METHOD AND APPARATUS FOR DEFLECTING BORE HOLES IN SUBSURFACE FORMATIONS

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In the drilling of deep bore holes in sub-surface formations, the direction of the hole frequently changes due to the relatively great transverse flexibility of the string of tubing that is used for carrying and rotating the bit. In no other mechanical drilling problem is there used a length of drill “rod” or drill pipe such as is regularly employed in rotary drilling of deep bore holes. For example, in exploratory and small well drilling operations the depth of hole may be many thousands of feet, whereas the diameter of the tubular shaft used for rotating the bit is measured in inches. The drill “rod,” which is almost always tubular, easily bends when used in such great lengths, and accordingly the rotary bit at the bottom of the hole can and does assume a direction of travel bearing no relationship to the direction of the hole at the surface. Consequently, in the drilling of such deep holes it is usual practice, periodically, to determine the direction of the hole as it progresses downwardly and to take appropriate steps for deflecting the bit, in order to maintain straight, or relatively straight, the direction of the hole. In some instances it is desirable to start the hole in a given direction and then as the bit progresses, to cause the hole to be deflected so that the hole is curved and assumes another direction. Such practice of deflecting holes is useful where it is expensive or difficult to set up the drill rig directly or in line with the region to be reached by a straight hole, and is also useful for avoiding certain formations through which progress of the drill may be expected to be accompanied with difficulties.

Heretofore, the deflection of the bit for the purpose of deflecting the hole has been accomplished by the use of wedges which were set in the hole and then permitted to remain in the hole for the purpose of deflecting the bit. After the bit had progressed past the wedge thus set, the wedge forms a part of the hole wall and is to remain in the hole and is not re-usable.

These wedges are relatively expensive, and since each wedge is incapable of producing more than a few degrees of deflection of the hole, many are needed in order to produce a substantial change in direction of the hole. As a result, changing the direction of a bore hole is an expensive proposition amounting, in many instances, to several thousands of dollars for wedges alone, to say nothing of the cost of the time involved for placing them in the holes.

It is an object of the present invention to provide improved methods and apparatus for deflecting the direction of bore holes in sub-surface formations.

It is a further object of the invention to provide methods and apparatus for economically deflecting bore holes in sub-surface formations and for deflecting them readily and with certainty.

It is another object of the invention to provide methods and apparatus for deflecting bore holes in sub-surface formations which can be carried out by relatively unskilled operators.

It is another object of the invention to provide methods and apparatus wherein the wedge or instrument for deflecting the bore hole is used and then removed from the bore hole, and re-used at successively lower levels to effect a total deflection in excess of that capable of being obtained with one wedging operation.

It is a further object of the invention to provide apparatus of simple character for deflecting bore holes in sub-surface formations and to provide methods and apparatus which can be utilized for deflecting bore holes, regardless of the direction of progress of the hole, whether up or down, horizontally or any intermediate direction.

It is another object of the invention to provide methods of deflecting bore holes in sub-surface formations utilizing a minimum of operational steps.

It is a further object of the invention to provide methods and apparatus for deflecting bore holes deep in sub-surface formations wherein all of the deflecting mechanisms are withdrawn from the bore hole and the bore hole left in condition such that removal or withdrawal of bits therefrom is not accompanied by hazard to the bit or the bore hole.

It is a further object of the invention to provide methods and apparatus for deflecting and continuing the drilling of bore holes without a reduction in the diameter of the bore hole.

Other and further objects of the invention are those inherent in the apparatus herein illustrated described and claimed.

