

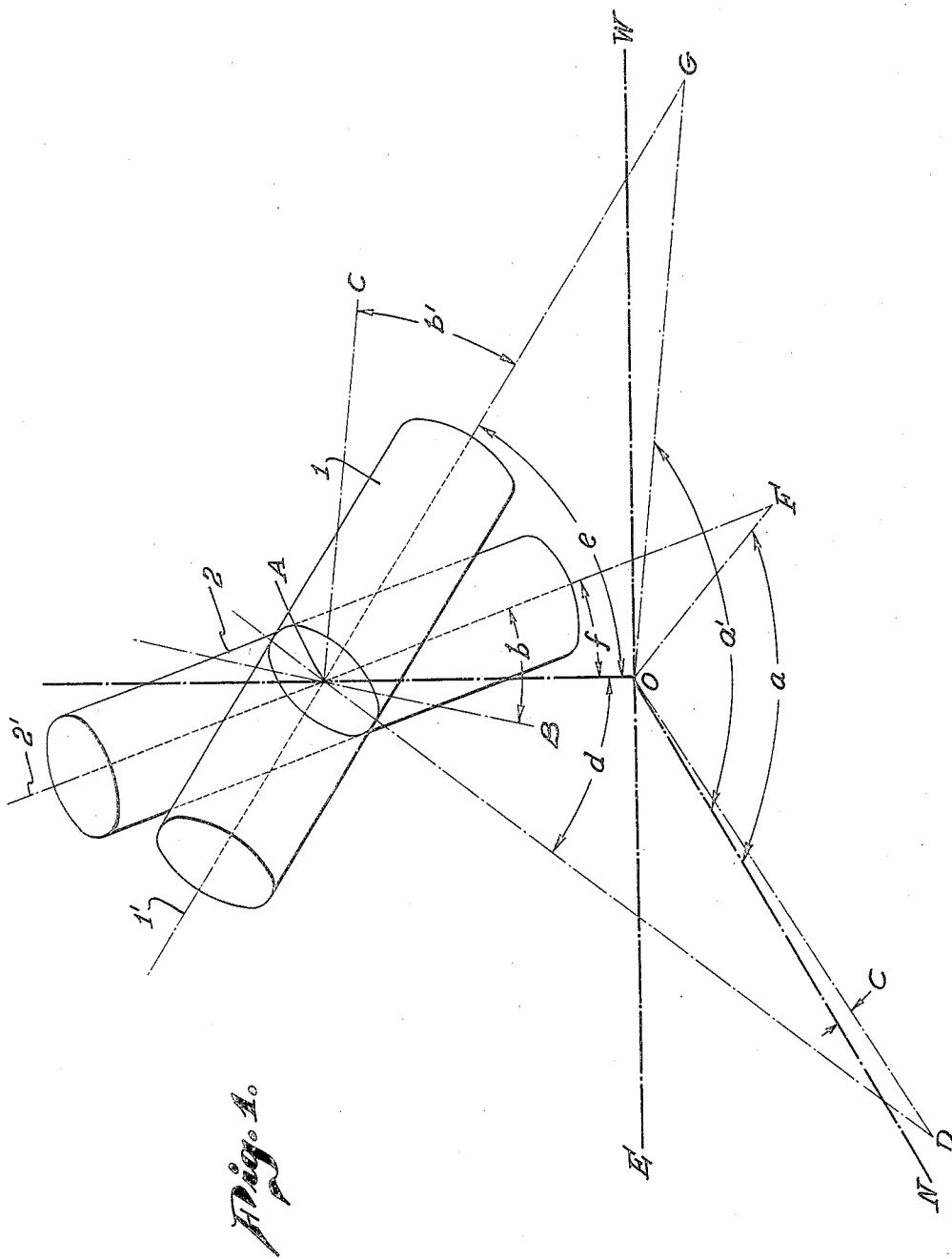
Feb. 7, 1950

P. SUBKOW
GEOMETRICAL DETERMINATION OF DIP
AND STRIKE OF CORED STRATA

2,496,422

Filed May 3, 1943

7 Sheets-Sheet 1



INVENTOR.

Philip Lubkow

Feb. 7, 1950

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7 Sheets-Sheet 2

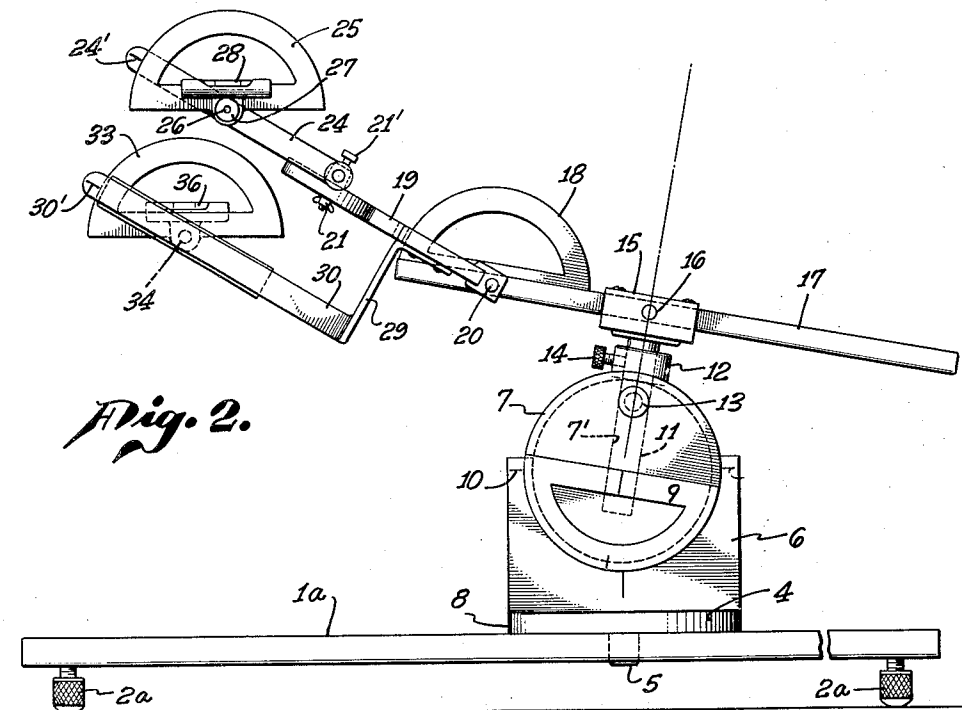
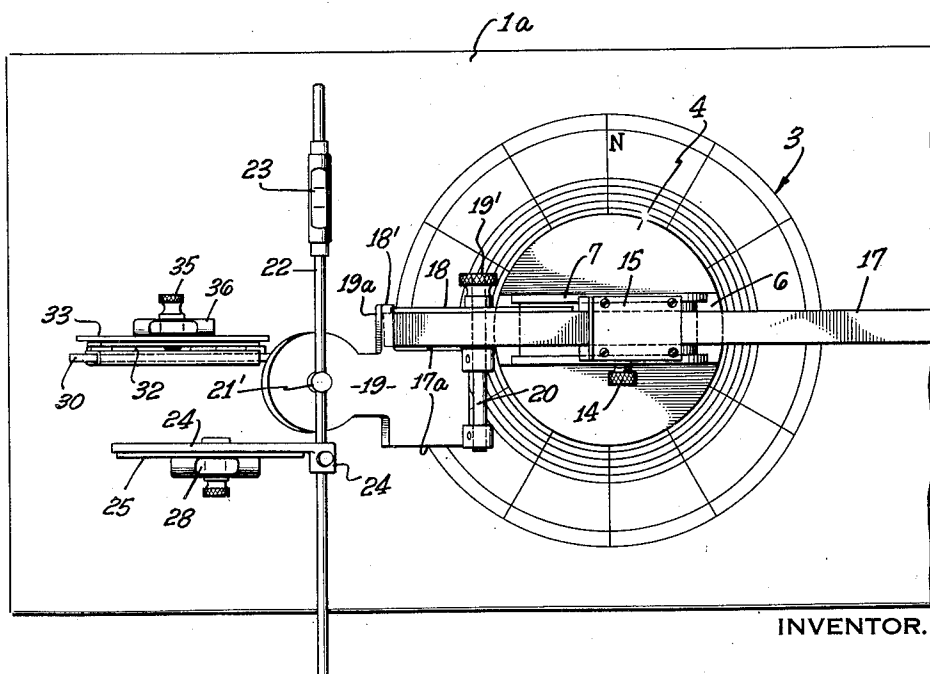


Fig. 2.



INVENTOR.

Fig. 3.

