Nov. 6, 1962 M. R. J. WYLLIE 3,062,286

SELECTIVE FRACTURING PROCESS

Filed Nov. 13, 1959 2 Sheets-Sheet 1

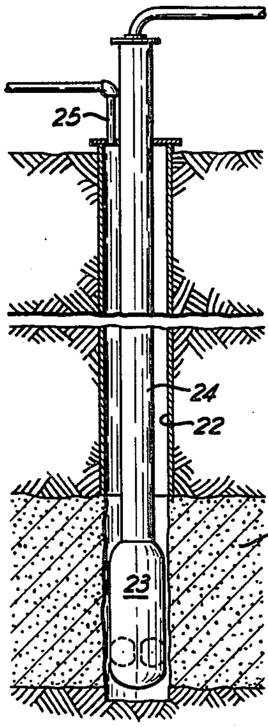

Fig. 1

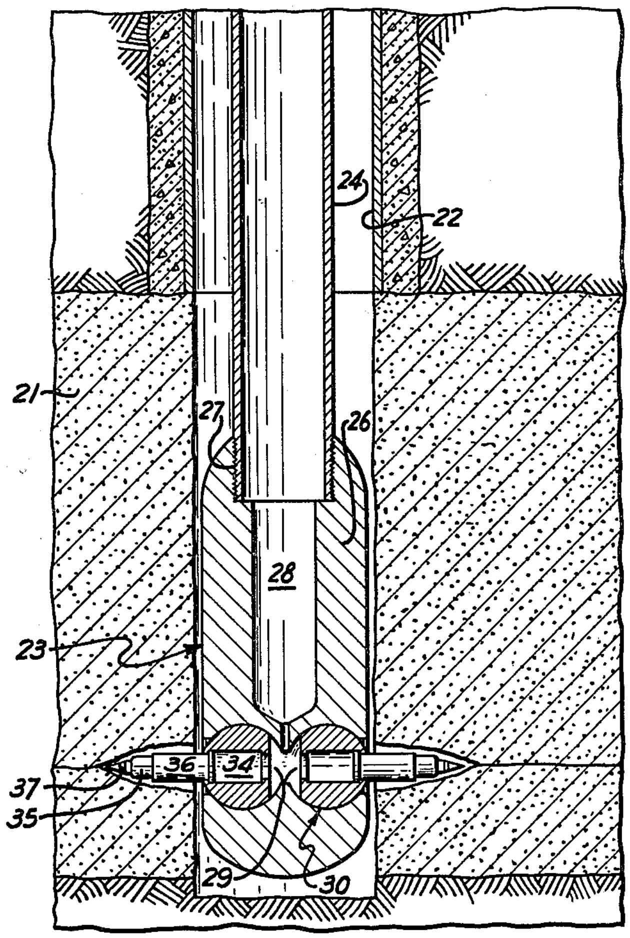

Fig. 2

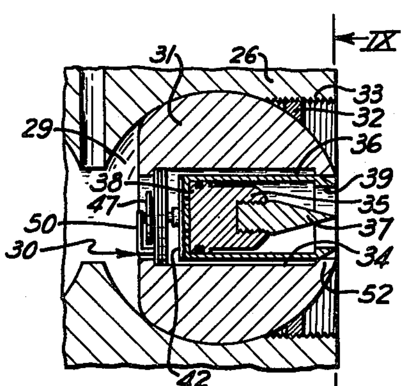

Fig. 3

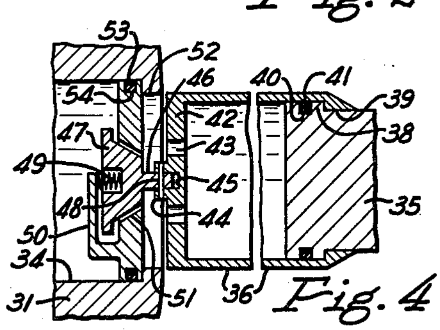

Fig. 4

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Filed Nov. 13, 1959 2 Sheets-Sheet 2