The invention is illustrated with reference to the drawings wherein corresponding numerals indicate the same parts and in which:

Figure 1 is a fragmentary sectional view, which may be a longitudinal section illustrating a sub-surface formation with a normal rotary bit and a reaming shell therein at the bottom of a hole being produced by the bit;

Figure 2 is likewise a sectional view through a sub-surface formation, showing a taper bit in place for producing a taper, as in accordance with the preferred step in the method of carrying out the instant invention;

Figure 3 is a sectional view of sub-surface formation showing the improved deflecting apparatus of the present invention attached to standard casing and set in place preliminarily and in a random position without the direction of deflection having been determined;

Figure 4 corresponds to Figures 3 and 4 and shows a sectional view through sub-surface formation with the casing string carrying the bore hole deflecting instrumentality rotated and hence re-oriented in a direction so as to produce deflection of the hole in a desired direction;

Figure 5 corresponds to Figures 3—5 and shows a sectional view through sub-surface formation and illustrates a further step in the method and utilizing apparatus of the invention wherein a smaller size bit is lowered through the casing and through the deflecting apparatus and is about to be used for producing a smaller diameter extension of the original hole, but in the desired deflected direction;

Figure 6 is a sectional view through sub-surface formation showing the hole as produced by the various steps illustrated in Figures 1—6, but with the deflection appara-
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tus and the casing on which it is carried, as in Figures 3–6 withdrawn from the hole and a reaming bit on drill rod lowered and in a position about to enter the smaller size hole;

Figure 8 corresponds to Figure 7 and shows the ream-

ing bit on Figure 7 progressed downward in its reaming operation;

Figure 9 corresponds to Figures 7 and 8 but shows the reaming bit further along in its reaming operation and illustrates how the bore hole of original large diameter is resumed along the deflected direction;

Figure 10 is a fragmentary transverse sectional view taken along the line and in the direction of arrows 10–10 of Figure 3;

Figure 11 is a fragmentary transverse sectional view taken along the line and in the direction of arrows 11–11 of Figure 4;

Figure 12 is a fragmentary transverse sectional view taken along the line and in the direction of arrows 12–12 of Figure 3;

Figure 13 is an enlarged separated view partly in lon-
gitudinal section illustrating the cliniometer apparatus where in Fig. 4 is shown assembled with other portions of the apparatus;

Figure 14 is a view, taken along the line and in the direction of arrows 14–14 of Figure 13;

Figure 15 is a vertical elevational view, partly broken away and therefore in longitudinal section, illustrating the cliniometer tube which is shown in position in Figure 13, removed from the apparatus and in a position to take the reading on the cliniometer tube;

Figure 16 corresponds to Figure 15, being a side eleva-
tional view taken along the line and in the direction of arrows 16–16 of Figure 15;

Figure 17 is a plan view of a portion of the drilling platform at the surface, illustrating index marks on the platform or other reference surface by means of which the operator may judge and correct the angular direction of the deflecting instrumentality as placed in the hole.

Referring to the drawings, a sub-surface formation is illustrated at 10 in Figure 1 and in the remaining figures. The sub-surface formation may be considered as deep in the rock forming the earth's crust and may be considered as hundreds or thousands of feet from the surface where the drill rig is situated. It is well known, of course, that when drilling is initiated from the surface, through drift, overlaying the underlying rock formations, it is customary to drill through the drift and to case the hole thus formed down to rock level with steel casing of suitable size so as to prevent caving through the overlaying drift. How-

ever, deep in the rock formation there is usually no cas-
ing, the hole wall being maintained by the strength of the formation itself assisted by the drilling fluid. Thus, in Figure 1 the drill rod at 11 carries a reaming shell at 12 below which there is situated the usual rotary bit 15.

At any depth the operator can by suitable instruments known in the art determine with comparative certainty the direction in which the hole is progressing, and when it is determined that the direction of the drill hole is not such as is desired, the direction of drilling must be cor-
rected. In accordance with this invention, such correc-
tion of drilling direction is accomplished in a plurality of novel manipulative steps and by the use of novel com-
binations of apparatus as follows:

