INSTRUMENT FOR THE MECHANICAL CONSTRUCTION OF BLOCK DIAGRAMS

BY

Dr. L. U. DE SITTER.

The construction of block diagrams is a very lengthy procedure if use be not made of one of the apparatuses described in Lit. 1 and 3. The non-mechanical construction can be effected in various ways:

1. By constructing a large number of parallel profiles, which are drawn usually in isometric projection where the length in the direction of the profiles, the distance between them, and the vertical scale remain similar. Cf. fig. 1*a* and 1*c* (the vertical scale of fig. 1*c* is increased to twice its size).

2. The shape of the contours themselves may be altered by sketching, thus that it corresponds to an oblique visual axis. Each successive contour is placed higher than the preceding one by moving the paper as described by LOBECK (Lit. 5, p. 140—41). Vide also fig. 1*a* and 1*b*).

3. Finally, as demonstrated by LOBECK (p. 152—53) prominent points of the map may be transferred to their proper place on the isometric block diagram, placed at their correct height, and taking this as a base the topography may be sketched in.

4. STACH (Lit. 4) developed a special method of construction for isometric projections by using an elliptic net. With this net fault constructions and the like can be represented spatially very well and accurately.

All these methods, however, either require a great deal of time or are too sketchy. The problem of carrying out mechanically, by means of an instrument which in a certain sense operates similarly to the pantograph, the construction of the reduction in the direction of the visual axis was solved by DUFOUR in 1917 (Lit. 1). Theoretically the method is the same as that of fig. 1*b*, or by means of distortion of the contours and movement of drawing paper.

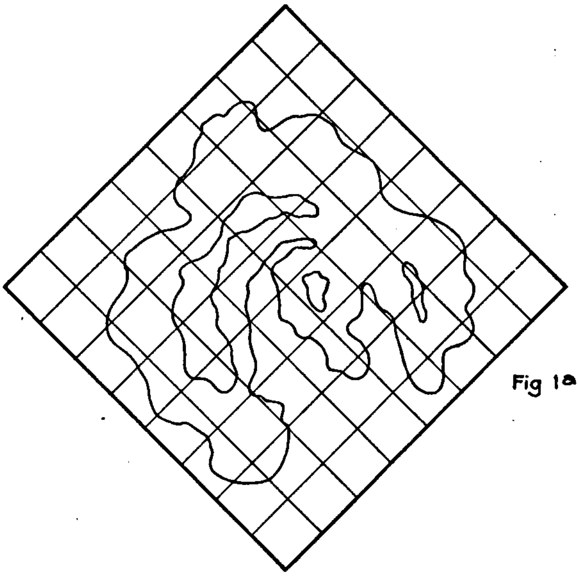

Fig 1ᵃ

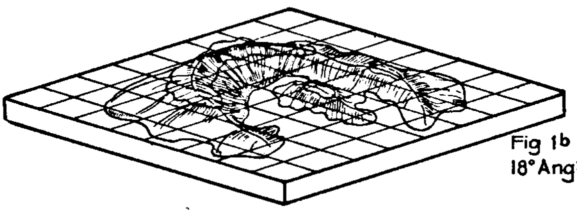

Fig 1ᵇ
18° Angle of vision.

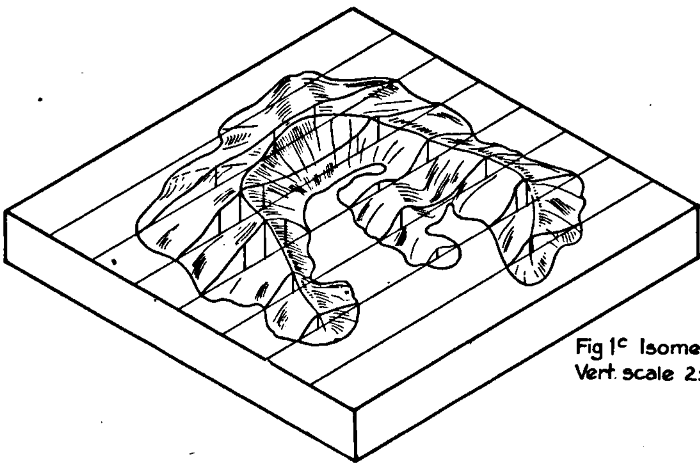

Fig 1ᶜ Isometric
Vert. scale 2x horiz. scale

The first instrument devised by him consists of a long arm, rotatable round a point, which has to be moved along a rail. Pencil (H) and pin (C) are affixed to this arm (fig. 2).

