Nov. 24, 1964 J. P. GALLUS ETAL 3,158,209

METHOD OF SAMPLING UNDERGROUND FORMATIONS

Filed July 30, 1962 2 Sheets-Sheet 1

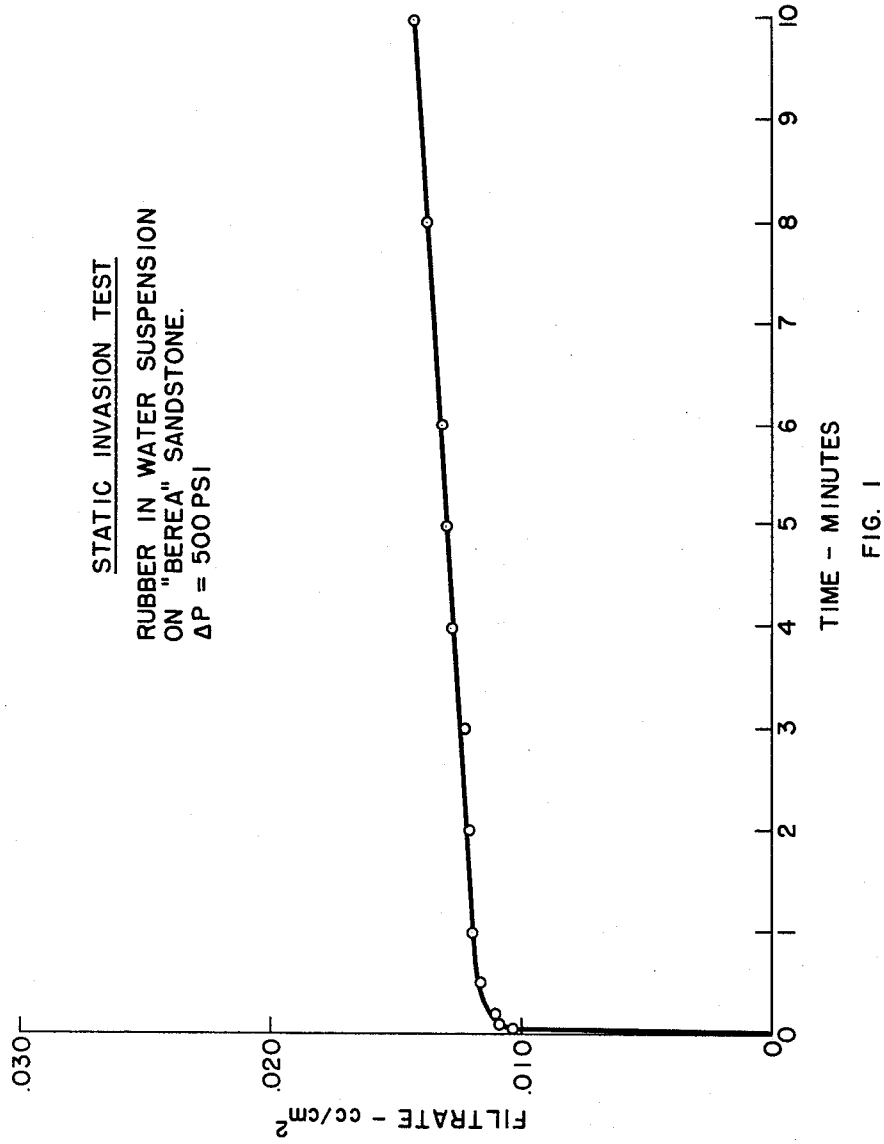

FIG. 1

JULIUS P. GALLUS
GERALD D. ORTLOFF
BERTRAM T. WILLMAN INVENTORS

BY Gary C. Honeycutt
ATTORNEY

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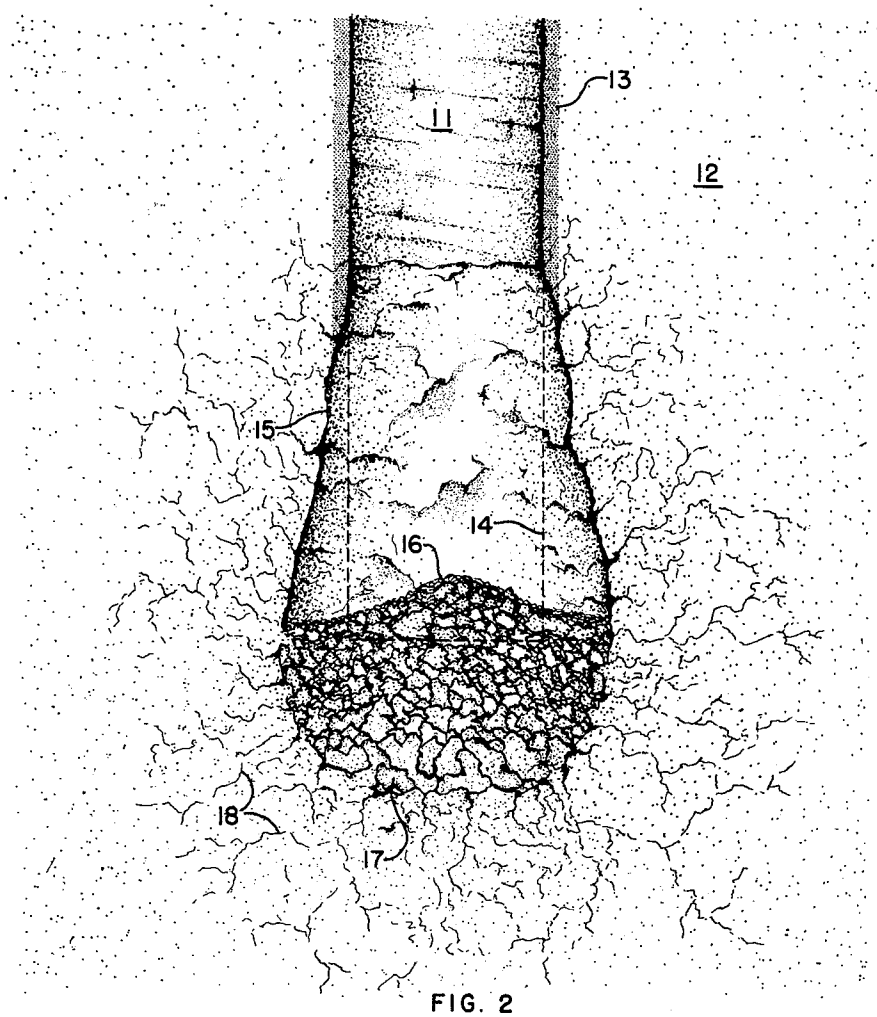

FIG. 2

JULIUS P. GALLUS
GERALD D. ORTLOFF
BERTRAM T. WILLMAN *INVENTORS*

BY Gary C. Honeycutt
ATTORNEY

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3,158,209
METHOD OF SAMPLING UNDERGROUND FORMATIONS

Julius P. Galius, Gerald D. Ortloff, and Bertram T. Willman, Tulsa, Okla., assignors to Jersey Production Research Company, a corporation of Delaware

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The present invention is generally concerned with the sampling of underground formations. The invention particularly relates to a method for obtaining samples of subterranean strata from the bottoms of well bores that have been drilled into the earth's crust in an effort to locate petroleum accumulations. It is especially directed toward a method for obtaining samples of essentially unaltered fluid content by a technique which involves fragmentation of a portion of a stratum to be sampled, and which further involves the use of a non-invading fluid to seal the fragments obtained.

The stock tank barrel volumetric petroleum content of a porous underground reservoir is normally calculated in terms of the reservoir volume, the formation volume factor, the average reservoir porosity and the average oil saturation within the porosity. In reservoirs wherein a number of development wells have been drilled, the reservoir volume and the formation volume factor can usually be determined with reasonable accuracy by comparing structural maps and by measuring the gravity, temperature, pressure and gas content of the oil under reservoir conditions. The average porosity of the reservoir is generally determined by analyzing cores recovered from a number of development wells. Experience has demonstrated, however, that volumetric oil content in the cores, as determined from core analysis, is usually not an accurate indication of the actual quantity of oil present in a reservoir. Reliable values for volumetric oil content, together with the other data, are extremely desirable to forecast the productive life of oil and gas reservoirs, to select the primary recovery techniques most suitable for particular reservoirs, and to assess the susceptibility of such reservoirs to later secondary and tertiary recovery processes. It is a principal object of the invention to obtain samples from a reservoir, the analysis of which will provide reliable values for volumetric oil content.

