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Filed Dec. 24, 1940

2 Sheets-Sheet 1

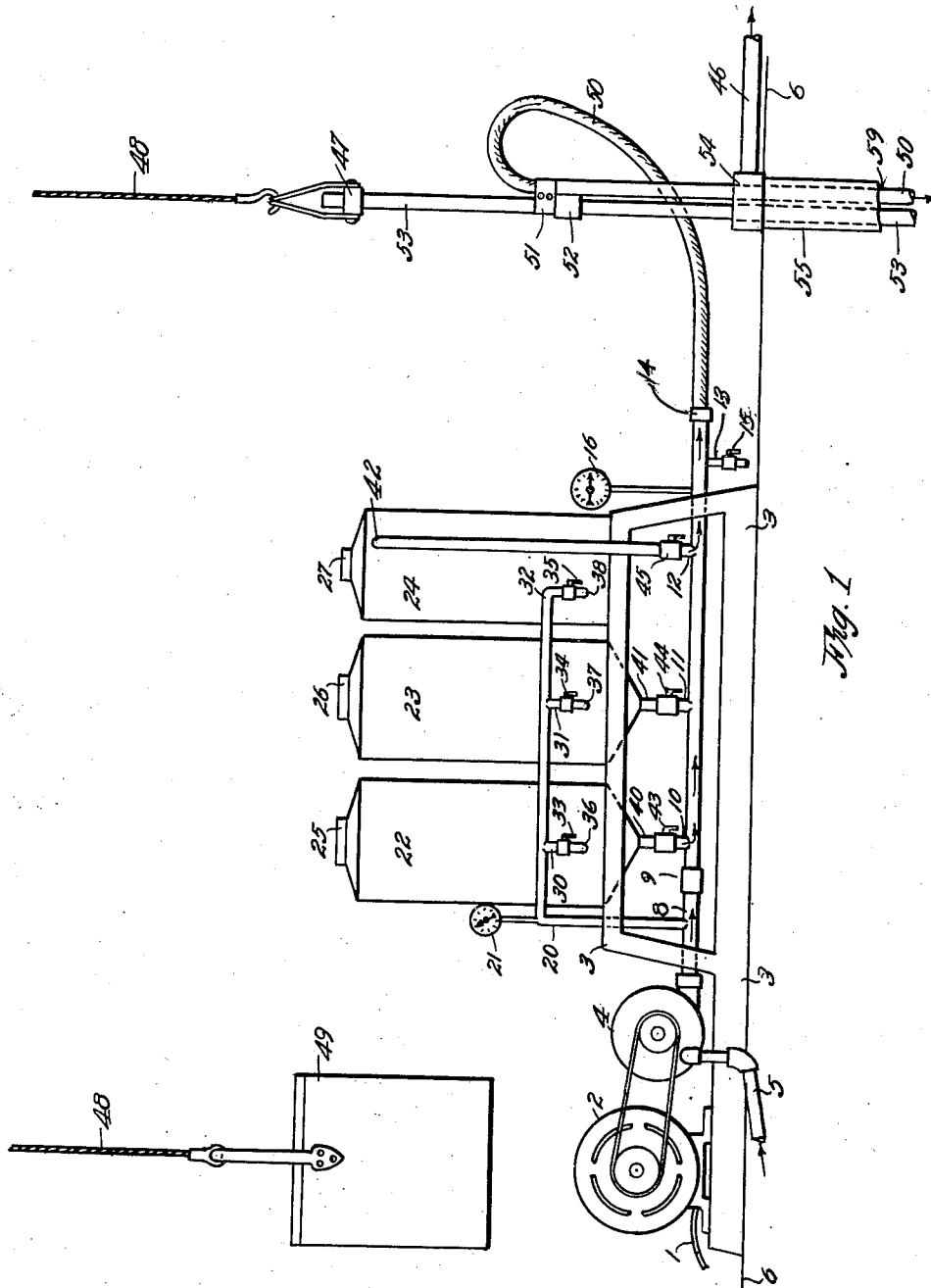


Fig. 1

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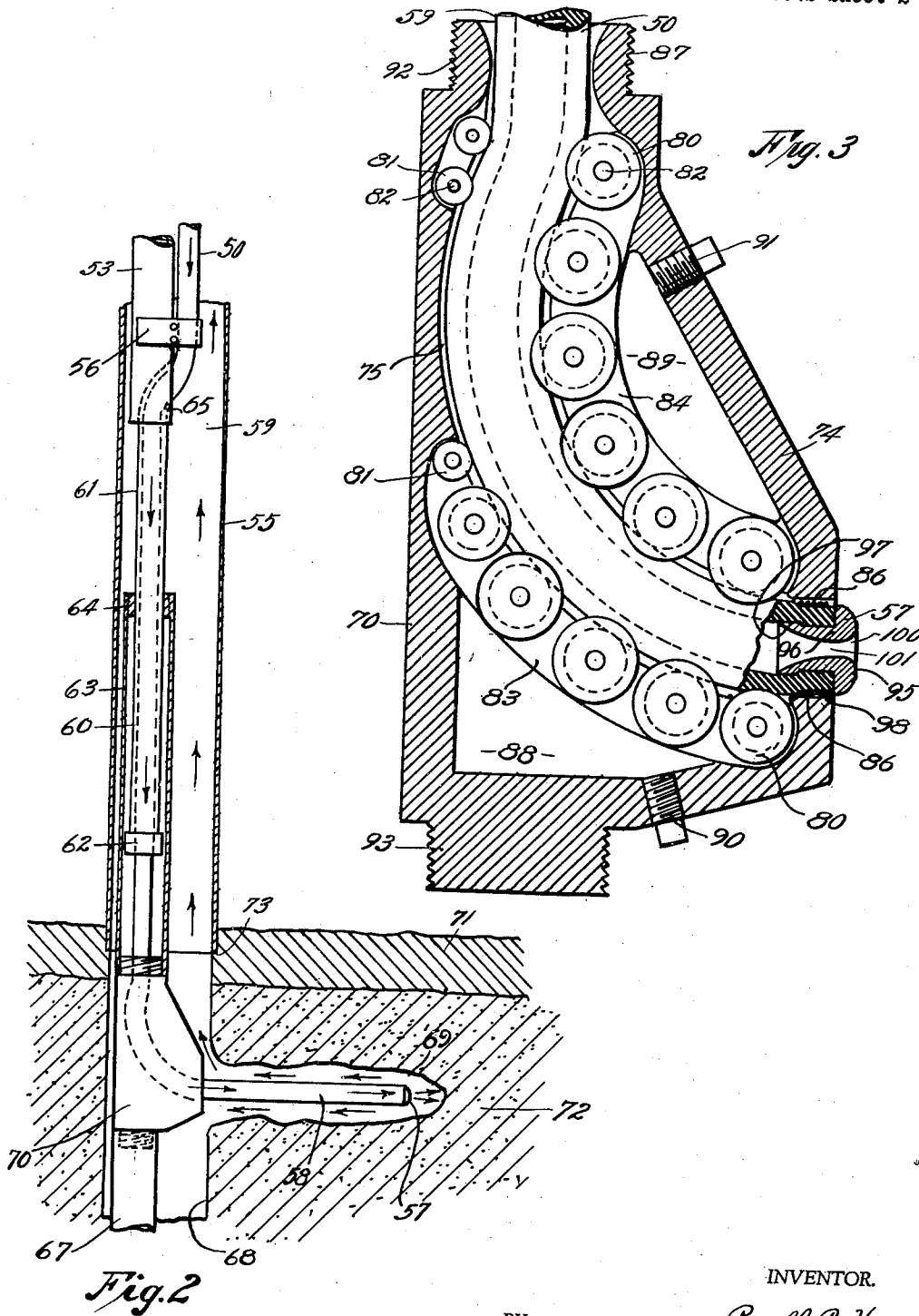
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HYDRAULIC DRILLING APPARATUS

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5 Claims. (Cl. 255—1.6)

This invention relates to fluid recovery from strata such as oil sands and water bearing formations, and is especially concerned with a method and apparatus for enlarging the drainage area of such strata in drilled wells.

