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BORE HOLE LOGGING APPARATUS
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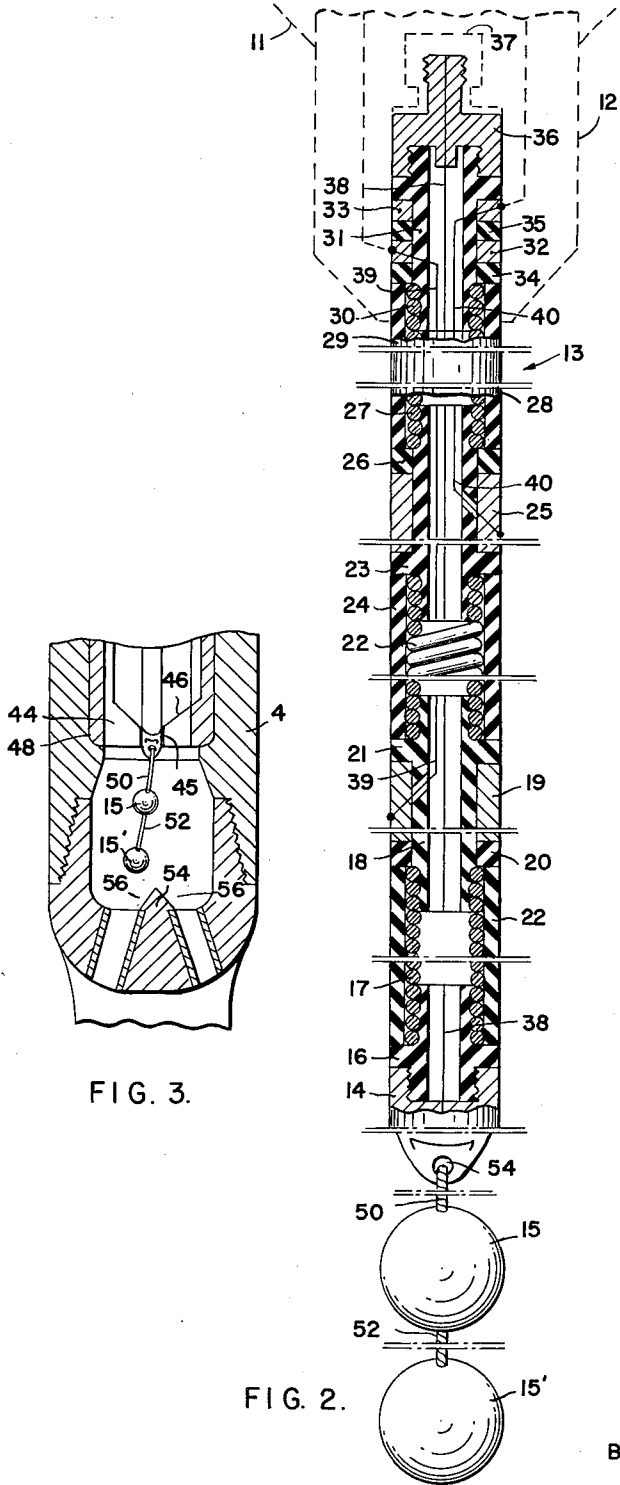
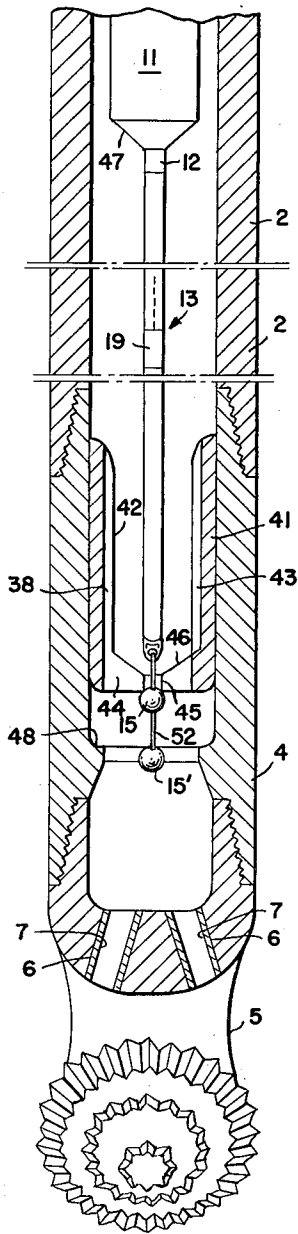


