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(54) METHOD AND SYSTEM FOR DETERMINING CORE ORIENTATION

VERFAHREN UND SYSTEM ZUR BESTIMMUNG DER KERNAUSRICHTUNG

PROCÉDÉ ET SYSTÈME PERMETTANT DE DÉTERMINER L'ORIENTATION D'UN NOYAU

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(73) Proprietor: **Reflex Instruments Asia Pacific Pty Ltd**
Balcatta, WA (AU)

(72) Inventors:
- **Tapson, Jonathan Craig**
  Telluride (US)
- **Brown, Kelvin**
  Balcatta (AU)
- **Jabbal, Gurtej Aingh**
  Balcatta (AU)
- **Mcleod, Gavin Thomas**
  Balcatta (AU)

(74) Representative: **Patentanwaltskanzlei Vièl & Wieske PartGmbB**
Feldmannstraße 110
66119 Saarbrücken (DE)

(56) References cited:
WO-A1-2016/154677 **US-A1- 2015 136 488**
US-A1- 2015 300 162

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Description

TECHNICAL FIELD

[0001] The invention relates to a method and a system for determining core orientation of a core sample cut from the ground by a drill rig.

BACKGROUND ART

[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.

[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 system 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 subtracted from a survey time of a downhole measuring device. The subtraction of times is use 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 date 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 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. 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 the application of the method and system as disclosed herein.

SUMMARY OF THE DISCLOSURE

[0007] 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 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; 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 wherein the event is extraction of the core sample from the drill string.

[0008] 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.

[0009] The method may comprise 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.

[0010] The rig operational data can 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.

[0011] 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, wherein 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.

[0012] 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.

[0013] 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.

[0014] 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.

[0015] The method may comprise 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.

[0016] In one embodiment the method comprises continuously acquiring the core orientation data and rig operational data at a known sample rate.

[0017] In one embodiment the at surface rig data comprises weight on bit.

[0018] In one embodiment the method comprises determining the core orientation involves using one or more of the acquired core orientation data.

[0019] Determining the core orientation can involve obtaining an average of a plurality of the acquired core orientation data.

[0020] The method may comprise determining the core orientation data involves using one or more of the core orientation data acquired within a user selectable time period. 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.

[0021] 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, wherein the near bit rig data acquisition system is provided in the DAT.

[0022] 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.

[0023] 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.

[0024] The system can comprise 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.

[0025] The DAT may comprise 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.

[0026] In one embodiment the DAT comprises an on-board memory to enable on-board storage of the downhole data.

[0027] In one embodiment the DAT comprises a processor capable of processing the downhole data to produce processed downhole data. The system can comprise a telemetry system arranged to enable the DAT to communicate the downhole data in real time to an electronic device located at the surface.

[0028] The system may comprise a telemetry system arranged to enable the DAT to communicate the processed drilling data to an electronic device located at the surface.

[0029] The system may comprise an inner core barrel assembly wherein the DAT is coupled to or housed within the inner core barrel assembly.

[0030] 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

[0031] 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:

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;

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;

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

[0032] 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.

[0033] 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 1 6 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.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] 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.

[0038] 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.

[0039] 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.

[0040] 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.

[0041] 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.

[0042] 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.

[0043] The table below summarises different embodiments of the system 50 arising from different possible combinations of the system components.

System Configurations

[0044]

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	✓	✓	✓	✓	

System Configurations

[0045] 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.

[0046] 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.

[0047] 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.

[0048] 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.

[0049] 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.

[0050] 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

[0051] The CODS 52C acquires core orientation data C1 , C2, (referred to herein in general as core orientation data Cn).

[0052] 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.

[0053] 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

[0054] 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 1 0/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;

N15 impact of an overshot 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 string or both ; and N19 torque on bit.

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

[0055] 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.

[0056] 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;

S3 pull-up applied to the drill string 16;

S4 ambient fluid pressure within the drill string;

S5 rate of fluid flow into the drill string; S6 rate of penetration of the drill rig 1 0/drill string 16 into the ground

S7 weight on the drill bit 20;

S8 make and break of a head rod from the drill string;

S9 tension in the drill string;

S10 tension in the wireline;

S11 activation of a winch on the drill rig used for tripping an overshot and/or the DAT

S12 drill rig pump pressure; and

S13 latent tension in the drill string.

[0057] 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 dill rod length). However it is believed that at surface rig data S7 and S8 above can be acquired at the surface only.

[0058] 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 improving accuracy in correlating the orientation data to the core break.

[0059] 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 ±5%, is detected an operator may make an informed decision as to whether to disregard a corresponding core orientation.

[0060] 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.

[0061] 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.

[0062] 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.

[0063] 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 CODS 52C in an inner core barrel assembly 24 such as, but not limited to, that described above and represented in Fig.2.

[0064] 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. 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.

[0065] 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.

[0066] 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).

[0067] 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).

[0068] 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 overshot landing event followed by an axial uphole movement of the overshot (i.e. a spike in N15 then reading of S1 1 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 date 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.

[0069] 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.

[0070] 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.

[0071] 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.

[0072] 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.

[0073] 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 , W2 ....Wn applied across the recorded data Cn, Rn as described in the text above.

