A PROPOSED GEOPHYSICAL METHOD FOR ORIENTING CORES*

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ABSTRACT

A new method of orienting cores is suggested, in which a fluid suspension of magnetic particles is made to solidify and adhere firmly to the formation at the bottom of the well. While the substance is still liquid, the magnetic particles line up in the direction of the earth's magnetic field so that upon solidifying a magnetized body is tightly cemented to the rock. The formation is then cored and the top-most core carrying an inclusion of the polarized material is oriented by means of a magnetometer. When such a core is recovered there can be no doubt as to the fidelity of the result.

Although attempts to orient cores have been made since 1844, there does not exist today an entirely satisfactory method for determining the orientation of the dip of buried geologic strata from a single core. It is true that several schemes which have been actually tried out achieved under favorable conditions a certain degree of success. However, none of them has withstood the test of time, for the industry has not adopted yet any one scheme to the exclusion of all others.

The primary requisite of a useful method for orienting cores is that the information obtained be definite. At the present time wildcat drilling is done principally on seismograph prospects, so that at least some information regarding the direction of dip is usually available at the outset. The application of core orientation is thus restricted to the function of providing additional information where it is felt that seismograph results are not reliable, as for example where very steep dips are encountered, or simply to furnish an independent method of measurement. It is doubtful whether a scheme of core orientation will ever be generally adopted for this purpose unless it can be shown that it is more reliable than the seismograph.

The successful mechanical methods of core orientation reached their ultimate development in Macready's device[1] which consists of a core-barrel on which is mounted a surveying instrument consisting essentially of a magnetic compass, a plumb-bob, and a photographic

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† Gulf Research & Development Company, Pittsburgh, Pa. Published by permission of Dr. Paul D. Foote, Executive Vice-President.

[1] G. A. Macready, Orientation of cores, Bull. Amer. Assoc. Petr. Geol., Vol. 5, 571, 1930.

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camera actuated by clock work. In nine years that have elapsed since the publication of Macready's paper his method, ingenious as it is, has been little used by the industry. According to Macready's paper the chief difficulty arose in making sure that the rock in the core barrel remained undisturbed in azimuth while drilling was in progress. If the column of the core fractured at its base the core barrel would rotate slightly, making it difficult to correlate the photographs with the discontinuities thus produced. This makes a relatively high percentage of doubtful measurements unavoidable, and furthermore in any particular case the reliability of the determination is difficult to estimate unless several runs are made. Macready's device is thus liable to serious error, even though it has measured dips successfully.

The polar core orientation developed by Herrick and Lynton[2] is open to the same fundamental objection. Its operation is restricted to formations which possess magnetic polarization and depends in addition on other factors the influence of which it is difficult to estimate. The origin of the magnetic polarization of core-samples of sedimentary rock is not clearly understood. In their publications[2] Herrick and Lynton ascribe the origin of the magnetic polarization of sedimentary rocks to the directive force of the earth's magnetic field on the magnetic particles during the deposition of the sediment. If this is the case then the sediment should likewise possess a vertical magnetization because in North America the vertical component of the earth's magnetic field is greater than the horizontal component. The recent work of McNish and Johnson[3] has demonstrated the existence of a vertical magnetization in Pleistocene clay and ocean deposits which is too large to be neglected. The projection of this vertical component onto a horizontal plane which will occur when the sediment is tilted adds vectorially to the projection of the original horizontal magnetization of the formation, so that in general the radial magnetization of a core extracted from a dipping formation is not necessarily directed along the magnetic meridian. Furthermore, McNish and Johnson have found in Pleistocene clay departures as large as 35°

[2] N. H. Herrick, U. S. Patent No. 1,792,639, Feb. 17, 1931. E. D. Lynton and N. H. Herrick, U. S. Patent No, 2,104,752, Jan. 11, 1938.

E. D. Lynton Laboratory Orientation of Well Cores by their Magnetic Polarity, Bull. AAPG., Vol. 21, pp. 580–615 (1937). E. D. Lynton, Recent Developments in Laboratory Orientation of Cores by their Magnetic Polarity, Geophysics, Vol. 3, pp. 122–129 (1938).

[3] A. G. McNish and E. A. Johnson. Magnetization of Unmetamorphosed Varves and Marine Sediments, Ter. Mag. Vol. 43, pp. 401–407, 1938.