As an optional but preferred first step, when the direc-
tion is to be changed, there is first inserted a taper bit, as illustrated by Figure 2, and a taper is drilled. Thus, in Figure 2 there is illustrated a taper bit 16 attached to the lower end of the string of "rods" 11. Even though the members 11 are actually tubes screwed together, throughout this specification the term "drill rods" will be used, since such nomenclature is almost universal among drillers. Such "rods" are screwed together, end to end by couplings, and collectively are called a "string of drill rods." For the purpose of this discussion the term "drill rods" may include a "core barrel" on the end of the drill rod, as is commonly used in exploratory drilling. The change from the bit 15 and reaming shell 12 to the bit 16 is accomplished by pulling the entire string of drill rods and sections of casing and未经 their removal, one length at a time until the bit end is out, after which the reaming shell 12 and bit 15 are removed and the taper bit 16 is then attached and the drill string re-assembled, a length at a time, and lower-
ed until bit 16 is on the bottom of the hole, whereupon rotation is resumed sufficiently to produce a taper at the bottom of the drill hole, until the conical tapered surface 17 is made.

The reason for optionally performing this preferred step of producing a taper at 17 is that in the hole, with the direction ultimately deflected to the correct direction, in accordance with the present invention, if the taper bit 16 were not used, a shoulder would be presented at the level or change of direction (as shown at 101 of Fig.

Figure 9), which would thereby be the source of hazard when bits are lowered later on during further drilling.

The use of the tapered bit 16 for the production of the tapered surface 17 is not absolutely essential and may be dispensed with where care is exercised in lowering the bit during later drilling operation, but the use of the tapered bit is recommended and is preferred.

The next step in the method of the invention and utilizing the apparatus thereof is carried out by removing the string of drill rods and the taper bit 16 from the hole, and then by assembling onto the appropriate size casing for the hole and then lowering a bit-deflecting instrumentality generally designated 20 to which atten-
tion is now directed.

The bit-deflecting instrumentality 20, hereinafter called the "bit deflector" consists of an elongated metallic mem-
ber, preferably of hard steel having a cylindrical outer surface at 21 of a size such that it can be lowered con-
veniently into the hole 9 produced by the bit 15 and reaming shell of Figure 1. Usually the diameter of member 20 is about intermediate between the diameter of the hole produced by a standard bit and reamer, and the diameter of the standard casing for such hole. No attempt is made to show these slight differences between the various diameters other than to show the clearance between the hole 9 and member 20 and the hole 9 and casing 13. In the drawings such clearance is exaggerated.

The bit-deflector 20 has a threaded coupling end 22 formed at its upper end, provided with standard threads so that the entire member 20 can be screwed onto the end of the lowermost length of standard casing in the string 13 of drill rod 11. The inner diameter of the broken member 13, as shown at 24, is the same as the diameter of the hole 25 through the bit-deflector 20 just below the coupling end 22. The upper portion of the bit-deflector 20 is designated as the coupling end 22.

The outer surface 21 at the coupling end continues downwardly to the opposite or lower end 26 and is cylindrical and of the same diameter as casing 13 or just slightly larger, as explained above. Below the coupling end 22 of the bit-deflector 20 the opening or hole 25 merges into the surface 28 which is also cylindrical. Surface 28 corresponds preferably to the next smaller size of standard drill bit than that used at 15 in Figure 1, although it may, if desired, be the same as the diameter of a bit which is several sizes smaller. Thus, the surface 28 is a cylindrical surface and extends from the coupling hole 25 on down to the lower end 26 of the member 20. However, the axis of the surface 28 is at a slight angle to the axis of the outer cylindrical surface 21. Thus, the axis of the cylindrical surface 21 is illustrated by the line 31 which is also the axis of the coupling 22 and casing 13, whereas the axis of the smaller, cylindrical surface 28 is shown by the line 32, there being a slight angle, usually 1 degree to 4 degrees between the two axes. The two axes 31 and 32 intersect preferably in the region ranging from the cou-
pling end 22 to slightly below the coupling. In this illustration the intersection is slightly below the coupling. In this illustration the intersection is slightly below the coupling. In this illustration the intersection is slightly below the coupling.