Where the fluid producing formation is of soft and unconsolidated rocks, neither shooting with explosives nor treating with acids under pressure has proven practical. Mechanical means of enlarging the drill hole, such as underreamers, are limited to relatively small diameters. Since recovery of fluid from porous formations is definitely associated with the area of the drainage surface, it follows that a practical method of enlarging the drill hole in such softer formations is highly desirable. Equally desirable is a means for creating a reservoir in low pressure sands of the stripper well type which will permit underground storage without increasing the pressure against the sand face, thus increasing the period between pumpings and avoiding evaporation in storage tanks until the oil accumulation is sufficient for transportation.

The general object of this invention is to provide a method and apparatus for cutting drainage channels and storage reservoirs transversely to the drill hole in fluid producing formations.

More specifically an object of this invention is the provision of apparatus for adding abrasives, alone or in conjunction with either acids or caustics, to a high pressure fluid stream, and provision of a conduit for conducting this stream down a drill hole at comparatively slow velocities until expelled through a high pressure nozzle against the face of the formation to be cut.

A further object is the provision of a mechanism for turning a flexible feed conduit through an arc of approximately 90° at any desired point in the drill hole, thus directing the cutting nozzle against the formation face.

Another object is the provision of a mechanism for extending the feed conduit radially from the drill hole as the rock is cut away ahead of it, and for retracting the feed conduit back into the drill hole when the cut is complete.

Still another object is the provision of partial rigidity in a flexible feed conduit, after it has been forced around a bend whose radius is slightly less than the diameter of the drill hole, thus maintaining it in an approximately horizontal position as it is extended away from the drill hole.

Other objects, such as the provision of a circulating stream of fluid for removing cuttings and abrasives from transverse drainage channels

and reservoirs and carrying them to the surface, thus providing a continuous cutting process away from the drill hole, will be more apparent from consideration of the following description.

5 In the accompanying drawings:

Figure 1 is a longitudinal view illustrating surface apparatus for supplying a continuous fluid stream containing abrasives and acids.

Figure 2 is a vertical longitudinal sectional view, partially in elevation, of the feed mechanism and conduit turning footpiece with the cutting nozzle partially extended, and,

Figure 3 is an enlarged cross-sectional view of the footpiece and cutting nozzle, taken from the same direction as in Figure 2.

10 Similar numerals refer to similar parts throughout the several views. Referring to Figure 1, an electrical conduit 1 supplies current to the motor 2, solidly affixed to the surface apparatus framework 3, and driving the pressure pump 4 which is fed by the supply line 5 running to a settling pond. The discharge line 8 of the pressure pump extends horizontally beyond the framework 3 to the union 14 and directly underneath the abrasive supply tanks 22 and 23, and the acid tank 24. These tanks are fitted with pressure tight caps 25, 26, and 27 respectively, which may be removed for recharging them. The abrasive tanks 22 and 23 are swaged at their bottoms into the nipples 40 and 41, carrying valves 43 and 44, running into nipples 10 and 11 respectively which are welded into the discharge line 8. On the acid tank 24 the outlet 42 is in the top and runs down through valve 45 before entering the discharge line through the welded nipple 12.

25 All three supply tanks are fitted near their bottoms with fluid inlets 36, 37, and 38 having valves 33, 34, and 35 respectively and connected by fittings 30, 31, and 32 to the supply line 20 which takes off from the discharge line 8 of the pressure pump ahead of the master valve 9 which can be cut down to give the supply line 20 a differential pressure over the discharge line extension beneath the supply tanks, thereby providing a fluid jet for washing abrasive from the tanks 22 and 23 into the discharge line and for forcing acid into the line from the supply tank 24. The gauge 21 on the supply line 20 and the gauge 16 on the discharge line 8 are used to regulate the degree of differential between these two lines, and the valve 46 on the outlet 13 is used for cutting samples on the discharge line to determine the fluid to abrasive ratio, or the fluid to acid ratio, of the discharge stream.

A flexible conduit, in this instance the heavy hose 50, is attached to the discharge line 3 at the union 14 and is carried across the derrick floor 6 to the open well head 54 on the casing string 55. In running the feed hose 50 down in the well, use is made of a conventional drilling rig or pulling machine for simultaneously running a string of tubing 53 to which the hose is attached by clamps 51 placed above the tubing collars 52, sufficient slack being left in the hose as it crosses the derrick floor to accommodate up and down movement of the tubing 53 for operation of the hose feeding mechanism in the bottom of the well.