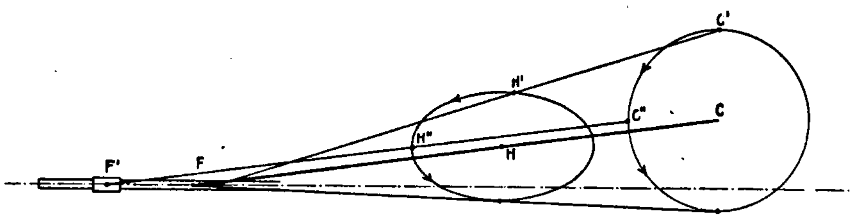

Fig. 2

The disadvantage of this system is that when the pin moves along a straight line, the pencil describes a slightly bent line. This may be partially circumvented by making the arm very long. The disadvantage, however, may be entirely remedied by substituting for the arm a „movable system of Paucellier'' as has also been described by DUFOUR (fig. 3).

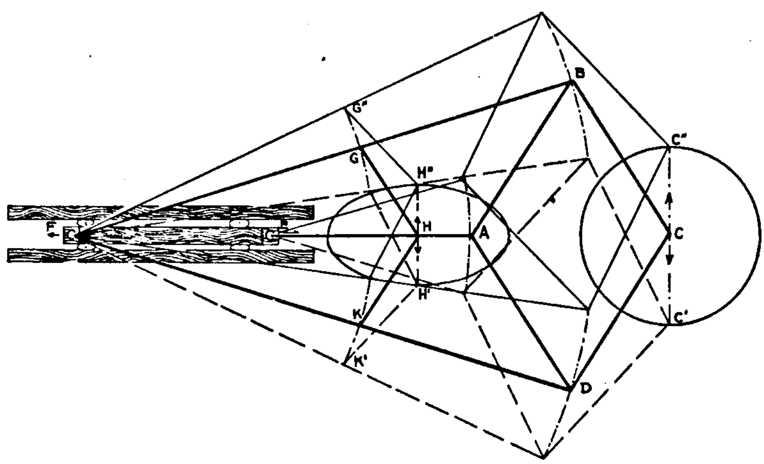

Fig 3

F and E are points, fixed as regards each other, movable in the direction stated. FB = FD, AD = DC = BC = AB. A is rotatable round E, B and D round F. FE = EA, GH // BC and KH // DC. H is a hinge point situated under the rod EA and not connected to it. When in this system A describes a circle round E, C and H then describe straight lines the lengths of which are in the same proportions as FD : FK. Vide Fig. 4.

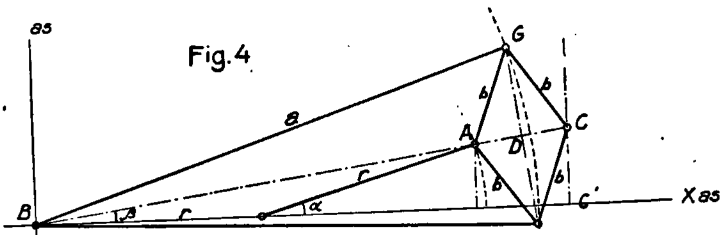

Fig. 4

$$X_C = BC\cos\beta \qquad \cos\beta = \frac{r + r\cos\alpha}{AB}$$

$$\begin{aligned}
X_C &= \frac{BC}{AB}(r + r\cos\alpha) \\
&= \frac{BC \times AB}{AB^2}(r + r\cos\alpha) \\
&= \frac{(BD + DC)(BD - DC)}{AB^2}(r + r\cos\alpha) \\
&= \frac{BD^2 - DC^2}{AB^2}(r + r\cos\alpha) \\
&= \frac{a^2 - GD^2 - DC^2}{AB^2}(r + r\cos\alpha) \\
&= \frac{a^2 - b^2}{(r + r\cos\alpha)^2 + r^2\sin^2\alpha}(r + r\cos\alpha) \\
&= \frac{a^2 - b^2}{2r^2 + 2r^2\cos\alpha}(r + r\cos\alpha) \\
&= \frac{a^2 - b^2}{2r} = \text{constant}
\end{aligned}$$

