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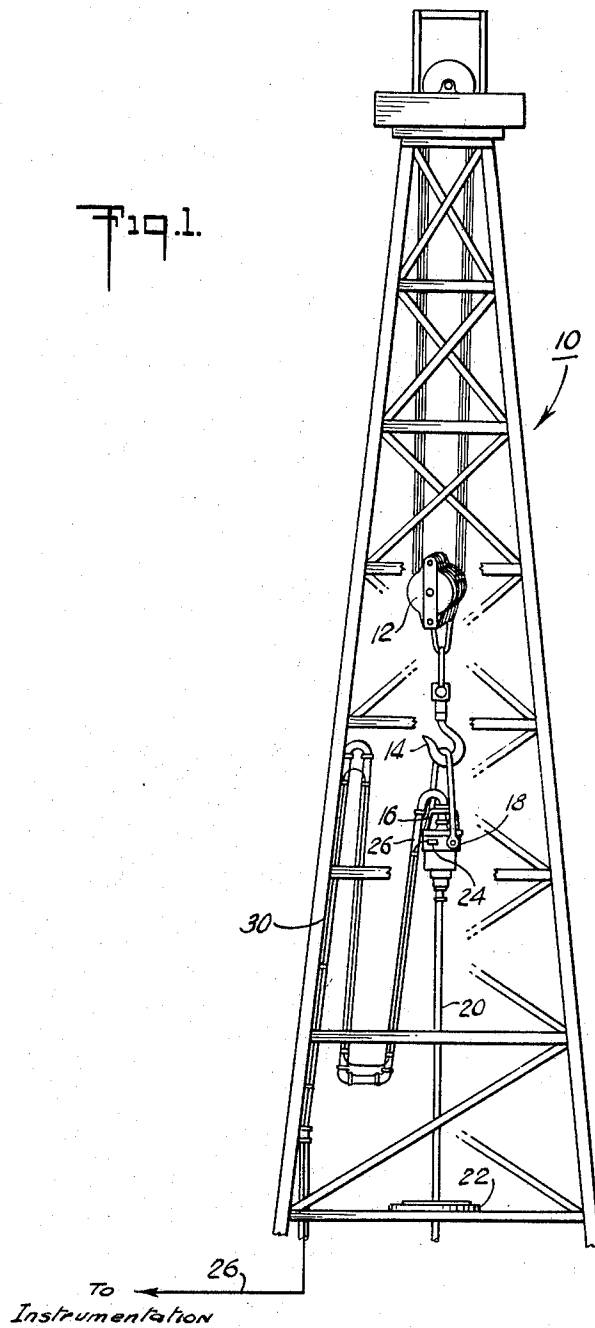
F. H. REDWINE ET AL

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APPARATUS FOR LITHOLOGIC LOGGING OF UNDERGROUND
FORMATIONS BY ACOUSTIC VIBRATIONS

Filed Jan. 22, 1968

2 Sheets-Sheet 1



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Fig. 2.

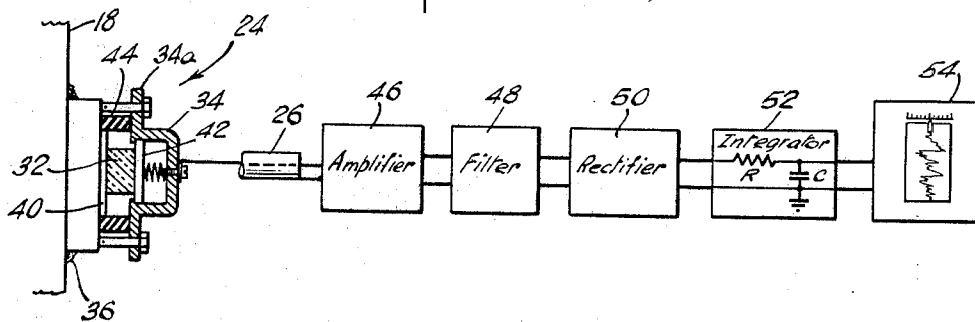
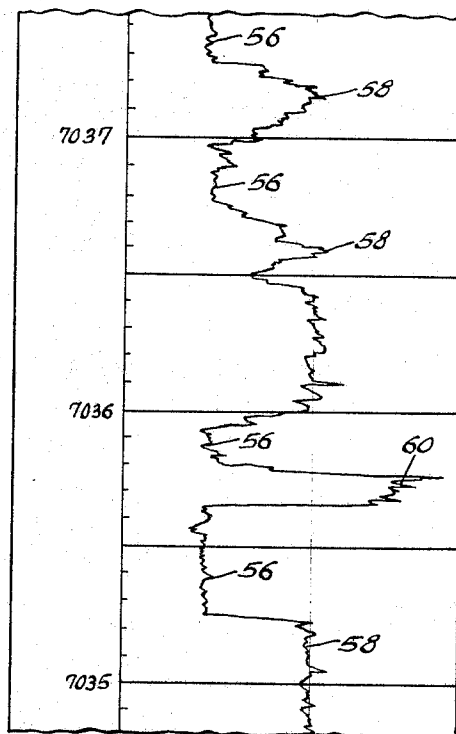


Fig. 3.