Conventional core drilling systems utilize an annular bit and core barrel which are rotated from the earth's surface by means of a rotary drill string. A coring fluid is circulated downwardly through passages in the drill string, barrel and bit, in order to maintain pressure on the formation and thus prevent the escape of fluids contained therein. Cuttings produced by the bit are entrained in the coring fluid and returned to the surface through the annulus surrounding the drill string. As the bit cuts away the formation the central core which remains is encased in the barrel. The core barrel is provided with means for breaking off the core after the barrel has been filled. Pressure core barrels which can be sealed against changes in pressure are also used. After the core has been cut the drill string is withdrawn from the borehole and the core is recovered.

It has been shown that the pressure maintained at the bottom of the borehole during a coring operation has a profound effect on the fluid content of the cores subsequently recovered. If this pressure is less than the formation pressure, fluids contained in the formation will tend to flow out of the core into the borehole until equilibrium is established. If, on the other hand, the bottom hole pressure exceeds the formation pressure, the coring fluid will tend to flow into the interstices of the formation and displace any oil, gas or water contained

therein. In either case the result is a change in the fluid content of a core such that subsequent measurements of the amount of fluid present will not accurately reflect the original fluid content of the cores formation. Since this change in fluid content occurs as the core is cut, the use of a pressure core barrel does not prevent it.

Several methods for avoiding the difficulty outlined above have been proposed in the past. The most obvious of these involves carrying out coring operations without any pressure differential between the core and fluid in the formation. This is impractical, if not impossible, because the formation pressure cannot be conveniently measured during core drilling, and moreover, because the fluid pressure cannot be controlled with sufficient accuracy. The use during rotary core drilling of a drilling fluid which will not invade a formation under pressures considerably in excess of the formation pressure has been disclosed, but efforts to develop an ideal fluid have not been entirely successful. Systems which include the use of radioactive tracers to permit a determination of the extent to which core invasion has occurred and systems for freezing the core in situ have been proposed but have not been found to be generally effective.

Non-invading core drilling fluids which have been used or suggested for use include various polymeric materials such as silicones and polyesters. Alkyd resins such as the reaction product of ethylene glycol and maleic anhydride; condensation products such as cresol-formaldehyde resins; mercury, molten metal and low melting metal alloys such as alloys of lead, bismuth, tin and the like have also been suggested.

The most promising of the non-invading coring fluids which have been developed are polymeric elastomer latices, dispersions or suspensions. These materials are aqueous dispersions of oil-resistant polymeric elastomers, including natural and synthetic rubber latices, both virgin and reclaimed. Mixtures of natural and synthetic latices have also been found suitable. Preferred latices may be derived from synthetic elastomers prepared by the polymerization of olefinically unsaturated hydrocarbons, or by the copolymerization of such hydrocarbons with other olefinically unsaturated monomers. The olefinically unsaturated hydrocarbons include olefins such as isobutylene and the pentylenes; diolefins such as butadiene, isoprene, piperylene, dimethyl butadiene and 2-methyl pentadiene; and vinyl aromatics such as styrene, methyl styrene and vinyl toluene. Mixtures of two or more of such hydrocarbons have also been found suitable. Olefinically unsaturated monomers which may be copolymerized with the hydrocarbons include halogenated olefinically unsaturated compounds such as vinyl chloride, allyl-chloride and chloroprene, unsaturated ester such as vinyl acetate, allyl propionate, methyl methacrylate, ethyl acrylate, methyl fumerate, ethyl maleate and propyl itaconate. Unsaturated nitriles such as acrylonitrile, methacrylonitrile, ethyl acrylonitrile and chloroacrylonitrile. Unsaturated ketones such as methyl vinyl ketones, cyclic vinyl compounds such as vinyl pyridine, and mixtures thereof. It will be recognized that not all of these elastomers are equally effective for use in preparing a non-invading coring fluid.