Or when B is a fixed point, CC′ can only be a straight line perpendicular to the X axis. The constant value for X_H can be proved in a similar way, and it follows immediately from the drawing that

$$CC' : HH' = FD : FK. \quad \text{(Fig. 3)}$$

If F and E are now made movable on a rail, an improved form of the first system is arrived at.

This improved system has not been applied in practice by DUFOUR as far as can be gathered from his publication. VAN KESSEL and VAN DER HOOP have not employed this system either.

VAN KESSEL (Lit. 2) had DUFOUR's first instrument made by an instrument-maker and demonstrated the use of it. It is to be regretted that the contours are not present in his otherwise well-drawn block diagrams, so that an accurate orientation which was possible on DUFOUR's drawings is not so here.

The problem was again studied by TH. à TH. V. D. HOOP. This investigator evolved an instrument of much simpler construction than PAUCELLIER's movable system, whilst it nevertheless offers mathematically accurate reproduction and is more practical in use for the purpose in question.

This instrument, constructed by v. d. Hoop only from „meccano'' parts, was properly built for the Geological Museum in Leyden by the school of instrument-makers of the Kamerlingh-Onnes Laboratory of Leyden (compare photographs Plate I).

Fig. 5 gives a diagrammatical representation of the instrument.

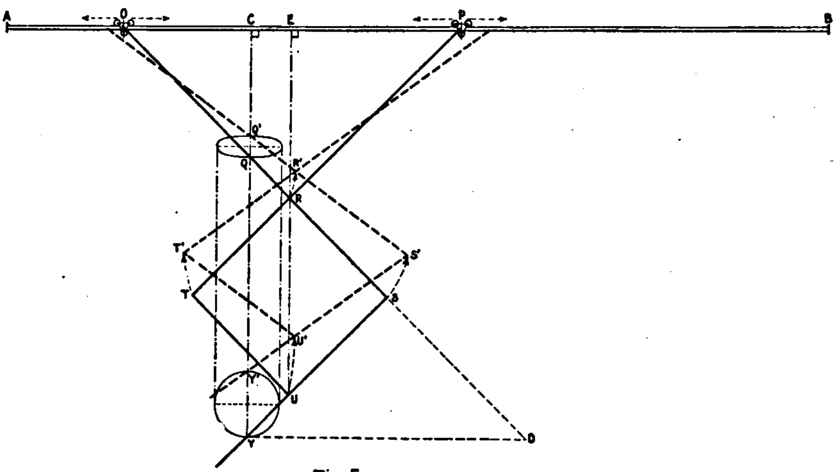

Fig. 5

The hinge points O and P are movable along the rod AB. Points O, P, R, S, T and U are hinge points.

RS = SU = TU = RT, whilst RS // TU and RT // SU. OR = PR, RQ = UY; Q and Y are movable along the arms OS and SUY. Since OR = RP, the triangle OPR is isosceles and thus URE ⊥ AB. Therefore also the line YQC, since RQ = UY and consequently runs parallel to UE. A movement of YY′ ⊥ AB thus produces a movement QQ′ ⊥ AB.

In Y is the pin which follows the contours on the map, and the pencil is affixed in Q. If Y describes a line parallel to AB, Q then describes the same line unshortened; the appliance simply moves in the same position along the rod AB. If Y describes a line ⊥ AB, Q then follows the movement but to a less extent, the points O, P and T and S move away from each other, the appliance is pressed together. Points R, S, T and U describe slightly curved lines. If Y describes a circle, Q then forms an ellipse the long axis of which is equal to the diameter of the circle and the short axis a shortening there of according to the adjustment of the apparatus.

