United States Patent

Lebourg

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[54] **DRILL BIT**

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[52] **U.S. Cl.** **175/329**

[51] **Int. Cl.** **E21b 9/36**

[58] **Field of Search** 175/65, 67, 327, 329, 330, 175/409

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[57] **ABSTRACT**

A rotary drill bit design of the type adaptable to rotary diamond-drilling bits or the like having a drilling face crossed by a number of fluid passageways to provide drilling lands on which cutting elements, such as diamonds, are mounted employs a construction wherein the matrix portion of each drilling land defines a wedgelike volume open in the direction of bit rotation with respect to the drilling surface or gage surface defined by the exposed portions of the cutting elements upon rotation of the bit. Accordingly, upon rotation of the bit, drilling fluid is subjected to an increasing pressure gradient in this wedgelike volume between the matrix of the bit and the formation being drilled to assist in preventing differential sticking and to create a hydraulic pressure pattern which assists in rapid drilling.

8 Claims, 6 Drawing Figures

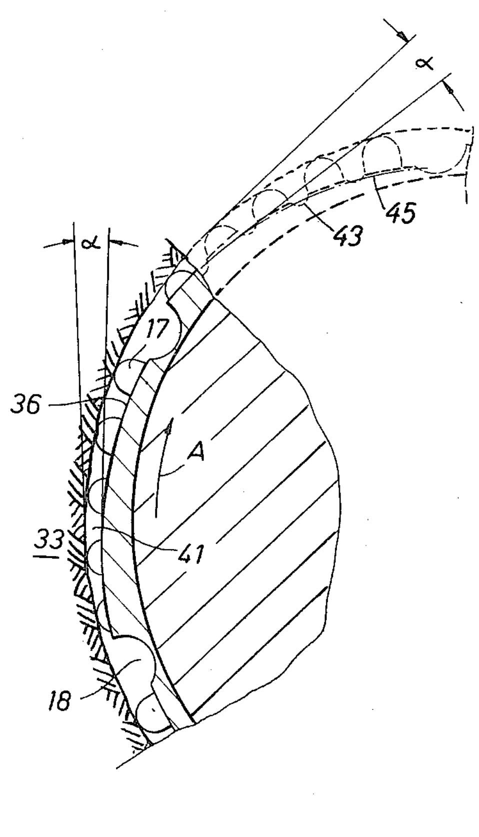

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FIG. 1

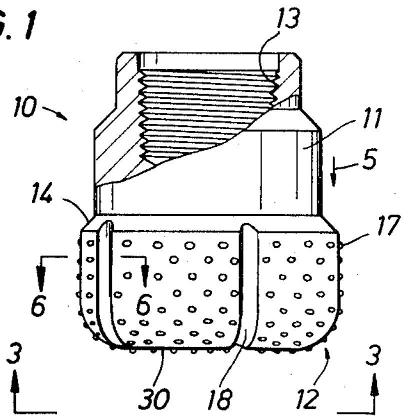
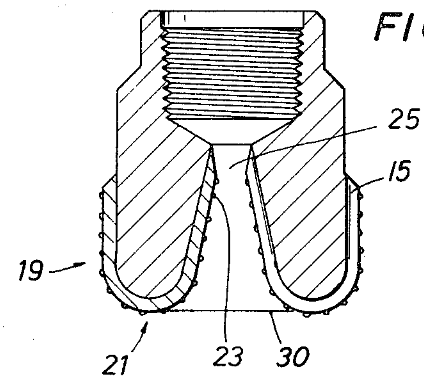


