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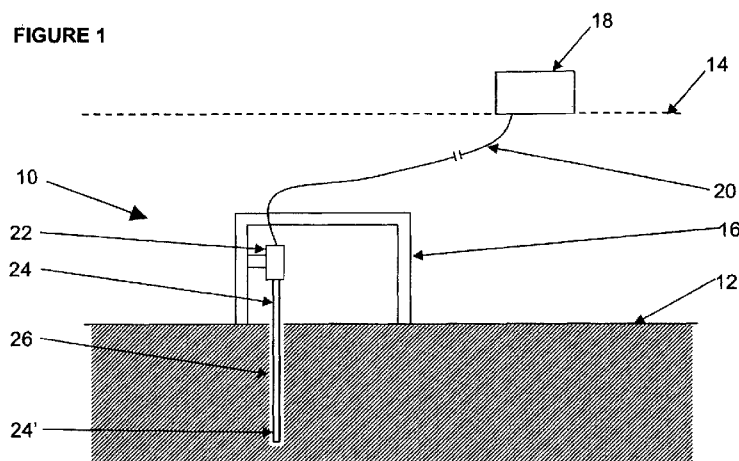
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(54) Title: AN APPARATUS, SYSTEM AND METHOD FOR ACTUATING DOWNHOLE TOOLS IN SUBSEA DRILLING OPERATIONS

FIGURE 1



(57) Abstract: A downhole logging tool and method of use for analysing portions of a seafloor borehole in seafloor drilling operations are provided. The downhole logging tool has an underwater chassis housing a power system and sensors including at least a conductivity sensor and a magnetic susceptibility sensor which, preferably, analyse the walls of the borehole. An automatically actuated switch, preferably actuated magnetically, provides power to the sensors from the power system when the downhole logging tool is not located in a designated portion of a seafloor drilling rig (e.g. when the tool is in use traversing a borehole) and removes power when the downhole logging tool is located in the designated portion of the seafloor drilling rig (e.g. when the downhole tool is not in use).

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AN APPARATUS, SYSTEM AND METHOD FOR ACTUATING DOWNHOLE TOOLS IN SUBSEA DRILLING OPERATIONS

FIELD OF THE INVENTION

[0001] The invention relates to an apparatus, system and method for deploying and actuating downhole logging tools from a seafloor drilling rig. In particular, the invention relates, but is not limited, to automatically actuating subsea downhole logging tools that may be used to determine downhole lithology.

BACKGROUND TO THE INVENTION

[0002] Reference to background art herein is not to be construed as an admission that such art constitutes common general knowledge in Australia or elsewhere.

[0003] Seafloor drilling, particularly in fairly deep bodies of water (e.g. 1,000m to 3,000m+), is a relatively complicated, time consuming, and expensive operation. Remotely operated seafloor systems, typically connected to a surface vehicle or platform by an 'umbilical' line, with a seafloor drilling rig have been known to be used for such drilling operations. A seafloor drilling rig typically includes a frame that provide support for various components such as a drill head support structure which would usually include a drill string capable of drilling a borehole in the seafloor.

[0004] One aspect of seafloor drilling that is identified as being particularly onerous is in determining the lithology of the seafloor deposits. Typically the lithology is determined by drilling, obtaining, and analysing core samples. Typically a core barrel on the end of a drill string is used to obtain a core sample.

[0005] Once the core barrel is filled, however, the core sample from the core barrel must then be retrieved. Typically this involves the retrieval of the entire drill string each time a core sample is recovered. The time and cost associated

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with recovering the core samples in this manner renders core drilling impractical for deep bores.

[0006] Some efforts have been made to reduce the problems, such as by providing a storage area for drill rods and core barrels, and a process for exchanging full core barrels with empty ones during drilling. Multiple core samples over a greater depth bore can then be obtained without the entire drill string being retrieved to obtain each core sample. Although the process is quicker it is still considered to be complex, time consuming, and expensive. Furthermore, if a core sample is lost (e.g. broken, damaged, or even physically lost) then the lithology of at least a portion of the borehole will be unclear.

[0007] A further problem with core samples in general is that it is not until the core samples have been retrieved and analysed that the lithology of a borehole is known. This time delay can be significant, and introduces a substantial inefficiency in understanding the characteristics of a borehole. One result of the time delay is that boreholes are often drilled past an optimum 'end of hole' (EOH) depth during drilling operations. This results in wasted drilling time and resources.

[0008] Having downhole logging tools which are lowered into a borehole to analyse the lithology of the borehole are being considered. It is desired to be able to turn the downhole logging tool on and off so that it is not continually running, which not only increases power usage but can provide interference. The increased power usage is particularly problematic for battery powered downhole logging tools where the tool is required to be recovered to surface in order to recharge the batteries.

[0009] Providing a physically actuated power switch on tools located on the seafloor is not considered to be practical. Not only are moving parts undesirable at such depths, but having means to remotely actuate the switch can be problematic. For example, a robotic arm could potentially be provided on a drilling rig to actuate the switch, but this further increases the cost and complexity of the drilling rig. Furthermore, if an operator forgets to actuate a switch before or after use, significant resources would likely be wasted.

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OBJECT OF THE INVENTION

[0010] It is an aim of this invention to provide an apparatus, system and method for deploying and actuating downhole logging tools from a seafloor drill rig assembly which overcomes or ameliorates one or more of the disadvantages or problems described above, or which at least provides a useful alternative.

[0011] Other preferred objects of the present invention will become apparent from the following description.

SUMMARY OF INVENTION

[0012] According to a first aspect of the invention, there is provided a downhole logging tool for use in a seafloor borehole of seafloor drilling operations, the downhole logging tool comprising:

- an underwater chassis comprising electronic components including a power system and sensors; and

- an automatically actuated switch that selectively provides power from the power system to the electronic components;

- wherein the sensors include at least a conductivity sensor and a magnetic susceptibility sensor, and the automatically actuated switch is actuated to remove power from the electronic components when the downhole logging tool is located in a designated portion of a seafloor drilling rig of seafloor drilling operations and to provide power to the electronic components when the downhole logging tool is not located in the designated portion of a seafloor drilling rig.

[0013] The automatically actuated switch preferably includes a magnetic switch that is actuated by proximity to a magnetic source. The magnetic source is preferably located in the designated portion of the seafloor drilling rig. Even more preferably the magnetic source is located adjacent a downhole logging tool storage rack of the drilling rig.

[0014] Preferably the magnetic switch is normally open and is closed by the magnetic field of the magnetic source. The magnetic switch is preferably a

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reed sensor. Preferably the reed sensor is part of an automatically actuated switch circuit that includes at least one transistor. Preferably the transistor is electrically connected to the power source and the magnetically actuated switch switches the transistor to selectively provide power to the electronic components.

[0015] Preferably the electronic components include a data transfer system in communication with the sensors. The sensors preferably comprise radial measurement sensors, i.e. sensors that conduct measurements of the walls of the borehole.

[0016] The sensors of the downhole logging tool may further comprise a temperature sensor, a resistivity sensor, and/or a natural gamma sensor. Preferably the resistivity sensor is an inductive conductivity sensor which may be a dual coil inductive conductivity sensor, a coil-focused inductive conductivity sensor, or some other form of an inductive conductivity sensor. Preferably the natural gamma sensor is utilised for depth correlation.