FIG. 1.

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BORE HOLE LOGGING APPARATUS

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9 Claims. (Cl. 324—10)

This invention relates to bore hole logging methods and apparatus and particularly to methods which involve the location of recording apparatus within a hole.

Conventional methods of well logging, whether of electrical or other types, involve the absence of the drill stem during the logging operation. This has two serious drawbacks in that not only must special time be consumed in running the well log, during which time the drill stem must be out of the hole, but after a period of drilling, due to the fact that the drill stem must be removed, there is inevitably a delay before the new part of the hole may be logged, during which delay there occurs invasion of the formation by drilling liquid. Since the drilling liquid has physical properties of its own, it may, by penetration of porous layers, greatly change their properties so as to interfere with their detection. For example, in the case of electrical logging, the conductivity of the liquid will effect changes in the apparent conductivity of the formations; and in the case of acoustic logging the absorption and velocity of sound will be changed, etc.

Proposals have been made to effect electrical logging by using the drill bit or one or more other parts of the drill stem as logging electrodes. In line with this it has been proposed to supply special drill stem tubing containing one or more conductors which are electrically connected in the assembly of the drill stem and extend to recording apparatus at the surface. The use of such an arrangement has been found to be impractical because of high cost and wear.

Proposals have also been made to support one or more electrodes on wire lines to be dropped below a core bit into the lower portion of a hole from which the bit has been raised. This procedure has also proved impractical inasmuch as special handling has been required at the surface, but particularly because core bits are not generally desired for the major drilling activities but are used only for special purposes.

In the application of Mayes and Jones, Serial No. 683,027, filed Sept. 10, 1957, and of Bennett, Chaney, Jones and Mayes, Serial No. 685,717, filed Sept. 23, 1957, of the latter of which this application is in part a continuation, there are disclosed methods and apparatus for logging below a drilling bit, which methods and apparatus avoid the shortcomings referred to above. In accordance with the disclosure of said applications, the logging methods and apparatus may be used when a drill string is in a bore hole and may be used at any time with a minimum of interruption of drilling. Not only may the logging be accomplished just prior to removal of the drill string for the purpose of changing a bit, but the logging may be carried out to be promptly followed by a continuation of drilling. In brief, a self-contained energizing and recording apparatus may be dropped through a drill string in go-devil fashion or may be pumped down therethrough when the drill string has been lifted to only a limited extent from the bottom of the hole to provide a region for reception of an electrode or other logging assembly. The apparatus particularly includes an assembly of a type suitable to pass through the mud flow openings of a jet bit which may be of any of the conventional popular types. Such bits are presently widely used since they effect the carrying away of cuttings and avoid their reworking by the drill. These jet openings are generally at relatively

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small angles with respect to the drill stem axis and a flexible assembly may, accordingly, be projected therethrough to extend beneath the bit. For electrical logging the assembly is an electrode assembly; for acoustic or other logging it may be of suitable type for exposure to the walls of the hole.

The self-contained assembly which is lowered to the vicinity of the bit contains, for electrical logging, not only means for supplying current to the earth, but also means for recording various potentials at the electrodes of the assembly, the recording being desirably, and as disclosed in said prior applications, effected magnetically. As disclosed in said prior applications, in order to insure projection of the assembly through an opening of a jet bit, the bit is modified from conventional form to afford guidance of what may be referred to as a "wand" which is flexible and nevertheless has considerable stiffness to prevent its buckling and to insure that when it is projected it will extend generally lengthwise of the bore hole.