FIG. 2



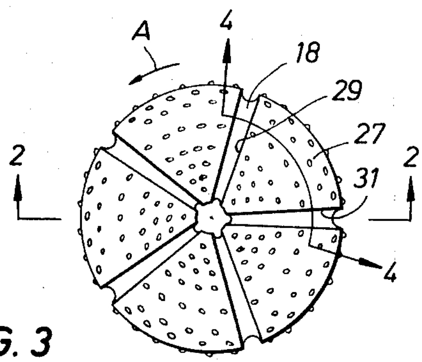


FIG. 3

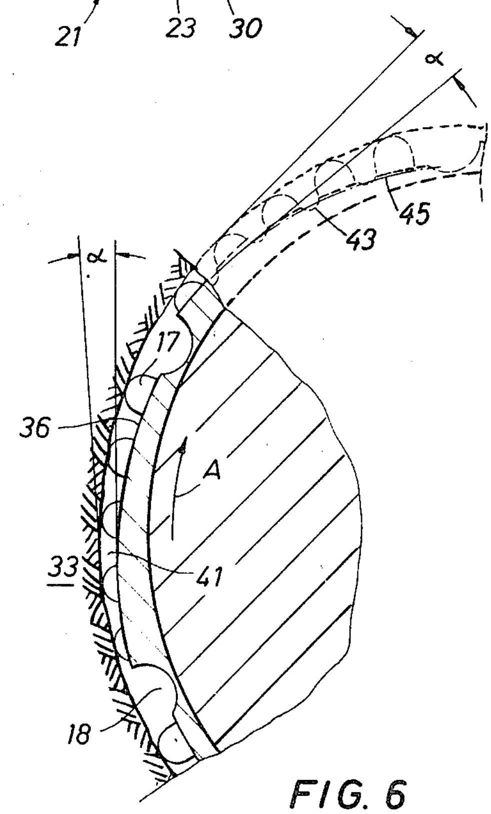
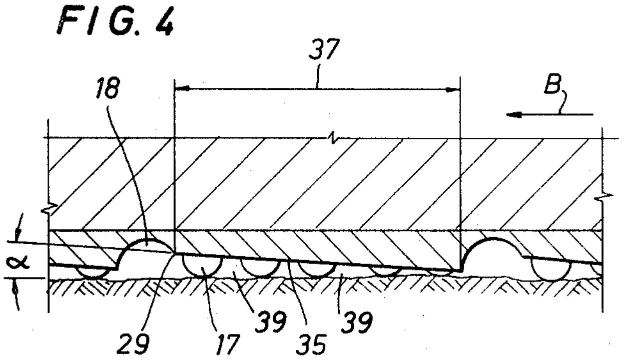


FIG. 6

FIG. 4



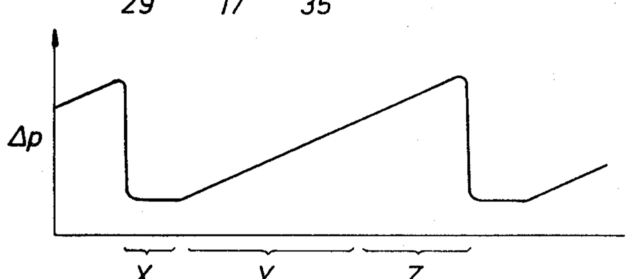


FIG. 5

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DRILL BIT

BACKGROUND OF THE INVENTION

This invention relates to rotary drill bits for drilling boreholes into subterranean formations. More particularly, this invention relates to a novel rotary drill bit design for primary use in diamond drill bits or similar drill bits utilizing hard cutting materials carried in a matrix.

Drill bits utilizing diamonds or similar hard cutting elements are commonly employed in drilling and coring operations, particularly in hard subterranean formations such as chert or the like. The construction of such diamond drill bits usually includes a body portion having means for interconnection of the bit into a drill string, and a matrix portion for mounting the diamonds or other cutting elements. Drilling fluid is directed down to the bottom of the borehole through the drilling string and from a port generally disposed in the central portion of the bit. Fluid passageways or water courses across the drilling surfaces of the bit are also provided to transport this drilling fluid across the bit face to cool and lubricate the drilling surface of the bit and to facilitate movement of drill cuttings from the drilling area.