The hose feeding mechanism 60, Figure 2, consists of a slip joint of the approximate diameter of the tubing 53. The bottom section 61 of the tubing 53 is reduced in diameter sufficiently to work freely inside another section of tubing 63 which has an inside flange 64 at its upper end which contacts the outside flange 62 on the bottom of the reduced tubing section 61 when the sections of the slipjoint are fully extended. The lower end of the slipjoint 60 is solidly attached to the hose turning footpiece 70, which in turn has an anchor 67 solidly attached to its lower end and extending to the bottom of the well or to a bridge below the fluid producing strata, in this instance, the sandstone 72.

The feed hose 50, after being fixed to the tubing immediately above the slipjoint by the clamp 56, enters the passage 65 in the tubing 53, and hence passes down through the slipjoint 60 and into the footpiece 70 from which it is projected out horizontally against the sand face 68 by downward pressure on the tubing from the derrick floor telescoping the slipjoint 60.

The extending end 58 of the feed hose is fitted with a high pressure nozzle 57 of special design through which the fluid stream carrying abrasive or other cutting material is discharged against the drill hole wall 68 thereby cutting a drainage channel 69 in the sandstone formation 72 lying beneath the caprock 71 which has the annular seat 73 for the casing string 55.

The footpiece 70, Figure 3, consists essentially of a narrow steel box 74 having a tubular passage 75 slightly larger in diameter than the diameter of the feed hose 50. This passage begins in alignment with the center of the slipjoint 60 and continues downward through an arc of approximately 90°, the radius of which is slightly less than the diameter of the drill hole. Flanged roller bearings 80 and 81 have end bearings 82 carried by the curved plates 83 and 84 solidly affixed to the inside of the sidewalls of the footpiece. The curved faces of the flanged roller bearings fit the sides of the feed hose 50 and extend slightly out from the walls of the tubular passage 75 so that they carry the feed hose without it actually touching the walls of the passage 75 except for a short space 85 at the back of the footpiece and at the swaged outlets 86 and 87. Lubrication is furnished the roller bearings 80 through grease boxes 88 and 89 charged through the threaded outlets 90 and 91 respectively.

Threaded pin 92 at the upper end of the footpiece 70 is for attaching it to the bottom section 63 of the slipjoint 60, and the threaded pin 93 at the lower end of the footpiece is for attaching the anchor 67. The extending end

of the feed hose 50 is fitted with a very short nozzle 57 of metal or crystal having a hardness greater than that of the abrasive used. This nozzle has a rounded face 95, a reduced center section 96, and a flanged end section 97. The two latter nozzle sections are inserted in the end of the feed hose, and substantially held there by constricting the end of the hose with steel wire 98.

The opening 100 in the hardened cutting head or nozzle 57 serves as a reducer by being swaged out at its upstream end until it contacts the abrasive resisting inside rubber wall 59 of the hose, and by contracting to a narrow orifice 101 near its center acts to maintain a pressure in the feed line only slightly less than that registered at the surface on the gauge 16. This combination of a restricted orifice or jet with a flexible conduit, has an unusual significance in this instance, since due to the inaccessibility of the formation to be cut to conventional tools and methods, the hydrostatic rigidity, introduced in the hose extension 58 by reason of the even pressure exerted radially against its walls, acts to straighten the hose 50 after being bent by reason of its passage through the curved conduit 75 in the footpiece 70, and further acts to maintain it in a rigid, or partially rigid state, as it is extended away from the drill hole 68.

The drill hole assembly, consisting of the hose 50, the tubing string 53, and the upper section 61 of the slipjoint 60, have a great deal of weight compared to the relatively small cutting head 57 and the horizontally extending hose section 58, Figure 2. Accordingly, in order to avoid overloads by reason of downward pressure of this assembly acting against the extending hose section 58, the drill hole assembly is counterbalanced at the surface, Figure 1, by attaching elevator 47 to the upward extending end of tubing 53, this being affixed to a cable 48 which is carried up over the crown pulley of the drilling rig or pulling machine, and hence outward and down through appropriate pulleys to the counterweight box 49 filled with sand or other forms of easily variable ballast.