One of the objects of the present invention is to provide an arrangement by the use of which conventional bits may be used without modification. Specifically in accomplishing this end, the wand carries at its lower end one or more balls secured thereto by flexible cords or cables. The approach flow of the mud to the jet openings tends to carry the ball or the lowermost ball of a series into and through one of the mud openings and thereby the wand is guided so that it also will enter such opening without possibly being held up by the interior wall of the bit.

The foregoing and other objects of the invention particularly relating to details of construction and operation will become apparent from the following description read in conjunction with the accompanying drawing, in which:

FIGURE 1 is a sectional view illustrating the lower end of a drill stem, including a jet bit, and the logging assembly in its approach to the position of the bit;

FIGURE 2 is a view, partly in section, showing a typical electrode assembly which may be used; and

FIGURE 3 is a fragmentary sectional view similar to FIGURE 1 but showing a slight modification of a conventional bit to aid in the guidance of a wand to and through a mud passage.

Referring first to FIGURE 1, there is indicated at 2 the lower end of a drill stem which may be considered to be located in the newly drilled portion of a hole, the drill stem having attached to it through the drill collar 4 a jet bit 5 which is illustrated as of the multiple cone rock type though it will be evident that in accordance with the invention any desired type of bit may be used providing either that it has jet passages or a central passage of the type involved in core bits. Under the conditions existing prior to the beginning of logging, the drill stem will have been raised to an extent to permit an electrode assembly to project below the bit free of engagement with the bottom of the hole.

The bit 5 is shown as provided with the usual jet openings 6 which are usually lined by abrasion-resistant tubes 7. Generally the total number of jet holes is equal to the number of cones of a cone type rock bit, there are two such openings in the case of a fish-tail bit, etc. The logging assembly is indicated at 11 and comprises a protective casing capable of withstanding the mud pressures which may be encountered at the bottom of a hole. This casing may be of the same general type as is conventionally used for well surveying instruments. If it is not to be recovered except upon removal of the drill stem, its upper end requires no special structure. If it is to be retrieved from the drill stem prior to the raising of the latter, it may be provided with a conventional spear-head adapted to be engaged by an overshot lowered on a wire line. If it is not to be dropped in go-devil fashion or pumped down through the drill stem, it may be supported

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by a wire line, whereby it may be lowered through the drill stem when drilling stops and whereby it may be retrieved after a logging operation. Electrically, the casing 11 becomes grounded to the drill stem and provides the ground for its enclosed circuitry.

In accordance with the present invention, the protective casing has extending downwardly from its lower end, supported by an adaptor 12, an electrode assembly 13 which will be hereafter referred to as a wand, inasmuch as it is flexible though with sufficient rigidity so that it may be forced downwardly along the wall of a hole without buckling so as finally to extend substantially parallel to the axis of the hole. Depending upon the particular electrode configuration which is desired, the wand may be either relatively short or quite long, being in the latter case upwards of twenty feet in length.