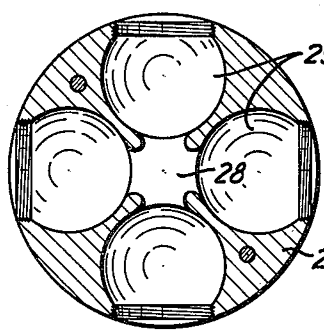

Fig. 5

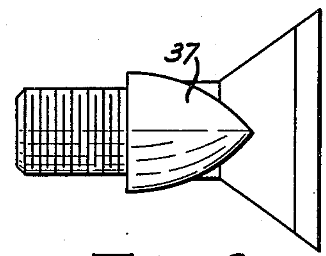

Fig. 8

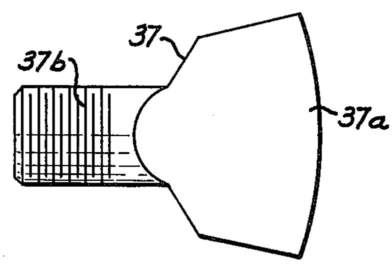

Fig. 6

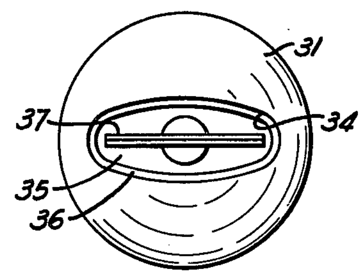

Fig. 9

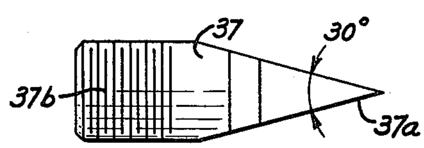

Fig. 7

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United States Patent Office

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3,062,286
SELECTIVE FRACTURING PROCESS

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3 Claims. (Cl. 166—42)

This invention relates to the treatment of wells. In particular the invention relates to a method for creating at a predetermined depth and orientation fractures in subterranean formations.

It is well known in the art of well stimulation to inject a fluid into a formation and to apply pressure to the fluid to create artificial fractures in the formation. The creation of artificial fractures in fluid bearing earth formations facilitates drainage of such formations into a well from which the desired fluids can be recovered. In hydraulic fracturing operations, a fracturing liquid, generally a viscous or non-penetrating liquid, is forced down the well and into the formation under sufficient hydraulic pressure to overcome the tensile strength of the formation, that is, to "break down" the formation thereby causing a crack to be produced in the formation. The fracturing fluid upon being forced into the induced crack extends the fracture substantial distances into the formation. Ordinarily, the pressure required to extend the fracture is considerably less than that required to initiate the fracture. Usually a propping agent such as sand is suspended in the fracturing fluid for deposit in the fracture to prevent closure of the newly created drainage channels by the pressure of the overburden of the earth.

Although hydraulic fracturing treatments have come into widespread use in the art of well stimulation, the fracturing process is not always successful in increasing the production of the well. The principal cause of unsuccessful fracturing operations is probably the lack of control of the direction and orientation of the fracture. Under the pressure of the hydraulic fluid the fracture is ordinarily initiated and extended along a plane of weakness in the formation which, of course, may extend in any direction. As a result the fractures often extend out of the oil bearing rock or out of the desired interval to be fractured into a gas cap above the oil in the pay zone or into water below the oil. The low viscosity of the gas or the water as compared with the oil may result in the gas or water flowing readily through the fracture to the well leaving the oil in the formation.

In attempts to control the location at which a fracture is created several techniques have been developed. For example, either single or dual formation or casing packers can be set in the well to isolate and confine a selected producing zone in which a fracture is desired. This technique provides control over the general location of the fracture but gives no control over the direction or orientation of the fracture. Underreaming a portion of the borehole has also been practiced in an attempt to induce the fracture at a desired location. By underreaming a portion of the borehole the total force available to put the rock under tension upon application of hydraulic pressure is increased.

This invention resides in a method of treating earth formations surrounding a well bore to create fractures therein at predetermined depth and orientation with respect to the well bore. In general, the invention comprises a method for creating an oriented fracture in subterranean formations by applying stress mechanically to the formation at the exact depth at which the fracture is desired. The mechanical stress is applied by driving

a tool having a sharp penetrating edge surface into the formation in a given radial direction to effect cleavage of the formation and to develop a surface or plane of weakness in the formation so oriented that it permits a fracture to be extended in the formation in a desired plane and direction. Thereafter, a fracture is extended in the formation along the plane of weakness which has been developed therein by the application of hydraulic pressure. In this manner, it is possible to control positively the location and direction of fractures in subterranean formations.