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1

2

3,486,375 APPARATUS FOR LITHOLOGIC LOGGING OF UNDERGROUND FORMATIONS BY ACOUSTIC VIBRATIONS

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14 Claims

ABSTRACT OF THE DISCLOSURE

Lithology logging apparatus including a transducer bonded to the drilling rig to generate electrical signals in accordance with the vibrations of the drill string, with means to modify the signals by attenuating at least the frequency components below about 10 kHz., rectifying them, and integrating them at a time constant on the order of 2.5 seconds, and means for visually presenting the modified signals.

The present invention relates to logging apparatus for use in analysis of the lithology of the underground formations being penetrated by the drill bit of a rotary drilling rig.

It is well known in the petroleum industry that the driller and geologist are constantly seeking new and more reliable means for ascertaining during the drilling of a well the nature of the strata traversed by the borehole so that they will know when geologic horizons possibly productive of oil or gas are being reached, and the drilling may be interrupted and tests conducted to determine whether production is in fact feasible. It has accordingly been a common practice to maintain a lithologic log of the drill cuttings. However, cuttings logs are subject to the recognized disadvantage that it is difficult, if not impossible, to determine with certainty the depths from which the respective samples of cuttings originated, due for example, to the mixing of the cuttings in the turbulent stream of drilling mud and the inaccuracy in calculating the "lag time" required for the mud to travel from the bottom of the borehole up the irregular annular space between the drill string and the sidewall of the borehole to the top of the well, and in estimating the "slippage" of the cuttings relative to the mud stream. Moreover, in deep wells it may take as long as an hour or more for the cuttings to travel from the bottom to the surface, so that the drilling may have progressed a substantial depth before analysis is possible.

Other well-known methods of determining the nature of the formations traversed by the borehole, such as electric logs, radiation logs, sonic logs, sidewall samples, and so on, all involve the interruption of the drilling operation, and most also involve a "round trip" of the drill string—that is, removing the drill string from and subsequently replacing it in the borehole, section by section, so that an analytical sonde may be lowered into the borehole on a wire line. This, of course, means substantial and expensive "down time" for the drilling rig. It also introduces a possible element of error due to lack of proper correlation between the depths as measured by the driller and those indicated by the wireline device.

It has previously been hypothesized that various rock formations generate characteristic acoustic vibrations upon being broken by a drill bit and that, by detecting and analyzing such vibrations, the nature of the formations may be ascertained even as they are being drilled. However, heretofore this hypothesis has not advanced beyond the theoretical or speculative stage and no practical and reliable system has yet been proposed for detect-

ing the vibrations at the surface and presenting them in such manner as to permit determination of the lithology of the formations penetrated.

We have now developed practical apparatus for detecting the acoustic vibrations produced by drilling underground formations, for converting such vibrations into fluctuating signals and for so modifying such signals and recording them in a form susceptible of ready and reliable analysis to determine the lithology of the source formations. Thus, we have confirmed the aforementioned hypothesis and have made available to the driller and geologist for the first time a practical tool permitting substantially instantaneous determination of lithology during the progress of drilling.

In the drawings:

FIGURE 1 is a somewhat diagrammatic illustration of a typical rotary drilling rig, showing a detecting device forming an element of an illustrative embodiment of the invention fastened to the swivel which rotatably supports the drill string.

FIGURE 2 is a schematic diagram of an illustrative electrical circuit which converts the signals produced by the detecting device to intelligible form and records them.

FIGURE 3 illustrates a typical log as produced by the apparatus of FIGURES 1 and 2.

The typical drilling rig diagrammatically illustrated in FIGURE 1 includes a derrick 10 with a draw works (not shown) supporting a travelling block 12 with a depending hook 14 engaging the bail 16 of a swivel 18 which rotatably supports the drill string. The top joint of the drill string is a square-section "kelly" 20 which is driven by the rotary table 22.

Fastened to the outer face of the swivel 18 is a transducer 24 which converts the mechanical vibrations of the drill string and swivel into electrical signals which are conducted to the associated instrumentation in a mobile laboratory near the drilling rig, through an electrical cable 26, for example a coaxial cable, which may be taped along the rotary hose 28 and the stand pipe 30 so as to be out of the way of operations around the rig.