Most drilling fluids that are in use today are drilling fluids characterized by possession of plastering properties, i.e., the drilling fluids will form a mud sheath or filter cake on the wall of the formation, which sheath is semipermeable or substantially impermeable to fluid in the borehole, thus preventing its escape to the formation. These drilling fluid filter cakes are formed particularly when the drilling fluids are maintained under pressure against the surface having small cracks or fissures which generally characterizes the formation. Consequently, such filter cakes or mud sheaths tend to form in the bottom of the borehole where the cutting elements of the bit are attempting to abrade the formation and also to form in the water courses of the bit between the drill bit and the formation. Since these filter cakes are relatively fluid impermeable, the buildup of a filter cake between the formation and the drill bit can tend to restrict passage of fluid across the actual cutting surfaces. Aside from potential loss of drilling speed because of failure to promptly carry away drill cuttings, and potential bit damage because of inadequate cooling and lubrication, this formation of the filter cake can be responsible for the problem of differential sticking.

Differential sticking is a phenomenon which occurs as a result of the differential pressure, above formation pressure, which must always be maintained at the bottom of a borehole. Since drilling fluid pressure must be greater than the formation pressure to prevent a well blowout, when drilling fluid is excluded from the drilling face of the bit because of the buildup of a filter cake in the water courses and around the cutting elements, the pressure differential between the drilling fluid and the formation is exerted directly upon the bit, causing it to stick. This can result in windup of the drill string while the bit is stuck, followed by a rapid unwinding of the string after sufficient torsional force is applied to the bit to free it. Exclusion of fluid from the lower face of the drill bit also imposes severe vertical shock loads in the drill string. When fluid is excluded from the face of the bit, the buoyant effect of the fluid on the face of the drill bit is eliminated and a downward shock load is imposed; and when the fluid reenters this space there is an upward pressure exerted resulting in an upward shock load. Hence, sticking of the bit is often accompanied by severe vertical shock loads in the drill string. All these effects result in wear on downhole equipment and also make for inefficient drilling.

In major part, it has been sought to overcome this problem of differential sticking by further increasing drilling fluid pressure to the bit, thereby to increase the speed of the drilling fluid across the face of the drill bit, hopefully to preclude the formation of such filter cakes in the water courses and around the cutting elements. But although this increased speed of fluid flow tends to wash away builtup filter cakes, it is also true that at increased pressures filter cakes more rapidly form.

Moreover, an increased pressure differential between the drilling fluid and the formation being drilled has a further adverse effect on drilling efficiency.

Subterranean formations, particularly hard formations such as are drilled with diamond bits or the like, exhibit an increase in plasticity when a pressure higher than the overburden pressure is exerted upon the formation. Thus, for example, if a cutting element such as a chisel is dropped from equal height on two identical formation samples wherein one sample is maintained under a higher pressure than the other, a decreased amount of formation fracture is found approximate the impact point of the chisel in the formation under higher pressure.

The theory of diamond bit operation is not simply to abrade the formation and thereby to make drilling progress, but rather to create tiny fractures as the cutting elements pass over the formation so that drilling fluid which is maintained at a higher pressure than the formation pressure can enter these fractures and remove the fractured portions of the formation. Accordingly, an attempted solution to the problem of this differential sticking by simply increasing the pressure and the flow rate of the drilling fluid across the bit has the ancillary effect of contributing additional plasticity to the formation, thereby making it more resistant to fracture under the cutting elements of the bit.

SUMMARY OF THE INVENTION

There is accordingly provided by the instant invention a novel design for drilling bits of the type which use diamonds or similar cutting elements, which design minimizes the problem of differential sticking without the necessity of increasing drilling fluid pressure to thereby increase the plasticity of the formation being drilled.

There is also provided by the instant invention a novel design for rotary drill bits of the type using diamonds or similar cutting elements wherein drilling fluid access to all the cutting elements on the drilling bit surface is improved.

There is further provided by this invention a novel drill bit design which results in the formation of a hydraulic wedge between the drill bit and the formation to thereby create pressure patterns which assist in removing fractured portions of the formation from the area being drilled.

