des Bohrturms zum Schneiden der Kernprobe bis zu jedem Ereignis umfasst, das nach dem Beginn des Betriebs des Bohrturms zum Brechen der Kernprobe aus den in situ Schichten auftritt.
3. Verfahren nach Anspruch 2, wobei das Ereignis das Aufbringen eines Hochzugs auf den Bohrstrang ist, um das Herausbrechen der Kernprobe aus den in situ Schichten zu beeinflussen.
4. Verfahren nach Anspruch 2, wobei das Ereignis die Entnahme der Kernprobe durch den Bohrstrang ist.
5. Verfahren nach einem der Ansprüche 2 bis 4, wobei die beim Auftreten des spezifischen Musters erfasste Kernausrückung kompensiert wird, um die relative Drehbewegung zu berücksichtigen, und die kompensierte Kernausrückung als die Kernausrückung der von dem Bohrturm geschnittenen Kernprobe verwendet wird.
6. Verfahren nach einem der Ansprüche 1 bis 5, wobei die Kernorientierungsdaten Neigung und Azimut eines bekannten Bezugspunktes auf der Kernprobe oder übertragbar auf diese enthalten.
7. Verfahren nach einem der Ansprüche 1-6, wobei die Bohrturmbetriebsdaten eines oder eine beliebige Kombination von zwei oder mehr der folgenden Elemente umfassen: Drehzahl des Bohrers, Verschiebung des Bohrers in einer Aufwärtsrichtung des Bohrlochs, Verschiebung des Bohrers in einer Abwärtsrichtung des Bohrlochs, Umgebungsflüssigkeitsdruck, Vorhandensein einer Flüssigkeitsströmung im Bohrstrang, Rate der Flüssigkeitsströmung in das Bohrloch, Vibration im Bohrstrang, mechanischer Stoß, Eindringgeschwindigkeit, Bohrlochtiefe, Anzahl der passierten Bohrgestängeverbindungen, wenn das DAT zur Spitze transportiert oder aus dem Bohrer oder beides, latentes Drehmoment im Bohrstrang, Gewicht auf dem Bohrer, Drehmoment auf dem Bohrer.
8. Verfahren nach einem der Ansprüche 1-7, wobei das spezifische Muster von Bohrparameterdaten Daten umfasst, die auf Folgendes hinweisen: (a) Beendigung der Drehung des Bohrstrangs und anschließend: (b) Anwendung eines Hochziehens des Bohrstrangs.
9. Verfahren nach einem der Ansprüche 1-8, wobei die Bestimmung der Kernorientierungsdaten die Verwendung von einem oder mehreren der Kernorientierungsdaten beinhaltet, die innerhalb eines vom Benutzer wählbaren Zeitraums erfasst wurden.
10. System zur Bestimmung der Kernorientierung einer von einem Bohrer aus dem Boden geschnittenen Kernprobe mit einem Bohrstrang und einer Bohrkronen, die mit einem untertägigen Ende des Bohrstrangs gekoppelt ist, umfassend:
ein Datenerfassungswerkzeug (DAT), wobei das DAT angeordnet ist, um kontinuierlich Kernorientierungsdaten zumindest während des Betriebs des Bohrturms zur Gewinnung der Kernprobe zu erfassen, und eines oder beide von einem (a) Datenerfassungssystem in der Nähe der Bohrkronen, und , (b) Datenerfassungssystem an der Oberfläche, die beide angeordnet sind, um kontinuierlich zugehörige Daten zu erfassen, während der Bohrturm in Betrieb ist, um die Kernprobe zu gewinnen.
11. System zum Erfassen von Bohrdaten nach Anspruch 10, wobei das DAT einen oder mehrere Kernorientierungssensoren umfasst, die so angeordnet sind, dass das DAT in der Lage ist, eine oder zwei oder mehrere der Folgenden zu erfassen: Neigung, Azimut, Gravitationsoberkante oder -sohle des Bohrlochs, Magnetische Werkzeugfläche oder Wahrer Norden eines bekannten Referenzdatums auf der Kernprobe oder übertragbar auf diese.
12. System zur Erfassung von Bohrdaten nach einem der Ansprüche 10-11, wobei das DAT einen oder mehrere Parametersensoren in der Nähe der Bohrkronen aufweist, die so angeordnet sind, dass das DAT in der Lage ist eine, oder eine beliebige Kombination von zwei oder mehr der folgenden Bohrparameterdaten zu erfassen: Rotationsgeschwindigkeit des Bohrers, Differenzrotation zwischen dem Bohrstrang und der Innenkernrohr-Baugruppe, Verschiebung des Bohrers in Aufwärtsrichtung, Verschiebung des Bohrers in Abwärtsrichtung Bohrlochrichtung, Umgebungsflüssigkeitsdruck, Vorhandensein eines Flüssigkeitsstroms durch den Bohrstrang, Rate des Flüssigkeitsstroms in das Bohrloch, Vibration, mechanischer Stoß, Eindringgeschwindigkeit, Bohrtiefe, Anzahl der passierten Bohrgestängeverbindungen, wenn das DAT zur Spitze transportiert oder aus dem Bohrer oder beides, Drehmoment