The wand construction is illustrated in detail in FIGURE 2, in which portions which may be of great length are shown broken, the breaks also indicating in some cases repetitions of sections as will be apparent hereafter. It comprises a nose portion 14 which is of metal and constitutes an electrode, which electrode, depending upon the electrical configuration used, may be either a current electrode or a potential electrode. Threaded into the nose 14 is a tubular insulator 16 which is provided with a threaded stem to which is secured the lower end of a tightly wound helical spring 17. Such a spring provides high resistance to direct end thrust, but at the same time provides sufficient flexibility for bending of the wand as it passes through a jet opening or must thereafter deflect to extend downwardly along the wall of a bore hole. As will become evident a series of springs such as 17 desirably provide the major body of the wand, there being interspersed insulated electrodes. The upper end of the spring 17 is threaded to the lower end of a tubular insulator 18 on which is mounted a metallic electrode tube 19, the tube being confined between an insulating washer and a flange 21 forming part of the tube 18. The spring 17 which connects the insulating members 16 and 18 is covered by a flexible insulating tube 22 which may be of rubber or flexible plastic. The type of construction just described is then essentially repeated, there being threaded to the upper end of member 18 another spring 22 which is threaded at its upper end to a further tubular insulator 23, the spring being covered by the flexible insulating tube 24 of rubber or plastic. The tube 23 supports between its flange and a washer 26 another tubular electrode 25. In further continuation upwardly, there is another spring 27 surrounded by a flexible insulating covering 28. The construction may be repeated to provide as many electrodes as desired in the required positions thereof. Finally, the assembly is terminated by the arrangement involving the spring 30 (which may be the same as spring 27 or different) covered by the insulating tube 29. The upper end of spring 30 is threaded to the insulating tube 31 on which are mounted a suitable number of collector rings such as 32 and 33 insulated from each other by insulating washers such as 34 and 35. To the top of the member 31 there is threaded the metallic member 36 which is arranged to be secured as indicated at 37 in a lug contained within the adaptor 12. An insulated wire 38 connects the member 36 to the nose electrode 14, while insulated wires such as 39 and 40 connect the individual collector rings to the electrodes such as 19 and 25.

The electrodes may be of lead or other suitable metal, depending upon the particular electrical system employed. In the case of an electrode employed for pick up of self-potential, the electrode may desirably be of the same metal as the drill stem furnishing a reference so as to minimize any direct potential differences due to the use of different materials.

It will be evident from the foregoing that there is provided an assembly which, except for the limited regions at the electrodes, is flexible and yet has sufficient stiffness

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and resistance to compression so that friction may be overcome during lowering in the bore hole to the end that the wand will extend along the hole and not tend to buckle upon itself. Any desired number of electrodes flush with the outer surface of the wand may be provided and located where desired for the particular configuration involved. It may be noted that the electrodes shown, though they are individually inflexible, are of such short lengths that, from the standpoint of the sinuous path that the wand may be required to follow through a jet bit passage and then along the wall of a hole, the wand as a whole is flexible, though stiff. Other sufficiently short sections of the wand may be inflexible, if desired, with only short flexible joint sections between them. The wand, nevertheless, will, as a whole, be resistant to buckling so that it will extend generally lengthwise of a hole.

Surrounding the lower end of the wand as it is lowered with the casing 11, there is a sleeve member 41 of metal provided with a socket opening 42 for the reception of the lower end of the casing 11. Restricted mud passage grooves 43 are provided in the inner surface of member 41 and communicate with restricted passages 44 at the bottom thereof. This bottom is provided with an opening 45 through which the wand may slide, the wand initially supporting the member 41 by reason of the enlargement provided by the uppermost ball 15. One of the functions of the member 41 is to serve as a weight and guide to maintain the wand 13 in substantially axial relationship with the drill stem during lowering. Another is to provide shock absorption to prevent damage to the apparatus contained within housing 11. The member 41 is provided with a conical seat 46 arranged to be engaged by the conical lower end 47 of the casing 11. An annular ledge 48 within the drill collar 4 is arranged to arrest downward movement of the member 41.

