Mapping of Faults by Isogams

By **Raoul Vajk**, Budapest — (With 3 fig.)

The author gives a method for mapping faults by isogams in a similar way as they are mapped by level lines. The method is as follows: The isogams are constructed after the gravity effect of the fault is eliminated from the observed gradients. The values of the isogam lines are raised on the upthrown side of the fault with a certain Δg value determined from the gravity curves.

One of the most popular ways for the interpretation of torsion balance surveys is the construction of isogams. The advantage of isogams is that in case of simple geological conditions there is some analogy between the isogam lines and the level lines of the subsurface geological formations. Therefore, the isogams give a graphic picture of the subsurface highs (anticlines and domes); also the subsurface lows (synclines). Because of these graphic properties, in many cases they can easily be understood by those also who are not particularly familiar with the physical meaning of the results of the torsion balance surveys and of the relation between these results and the geological conditions. The analogy between the isogams and the level lines of the subsurface geological formations is diminished, even in the case of simple geological conditions, when we have to deal with faults. In other words, the weakness of the analogy between the isogam lines and the level lines of the subsurface geological formations is more outstanding in the case of faults than in case of other geological formations with continuous surfaces.

A claim was raised by business men and geologists, using the results of torsion balance surveys, to construct the isogam maps in such a manner that the fault lines should be shown, similarly to the mapping by level lines, by the interruption of the isogam lines.

This claim at first sight seems to be unfulfillable because of the continuity of the gravity potential; still, by referring the isogams above each wing of the fault to base points with different potentials, it is not impossible. The method will be explained below by an example.

The gradients shown on Map 1 represent the subterranean anomalies obtained by a torsion balance survey. This map shows the isogams constructed in the usual way. Supposing one contact surface between two strata with different densities and with the denser stratum below, we can draw the following conclusions in regard to the geological conditions based on the gravity map:

(1) The subsurface stratum with greater density rises to the north.

(2) In the vicinity of the place marked "*E*", the lower stratum has a dome shaped elevation.

(3) Along the line *B*—*E*—*H*—*K*—*N* is located a fault, the upthrown side of which is to the north-northwest and the downthrown side to the south-southeast.

In the vicinity of the point "E", the isogams have no closure, partly because of the gravity effect of the fault and partly because of the rising of the denser stratum to the north. The isogams form only a nose pointing to the south, indicating the subsurface high. The fault is indicated by the thickening of the isogam lines along the line B—E—H—K—N. Let us first separate the gravity effect of the fault from the other gravity effects. For this purpose we construct gradient and Δg curves along the lines A—B—C, D—E—F, G—H—I, J—K—L, M—N—O. Using these lines as abscissa axes, we mark on them the locations of the stations and measure as ordinates the projections of the gradients to these lines on the proper places. The connection of the points obtained will form the gradient curves. (See Figure 2). We obtain the Δg curves, which are the integral curves of the gradient curves, by mechanical quadrature. The examination of

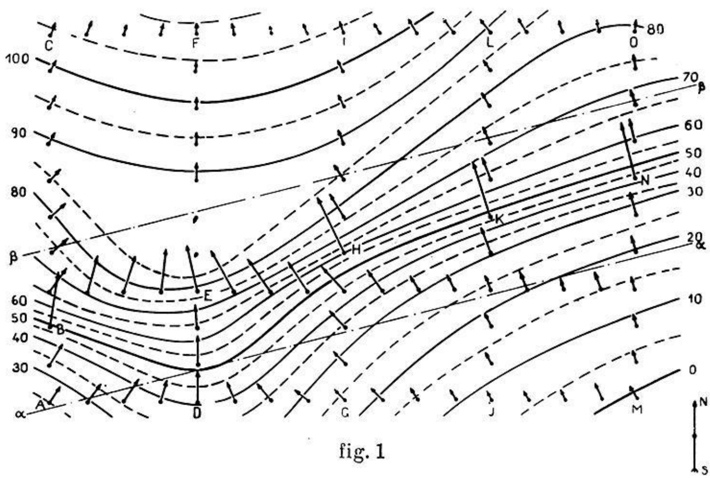

fig. 1

these curves shows that, along the lines A—B—C, G—H—I, J—K—L, and M—N—O, there is only the indication of a fault besides a gravity effect which can be regarded as regional for the area under examination. The gravity effect of the fault can be easily separated from the regional effect[1]). On the curves constructed along the line D—E—F is clearly shown the indication of the fault, but it is combined with some other gravity effects. Considering that the indication of the fault along the line A—B—C is similar to the indication along the lines lying to the east, we may suppose that the fault has no change at the line D—E—F.

After separating the gravity effect of the fault from the regional effect by the aid of these curves, we subtract the gradient components, due to the fault, at each station from the observed gradients. In doing this we must pay attention that the direction of the lines A—B—C, etc., are not normal to the direction of the fault and therefore only the projection of the gradient components, due to the fault, are noticeable in the gravity curves. The corrected gradients are shown on Figure 3.

