UNDERGROUND SURVEYING.

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I have divided this subject under the following headings, viz.:—

I. Transferring the meridian or some fixed line on the surface to the underground workings.

II. Traversing, &c., underground:—
- (a) Practical hints on traversing.
- (b) Work in connection with underground surveying; e.g., measuring stopes, laying out lines for driving bore-holes, &c., connecting rises and winzes, sampling and ore reserves.

III. Plotting the Survey:—
- (a) By protractor.
- (b) By co-ordinates: (1) The English System.
  (2) The South African System.

I. Transferring the Meridian or some fixed line on the Surface to the Underground Workings:—There are various methods of doing this, the two most common of which are—(1) By triangulation, in which the instrument is set up and each wire sighted separately.; and (2) that method in which the instrument is brought in line with the wires. Method (1) is described in "Brough's Treatise on Mine Surveying," Chapter XIV., Section 3.

Methods (2) is as follows:—

Two wires with light weights attached are lowered down the middle compartment of the shaft from two reels, supported on a board specially kept for this purpose. This board is slotted at each end, and in these slots small rollers are fixed for the wires to run over. The rollers are set at different intervals along the board for convenience in plumbing large or small shafts, but always get the greatest distance posssible between the wires. When the wires reach the level which it is required to fix, the light weights are removed and heavy weights, about 20lbs., either of lead or iron, and preferably with wings, are secured to the wires and hung in buckets of water or oil to prevent swinging as much as possible. The instrument is now set over some surface point previously fixed in the surface survey of the lease, about 10 feet to 15 feet from the shaft, and the wires brought in line with the vertical axis of the telescope by moving the board holding the wires to one side or the other. When this is accomplished, a sight is taken on to some fixed point on the lease, thence to the wires, and the angle read and the distances to each wire measured. Thus the line joining the wires is the continuation of a line in the surface survey of the lease whose length and direction are absolutely fixed, and it is this line that is transferred to the underground levels by the wires. The instrument is now taken below and set up on the plat in line with the two wires. This operation takes a little time, but with an instrument provided with telescopic legs, and a moveable head, the work is greatly facilitated. Having got into line with the wires, sight them, read the vernier, and then sight on to two points conveniently placed in the crosscut, or drive, whichever it may be, read the vernier, and measure the distances to these points. To make sure that the lines are hanging freely in the shaft, measure the distance between them, which should coincide with the measurement on the surface. We now have a triangle, A B C, of which we know the angle at A (where the instrument was set) and the sides A B and A C, we also have the direction of the line W A by our surface survey, and the distance W A from actual measurement underground, hence, by calculating the angles at B and C, we have all the data required for calculating the co-ordinates of B and C. The angles at B and C can be calculated by the formula:—

$$\tan \frac{B - C}{2} = \frac{B - C}{B + C} \cot \frac{A}{2}$$

The length and direction of the line C B is very important for future work on the level, and can be calculated as shown below under heading III. (b), (2). Thus we get two points accurately fixed on the level and connected with the surface survey of the lease. These points can also be used when a lower level is opened up, as a line joining two wires hung from the level can be referred to these points instead of to points on the surface, thus doing away with excessive lengths of wire. Wire used is either brass or copper, of about 14 gauge. Brass wire is stronger, but in case of a break it tangles, and the smallest kink is fatal. For depths up to 600 feet, copper wire is preferable, as it is much more easily handled.

II. Traversing, &c., Underground.

(a) Practical Hints on Traversing.

With regard to stations in drives and crosscuts, it is customary to bore a pop-hole about 4 inches deep in the roof and drive in a peg, into which is screwed a screw eye; but where the level is timbered a screw eye in a cap-piece makes a good station, and at the junction of a drive and crosscut, where neither of the above can be fixed, a hole in a flat-sheet makes a good temporary mark. It is always necessary to number the stations, and the following is a convenient method:—

All stations in N. drives are denoted by odd numbers.
All stations in S. drives are denoted by even numbers.
All stations in E. crosscuts are denoted by odd letters.
All stations in W. crosscuts are denoted by even letters.

By sticking to these nominations, all back work can be picked up with the greatest ease from note-books.

When setting at a station, hang a plumbob from the screw-eye and transfer the point to the bottom of the level by making a mark with the point of a pencil in a piece of candle-grease, the instrument being set over this point. The setting is greatly accelerated by using telescopic legs, which can be lengthened or shortened as required, making the final adjustment with the moveable head. When sighting plumb-lines a very clear image can be obtained by holding a candle directly behind, while the cross wires of the telescope can be illuminated by shining a candle directly down the telescope. Always work in one direction, generally from left to right, as most instruments are graduated thus.

(b) Work in Connection with Underground Surveying.