[0074] 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.

[0075] 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.

[0076] 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.

[0077] 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.

[0078] 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.

[0079] 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.

[0080] 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 (60) of determining core orientation of a core sample (12) cut from the ground by a drill rig (10) having a drill string (16) and a drill bit (20) coupled to a downhole end of the drill string (16), the method comprising:

continuously acquiring drilling data (Cn, Rn), while the drill rig (10) is operating to acquire the core sample (12) wherein the drilling data (Cn, Rn) is a combination of core orientation data (Cn) and rig operational data (Rn), wherein the rig operational data (Rn) is constituted by either one or both of: (a) near bit rig data (Nn); and (b) at surface rig data (Sn); and

analysing the drilling data (Cn, Rn) for a specific pattern of rig operational data (Rn) indicative of the core sample (12) being broken from ground by operation of the drill rig (10) and on detection of the specific pattern determining orientation of the core sample (12) prior to being broken from the ground using the acquired core orientation data (Cn),

wherein acquiring the drilling data (Cn, Rn) comprises acquiring the drilling data (Cn, Rn) at least for a period which includes a continuous period from commencement of operation of the drill rig (10) to cut the core sample (12) to any event occurring after commencement of operating the drill rig (10) to break the core sample (12) from in situ strata wherein the event is extraction of the core sample (12) from the drill string (16).

2. The method (60) according to claim 1 wherein acquiring the drilling data (Cn, Rn) includes acquiring, during the operation of the drill rig (10) to break the core sample (12), rig operational data (Rn) relating to relative rotational motion between the core sample (12) and an inner core tube (32) supported by the drill string (16) and into which the core sample (12) advances during drilling.

3. The method (60) according to any one of claims 1-2 wherein the specific pattern of drilling parameter data comprises data indicative of: (a) cessation of rotation of the drill string (16); and subsequently: (b) application of pull-up to the drill string (16) wherein the specific pattern of rig operational data (Rn) 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 (30) of an inner core barrel assembly (24) containing the core sample (12) cut by the drill rig (10).

4. The method (60) according to any one of claims 1-3 comprising storing the acquired downhole data (64) on a memory device which is disposed near the drill bit (20) while the drill rig (10) is in operation cutting the core sample (12).

5. The method (60) according to any one of claims 1-4 wherein core orientation data (Cn) and near bit rig data (Nn) are electronically communicated to an at surface electronic device or system either (a) while the drill rig (10) is in operation cutting the core sample (12); or (b) while the core sample (12) is within the drill string (16); or (c) at the surface after retrieval of the core sample (12).

6. The method (60) according to any one of claims 1-5 wherein analysing the drilling data (Cn, Rn) occurs: while the drill rig (10) is in operation cutting the core sample (12); or, while the core sample (12) is within the drill string (16); or after retrieval of the core sample (12).

7. The method (60) according to any one of the preceding claims comprising continuously acquiring the core orientation data (Cn) and rig operational data (Rn) at a known sample rate.

8. The method (60) according to any one of the preceding claims wherein the at surface rig data (Sn) comprises weight on bit.

9. The method (60) according to any one of claims 1-8 wherein determining the core orientation involves using one or more of the acquired core orientation data (Cn).

10. A system (50) for determining core orientation of a core sample (12) cut from the ground by a drill having a drill string (16) and a drill bit (20) coupled to a downhole end of the drill string (16) comprising:

a data acquisition tool (DAT) wherein the DAT is arranged to continuously acquire core orientation data (Cn) at least while the drill rig (10) is operating to acquire the core sample (12); and
one or both of a (a) near bit rig data acquisition system (54N); and (b) at the surface rig data acquisition system (56S), both arranged to continuously acquire associated data while the drill rig (10) is operating to acquire the core sample (12),
wherein the near bit rig data acquisition system (54N) is provided in the DAT.

11. The system (50) according to claim 10 further comprising a DAT tripping system capable of transporting the DAT through the drill string (16) toward a toe (40) of a hole drilled by the drill rig (10) and subsequently retrieving the DAT from the drill string (16).

12. The system (50) for acquiring drilling data (Cn, Rn) according to any one of claims 10-11 comprising:
a releasable locking system arranged to lock the DAT to the drill string (16) at a location near the drill bit (20) 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.

13. The system (50) for acquiring drilling data (Cn, Rn) according to any one of claims 10-12 wherein the DAT comprises an on-board memory to enable on-board storage of the downhole data (64).

14. The system (50) for acquiring drilling data (Cn, Rn) according to any one of claims 10-13 wherein the DAT comprises a processor capable of processing the downhole data (64) to produce processed downhole data.

15. The system (50) for acquiring drilling data (Cn, Rn) according to any one of claims 10-14 wherein the DAT comprises an event sensor arranged to automatically activate the DAT to continuously acquire the downhole data (64) in response to a sensed event pertaining to the lowering or locking of the DAT.