In operation, the pressure pump 4 draws fluid from a settling pond to produce a continuous circulatory fluid discharge into the line 8. By manipulating the differential valve 9, and the tank valves 33 and 43, or 34 and 44 of the surface assembly, the abrasive tanks 22 and 23 can be used alternately as they are refilled, thus providing a continuous movement of abrasive into the discharge line. In a similar manner, acid from the tank 24 can be run into the feed line simultaneously with abrasive, or can be run in as a slug independently of either water or abrasive. This latter is highly desirable since in many instances where limestone shells or other calcareous rocks are encountered in the producing formation, they may be subjected to acidizing alone, and neutralizing reagents used to thoroughly flush the drainage channel afterwards.

Before beginning transverse cutting in a drill hole, certain preliminary steps are necessary. A drilling rig, or the equivalent having a mast and appropriate power operated winches, is set up over the hole in the conventional manner, and the surface assembly of the hydraulic drilling apparatus placed on the drilling platform or derrick floor. A settling pond is dug and a sand separator installed on the discharge line 46 from

the wellhead 54 to reclaim the abrasive used in the cutting stream.

The drill hole is filled with fluid. The feed hose 50 is removed from the bottom hole assembly and the nozzle 57 clamped a few inches from the end of a joint of tubing so that the opening 100 is directed vertically downward or at a slight angle thereto. The feed hose 50 is then run into the well on the string of tubing 53, being attached to the tubing by clamps 51 affixed above tubing collars 52. When the cutting head 57 has cleared the casing seat 73, a high pressure stream of fluid and abrasive is directed into the supply hose 50. The return stream comes up the annular space 59 between the drill hole assembly and the walls of the casing 55, washing up cavings and sand from the bottom of the drill hole 68 in a manner analogous to the return flow of a rotary drilling string.

The discharge from the top of the casing is carried by conduit 46 to the sand separator and settling pond, from which both fluid and abrasive are taken for recirculation in the conventional manner. After cleaning is started, the tubing 53 is slowly lowered until a solid base is found. The abrasive is then shut off from the discharge line 8 and fluid circulation allowed to thoroughly clean the hole. A careful measurement of the exact depth to the bottom of the hole is then made as tubing and supply line are pulled.

The slipjoint 60 and the footpiece 70 are then laid out on the derrick floor and packed with grease which serves to keep out water and grit, as well as to lubricate the feed hose 50 as it passes through them. The discharge end of the hose 50 is then run into them until the face of the nozzle 57 barely clears the footpiece, as illustrated by Figure 3, when the slipjoint 60 is fully extended. The clamp 56, Figure 2, is then fixed to hold the hose in this position, and tubing 53 and supply hose 50 rerun until the end of the anchor 67 touches the bottom of the hole according to the measurements previously made. A representative ratio of fluid to abrasive is then discharged at a comparatively low pressure until the weight of the counterbalancing box 47 is adjusted by throwing in sand to equal the weight of the moving assembly in the hole.

The pressure on the discharge line is then brought up to full load and the desired charge of abrasive turned into it. The discharge from the nozzle 57 then begins cutting away the face of the sandstone 72 as illustrated in Figure 2, the cuttings and abrasive being washed back into the drill hole 68 and hence to the surface by the return stream. Since the cutting rate of the formation can be estimated before beginning operation, this serves as a guide in manually feeding the counterbalanced hole assembly from the derrick platform. In the event a harder structure is encountered by the cutting nozzle, the slipjoint 60 will resist movement, and simultaneously restriction of the ejection orifice 101 by reason of an obstruction will be reflected by an increased pressure on the supply line as shown by the gauge 16 on the discharge pipe 8. In a similar fashion, a break in the discharge line 50 will be reflected by a decreased pressure on the gauge 16.