There is also provided by this invention a novel drill bit design which enables drilling by using a novel method wherein a series of abrupt pressure changes are brought to bear upon tiny fractures in the formation to assist in their removal.

The novel rotary drill bit of this invention comprises a body portion including a matrix to provide a face of the bit; means defining passageways across the matrix which divide the face of the bit into a plurality of drilling lands; and cutting elements carried in the drilling lands of the matrix, the exposed portions of which define a cutting surface upon rotation of the bit; the surface of the matrix portion of each of said lands being spaced a greater distance from the said cutting surface defined by the exposed portions of the cutting elements at one edge of the lands than at the other to define a wedge-shaped volume between the matrix and this cutting surface, which wedge-shaped volume is open in the direction of bit rotation.

The drill bit construction providing this wedge-shaped volume between the surface of the matrix of the bit and the cutting surfaces defined by the exposed cutting elements is provided by placing larger cutting elements, e.g., diamonds, proximate the forward or leading edge of the drilling lands on the face of the bit, and using smaller diamonds toward the trailing edge of the land. This construction permits all cutting elements to drill or ream the formation while providing a wedge-shaped volume between the matrix and the formation being drilled.

Generally, the angle of inclination, as explained hereinbelow, of the matrix with respect to the cutting surface is at least about 1°. However, as will be appreciated by those skilled in the art, the angle at which the surface of the matrix approaches the cutting surface of the bit will be primarily determined by the distance between the fluid passageways and the comparative size of cutting elements available which can enable spacing the forward edge of each drilling land further from the cutting surface than the trailing edge of each drilling land.

There is also provided by this invention a method of drilling which comprises abrading and fracturing a subterranean formation with cutting elements in the presence of a flowing drilling fluid maintained at a pressure higher than the formation pressure, increasing local fluid pressure in the region of abrasion and fracture as successive cutting elements traverse the formation, and abruptly decreasing the pressure while exposing the region of abrasion and fracture to increased drilling fluid flow.

BRIEF DESCRIPTION OF THE DRAWINGS

The instant invention will be more particularly understood with reference to the accompanying drawings.

FIG. 1 is an elevational view of a diamond drill bit which incorporates the novel design of the instant invention and constitutes an illustration of a specific embodiment of a drill bit in accordance with this invention.

FIG. 2 is a sectional view of the drill bit shown in FIG. 1.

FIG. 3 is a bottom view of the drill bit of FIG. 1 along line 3—3.

FIG. 4 is a developed illustration of a partial section of the drill bit of FIG. 3 along line 4—4.

FIG. 5 is a schematic plot of hydraulic pressure illustrating the pattern of hydraulic pressure as the section illustrated in FIG. 4 traverses a formation.

FIG. 6 is a sectional view of the bit shown in FIG. 1 along line 6—6 illustrating the wedge-shaped volume on the gage portion of the bit.

DESCRIPTION OF THE SPECIFIC AND PREFERRED EMBODIMENTS

Referring now specifically to the drawings, in FIG. 1 there is illustrated a drill bit 10 of the type which may be constructed in accordance with the instant invention. Drill bit 10 comprises a body 11 formed of suitable material to withstand stress during operation. The upper portion of the body is provided with an interiorly threaded neck 13 so that the bit 10 may be interconnected at the bottom of a drilling string. The lower body section or crown of the bit 12 is surfaced with a metal matrix 15 in which diamonds or similar cutting elements 17 may be embedded. The matrix is a relatively hard, tough material such as bronze, or a similar metal alloy such as copper nickel alloy containing powdered tungsten carbide in quantities sufficient to convey the required strength and erosion resistance. Alternatively, the matrix may be composed of a suitably hard plastic material capable of being cast upon the bit and having the property of resisting wear and retaining the cutting elements. The material is of suitable thickness to provide the required strength, resistance to erosion and abrasion, and to bed the cutting elements firmly therein.

In casting the matrix material upon the bit body 11, it is common to provide recesses or a roughened surface on the bit body so that the matrix material will rigidly and firmly anchor to the bit body and form a permanent and fixed part of the drill bit.