Patentansprüche

1. Ein Verfahren (60) zum Bestimmen der Kernausrichtung einer Kernprobe (12), die von einem Bohrturm (10) aus dem Boden geschnitten wird, der einen Bohrstrang (16) und eine Bohrkrone (20) aufweist, die mit einem unterirdischen Ende des Bohrstrangs (16) gekoppelt ist, wobei das Verfahren umfasst:

kontinuierliches Erfassen von Bohrdaten (Cn, Rn), während der Bohrturm (10) in Betrieb ist, um die Kernprobe (12) zu erfassen, wobei die Bohrdaten (Cn, Rn) eine Kombination von Kernorientierungsdaten (Cn) und Bohrturmbetriebsdaten (Rn) sind, wobei die Bohrturmbetriebsdaten (Rn) durch entweder eines oder beide von Folgenden gebildet werden: (a) Bohrturmdaten in der Nähe der Bohrkrone (Nn); und (b) Bohrturmdaten an der Oberfläche (Sn); und

Analysieren der Bohrdaten (Cn, Rn) auf ein spezifisches Muster von Bohrturmbetriebsdaten (Rn), das darauf hinweist, dass die Kernprobe (12) durch den Betrieb des Bohrturms (10) aus dem Boden gebrochen wird, und bei Erkennung des spezifischen Musters Bestimmen der Orientierung der Kernprobe (12), bevor sie aus dem Boden gebrochen wird, unter Verwendung der erfassten Kernorientierungsdaten (Cn),

wobei das Erfassen der Bohrdaten (Cn, Rn) das Erfassen der Bohrdaten (Cn, Rn) mindestens für einen Zeitraum umfasst, der einen kontinuierlichen Zeitraum vom Beginn des Betriebs des Bohrturms (12) zum Schneiden der Kernprobe (12) bis zu jedem Ereignis umfasst, das nach dem Beginn des Betriebs des Bohrturms (12) zum Brechen der Kernprobe (12) aus den in situ Schichten auftritt, wobei das Ereignis die Entnahme der Kernprobe (12) durch den Bohrstrang (16) ist.

2. Verfahren (60) nach Anspruch 2, wobei das Erfassen der Bohrdaten (Cn, Rn) das Erfassen der Bohrturmbetriebsdaten (Rn) während des Betriebs des Bohrturms (10) zum Brechen der Kernprobe (12) umfasst, die sich auf die relative Drehbewegung zwischen der Kernprobe (12) und ein Innenkernrohr (32) beziehen, das von dem Bohrstrang (16) getragen wird und in das die Kernprobe (12) während des Bohrens vorrückt.

3. Verfahren (60) nach einem der Ansprüche 1-2, wobei das spezifische Muster von Bohrparameterdaten Daten umfasst, die bezeichnend sind für: (a) Beendigung der Drehung des Bohrstrangs (16); und anschließend: (b) Aufbringen eines Hochziehens auf den Bohrstrang (16), wobei das spezifische Muster von Bohrturmbetriebsdaten (Rn) nach dem Auftreten des Aufbringens des Hochziehens Daten umfasst, die (c) eine Vibration anzeigen, die aus dem Aufprall eines Überschusses auf eine Kopfbaugruppe (30) einer Innenkernrohr-Baugruppe (24) entsteht, die die von dem Bohrturm (10) geschnittene Kernprobe (12) enthält.

4. Verfahren (60) nach einem der Ansprüche 1-3 bei dem die erfassten Bohrlochdaten (64) auf einer Speichervorrichtung gespeichert werden, die in der Nähe der Bohrkrone (20) angeordnet ist, während der Bohrturm (10) beim Schneiden der Kernprobe (12) in Betrieb ist.

5. Verfahren (60) nach einem der Ansprüche 1-4, bei dem Kernorientierungsdaten (Cn) und bohrkopfnahe Daten (Nn) elektronisch an eine elektronische Vorrichtung oder ein elektronisches System an der Oberfläche übermittelt werden, entweder (a) während der Bohrturm (10) in Betrieb ist und die Kernprobe (12) schneidet; oder (b) während sich die Kernprobe (12) innerhalb des Bohrstrangs (16) befindet; oder (c) an der Oberfläche nach der Entnahme der Kernprobe (12).

6. Verfahren (60) nach einem der Ansprüche 1-5, wobei das Analysieren der Bohrdaten (Cn, Rn) erfolgt: während der Bohrturm (10) in Betrieb ist und die Kernprobe (12) schneidet; oder während sich die Kernprobe (12) innerhalb des Bohrstrangs (16) befindet; oder nach der Wiedergewinnung der Kernprobe (12).

7. Das Verfahren (60) nach einem der vorhergehenden Ansprüche umfassend das kontinuierliche Erfassen der Kernorientierungsdaten (Cn) und der Bohrturmbetriebsdaten (Rn) mit einer bekannten Abtastrate.

8. Verfahren (60) nach einem der vorhergehenden Ansprüche, wobei die Daten (Sn) des Bohrturms an der Oberfläche das Gewicht des Bohrers umfassen.

9. Verfahren (60) nach einem der Ansprüche 1-8, wobei die Bestimmung der Kernausrichtung die Verwendung eines oder mehrerer der erfassten Kernorientierungsdaten (Cn) beinhaltet.