[0017] Preferably the underwater chassis comprises a mating portion that releasably secures to a corresponding mating portion of the seafloor drilling rig. Preferably the underwater chassis contains the sensors, the data transfer system, and the power system. The automatically actuated switch is preferably located on downhole logging tools where the power system includes batteries.

[0018] The data transfer system may comprise data storage for storing data received from the sensors. The data transfer system may store the data for transmission at a requested time.

[0019] The downhole logging tool may further comprise a processor. The processor is preferably in communication with the sensors, the data transfer system, and/or the power system. The processor may process raw data from the sensors. The data transfer system is then preferably in communication with the sensors via the processor; and preferably receives processed sensor data from the processor.

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[0020] The power system preferably comprises a battery. The power system may also comprise a power transfer system. The battery may comprise a plurality of smaller batteries. The power transfer system preferably transfers power from an external power source such as a powered portion of the drilling rig of the seafloor drilling operation.

[0021] The battery may be rechargeable and the power system may further comprise a battery charging system. The battery charging system may charge the battery from the power transfer system or inductively. The battery charging system may also be actuated by the automatically actuated switch. Alternatively, the automatically actuated switch may be actuated when the battery charging system is detected, preferably when an inductive charging field is detected.

[0022] Preferably the mating portion of the downhole logging tool secures the downhole logging tool to a wireline system or to a drill string. Where the mating portion of the downhole logging tool is secured to a wireline system, preferably the mating portion includes a latch head. Where the mating portion of the downhole logging tool is secured to a drill string, preferably the mating portion includes an adapter. The adapter preferably connects the downhole logging tool as a bottom hole assembly of the drill string. The downhole logging tool may have a mating portion for connecting to a wireline system and a mating portion for connecting to a drill string.

[0023] The wireline system may also be used to lower the downhole logging tool through the drill string whilst the drill string is in the borehole, preferably at total depth, and unlatch the logging tool to be received by the a portion of the drill string, preferably a bottom hole assembly portion. Preferably at least a sensor portion of the downhole logging tool protrudes from the bottom of the drill string. In this instance the drill string is recovered from the borehole to the seafloor drill rig as normal, while the downhole logging tool logs data in relation to the bore wall of the borehole from the sensors as it is raised with the drill string.

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[0024] Preferably the underwater chassis is less than 6m long and has an outer diameter less than 150mm. Even more preferably the underwater chassis is less than 3m long and has an outer diameter less than 75mm. Forms of the invention are preferably less than 2m in length and have an outer diameter of 50mm or less.

[0025] According to a second aspect of the invention, there is provided a seafloor drilling rig comprising the hereinbefore described downhole logging tool.

[0026] According to a third aspect of the invention, there is provided a system of utilising a downhole logging tool in seafloor drilling operations comprising:

- a downhole logging tool for traversing a seafloor borehole with a power system, sensors, and an automatically actuated switch, wherein the sensors include at least a conductivity sensor and a magnetic susceptibility sensor and the automatically actuated switch selectively provides power from the power system to sensors of the downhole logging tool;

- the automatically actuated switch being configured to activate the downhole logging tool when leaving a designated portion of a seafloor drilling rig and deactivate the downhole logging tool when entering the designated portion of the seafloor drilling rig.

[0027] According to a fourth aspect of the invention, there is provided a method of utilising a downhole logging tool in seafloor drilling operations comprising the steps of:

- selecting a downhole logging tool to traverse a seafloor borehole;
- manoeuvring the downhole logging tool from a designated portion of a seafloor drilling rig; and

- automatically actuating an automatically actuated switch of the downhole logging tool to activate the downhole logging tool when leaving a designated portion of a drilling rig and to deactivate the downhole logging tool when entering the designated portion of the seafloor drilling rig.

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[0028] The method of utilising a downhole logging tool preferably further comprises the steps of:

- connecting the downhole logging tool to a wireline;
- lowering the downhole logging tool down the seafloor borehole through a drill string;
- seating the downhole logging tool in a receiving portion of the lowermost drill string;
- disconnecting and retracting the wireline; and/or
- conducting measurements on the downhole tool as the drill string is removed from the borehole.

[0029] Preferably the downhole logging tool conducts radial measurements of walls of the borehole. Preferably the downhole logging tool has sensors including at least a conductivity sensor and a magnetic susceptibility sensor. Preferably the downhole logging tool in the system and method of utilising a downhole logging tool in seafloor drilling operations is a logging downhole logging tool as previously described.

[0030] Preferably the downhole logging tool is secured and unsecured from the seafloor drilling rig of the seafloor drilling operation by a remotely operated mechanism. Preferably the remotely operated mechanism is operated from a surface vehicle or platform.

[0031] Further features and advantages of the present invention will become apparent from the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] By way of example only, preferred embodiments of the invention will be described more fully hereinafter with reference to the accompanying figures, wherein:

[0033] Figure 1 is a diagrammatic view of seafloor drilling operations including a drill string located in a borehole;

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[0034] Figure 2 is a diagrammatic view of a seafloor drilling rig lowering a downhole logging tool into a borehole using a submersible wireline winch;

[0035] Figure 3a is a diagrammatic view of a downhole logging tool being lowered into a drill string;

[0036] Figure 3b is a diagrammatic view of the downhole logging tool of figure 3a in position in the bottom hole assembly of the drill string;

[0037] Figure 3c is a diagrammatic view of the downhole logging tool in figure 3a taking measurements as the drill string is removed;

[0038] Figure 4 is a side elevation view of a portion of a seabed drilling rig including a downhole logging tool storage area

[0039] Figure 5 is an electronic circuit schematic for an automatically actuated switch; and

[0040] Figure 6 is a side elevation view of a downhole logging tool.

DETAILED DESCRIPTION OF THE DRAWINGS

[0041] Figure 1 illustrates a diagrammatic view of a seafloor drilling operation 10 located on a seafloor 12 below sea level 14. The seafloor drilling operation 10 may be located at various depths below sea level 14, but typically the seafloor 12 will be greater than 1000m below sea level 14 and, in many cases, approximately 3000m below sea level 14.

[0042] The seafloor drilling operation 10 has a seafloor drilling rig 16 connected to a surface vehicle or platform 18 by an 'umbilical' cable 20. The umbilical cable 20 provides the seafloor drilling rig 16 with power, control, and telemetry. Typically the drilling rig 16 is powered and operated remotely, via umbilical cable 20, from the surface vehicle or platform 18. Although the surface vehicle or platform 18 is illustrated as being located on the surface of the sea level 14, it will be appreciated that the surface vehicle or platform could also be located elsewhere, such as on land.

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[0043] The seafloor drilling rig 16 has a drill head assembly 22 connected to a drill string 24 in a borehole 26. During drilling operations, the drill head assembly 22 controls the drill string 24 to drill the borehole 26. A typical drill string 24 has a conduit that transfers drilling fluid to a drill bit (not shown) of a bottom hole assembly at a distal end 24' of the drill string 24. A downhole logging tool 100 (not shown in figure 1), which will be described in further detail in relation to figure 6, can also be secured as the bottom hole assembly at a distal end 24' of the drill string 24 to determine the lithology of seafloor deposits adjacent the borehole 26 wall.