Philip Subkow

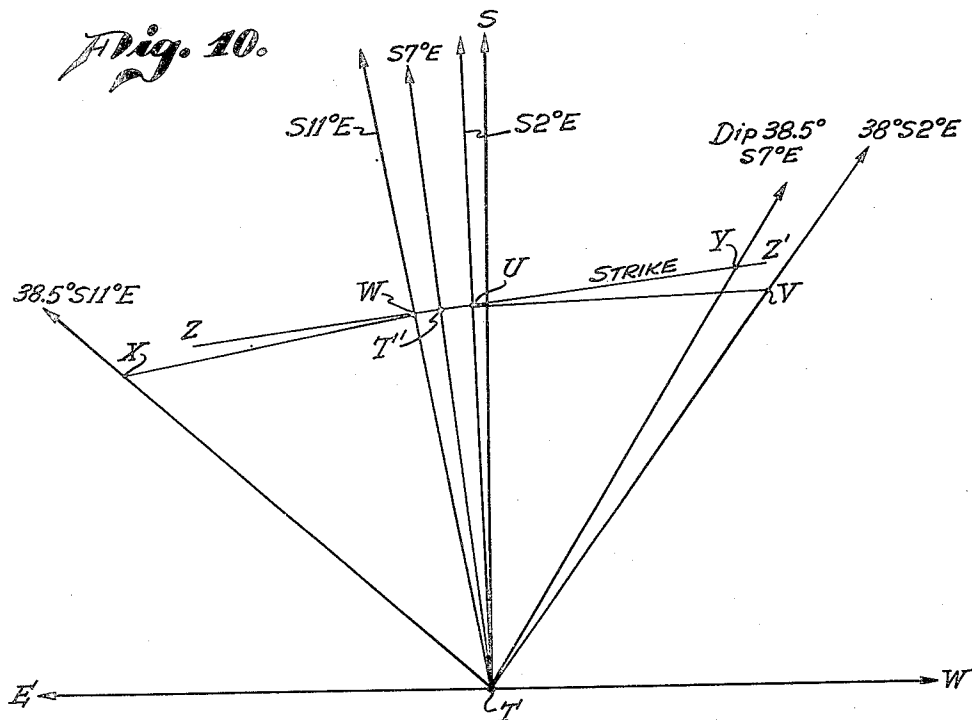
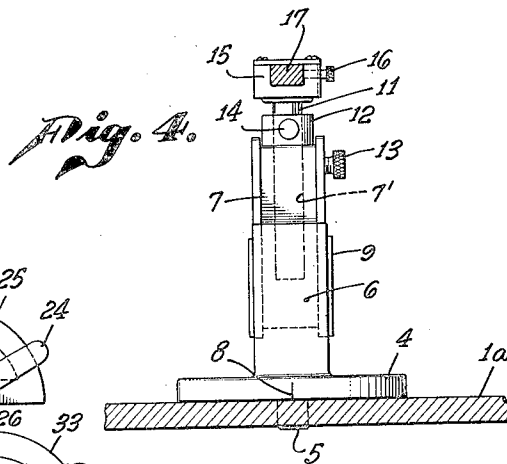
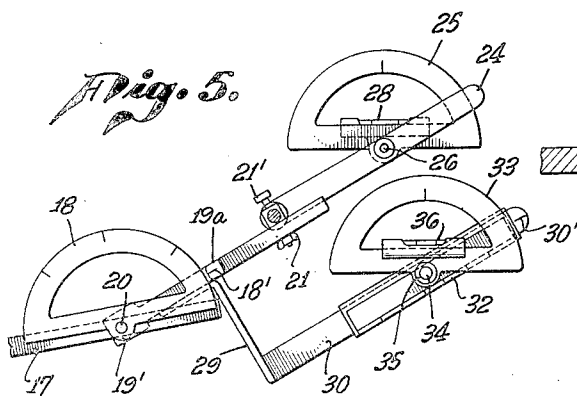
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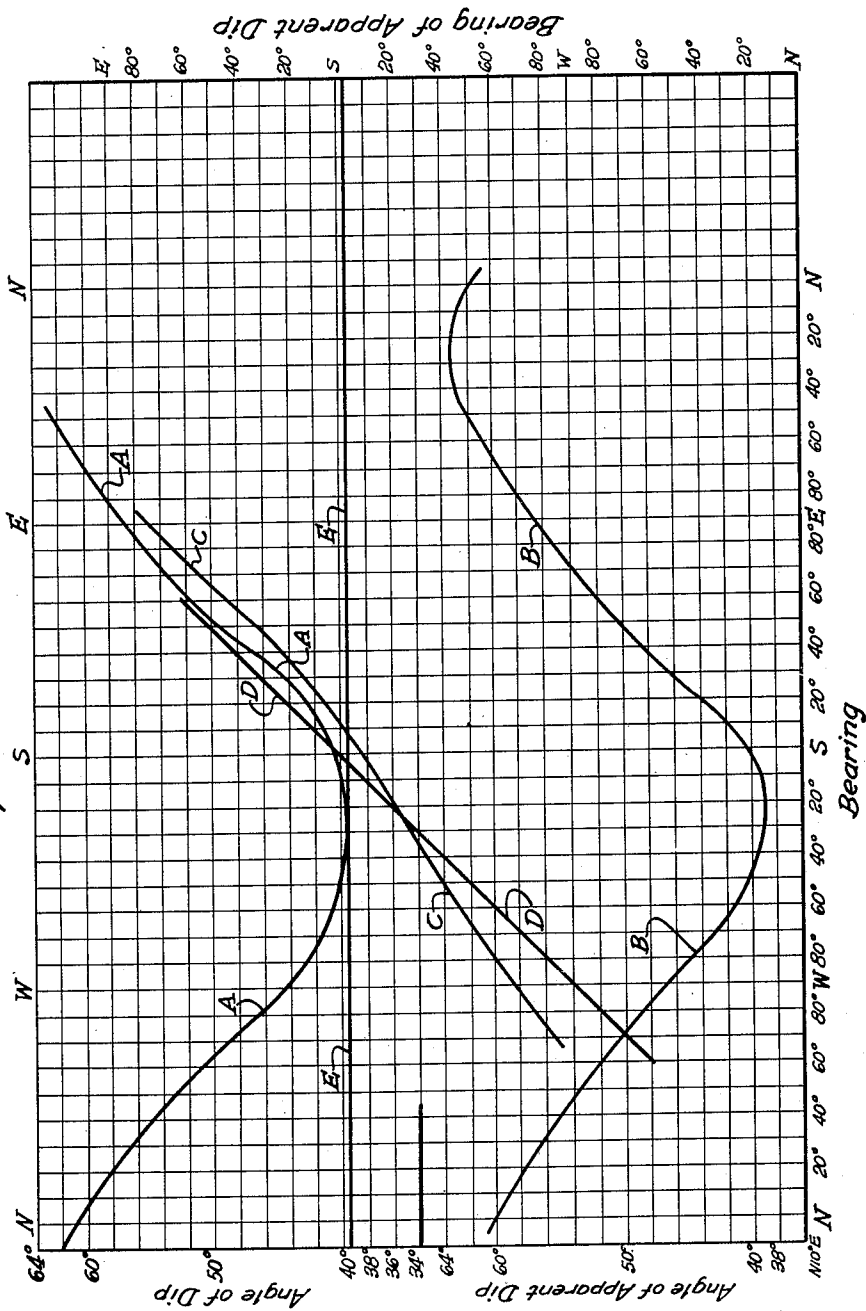
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Fig. 6.



INVENTOR.

Philip Subkow

Feb. 7, 1950

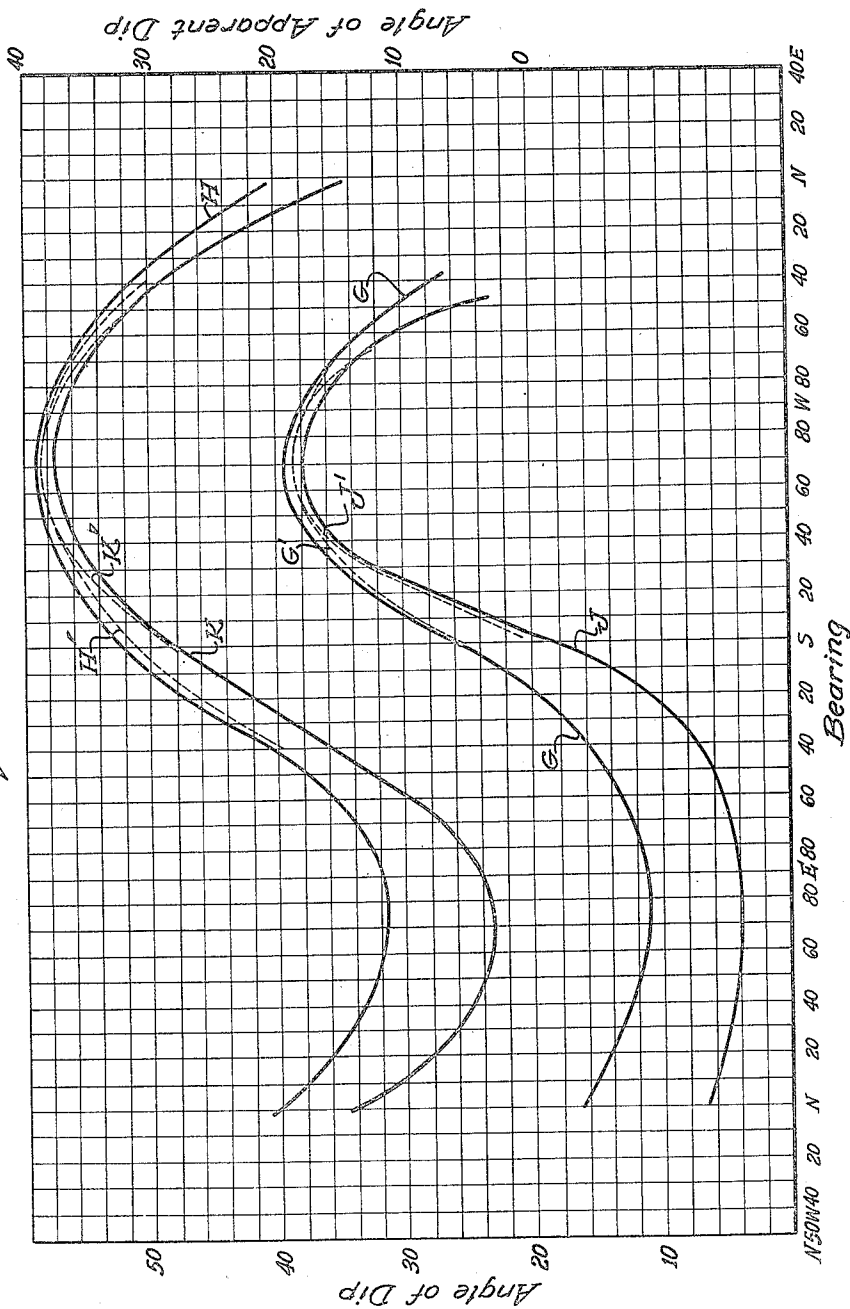
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Fig. 7



INVENTOR.