Measuring Stopes.—When measuring stopes, a start is generally made from a winze down which a measurement can previously have been taken from the level above, or, failing this, the distance to the level below can be taken by lowering the tape with a candle fixed to it down a pass. It is usual to measure from stope to stope horizontally, also to passes, and, where convenient, the vertical heights are taken down passes. The width of the lode is taken every 15 feet to 20 feet, which is near enough for regular lodes.

Setting out lines for driving or crosscutting can be done either with the prismatic compass or the theodolite.

(1) By the Prismatic Compass.—Draw a line on the plan in the required direction, and with protractor measure the angle this line makes with the magnetic north. This angle can be transferred underground, and the direction of the line fixed by plug-holes.

(2) The Theodolite.—This is a longer process, as a previous survey has to be made and plotted, and then the direction of the required line layed off from the last point in the survey. Lines for diamond drilling are set out in a similar manner to the above.

Connecting Rises and Winzes.—Where lodes are vertical, this resolves itself into a mere matter of measurement, that is, starting your rise directly under the bottom of the winze and rising vertically; but more care has to be taken where the lodes have an underlie. Presuming that the mine plans are accurate, it is near enough to scale off the distance, from some fixed point on the plan, at which to start the rise, at the same time determining what amount must be gained over east or west, as the case may be, *e.g.*, suppose the bottom its distance N. or S. is the same as the winze, then the rise at the same time determining what amount must be gained over east or west, as the case may be, *e.g.*, suppose the bottom of a winze is 10 feet east of the lower level, and is 75 feet above that level,—Mark off a point on the lower level so that its distance N. or S. is the same as the winze, then the rise has to hole over east 10 feet in 75 feet, or 1 foot in 7.5 feet, or about 6 inches per cent., which is the best method of expressing it to the average miner. When sinking a winze, miners often gain N., S., E., or W., instead of going down vertically, hence it is always necessary to make a rough estimation of the position of the bottom of a winze before giving a mark to rise from: This can be done by lowering a candle at the end of a tape and noting where the candle swings.

Geological features are a good guide in rising. For instance, a hard seam, a soft dig on one wall, &c., &c.,

Sampling and Estimation of Ore in a Mine.—A series of papers with the above title, by Mr. T. A. Rickard, appeared in the "Engineering and Mining Journal" of date February to May, 1903, where the subject was thoroughly dealt with, and members requiring information on this subject could not do better than read these papers.

III. Plotting the Survey:

(a) By Protractor.
(b) By co-ordinates: (1) The English Method.
(2) The South African Method.

(a) By the Protractor.—For rough and temporary work, this method is quite near enough, but should not be relied on for close work. Monthly additions to plans are made thus, but at the end of every three months points are calculated and permanently fixed.

(b) By Co-Ordinates.—This method, whichever system is used, is the only safe one.

(1) The English System.—In this system all bearings are referred to the true meridian, and latitudes and departures calculated by the following formulæ:—

Lat. = cos. bearing × distance.
Dep. = sin bearing × distance.

This system is described in all standard text-books.

(2) THE SOUTH AFRICAN SYSTEM.—In this method the position of all points in a survey are referred to two straight lines at right angles, just as in the case of the English system of co-ordinates, but one of these straight lines or axis is not necessarily in the direction of the true meridian, but any two lines are taken, of which one is called the x or horizontal axis, and the co-ordinates are expressed in terms of x and y, with the + or − sign attached. Very often a long line in the survey is taken as the x axis, in which case the station at the right hand extremity of the line is always taken as the zero or origin. The angles are referred to the horizontal axis and increase in the direction of the hands of a clock, whence the angle of direction or the bearing of any line is the angle which it makes with the positive, or left hand side of the x axis, thus making the top left hand quadrant the first or positive one in which the sine and cosine are both positive. In the second quadrant, the sine is positive and the cosine negative: in the third the sine and cosine are both negative, and in the fourth the sine is negative and the cosine positive. Calculating the y's and x's by the formulæ—

y = sine bearing × distance.
x = cosine bearing × distance.

it will be seen that:—

the y's in the 1st and 2nd quad are +
the y's in the 3rd and 4th quad. are −
the x's in the 1st and 4th quad. are +
the x's in the 2nd and 3rd quad. are −

To calculate the co-ordinates of the points in a survey, and taking any line in the survey as the x axis (assuming a line at right angles as the y axis), the co-ordinates of the station at the right extremily of this line are oo : oo : while those of the point at the other extremity are y = x oo = length of line joining these two points. The bearing of the next point is the angle between the two lines, taking the sine and cosine of this angle and multiplying by the length of the line (as above), we get the y's and x's of the second point. The bearing of the next point is found by adding the included angle at that point to the last bearing, and if the sum exceeds 180 degrees, subtract 180 degrees from it, and if, after deducting 180 degrees, the remainder exceeds 360 degrees, subtract that amount from it, and if the sum is less than 180 degrees, add 180 degrees to it.