The matrix in the drill bit illustrated is shaped to have a generally semitoroidal end face defining an outer cylindrical gage face, a lower, generally curved drilling face 21, and an interior coring face 23. The interior face 23 opens into a central passageway 25 extending through the bit body, and through which drilling fluid is directed down the drill string to the formation and across the face of the bit. A series of channels or water courses 18 extend outwardly from the interior face of the bit across the drilling face and up the gage or reaming face of the bit and have outlets through the annular shoulder 14 formed by the matrix material. Accordingly, drilling fluid delivered through the drill pipe and through passageway 25 is distributed through these fluid passageways or water courses 18 to wash cuttings from the drilling area and upwardly to the top of the well as is well known in the art. The fluid passageways 18 intersect the matrix of the bit to define a plurality of drilling lands 27 on which the cutting elements 17 are mounted.

It will be understood in accordance with this invention that in addition to diamond-cutting elements, other irregularly or regularly shaped particles or cutting elements of tungsten carbide, or particles of multiple carbide containing tungsten carbide plus titanium carbide or tantalum carbide, or particles of a similar hard metallic, intermetallic or nonmetallic material may be employed as cutting elements in lieu of diamonds.

In addition, it should be noted that a number of other bottom configurations suitable for use on a diamond-drilling bit or a bit of similar type will be suggested to those skilled in the art. Accordingly, the matrix of the bit may be additionally provided with junk slots which may be similarly designed to discharge cuttings from the drilling area. The inclined face of the drilling lands permitting the formation of a hydraulic wedge during drilling in accordance with this invention can accordingly be defined as the areas mounting the cutting elements between water courses, junk slots, or other analogous passageways of significant size which might intersect or traverse the matrix of the bit.

It is further to be noted that although the water courses in the bit illustrated are shown to be substantially straight water courses, the use of spiral water courses or fluid passageways may be desirably used in accordance with this invention. Accordingly, a variety of water course and junk slot designs suitable for use on diamond bits or bits using similar cutting elements such as have been developed in the art may be used on the novel bits of this invention.

With reference now more specifically to FIGS. 4, 5, and 6, the particular preferred embodiments of this invention can be more readily seen.

FIG. 4 is an exploded view of a section of the bit illustrated in FIGS. 1 through 3 along line 4—4. Accordingly, FIG. 4 shows a development of a circular section of the bit and also shows the bit in contact with a formation 29 which the bit is to drill.

Inasmuch as the general direction of rotation of the bit would be in the direction indicated by arrow A, the leading edge 29 and the trailing edge 31 of each of the drilling lands is established. Accordingly, in FIG. 4 the direction of rotation would be seen as proceeding in the direction indicated by arrow B and the leading and trailing edges of drilling land 27 are established at 29 and 31, respectively.

The cutting elements 17 embedded in land 27 are illustrated to be in contact with a substantially planar surface of the formation 30, for ease in illustration. Accordingly, the plane of surface 30 in FIG. 4 would be the "cutting surface" defined by the cutting elements existing at the radius at which section 4—4 was taken. Inasmuch as section 4—4 is taken at a radius where the cutting elements 17 are facing directly downwardly, it will be appreciated that for these cutting elements the "cutting surface" is planar. However, proceeding up the face of the bit toward the reaming or gage surface 19, it will be appreciated that the "cutting surface" assumes the shape of a frustocone, and eventually, in the upper vertical reaming portion of gage 19 of a cylinder. Hence, at every radius from the axis of rotation of the bit (more specifically the surfaces in the cutting elements extending outermost from the bit), cutting elements will define a cutting surface which, according to the design of the bit, may vary from frustoconical cutting surface on the interior surface of the bit to a substantially planar cutting surface described by the lowermost cutting elements on drilling face 21, to a substantially cylindrical cutting surface defined by the vertically disposed cutting elements on gage surface 19.