[0044] Figure 2 illustrates an alternative method of manoeuvring a downhole logging tool 100 into a borehole 26. Instead of securing the downhole logging tool 100 as the bottom hole assembly of a drill string 24, the downhole logging tool 100 is secured to a wireline 28 that is raised and lowered by a submersible wireline winch 30. Electrical connection between the wireline 28 and other portions of the drilling rig 16, such as to the umbilical 20, can be provided by an electric slip ring 32. Alternatively, the wireline may be purely mechanical, used only to raise and lower the downhole logging tool 100 in the borehole 26.

[0045] Figures 3a to 3c illustrate yet another method of manoeuvring a downhole logging tool 100 into a borehole 26. As shown in figure 3a, the downhole logging tool 100 is connected to a wireline 28 via a mating portion 112 and is lowered into the borehole 26 by a wireline winch 30. The wireline winch 30 lowers the downhole logging tool 100 through the inside of a plurality of drill rods 24'' that make up the drill string 24. Illustrated in figures 3a to 3c are three drill rods 24a to 24c, with 24a being the uppermost drill rod 24'' being received by a drill rod footclamp 34, 24b being the middle drill rod 24'', and 24c being the lowermost drill rod 24'' with a downhole logging tool 100 receiving portion 36 at the distal end 24' of the drill string 24.

[0046] Figure 3b illustrates the downhole logging tool 100 in the lowered position where it is received by the receiving portion 36 of the lowermost drill rod 24c. A wireline connector 28' at the end of the wireline 28 is detached from the mating portion 112 of the downhole logging tool 100 and the wireline winch

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30 raises the wireline 28 out of the drill string 24. The downhole logging tool 100 is seated in the receiving portion 36 of the lowermost drill rod 24c with a majority portion, including the sensors, protruding from the end of the downhole string 24. This allows the sensors in the downhole logging tool 100 to take measurements in relation to the walls of the borehole 26 without being obstructed or interfered with by the drill string 24.

[0047] Figure 3c illustrates the drill string 24 being removed from the borehole 26 once the wireline winch 30 has raised the wireline 28 completely out of the drill string 24. As the drill string 24 is raised, individual drill rods 24'' are removed from the string for storage. As shown in figure 3c, uppermost drill rod 24a has already been removed from the drill string and is stored on the seabed drilling rig 16. During raising of the drill string the downhole logging tool 100 is active and obtains radial measurements of the bore hole 26 wall. When the drill string 24 is fully removed from the borehole 26, the downhole logging tool 100 can then be retrieved and, at an appropriate time, the sensor data can be downloaded.

[0048] A portion of a seabed drilling rig 16 is illustrated in figure 4, showing a designated storage portion of the drilling rig 16 in the form of downhole logging tool storage rack 200. Figure 4 also illustrates a drill head 22 having a spindle 202. Tool arms 204 are provided which can manoeuvre tools, such as downhole logging tools, from the rack 200 and thread them onto the drill string 24, which is attached to the spindle 202. The drill head 22 can be moved vertically to controllable rates and forces in order to control the drill string 24 and logging tool within a borehole 26. The tool Arms 204 may also be used to manoeuvre the downhole logging tool 100 into position for mating with the wireline 30.

[0049] As will be discussed in more detail in relation to figure 6, the downhole logging tool 100 is battery powered and has a switch 152. That switch 152 is an automatically actuated switch. The automatically actuated switch 152 of the downhole logging tool 100 is actuated such that the downhole logging tools 100 are deactivated (i.e. using substantially no power) when in

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storage in the tool rack 200 and are then activated when taken from the tool rack 200 for use.

[0050] In a preferred embodiment the automatically actuated switch is actuated magnetically by a magnet 206 located adjacent the tool rack 200, preferably directly adjacent the location of the switch of the downhole logging tool 100 when the downhole logging tool 100 is located in the tool rack 200. When the switch 152 is proximal the magnet adjacent the tool rack 200, the switch 152 is actuated, thereby automatically deactivating the tool 100.

[0051] The downhole logging tool may be charged when located in the tool rack 200. An inductive charging device (not shown) may be provided on or adjacent the tool rack 200. Using power from the seafloor drill rig 16, the inductive charging device creates an electromagnetic field by way of an induction coil. When the downhole logging tool 100 is located in proximity to the inductive charging device, a second induction coil in, or at least electrically connected to, the battery of the downhole tool 100 converts the electromagnetic field into electrical charge to charge the battery. As an alternative to the magnetic switch, the detection of the induction charging field may instead be used to actuate the automatically actuated switch.

[0052] Figure 5 illustrates a preferred automatically actuated switch circuit layout 500. The circuit 500 includes four resistors (R1, R2, R3, and R4), a reed switch 510, and two transistors in the form of MOSFETs 512 and 514. The reed switch 510 is normally open and is closed when subjected to a magnetic field, such as by the magnet 206 adjacent the tool rack 200. The circuit 500 connects directly to a power source in the form of an 18 cell battery pack 502.

[0053] Typically reed switches allow a limited amount of current to pass through (e.g. 0.1A). The circuit 500 allows the reed switch 510, which has good sensitivity to a magnetic field, to be used without unduly limiting current from the battery pack 502. In a preferred embodiment the circuit 500 allows a current of approximately 7.5A to pass when the reed switch 510 is open.

[0054] In a preferred embodiment, when the reed switch 510 is open, i.e. when it is not subject to a magnetic field, the resistance measured between V_{in}

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and V_{out} is 0.0226Ω to 0.028Ω . When the reed switch 510 is closed, i.e. when it is subject to a magnetic field, the resistance measured between V_{in} and V_{out} is $4.8M\Omega$ to $24M\Omega$. The high resistance when the reed switch 510 is closed results in minimal, if any, current flowing through V_{out} .

[0055] Figure 6 illustrates a preferred downhole logging tool 100. The downhole logging tool 100 has an underwater chassis 110 in the form of a high pressure housing shaped to traverse the borehole 26. The chassis 110 has a mating portion 112 and contains: one or more sensors, a data transfer system in communication with the sensors, and a power system that provides power to the sensors and data transfer system. Specifically, the downhole logging tool 100 has a battery pack 150, a power switch 152, an electronics portion 170, a natural gamma sensor 172, a conductivity sensor 174, a magnetic susceptibility sensor 176, and an external temperature sensor 178. The electronics portion 170 includes a processor and data storage memory.

[0056] The mating portion 112 of the downhole logging tool 100 is connectable to both a drill string 24 and wireline 28. This allows the downhole logging tool 100 to traverse and conduct measurements in borehole 26 using any of the methods described in relation to figures 1, 2, or 3a to 3c. Most preferably, the downhole logging tool 100 is used in the method described in relation to figures 3a to 3c, where the downhole logging tool 100 is lowered through the drill string 24 using a wireline 28 and is then raised with the drill string 24 while conducting measurements of the walls of the borehole 26.

[0057] Prior to use, downhole logging tools 100 are located in the tool storage rack 200 of the drilling rig 12. The automatically actuated switches 152 are held open (i.e. in circuit 500 the reed switch is closed and the downhole logging tools 100 are turned off, conserving power) by one or more magnets adjacent the tool rack 200. When it is desired to use a downhole logging tool 100, the downhole logging tool 100 is selected and removed from the tool rack 200. As the downhole logging tool 100 is removed from the rack the switch 152 is removed from the magnetic field adjacent the tool rack 200 and the switch 152 is automatically actuated to the closed position (i.e. in circuit 500 the reed

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switch is opened and the downhole logging tool 100 is turned on). The downhole logging tool is then automatically activated by the switch 152 for use in the borehole 26.