Referring to Figure 1, one will note the location of the lower end of the bit-deflector. It will be noted how the outer cylindrical surface 21 corresponds to that of the drill hole being produced, less clearance, whereas the inner partial cylindrical surface 28 is offset slightly and at the lower end 35 of the bit-deflector by an amount illustrated by the dimension 38, which is the distance between the axes 31 and 32 at the bottom end 35 of the bit-deflector.

The diameter of the inner cylindrical surface 28 is approximately equal to the diameter of the selected smaller size standard bit, as compared with bit 15, Figure 1, and hence such a smaller size standard bit will fit in the circle shown by the dotted lines 36 and surface 28 between the hole wall at 30 and the surface 28 at the lower edge 35 of the bit-deflector 20. Such a smaller size standard bit will thus be in contact with the original bore hole 9 of the original diameter at the place 30 and the bit is displaced from the original axis of the original bore hole by the amount of dimension 38. The dimension 38 is approximately equal to the thickness 46, Figure 3, and is also the same as the displacement of the axis (line 32, Figures 3–5) of the smaller bit (circle 36–28, Figure 12) from the axis (line 31, Figures 3–5) of the original bore of the original hole of the member 20. Stated another way, the diameter of the smaller bit (circle 36–28 of Figure 12) is equal to or very slightly less than the diameter of the original hole being produced minus the thickness 46 of the bit-deflector 20 at the bottom. The surface 28 of the bit-deflector 20 is cylindrical and fits the diameter of the chosen smaller size bit.

The bit-deflector 20 is preferably, though not necessarily, cut away along the line 40 near the coupling end 22 and then cut away longitudinally along the line 42. This cutaway portion is provided mainly to allow access for placing a keying block 45, as shown in Figures 3–5, but access to such a keying block or key can be provided in other ways and the deflecting instrumentality need not necessarily be cut away along the lines 40 or 42.

It is noted in passing that the increased thickness of the deflecting instrumentality, as shown by the dimension 46 in Figure 3, means that if the wall were not cut away along the lines 40–42, the wall at the opposite side would feather out to a knife edge, at least at one point, and hence the cut-away portion of the wall is the weakest portion and its removal does not seriously reduce the strength of the device. It may be left in place or removed, as desired.

Adjacent the coupling end 22 or elsewhere on the bit-deflector 20 there is provided a keying block 45 or other land or surface, by means of which the angular position of the bit-deflector 20 can be determined at the surface. At the surface where the drill rig is located, there is provided on the drill platform, or on some fixed reference surface, a quadrant marked off in degrees, as shown by the quadrant 48 in Figure 17. These can be simple marks on a board surrounding the casing at the surface or may be a formal quadrant and are used by the operator in judging the angular position of the various devices placed in the hole.

The bit-deflector 20 is provided with the land 45. This land serves to locate approximately the clinometer shown generally at 59 in Figure 4 and separated in Figure 13. Once the land 45 is sheared or drilled out and is replaced the next time the bit-deflector is used. Hence, the only requirement in regard to land 45 is that it should be capable of being easily sheared or drilled away and need not be of the type shown in Figure 4 but can be a knob, land, projection or groove of any sort into the interior of the bit-deflector 20 and should preferably be near the coupling end 22.

When the bit-deflector 20 is cut away along the lines 40–42, as is preferred, the land 45 is easily accessible for replacement and is preferably a hard wood block which is held in place by the rivets 51, as shown in Figures 10 and 11. A heavy brass screw or pin through the wall of the bit-deflector 20 would serve as well as a locating device and is included within the purview of the invention.

Referring to Figures 4 and 13, particularly, the clinometer generally designated 50 consists of a body portion 52 having screw threads at 53 so that the cap 54 can be screwed on, the cap in turn being provided with screw threads at 55 so that the entire clinometer can be attached to the lower end of the string of drill rods 56. The diameter of the clinometer 50 and rods 56 is such that they can be lowered through casing 13. The coupling member 54–55 is provided with a hole at 54′–54″ in order to permit water entrained in the string of drill rods 56 to drain out when the rods are pulled from the hole.