The transducer 24 may, for example, be a piezoelectric crystalline material, such as a ceramically fused and ground wafer of barium titanate or lead zirconium titanate, or a quartz or tourmaline crystal, having a resonance frequency between 150 and 500 kHz., for example, 183 kHz. The crystal may be bonded directly to the swivel 18, for example by means of an epoxy adhesive.

However, in FIGURE 2, a preferred detachable mounting arrangement is shown, in which a piezoelectric crystal 32 is mounted in a recessed support member 34 of insulating material, such as a thermosetting resin, which is removably fastened to a mounting plate 36 welded or otherwise bonded to the swivel 18, by means of screws 38 extending through the circumferential flange 34a of the support member 34 and threaded into the mounting plate 36. The inner face of the crystal 32 abuts the outer surface of a fixed electrode 40 formed integrally with or brazed to the mounting plate 36 while its outer face is engaged by a movable electrode 42 mounted in the recess of the mounting plate 36 and urged outwardly thereof by a coil compression spring connected at its inner end to the movable electrode and at its outer end to a terminal screw 42 extending through the outer wall of the support member. A gasket 44 of resilient material, such as rubber or neoprene, is compressed between the flange 34a and the mounting plate 36 to seal the crystal from moisture and dirt. The inner conductor 26a of the coaxial cable 26 is connected to the terminal screw 42. The shield braid 26b may, if desired, be secured to a terminal screw threaded into the mounting plate 38 and

thus be conductively connected to the fixed electrode 40, or it may be left ungrounded at this end to obviate the possibility of difficulty due to a ground loop.

As will be understood, the mechanical vibrations of the swivel 18 resulting from the drilling operation are transmitted to the crystal 32 through the fixed electrode 40, causing the crystal to generate an electrical voltage varying in accordance to such vibrations, and this electrical voltage is picked up by the electrodes 40 and 42 and conveyed through the cable 26 to the electrical modifying and recording apparatus. As shown in FIGURE 2, this apparatus includes an amplifier 46 which increases the amplitude of the electrical voltage to a usable value. The amplified signal is passed through a filter 48 which limits the range of frequencies therein.

We have found that in order to reduce the background electrical "noise" produced by local vibrations of the drilling rig due, for example, to operation of the rotary drive motor, drive train and rotary table, the mud pumps, etc., as well as to vibrations of the swivel and drill string produced by friction of the swivel bearings, by the pulsating flow of drilling mud, by rubbing of the pipe against the sidewalls of the borehole, and so on, the lower frequency components of the signal, for example, all those below a frequency on the order of 10 to 30 kHz., should be attenuated. Preferably, but not necessarily, the filter may also attenuate higher frequency components above an upper cutoff frequency dependent upon the type of bit being used. Where a conventional tri-cone rock bit is used, it has been found that a pass band of about 30 to 40 kHz. may be used effectively. Where a "button bit"—i.e., a multi-cone bit having buttons of a hard material such as tungsten carbide welded to the roller cones in place of the usual integral projecting teeth—is used, a higher cutoff frequency to provide a pass band of about 30 to 130 kHz. has been found more advantageous, although the lower cutoff frequency may be reduced as low as 10 kHz. without intolerable background effects.

The modified signals appearing at the output of the filter 48 are fed first to a rectifier 50, for example, a silicon diode, which converts the high frequency alternating current to pulsating direct current, and then to an integrator circuit 52, having a time constant between 0.25 and 100 seconds, for example a conventional R-C integrator circuit incorporating a 2,500-ohm resistor and a 100-microfarad condenser, to give a time constant on the order of 2.5 seconds, which further modifies the signal by averaging out the individual high-frequency pulsations to give a smoothed low-frequency signal susceptible of being transduced into an intelligible visual form, for example by recording on a moving strip chart.

The further modified signal is fed to a visual indicator device, such as an oscillograph, or preferably, as shown in FIGURE 2, a conventional millivolt strip chart recorder 54 whereby the signal is recorded as the ordinate of a graph whose abscissa may be either time or depth. Preferably, the chart drive of the recorder is coupled through a wire line device to the swivel 18, and the chart calibrated and synchronized so that its horizontal divisions represent the depth of the borehole in feet.

FIGURE 3 illustrates a typical chart produced in the manner indicated. As may be seen, the abscissa of this chart represents the depth of the borehole, with the horizontal divisions marked to indicate the depth in feet. The ordinate represents the amplitude of the modified electrical signal. The graph illustrated is typical of the type we have observed during drilling.