(See "Brough's Treatise on Mine Surveying," Chap. IX.)

Another rule for finding the bearing is given by Leopold Marquard in "Co-ordinate Geometry Applied to Land Surveying," and is as follows:—

When two known angles have the same vertex, their algebraical sum is the required bearing, and when two known angles have different vertices, their algebraical sum either diminished or increased by 180 degrees, as may be most convenient, is the required bearing, always subtracting 360 degrees if the sum of the two angles exceed that amount. The co-ordinates of each successive point thus found are added algebraically to the preceding ones, care being taken that the correct signs are given; these signs depending on the quadrant in which the bearing falls.

In calculating the y's and x's, it is necessary, when a bearing exceeds 90 degrees, that is, when the bearing falls in the second, third, or fourth quadrant, to deduct from it 90 degrees, 180 degrees, or 270 degrees, so that the remainder is an acute angle, remembering that when:—180 degrees are deducted, the sine and cosine of the remainder will be the same in magnitude as the sine and cosine of the given bearing, and that when 90 degrees or 270 degrees have been deducted, the cosine and sine of the remainder will be equal in magnitude to the sine and cosine of the given bearing. In all cases, the correctness of the logarithmic part of these calculations is checked by multiplying each line by the natural sine and cosine of the bearing, using the contracted form of multiplication.

To Find the Length and Direction of a Line Joining any Two Parts in a Survey, given Co-Ordinates.—This is a problem that often presents itself in underground work.

The method adopted is as follows:—

In the figure suppose we want to find the length and direction of the line joining C and G. Subtract algebraically the y and x of C from those of G. The differences will be the y and x distances of G from C. Divide the y distance by the x distance and the quotient is the tan. of the angle which the line makes with the x axis. According as the y distance or the x distance is the greater, divide the greater by the sine or the cosine of this angle; the quotient is the length required. The bearing is determined by the signs of the y and x distances of G from C, remembering that if the signs are:—

+	+	the bearing is in the	1st	quadrant	and angle obtained must be
+	−	,, ,, ,,	2nd	,,	substracted from 180 deg.
−	−	,, ,, ,,	3rd	,,	and 180 deg. added.
−	+	,, ,, ,,	4th	,,	and must be substracted from 360 deg.

(See example).

To calculate the area of a rectilineal figure, given the co-ordinates of its angular points.—There are four rules for this operation, viz.:—

(1) Multiply the sums of the y's of every two adjoining stations by the difference of the x's of the same stations. The sum of the product equals twice the area.

(2) Multiply the sums of the x's of every two adjoining stations by the difference of the y's of the same stations. The sum of the product equals twice the area.

(3) Multiply in succession the y of every station by the difference of the x's of the two adjoining stations on opposite sides of it. The sum of the product equals twice the area.

(4) Multiply in succession the x of every station by the difference of the y's of the two adjoining stations on opposite sides of it. The sum of the product equals twice the area.

EXAMPLE.—To find the length and direction of C G:—

Taking the co-ordinates of—

	y's	x's
G	− 81·14	+ 52·98
C	+ 35·67	+ 13·05

y dist. of G from C = − 116·81
x dist. of G from C = + 39·93
log. 116·81 = 2·0674800
log. 39·93 = 1·6012993

diff. 0·4661807 = L tan 71 deg. 8 m. nearly.

log. 116·81 = 2·0674800
L sin 71 deg. 8m. = 9·9760024

diff. 2·0914776 which is log. of 123·45.

Hence length of C G = 123·45,

and since the y and x distances had the signs (— +), the angle that C G makes with the x axis is in the 4th quadrant, therefore the bearing is—

360 deg. − 71 deg. 8m. = 288 deg. 52m.

EXAMPLE.—Required the area of G F E D C G.

Given the co-ordinate of the points as—

	y's	x's
G =	− 81·14	+ 52·98
F =	− 49·24	− 92·10
E =	+ 108·77	− 35·78
D =	+ 63·37	+ 73·46
C =	+ 35·67	+ 13·06

By Rule 1 (sums of y's) = (differences of x's).

G & F	− 130·38	+ (− 145·08)	18915 feet.
F & E	− 59·53	+ (+ 56·32)	3353 ,,
E & D	+ 172·14	+ (+ 109·24)	18804 ,,
D & C	+ 99·04	+ (+ 60·41)	5983 ,,
C & G	− 45·47	+ (+ 39·93)	1815 ,,
	Algebraical sum	=	33274 ,,
	Area		16637 sq. feet.