10. System (50) zum Bestimmen der Kernausrichtung einer Kernprobe (12), die von einem Bohrer aus dem Boden geschnitten wurde, der ein Bohrgestänge (16) und eine Bohrkrone (20) aufweist, die mit einem untertägigen Ende des Bohrgestänges (16) gekoppelt ist, umfassend:

ein Datenerfassungswerkzeug (DAT), wobei das DAT so angeordnet ist, um kontinuierlich Kernorientierungsdaten (Cn) zumindest während des Betriebs des Bohrturms (10) zur Gewinnung der Kernprobe (12) erfasst; und eines oder beide von einem (a) Datenerfassungssystem (54N) in der Nähe der Bohrkrone, und, (b) Datenerfassungssystem (56S) an der Oberfläche, die beide angeordnet sind, um kontinuierlich zugehörige Daten zu erfassen, während der Bohrturm (10) in Betrieb ist, um die Kernprobe (12) zu gewinnen,
wobei das Datenerfassungssystem in der Nähe der Bohrkrone (54N) im DAT vorgesehen ist.

11. Das System (50) nach Anspruch 10 umfasst ferner ein DAT-Auslösesystem, das in der Lage ist, das DAT durch den Bohrstrang (16) zu einer Sohle (40) eines von einem Bohrturm (10) gebohrten Lochs zu transportieren und anschließend das DAT aus dem Bohrstrang (16) zurückzuholen.

12. System (50) zum Erfassen von Bohrdaten (Cn, Rn) nach einem der Ansprüche 10-11, umfassend:
ein lösbares Verriegelungssystem, das so angeordnet ist, dass es das DAT an dem Bohrstrang (16) an einer Stelle in der Nähe der Bohrkrone (20) verriegelt, wenn das Auslösesystem das DAT zu der Stelle transportiert; und das DAT freigibt, um es dem Auslösesystem zu ermöglichen, das DAT von der Stelle zurückzuholen.

13. System (50) zum Erfassen von Bohrdaten (Cn, Rn) nach einem der Ansprüche 10-12, wobei das DAT einen On-Board-Speicher umfasst, um eine On-Board-Speicherung der Bohrlochdaten (64) zu ermöglichen.

14. System (50) zur Erfassung von Bohrdaten (Cn, Rn) nach einem der Ansprüche 10-13, wobei das DAT einen Prozessor umfasst, der in der Lage ist, die Bohrlochdaten (64) zu verarbeiten, um verarbeitete Bohrlochdaten zu erzeugen.

15. System (50) zum Erfassen von Bohrdaten (Cn, Rn) nach einem der Ansprüche 10-14, wobei das DAT einen Ereignissensor umfasst, der so angeordnet ist, dass er das DAT automatisch aktiviert, um die Bohrlochdaten (64) als Reaktion auf ein erfasstes Ereignis, das das Absenken oder Verriegeln des DAT betrifft, kontinuierlich zu erfassen.

Revendications

1. Procédé (60) de détermination de l'orientation d'une carotte (12) découpée dans le sol à l'aide d'un appareil de forage (10) doté d'un train de tiges (16) et d'un trépan (20) couplé à une extrémité de fond de trou du train de tiges (16), le procédé comprenant :

l'acquisition en continu de données de forage (Cn, Rn), pendant que l'appareil de forage (10) fonctionne pour acquérir la carotte (12), les données de forage (Cn, Rn) étant une combinaison de données d'orientation de la carotte (Cn) et de données opérationnelles de l'appareil de forage (Rn), les données opérationnelles de l'appareil de forage (Rn) étant constituées soit de l'un soit des deux éléments suivants : (a) des données de l'appareil de forage à proximité du trépan (Nn) ; et (b) les données de l'appareil de forage en surface (Sn) ; et
l'analyse des données de forage (Cn, Rn) à la recherche d'un motif spécifique de données opérationnelles de l'appareil de forage (Rn) indiquant que la carotte (12) a été détachée du sol par le fonctionnement de l'appareil de forage (10), et, sur détection du motif spécifique, détermination de l'orientation de la carotte (12) avant son détachement du sol à l'aide des données d'orientation de la carotte acquises (Cn),
où l'acquisition des données de forage (Cn, Rn) comprend l'acquisition des données de forage (Cn, Rn) au moins pendant une période qui inclut une période continue depuis le début du fonctionnement de l'appareil de forage (10) pour couper la carotte (12) jusqu'à tout événement survenant après le début du fonctionnement de l'appareil de forage (10) pour séparer la carotte (12) des strates in situ, l'événement étant l'extraction de la carotte (12) du train de tiges de forage (16).

2. Procédé (60) selon la revendication 1, dans lequel l'acquisition des données de forage (Cn, Rn) comprend l'acquisition, pendant le fonctionnement de l'appareil de forage (10) pour séparer la carotte (12), de données opérationnelles

de l'appareil de forage (Rn) relatives au mouvement de rotation relatif entre la carotte (12) et un tube de carotte interne (32) supporté par le train de tiges de forage (16) et dans lequel la carotte (12) progresse pendant le forage.

3. Procédé (60) selon l'une quelconque des revendications 1 à 2, dans lequel le motif spécifique de données de paramètres de forage comprend des données indiquant : (a) l'arrêt de la rotation du train de tiges de forage (16) ; et par la suite : (b) l'application d'une traction sur le train de tiges (16), le motif spécifique des données opérationnelles de l'appareil de forage (Rn) comprenant, après l'application d'une traction, des données indiquant (c) une vibration résultant de l'impact d'un overshot avec un ensemble de tête (30) d'un ensemble de carotte interne (24) contenant la carotte (12) coupée par l'appareil de forage (10).