während des Bohrens, latentes Drehmoment im Bohrstrang.

13. System zur Erfassung von Bohrdaten nach einem der Ansprüche 10 bis 12, umfassend ein Telemetriesystem, das so eingerichtet ist, dass das DAT die Bohrlochdaten in Echtzeit an ein elektronisches Gerät an der Oberfläche übermitteln kann.
14. System zur Erfassung von Bohrdaten nach Anspruch 13, das ein Telemetriesystem umfasst, das so angeordnet ist, dass das DAT die verarbeiteten Bohrdaten an eine an der Oberfläche befindliche elektronische Vorrichtung übermitteln kann.
15. System zum Erfassen von Bohrdaten nach einem der Ansprüche 10 bis 14, das eine Innenkernrohr-Baugruppe umfasst, wobei das DAT mit der Innenkernrohr-Baugruppe gekoppelt oder darin untergebracht ist.

Revendications

1. Procédé pour déterminer l'orientation de la carotte d'un échantillon de carotte prélevé dans le sol par un appareil de forage ayant un train de tige et un trépan couplé à une extrémité de fond de trou du train de tiges, le procédé comprenant :

l'acquisition en continu de données de forage, pendant que l'appareil de forage fonctionne pour obtenir l'échantillon de carotte, les données de forage étant une combinaison de données d'orientation de la carotte et de données opérationnelles de l'appareil, les données opérationnelles de l'appareil étant constituées soit par (a) les données de l'appareil à proximité du trépan, soit par (b) les données de l'appareil en surface, soit par les deux ; et

l'analyse des données de forage pour un motif spécifique de données opérationnelles de l'appareil indiquant que l'échantillon de carotte a été séparé du sol par le fonctionnement de l'appareil de forage et sur détection du motif spécifique la détermination de l'orientation de l'échantillon de carotte avant qu'il ne soit séparé du sol en utilisant les données d'orientation de la carotte obtenue.

2. Procédé selon la revendication 1, dans lequel l'acquisition des données de forage comprend l'acquisition des données de forage au moins pendant une période qui comprend une période continue à partir du début du fonctionnement de l'appareil de forage pour couper l'échantillon de carotte jusqu'à tout événement survenant après le début du fonctionnement de l'appareil de forage pour séparer l'échantillon de carotte à partir de strates in situ.
3. Procédé selon la revendication 2, dans lequel l'événement consiste à appliquer une traction vers le haut au train de tiges pour entraîner la séparation de l'échantillon de carotte des strates in situ.
4. Procédé selon la revendication 2, dans lequel l'événement est la récupération de l'échantillon de carotte par le train de tiges.
5. Procédé selon l'une des revendications 2 à 4 comprenant la compensation de l'orientation de la carotte obtenue lors de la survenue du motif spécifique pour tenir compte du mouvement de rotation relatif, et l'utilisation de l'orientation de la carotte compensée comme orientation de la carotte de l'échantillon de carotte prélevé par l'appareil de forage.
6. Procédé selon l'une quelconque des revendications 1-5 dans lequel les données d'orientation de la carotte comprennent le pendage et l'azimut d'une donnée de référence connue de l'échantillon de carotte, ou transférable à celui-ci.
7. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel les données opérationnelles de l'appareil comprennent l'une quelconque des caractéristiques suivantes, ou toute combinaison de deux ou plusieurs d'entre elles : la vitesse de rotation du trépan, le déplacement du trépan vers le haut du trou ; le déplacement du trépan vers le bas du trou ; la pression ambiante du fluide ; l'existence d'un écoulement de fluide dans le train de tiges ; le débit d'écoulement du fluide dans le trou de forage ; les vibrations dans le train de tiges ; les chocs mécaniques ; la vitesse de pénétration, la profondeur du trou ; le nombre de joints de tubes de forage passés lorsque le DAT est transporté vers le bas du train de tiges ou récupéré du train de tiges, ou les deux ; le couple latent dans le train de tiges ; le poids sur le trépan ; le couple sur le trépan.