As the assembly comprising the casing 11 the wand 13 and the member 41 is lowered through the drill stem, either by being dropped in go-devil fashion, by being pumped downwardly therethrough by the mud, or by being lowered on a wire line, the member 41 ultimately engages and is arrested by the annular seat 48. Once this occurs, mud flow is restricted by confinement of flow to openings 44 which provide a cross-section substantially provided by the bit openings. Thus a shock absorption results. The lower end of the wand is centralized by the member 41 so that it cannot be held up by pipe joints. The fact that seating has finally occurred will be signaled to the surface by the fact that the pump pressure gauge will show a partial obstruction to free mud flow as the casing 11 enters the seated member 41. Flow of mud is not completely arrested since restricted flow may still continue through the grooves 43. When seating has been accomplished, the wand, and the electrodes thereon, will occupy particular definite positions with respect to the bit, so that their positions within the bore hole will be known. Thereafter, logging is effected by the raising of the drill stem with notation of the times at which the drill stem occupies various positions. The upward motion of the drill stem during logging may be uniform or intermittent, depending upon the length of the hole which is to be logged. If the length to be logged in a single operation is less than the free movement of the drill stem within the derrick without involving removal of sections, the logging may be continuous at a substantially uniform rate. If a greater length is to be logged, involving removal of drill stem sections, there will be interruptions of movement of the electrodes during the removal of successive sections. A depth-time record will, in any event, be made so that the ultimate log may be correlated with depth through time.

In the foregoing general outline of operation reference has not been made to the guidance of the wand through a jet opening, but this will be more fully described in connection with the description of those matters which constitute the invention herein claimed. What has been so far described is essentially what is shown and described in

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the prior applications referred to above. The invention is not specifically limited to any particular type of logging. The logging may be of electrical type as already indicated. However, it may be of other types. It may, for example, be high frequency logging, in which case the wand may carry a radiating coil or may provide spaced coupling capacitances. Radioactive logging may be effected, in which case the wand may contain radiation detecting means. Acoustic logging may also be carried out, in which case the wand may contain either pick up devices only or both pick up devices and means for producing acoustic signals. In any case, the wand is flexible so as to be capable of lateral diversion to pass through jet openings or other non-central openings in a bit.

In the case of electrical logging, any of the many known electrode arrangements and systems may be used. For the so-called resistivity logs these systems involve, in common, an arrangement for producing alternate current flow in the vicinity of the bore hole between one pair of electrodes and other electrodes for picking up potentials. In some cases these electrodes may all be independent. In other cases common electrodes may be used for performing different functions. When self-potential logs are also to be made, the potential may be picked up between electrodes which also function as resistivity electrodes. The invention is broadly applicable to all of the ordinary systems as well as to others which are known but not generally used. As disclosed in said prior applications, a typical system is one in which current is introduced into the earth between one electrode (the lowermost of the wand electrodes) and the drill stem, the latter functioning as an electrode, with the picking up of a pair of resistivity potentials, one between the drill stem and an electrode located above but in the vicinity of the current electrode, and the other between the drill stem and a still higher electrode considerably spaced from the current electrode. The electrodes should be located remote from the lower end of the drill stem when measurements are being made, and consequently the length of wand between the uppermost electrode and its upper end may be many feet, e.g., twenty feet or upwards. Self-potential in this system is picked up between either of the resistivity electrodes just mentioned and the drill stem; in fact, the self-potential may be picked up between the current electrode and the drill stem. Thus the drill stem functions as a reference for all three potentials and also as a current electrode. The recording apparatus associated with the system may be applied to other systems in which there may be more individual separations of electrode functions. It may be remarked that due to the conductive extent of the drill stem the resistance between the drill stem and the earth may be regarded as negligible. As a particular special arrangement to which the invention is obviously applicable, reference may be made to that involving a relatively large number of electrodes to "beam" currents into the formations with the objective of securing indications of particularly thin strata.

The current-supplying and recording apparatus contained within the casing 11 may be of various types and, desirably, may be specifically of the type described in detail in the applications referred to above. Since this apparatus forms no part of the invention herein claimed, so far as its details are concerned, it is not shown herein in detail, and it may be generally stated that it comprises both means for supplying alternating current to the earth and magnetic recording means for providing pulse records serving as measures of the potentials which are picked up. A battery supply is used so that the apparatus is not dependent for its operation on any surface connection.