Let SD = SY, then

$CQ : CY = OQ : OD$, and also

$CQ' : CY' = OQ : OD$, thus also the difference is

$$QQ' : YY' = OQ : OD, \qquad (1)$$

which ratio therefore gives the shortening in the direction CY at a certain position of Q and Y in relation to R and U.

In the case of a block diagram, where infinite distance must always be imagined ,the shortening is a function of the visual angle. If we term this last magnitude α, the shortening is then $= \sin. \alpha$; vide fig. 6.

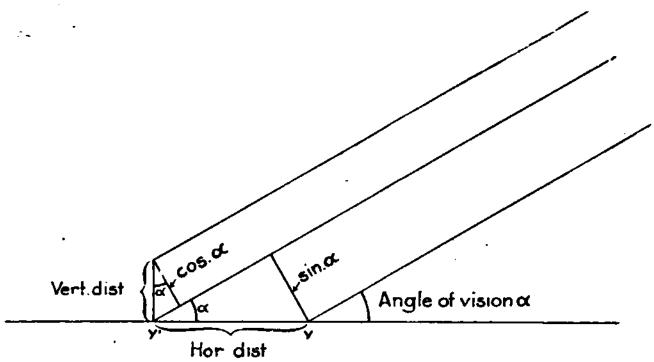

Fig. 6

Thus $$QQ' : YY' = \sin. \alpha .$$

We can therefore alter this ratio by placing Q, and therefore also Y, at different distances from O and from U, i. e. according to the formula (1)

$$OQ : OD = \sin. \alpha \text{ or}$$
$$OQ : (OS + SD) = \sin. \alpha \text{ or}$$
$$OQ : (OS + SQ) = \sin. \alpha \text{ or}$$
$$OQ : (2OS - OQ) = \sin. \alpha$$
$$OQ = \frac{2 . OS . \sin. \alpha}{1 + \sin. \alpha} \qquad (2)$$

OS is a constant of the apparatus, so that the position of Q and Y can readily be calculated for every visual angle by using the formula (2). In our apparatus OS = 67.85 cm and OR = 41.75 cm.

It is also evident from eq. (2) that the position of R on the rod OS is theoretically of no importance. For the firmness of the whole RS must not be too small, however, and to ensure wide freedom of motion of the whole, the sides OR and RP must be generously long.

Point Q in our apparatus at about $\alpha = 26°$ corresponds with R and therefore Y with U. With a larger visual angle Q moves from R to S and Y from U to S. The formula remains the same for this position of the points. Soon, however, points Q and Y come so close together that the drawing paper and map partially overlap one another.

Another position of Y in relation to Q also fulfils the requirements of the problem. Y could also be placed on the rod TU and the extension thereof, and move parallel to Q.

The ratio $CQ : CY = \sin. \alpha$ remains, but on working out the formula

$$OQ = \frac{2 . RS . \sin. \alpha}{1 - \sin. \alpha} \qquad (3)$$

is obtained.

It follows from the eq. (3) and from the dimensions of our apparatus that if α is greater than about 33°, a position of Q in the extension of OS becomes necessary already. If α is smaller than about 26°, the normal position of the points is certainly preferable. Only at an visual angle of 30° a somewhat more advantageous position is obtained with OQ = 52.2 cm and TY (// OS) = 32.05 cm, where the distance between Q and Y is somewhat greater than in the case of the normal position of the points, and drawing paper and map thus come further from one another.