Philip Subkow

Feb. 7, 1950

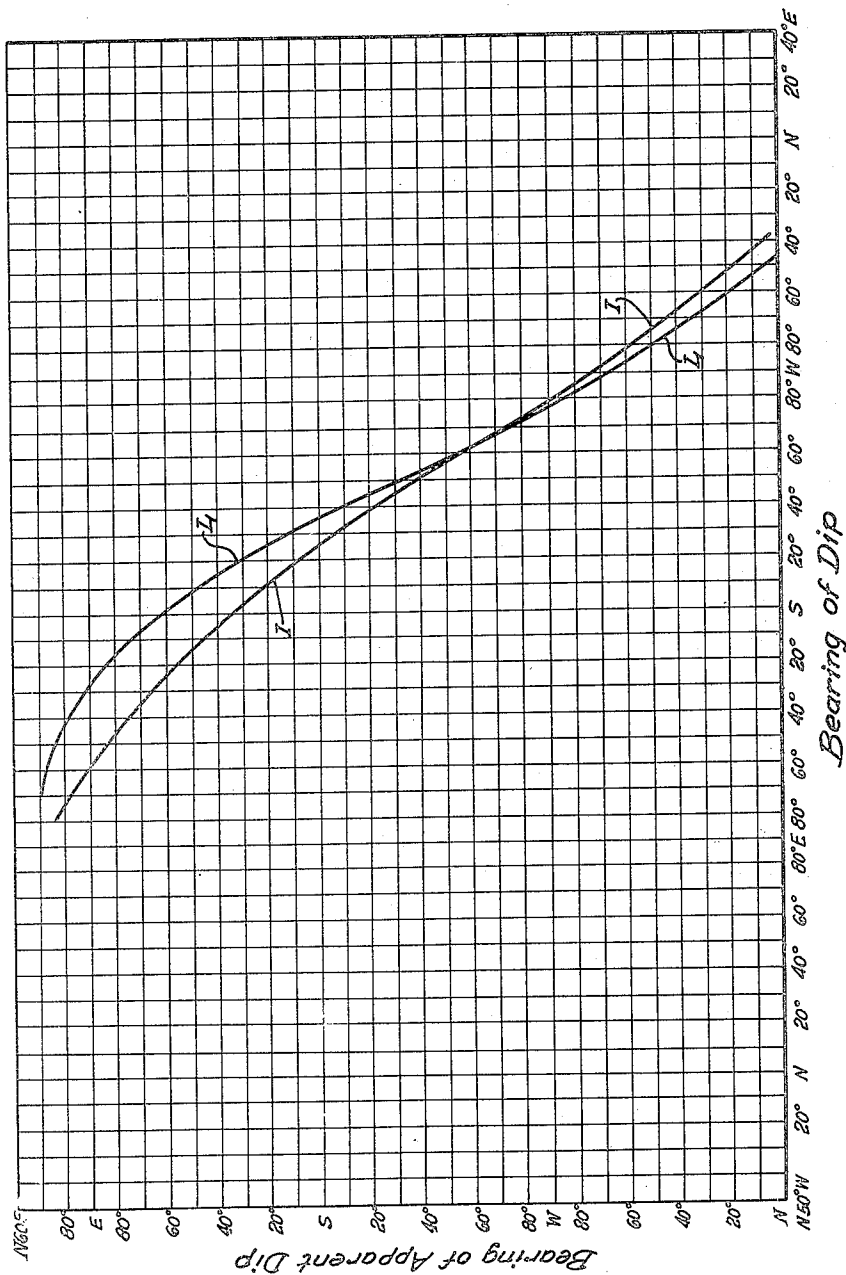
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Fig. 8.



INVENTOR.

Philip Subkow

Feb. 7, 1950

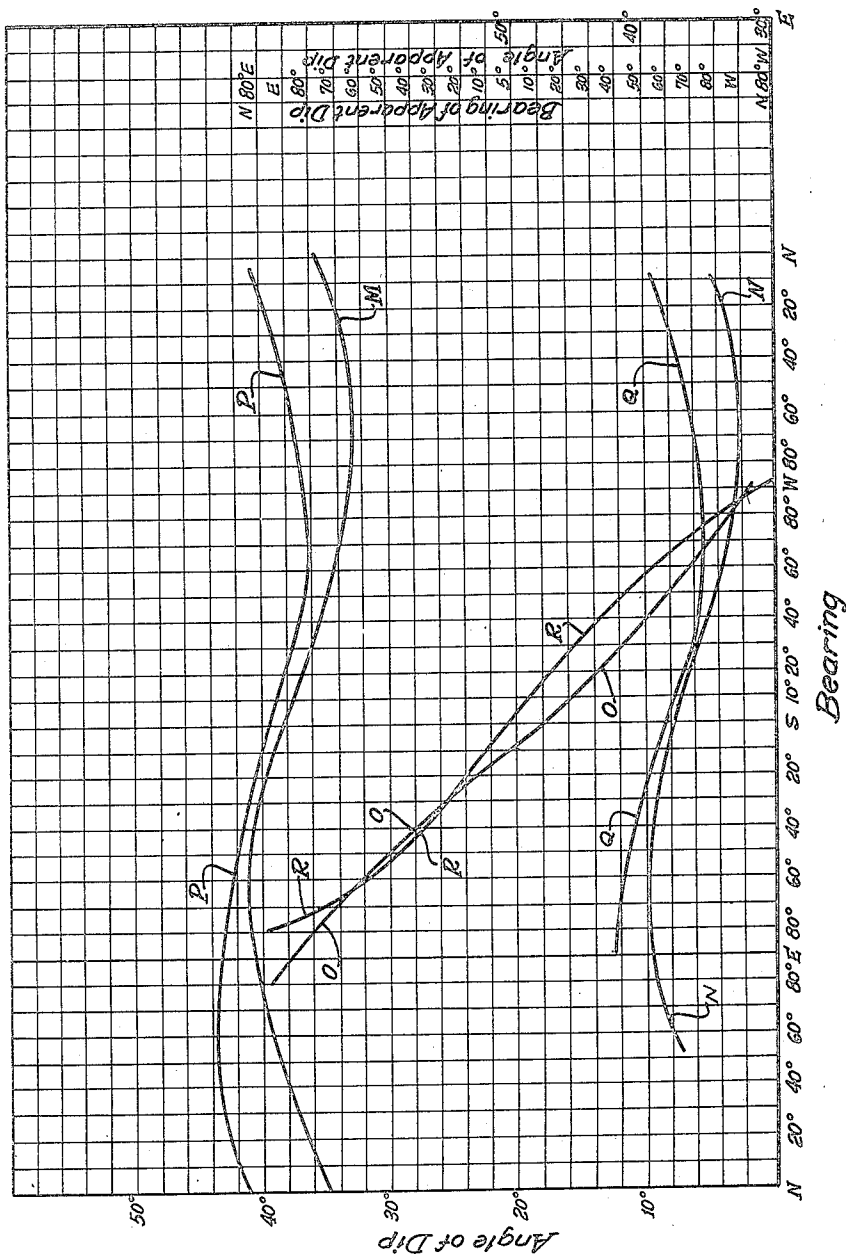
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Fig. 9.



INVENTOR.

Philip Subkow

UNITED STATES PATENT OFFICE

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GEOMETRICAL DETERMINATION OF DIP
AND STRIKE OF CORED STRATA

Philip Subkow, Los Angeles, Calif.

Application May 3, 1943, Serial No. 485,540

12 Claims. (Cl. 33—1)

1

This invention relates to core orientation, and more particularly to a method and apparatus for the determination of the direction of strike of stratum, or direction of dip and angle of dip of stratum traversed by an earth bore hole. The importance of such information is now generally recognized by geologists, petroleum engineers, and mining engineers.

This case will be better understood by reference to the following figures taken together with the description of the invention.

In the drawings:

Fig. 1 is a diagrammatic illustration of the principles of this invention;

Fig. 2 is a vertical elevation of the apparatus employed in this invention;

Fig. 3 is a plan view of the apparatus;

Fig. 4 is a fragmentary side elevation showing the mounting of the cylinder;

Fig. 5 is a fragmentary side elevation showing the mounting of the plane; and

Figs. 6 to 10 are charts showing the application of the method of this invention to three specific cases to illustrate the principles of the invention.

In ordinary core drilling of bore holes, the core which is removed usually shows the strata of the formations which have been cored. Usually these may be visually observed, but if the strata are not visible to the unaided naked eye, the strata may usually be discovered by viewing the core under ultra-violet light passing from a source, such as a quartz mercury lamp, the light from which has been filtered through a suitable filter which will exclude a major portion of the visible spectrum portion of the light and transmit the deep violet and ultra-violet end of the spectrum. The core will be found to fluoresce at the otherwise invisible surfaces of contact between strata, clearly showing up the strata lines. The thus observed strata may then be traced with pencil, chalk, or other suitable means and their positions thus permanently marked on the core. The thus observed strata usually form an ellipse where their planes intersect the cylindrical surface of the core, unless, of course, as rarely occurs, the core has been taken so that its vertical axis is perpendicular to the plane of the stratum. When the core has been marked in the manner hereinbefore described so as to delineate the stratum, the angle that its plane makes with the axis of the core is determined in the conventional manner. This determination of the stratum angle may be conveniently accomplished, for example, by reflecting the core in a mirror and laying off

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the reflection of the stratum, marking and determining the angle thereof with respect to the vertical axis of the core. The low point on the ellipse is then determined and the line connecting this low point and the axis positioned vertically is the line of maximum inclination, or the dip of the strata with respect to the core axis. I can also determine this angle by grinding the core to a perfect cylinder and measuring the distance between the high and low point of the ellipse. This distance divided by the diameter of the cylinder is the tangent of the angle of apparent dip. I shall call this angle the apparent angle of stratum dip of the core.