The clinometer has a hollow cylindrical cavity at 57 in which there is placed a glass tube 58 provided with a rubber stopper at 59. In use the glass tube is partially filled with a solution of hydrofluoric acid. The lower end of the clinometer body 52 is cut away along the longitudinal diametric plane 61 and is provided with a chamfer at 62. Thus, in transverse section, the lower end of the member 52 of the clinometer is the half circular shape shown at 63 in Figure 11 and is adapted to make a sliding fit with the corresponding surface 64 of the block or locating land 45 which is provided in the coupling end 22 of the bit-deflector 20. The only requirement in regard to the shape of surfaces 61 and 64 is that they should fit each other with a longitudinal sliding fit and all variations of such mating surfaces will be understood to be within the purview of the instant invention.

It will be noted that the clinometer body and the string of drill tubes 56 are of the selected smaller diameter, as compared with the string of casing 13 and the string of drill rods 56 and clinometer 50 thus lower neatly through casing 13 and consequently passes through the coupling at 22 of the bit-deflector 20. When the bit-deflector 20 is first lowered into the hole, its position is random and bears only a chance relationship to the desired position for deflecting the hole. Hence, the bit-deflector must be rotated more or less to a new position if it is to serve to correct the direction of the hole. It would only be chance, however, if, when originally lowered, the bit-deflector 20 happened to be in the correct position to correct the direction of the hole. Thus, in respect to Figure 3 it can be assumed that the bit-deflector 20, when originally lowered would produce a deflection off to the left, as shown in Figure 3, at the bottom and that the driller actually desires to bring the hole to a vertical position with respect to the sheet of drawings, or vertical in respect to the position shown in Figure 3, which hence would be the position of Figure 5. It is therefore assumed, for purposes of illustration herein that the bit-deflector 20 is in exactly opposite direction, the surface 28 in Figure 3 oriented so that, if used in that position, it would increase the amount of deflection to the left, which would not correct the hole, but make it worse. Stated another way, the bit-deflector 20 must be rotated 180 degrees from the position of Figure 3 to the position of Figure 5.

The next step in the process is the lowering of the clinometer at 59, as shown in Figure 4. The glass tube 58 is partially filled with hydrofluoric acid 60, is stopped at 59 and set in the clinometer body with the scratch mark 73 of the glass tube and aligned with the marks 72–72A of the clinometer body. It is noted that mark 72 extends lengthwise of the long side 61A of the clinometer body and corresponding mark 72A is indicated up over the threads 53 for easy reading with reference to mark 73 on tube 58. The clinometer is coupled to the string 56 of drill rods and lowered through the hole in
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When reaching the level of the coupling 22 the operator rotates the string of drill rods 56 by hand until the surface 62 of the clinometer body keys into and finds its way downward into the space between the block 45 and the opposite part of hole 25. Then the operator lowers the clinometer body 50, and the position shown in Figure 15 and the clinometer body 50 is accordingly in a fixed position with reference to the bit-deflector 20. Hence, the operator will know at the surface that the clinometer body 50 has been set at a fixed position with reference to the bit-deflector 20, which in turn is set at random in the hole, but the operator still does not know the amount of angular rotation of the bit-deflector that will be needed to bring the direction of the hole back towards a correct direction.

The operator then permits the clinometer 50 to remain in the hole for a given period, such as 30 minutes, and then removes it.