8. Procédé selon l'une quelconque des revendications 1 à 7, dans lequel le motif spécifique des données de paramètres de forage comprend des données indicatives de :

a) l'arrêt de la rotation de la tige de forage ; et ensuite ; (b) l'application d'une traction vers le haut sur le train de tiges.

9. Procédé selon l'une quelconque des revendications 1-8 dans lequel la détermination des données d'orientation de la carotte implique l'utilisation d'une ou plusieurs des données d'orientation de la carotte acquises dans une période de temps sélectionnable par l'utilisateur.

10. Système pour déterminer l'orientation de la carotte d'un échantillon de carotte prélevé dans le sol par une foreuse ayant un train de tiges et un trépan couplé à une extrémité de fond de trou du train de tiges, comprenant :

un outil d'acquisition de données (DAT), le DAT étant conçu pour acquérir en continu des données d'orientation de la carotte au moins pendant que l'appareil de forage fonctionne pour obtenir l'échantillon de carotte ; et l'un ou les deux parmi (a) un système d'acquisition de données d'appareil de forage à proximité du trépan ; et (b) un système d'acquisition de données d'appareil de forage à proximité de la surface, les deux étant conçus pour acquérir en continu des données associées pendant que l'appareil de forage fonctionne pour obtenir l'échantillon de carotte.

11. Système d'acquisition de données de forage selon la revendication 10, dans lequel le DAT comprend un ou plusieurs capteurs d'orientation de carotte disposés pour permettre au DAT d'acquérir une ou deux ou plusieurs des caractéristiques suivantes :

l'inclinaison, l'azimut, la gravitation en haut ou en bas du trou de forage, face de l'outil magnétique ou nord vrai d'une date de référence connue de l'échantillon de carotte ou transférable sur celui-ci.

12. Système d'acquisition de données de forage selon l'une quelconque des revendications 10-11, dans lequel le DAT comprend un ou plusieurs capteurs de paramètres proches de l'appareil de forage, conçus pour permettre au DAT d'acquérir une des données de paramètres de forage suivantes, ou toute combinaison de deux ou plusieurs de ces données : une vitesse de rotation de foreuse, une rotation différentielle entre le train de tiges et l'ensemble de tubes de carottage intérieur, un déplacement de la foreuse dans une direction vers le haut du trou ; un déplacement de la foreuse dans une direction vers le bas du trou ; une pression de fluide ambiante ; l'existence d'un écoulement de fluide à travers le train de tiges ; un débit de fluide dans le trou de forage ; une vibration ; un choc mécanique ; un taux de pénétration, une profondeur du trou ; un nombre de joints de tubes de forage passés lorsque le DAT est transporté vers la pointe ou récupéré de la foreuse, ou les deux ; un couple lorsque la foreuse est en train de forer ; un couple latent dans le train de tiges.

13. Système d'acquisition de données de forage selon l'une quelconque des revendications 10-12, comprenant un système de télémétrie conçu pour permettre au DAT de communiquer les données de fond de trou en temps réel à un dispositif électronique situé à la surface.

14. Système d'acquisition de données de forage selon la revendication 13, comprenant un système de télémétrie conçu pour permettre au DAT de communiquer les données de forage traitées à un dispositif électronique situé à la surface.

15. Système d'acquisition de données de forage selon l'une quelconque des revendications 10-14 comprenant un ensemble de tubes de carottage intérieur, le DAT étant couplé à l'ensemble de tubes de carottage intérieur, ou logé dedans.