The angular and azimuthal deviation of the core when it was taken is then determined by taking a survey reading of the bore hole at the point where the core has been removed. Various methods are now commonly employed for this purpose, as will be well understood by those in the art.

In my method I take two or more cores from the same or closely adjacent strata or from strata known to be substantially parallel at the points at which the cores are taken. It is desirable to obtain such cores which are not identical in their angular or azimuthal deviation. I shall speak of such cores as "differently deviated." Thus, if the azimuthal deviations of the bore at the points where the cores are taken are the same, I desire that the inclinations of the bore at those points be different; or if the inclinations are the same, I prefer that the azimuthal deviations be different. Also, both the inclination and azimuthal deviations may be different. These cores preferably may be obtained from the same bore hole or, if unobtainable from the same bore hole, from a plurality of bore holes sufficiently close together to be drilled through the same or substantially parallel strata in a common formation. If they are taken from the same bore hole, it will be found that the normal drilling operations will usually produce cores which are sufficiently "differently deviated" for my purposes. Frequently, moreover, bore holes are deliberately deviated by means of directional drilling, in which case substantial differences in deviation between cores taken from adjacent strata may be produced. Cores obtained under such conditions are particularly applicable in the process of my invention.

The principle of my method will now be more fully understood by reference to Fig. 1, which diagrammatically illustrates the relative positions of the cores in space under the conditions

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for ascertaining the true dip of the stratum. I first establish the co-ordinate system NOWA, where OA is a vertical line to the horizontal plane NOW, which is in turn parallel to the horizontal surface of the earth. N represents north, W represents west. A is the point of intersection of the axes 1' and 2' of cores 1 and 2. Let core 1 and core 2 be two given cores taken from the same or from parallel strata. The angle of dip of the stratum with respect to core 1 (i. e., the apparent dip of the stratum with respect to core 1) is given by the angle which the line AC makes with a plane perpendicular to the axes 1' (i. e. $90^\circ - b'$). The angle of dip of the stratum with respect to the core 2 (i. e., the apparent dip with respect to core 2) is given by line AB which makes an angle $90^\circ - b$ with respect to a plane perpendicular to the axis 2' of core 2. The axis 1' of core 1 has an azimuthal direction shown by angle a' . The inclination from the vertical of the core axis 1' corresponding to the bore hole at the point at which the core is taken is shown by vertical angle e . The position of the core is thus fixed in space except that its angular orientation around its axis 1' as a center of rotation is not yet determined. In other words, the core may take an infinite number of positions, as shown, by rotating core 1 around its fixed axis 1'. Core 2, the second core which has been taken, has its axis directed in the direction shown by angle a . The inclination of its axis from the vertical is shown by the vertical angle f . The position of core 2, then, is similarly fixed in space except for its angular orientation around its axis 2'. In order to fix completely the positions of the cores in space, a third criterion must be satisfied, that is, that the planes of the strata in core 1 and in core 2 be parallel, as they necessarily were in the earth formation from which they were taken. In other words, for convenience of illustration in Fig. 1, the strata of cores 1 and 2 must lie in parallel planes, and in order to accomplish this, cores 1 and 2 must be rotated around their axes 1' and 2' until a common stratum plane is established. When this is done, the orientations of the cores are established and the direction and inclination of the line of maximum inclination of the stratum plane line A—D may then be readily determined. This may be done by establishing a vertical plane DAO passing through the line of maximum inclination of the common stratum plane. The line DO at the intersection of the said vertical plane DAO with the horizontal plane DOW indicates the azimuthal direction c of this line of maximum inclination, i. e., the dip of the stratum. This line may be established by laying off a line in plane A parallel to the plane NOW, i. e., parallel to the earth. This is the strike of plane A. The dip (i. e., the line of maximum inclination) is the line DA in plane A which is perpendicular to the strike. The dip angle is indicated by the angle $90^\circ - d$. The position of the plane of the stratum, and its dip determined both in direction and amount, is thus established.

Briefly, I may thus fix these parameters of the strata as hereinbefore described by first establishing the inclination of the strata with respect to the vertical axis of each of two or more differently deviated cores taken from said strata or adjacent strata and then establishing the vertical inclination and the azimuthal direction of the vertical inclination of the axis of each of the cores. Finally, I may establish the position of the common or parallel strata planes in the cores

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by rotating the cores about their axes until the planes of the strata in the cores are parallel to each other. All of the original geometrical parameters of the cores are then re-established in space as they were in the earth, and I then can measure the actual direction and angle of dip of the parallel strata planes by establishing the direction of the line of maximum inclination of the strata which will always be perpendicular to the strike.

Conversely, I may establish the inclination and azimuthal orientation of each of the axes of two or more differently deviated cores by determining the true dip, both in angle of dip and direction of dip. This I may do by the methods herein described or by employing any other method, such as magnetic orientation, or by employing electrical coring, or by ordinary geological methods. I will then have established the line A—D both in its azimuthal orientation, angle c , and angle of dip, to wit, the angle $90^\circ - d$. I then determine the azimuthal orientation and angular deviation of core 1, and thus fix the axis of said core in space at said orientation. I also fix the plane of the core stratum so that its known line of maximum inclination is in the direction of dip and at the angle of dip. This I do by rotating the core 1 around its axis 1' until this is accomplished. I then find the direction and inclination of the axis 2', which is necessary to place its core stratum A in the plane of the core stratum of core 1. This is the desired position of the axis of core 2, both in inclination and azimuthal orientation. I may thus establish the direction and inclination of the axes 1' and 2' of cores 1 and 2 required for the parallelism of their strata or that necessary to make the plane A in both core 1 and core 2 identical. In this manner, having determined the angle and direction of dip of a stratum, I can determine the azimuthal direction and deviation of cores taken from the same or parallel strata without surveying the bore hole.

While in the application the method is generally characterized by reference to the cores and their manipulation, it is not necessary to employ the cores themselves in operating my method, although they may be so used. The cores may be simulated by mounting a plane which will simulate the stratum of the core such that the dip of the plane to the earth is equal to the apparent dip of the core stratum when the axis of the core is vertical. The angle which the line of maximum dip of the core stratum makes with the plane of the earth will be termed the "apparent dip" of the core stratum. I shall call such a plane the "simulated" core stratum. The axis of the core is then the line dropped from the plane perpendicular to the plane of the earth. I shall call this line the "simulated" core axis. The plane may be positioned so that the simulated core axis is inclined and directed as is the core or the bore hole at the point at which it is taken in the earth. I shall call the inclination and direction the "simulated deviation" of the core axis. As the simulated core stratum is rotated around the simulated core axis, the plane will take various inclinations and directions. In each such position, the line in the plane which is parallel to the earth is the "simulated strike" of the simulated core stratum, and a line in the plane perpendicular to the simulated strike when the line is directed down-dip is the "simulated dip," and its inclination with the horizontal plane of the earth

and its bearing is the angle of simulated dip and the direction of simulated dip.

In carrying out this method, it is sometimes difficult to locate the positions of parallelism of the several planes, and a considerable number of settings must be made until, by trial and error, the region of parallelism is determined.

This difficulty may be avoided by employing the following method. The angle and direction of dip of the plane of the core stratum, when the core is oriented in space in direction and inclination equal to that at which it has been taken, are determined for various positions by rotating the core around its axis preferably through 360°. A curve may then be drawn in which one ordinate is the direction of the dip and the other ordinate is the angle of dip. The same procedure is followed for the second core. A second curve is drawn. The point of tangency of the two curves will be the position where the direction and angle of dip of the planes are equal, i. e., where the planes are parallel. Instead of using the cores themselves, I may use the simulated cores by establishing the direction and angle of dip of the simulated core strata of two differently deviated cores and determine the position of parallelism as the point of tangency of the curves, relating the angle of simulated dip to the direction of simulated dip of the simulated core stratum. In this method it is not necessary to employ two planes simultaneously, that is, each core, or the simulated core, may be traversed independently and its curve drawn. The point of tangency of the two curves gives the direction and angle of the dip of the core stratum when the curves are parallel in space. This is the direction and angle of dip of the core stratum in which the core is taken.

The method also includes the determination of the angle which the apparent dip makes with the plane of the earth and the direction of the line of apparent dip for various positions of the simulated dip of the core stratum. I may then draw curves relating the direction of apparent dip to the direction of simulated dip and a curve relating the direction of apparent dip to the angle of apparent dip.

Two cases must be distinguished. In one case the lines of apparent dip, when positioned in the plane of the stratum from which the core is taken, are sensibly parallel. This may occur, for example, when the axes of the cores are similarly directed but differently inclined, or when one of the cores is taken vertically and the axis of the other core is in the direction of the dip of the stratum which is cored, or is 180° in the other direction.

The other case is when the cores differ in inclination and direction substantially, i. e., the lines of apparent dip are not parallel when positioned in the plane of the stratum from which the core is taken.

In the first case, the lines of apparent dip are parallel in space when the core strata of the two cores are oriented in the direction and inclination simulating that of the strata from which the cores are taken and the inclination of the lines of apparent dip to the earth plane will be equal.