When the clinometer 50 is brought to the surface, the operator removes the glass tube 58 and dumps out the hydrofluoric acid. When this is done and the test tube is washed it will be found that on its inside there will be produced an etched line at level 70, Figure 15. It is noted parenthetically that the etching is exaggerated as compared to Figure 3, so that the devices and methods can be better illustrated. This line 70 defines a plane of reference through the glass tube 58 which may be at any angle with reference to the axis of the tube 58 and rotated at any angle. By wrapping a piece of paper 71 having a straight edge around the glass tube 58 the “low point” of the etched line 70 can be “read” with a comparatively high degree of accuracy, this operation being illustrated in Figures 15 and 16. The low point is marked by a scratch line 73B. It has been noted that the clinometer body 52 is provided with an index mark 73A, which is made up over the coupling end as at 72A, and the glass tube 58 is likewise provided with an index mark on the side at 73 and also up top the outer stopper, as at 73A. The lines 73—73A of the glass tube were aligned with the marks 72—72A of the clinometer body and hence were in a diametral longitudinal plane normal to the surface 61 when the clinometer was in the hole. Hence, the marks 73—73A of the glass tube were likewise in a longitudinal diametric plane normal to the bit-deflector locating block 45, which plane also bisects the surface 28 and hence line 73—73A of tube 58 was in the direction the wedging surface 28 is directed, regardless of how the surface 28 is located relative to the angle (or tilt) of the hole. The acid in the tube simultaneously writes its record of the angle (tilt) of the hole (namely line 70). By then determining the lower point of the etched line 70 on the glass tube 58, with reference to the scratch line 73 the operator can determine another line at 73B which is the “lowest point on the etched line.” It is mere accident that lines 73 and 73B are at the same place on the tube shown in Figure 16, the more usual case being that the two lines 73 and 73B are separated by a certain number of degrees. The angle between these lines 73 and 73B measured along a circular cross-section of tube 58 taken perpendicular to the axis of tube 58 is then read in degrees with a protractor held normal to tube 58, and from this “angle” between lines 73 and 73B the driller determines the amount of “rotation” that must be provided for the bit-deflector 20 in order to correct the direction of the hole. The easy way to read the angle is to use a protractor with a hole in the center the size of the tube 58. The tube is then slipped through the hole in the protractor, which is thus in a plane normal to the axis of tube 58 and the angle between lines 73 and 73B is then read on the protractor.

In the instance illustrated herein for convenience of drawing, it has been assumed that the member 20 is placed, as in Figure 3, 180 degrees from the right place (Figure 5) when originally lowered into the hole. Thus, in Figure 3 the surface 28 slants downwardly to the left, which thus would cause the hole to be deflected even more to the left than it already is and hence would be in the wrong direction, whereas in Figure 5 the direction is as desired, namely to the right, which then brings the axis of the bore hole directly vertically. It will be appreciated that any smaller angle than 180 degrees of rotation might be required as determined by the scratch lines 73 and the etching line 70.

The amount of “rotation” needed to re-position the bit-deflector 20 is read from the marks 73 and 73B for any case as follows:

If the driller desires to deflect the hole in a direction so as to bring it back towards vertical the angle between lines 73 and 73B are at the same place on the tube shown in Figure 16, the more usual case being that the two lines 73 and 73B are separated by a certain number of degrees. To re-position the bit-deflector 20 in the particular case illustrated herein the Figure 3 and Figure 5 positions were chosen because they are easy to draw, and it is assumed that the Figure 3 position (off to the left) shows the hole headed in the wrong direction and that Figure 5 (vertical) is what is desired. With such assumptions, and as shown in Figures 4 and 13-17, the clinometer reading showed zero degrees (0°) between lines 73 and 73B, and the complement of this reading is 180 degrees minus zero degrees or 180 degrees. Accordingly, in this illustration it is necessary to re-position the bit-deflector 180 degrees from the original (Figure 3) position by rotating it 180 degrees. Rotation can obviously be accomplished by turning the bit-deflector and casing string 13 180 degrees either way, and the direction of “rotation” chosen depends upon whether threads 22 of the bit-deflector and casing 13 are “right” or “left” hand. The casing 13 is always turned in a direction such as would “tighten” the threads so as to avoid loosening any coupling and thereby obtaining a false setting of the bit-deflector.