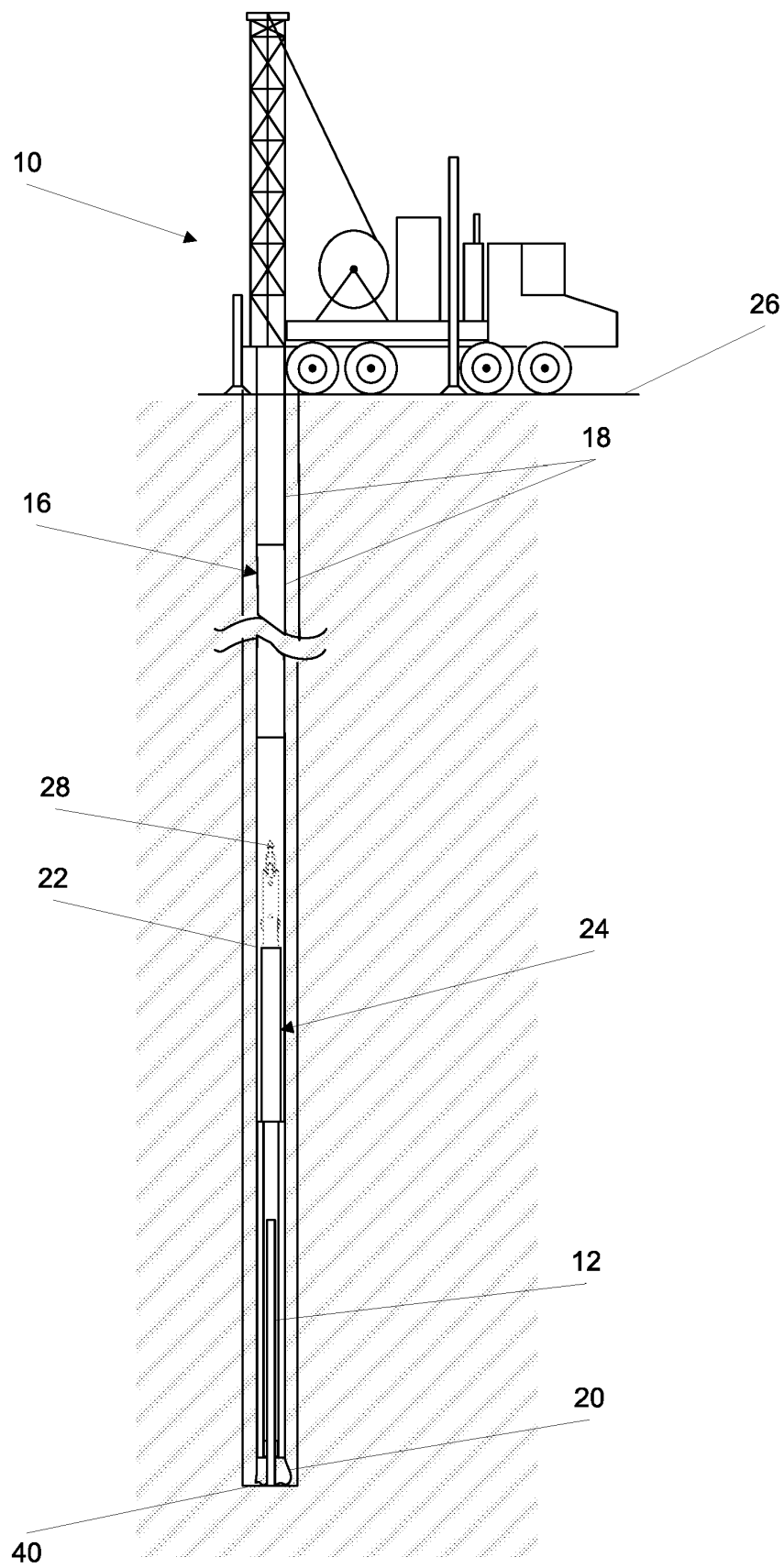


Figure 1