Therefore, in the first case, the region of tangency of the curves of the simulated dip and the parallelism of the planes and therefore the direction and angle of simulated dip, may be confirmed by the curves relating the direction to the inclination of the apparent dip and the direction of simulated dip to the direction of simulated

dip. In such case the direction of each of the lines of apparent dip should be the same and the difference in inclination of the lines of apparent dip to the earth's plane should be equal to the difference in the vertical deviation of the cores.

In the second case I employ the theorem of descriptive geometry which defines the dip and strike of a stratum when the direction and inclination of two non-parallel lines in the stratum are known. This theorem is described in "Engineering Descriptive Geometry," by C. E. Rowe (1938), pp. 158 and 159. Since I have determined the direction and inclination of the lines of apparent dip for various positions of their simulated core strata (i. e., for various directions of the simulated dip), the direction of the true dip must be sensibly equal to the dip as determined by the above theorem from the lines of apparent dip which lie in such plane. If the dip so determined by this theorem of descriptive geometry confirms the direction and inclination of dip as determined by the methods herein described, the determination of dip is thus confirmed.

A convenient apparatus to be used in any method for determining the strike, dip, and direction of dip is illustrated in Fig. 2. In Fig. 2, 1a is the base of the apparatus mounted on adjusting legs 2a so that the base may be levelled (i. e., made parallel to the plane of the earth); 3 is a polar coordinate graph in the center of which is rotatably mounted a disc 4 upon a spindle 5. Permanently mounted upon said disc is a bearing bracket 6 in which is positioned a cylinder 7 in frictional engagement therewith, so mounted that cylinder 7 may be rotated within the bearing bracket 6. On said bearing bracket is positioned a scribe mark 8 in the plane bisecting the cylinder, and on the cylinder 7 is mounted a protractor 9. In the cylinder is a hole 7' whose axis passes parallel to the 90° mark on the protractor and is in the plane containing the scribe mark 8. There is a scribe mark 10 on the bracket 6. The scribe mark is so positioned that when the axis of the hole is vertical (i. e., perpendicular to the base), the scribe mark is coincident with the zero on the protractor 9. Through the hole in cylinder 7 passes a spindle 11 around which is a collar 12. In the cylinder is a set screw 13 and in the collar is a set screw 14. Mounted upon the spindle is a slide bearing 15 so mounted that the bearing surface is perpendicular to the axis of the spindle and the hole. The bearing block carries a set screw 16. Slidably mounted in the bearing is an arm 17, the arm therefore being at 90° to the axis of the spindle. Upon this arm is mounted a protractor 18. The base of the protractor is parallel to the arm 17. A plane 19 is hingedly mounted on spindle 20 and held in adjustment by set screw 19'. The spindle 20 is perpendicular to the axis of arm 17 and side 17a and perpendicular to the protractor 18 and the axis of spindle 20 passes through the center of the protractor 18. The arm 19a which is an extension of the plane 19 carries a scribe mark 18' on the end of arm 19a. The scribe mark is in line with the axis of the rod 20. The end of the plane 19 is made circular to permit the passage of the arm 24, as the rod 22 is rotated, to different positions, as will be described below.

Swivelly mounted by means of bolt 21' and nut 21 on the plane 19 is a rod 22 carrying a level 23 so mounted as to be rotatably adjustable upon the rod. The rod carries an arm 24 so mounted that the line 24' on arm 24 is parallel to the plane

19 and perpendicular to the axis of rod 22. The rod carries a protractor 25 which may be rotated around a bolt 26 and held at any desired position by means of a set screw 27. The bolt 26 passes through the center of protractor 25 and the line 24'. The protractor carries a level 28. Mounted on plane 19 by means of bracket 29 is an arm 30. The line 30' is parallel to the side 17a and the plane of protractor 18 and parallel to the plane 19. Mounted on arm 30 is a protractor 33 which is mounted on a hinge 32. The hinge 32 is parallel to the line 30'. On hinge 32 is rotatably mounted a protractor 33 on bolt 34 and held in place by nut 35. The axis of bolt 34 passes through the center of protractor 33 and through line 30'. A bubble 36 is mounted on protractor 35.

To adjust the instrument, set the scribe mark 10 at the zero mark of protractor 9; set the plane 19 so that the scribe mark 18' is opposite the 0 mark on protractor 18; set the protractor 25 so that the zero is opposite the line 24'; set the hinge vertical and set the protractor 33 at the zero position opposite the line 30'; adjust the legs 2a until the bubbles 28, 36, and 23 are in the central position; and rotate the arm 17. The bubbles should be in the central position at all positions of the arm 17. Proper adjustments may be made by means of the adjusting screws 2a.

The procedure for carrying out my method may be best described by reference to particular examples.

EXAMPLE 1

This example illustrates a case where the directions of the apparent dip of the cores are parallel and in this case parallel to the dip of the strata from which they are taken. This example shows also the application of the method to vertical cores:

Core 1 was taken at 10,595 feet. The bore hole at this depth had a vertical inclination of $11\frac{3}{4}^\circ$ and it was directed S. 33° W. The apparent dip of the core stratum was measured as 51° . After levelling the instrument as previously described, the plane 19 with the mark 18' was set at 51° on the protractor 18 and locked in place by set screw 19'. The cylinder 7 was rotated so that the scribe mark 10 was opposite $11\frac{3}{4}^\circ$ on protractor 9. The disc 4 was rotated until the scribe mark 8 was at the position S. 33° W., taking north arbitrarily as shown in Fig. 3. Arm 17 is now directed arbitrarily to any position. The set screw 13 is tightened. The rod 22 is rotated until the bubble 23 shows that the arm is level, that is, parallel to the base 1 and the plane of the earth. The direction of the line 24' and arm 24 is read by projecting the axis of the rod 22 onto the coordinate chart 3 and reading the direction of the arm and line 24' down-dip on plane 18 as the direction of a line directed down-dip and perpendicular to the said projection.

A convenient device for making the projection and reading the direction of the perpendicular is a base having two vertical uprights which may be set against the ends of the rod 22. The edge of the base which sits on 1a is thus parallel to the rod 22. Set a right triangle against the parallel edge of the base and read the angle that this perpendicular makes with the direction north, or any other direction on chart 3. This gives the direction of the simulated dip of the plane of the simulated core stratum.

Set the protractor 25 so that the bubble is level and read the angle protractor 25 opposite the line

24'. This gives the angle that the simulated dip makes with the plane of the earth. Set the hinge 32 so that it is vertical. This may be done conveniently by setting it against a straight edge on a base so that it is perpendicular to base 1. Set the protractor 33 until bubble 36 is level. Read the angle on protractor 33 opposite the line 30'. This gives the angle that the apparent dip makes with the plane of the earth when the simulated core stratum is positioned so that the simulated dip is in the direction as determined above. Measure the direction of the apparent dip, again reading down-dip of the plane 19. This may be done as before by projecting the line 30' and arm 30' onto the base 1 and reading the direction, down-dip, by measuring the angle made by this projection with a direction such as north. Repeat this procedure for several positions spaced throughout 360° . Such readings will be hereinafter termed a "traverse."

The following Table 1 gives the readings of the direction of dip, angle of dip, and the corresponding direction of apparent dip, and the angle of apparent dip in making the traverse for core 1.

Table 1

Bearing of Dip	Angle of Dip	Bearing of Apparent Dip	Angle of Apparent Dip
	Degrees		Degrees
S. $1\frac{1}{2}^\circ$ W.	$41\frac{1}{2}$	S. 9° W.	39
S. 26.5° W.	39.5	S. 25.5° W.	39
S. 54° W.	40	S. 44° W.	39
S. 86° W.	44	S. 69.5° W.	$42\frac{1}{2}$
N. $66\frac{1}{2}^\circ$ W.	49	S. 87° W.	$45\frac{1}{2}$
N. $8\frac{3}{4}^\circ$ E.	62	N. $4\frac{1}{4}^\circ$ E.	61
N. 43° E.	63	N. 43° E.	$62\frac{1}{2}$
N. 89° E.	57	S. $77\frac{1}{2}^\circ$ E.	$55\frac{1}{2}$
S. 43° E.	48	S. $26\frac{1}{2}^\circ$ E.	45
S. $36\frac{1}{2}^\circ$ W.	$39\frac{1}{2}$	S. $31\frac{1}{2}^\circ$ W.	$39\frac{1}{2}$

Fig. 6 charts this data. On this figure the abscissa gives the bearing of the dip and the apparent dip, depending upon whether we are reading curve A or curve B or curve C. Curve A charts the bearing of the simulated dip which is read on the abscissa and the angle of the simulated dip read on the ordinate. Curve B charts the bearing of the apparent dip, which bearing is read on the abscissa against the angle of apparent dip which is read on the ordinate. Curve C charts the bearing of the apparent dip which is read on the ordinate against the corresponding bearing of the simulated dip which is read on the abscissa.

A second core was taken at a depth of 10,561 feet in the same well. It was a vertical core and the angle of apparent dip was measured on the core as 39.5° . When this core is traversed the cylinder 7 is rotated so that the scribe mark 10 is opposite the zero on the protractor 9. The spindle 11 is then vertical, in which case, of course, the position of the scribe mark 8 is immaterial. The protractor 9 is set at an angle of 39.5° . A traverse made as previously described in regard to core 1 will show the direction of simulated dip for all positions of the plane is the same as the direction of the apparent dip and the angle of dip of the simulated core stratum represented by the protractor 9 is equal to the angle of apparent dip, and that these angles are equal to the original apparent dip, to wit, 39.5° . This may be predicted without such traverse. A straight line E, therefore, drawn on the chart, Fig. 6, at 39.5° will represent the angle of the simulated dip for all bearings of the simulated

dip, and the straight line D will represent the bearings of the apparent dip for various bearings of the simulated dip.