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from the present magnetic declination. In addition to this uncertainty, the stability of the magnetism of sediments varies greatly from rock to rock, and the influence of the magnetic field of the drilling tools under conditions of severe mechanical shock encountered in drilling cannot help altering, in many cases, the original direction of the magnetization. All this does not mean that the method is considered to be without commercial value. Because of its simplicity and low cost it is definitely worth while to establish the degree of its reliability by a statistical study of its successes and failures. It should be realized, however, that by the very nature of the method, it is bound to give a certain percentage of faulty measurements.

The purpose of this paper is to propose another scheme of core-orientation[4] the essential characteristic of which is that it either gives the correct answer or fails completely, the two possibilities being immediately distinguishable at the time the cores are extracted from the well. Briefly, the method consists in attaching to or diffusing into the rock a substance which, after a short time, solidifies and acquires a permanent magnetic moment in the direction of the earth's magnetic field. The formation is then cored with customary tools and the top portion of the core containing the polarized magnetic material is tested with a portable magnetometer. The obvious objection that the success of this method depends upon the recovery of the first few inches of the core is not felt to be as serious as one might be led to believe at first, because by means of wire-line coring it is now possible to ascertain not only the presence of dipping bedding planes, but also the mechanical properties of the formations encountered by the drill. It is thus possible to select for orientation formations which are sufficiently well consolidated to assure a high percentage of recovery.

There is a variety of magnetic materials which might be introduced into the rock. We need not be afraid of the influence of artificial magnetic fields on the polarized material because magnetic alloys possessing coercive forces of several hundred oersteds could be used. In the process under consideration the magnetic material is in the form of very small particles, say about 1 μ in diameter dispersed in a fluid which is capable of solidfying and of firmly adhering to rock. This fluid may be quick-setting cement or an organic silicate[5] which, upon reacting with the water in the well, or with the connate water in porous formations, forms a tough gel.

[4] Victor Vacquier, U. S. Patent No. 2,140,097, Dec. 13, 1938.

[5] Deering and Reed. Alkylorthosilicates. Jour. Am. Chem. Soc. Vol. 50, p. 3058, 1928.

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The procedure by which the fluid suspension of magnetic particles may be introduced into the formation has not been worked out in detail, but the following method is being seriously considered. It is assumed that by means of wire-line coring we have discovered that the drill is passing through a formation showing dipping bedding

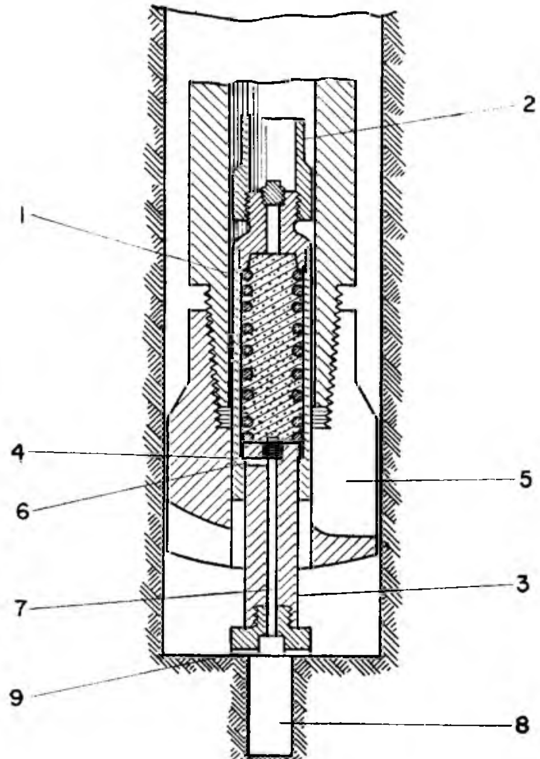

Fig. 1.

planes and that this formation is likely to yield a recoverable specimen. A special tool is lowered on the wire-line by means of which a hole about one inch in diameter and three or four inches deep is drilled into the floor of the well. Upon completion of this pilot hole the tool is replaced by a device capable of injecting the magnetic suspension. Fig. 1 gives a general idea of the construction and operation of this container. It consists of a hollow cylinder 1 attached to the retractable member 2 of a conventional wire-line coring outfit. The bottom of cylinder 1 is closed by a piston 3 which is prevented

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from falling off by collar 4. As in the case of standard wire-line tools, the retractable member locks itself to the main tool when the drill-bit 5 is off bottom. The tool string is then lowered very slowly. As the piston is pushed up into the cylinder it uncovers port 6 and the magnetic suspension is squirted through duct 7 into the hole 8. The mud previously held in the hole and the excess of the injected fluid pass through ports 9 in the shoe of the piston. The tool string is now slowly lifted so as to suck back into the container the largest part of the injected fluid which spread out around the piston shoe. The tool string is then pulled out and standard coring tools capable of extracting a core of large diameter (say, 3 inches) are dropped into the well. In the meantime the magnetic particles in hole 8 have acquired their orientation and have become fixed to the rock, so that coring can proceed without further delay.