The lower amplitude signals indicated at 56 are typical of those produced when drilling through softer formations such as shale or anhydritic shale having a certain degree of plasticity. The higher amplitude signals indicated at 58 are typical of those produced by harder formations such as limestone or lithified sandstone which are more perfectly elastic in their mechanical properties. The high amplitude, high frequency signal 60 is indicative

of the type experienced in drilling through an extremely hard formation, for example, one rich in minerals such as pyrite.

During the drilling of wells in which charts of the type illustrated were being recorded by the equipment of our invention, neither we nor the experienced drillers involved have been able to detect on the drilling floor any differences in the operation of the drilling rig which could possibly have been interpreted to indicate significant differences in the nature of the formations being drilled, such as are represented by the readily apparent changes in the signals recorded on the chart.

It will be readily appreciated that a skilled geologist, after familiarization with the type of signals produced by the present equipment, would be readily able to correlate such signals with downhole logs made in other wells in the area, including even diverse types of logs, such as electric logs, thereby ascertaining quickly during the course of drilling the exact point in the geologic profile which has been reached, and when formations possibly containing commercially producible accumulations of oil or gas are expected to be penetrated.

It will therefore be appreciated by those familiar with petroleum exploration techniques, that the present invention provides a practical apparatus for accomplishing the aforementioned and other desirable objectives. However, it should be emphasized that the particular apparatus described herein and shown in the accompanying drawings is intended as merely illustrative of the principles of the invention and not as restrictive of the scope thereof, which is defined only by the appended claims.

We claim:

1. Apparatus for logging the lithology of underground formations being traversed by the drill bit of a rotary drilling rig comprising a transducer for converting mechanical vibrations to electrical signals, said transducer being fastened to a non-rotating part of the drilling rig above ground, an amplifier for amplifying the electrical signals produced by said transducer, a filter for modifying said signals by attenuating at least the frequency components of said signals below a predetermined cutoff frequency, a rectifier and an integrator circuit through which said signals are transmitted to convert said signals to pulsating direct current and further modify the same in accordance with the time constant of said integrator circuit, and an indicator means for presenting such further modified signals in visible form.

2. Apparatus as claimed in claim 1 in which said indicator means is a strip chart recorder.

3. Apparatus as claimed in claim 2 in which said recorder includes a chart drive coupled to said drilling rig to plot said signal as a function of the depth of said drill bit.

4. Apparatus as claimed in claim 1 in which said transducer is a piezoelectric crystalline material.

5. Apparatus as claimed in claim 4 in which said transducer is a fused titanate material.

6. Apparatus as claimed in claim 1 in which said transducer has a usable output between 100 and 500 kHz.

7. Apparatus as claimed in claim 1 in which said transducer is bonded to said part by means of an adhesive.

8. Apparatus as claimed in claim 1 in which said transducer is carried by a support assembly which is removably attached to a mounting plate bonded to said part of the drilling rig.

9. Apparatus as claimed in claim 1 in which said transducer is fastened to the swivel which rotatably supports the drilling string.

10. Apparatus as claimed in claim 1 in which said filter is a high pass filter with a cutoff frequency between about 10 and about 30 kHz.

11. Apparatus as claimed in claim 1 in which said drill bit is of the hardened button type and said filter is

5

a band pass filter with a pass band on the order of 10 to 130 kHz.

12. Apparatus as claimed in claim 1 in which said drill bit is of the toothed multi-cone type and said filter is a band pass filter with a pass band on the order of 30 to 40 kHz.

13. Apparatus as claimed in claim 1 in which said integrator circuit has a time constant between .25 and 100 seconds.

14. Apparatus for logging the lithology of underground formations being traversed by the drill bit of a rotary drilling rig comprising a piezoelectric transducer for converting mechanical vibrations to electrical signals, said transducer being attached to a non-rotating part of the drilling rig which functions in the support of the drill string; an amplifier for amplifying the electrical signals produced by said transducer; a filter for modifying said signal by attenuating all frequencies below a frequency on the order of 30 kHz.; a rectifier and an integrator cir-

6

cuit through which said signals are transmitted, said circuit having a time constant on the order of 2.5 seconds for further modifying said signal; and a recorder for plotting on a moving chart the amplitude of such further modified signals.

References Cited

UNITED STATES PATENTS

2,161,256	6/1939	Karcher	-----	73—152	X
2,469,383	5/1949	Gibbs et al.			
2,550,420	4/1951	McNatt	-----	73—151.5	
2,769,867	11/1956	Crownover et al.			
2,810,546	10/1957	Eaton et al.			

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