It will appear that line D crosses curve C at a bearing of S. 25° W. That is to say, when the simulated core strata of cores 1 and 2 are both directed so that the bearings of the simulated dips are each S. 25° W., the bearings of the line of apparent dip of each core strata will also be S. 25° W.

Referring to curve A, it will be seen that the angle of dip of the simulated core stratum of core 1 is at 39.5° when the dip is S. 25° W. It will also be seen by reference to curve B that the angle of the apparent dip of core 1 is 39.5°. At this position of the simulated core stratum the direction of the dip and its inclination of each plane are the same (i. e., the simulated core strata are parallel). At all other positions the angles of dip are different (i. e., the planes are not parallel). It will also be seen that the bearing of the apparent dip of core 1 is S. 25° W., which is the same as the bearing of the dip. It therefore appears that the line of apparent dip is coincident with the simulated dip of the plane in this position of the apparent dip and the simulated dip. It will also be seen that the direction of the bearing of apparent dip is substantially the same as the direction of the axis of the core. In other words, the line of apparent dip when positioned in the plane whose dip is 39.5°, S. 25° W. is substantially sensibly in the same plane as the axis of the core. It will be observed that the sum of the angle of the dip, that is, 39.50°, and the inclination of the axis, 11.75°, is equal to 51.25°, which is sensibly that of the apparent dip, 51°. This further confirms the fact that the direction of the apparent dip and the direction of the simulated dip and the direction of the axis of the core are the same.

These curves therefore show that core 1 was taken so that its axis was sensibly in the direction of the dip and that the direction of the dip was S. 25° W. with an inclination of 39.5°. At this point only are the simulated planes of cores 1 and 2 parallel, to wit, they have the same direction of dip and the same angle of dip. This direction is confirmed by the fact that only if the bearing is substantially equal to the direction of the core axis of core 1 would the difference between the apparent dip of core 1, 51°, and the vertical inclination of the core, i. e., 11.75°, be equal to the dip, to wit, 39.5°, and only in this position will we find that the direction of the apparent dip of the core strata of each of the cores 1 and 2 when positioned in the strata from which they are taken and the direction of the dip of the strata are the same.

EXAMPLE 2

In the following example, cores were taken in similarly directed positions but differently inclined, neither of the cores being vertical. The direction of the apparent dips are the same but of different inclinations to the core axis. In this case, since the lines of apparent dip are in the same plane, to wit, in the plane of the cored stratum, and being similarly directed, they must be parallel, that is, they must have the same inclination to the plane of the earth.

Core 3 was taken at a depth of 4494 feet. The bore hole at this point had a vertical inclination of 14° and a direction of N. 67° E. The apparent dip of the core stratum was measured as 25.5°.

This core was traversed as previously described. The angle of 25.5° was set upon the protractor 18 and the scribe mark 8 was set at N. 67° E., and the scribe mark 10 was set opposite 14°. Table 2 records the bearing of the simulated dip, corresponding angle of dip, corresponding bearing of apparent dip, and corresponding angle of apparent dip.

Table 2

Bearing of Dip	Angle of Dip	Bearing of Apparent Dip	Angle of Apparent Dip
	Degrees		Degrees
S. 25.5° E.	25.65	S. 39° E.	21
S. 55.5° E.	14	S. 86° E.	12
N. 89° E.	11	N. 71° E.	10
N. 49° E.	12	N. 62.5° E.	10.5
N. 16.5° W.	16.5	N. 36° E.	13
N. 37° W.	26.5	N. 1.5° W.	20.5
N. 61° W.	33	N. 35.5° W.	27.5
W.	39	N. 77° W.	37.5
S. 70° W.	40	S. 71° W.	39
S. 45.5° W.	38	S. 26° W.	36
S. 25° W.	35.5	S. 10° E.	30

In Fig. 7 I have charted (see curve G) the bearing of the simulated dip read upon the abscissa against the angle of dip read on the ordinate. On curve H, I have charted the bearing of the apparent dip against the angle of apparent dip.

In Fig. 8 (curve I) I have charted the bearing of the dip read on the abscissa against the bearing of the apparent dip read on the ordinate.

Core 4 was taken from the same well at a depth of 4520 feet. The bore was directed at this point N. 68° E. and had a vertical inclination of 17°. The apparent dip of the core stratum was read as 21°. This core was traversed as previously described by setting 21° on the protractor 18, setting the scribe mark 8 at N. 68° E. and the scribe mark 10 opposite 17° on protractor 9. Table 3 gives the bearing of the dip and the corresponding angle of dip, the corresponding bearing of apparent dip, and the corresponding angle of apparent dip.

Table 3

Bearing of Dip	Angle of Dip	Bearing of Apparent Dip	Angle of Apparent Dip
	Degrees		Degrees
S. 3° W.	20.5	S. 55.5° E.	11.5
S. 40° E.	7	N. 88.5° E.	4
E.	4	N. 71° E.	3
N. 51° E.	4	N. 66.5° E.	3 1/2
N. 51 1/2° E.	6 1/2	N. 56 1/2° E.	3 1/2
N. 45° W.	23	N. 1° W.	14 1/2
W.	37	N. 66° W.	34 1/2
S. 67 1/2° W.	38	S. 64° W.	37 1/2
S. 51 1/2° W.	37	S. 31° W.	34 1/2
S. 28 1/2° W.	31 1/2	S. 11° E.	24 1/2

These data are plotted on Fig. 7 (curve J) giving the bearing of the dip read upon the abscissa against the angle of dip read on the ordinate. Curve K gives the bearing of the apparent dip read on the abscissa against the angle of apparent dip read on the ordinate. Curve L (Fig. 8) gives the bearing of the apparent dip read on ordinate against the bearing of simulated dip read on the abscissa.

It will be observed that curves G and J, while not tangent, approach each other in the region of about S. 60° W. to S. 80° W., being separated by about 1 1/2° in angle of dip.

It will also be observed that curves I and L cross in the region of about S. 65° W. The cross-

ing of the curves of I and L indicates that when the bearing of the dip of both planes of cores 3 and 4 are S. 65° W., the bearings of the apparent dip of both cores are likewise S. 65° W. In other words, in this position of each of the core strata, the bearings of the apparent dips of both planes are the same and are equal to the bearings of the dip of each plane, i. e., the simulated core strata, and their apparent dips are coincident or parallel. In view of the sensibly identical direction of the core axes of cores 3 and 4, this identity of the bearings of the apparent dips is to be expected.

The separation of curves G and J is therefore to be explained as arising from a small inaccuracy in the reading of the apparent dip of the planes. If the apparent dip of core 3 is 24.75° and the apparent dip of core 4 is 21.75°, these curves G and J approach each other and become tangent. Table 2—*a* gives the readings of the bearing of dip and the corresponding angle of dip, the bearing of apparent dip, and the angle of apparent dip on the assumption that the apparent dip is 24.75°.

Table 2—*a*

Bearing of Dip	Angle of Dip	Bearing of Apparent Dip	Angle of Apparent Dip
	Degrees		Degrees
S. 89.5° W.	38	N. 76° W.	35.5
S. 60.5° W.	38.5	S. 50.5° W.	35
S. 45.5° W.	37	S. 26.5° W.	35
N. 66° W.	34.5	N. 39° W.	30
S. 2° E.	25	S. 39° E.	20

Curve G' is the curve corresponding to G for the new setting of 24.75°. Table 3—*a* gives the bearing of dip, corresponding angle of dip, the bearing of apparent dip, and the angle of dip, for the new setting of 21.75° of core 4.

Table 3—*a*

Bearing of Dip	Angle of Dip	Bearing of Apparent Dip	Angle of Apparent Dip
	Degrees		Degrees
W.	38	N. 67.5° W.	35.5
S. 70° W.	39	S. 67° W.	38.5
S. 52° W.	37.5	S. 33.5° W.	36
S. 40° W.	35	S. 15.5° N.	3
S. 2° W.	20.5	S. 52° E.	12.5
N. 73.5° W.	34	N. 40° W.	28.5

Curve J' gives the curve corresponding to curve J for this new setting of 21.75°.

It will be seen that these curves are tangent in the region of S. 56° W. to W. Curve H' gives the bearing of the apparent dip against the angle of apparent dip corresponding to new setting of 24.75° and corresponds to curve H. Curve K' is the corresponding curve for the new setting of 21.75 corresponding to curve K. It will be seen that the region of tangency here is also in the region of about S. 50° W. to W. In this region, therefore, the apparent dips of both core strata are equal in direction. The planes are parallel and at no other bearing of their dips are they parallel. The inclination of the lines of apparent dip of each of said core strata are also parallel, and parallel to the dips. The tangency of these curves in this region of S. 50° W. to W. confirms the crossing of the curves I and L in the region of S. 65° W. It will be observed that S. 65° W. is sensibly 180° in the opposite direction from the bearings of the core axes, to wit, N. 67° E. to

N. 68° E. The conclusion therefore is that the cores were taken with their axes directed 180° away from the direction of apparent dip which was S. 65° W., and the dip had an angle of 38.5°.

The lines of apparent dip were directed in the same direction as the apparent dip at S. 65° W. and the angle of apparent dip was, for core, 24.75°, and for core 4 was 21.75°, a difference of 3°. It will be observed that the difference between the vertical inclination of the two cores is also 3°, and this would occur only if the lines of apparent dip were directed in the same plane with the core axes. Since, obviously, a line directed S. 65° W. is sensibly in the same plane as a line directed N. 67° E., this confirms the conclusion reached by this method. The result of this orientation is therefore that the plane of the strata from which the cores were taken was directed S. 65° W. and had an inclination of 39.5°.

The previous two examples illustrated case 1, wherein the lines of apparent dip, when positioned in the strata from which the cores are taken, are parallel. Example 3 illustrates a case where the lines of apparent dip are not parallel but are differently directed.