The present invention is particularly concerned with the arrangement whereby the wand is guided through one of the jet openings in the bit without necessitating departure from conventional bit construction. To this end, the lower end of the wand has secured thereto one or more balls, there being desirably at least two of these as indicated

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at 15 and 15' supported by freely flexible cords or cables 50 and 52, the former being secured in the eye 54 of the nose member 14 of the wand. In the preferred arrangement the spacing between the balls 15 and 15' and between the ball 15 and the nose member 14 of the wand are each somewhat less than the length of the tube located in a jet opening. By reason of this arrangement, the following occurs as the wand approaches the position of the bit 5:

The mud flow occurs at a rapid rate producing high velocity streams through the jet openings. As the ball 15' approaches the upper ends of these openings it is entrapped in one of the streams and enters the upper end of the opening. Due to the fact that it will partially close the opening which it enters, there is a considerable pressure tending to force it through the opening and as a consequence the cord or cable 52 will be tensioned so as to lead the upper ball 15 into the same opening, and this entry will take place before the lowermost ball 15' is ejected from the opening. At the same time the tension exerted through the cord or cable 50 will divert the lower end of the wand toward the same opening and it will be guided into that opening before the ball 15 is ejected. As further lowering takes place the wand due to its substantial stiffness will be pushed through the opening by the descending assembly. The arrangement just described has been found to be highly reliable in insuring that the flexible wand will enter one of the openings. It is, of course, immaterial which of the openings it enters since in the case of jet bits the openings are directed free of the bit elements such as the cones of a cone-type rock bit. After passage through the openings the wand will ordinarily engage the wall of the hole but due to its flexibility it will bend so as to move freely downwardly along the wall, its stiffness being sufficient to prevent any buckling and also sufficient to prevent its being diverted upwardly by the flow of mud upwardly about the bit and drill stem. The actions occurring upon seating of the casing 11 and thereafter during logging have already been described.

It will be evident from the foregoing that reliable projection of the wand may be secured without any modification of a conventional bit such as that illustrated in FIGURE 1. However, if desired, the bit may be very slightly modified from conventional form by extending, during its formation, the portion 54 as illustrated in FIGURE 3 so as to furnish a set of conical or other converging openings 56 communicating with the jet passages. With such an arrangement it is essentially impossible that there can occur any hanging up of the wand on a portion of the bit between the passages.

It will be evident that the invention may be embodied in various forms without departing from its scope as defined in the following claims.

What is claimed is:

1. Well logging apparatus comprising an assembly of recording means and a flexible elongated member adapted to move downwardly through a drill stem carrying a bit, which bit has at least one opening through which said member may pass, said member comprising at least one logging element responsive to conditions existing along a bore hole and electrical means for transmitting signals from said element to said recording means, and means connected to the lower end of said member and arranged to be deflected by fluid flow into said bit opening, thereby to guide the lower end of said member into the opening.

2. Apparatus according to claim 1 in which said member has substantial stiffness tending to prevent its buckling.

3. Well logging apparatus comprising a flexible elongated member adapted to move downwardly through a drill stem carrying a bit, which bit has at least one opening through which said member may pass, said member comprising at least one logging element responsive to

conditions existing along a bore hole and means for providing electrical connection from said logging element through the upper portion of said member, and recording means adapted to move downwardly through a drill stem with said member and connected to said means for providing electrical connection to receive and record signals from said logging element, said member being arranged to be deflected by fluid flow into and through said bit opening.

4. Apparatus comprising a hollow drill stem carrying at its lower end a drill bit of a type having at least one mud passage extending downwardly and non-concentric with the drill stem axis, logging apparatus arranged to move downwardly through the drill stem and including a housing and an elongated member supported thereby and extending downwardly therefrom, said member carrying a logging element requiring for operation projection below the bit, said member having flexibility such that it may deflect from parallelism with the drill stem axis to pass through said mud passage and extend downwardly in substantially straight condition along a bore hole below the bit, said drill stem containing means for holding the housing in a predetermined position relative to the bit so that logging may be effected by moving the drill stem lengthwise of the bore hole to cause said member to traverse predetermined portions thereof, at least the lower end of said member being freely flexible and thereby subject to entrainment in flow of fluid through said mud passage to be carried therethrough by such flow.