In accordance with the invention, fractures are formed in earth formations by driving a tool having a sharp penetrating edge surface into the formation with sufficient force to split or part the formation and to develop at the apex of the initial parting caused by penetration of the tool an oriented plane of weakness. The tool is positioned within the well bore and forced into the formation in a specific radial direction from the well so that the penetrating edge of the tool enters the formation in the compass direction in which the fracture is desired. The radial direction in which the tool enters the formation establishes the direction of the initial parting and also the direction in which the fracture is extended by the subsequent application of fluid pressure. Not only is the compass direction of the fractures positively controlled by orientation of the penetrating tool in the borehole but also the fractures are oriented as to the angle the fracture plane makes with the horizontal. Thus, the penetrating tool can be so positioned within the well bore to penetrate the earth formation at a desired angle, to create therein fractures that are horizontal, vertical, or sloping at an angle between the horizontal and the vertical.

If a vertical fracture is desired, the tool is positioned within the well bore with its penetrating edge surface disposed in a vertical plane and forced into the formation in the compass direction in which the fracture is to extend. When making vertical fractures, it is often desirable to limit their vertical extent, for example, to preclude fracturing the cap rock over the pay zone and direct the fracture radially outward from the well. Such limitation can be accomplished by first forming horizontal fractures or fractures in a plane along which the vertical fracture is to be limited, and then forming the vertical fracture. Both the vertical fracture and the fracture in a plane other than vertical are oriented by the method herein described. For fractures sloping at angles between the horizontal and vertical the tool is positioned within the well bore with the penetrating edge thereof suitably disposed at the desired angle.

When a substantially horizontal fracture or a fracture sloping at an angle from the horizon is desired in the formation it is generally preferred to create a plurality of radially extending fractures in the walls of the borehole which when extended by known hydraulic fracturing methods may meet to form a single fracture in the desired plane radiating in all directions 360° around the borehole. Thus, by means of the present invention a plurality of fractures extending in the same plane but in different radial directions from the borehole will usually be created in the formation. By creating a plurality of radial fractures in the formation the space between the individual fractures is reduced thus facilitating the creation of a single 360° fracture in the formation. This is accomplished in accordance with the invention by penetrating the formation with a suitable penetrating tool a number of successive times in the desired radial directions, or by simultaneously penetrating the formation with a plurality of penetrating tools arranged to penetrate the formation in the same plane but in various radial directions. However, while a plurality of radial fractures are ordinarily created in practical operation it is within the scope of the invention to create a single fracture extending in one radial direction from the borehole.

Various shaped tools having a relatively sharp penetrating edge surface can be employed for penetrating the earth formation in accordance with the invention. It is preferred to employ a tool in which the opposed working surfaces leading back from the sharp earth penetrating edge are inclined from one another so that the tool increases in thickness from the penetrating edge rearwardly. A tool having this shape upon penetrating the earth formation will cleave the formation and produce a V-shaped fracture therein. In addition, the sharp penetrating edge of the tool will develop a sufficient concentration of stress in the formation to establish a plane of weakness therein extending from the apex of the V-shaped fracture a substantial distance into the formation.

After the initial parting is made at a desired depth and orientation in the formation by means of a suitable tool, this portion of the formation is isolated from the remainder of the formation and a hydraulic pressure applied thereto to extend a fracture in the formation. The hydraulic pressure is provided by injecting into the well any of the fracturing fluids commonly employed in conventional hydraulic fracturing operations. These fluids for the most part, comprise hydrocarbon gels obtained by dispersing a suitable gelling agent in a hydrocarbon oil such as gasoline, kerosene or crude oil. Commonly employed gelling agents include aluminum naphthenate and mixtures thereof, with aluminum oleate, hydroxy aluminum soaps of fatty acids, aluminum and other metal soaps of the various fatty acids derived from coconut oil, peanut oil and the like. Aqueous fracturing fluids which may or may not contain a thickening agent such as a natural gum, as for example, Karaya, Batu or Guar gum, which will allow the build-up of pressures sufficient to extend the fracture in the formation can also be employed. Application of the hydraulic pressure causes the formation to fracture along the plane of weakness which has been developed in the formation by penetration of the tool. Extension of the fracture substantial distances into the formation is achieved utilizing much lower hydraulic pressures than are ordinarily required in conventional hydraulic fracturing operations. This, of course, is an important advantage of the invention in that it lessens the high pressure equipment requirements.