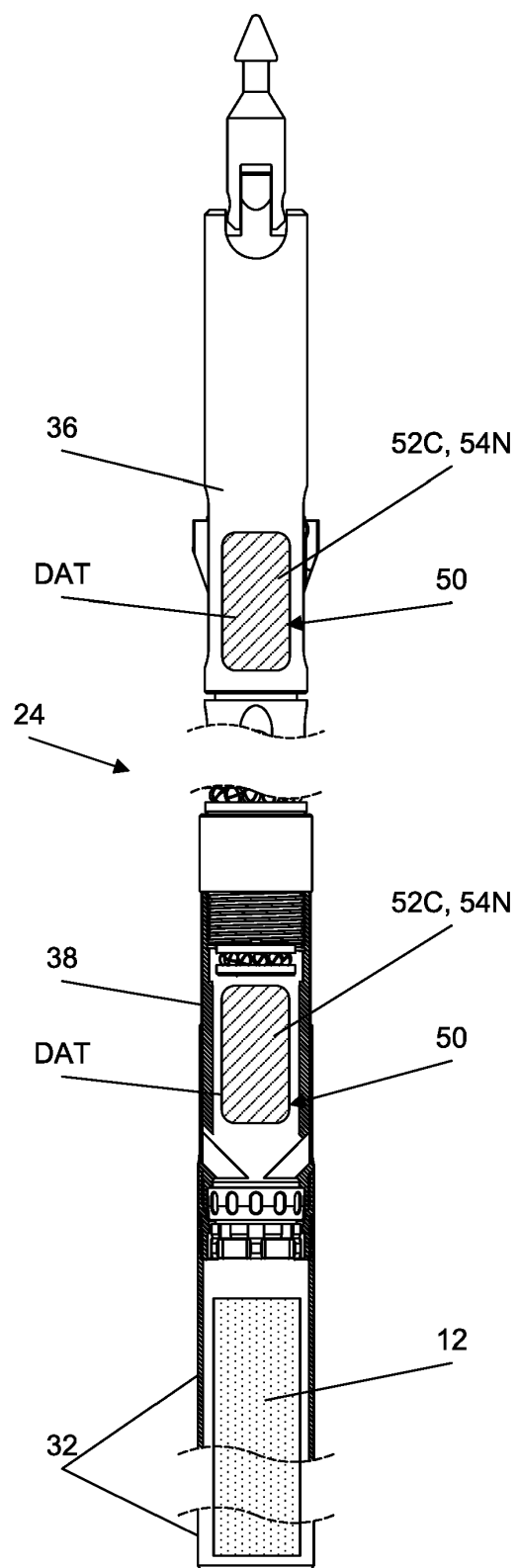
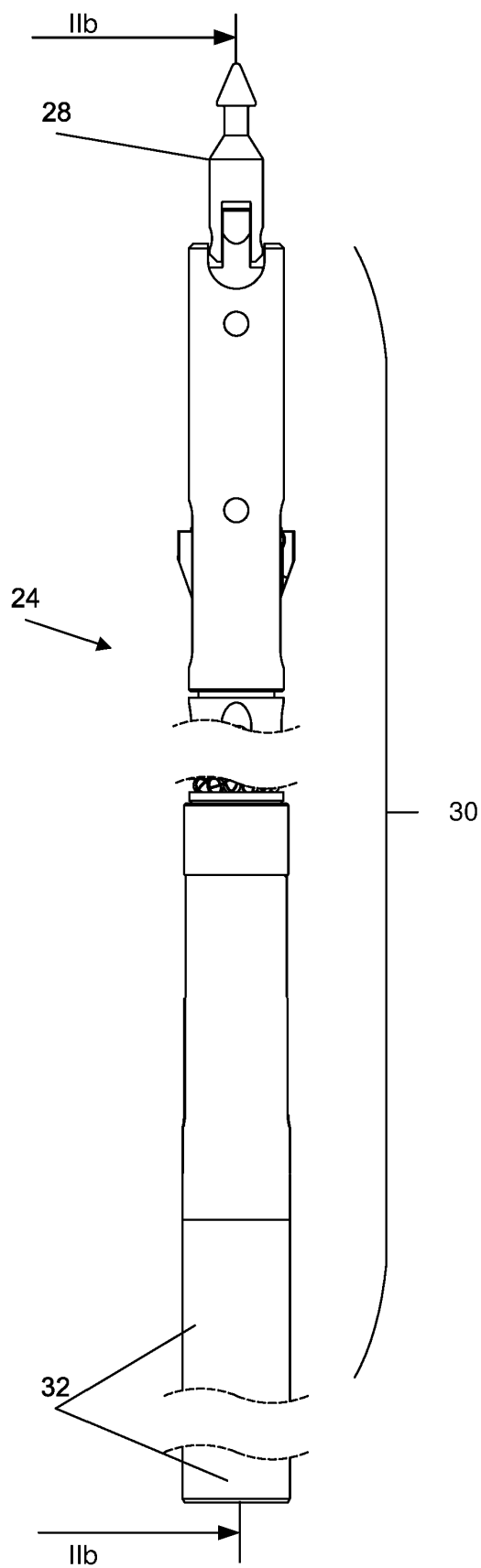