By this operation we succeeded to eliminate the anomalies due to the fault from the subterranean anomalies and therefore we obtained approximately the gravity indication of the geological formations not disturbed by the fault. The approximation is the better the smaller the heighth of the relief of the subsurface geological formation and the throw of the fault compared to the depth measured from the surface. After deducting the gravity effect of the fault, we can imagine that we brought the one wing of the geological formation, displaced by the fault, on the same level with the other wing and the new gravity map is the gravity map of the geological formation united again and obtained by a torsion balance survey. It is clear that the smaller the throw of the fault, the less is the change in the gravity effect caused by this displacement.

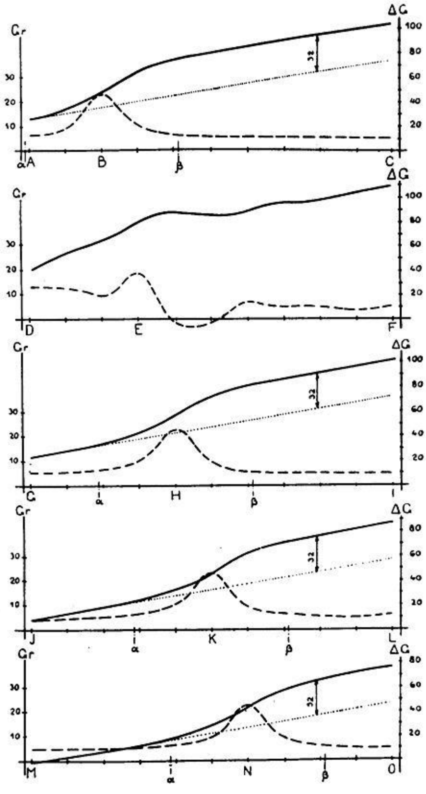

fig. 2

After subtracting the gravity effect of the fault from each and every gradient, we construct new isogams on the new gradients shown on Figure 3. These isogams with the approximation discussed above, can be regarded as the isogams of the geological formation from which the fault is eliminated. Now we have to distinguish the fault by the interruption of the isogam lines.

Mark the throw of the fault "h", the difference of densities of the two strata $\sigma_2 - \sigma_1 = \Delta\sigma$. Furthermore, let the isogam value of the starting point of isogams be 0 if we eliminate the fault and imagine the whole geological formation placed in the horizont of the downthrown wing. If we then raise the whole geological formation to the horizont of the upthrown side of the fault, the value of the starting point of the isogams and conclusively the Δg value of all the points of the area under examination will increase. This increasing is equal to the gravity effect of a stratum with the density of $\Delta\sigma$ and with the thickness "h" extended horizontally to the infinite. This effect is[2])

$$\Delta g_h = 2\pi f h \Delta\sigma,$$

where "f" is the constant of gravitation. On the right side of this formula "h" and $\Delta\sigma$ are unknown. If, regarding the area under examination, some geological information is at hand we can determine for "h" and $\Delta\sigma$ probable values by calculation However, the geological conditions of the area under examination are usually so little known that there are not data enough for the calculations. Therefore, it is more practical and for practical purposes it is satisfactory to take the Δg value from the Δg curves shown on Figure 2. There is marked by dotted lines at every Δg curve, except the curve along the line $D—E—F$, the course of the Δg curve in case the gravity effect of the fault is deducted. As the gravity indication of the fault is the same in each curve, the difference between the Δg curves drawn in dotted line and in continuous line is the same along each line and is constant north of the fault with the exception of the transitional zone between lines $\alpha - \alpha$ and $\beta - \beta$. This difference is $32 \, . \, 10^{-4}$ c. g. s. units. In other words, the Δg values of the points north of the fault on isogam Map No. 1 are

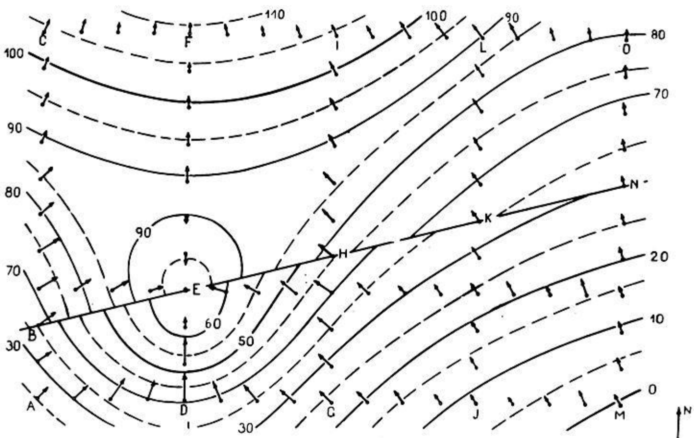

fig. 3

$32 \, . \, 10^{-4}$ c. g. s. units greater than the values we obtain if we eliminate the fault by sinking the upthrown wing to the level of the downthrown wing. The increasing of the Δg values caused by the fault occurs — because of the continuity of the potential function — continuously on a strip $\overline{\alpha\beta}$ along the line $B—E—H—K—N$ and not abruptly*). This continuous increasing of the Δg values causes the essential difference between the form of the isogams and the level lines.