The hydraulic fluid employed to extend the fracture in accordance with the invention may contain a granular solid propping agent. Thus, the hydraulic fluid may contain as props, materials such as glass beads, ceramic particles, metal particles, crushed rock, wood chips, and the like. Sand because of its cheapness and general availability is a preferred propping material. The particle size of the propping material can range from those quite small enough to pass through a #4 standard mesh sieve to those just large enough to be retained on a #100 mesh sieve.

It is a fundamental feature of the present invention that the penetrating tool be driven into the formation in a given radial direction with sufficient force to part the formation and to develop a plane of weakness in the formation extending from the apex of the initial parting back into the formation. This is absolutely necessary in initiating fractures in accordance with this invention in order to achieve positive control over the direction and plane in which the fracture propagates through the formation upon application of the fluid pressure. Thus, it is to be clearly understood that the penetrating tool does not function to produce merely a notch in the formation around the well bore such as would be produced by abrasive jets or explosive jet charges as are employed in the treatment of wells to perforate casing, cement sheaths around such casing and the like.

The creation of oriented fractures by the method of the invention will be illustrated in part by reference to the drawings wherein:

FIGURE 1 is a diagrammatic view in vertical section of a borehole having positioned therein opposite the producing formation one preferred form of apparatus suitable for use in the method of the invention.

FIGURE 2 is a similar view of the well after the walls of the horehole have been penetrated by the apparatus of FIGURE 1.

FIGURE 3 is a vertical view in cross-section of one of the bit-projecting units of the apparatus of FIGURE 1.

FIGURE 4 is a detailed cross-sectional view of valve means for shutting off fluid flow through the bit-projecting unit of FIGURE 3.

FIGURE 5 is a plan view in cross-section of one embodiment of the apparatus of FIGURE 1 in which four bits may be employed to penetrate the formation at 90° angles.

FIGURE 6 is a plan view of a bit member having an arcuate penetrating edge surface which is employed in the apparatus of FIGURE 1.

FIGURE 7 is a side view of the bit of FIGURE 6.

FIGURE 8 is a plan view of a bit having a straight penetrating edge surface which is employed in the apparatus of FIGURE 1.

FIGURE 9 is a frontal view taken on the line IX—IX of FIGURE 3.

Referring particularly to the drawings, FIGURE 1 shows a vertical section of an underground earth formation **21** penetrated by a well bore and casing **22**. Disposed within the well bore opposite an oil-saturated zone is one form of apparatus designated generally by the numeral **23** which is suitable for use in accordance with the invention. The apparatus is adapted to create substantially horizontal fractures in the formation at 90° from one another. This preferred form of apparatus is disclosed and claimed in the copending application of Jimmie L. Huitt, Joseph L. Pekarek and Abraham J. Teplitz, Serial No. 852,846 filed November 13, 1959 which application and the description therein is by reference incorporated herein.

Drill string **24** extends downwardly through the casing head and connects the fracturing apparatus **23** with a source of fluid supply (not shown). Tubing **25** is provided for injection of a conventional fracturing fluid.

As shown more particularly in FIGURES 2 and 3, the preferred form of apparatus employed to create a plurality of radially extending horizontal fractures in accordance with the invention comprises a body member or mandrel **26** having a threaded portion **27** at its upper end which is adapted to receive the threaded lower end of drill string **24**. In this manner the apparatus is connected to, supported from, and receives pressure fluid from the drill string. The mandrel **26** is provided with an interior longitudinal chamber **28** which is in fluid communication with chambers **29** which are disposed around the periphery of the mandrel. The chambers **29** have a generally globular configuration and are illustrated in the drawings as being spheroidal in shape. However, the chambers can also be spherical in shape and can be varied in number.