EXAMPLE 3

Core 5 was taken at a depth of 7123 feet. The bore had at this point a vertical inclination of 3.75° and a bearing of N. 59° W. This core was traversed in the manner previously described. The core had an apparent dip 36°. This angle was set upon protractor 18. Scribe mark 8 was placed opposite N. 59° W. and the scribe mark 18 was set opposite 3.75° on protractor 9. Table 4 gives the bearing or direction of dip and the corresponding angle of dip, the corresponding bearing of the apparent dip, and the corresponding angle of apparent dip.

Table 4

Bearing of Dip	Angle of Dip	Bearing of Apparent Dip	Angle of Apparent Dip
	Degrees		Degrees
N. 1° E.	35	N. 10° W.	34
N. 36° W.	33.5	N. 47° W.	32.5
N. 66.5° W.	33	N. 70° W.	32.5
W.	32.5	N. 87.5° W.	32.5
S. 54.5° W.	35	S. 63° W.	33.5
S. 8.5° W.	37	S. 16° W.	36
S. 1° E.	38.5	S. 6° W.	37.5
S. 31.5° E.	40.5	S. 29° E.	39
S. 66° E.	40.5	S. 71.5° E.	39.5
N. 79° E.	40	N. 83° E.	39
N. 60° E.	38.5	N. 52° E.	37.5
N.	35	N. 8.5° W.	34

On Fig. 9 I have charted curve M, which charts the bearing of the dip read on the abscissa against angle of dip read on the ordinate. Curve N charts the bearing of the apparent dip read on the abscissa against the angle of dip read on the ordinate, and curve O charts the bearing of the dip read on the abscissa against the bearing of apparent dip read on the ordinate.

Core 6 was taken at a depth of 7183 feet. The bore at this point had a vertical inclination of 2.75° and had a bearing of N. 80° W. The scribe mark 10 was set at 2.75° on protractor 9 and scribe mark 8 was set at N. 80° W. The apparent dip of the core stratum was 39°. The plane 19 was set at an angle of 39° on the protractor 18. Table 5 gives the direction of dip, the corresponding angle of dip, corresponding direction of apparent dip, and the corresponding angle of apparent dip.

Table 5

Bearing of Dip	Angle of Dip	Bearing of Apparent Dip	Angle of Apparent Dip
	Degrees		Degrees
N. 1° E.	41	N. 8° W.	39.5
N. 30° W.	39	N. 39° W.	38
N. 67° W.	37	N. 70° W.	36
N. 88° W.	36.75	N. 79.5° W.	35.75
S. 34° W.	37	S. 30° W.	36
S. 71° W.	36.5	S. 71° W.	35
S. 87° W.	36.5	S. 89° W.	35.5
S. 25.5° E.	41	S. 21° E.	39.5
S. 52.5° E.	42.5	S. 49° E.	41
S. 79° E.	43.25	S. 88.5° E.	42.5
S. 58° E.	43	S. 56° E.	42
N. 1° E.	40.5	N. 9° W.	39.5

Curve P gives the bearing of the dip read on the abscissa against angle of dip read on the ordinate. Curve Q charts the bearing of apparent dip read on the abscissa against the angle of apparent dip read on the ordinate. Curve R gives the bearing of dip read on the abscissa against the bearing of apparent dip read on the ordinate. It will be observed that curves M and P most closely approach each other in the region of S. to S. 40° E., being more separated at all other bearings of the dip. The separation of the two curves is about 1° of angle of dip, and the two curves may therefore be said to be sensibly tangent in this region. The conclusion which these curves direct is that the bearing of the dip is therefore in the region of about S. to S. 30° to 40° E. I may select the bearing of the dip more closely. By reference to curves N, O, Q, and R, I make the following series of assumptions:

Assume that the bearing of the dip is S. 10° E., the bearing of the apparent dip of core 5, for this position of the dip is given on curve O, and its angle of dip is given on curve N. The bearing of the apparent dip of core 6 for this direction of the dip is taken from curve R, and the angle of apparent dip is given on curve Q. If the dip is S. 10° W., these lines of apparent dip of each core should be in this plane, and since their direction and inclination are known, we may, applying the theorem of descriptive geometry previously referred to, determine if the dip thus calculated equals the dip so assumed to be S. 10° E.

From the data of Tables 4 and 5 and curves of Fig. 9 when the dip is S. 10° E., the angle of dip is 39.5°. The bearing of apparent dip of core 5 corresponding to a dip of S. 10° E. was S. 2° E. and its inclination was 38°. The bearing of the apparent dip of core 6 corresponding to a dip of S. 10° is S. 11° E. and its inclination was 38.5°. Assume S. as indicated at the top of Fig. 10, with W. and E. as indicated. Draw a line UT with a bearing of S. 2° E. Draw a line TV to make an angle UTV equal to 38°. Draw a line TW with a bearing of S. 11° E. Draw a line XT so that the angle XTW equals 38.5°. Draw a line UV perpendicular to line TU. Draw a line XW equal in length to UV and perpendicular to TW. Draw a line ZZ' through the points W and U as the strike of the plane defined by the lines of apparent dip. Draw the line TT' perpendicular to the line ZZ'. Line TT' is the bearing of the dip of the plane and its bearing is S. 7° E. Lay off the line T'Y equal to the line UV. Draw the line TY. The angle T'Ty is the angle of dip of the dip TT'. This angle is 38.5°. This construction gives the dip as 38.5° S. 7° E. The assumed dip from the curves of Fig. 9 is 39.5° S. 10° E. The difference is 3° in bearing and 1.5° in inclination.

Assume the dip as 39° S. The bearing of the apparent dip of core 5 is S. 10° W. and its inclination is 37°. The bearing of the apparent dip of core 6 is S. 3° E. and its inclination is 38°. By construction by the method previously set forth the dip was determined to be 38° S. 7° E. compared with the assumed dip of 39° S., a difference of 7° in bearing and 1° in inclination.

Assume the dip to be S. 10° W. The corresponding bearing of the apparent dip of core 5 is S. 22° W. and its inclination is 36°. The corresponding bearing of the apparent dip of core 6 is S. 5° W. and its inclination is 38°. The dip was determined by construction according to the above method to be S. 2° W. and its inclination was determined to be 38°. This compares with the assumed dip 39.5° S. 10° W. This indicates a difference of 8° in bearing.

The closest agreement therefore between the dip as determined by the curves for the position of parallelism of the simulated dips of cores 5 and 6 and the dip of the plane defined by the lines of apparent dip is that for a position of S. 10° W. where the agreement is within 3°. I therefore determine the dip of the strata from which cores 5 and 6 were taken as having a dip of about 39.5° in inclination with a bearing of about S. 10° E.

It will be seen that whereas a vertical core, i. e., one not having any direction or inclination, may be employed in this method, as in the cases illustrated by Examples 1 and 2, it may not be employed in the case illustrated by Example 3. In that case the traverse of a vertical core will give a straight line on Fig. 9 at an angle of dip of 39.5°, and this line will intersect curves M or P at two points, giving an indeterminate answer for the dip. However, if two differently deviated cores, such as cores 5 and 6, are employed, an additional vertical core taken from the same stratum will intersect the curves of the traverse of both cores at their region of tangency, and thus further confirm the results obtained.

The instrument herein described may also be employed for correction of the readings obtained by the so-called magnetic method of core orientation. In that method but a single core is required. The core is surveyed by a magnetometer or other exploring magnet and the magnetic north pole of the core is determined. Since the position of the line of apparent dip with respect to the north pole is fixed, and knowing the magnetic declination at the point where the location of the core's north pole is determined, the bearing of the line of apparent dip is thus established. Since, however, if the core is not a vertical core but has a vertical inclination or an azimuthal deviation when taken in the stratum, a correction for such deviation must be made in order to get the true dip of the core stratum.

My instrument permits of this correction. I proceed in the following manner. With spindle 11 vertical and base 1a level, set the angle on protractor 18 to the angle of apparent dip of the core stratum. Rotate arm 17 until rod 22, when brought level, is so directed that a perpendicular to the projection of rod 22 on base 1a has the bearing as determined for the line of apparent dip by means of the magnetic orientator. Tighten the set screws 13 and 16. Set the scribe marks 8 and 10 at the bearing and inclination of the core axis as determined by the well survey, i. e., that of the bore from which the core is taken. Read the bearing of the dip by setting the rod 22 level and determining the bearing of

the perpendicular to the projection of 22 on base 1a. Set the protractor 27 so that the bubble is level and read the dip.

Thus, for example, a core has a core stratum of apparent dip of 30° and an axis which when the core was taken had a vertical inclination of 20° and a bearing N. 30° W. The bearing of the line of apparent dip with the core vertical is determined by the magnetic method to be S. 26.5° W. Set spindle 11 vertical. Set 30° on protractor 18. Set the rod 22 level, and rotate rod 17 so that a perpendicular to the projection of 22 on base 1a has a bearing of S. 28° W. Set the set screws. Set the scribe mark 8 at N. 30° W. Set the scribe mark 10 at 20°. Level the rod 22 and read the bearing of the dip as previously described. It is S. 8° W. Read the angle of dip on protractor 25. It is 43°. The true dip is then 43° S. 8° W.

Where in the claims reference is made to core strata and to core axis and to procedural steps involving the same, they include the simulated core strata and the simulated core axis as set up on the apparatus herein described and to procedural steps therewith.

It is to be understood that the foregoing description of my invention is illustrative only, and various changes and modifications may be made therein coming within the scope of the appended claims.