Specific examples of elastomers prepared from the foregoing monomers which have been found suitable in the form of latices for use as non-invading fluids include polyisobutylene, polystyrene, polybutadiene, polyisoprene, butadiene-isoprene copolymers, isoprene-isobutylene copolymers, isobutylene-styrene copolymers, piperylene-vinyl acetate copolymers, butadiene-styrene-vinyl chloride copolymers, butadiene-acrylonitrile copolymers, butadiene-methacrylonitrile copolymers and isoprene-chloroprene-vinyl acetate copolymers.

A wide range of concentrations of dispersed elastomer in the latices is useful for the purposes of the invention. Latices containing from about 15% to about 75% elastomer are generally suitable. Those containing from about 30% to about 70% by weight are preferred.

It has now been found that rotary core drilling with the use of the above non-invading latex fluids is not a perfect solution to the problem of how to recover at the surface of the earth a sample of subterranean reservoir rock, unaltered with respect to its original fluid content. Laboratory tests have shown that the static exposure of a reservoir rock surface to any of the above latices, under substantial pressures, does not result in significant invasion of the rock. However, attempts to secure uninvaded cores by rotary coring, with the circulation of the same latices as drilling fluids, have shown that the static tests are not a satisfactory indication of the latex behavior in the dynamic environment of rotary core drilling conditions. The difficulty is not caused by any invasion of the core by dispersed elastomer particles, but by "filtrate invasion," which is a leakage of the aqueous portion of the latex through the film of solids deposited on the rock surface.

Referring now to FIGURE 1, the results of a typical static invasion test are shown as a plot of filtrate invasion, measured in cubic centimeters of filtrate per square centimeter of rock surface exposed to the fluid, versus the total time of exposure. The principal significance of the test is that it shows about 70% of the ten-minute invasion total to have occurred in less than one second of exposure. But the total invasion of about 0.014 cc./cm.^{2} at the end of ten minutes is still negligible. Therefore, the initial "spurt loss" shown by FIGURE 1 can nevertheless be tolerated, as such, if an essentially static exposure of the sample is maintained.

The present invention is based primarily upon the discovery that filtrate invasion during conventional rotary coring operations is greatly increased by a continuous or repeated removal of the impermeable film ahead of the rotary core bit as coring proceeds. The effect produced is a "spurt loss" repeated with each cut of a tooth. Accordingly, it is an object of this invention to avoid the detrimental effect attributed to rotary core drilling in connection with the use of a non-invading fluid by providing a sampling technique which involves a virtually instantaneous separation of samples from the formation, such that the fragments obtained are immersed in the non-invading fluid under essentially static conditions whereby any significant invarsion is avoided.

Broadly, the invention is a method for recovering a sample of essentially unaltered fluid content from a subterranean stratum penetrated by a borehole which comprises at least partially filling said borehole with a non-invading fluid, fragmentizing a region of said stratum adjacent the bottom of said borehole, whereby the resulting fragments are sealed by exposure to said non-invading fluid, and then raising the sealed fragments to the surface while maintaining a pressure thereon which is not substantially less than the natural pressure of said stratum.

The preferred embodiment of the invention comprises the steps of drilling a borehole in the vicinity of the stratum to be sampled, filling at least a portion of said borehole with a non-invading fluid, introducing an explosive charge into the borehole, firing said charge at or near the bottom of the borehole, said charge being of sufficient magnitude to fragmentize a region of said stratum adjacent the explosion, whereby the resulting fragments are sealed by exposure to one-invading fluid, and thereafter raising the sealed fragments to the surface while maintaining a pressure thereon which is not substantially less than the natural pressure of said stratum.

The method of the present invention may be employed to obtain samples from the bottoms or the side walls of existing wells, or it may be employed to obtain samples by drilling a new borehole from the earth's surface down to a given substratum the sampling of which is desired.