4. Procédé (60) selon l'une quelconque des revendications 1 à 3, comprenant le stockage des données de fond de puits acquises (64) sur un dispositif de mémoire disposé à proximité du trépan (20) pendant que l'appareil de forage (10) est en fonctionnement et découpe la carotte (12).

5. Procédé (60) selon l'une quelconque des revendications 1 à 4, dans lequel les données d'orientation de la carotte (Cn) et les données de l'appareil de forage à proximité du trépan (Nn) sont communiquées électroniquement à un dispositif ou à un système électronique en surface soit (a) pendant que l'appareil de forage (10) est en train de découper la carotte (12), soit (b) pendant que la carotte (12) se trouve à l'intérieur du train de tiges (16), soit (c) à la surface après récupération de la carotte (12).

6. Procédé (60) selon l'une quelconque des revendications 1 à 5, dans lequel l'analyse des données de forage (Cn, Rn) a lieu : pendant que l'appareil de forage (10) est en train de découper la carotte (12) ; ou pendant que la carotte (12) se trouve à l'intérieur du train de tiges (16) ; ou après la récupération de la carotte (12).

7. Procédé (60) selon l'une quelconque des revendications précédentes comprenant l'acquisition en continu des données d'orientation de la carotte (Cn) et des données opérationnelles de l'appareil de forage (Rn) à une fréquence d'échantillonnage connue.

8. Procédé (60) selon l'une quelconque des revendications précédentes, dans lequel les données de l'appareil de forage en surface (Sn) comprennent la charge sur le trépan.

9. Procédé (60) selon l'une quelconque des revendications 1 à 8, dans lequel la détermination de l'orientation de la carotte implique l'utilisation d'une ou de plusieurs des données d'orientation de la carotte (Cn) acquises.

10. Système (50) pour déterminer l'orientation d'une carotte (12) découpée dans le sol à l'aide d'un appareil de forage doté d'un train de tiges (16) et d'un trépan (20) couplé à une extrémité de fond de trou du train de tiges (16), comprenant :

un outil d'acquisition de données (DAT) dans lequel le DAT est conçu pour acquérir en continu des données d'orientation de la carotte (Cn) au moins pendant que l'appareil de forage (10) fonctionne pour acquérir la carotte (12) ; et
l'un ou les deux de a) un système d'acquisition de données de l'appareil de forage à proximité du trépan (54N) ; et b) un système d'acquisition de données de l'appareil de forage en surface (56S), tous deux conçus pour acquérir en continu des données associées pendant que l'appareil de forage (10) fonctionne pour acquérir la carotte (12),
le système d'acquisition de données de l'appareil de forage à proximité du trépan (54N) étant présent dans le DAT.

11. Système (50) selon la revendication 10 comprenant en outre un système de déplacement du DAT capable de transporter le DAT à travers le train de tiges (16) vers une extrémité (40) d'un trou foré par l'appareil de forage (10) et de récupérer ensuite le DAT du train de tiges (16).

12. Système (50) d'acquisition de données de forage (Cn, Rn) selon l'une quelconque des revendications 10 à 11, comprenant :
un système de verrouillage pouvant être libéré conçu pour verrouiller le DAT au train de tiges (16) à un endroit proche du trépan (20) lorsque le système de déplacement transporte le DAT à cet endroit ; et pour libérer le DAT afin de permettre au système de déplacement de récupérer le DAT à cet endroit.

13. Système (50) d'acquisition de données de forage (Cn, Rn) selon l'une quelconque des revendications 10 à 12, dans lequel le DAT comprend une mémoire embarquée pour permettre le stockage à bord des données de fond de puits (64).

14. Système (50) d'acquisition de données de forage (Cn, Rn) selon l'une quelconque des revendications 10 à 13, dans lequel le DAT comprend un processeur capable de traiter les données de fond de trou (64) pour produire des données de fond de trou traitées.

15. Système (50) d'acquisition de données de forage (Cn, Rn) selon l'une quelconque des revendications 10 à 14, dans lequel le DAT comprend un capteur d'événements conçu pour activer automatiquement le DAT afin d'acquérir en continu les données de fond de trou (64) en réponse à un événement détecté relatif à la descente ou au verrouillage du DAT.