The vertical distance of the contours which can be read on the map only by means of the equidistances, must, for a block diagram, be constructed in the drawing itself. We manage this by placing each contour higher than the previous one, the distance being the equidistance multiplied by the scale of the map. However, allowance must be made for the shortening of the vertical distance = cos. α (vide Fig. 6). In many cases, however, the vertical scale is taken larger than the horizontal in order to obtain a better, though exaggerated, relief, but the increase must then be a whole number of times (n ×) the original scale. The movement of the drawing paper is then

$$n \,.\, \cos.\, \alpha \times \text{scale} \times \text{equidistance}.$$

Below is a table in which the distances

$$SQ = SY = OS - OQ \text{ in mm}$$

are worked out for our apparatus for different visual angles, with the corresponding values for the movement of the drawing sheet, or the vertical scale. The numbers 1, 2, 2.5, etc., at the top of the columns, represent here the above-mentioned product of equidistance and the scale of the map, and in such a way that in the column under 1 those equidistances have been compiled which are once the number of the thousands of the scale, in the column under 2 those which are twice that number, and so on, the number of mm representing the equidistance in the scale of the map. The shortening is then found for different visual angles in the column under that number. On the Netherlands Indies topographic maps, for instance, the equidistance is always ½ of the thousands of the scale, or, in other words, ½ mm gives for each scale the difference in height of the equidistance in that scale. If for drawing a block diagram each fifth contour be selected here, then the amount of the movement must be found in the column under 2.5. On the Swiss maps 1:25,000, equidistances of 10 and 30 m are to be found according to the steepness of the area. For these maps column $\frac{10}{25}$ or 0.4 and column $\frac{30}{25}$ or 1.2 must be consulted.

When erecting the apparatus allowance must be made for the fact that a vertical movement of Y over the map causes a greater movement from P to B than from O to A if Y lies in the extension of SU. The greatest freedom of motion is then necessary between P and B.

α	SQ in mm	1	2	2.5	3	4	5	6	8	12 mm
10°	478	1	2	2.5	2.9	3.9	4.9	5.9	7.9	11.8
15°	399.5	1	1.9	2.4	2.9	3.9	4.8	5.8	7.7	11.6
20	333	0.95	1.9	2.3	2.8	3.8	4.7	5.6	7.5	11.3
25	275	0.9	1.8	2.2	2.7	3.6	4.5	5.4	7.2	10.9
30	226	0.85	1.7	2.1	2.6	3.5	4.3	5.2	6.9	10.4
35	184	0.8	1.6	2.0	2.5	3.3	4.1	4.9	6.5	9.8
is.m.	182	0.8	1.6	2.0	2.5	3.3	4.1	4.9	6.5	9.8
40	147.5	0.75	1.5	1.9	2.3	3.0	3.8	4.6	6.1	9.2
45	116.5	0.7	1.4	1.8	2.1	2.8	3.5	4.2	5.6	8.5
50	90	0.65	1.3	1.6	1.9	2.6	3.2	3.8	5.1	7.7
55	67.5	0.6	1.1	1.4	1.7	2.3	2.9	3.4	4.6	6 9

The isometric projection, where the visual angle coincides with the diagonal of the body of a cube and which is preferred for block diagrams since the same scale applies to the three coordinates of the drawing, is to be found in this apparatus by making the ratio OQ : OD $= 1/\sqrt{3}$. The angle of vision is 35° 15′ 54″.

It is always necessary to introduce a scale division on the drawing, as stated by TH. à TH. v. D. HOOP. This is effected by following with the pin a number of concentric circles, the difference in the radii of which indicates the scale of the map, as a result of which the pencil draws ellipses. Radii of the circles forming equal angles with each other, transferred to the ellipses, show the directions on the drawing (vide fig. 7). This set of ellipses for isometric projection is the same as STACH's protractor (Lit. 4).

Making the pencil and pin interchangeable renders it possible to effect an enlargement of the circle to ellipse, instead of the reduction. The diameter of the circle is then equal to the short axis of the ellipse. Tracing the contours of the map, which now lies on the board previously occupied by the drawing, with the new pin, an enlarged block diagram is obtained. The direction of vision is then no longer at right angles to the axis AB but parallel to this axis. The movement of the drawing must therefore also be parallel to this axis and this can be readily achieved by mounting the drawing on a separate board and moving this along a T-square over the desired distance.