Once a borehole has been selected or drilled, the next step of the invention is to fill the borehole with sufficient non-invading fluid to prevent the flow of fluid from the substratum into the borehole. This is accomplished by filling the borehole with a column of non-invading fluid to a height which will produce a hydrostatic pressure at the level of the formation which is approximately equal to the naturally existing pressure of the formation fluids. When the preferred non-invading latex fluids mentioned above are used, a considerably greater hydrostaitc head may be tolerated.

The next step involves a fragmentation of the formation at the bottom of the borehole in order to produce fragments which are suitable and of adequate size for analysis as samples when retrieved at the surface of the earth. Suitable fragments may be made by using a chip-coring tool at the end of a wire line or mounted on the end of a tubing string in order to break chips from the formation at the bottom of the borehole. A suitable example of this technique is found in U.S. 2,819,-038. Any conventional drilling tool of a reciprocating or percussive design is useful for the purposes of the present invention, provided that no rotary grinding mechanism is obtained.

The preferred method of fragmentizing the bottom of the borehole is to introduce and discharge or detonate an explosive at the bottom of the borehole. Essentially any conventional explosive charge may be employed in accordance with the invention, examples of which include commercial dynamite, nitroglycerin and TNT. The quantity of explosive required to create optimum fragmentation varies over a wide range. In the case of nitroglycerin, for example, the amount required will vary from one quart to one hundred quarts or more depending upon the character of the rock and upon the extent of fragmentation desired. Equivalent amounts of dynamite or TNT are also useful.

Suitable techniques for placing and detonating an explosive charge in a borehole are well known, especially in the art of completing wells. It has been a common practice, for example, when "shooting" a well to pack a substantial portion of the borehole above the charge with gravel, sand or other material, in order to concentrate the effects of the blast at the desired level. Similarly, gravel packing will be desirable in some instances when sampling a formation in accordance with the present invention.

The fragments created by the blast, or other technique, are immediately sealed by immersion in the non-invading fluid standing, in the wellbore. In accordance with one embodiment of the invention, a pressure core barrel is then lowered into the borehole to gather the sealed fragments and bring them to the surface without changing the original pressure. The pressure barrel and contents may then be frozen, with or without first replacing some of the fluid with nitrogen gas under pressure. The frozen samples are then ready for shipment to the laboratory for analysis.

An important feature of the invention is that an explosion of sufficient magnitude to fragmentize the bottomhole rock will not at the same time cause significant invasion of the fragments produced, and thereby defeat the essential object of the invention. Calculations show that the exposure of a typical rock surface to a blast pressure differential of 1,000 atmospheres results in only negligible invasion, because of the extremely short duration of the blast. This is true, even before taking into account the added resistance to invasion provided by the sealing action of the borehole fluid.

Moreover, the fragments produced from rock lying immediately adjacent the explosion, and therefore most affected by the blast, are of relatively little interest anyway. The larger fragments created come from points within the formation relatively more remote from the center of the blast, and are therefore less disturbed by it and by the drilling fluid used to sink the hole. The force

of the blast is transmitted to these latter regions of the formation primarily by shock waves traveling through the rock, rather than by direct exposure to the high pressure gases released in the explosion. This further lessens the chance of invasion. Accordingly, it becomes clear that the larger fragments not only permit a more accurate analysis because of their size alone, but are also inherently more representative of the undisturbed formation.

In accordance with another embodiment of the invention, the sealed fragments are lifted to the surface with the aid of an ordinary bailer. In order to retrieve the samples by this technique, it is necessary to maintain surface pressure control in the wellbore during the bailing operation in order to avoid a bleeding of the samples as they are brought to the surface.

A lubricator is attached to the well casing at the surface, and the bailer is run on a cable or wire line through the lubricator and downhole to pick up the fragment samples. As the bailer is lifted, the pressure maintained in the lubricator must be at least as great as the natural pressure of the formation from which the sample fragments were taken. The bailer is pulled into the lubricator, the lubricator valves are closed, and the lubricator and its contents are frozen to permit removal of the samples without bleeding them.