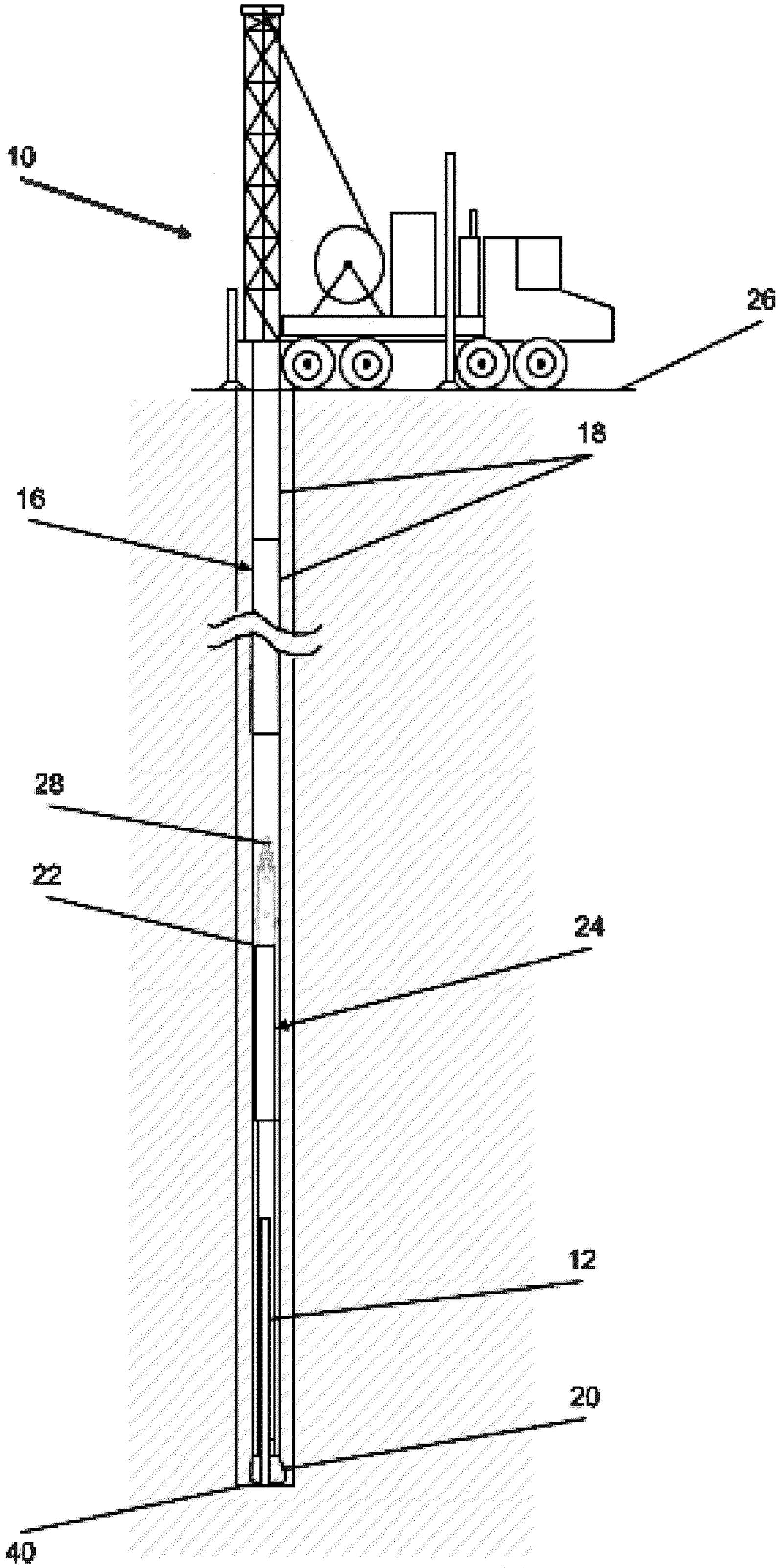

Figure 1

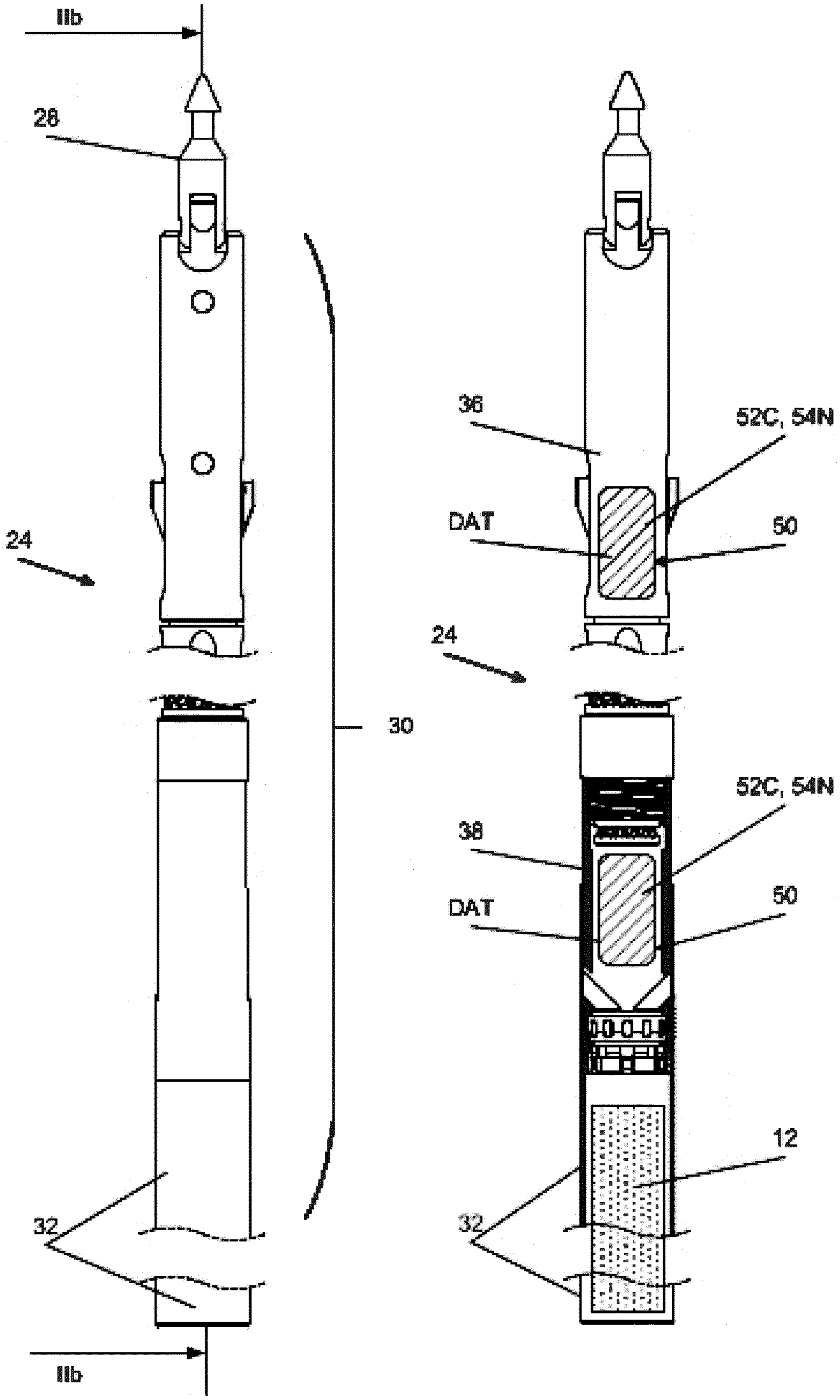

Figure 2a

Figure 2b

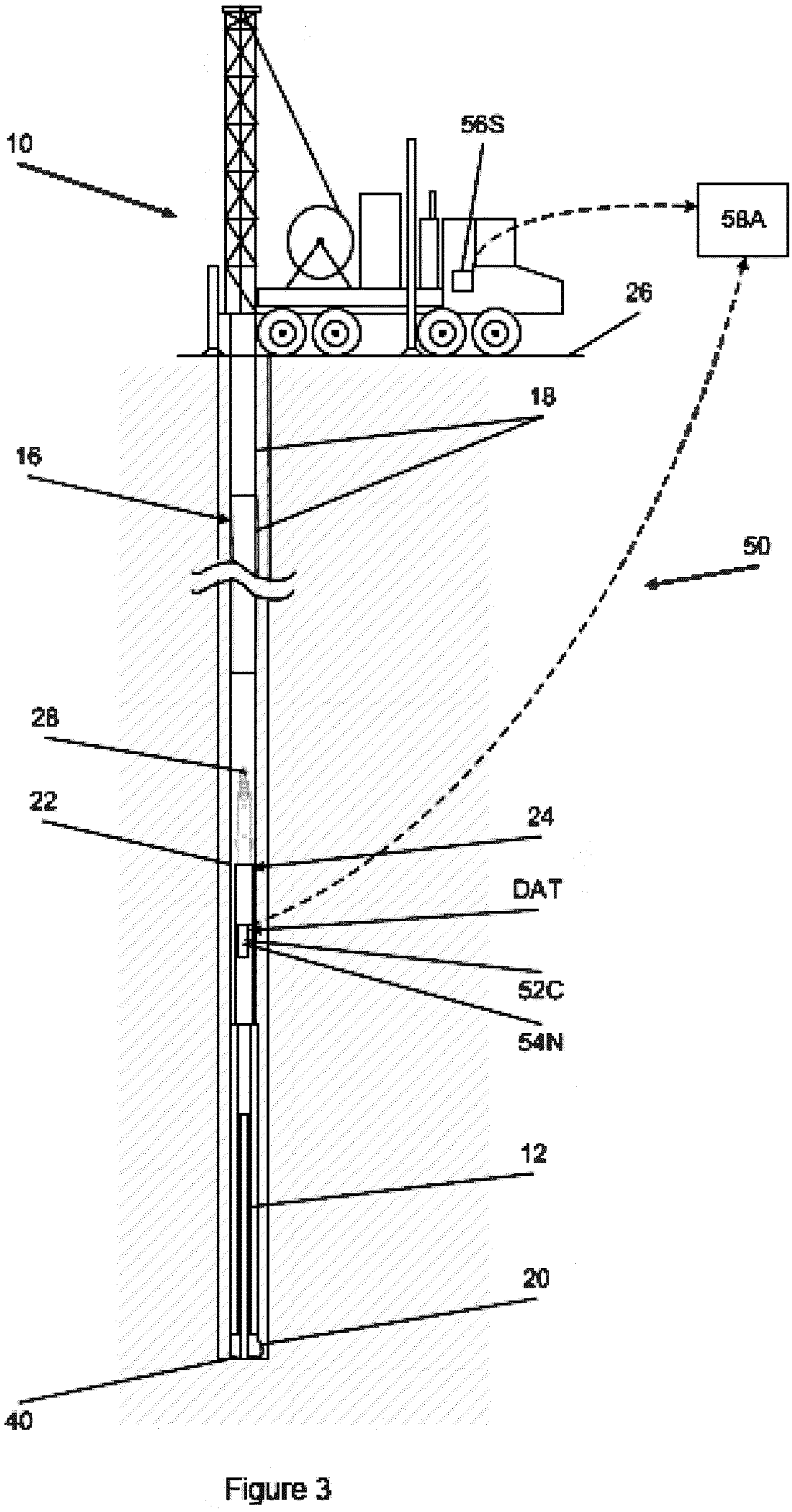