The main objection against the procedure outlined above is that a round trip down the hole is made for the sole purpose of recovering the first few inches of the core, and it is feared that the process might have to be repeated several times before a satisfactory specimen is retrieved. On the other hand, the possibility of performing all the necessary operations by wire-line should not be overlooked. Off hand it seems that the small size of the wire-line cores will necessitate the reduction of the diameter of the pilot hole to about half an inch or less and it is felt that for this reason the percentage of recoveries will be considerably smaller than if conventional coring tools are used. It should be remembered, however, that many wire-line attempts could be made in the time required for a round trip, and that therefore a greater number of failures can be allowed. Further consideration of these practical matters will have to wait until the scheme is given a trial. It is quite possible that better methods of carrying it out can be devised, and that the difficulties mentioned above will be found less formidable in the course of engineering development than they appear at present.

The question of how cheap a method for orienting cores should be before it can be adopted is rather difficult to answer. It is not very often that a considerable amount of money, say the cost of another well, can be saved by its application. However, when such an opportunity arises it is felt that the actual cost of orienting the dip which might be equivalent to making four or five round trips down the well, is really insignificant, as long as the information obtained can be relied upon. Neither the Macready core-barrel nor the Herrick-

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lynton scheme are sure fire. The former is predicated on pulling pipe for each trial, while the latter, as far as published information allows us to judge, has not been used on wire-line cores. The method here proposed does not seem therefore to be much more expensive to use, and in addition offers the possibility of obtaining unambiguous data while carrying out all the steps involved in its operation through the drill-pipe.

In conclusion I wish to thank Dr. E. A. Eckhardt for his constant encouragement and to express my gratitude to Dr. Paul D. Foote and Dr. B. B. Wescott for the guidance they gave me in the prosecution of this problem.

DISCUSSION

We have read with interest the author's proposed ingenious method for orienting cores in a drilling well, but certain practical difficulties would have to be overcome in applying it:

1. It would be no easy matter to drill a 1″ diameter pilot hole in the bottom of an oil well.

2. The bottoms of most holes that have been drilled to any depth are usually covered with steel fragments, worn or broken off the bit, and with magnetite grains sorted out of the cuttings because of their desnity. We have repeatedly found such material in the mud coating ordinary cores, which prevents them from being oriented unless a considerable amount is ground off to present a surface absolutely free of all foreign substances. This mixture of cuttings and magnetite would be fixed in the pilot hole by the cementing composition and should give results more interesting than usable.

3. The magnetic composition introduced into the pilot hole would have to remain very fluid for several hours and then set quickly. The directive force of the earth's field is very weak, and could not overcome much viscosity or shearing strength in a short time.

4. Assuming that the practical difficulties can be overcome and the method made to work with exact accuracy as far as magnetic orientation of the sample is concerned, there would probably still be an uncertainty of 10° to 15° in determining the direction of dip on the 2″ length of beds exposed in a core. Precise accuracy in one part of the operation only is useless.

In the Herrick-Lynton method of orienting cores by their residual magnetism, we have two very considerable advantages not enjoyed by other methods, (1) the method does not interfere with the drilling of the well, and (2) the choice of suitable cores on the surface as to dip and mineral grain contents. Any method which delays the drilling of a well is immediately an item of great expense.

Whereas the Herrick-Lynton method of core orientation is restricted to formations possessing magnetic polarization, our experience over a period of years indicates that 80% of the cores from a drilling well possess such polarization. In California, the only formation which does not give us polarity is the diatomaceous shale of the Monterey, while of course the limestone, anhydrite and dolomite formations of the Mid-Continent area also have proven unworkable in their pure states. However, results can be obtained where these formations are interbedded with shales or sands which do carry heavy minerals.

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