With reference to FIG. 6, therefore, there is seen a section along line 6—6 of FIG. 1 illustrating cutting element 17 having their exposed portions so disposed that they will ream the formation to form a virtually cylindrical cutting surface as illustrated by the face of formation 33. In accordance with the novel design of drilling bits in accordance with this invention, the exposed portions of the cutting elements carried in the drilling lands of the matrix are aligned to define a cutting surface, as defined above, upon rotation of the bit while the surface of the matrix portion of each of the drilling lands is spaced at a greater distance from the cutting surface at the forward or leading edge of the land than at the trailing edge of the land. Thus, in FIG. 4 surface 35 of land 27 defines an angle alpha with respect to the cutting surface. Similarly, in FIG. 6, curved surface 36 of the drilling land defines an angle alpha with respect to cutting surface 33. However, in the latter case it will be appreciated that measurement of the angle alpha must be made by measuring between the tangents to the cutting surface 33 and the matrix surface 17.

It will be appreciated that the matrix surface need not be completely flat as illustrated in FIG. 4 on the drilling face of the bit, nor need the matrix surface describe the arc of a circle as illustrated in FIG. 6. Indeed the surface of the drilling land may be provided with minor ridges or recesses between individual diamonds. Such minor recesses or ridges are not to be regarded as water courses or passageways defining drilling lands on the face of the bit. Rather such minor recesses between individual diamonds carry only small amounts of fluid in comparison to the amounts carried by the water courses or junk slots or other major passageways. Accordingly, bits in accordance with this invention may have such ridges in the drilling land. In such cases, the mean surface of the matrix, disregarding these minor ridges and recesses is to be considered in determining the existence of an angle alpha, which is the angle of inclination between the matrix surface and the cutting surface.

Thus, with reference to FIG. 6, specifically the dotted portion, there is illustrated a gage portion of a bit having minor ridges 43 between diamonds. Line 45 illustrates a determination of the mean surface of the matrix, and angle alpha is determined between that mean surface and the cutting surface 47, again illustrated as the formation.

In accordance with this invention, the angle alpha is not critical but is determined by the width 37 of the drilling land at any particular distance from the axis of rotation of the bit and the comparative size of cutting elements 17 available. In order to maintain the exposed faces of the cutting elements 17 along the cutting surface while permitting the matrix surface to approach the cutting surface as one proceeds from the leading to trailing edge of each individual drilling land, it is necessary to place the larger cutting elements proximate the leading edge of the drilling land and place smaller cutting elements proximate the trailing edge of the drilling land. Since the relative size and consequently the height of cutting elements is limited by practical considerations, it can be seen that the angle alpha will be largely determined by the relationship between the width of the drilling land, such as illustrated at 37 and the difference in spacing which may be accomplished by using different sized cutting elements, i.e., elements of different height. Generally, it is preferred to maintain the angle alpha at at least about 1° and preferably at 2° or more. Since the width of the drilling land, in the embodiment illustrated, increases as one proceeds from the center of the drill bit outwardly, it also will be understood that the bit may be constructed so that the angle alpha is greater in that portion of the drilling land closer to the center of the bit than in those portions of the drilling land near the outer periphery of the bit. If equally sized large cutting elements were placed proximate leading edge 29 of drilling land 27 and the smallest operable cutting elements were placed proximate the trailing edge 31, it is seen that the angle between the matrix and the cutting surface can be greatly increased in the interior portion of the bit as opposed to the outermost portion of the bit.

Reference will now be had to FIG. 5 to illustrate the method of operation of the instant novel drill bit design intending to minimize differential sticking and in creating pressure patterns which assist in drilling. As the drill bit moves in direction B as illustrated in FIG. 4, fluid is flowing through water courses 18. The motion of the drill bit is such that the open end of wedged-shaped volume 39 proximate the leading edge 29 of drilling land 27 will readily accept fluid between cutting elements 17 as the bit is rotated. However, because of the inertia of the fluid and the movement of the bit as the bit continues to move in the direction indicated by the arrow B, a hydraulic wedge will be formed in volume 39 and the pressure of fluid in that area will increase.