Figure 2a

Figure 2b

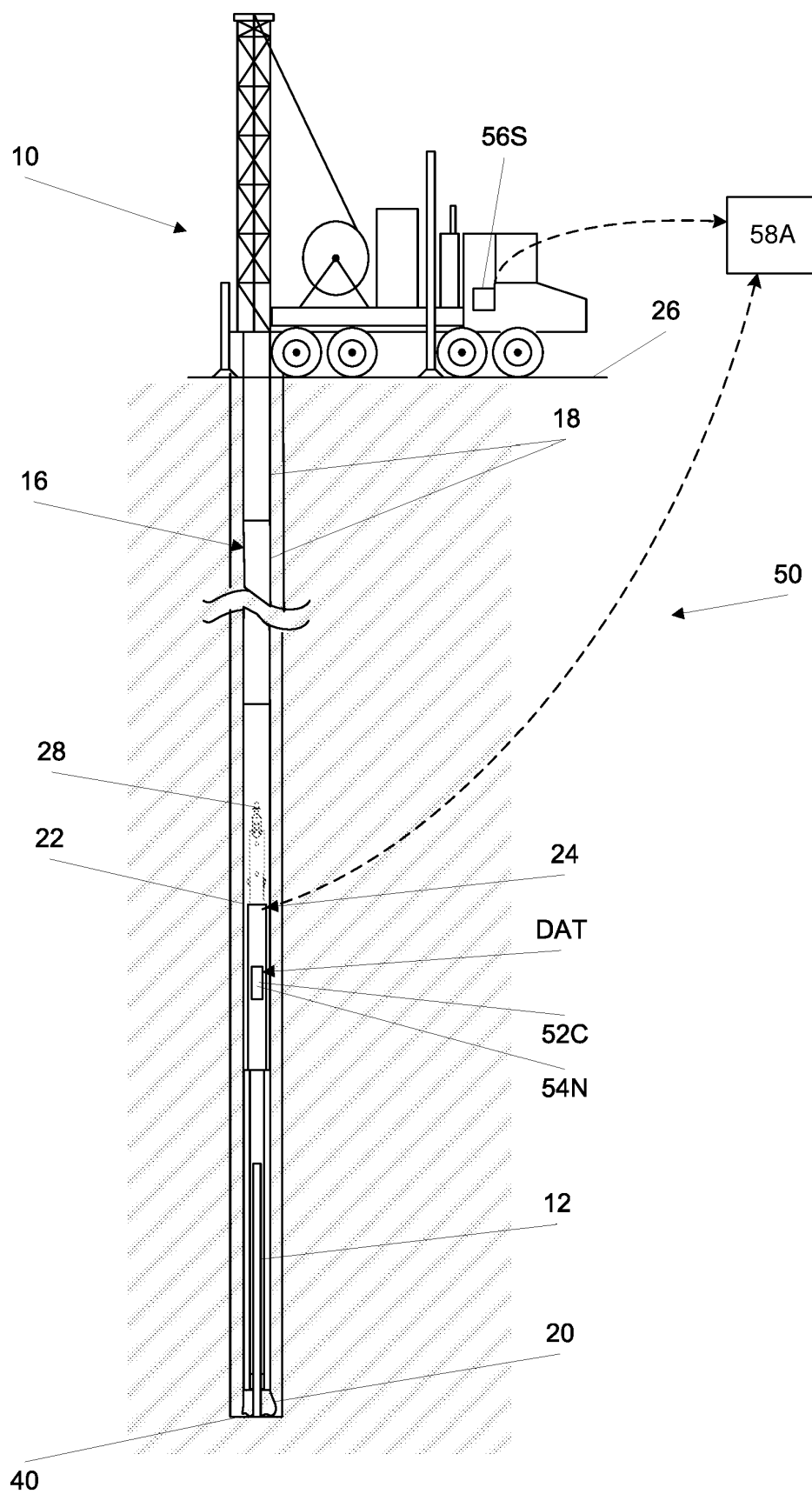


Figure 3

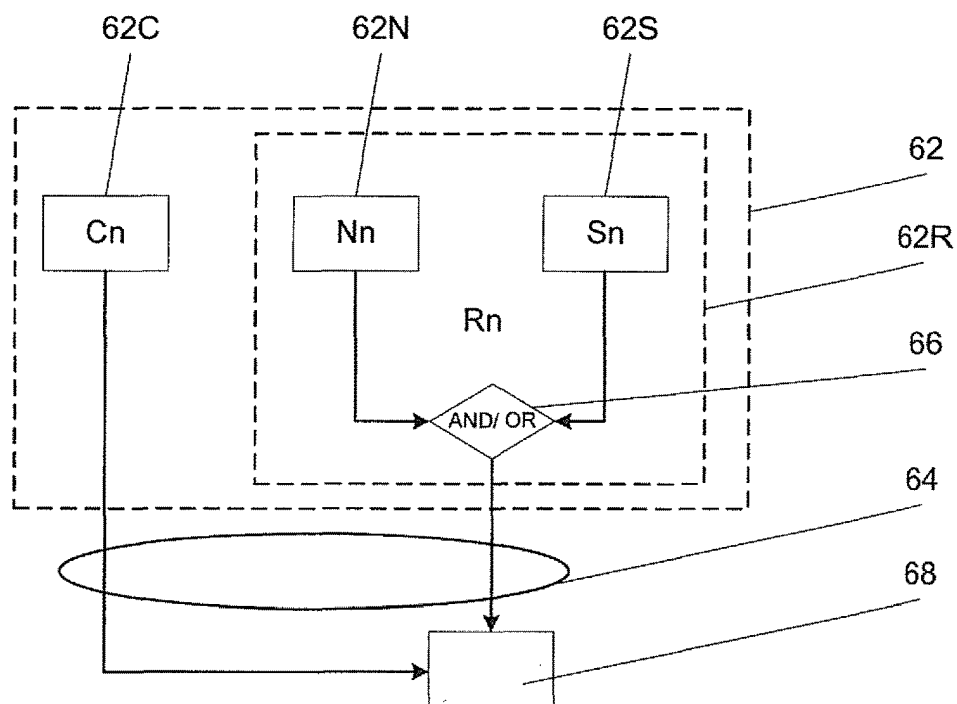


Figure 4