[0058] The automatically activated downhole logging tool 100 may then be lowered into the borehole 26 to provide measurements which can be used to determine the lithology of seafloor deposits.

[0059] Where the downhole logging tool 100 is connected to a drill string 24 as illustrated in Figure 1, the tool arm 204 connects the mating portion 112 of the downhole logging tool 100 to distal end 24' of a drill string 24 such that the downhole logging tool 100 is deployed as a bottom hole assembly. Where the downhole logging tool 100 is connected to a wireline 28 (as illustrated in figures 2 and 3a) then the wireline winch 30 is positioned above the borehole 26 and the downhole logging tool 100 is lowered down the borehole 26.

[0060] Where the downhole logging tool 100 is to be seated in a receiving portion 36 of a drillstring 24 as illustrated in figures 3a to 3c, the wireline winch 30 lowers the downhole logging tool 100 into the receiving portion 36, detaches from the mating portion 112 of the downhole logging tool 100 and retracts the wireline 28 back out of the drill string 24. The downhole logging tool 100 then conducts measurements and logs data as it traverses up the borehole 26 during normal drill string retrieval operations. Once the lowermost drill rod 24c is situated in the drill rod footclamp 34 the wireline 28 can be utilised to connect to the downhole logging tool 100 and manoeuvre it back to the tool storage area 200, where the downhole logging tool 100 is automatically powered down by the automatically actuated switch 152 in the presence of the magnetic field of the magnet 206.

[0061] The sensors of the downhole logging tool 100 measure characteristics of the walls of the borehole 26 and communicate the data, typically via a processor, to a data transfer system. The data transfer system stores the data for transmission at a later date (e.g. upon retrieval). The data from the sensors provide down hole geophysical properties which can be used to determine lithology of the analysed section of the borehole.

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[0062] . Data from magnetic susceptibility sensors can be used to determine areas of seabed massive sulphides and non-mineralised basement volcanic rocks. Altered volcanics and sulphides have magnetic susceptibility destroyed by high temperature and, accordingly, magnetic susceptibility sensors can be used to discriminate areas of interest and determine 'end of hole' when non-mineralised basement volcanic rocks are reached.

[0063] The downhole logging tool 100 of figure 6 does not have a dedicated power or communication line to the drilling rig 16. It is therefore powered by rechargeable batteries, which may be recharged inductively when stored in the drilling rig 16. Alternatively, the downhole logging tool 100 may be recharged at the surface. Typically the downhole logging tool 100 stores data locally in on-board memory, but it is envisaged that it could transmit the data using existing data transmission techniques such as acoustic transmission or via an umbilical cable.

[0064] When finished with a downhole logging tool 100, it is retracted from the borehole 26 and placed back in the tool rack 200 of the drilling rig 12. As the tool is placed back in the tool rack the automatically actuated switch 152 is actuated open (i.e. the reed switch 510 in circuit 500 is closed) by the presence of the magnetic field from magnet 206 adjacent the tool rack 200. This process automatically deactivates the downhole logging tool 100 to conserve battery power and also to prevent any interference that the downhole logging tool may create.

[0065] Advantageously, the downhole logging tool 100 provides quick and relatively easy lithology analysis of a borehole 26. The downhole logging tool 100 can be used in areas of interest and also where there has been core loss. Retrieving data from the downhole logging tool 100 is significantly less burdensome than having to retrieve and analyse core samples. The decreased time to receive borehole lithology data further provides increased confidence in terminating drilling operations, i.e. calling 'end of hole', which improves efficiency and thereby reduces operational costs. Use of the downhole logging

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tool 100 may be used in conjunction with core samples or, if sufficient information is provided, instead of core samples altogether.

[0066] The use of an automatically actuated switch that automatically activates and deactivates downhole logging tools as they are removed and replaced (respectively) from a tool rack advantageously reduces power consumption of the downhole logging tools. As the downhole logging tools are typically only removed from the tool rack for use, the automatically actuated switch only activates a downhole logging tool when it is in use, or about to be used. This improves longevity of batteries in the downhole logging tool as well as reducing overall power consumption.

[0067] The magnetic switching circuit 500 advantageously allows a magnetically sensitive reed switch 510 to be used without unduly limiting the current that can be supplied from the battery pack 502. Furthermore, the circuit 500 avoids burn out of the reed switch 510 during start-up.

[0068] A specific combination of components of a downhole logging tool has been described, including a specific combination of sensors and mating portions. These specific combinations are preferred embodiments of the invention, but it will be appreciated that other combinations of sensors and/or mating portions may also be utilised.

[0069] Although a seafloor drilling rig is referred to herein, it will be appreciated that this may not necessarily be a stationary drilling rig but may be a manoeuvrable drill rig in the form of, for example, a remotely operated vehicle (ROV).

[0070] References herein to the seafloor, seabed, subsea, or the like are for convenience only and could equally be applied to other bodies of water such as, for example, a lake with a lakebed, etc.

[0071] In this specification, adjectives such as first and second, left and right, top and bottom, and the like may be used solely to distinguish one element or action from another element or action without necessarily requiring or implying any actual such relationship or order. Where the context permits,

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reference to an integer or a component or step (or the like) is not to be interpreted as being limited to only one of that integer, component, or step, but rather could be one or more of that integer, component, or step etc.

[0072] The above description of various embodiments of the present invention is provided for purposes of description to one of ordinary skill in the related art. It is not intended to be exhaustive or to limit the invention to a single disclosed embodiment. As mentioned above, numerous alternatives and variations to the present invention will be apparent to those skilled in the art of the above teaching. Accordingly, while some alternative embodiments have been discussed specifically, other embodiments will be apparent or relatively easily developed by those of ordinary skill in the art. The invention is intended to embrace all alternatives, modifications, and variations of the present invention that have been discussed herein, and other embodiments that fall within the spirit and scope of the above described invention.

[0073] In this specification, the terms 'comprises', 'comprising', 'includes', 'including', or similar terms are intended to mean a non-exclusive inclusion, such that a method, system or apparatus that comprises a list of elements does not include those elements solely, but may well include other elements not listed.

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CLAIMS:

1. A downhole logging tool for use in a seafloor borehole of seafloor drilling operations, the downhole logging tool comprising:
 - an underwater chassis comprising electronic components and a power system, the electronic components including sensors; and
 - an automatically actuated switch that selectively provides power from the power system to the electronic components;wherein the sensors include at least a conductivity sensor and a magnetic susceptibility sensor, and the automatically actuated switch is actuated to remove power from the electronic components when the downhole logging tool is located in a designated portion of a seafloor drilling rig of seafloor drilling operations and to provide power to the electronic components when the downhole logging tool is not located in the designated portion of a seafloor drilling rig.
2. The downhole logging tool of claim 1, wherein the automatically actuated switch includes a magnetic switch that is actuated by proximity to a magnetic source.
3. The downhole logging tool of claim 2, wherein the magnetic source is located in the designated portion of the seafloor drilling rig.
4. The downhole logging tool of claim 2 or claim 3, wherein the magnetic source is located adjacent a downhole logging tool storage rack of the drilling rig.
5. The downhole logging tool of any one of claims 2 to 4, wherein the magnetic switch is normally open and is closed by the magnetic field of the magnetic source.