I claim:

1. A method for determining the dip of strata, which comprises taking a plurality of differently deviated cores from the same or substantially parallel strata, determining the inclination and direction of the axes of such cores as taken, establishing the apparent angle of dip of the core strata in each of said cores, establishing the axes of said cores in space in the said direction and at the said inclination, determining the angle of dip of said core strata for various bearings of the dip of the core strata when said core strata are rotated about the axis of their respective cores when so directed and inclined, establishing the bearing and angle of dip of each of said core strata at which said angle and bearing of dip of each of said core strata are equal, and thus determining the bearing and angle of dip of the strata from which the cores are taken.

2. A method for determining the dip of strata, which comprises taking a plurality of differently deviated cores from the same or substantially parallel strata, determining the inclination and direction of the axes of such cores as taken, establishing the apparent angle of dip of the core strata in each of said cores, establishing the axes of said cores in space in the said direction and at the said inclination, determining the angle and bearing of the apparent dip of said core strata for various bearings of the dip of the core strata when rotated about the axis of their respective cores when so inclined and directed, determining also the angle of dip of said core strata and the bearing of the dip of said core strata for each of the said determined directions of the apparent dip of said cores, and from said determinations establishing the angle of dip and the bearing of the dip of said strata from which said cores are taken.

3. A method for determining the dip of strata, which comprises taking a plurality of differently deviated cores from the same or substantially parallel strata, determining the inclination and direction of the axes of such cores as taken, establishing the apparent angle of dip of the core

strata in each of said cores, establishing the axes of said cores in space in the said direction and at the said inclination, determining the angle of dip of said core strata for various bearings of the dip of the core strata when said core strata are rotated about the axis of their respective cores when so directed and inclined, and from said determination establishing a plurality of curves relating the angle of dip of each of said core strata determined for each of said various directions of dip to the bearing of the dip, and determining the direction and angle of dip of said strata from which said cores are taken as that direction and angle of dip at which the curves are at their closest approach.

4. A method for determining the dip of strata, which comprises taking a plurality of differently deviated cores from the same or substantially parallel strata, determining the inclination and direction of the axes of said cores as taken, establishing the apparent angle of dip of the core strata in each of said cores, determining the angle of dip of said core strata for various bearings of the dip of the core strata when rotated about the axis of their respective cores when said axes are inclined and directed in accordance with said determinations of the inclination and direction of the cores in the formations from which they are taken, determining the angle and bearing of the apparent dip of said core strata for said various bearings of the dip of the core strata when so rotated about the axes of their respective cores so inclined and directed, and from said determination establishing a plurality of curves relating the bearings of the dip of each of said core strata as determined for each of said various bearings of the dip, establishing a plurality of curves relating the angle of apparent dip to the various bearings of the apparent dip, establishing the angle and bearing of the dip of said strata from which the cores are taken as that determined by the closest approach of the curves relating the angle of dip to the bearing of the dip, and confirming said dip so determined by establishing that the corresponding angles and bearings of the apparent dip determined for said bearing of the dip and angle of dip lie substantially in the plane whose dip has a bearing and inclination as determined.

5. A method for determining the dip of strata, which comprises taking a plurality of differently deviated cores from the same or substantially parallel strata, determining the inclination and direction of the axes of said cores as taken, establishing the apparent angle of dip of the core strata in each of said cores, determining the angle of dip of said core strata for various bearings of the dip of the core strata when rotated about the axis of their respective cores when said axes are inclined and directed in accordance with said determinations of the inclination and direction of the cores in the formations from which they are taken, determining the angle and bearing of the apparent dip of said core strata for said various bearings of the dip of the core strata when so rotated about the axes of their respective cores so inclined and directed, and from said determination establishing a plurality of curves relating the bearings of the dip of each of said core strata as determined for each of said various bearings of the dip, establishing a plurality of curves relating the angle of apparent dip to the various bearings of the apparent dip and a plurality of curves relating the bearing of apparent dip to the bearing of the dip for various

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bearings of said dip, establishing the angle and bearing of the dip of said strata from which the cores are taken as that determined by the closest approach of the curves relating the angle of dip to the bearing of the dip, and confirming said dip so determined by establishing that the corresponding angles and bearings of the apparent dip determined for said bearing of the dip and angle of dip lie substantially in the plane whose dip has a bearing and inclination as determined.

6. An apparatus for the determination of dip of strata, which comprises a base, a rod mounted on said base, means for fixing said rod at a desired bearing and at a desired inclination to the vertical to said base, a plane, means for mounting said plane on said rod, means for adjusting said plane to the desired inclination to said rod, means for rotating said plane around said rod, a second rod mounted on said plane, means for positioning said rod on said plane parallel to said base, a third rod mounted on said second rod and perpendicular thereto, means for determining the inclination of said third rod to the base, means for determining the direction or bearing of said third rod comprising a protractor swivelly mounted on said third rod, and means for levelling the edge of said protractor.

7. An apparatus for the determination of dip of strata, which comprises a base, a rod mounted on said base, means for fixing said rod at a desired bearing and at a desired inclination to the vertical to said base, a plane, means for mounting said plane on said rod, means for adjusting said plane to the desired inclination to said rod, means for rotating said plane around said rod, a second rod mounted on said plane, means for positioning said rod on said plane parallel to said base, a third rod mounted on said second rod and perpendicular thereto, means for determining the inclination of said third rod to the base comprising a protractor swivelly mounted on said third rod and means for levelling the edge of said protractor, means for determining the direction or bearing of said third rod, a hinge, means for mounting said hinge parallel to said plane and at an angle to said first-named rod equal to that at which said plane is set, a protractor swivelly mounted on said hinge, and means for levelling the edge of said protractor.

8. A method for determining the dip of strata from which a plurality of differently deviated cores have been taken from the same or substantially parallel strata and for which the inclination and direction of the axes of such cores are known, which comprises establishing the apparent angle of dip of the core strata in each of said cores, establishing the axes of said cores in space in the said direction and at the said inclination, determining the angle of dip of said core strata for various bearings of the dip of the core strata when said core strata are rotated about the axis of their respective cores when so directed and inclined, establishing the bearing and angle of dip of each of said core strata at which said angle and bearing of dip of each of said core strata are equal, and thus determining the bearing and angle of dip of the strata from which the cores are taken.

9. A method for determining the dip of strata from which a plurality of differently deviated cores have been taken from the same or substantially parallel strata and for which the inclination and direction of the axes of such cores are known, which comprises establishing the apparent angle of dip of the core strata in each

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of said cores, establishing the axes of said cores in space in the said direction and at the said inclination, determining the angle and bearing of the apparent dip of said core strata for various bearings of the dip of the core strata when rotated about the axis of their respective cores when so inclined and directed, determining also the angle of dip of said core strata and the bearing of the dip of said core strata for each of the said determined directions of the apparent dip of said cores, and from said determinations establishing the angle of dip and the bearing of the dip of said strata from which said cores are taken.

10. A method for determining the dip of strata from which a plurality of differently deviated cores have been taken from the same or substantially parallel strata and for which the inclination and direction of the axes of such cores are known, which comprises establishing the apparent angle of dip of the core strata in each of said cores, establishing the axes of said cores in space in the said direction and at the said inclination, determining the angle of dip of said core strata for various bearings of the dip of the core strata when said core strata are rotated about the axis of their respective cores when so directed and inclined, and from said determination establishing a plurality of curves relating the angle of dip of each of said core strata determined for each of said various directions of dip to the bearing of the dip, and determining the direction and angle of dip of said strata from which said cores are taken as that direction and angle of dip at which the curves are at their closest approach.

11. A method for determining the dip of strata from which a plurality of differently deviated cores have been taken from the same or substantially parallel strata and for which the inclination and direction of the axes of said cores are known, which comprises establishing the apparent angle of dip of the core strata in each of said cores, determining the angle of dip of said core strata for various bearings of the dip of the core strata when rotated about the axis of their respective cores when said axes are inclined and directed in accordance with said determinations of the inclination and direction of the cores in the formations from which they are taken, determining the angle and bearing of the apparent dip of said cores strata for said various bearings of the dip of the core strata when so rotated about the axes of their respective cores so inclined and directed, and from said determination establishing a plurality of curves relating the bearings of the dip of each of said core strata as determined for each of said various bearings of the dip, establishing a plurality of curves relating the angle of apparent dip to the various bearings of the apparent dip, establishing the angle and bearing of the dip of said strata from which the cores are taken as that determined by the closest approach of the curves relating the angle of dip to the bearing of the dip, and confirming said dip so determined by establishing that the corresponding angles and bearings of the apparent dip determined for said bearing of the dip and angle of dip lie substantially in the plane whose dip has a bearing and inclination as determined.

12. A method for determining the dip of strata from which a plurality of differently deviated cores have been taken from the same or substantially parallel strata and for which the inclination and direction of the axes of said cores are known, which comprises establishing the ap-

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parent angle of dip of the core strata in each of said cores, determining the angle of dip of said core strata for various bearings of the dip of the core strata when rotated about the axis of their respective cores when said axes are inclined and directed in accordance with said determinations of the inclination and direction of the cores in the formations from which they are taken, determining the angle and bearing of the apparent dip of said core strata for said various bearings of the dip of the core strata when so rotated about the axes of their respective cores so inclined and directed, and from said determination establishing a plurality of curves relating the bearings of the dip of each of said core strata as determined for each of said various bearings of the dip, establishing a plurality of curves relating the angle of apparent dip to the various bearings of the apparent dip and a plurality of curves relating the bearing of apparent dip to the bearing of the dip for various bearings of said dip, establishing the angle and bear-

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ing of the dip of said strata from which the cores are taken as that determined by the closest approach of the curves relating the angle of dip to the bearing of the dip, and confirming said dip so determined by establishing that the corresponding angles and bearings of the apparent dip determined for said bearing of the dip and angle of dip lie substantially in the plane whose dip has a bearing and inclination as determined.

PHILIP SUBKOW.

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