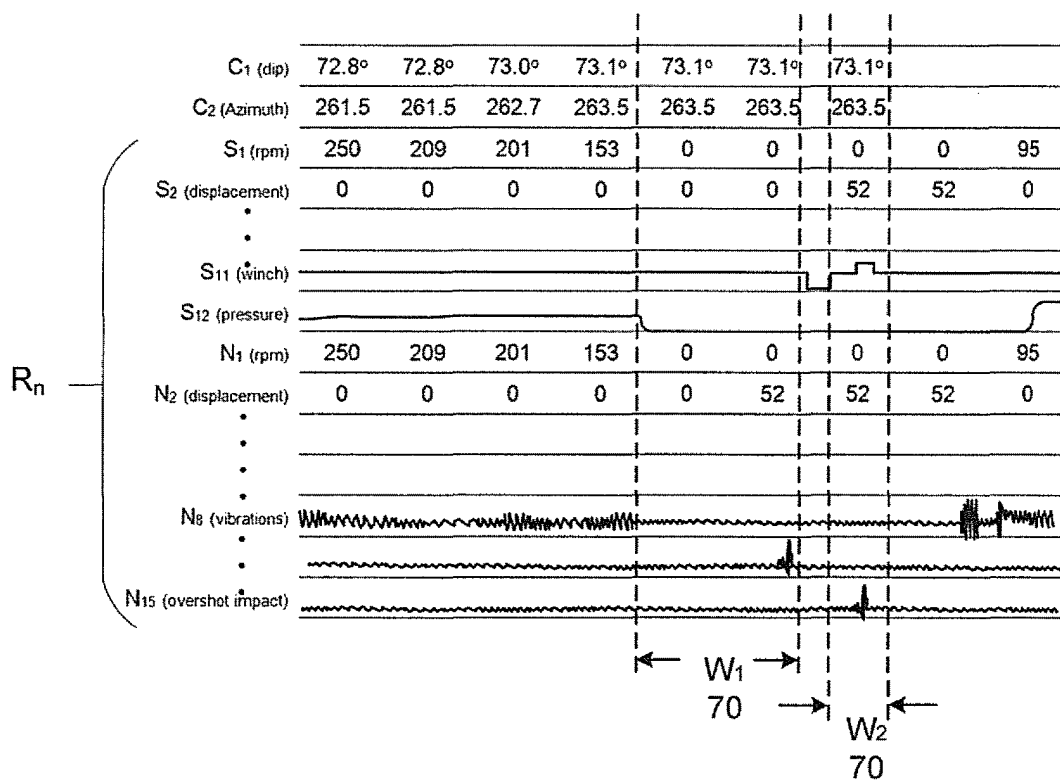


Figure 5

REFERENCES CITED IN THE DESCRIPTION

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