If, however, the driller desires to deflect the hole further from the vertical, the “rotation” or change of angle that is applied to casing 13 to re-position the bit-deflector is made equal to the angle between the index line 73 and the low point of the etched line, viz. mark 73B. Thus in the illustration herein, if the driller desires to increase the deflection to the left in Figure 3, he would read the angle 0 degrees between lines 73 and 73B and he would then change the position of the bit-deflector 20, since from the 0 degrees reading of the clinometer tube the driller would know that he had (by mere chance) happened to lower the bit-deflector in the precise position (Figure 3) in which, left where it is, it would produce the maximum deflection of the hole in the direction the deflection is already headed.

Re-positioning of the bit-deflector 20 by means of casing string 13 is accomplished by the driller as follows:

A chisel or other mark 47 is made on casing 13 aligned with one of the index marks 48 (as in Figure 17); to show the first position of the casing 13 in the first (random and incorrect) position, shown in section in Figure 3. In the example illustrated herein casing 13 must be re-positioned 180 degrees to bring it to the mark at 49 in Figure 17, in order to relocate member 20 to the Figure 5 position. The amount of “rotation” necessary for such re-positioning having been determined, the next operation is that of turning the casing 13 and bit-deflector 20 the requisite number of degrees (180 degrees in the illustrated instance) for correcting the direction of the hole. This is easily accomplished in accordance with the present invention by turning the string of casing 13 with the bit-deflector 20 attached thereto, and while they are in motion, that is to say, while casing 13 is being lifted, it is rotated the requisite number of degrees and the string of casing 13 then lowered to the new position. This lifting, turning and lowering as accomplished in one smooth motion. Experienced operators find that several thousands of feet of casing 13
9 can be rotated angularly by hand if vertical movement is provided to overcome static friction. The lifting, rotation and being repeated if the original try happens to leave the bit-deflector 20 and casings 13 in an incorrect position. Thus by one or more tries, the mark 47 on the casing 13 is brought around to point 49 on quadrant 48. Where the coupling threads 20 are "right-hand" threads, rotation of the string of casing 13 is in the right-hand direction as shown by arrow R in Figure 17, as so not to take any chance on loosening the couplings and hence throwing the results off. When the coupling threads 22 are "left-hand" threads, rotation is, of course, then in the left direction, as shown by dotted arrow I. in Figure 13.

After the bit-deflector 20 has been rotated by means of casing 13 and re-located in the correct position shown in Figure 5, a smaller bit, corresponding in diameter to the diameter of surface 28 of the bit-deflector, is attached to the string 56 of drill rods, as shown in Figure 6, and is lowered through the casing 13. The bit 75 and rods 56 easily pass through the coupling at 22 and slide along (but do not rotate against) the surface 28 until the bit reaches the bottom end 26 where it displaced by the dimension 46 from the center line of the original hole. Boring is then resumed, and the smaller hole, as produced by the bit 75, is then drilled down 2 or 10 feet, as at 76. Usually, it is desirable to drill 8 or 10 feet, or even farther, along the new direction 76. The direction is, of course, determined by the string 56 of drill tubes which are held in the corrected direction by the wedging surface 28 of the bit-deflector 20. It will be noted that rotation of bit 75 does not start until it has reached the lower end of member 20 and hence does not grind away the guiding surface 28. After hole 76 has been drilled, the rods 56 and bit 75 are pulled, and then casing 13 and the bit-deflector 20 are pulled. Then to the larger size drill rods 11 (used in Figures 1 and 2) there is attached a reaming bit at 78, Figure 7, having a tubular cylindrical pilot 79 provided with a tapered surface at the end 80. As the bit 78 reaches the taper 17 originally produced, as in Figure 2, the tapered end 80 engages such surface and gradually guides the bit surface 78 toward the axis of hole 76. Drilling begins at 81, Figure 7, and gradually progresses along the line at 82, as shown in Figure 8. As the pilot 79 enters its full diameter in the hole 76, and as drilling progresses, the bit 78 begins first to cut into the surface 17 and then to ream the hole 76 in the corrected direction producing the corrected hole of larger diameter 84, as shown in Figure 9. The corrected hole of larger diameter 84 is reamed down until the pilot 79 hits on the bottom 90 of the smaller hole 76. Then the string of rods 11, with the reaming bit 78 attached thereto are withdrawn from the hole, and the reaming bit is replaced by the standard bit 15 and reaming shell 12 of Figure 1. These can easily be lowered into the hole and past the point generally designated 100 at which direction is corrected. The surface 17, where used, easily guides the large bit and reaming shell into the corrected direction portion 84 of the hole. As pointed out above, the taper bit 16 is preferably used. Where not used a shoulder remains at 101 and a longer reamer 80A (Figure 7) serves to guide the reamer 78 into the smaller hole 76, where a shoulder remains at 101, care must be exercised when the large bit is ever lowered past the shoulder.