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6. The downhole logging tool of any one of claims 2 to 5, wherein the magnetic switch is a reed sensor that is part of an automatically actuated switch circuit that includes at least one transistor.
7. The downhole logging tool of claim 6, wherein the transistor is electrically connected to the power source and the reed sensor switches the transistor to selectively provide power to the electronic components.
8. The downhole logging tool of any one of the preceding claims, wherein the electronic components include a data transfer system in communication with the sensors.
9. The downhole logging tool of any one of the preceding claims, wherein the sensors comprise radial measurement sensors that conduct measurements of the walls of the borehole.
10. The downhole logging tool of any one of the preceding claims, wherein the sensors of the downhole logging tool further comprise a temperature sensor, a resistivity sensor, and/or a natural gamma sensor.
11. The downhole logging tool of claim 10, wherein the resistivity sensor is an inductive conductivity sensor.
12. The downhole logging tool of claim 11, wherein the inductive conductivity sensor is a dual coil inductive conductivity sensor or a coil-focused inductive conductivity sensor.
13. The downhole logging tool of any one of the preceding claims, wherein the underwater chassis comprises a mating portion that releasably secures to a corresponding mating portion of the seafloor drilling rig.

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14. The downhole logging tool of claim 13, wherein the mating portion includes a latch head to mate the downhole logging tool to a wireline system.

15. The downhole logging tool of claim 13, wherein the mating portion includes an adapter to mate the downhole logging tool to a drill string.

16. The downhole logging tool of any one of the preceding claims, wherein the power system comprises a battery.

17. The downhole logging tool of claim 16, wherein the battery is rechargeable and the power system further comprise a battery charging system.

18. The downhole logging tool of claim 17, wherein the battery charging system charges the batteries inductively from the seafloor drilling rig.

19. A seafloor drilling rig comprising a downhole logging tool as claimed in any one of claims 1 to 18.

20. A system of utilising a downhole logging tool in seafloor drilling operations comprising:

a downhole logging tool, for traversing a seafloor borehole, with a power system, sensors, and an automatically actuated switch, wherein the sensors include at least a conductivity sensor and a magnetic susceptibility sensor and wherein the automatically actuated switch selectively provides power from the power system to sensors of the downhole logging tool;

the automatically actuated switch being configured to activate the downhole logging tool when leaving a designated portion of a seafloor drilling rig and deactivate the downhole logging tool when entering the designated portion of the seafloor drilling rig.

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21. A method of utilising a downhole logging tool in seafloor drilling operations comprising the steps of:

- selecting a downhole logging tool to traverse a seafloor borehole;
- manoeuvring the selected downhole logging tool from a designated portion of a seafloor drilling rig; and
- automatically actuating an automatically actuated switch of the downhole logging tool to activate the downhole logging tool when leaving the designated portion of a drilling rig and to deactivate the downhole logging tool when entering the designated portion of the seafloor drilling rig.

22. The method of claim 21, wherein the method further comprises the steps of:

- connecting the downhole logging tool to a wireline;
- lowering the downhole logging tool down the seafloor borehole through a drill string;
- seating the downhole logging tool in a receiving portion of the lowermost drill string;
- disconnecting and retracting the wireline; and
- conducting measurements on the downhole tool as the drill string is removed from the borehole.

23. The method of claim 21 or claim 22, wherein the downhole logging tool has sensors including at least a conductivity sensor and a magnetic susceptibility sensor.

24. The method of any one of claims 21 to 23, wherein the downhole logging tool conducts radial measurements of walls of the borehole.

25. The method of any one of claims 21 to 24, wherein the downhole logging tool is a downhole logging tool as claimed in any one of claims 1 to 18.