Let us connect with a continuous line the points $B—E—H—K—N$. We retain the isogams drawn on the gradients shown on Figure 3 in their original form south of this line, while we increase the Δg values with $32 \, . \, 10^{-4}$ c. g. s. units obtained from the Δg curves, as was mentioned above, north of this line.

*) Theoretically this strip is infinitely wide but, because the gravity effect of the fault can be neglected beyond a relatively small distance, the width of this transitional zone can be taken practically corresponding to this distance.

We draw the isogams on these increased Δg values. The isogams drawn on the area north and south of the fault line show interruption, similar to the level lines, along the fault line. Our aim is now accomplished.

The gravity indication of the geological formations is clearer on the new isogam map than it was on the previous map. The gravity maximum at "E" on Map 1 is indicated only by a nose of isogams. At this point on Map 3 two isogams close to the north. Therefore the latter isogam map gives a more graphic and easier understandable picture of the geological formations.

The method given above is briefly as follows:

(1) Construct gradient and Δg curves along lines normal, or nearly normal to the strike of the fault.

(2) Determine the location of the fault from the gradient and Δg curves and eliminate the gravity effect of the fault from the gravity effect of other geological formations.

(3) Draw the strike of the fault on the gravity map and subtract vectorially from the gradient of each station the gradient component caused by the fault.

(4) Using these gradients calculate Δg values for each station and draw isogams on these new Δg values in the area above the downthrown wing of the fault.

(5) Determine from the Δg curves the increase of the Δg values: Δg_h, which occurs by crossing the fault from the downthrown side to the upthrown side and which is due to the fault.

(6) Add this Δg_h value determined in the previous paragraph to the Δg values of the stations on the upthrown side of the fault and draw isogams on these increased Δg values in the area above the upthrown side of the fault, which will complete the isogam map.

I wish to make a few remarks in regard to the above method. We must not forget that the isogams constructed this way are not real but imaginary. Still, the Δg values taken from the second isogam map correspond to the real isogam values, except in the transitional zone mentioned above. The difference between the original and the imaginary isogams is that, while on the original map the increase of the Δg values due to the fault occurs continuously within the transitional zone, on the latter isogam map it takes place suddenly by crossing the fault line.

The isogams divided into two parts by the fault are the different parts of the isogams of the same geological formations. One set of the isogams differs only by a constant from the complementary part of the other set of isogams. In other words, the value of the isogams rises abruptly by crossing the fault line. If the Δg_h difference caused by the fault, determined from the Δg curves, is a multiple of a whole number of the isogam interval, so the isogam lines will continuously cross the fault line, only their values will change analogically to the level lines in case of a vertical elevation, the heighth of which is a multiple of a whole number of the level line interval.

The example shown in the discussion is a possibly simple one: the discussed fault is rectilinear, and its throw is constant in the entire area. If the strike of the fault is not a straight line, but curved, it does not make any essential difference unless the curving is extreme.

The method is more complicated if the throw of the fault changes within the limits of the area under examination. In this case the Δg curves give a different Δg_h value along each line normal to the fault line. Supposing that the Δg_h value is lineally changing between the traverse lines, we can calculate the change of the isogam lines by crossing the fault line to each point of the fault line. It is possible in some cases that the supposition of the linear changes of the Δg_h values causes an error which will lead to contradiction in the drawing of the isogams. In such cases it is necessary to readjust the calculated Δg values by taking into consideration the Δg_h values determined from the Δg curves.

I wish to express my thanks to Professor Eugene Fekete who called my attention to this problem and who helped me in my work by his advice.

Literatur

1) See author's "The Problem of the Regional Gradient" in the Bányászati és Kohászati Lapok (Mining and Metallurgical Magazine), Nos. 11 and 12, Budapest, 1932.
2) See B. R. Eötvös: Bestimmung der Gradienten der Schwerkraft und ihre Niveauflächen mit Hilfe der Drehwage, 1907.

Beitrag zum Thema: Seismische Bodenunruhe

Von **H. Landsberg**, Frankfurt a. M. — (Mit 5 Abbildungen)

Als meßbare Größen der seismischen Bodenunruhe treten die Perioden und Amplituden der Unruhewellen in den Diagrammen auf. Beide Größen sind das Endergebnis vielfacher Einwirkung bei Entstehung und Ausbreitung elastischer Wellen. Eine Reihe neuerer Arbeiten streift diese Fragen gelegentlich, die es verdienen, einmal im Zusammenhang erwähnt zu werden, damit beim Aufsuchen von Beziehungen zwischen den erwähnten meßbaren Größen und den Ursachen der Unruhe keine allzu engen rechnerischen Korrelationen erwartet werden. B. Gutenberg hat gezeigt, wie stark ursprünglich verschiedene Perioden von Bodenunruhe sich einander annähern durch den Einfluß der inneren Reibung fester Körper[1]), was aus den theoretischen Betrachtungen von Sezawa[2]) sowie von Gutenberg und Schlechtweg[3]) gefolgert werden konnte. Weitere Betrachtungen von Sezawa und Nishimura[4]) erwiesen, daß die resultierenden Amplituden des Bodens bei langperiodischer Anregung geringer sind als bei gleich-