Located within the spheroidal chambers **29** are the bit-projecting units designated generally by the numeral **30**. The bit-projecting units **30** consist of a barrel **31** which conforms in shape to chambers **29** and fits snugly therein. The globular shape of chambers **29** and barrels **31** is important since this configuration enables the barrels **31** to be mounted within the chambers **29** in any desired position so as to initiate substantially horizontal fractures or fractures sloping at a desired angle from the horizon. Lock ring **32** threadably engages the threaded portion **33** of body **26** and serves to maintain the barrel **31** in fixed position within the chamber **29**. Barrel **31** is formed with an elongated non-cylindrical central bore **34** in which is located piston **35**. As shown more clearly in FIGURE 9, bore 34 within barrel 31 is non-cylindrical or non-circular in cross-section. This configuration effectively prevents rotation of the piston 35 relative to the barrel 31 thereby insuring that the penetrating bit members attached to piston 35 enter the formation in the desired plane. Bore 34 within barrel 31 can have any configuration which will prevent rotation of the piston 35 relative to barrel 31. Piston 35 fits slidably within the sleeve member 36 and has attached to its outer end the penetrating bit members 37 which are adapted to penetrate and cleave the earth formation. The rear portion 38 of piston 35 abuts against inwardly projecting flange 39 on sleeve 36 to limit the extent of the forward movement of piston 35 relative to sleeve 36. The rear portion 38 of piston 35 is provided with a circumferential groove 40 within which is disposed suitable packing material 41 for providing a fluid tight seal.

As shown in FIGURE 4, the rear wall 42 of sleeve member 36 is provided with a number of openings 43 which allow passage of a pressure fluid to act upon piston 35 and thereby drive the bit members 37 into the formation. The enlarged center portion 44 of wall 42 is provided with a recess 45 which receives in loose fit extension or lug 46 of valve 47. Valve 47 is attached to the rear wall 42 of sleeve 36 by means of shear pin 48 so that the valve 47 moves in conjunction with sleeve 36. Spring 49 attached to valve 47 and and arm 50 of valve seat 51, in cooperation with shear pin 48, maintains valve 47 in the open position as shown in FIGURE 4. Valve seat 51 is dimensioned to fit slidably within bore 34 and to form a fluid-tight seal when abutting against the inwardly projecting flange 52 on barrel 31. O-rings 53 of suitably deformable material are disposed in outer circumferential grooves 54 in the valve seat 51 to form a fluid-tight seal between the valve seat 51 and bore 34.

The bit members 37 which are adapted to penetrate and fracture the earth formation can be of various design. The bit members 37 will, in general, be formed of hardened steel or the like and be provided with sharp penetrating edge surfaces which enable the bits to readily penetrate the earth formation. The opposed working surfaces leading back from the penetrating edges of the bits are preferably inclined so that the bits increase in thickness from the penetrating edge rearwardly. This structure enables the bits to readily cleave the formation. The sharp forward or penetrating edges of the bits develop a sufficient concentration of stress in the formation to establish a plane of weakness therein extending from the apex of the V-shaped fracture a substantial distance into the formation. The included angle at the forward or penetrating edge of the bit may thus range from about 10° to 60°.

In accordance with the method of the present invention the apparatus 23 is connected to drill string 24 and run into the borehole to the desired depth. Fluid pressure is then supplied to the apparatus through drill string 24. The pressure fluid passes through the interior longitudinal chamber 28 into spheroidal chambers 29 and central bore 34 within the barrel 31. Valve 47 in its normally open position permits passage of pressure fluid through the valve and through openings 43 in the rear wall 42 of sleeve element 36 to act upon the piston 35. The fluid pressure forces piston 35 outwardly thereby causing the bits 37 to penetrate the walls of the borehole and produce a parting in the formation. Sufficient force is directed outwardly against piston 35 by the fluid pressure to insure that the bits 37 penetrate the formation a sufficient distance to cleave the formation and to develop an artificial plane or weakness therein extending in the desired plane and compass direction.

As piston 35 continues its outward travel under the action of the fluid pressure, the rear portion 38 of the piston engages flange 39 on sleeve 36 causing the sleeve together with valve 47 to which it is attached to move outwardly through the bore 34. By continuing the application of fluid pressure piston 35 and sleeve 36 eventually emerge from barrel 31. The emergence of sleeve 36 from the barrel 31 permits the pressure fluid to flow freely into the borehole thereby creating a substantial pressure differential across the valve 47. The pressure differential across valve 47 is sufficient to shear pin 48 and to seat valve 47 in valve seat 51 against the resisting force of spring 49. The seating of valve 47 in valve seat 51 prevents further fluid flow through the bore 34, and causes a significant build up in pump pressure which indicates to the operator that the earth penetrating bits have separated from the apparatus. The fluid pressure in drill string 24 is released to allow valve 47 to open and withdraw lug 46 from recess 45. The fracturing apparatus can then be withdrawn from the wellbore leaving the bits within the formation to maintain open the induced fracture.