In addition to the fact that the apparatus greatly simplifies the construction of a topographical block diagram, there is the advantage of obtaining a drawing accurate in all respects. By using the elliptic horizontal and the vertical scale, moreover, fresh points can always be plotted at their correct position in the diagram, direction and distance being read off the original map. If it be finally intended to draw a geological block diagram, all outcrops can then be constructed very simply by noting the points of intersection of the geological outcrops with the contours followed by the pin.

The weight of the apparatus itself was found during use to make drawing difficult. The affixing of a counter balance has entirely obviated this objection. The construction of the apparatus and the suspension of a counter balance may be seen on the photographs.

Crater of the Soembing, Java. (D.E.I.)

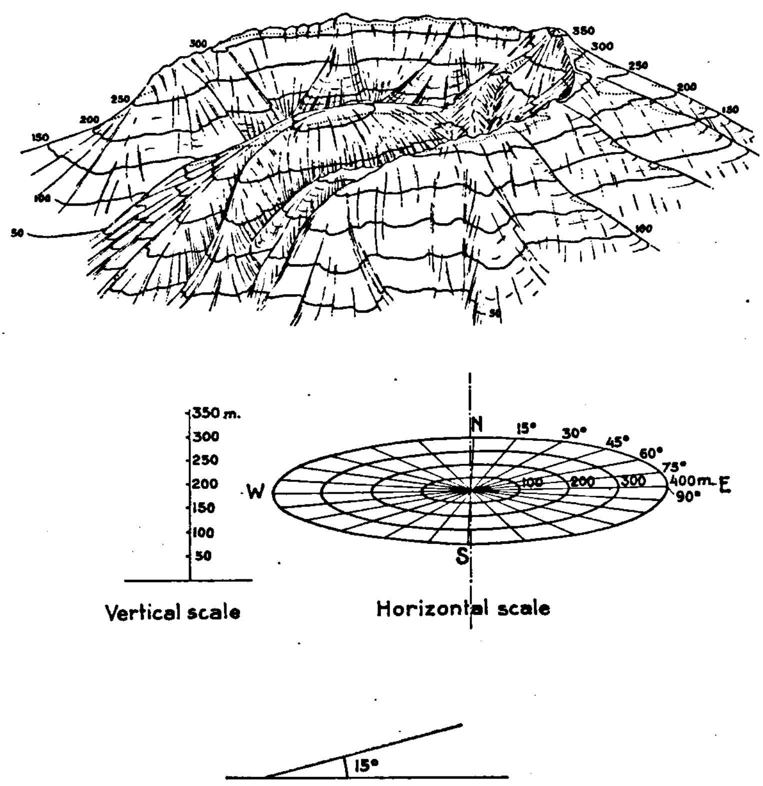

Fig.7

The construction of the apparatus was not simple. Points O and P in particular, which had to be both rotatable and movable, caused much trouble. The solution was finally found with three small wheels running on ball bearings, between which the firm, round rod AB passes.

The pencil is movable along a square rod which runs under OS. The affixing of the pin should have been done in the same way, under the rod SY. With our apparatus this last construction has not been carried out and there are still two pins present.

Leyden, December 1936.

List of Literature:

1. P. TH. DUFOUR: Nouveau procédé permettant d'obtenir les perspectives-reliefs de formes géographiques représentées sur les cartes hypsométriques. Thèse de la faculté des Sciences de Paris 1917.
2. P. J. B. v. KESSEL: Proefnemingen met een instrument ter vervaardiging van Blokdiagrammen. Jaarverslag Top. Dienst N. Ind. 1929.
3. Dr A. N. J. TH. à TH. v. D. HOOP: Een toestel voor het teekenen van blokdiagrammen. T. K. A. G. 1934.
4. E. STACH: Stereographische Darstellung tektonischer Formen im Würfeldiagramm auf Stereomillimeterpapier. Zeitschr. Deutsche Geol. Ges., Bd. 74, 1922.
5. A. K. LOBECK: Blockdiagrams. New York 1924.
6. PH. K. RÜSEWALD: Skizze und Blockdiagramm. Geographische Bausteine, Heft 11, 1925.