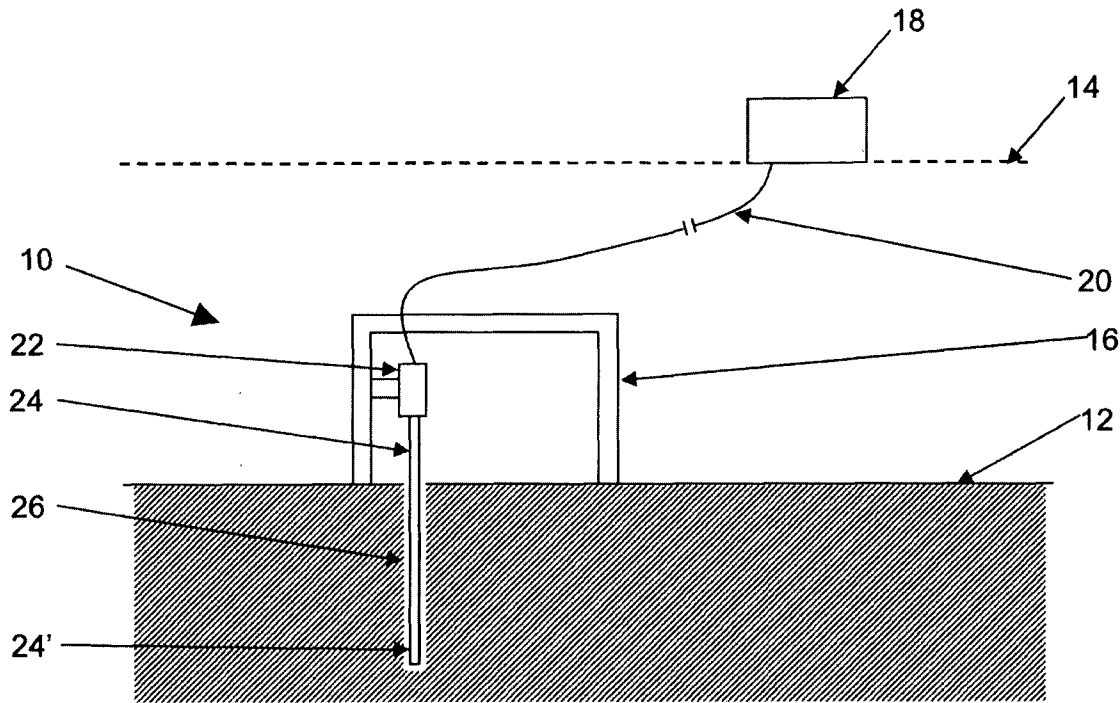


FIGURE 1

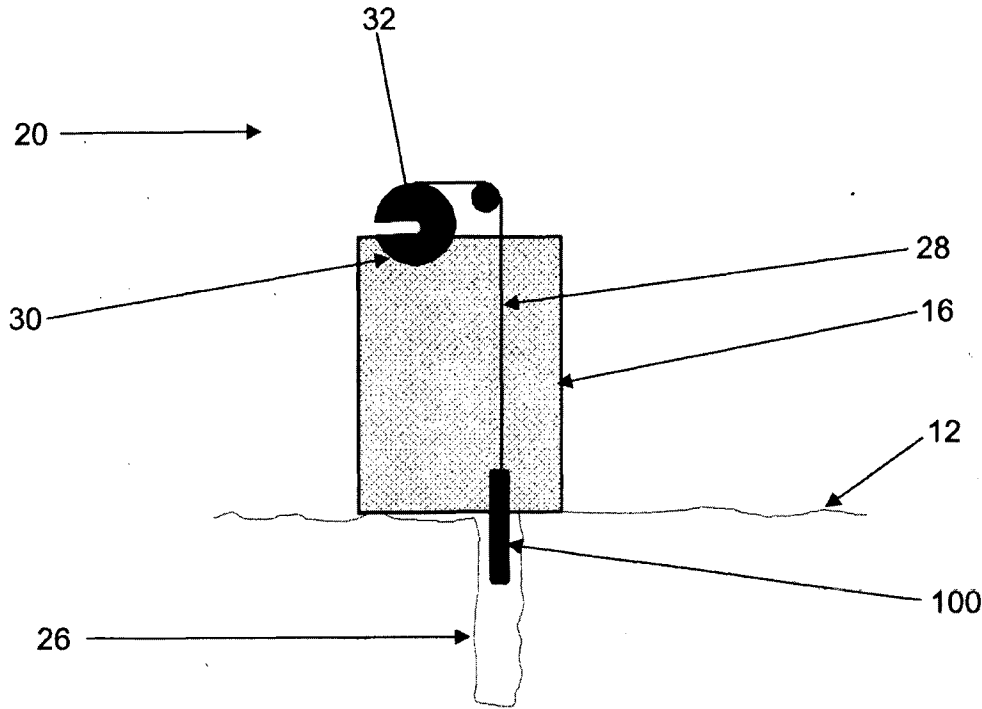


FIGURE 2

- 2/6 -

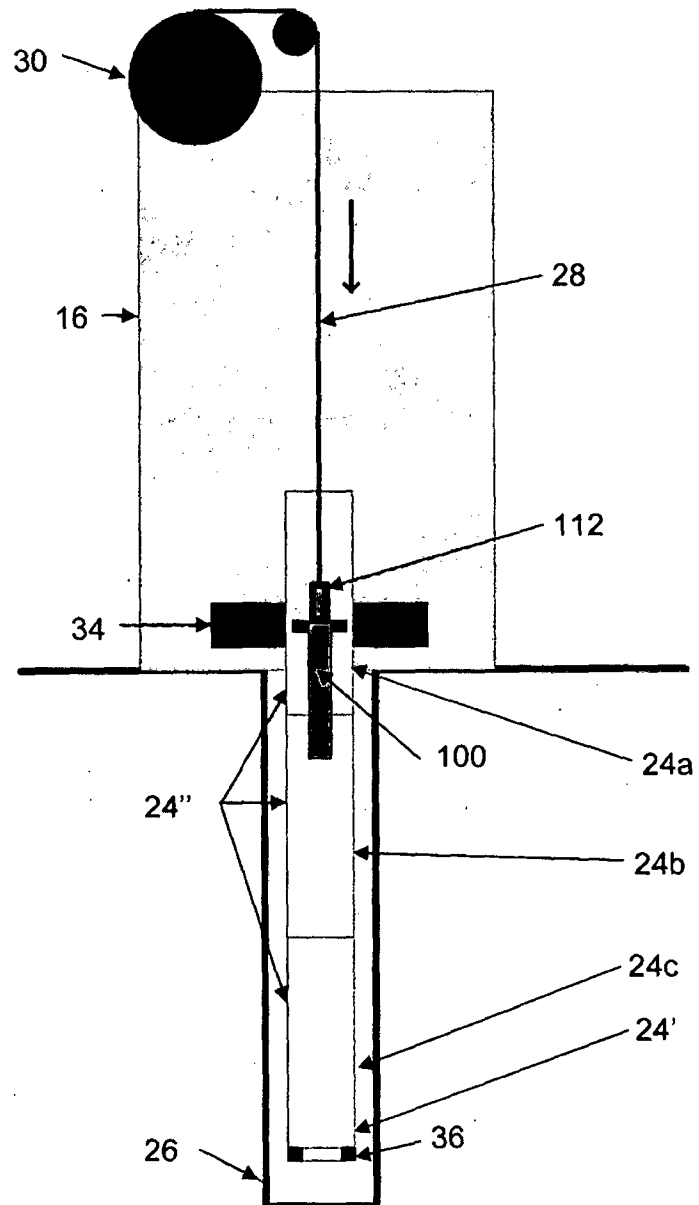


FIGURE 3a

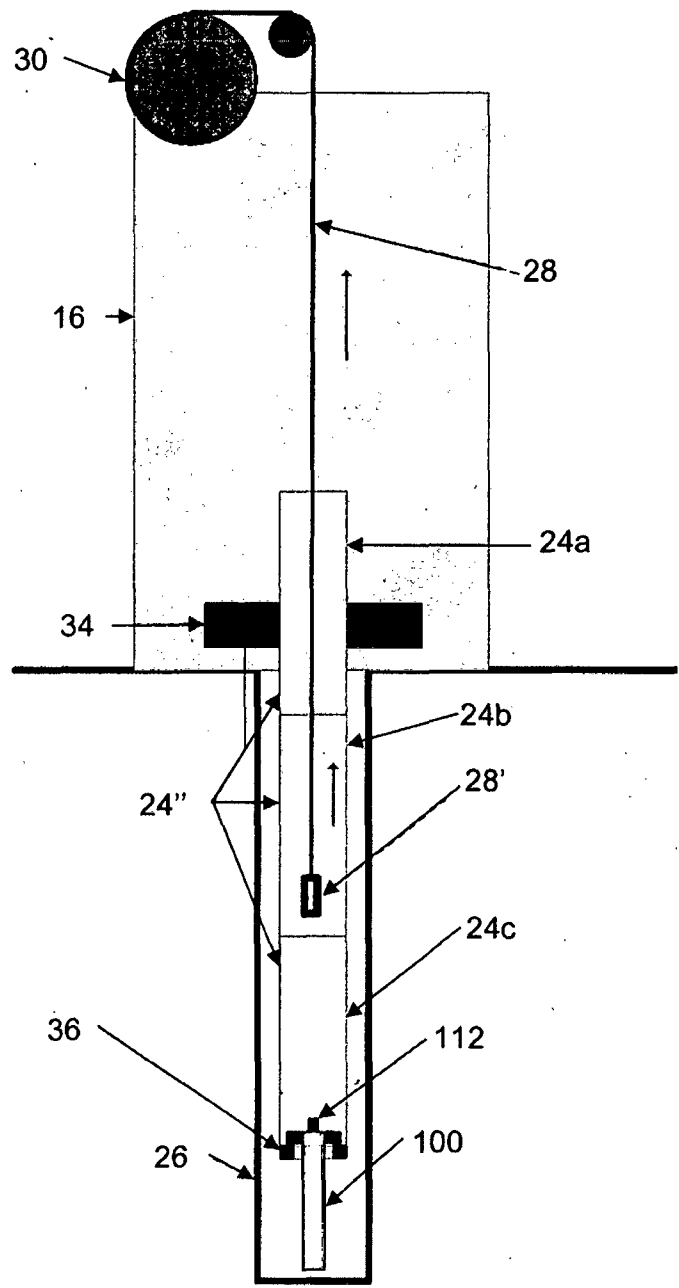


FIGURE 3b

- 4/6 -

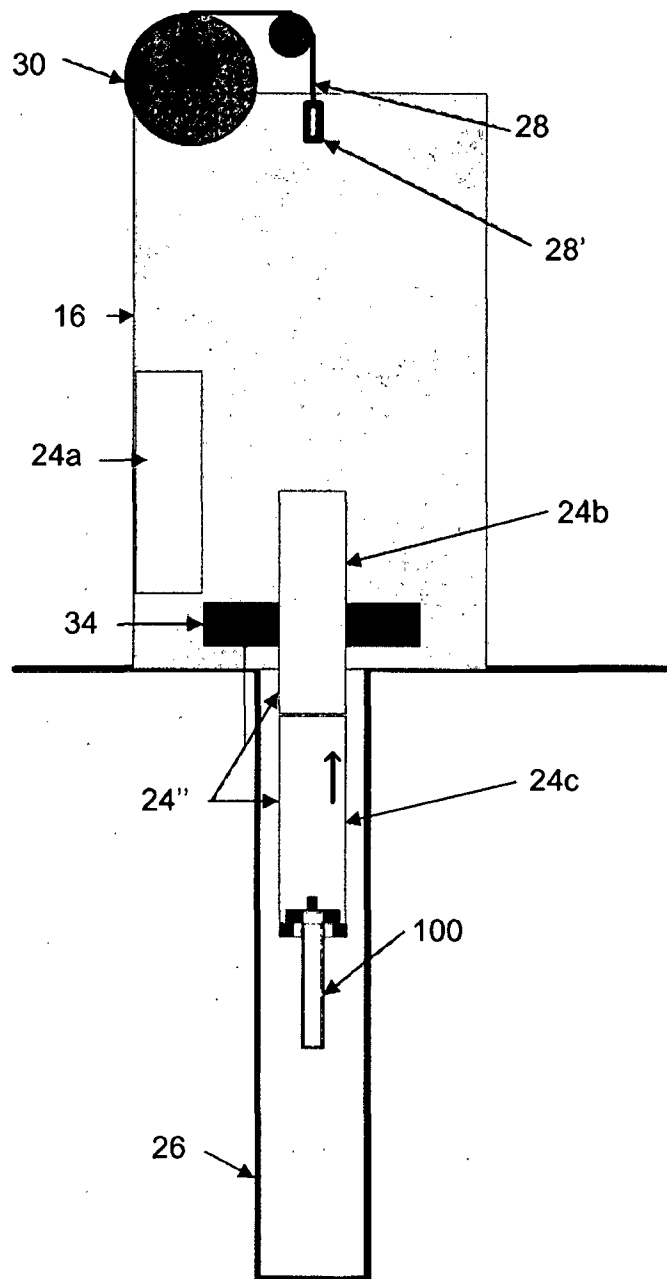


FIGURE 3c

- 5/6 -

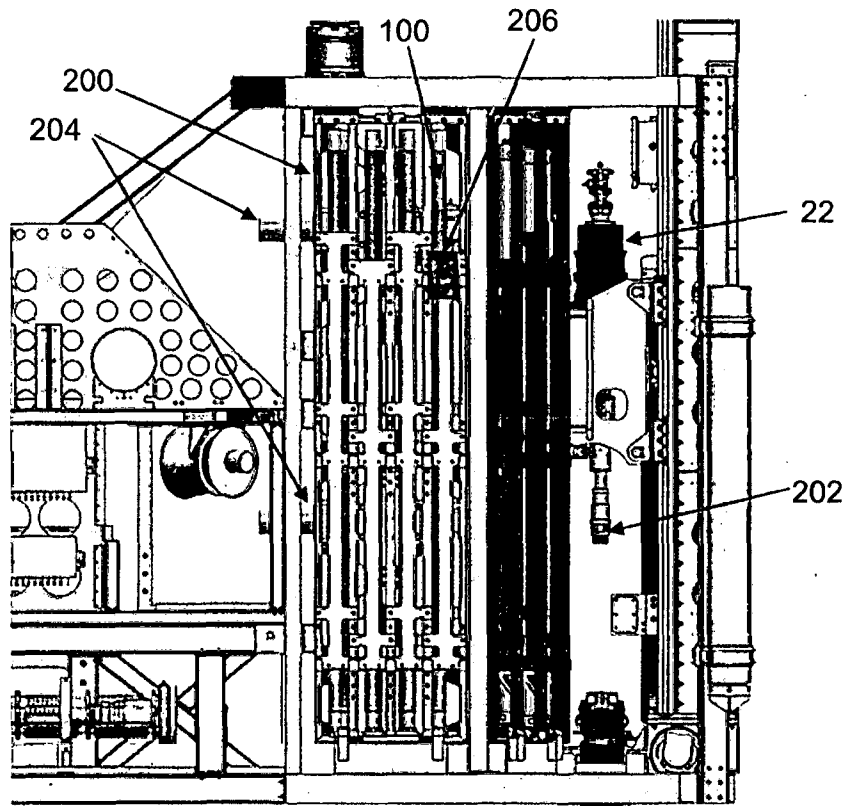


FIGURE 4

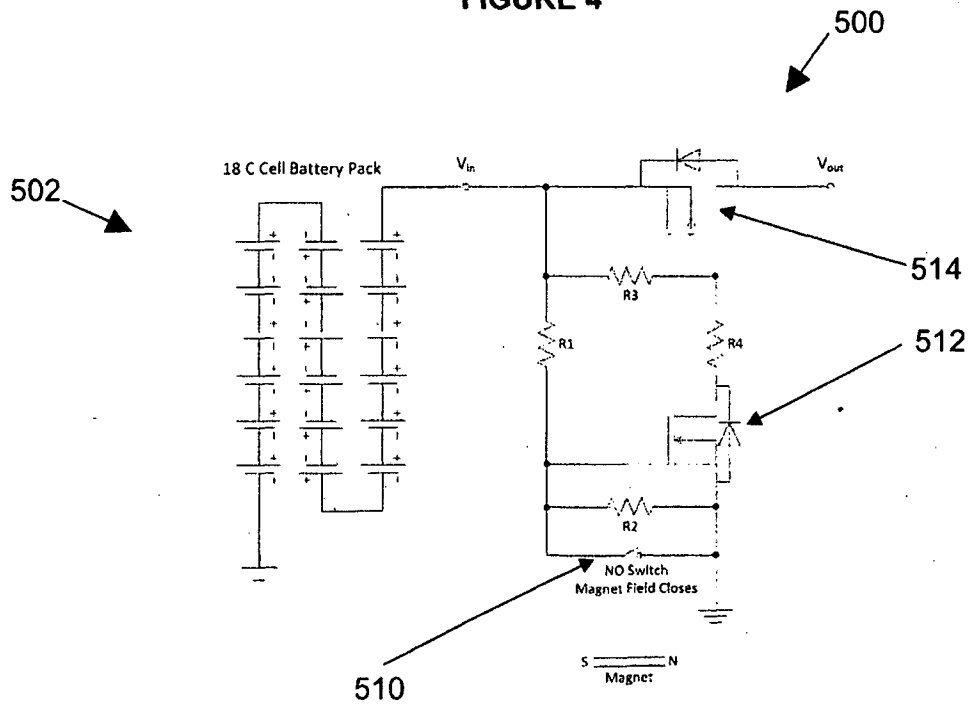


FIGURE 5

- 6/6 -

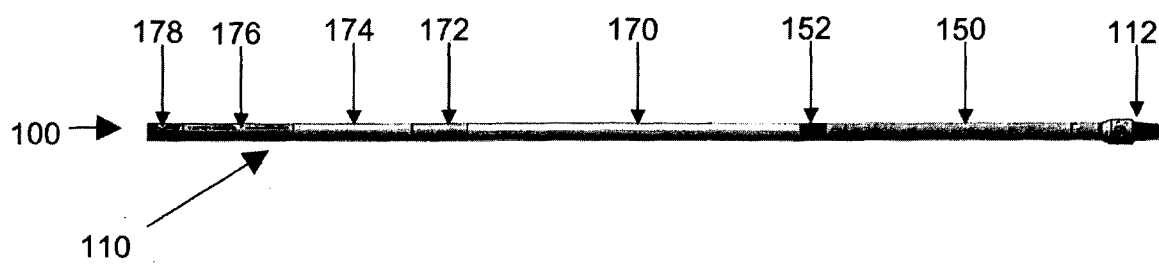


FIGURE 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2013/000625

A. CLASSIFICATION OF SUBJECT MATTER

E21B 47/001 (2012.01) E21B 19/14 (2006.01) E21B 33/076 (2006.01) E21B 41/04 (2006.01) G01N 33/24 (2006.01) G01V 3/18 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

- 1) WPI & EPODOC: IPC & CPC E21B 47/001 and KEYWORDS down hole, well, logging, survey, subsea, under water, switch, automatic, battery, power, magnetic, conductivity, and similar terms.
- 2) WPI & EPODOC: IPC & CPC G01V 3/18 - 3/34, G01N 33/24 and KEYWORDS down hole, well, magnetic, conductivity, subsea, under water, and similar terms.
- 3) EPOQUE full text English language database: IPC E21B and KEYWORDS subsea, under water, logging, tool, switch, power, and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search
1 July 2013

Date of mailing of the international search report
01 July 2013

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Telephone No. 0262256116

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2013/000625
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2006/076758 A1 (BENTHIC GEOTECH PTY LTD) 27 July 2006 Page 11 line 384 - page 12 line 420, page 10 lines 332, 355, 386, and figures 1, 2, and 4 Page 11 line 384 - page 12 line 420, page 10 lines 332, 355, 386, and figures 1, 2, and 4	1 - 13, 15 - 18, 21 14, 19, 20, 22 - 25
A	US 3758847 A (DOWLING) 11 September 1973 Abstract and figure 2	1 - 25
A	US 4551681 A (SEELEY) 05 November 1985 Abstract and figure 1	1 - 25
Y	WO 2002/020938 A1 (OFF-SHORE & MARINE AS) 14 March 2002 Page 15 line 11 - page 20 line 18, page 5 line 12, page 6 lines 17 - 28, and figure 1	14
A	GB 2365895 B (SCHLUMBERGER HOLDINGS LIMITED) 26 June 2002 Whole document, in particular page 4	1 - 25
Y	US 7600570 B2 (HAUGHOM) 13 October 2009 Abstract and figure 2	19 - 25
Y	US 2010/0096187 A1 (STORM, Jr. et al.) 22 April 2010 Whole document, in particular paragraphs 24 - 33 and figures 1 - 1C	22
A	EP 2415961 A1 (VETCO GRAY CONTROLS LIMITED) 08 February 2012 Paragraphs 14 - 16 and figure 2	1 - 25

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a)

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

See Supplemental Box for Details