Liquids or gases such as air may comprise the fluid pressure working medium. The fluid pressure required to force the bits into the formation will depend upon various factors and particularly the area of the piston 35, the extent of overburden and geological characteristics of the formation such as the tensile strength of the formation, plasticity of the formation, that is, the amount of distortion the formation exhibits between the yield point and the point of rupture and so forth. Another factor which influences the fluid pressure required to force the bit into the formation is the sharpness of the penetrating edge of the bit. Generally, bits having sharp penetrating edges will penetrate and cleave the formation under lower fluid pressure than bits having more blunt edges. The fluid pressure required to cleave a particular formation can readily be determined experimentally by those skilled in the art. The fluid pressure applied through the drill string to force the bits into the formation may be applied continuously or intermittently to drive the bit into the formation with an impulsive force. Thus, for example, the penetrating bits 37 can be forced into the formation by applying pressure to within 200 pounds per square inch of the determined fracture pressure, releasing the pressure and repeating this operation for a number of cycles.

After withdrawal of the apparatus employed to cleave the formation initially a conventional fracturing fluid is then injected into the well. The hydraulic fracturing fluid is injected under pressure at a sufficient rate to extend the fracture a desired distance into the formation. Upon application of the hydraulic pressure the fracture propagates along the plane of weakness which is developed in the formation by penetration of a suitable penetrating tool.

The method of the invention has been illustrated in detail utilizing one embodiment of the apparatus described and claimed in the aforementioned patent application of Jimmie L. Huitt, Joseph Pekarek and Abraham J. Teplitz. Other embodiments of the apparatus described in said application can be utilized in accordance with the invention to create fractures in the earth formation extending in the desired plane. The fracturing method disclosed herein is independent of the apparatus employed and other suitable apparatus can be employed in accordance with the invention.

From the foregoing, it is apparent that the present invention provides a method for creating at a desired depth in earth formations fractures having a predetermined orientation with respect to the well bore. By means of the present invention fractures extending in horizontal, vertical or planes sloping in any desired angle from the horizon can be created at strategic locations in the earth formation. The invention not only provides for positive control of the location and orientation of fractures in earth formations but also substantially reduces the fluid pressure required for fracturing.

The method of the invention can be used in all instances where fractures are desired in earth formations. Thus, the method of the invention can be utilized in fracturing oil, gas or water formations to increase the productivity of the formation. Moreover, the invention can be employed in conjunction with secondary recovery operations employing gas- or water-drive to improve the permeability of the formation. The method of the invention can be used in open hole completions or in cased wells, in which case sections of the casing would be removed to permit penetration of the earth formation.

Those modifications and equivalents which fall within the spirit of the invention and the scope of the appended claims are considered part of the invention.

We claim:

1. A process for creating a fracture in a desired plane in a subterranean formation penetrated by the borehole of a well, comprising positioning a wedge in the borehole with its edge aligned in the desired plane, driving the wedge into the borehole wall to cleave the formation in the desired plane, and thereafter applying fluid pressure to the formation to extend the fracture in the formation along the plane of the cleavage.

2. A process for creating a fracture in a desired plane in a subterranean formation penetrated by the borehole of a well, comprising positioning each of a plurality of wedges in the borehole adjacent the formation with the edge of each of said wedges aligned in substantially a single desired plane, driving said wedges into the formation to part the formation in the desired plane, and thereafter applying a fluid pressure to the formation to extend the fracture from said parting of the formation.

3. A process for creating a fracture in a desired plane in a subterranean formation penetrated by the borehole of a well, comprising positioning a plurality of wedges in the borehole adjacent the subsurface formation with the edges of said wedges oriented to extend substantially in the desired plane toward the borehole wall, said wedges being slidably mounted in sleeves for movement radially outward from the borehole into the formation, applying hydraulic pressure in the sleeves behind the wedges to drive the wedges radially outward into the formation and part the formation along the desired plane, and applying a fluid pressure to the formation to extend the fracture from the parting created by the wedges.

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