Referring now in detail to FIGURE 2, borehole 11 has been drilled into formation 12 to be sampled. Shaded area 13 indicates the zone of drilling fluid invasion into the formation while drilling. Dotted line 14 indicates the position of the borehole wall prior to the detonation of an explosive charge in accordance with the preferred embodiment of the invention. Fragments 16 and 17 created by the blast are dislodged from the borehole wall as well as from the zone immediately below the original borehole bottom. Thus the borehole is enlarged in the region of the blast as indicated by numeral 15. This caving of fragments from the borehole wall creates a mound of debris 16. The larger and more useful fragments are created below the borehole bottom and are designated by numeral 17.

When bailing out the debris and fragments from the borehole it becomes apparent that the smaller fragments produced from rock lying immediately adjacent the explosion will be relatively more affected by the last than will the larger fragments 17. It is important to observe that fragments 17 were outside the region of original fluid invasion 13 and were also out of contact with drilling fluid at the time of the explosion. Larger fragments 17 are of course sealed subsequent to the blast by the non-invading fluid standing in the borehole. Thus, as pointed out earlier, the larger fragments not only permit a more accurate analysis because of their size alone, but are also inherently more representative of the undisturbed formation.

What is claimed is:

1. A method for recovering a sample of essentially unaltered fluid content from a subterranean stratum, which comprises drilling a borehole into the vicinity of the stratum to be sampled, at least partially filling said borehole with a non-invading fluid, firing an explosive charge near the bottom of said borehole, said charge being of sufficient magnitude to fragmentize a region of said stratum adjacent the explosion, whereby the resulting fragments are sealed by exposure to said non-invading fluid, and then raising the sealed fragments to the surface while maintaining a pressure thereon which is not substantially less than the natural pressure of said stratum.

2. A method as defined by claim 1 wherein said non-invading fluid comprises an oil-resistant polymeric elastomer suspension.

3. A method for recovering a sample of essentially unaltered fluid content from a subterranean stratum penetrated by a borehole which comprises at least partially filling said borehole with a non-invading fluid, firing an explosive charge within said borehole near that portion of the stratum to be sampled, whereby the resulting fragments are sealed by exposure to said fluid, and then raising at least one of said fragments to the earth's surface while maintaining a pressure thereon which is not substantially less than the natural pressure of said stratum.

4. A method for recovering a sample of essentially unaltered fluid content from a subterranean stratum penetrated by a borehole which comprises at least partially filling said borehole with a non-invading fluid, fragmentizing a region of said stratum adjacent said borehole, whereby the resulting fragments are sealed by exposure to said fluid, and then lifting at least one of said fragments to the earth's surface in a bailer, while gradually increasing the pressure maintained at the wellhead to a maximum pressure at least as great as the natural pressure of the sampled stratum.

5. A method for recovering a sample of essentially unaltered fluid content from a subterranean stratum penetrated by a borehole which comprises at least partially filling said borehole with a non-invading fluid, substantially instantaneously separating a plurality of fragments from a region of said stratum adjacent said borehole, whereby the resulting fragments are immediately sealed by exposure to said fluid, and then raising at least one of said fragments to the earth's surface while maintaining a pressure thereon which is not substantially less than the natural pressure of said stratum.

6. A method as defined by claim 5, wherein said step of substantially instantaneously separating a plurality of fragments from said stratum is accomplished by firing an explosive charge within said borehole near that portion of the stratum to be sampled.

7. A method as defined by claim 5, wherein said step of substantially instantaneously separating a plurality of fragments from a region of said stratum adjacent said borehole is accomplished by mechanical impact.

References Cited in the file of this patent

UNITED STATES PATENTS

2,146,263	Johnston	Feb. 7, 1939
2,264,449	Mounce	Dec. 2, 1941
2,373,323	Macready	Apr. 10, 1945
2,880,969	Williams	Apr. 7, 1959
3,064,742	Bridwell	Nov. 20, 1962
3,112,799	Gallus	Dec. 3, 1963