There is illustrated in FIG. 5 a plot of pressure across the face of the bit as illustrated in FIG. 4. Thus in the region of water course 18, the pressure is comparatively low (FIG. 5 being a plot merely of relative pressures and not intending to be a plot of absolute pressure). As the fluid enters under the leading edge 29 of drilling land 27, the pressure begins to slowly increase as indicated in region Y of the graph in FIG. 5 as it is subjected to the taper of the hydraulic wedge formed between matrix surface 35 and drilling surface 30. The pressure continues to build to a high point at trailing edge 31 of land 27 and then drops abruptly in the water course immediately beyond trailing edge 31.

Accordingly, it can be appreciated that this wedge action tends to encourage the flow of fluid around cutting element 17 and hence tends to prevent differential sticking. Moreover, the hydraulic wedge action initiated by the novel design of this invention results in desirable pressure patterns upon the formation which assists in drilling.

It has been recognized in the prior art that diamond bits and similar bits which operate with very hard cutting elements do not only abrade the formation but accomplish their drilling by causing the yield shear strength of the rock in the region of the cutting elements to be exceeded, causing a rupture in the formation. As each cutting element successively moves over the formation, additional rupture is induced along the path of the cutting element while the initial ruptured area remains within a region of relatively high compressive stress. However, as the cutting element continues to move and the areas of initial rupture lie outside the compressive stress field of the cutting element, the sudden elastic recovery of the formation tends to propagate the fracture in the formation which emerges at the surface.

An explanation of this method of operation of diamond drill bits is set forth in *Engineering and Mining Journal*, Vol. 163, No. 10, Oct. 1962, pg. 82 et seq.

Accordingly, returning to FIG. 4 with this method of operation of diamond drill bits in mind, the behavior of an isolated part of the formation will be examined. If an isolated portion of the formation below the cutting elements proximate the leading edge 29 of drilling land 27 is considered, it will be seen that as the largest cutting element 17 passes over this region, it will exceed the shear strength of the formation and cause rupture. When the bit moves in direction B, this same cutting element will cause additional rupture in additional portions of the formation to the left of the original rupture. When the initial point of rupture passes out of the region of compressive stress of the first set of cutting elements, a minor fracture is likely to occur. But at this same time, the fluid pressure on these portions of the formation increases as the formation approaches the trailing edge of the drilling land. Consequently, any fracture which occurs is subjected to fluid at an increased pressure in accordance with the graph shown in FIG. 5 until it is traversed by the entire width 37 of the drilling land. Hence, when the isolated portion of the formation comes under trailing edge 31 of the drilling land, the pressure of any fluid in a fracture will be at a maximum. But as the drill bit continues to rotate, the same portion of formation passes under the region of the next water course or fluid passageway and pressure drops abruptly. Accordingly, high-pressure fluid which might have been forced into the fracture as the drilling land passed over it will tend to erupt the fracture into the low-pressure water course and accordingly assist in both the loosening and removal of drill cuttings.

In accordance with the operation as above described, there is accordingly provided by this invention a method of drilling which comprises abrading and fracturing a subterranean formation with cutting elements in the presence of a drilling fluid maintained at a pressure higher than the formation pressure, increasing localized fluid pressure in the region of abrasion and fracture as a plurality of cutting elements traverse the formation, and abruptly decreasing pressure while exposing the region of abrasion and fracture to increased drilling fluid flow. Repetitively subjecting the formation to this action will tend to force fluid at higher pressure than the pressure in the fluid passageways or water courses into minute fractures in the formation and cause them to erupt into the water courses when the reduced pressure region of the water courses passes over them.

In addition, because of the increased volume between the matrix of the drilling bits in accordance with this invention and the formation which effectively comprises the cutting surfaces defined by the rotation of the exposed cutting elements, the pressure drop across the bit is reduced and accordingly the pressure at which drilling fluid is supplied to the bit may be reduced. Accordingly, the formation is not subjected to higher pressures which can increase the plasticity of the formation and consequently, its resistance to fracture.