Where the clinometer reading (etch line 70) shows an angular deviation which is more than can be corrected with the use of the bit-deflector 20, or where a considerable deflection is for other reasons required, this can be accomplished with only one setting of the clinometer as follows:

When the clinometer is set as in Figure 4 and withdrawn and read, the amount of rotation of casing 13 required to correct direction of the hole is known. Cas-
What I claim is:

1. The method of deflecting substantially square bottom bore holes of predetermined diameter which comprises determining the amount and angular direction of deflection of said bore hole from a predetermined bore hole direction, drilling the bottom of said hole to a taper, lowering into the bottom of the original hole a guide for deflecting a bit of smaller diameter from the direction of the hole at the point of placement of said guide and orienting said guide angularly for directing said smaller diameter bit in the desired bore hole direction, boring with a smaller diameter bit through the guide thus placed and through the taper and thence onward so as to produce a smaller diameter extension of said bore hole in said desired direction below said taper, removing said smaller diameter bit and guide and reaming out said smaller diameter hole to said predetermined bore hole size.

2. The process of deflecting a bore hole of predetermined diameter when said bore hole is drilled to a given depth in sub-surface formation which comprises lowering into said bore hole a guide having a shears oriented surface thereon and a cylindrical longitudinal surface of smaller diameter than the bore hole, locating the position of the guide by reference to said orienting surface until said guide is oriented along an axis slightly out of line with the axis of said bore hole of predetermined diameter at the bottom of said bore hole, lowering a bit of said smaller diameter into the hole until it hits and shears off said orienting surface, then rotating said smaller diameter bit as it is guided in the direction of said slightly-out-of-line axis as determined by said guide until an extension of said hole but of said smaller diameter has been made below said predetermined diameter hole, then removing said smaller diameter bit and said guide and reaming said smaller diameter extension to said predetermined diameter.

3. The process of claim 2 further characterized in that said extension is reamed by piloting a reamer of said predetermined diameter on the walls of said smaller diameter extension.

4. A drill guide for deflecting bore holes in sub-surface formations comprising an elongated semi-circular bit-deflecting member having inner and outer arcuate surfaces and having a short cylindrical portion provided with coupling threads on one end thereof, said cylindrical portion having a bore centrally thereof adapted to receive therethrough a drill rod and bit smaller than said bore, the outside diameter of said cylindrical portion being the same as the diameter of the outer arcuate surface of said semi-circular bit-deflecting member, the diameter of the bore of said cylindrical portion being the same as the diameter of the inner arcuate surface of said semi-circular bit-deflecting member, the longitudinal axis of the inner arcuate surface of said semi-circular bit-deflecting member being inclined with respect to and spaced inwardly of the longitudinal axis of said outer arcuate surface of said semi-circular bit-deflecting member, an inclinometer supporting land secured to said cylindrical portion within the bore thereof, said land having a laterally extending surface and a substantially vertical surface thereon and spaced from the wall of said bore for supporting an inclinometer in a fixed longitudinal and transverse position with respect to said semi-circular bit-deflecting member, said inclinometer supporting land being secured to said short cylindrical portion by shearable means whereby said land may be detached in response to pressure exerted thereon by a drill rod and bit forced through said cylindrical portion after said inclinometer has been removed.

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