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

Supplemental Box**Continuation of: Box III**

This International Application does not comply with the requirements of unity of invention because it does not relate to one invention or to a group of inventions so linked as to form a single general inventive concept.

This Authority has found that there are different inventions based on the following features that separate the claims into distinct groups:

- Claims 1-20 are directed to an apparatus and associated system including a downhole logging tool comprising an underwater chassis having a power system and electronic components including sensors, where the sensors include a conductivity sensor and a magnetic susceptibility sensor, an automatically actuated switch that selectively provides power from the power system to the sensors, wherein the automatically actuated switch is actuated to remove power from the electronic components when the downhole logging tool is located in a designated portion of a seafloor drilling rig and to provide power to the electronic components when the downhole logging tool is not located in the designated portion of a sea floor drilling rig.
- Claims 21 - 25 are directed to a method of utilising a downhole logging tool comprising the steps of selecting a downhole logging tool, manoeuvring the selected tool from a designated portion of a seafloor drilling rig, and automatically actuating an automatically actuated switch to activate the logging tool when leaving the designated portion of a drilling rig and to deactivate the logging tool when entering the designated portion of the seafloor drilling rig.

PCT Rule 13.2, first sentence, states that unity of invention is only fulfilled when there is a technical relationship among the claimed inventions involving one or more of the same or corresponding special technical features. PCT Rule 13.2, second sentence, defines a special technical feature as a feature which makes a contribution over the prior art.

When there is no special technical feature common to all the claimed inventions there is no unity of invention.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. The only feature common to all of the claimed inventions and which provides a technical relationship among them is the apparatus and associated method of use of a downhole logging tool comprising an automatically actuated switch to activate the logging tool when leaving a designated portion of a drilling rig and to deactivate the logging tool when entering the designated portion of the seafloor drilling rig.

However this feature does not make a contribution over the prior art because it is disclosed in:
D1 as discussed in Box V.

Therefore in the light of this document this common feature cannot be a special technical feature. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a posteriori*.

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2013/000625	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
WO 2006/076758 A1	27 Jul 2006	AU 2005325649 B2	17 Jun 2010
		BR PI0519848 A2	17 Mar 2009
		BR PI0519848 B1	19 Feb 2013
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		WO 0220938 A1	14 Mar 2002
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		AU 2004218672 A1	04 Nov 2004
		AU 2004218672 B2	01 Nov 2007
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		GB 2365894 B	04 Jun 2003
		GB 2367079 A	27 Mar 2002
		GB 2367079 B	18 Dec 2002
		GB 2365895 A	27 Feb 2002

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.
Form PCT/ISA/210 (Family Annex)(July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2013/000625	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
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		GB 2375785 B	14 May 2003
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		US 7779916 B2	24 Aug 2010
		US 2002066556 A1	06 Jun 2002
		US 8171989 B2	08 May 2012
		US 2011203803 A1	25 Aug 2011
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			
Form PCT/ISA/210 (Family Annex)(July 2009)			

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2013/000625	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
US 7600570 B2	13 Oct 2009	CA 2609027 A1	11 Jan 2007
		EP 1899570 A1	19 Mar 2008
		NO 20053279 A	08 Jan 2007
		NO 323508 B1	29 May 2007
		RU 2007119129 A	27 Nov 2008
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		US 7600570 B2	13 Oct 2009
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		CA 2777471 A1	28 Apr 2011
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		EP 2491225 A2	29 Aug 2012
		MX 2009002929 A	22 Jul 2009
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		US 2008066961 A1	20 Mar 2008
		US 7708057 B2	04 May 2010
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		US 2010096187 A1	22 Apr 2010
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		EP 2415962 A1	08 Feb 2012
		EP 2463476 A1	13 Jun 2012
		EP 2520759 A1	07 Nov 2012
		SG 177877 A1	28 Feb 2012
		US 2012032523 A1	09 Feb 2012
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

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INTERNATIONAL SEARCH REPORT Information on patent family members		International application No. PCT/AU2013/000625	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001. Form PCT/ISA/210 (Family Annex)(July 2009)			