5. Apparatus comprising a hollow drill stem carrying at its lower end a drill bit of a type having at least one mud passage extending downwardly and non-concentric with the drill stem axis, logging apparatus arranged to move downwardly through the drill stem and including a housing containing log recording means and an elongated member supported thereby and extending downwardly therefrom, said member carrying a logging element connected to said log recording means to provide signals thereto and requiring for operation projection below the bit, said member having flexibility such that it may deflect from parallelism with the drill stem axis to pass through said mud passage and extend downwardly in substantially straight condition along a bore hole below the bit, said drill stem containing means for holding the housing in a predetermined position relative to the bit so that logging may be effected by moving the drill stem lengthwise of the bore hole to cause said member to traverse predetermined portions thereof, at least the lower end of said member being freely flexible and thereby subject to entrainment in flow of fluid through said mud passage to be carried therethrough by such flow.

6. A method of logging a bore hole after cessation of drilling by the use of a rotary bit carried by a hollow drill stem, the bit being of a type having at least one mud passage extending downwardly and non-concentric with the drill stem axis, which method comprises lowering through the drill stem, after cessation of drilling, logging apparatus including an elongated flexible member carrying a logging element while providing a flow of fluid downwardly through the drill stem to entrain the lower end of said member to guide it through such mud passage, and to a predetermined position relative to the bit, when the bit is raised from the bottom of the hole, thereby to effect projection of said logging element below the bit, and then progressively moving the drill stem to cause

said element to traverse a portion of the hole to effect logging.

7. A method of logging a bore hole after cessation of drilling by the use of a rotary bit carried by a hollow drill stem, the bit being of a type having at least one mud passage extending downwardly and non-concentric with the drill stem axis, which method comprises lowering through the drill stem, after cessation of drilling, logging apparatus including a housing containing log recording means and an elongated flexible member supported thereby and carrying a logging element connected to said log recording means to provide signals thereto, while providing a flow of fluid downwardly through the drill stem to entrain the lower end of said member to guide it through such mud passage, and to a predetermined position relative to the bit, when the bit is raised from the bottom of the hole, thereby to effect projection of said logging element below the bit, and then progressively moving the drill stem to cause said element to traverse a portion of the hole to effect logging.

8. A method of logging a bore hole after cessation of drilling by the use of a rotary bit carried by a hollow drill stem, the bit being of a type having at least one mud passage extending downwardly and non-concentric with the drill stem axis, which method comprises lowering through the drill stem, after cessation of drilling, logging apparatus including an elongated flexible member carrying a logging element while providing a flow of fluid downwardly through the drill stem to entrain the lower end of said member to guide it through such mud passage, and to a predetermined position relative to the bit, when the bit is raised from the bottom of the hole, thereby to effect projection of said logging element below the bit, and then progressively moving said element to traverse a portion of the hole to effect logging.

9. A method of logging a bore hole after cessation of drilling by the use of a rotary bit carried by a hollow drill stem, the bit being of a type having at least one mud passage extending downwardly and non-concentric with the drill stem axis, which method comprises lowering through the drill stem, after cessation of drilling, logging apparatus including a housing containing log recording means and an elongated flexible member supported thereby and carrying a logging element connected to said log recording means to provide signals thereto while providing a flow of fluid downwardly through the drill stem to entrain the lower end of said member to guide it through such mud passage, and to a predetermined position relative to the bit, when the bit is raised from the bottom of the hole, thereby to effect projection of said logging element below the bit, and then progressively moving said element to traverse a portion of the hole to effect logging.

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