Figure 3

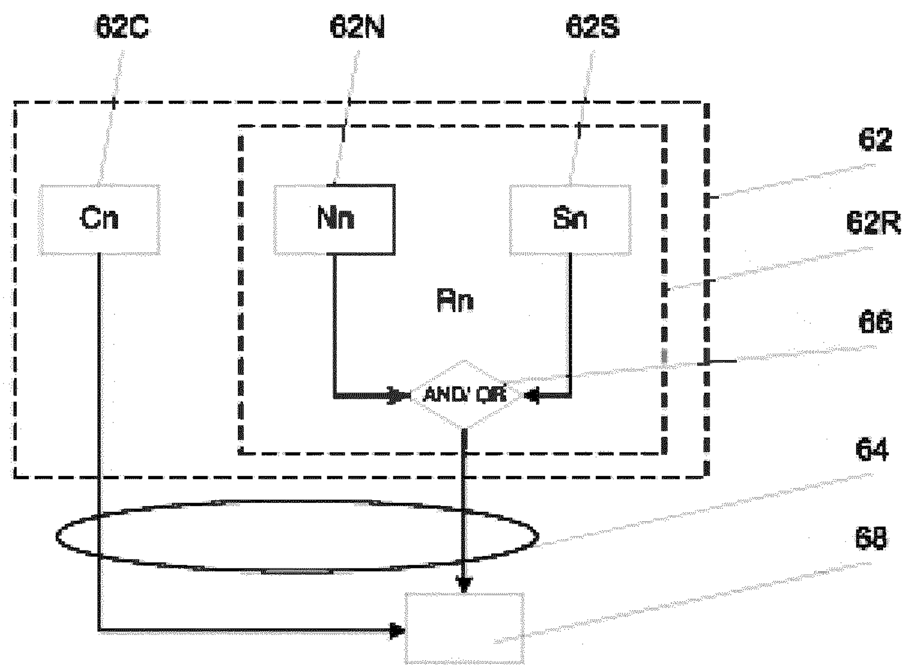

Figure 4

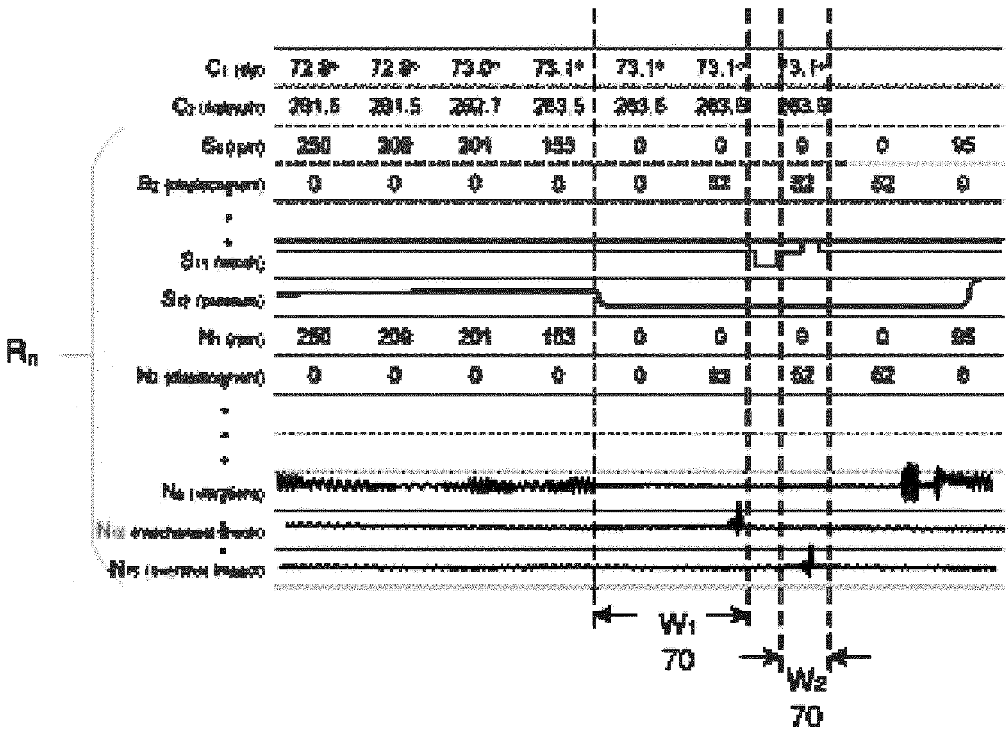

Figure 5

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2016154677 A **[0005] [0006]**
- US 20150300162 A **[0005] [0006]**
- US 20150136488 A **[0006]**