In the extension of the feed hose 50 from the footpiece 70 by reason of closing of the slipjoint 60, several things occur. The first of these is that the feed hose being restrained from lateral movement by the walls of the lower section 63 of the slipjoint 60, is forced down into the footpiece 70

and through the flanged roller bearings 80 and 81 which also restrain lateral movement while acting to compress one side of the hose and to stretch the opposite side to make it conform with the curved passage 75. However, as soon as the hose emerges from the side opening 86 of the footpiece, the bending forces exerted by the roller bearings 80 and 81 in conjunction with pressure applied from above through the medium of the slipjoint 60, no longer act on it, and the ability of the hose extension 58 to straighten itself and to maintain the horizontal position in which it is then directed is dependent upon three factors; first, the inherent rigidity of the conduit 58 which may be increased by the addition of coil springs incorporated in the walls of the conduit; second, the rigidity introduced in the conduit by reason of the pressure exerted against its walls by its fluid content; and third, the skill of the operator in not crowding his cut.

As the feed line 58 is farther extended, the trailing portions of it will rest upon and be restrained by the walls of the drainage channel already cut away. Varying hardness of the material to be cut, as well as crowding of his cut by the operator will cause deviations from a straight line, but this in itself is no great drawback as long as the general direction of travel is away from the drill hole. When limestone shells are encountered, acid is added to the feed charge, and in some cases it may be desirable to place a charge of less dilute acid, retract the cutting nozzle, and wait several hours before continuing operations.

When the hose section 58 is fully extended, the cutting charge will continue to be directed into the drainage channel 69 thereby enlarging it by reason of the cutting action of the return flow against its walls, thus providing a reservoir space as well as increasing the drainage surface of the fluid bearing formation.

What I claim is:

1. Apparatus for drilling lateral holes in a deep well, comprising a rigid pipe extending into the well, a slip joint secured at its one end to the lower end of said pipe, an elbow having two diametrically opposed series of rotatably mounted rollers secured to the other end of said slip joint and supported in said well against downward movement, and a flexible tube extended into said well with its lower portion extended through said slip joint and said elbow and secured against longitudinal movement relative to said pipe whereby when said pipe is moved downwardly said flexible tube will contact said opposed series of rollers and be forced transversely of said well hole.

2. Apparatus for drilling lateral holes from wells comprising a rigid pipe extended into the well, a rigid tube mounted for limited telescoping movement on the lower portion of said rigid pipe, an elbow mounted on the lower extremity of said rigid tube having an arcuate series of rollers, means to support said elbow against vertical movement in said well, and a flexible drill tube having a smooth outer surface extending through said telescoping pipe and tube and said elbow and being secured against longitudinal movement relative to the lower extremity of said pipe whereby as said pipe is lowered said flexible drill tube will be forced through said elbow against said series of rollers and transversely of said well.

3. In lateral drilling apparatus of the character described, means for positioning a drill in a trans-

verse cavity in the well, including a rigid pipe extending into said well and carrying adjacent said cavity an elbow for limited longitudinal movement relative thereto, means for securing said elbow against downward movement, a flexible drill tube extending into said well with its lower portion secured to said pipe and its free end extending through said elbow, and rollers mounted in said elbow to serve as bearings to change the direction of travel of said tube as said rigid pipe is moved relative to said elbow.

4. Apparatus for drilling lateral holes in deep wells, comprising a rigid pipe extended into the well, an elbow carried by said pipe for limited longitudinal movement thereon, two arcuate series of rollers mounted in said elbow, a flexible drill tube extended into said well and between the two series of rollers in said elbow with means securing it to said pipe adjacent said elbow, and

means for supporting said elbow against downward movement in said well whereby when said pipe is raised or lowered said tube will be forced laterally of said pipe.

5. Apparatus for drilling lateral holes in deep wells, comprising a rigid pipe extending into the well, an elbow carried by said pipe for limited longitudinal movement thereon, two arcuate series of rollers mounted in said elbow, a flexible drill tube extended into said well and between the two series of rollers in said elbow with means securing it to said pipe adjacent said elbow, means for supporting said elbow against downward movement in said well whereby when said pipe is raised or lowered said tube will be forced laterally of said pipe, and means to feed an abrasive under pressure to said drill tube whereby it is forced from said drill tube to form a lateral hole.

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