Therefore, it can be appreciated that within limits it is desirable, in accordance with the design of drill bits of this invention, to space the leading edge of the drilling land as far from the cutting surface defined by the exposed portion of the cutting elements as possible in order to assist in obtaining flow of drilling fluid around the cutting elements and to reduce the need for supplying the drilling fluid to the drill bit at unduly high pressures. As stated above, the angle of inclination between the surface of the drilling bit matrix and the cutting surface is preferably at least 1°, but if possible, this angle should be increased to as much as 7° or 8° or more to provide a wedge-shaped volume which has an opening or throat beneath the leading edge of the land which is as open as possible to permit drilling fluid flow into the wedge-shaped volume. However, it will be understood that since the primary drilling function is accomplished on the drilling face of the bit, it is more important that the increased angles be employed on the lower drilling face of the bit as opposed to on the reaming portions of the bit.

With respect to the phrase used herein defining the volume between the surface of the matrix and the cutting surface as a "wedge-shaped volume" it will be understood that this phrase includes the curved wedge-shaped volume such as illustrated at **41** in FIG. **6**.

The instant novel invention can be adapted to a variety of drilling bits which utilize diamonds or like cutting elements. Thus, for example, the instant invention can be adapted to coring bits, stepped face bits, eccentric bits and the like. In all instances where such bits are used, the drilling faces are intersected and traversed by fluid passageways or water courses and accordingly design of the matrix to enable the creation of a hydraulic wedge between the matrix and surface being drilled can be adapted to such other drilling bits as are known to the art by methods that are well known. These and similar modifications and adaptations of the instant invention described above will readily be suggested to the skilled artisan.

What is claimed is:

1. A rotary drill bit comprising:

a body portion including a matrix;

means defining passageways across said matrix, said means dividing said matrix into a plurality of drilling lands; and

a plurality of cutting elements carried in each of said drilling lands, the exposed portions of said cutting elements in each drilling land being disposed to successively drill the formation and to define a cutting surface upon rotation of the bit, said rotation also defining leading and trailing edges of said drilling lands;

the surface of said matrix of said drilling lands being spaced a greater distance from said cutting surface at the leading edge of such drilling land than at the trailing edge of such drilling land to define a tapering volume between said surface and said cutting surface defined by rotation of said bit.

2. The rotary drill bit of claim **1** wherein the exposed height of said cutting elements in each of said drilling lands decreases with increasing distance from the leading edge of said drilling land.

3. The rotary drill bit of claim **1** including:

means for interconnection of said drill bit in a drill string; and

a central opening in said bit communicating with the interior of said drill string;

said passageways extending into said central opening.

4. The rotary drill bit of claim **1** including shallow ridges between individual cutting elements in each drilling land to afford increased fluid access around said individual cutting elements.

5. The rotary drill bit of claim **1** wherein the cutting elements carried in said drilling lands are diamond-cutting elements.

6. The rotary drill bit of claim **1** wherein a tangent to the matrix portion of said drilling land and a tangent to said cutting surface defines an angle, which angle has a magnitude of at least 1°.

7. The rotary drill bit of claim **6** wherein:

said passageways proceed substantially radially across the face of said matrix and wherein said angle decreases as the width of said drilling lands between adjacent passageways increases.

8. In a rotary drill bit having a body portion including a matrix, means defining passageways across the matrix and dividing said matrix into a plurality of drilling lands, and a plurality of cutting elements carried in each of said drilling lands and arranged to successively drill the formation, the exposed portions of said cutting elements defining a cutting surface upon rotation of the bit and establishing leading and trailing edges of said drilling lands; the improvement wherein the surface of said matrix of said drilling lands is spaced a greater distance from said cutting surface at the leading edge of such drilling land than at the trailing edge of such drilling land to define a tapering volume between said surface of said matrix and said cutting surface defined by rotation of said bit.

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