VERTICAL CRUSTAL MOVEMENTS AND GEO-SCIENCES

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The most efficient means of measuring and timing the actual vertical crustal movements is repeated geodesic measurement, more exactly, repeated precise levelling. Its efficiency is due to the fact that the crustal movement entrains the displacement of the superposed bench marks, hence alteration of height differences between bench marks — accessible to direct measurements by precise levelling in defined intervals (e. g. each 25 years) — is likely to reflect the timely sequence (rate, acceleration) of vertical crustal movements in the tested area, with certain assumptions.

Nevertheless, major difficulties are due to the identical order of magnitude of measurement errors likely to accumulate in levelling a country-wide net, and of 25-year movements — especially in areas characterized by slow (0 to 2 mm/year) crustal movements, and to the coincidence of the crustal movement effect with other effects attributable to the deficiencies of the special levelling net as measurement tool. Besides, only the top boundary surface of the earth crust, i. e. the Earth surface is accessible to geodesic measurements; therefore only the surface shaping effect of crustal movements can be perceived. (All these difficulties and restrictions of geodesic testing methods have been discussed in [1].)

In view of the above we feel the capacity limit of geodesic movement testing possible by precise levelling has been reached for the given technical standard beyond that nothing but certain refinements are possible even at the cost of important work excess; purely geodesic methods are insufficient to get a still better insight into the mechanism of vertical crustal movements (processes in deeper crustal layers, movement causes and consequences).

Consequently, far-reaching use of research results of other geo-sciences (especially those of geology and geophysics) and comparison with those of geodesy is a must, partly to advance, and partly to check and confirm surface movements determined by geodesic methods.

Even the Hungarian special literature offers a number of examples of such comparisons: studies by Bendefy, L. on the comparison between geodesic, geologic and geophysic data [2, 3], those by Stegena, L. on the analysis of the correlation between the geodesic map of velocities and geothermic data [4] etc. There is an infinity of possibilities to compare interdisciplinar results.

In what follows, comparison between the velocity map constructed by Joó, I.—Lukács, T.—Németh, F. from geodesic measurements [5], and the map of velocities of geological-geomorphological origin by Rónai, A. [6] will be analyzed.

The map by Joó, I.—Lukács, T.—Németh, F. contains the iso-lines of relative velocity values of vertical crustal movements in Hungary (with Mount Gellért as reference point), based on 1921 to 1944, and 1948 to 1964 national levelling results, for a period of about 25 years (Fig. 1).

Rónai has examined the Quaternary vertical crustal movements during the last one and a half million years, based on the thickness of Quaternary sediments of Hungarian plains, and on the contemporary height of mountain river terraces. These data were applied to construct the map of Quaternary vertical crustal movements. His method will not be described here, neither his map presented, simply referred to [6].

The map presents *the secular level changes of the Quaternary basin floor* at a certain accuracy, these accumulated, however, from accelerating and slowing, rather than uniform, subsidences and uplifts; assuming, however, that the movement trends prevalent since one and a half million years did not

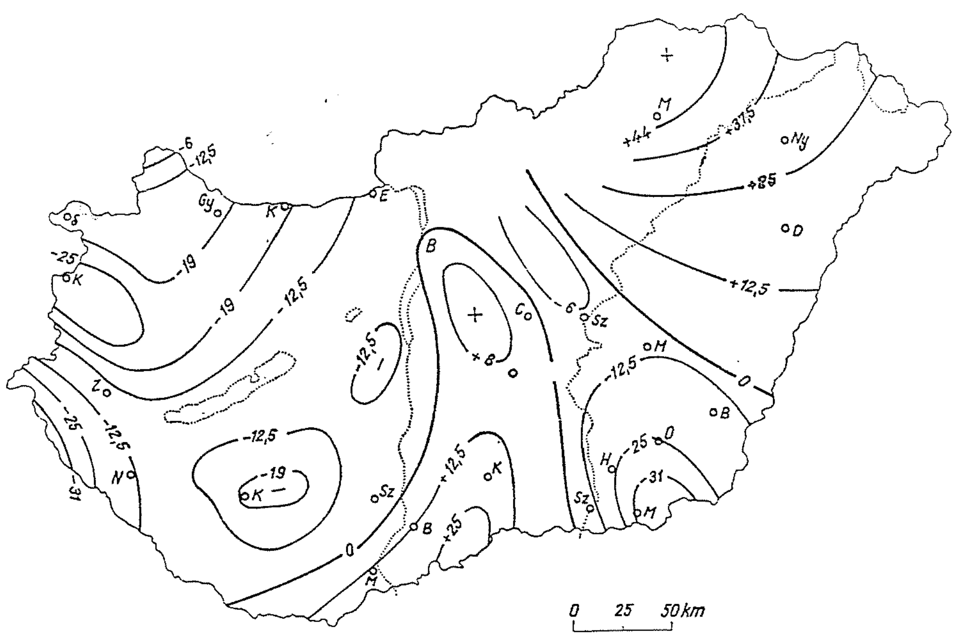

Fig. 1. Map of vertical movements according to I. Joó—T. Lukács—F. Németh (1969). Movement rate in mm/25 years get inverted in our days, and that the *average* rate of quaternary movements may be considered as about characteristic for the present, then Rónai's map can be applied to simply plot the sketchy, approximate map of *contemporary secular crustal movements*.

The map in Fig. 2 has been constructed by reducing the movement values referred to one and a half million years to 25 years, acceptable as time interval of actual geodesic crustal movement levellings. (Accordingly, 10 mm, and 5 mm level changes in an interval of 25 years correspond to 600 m, and 300 m of Quaternary level changes, respectively.) For a better understanding, and in view of the approximate reliability of data, only 10 mm, 5 mm and 3 mm isolines have been plotted on the map in Fig. 2.

To check the order of magnitude of the deduced velocity values, the map by L. Kőrössy, on the depth relations of the Hungarian Pliocene basin [7] has been applied. Since the actual depth of the basin can approximately be identified with subsidences occurred from the early Pliocene to now, the map shows the secular subsidences during the last ten or eleven million years.

This has been applied — using the quoted assumptions — to construct again the map of secular level variations during 25 years (Fig. 3).

The close agreement between Figs 2 and 3 partly argues for the correctness of the deduced order of magnitude of actual secular crustal movements, and partly shows that the mean velocity of secular crustal movements can be assumed to be about constant during the last 1,5 million, and 10 to 11 million

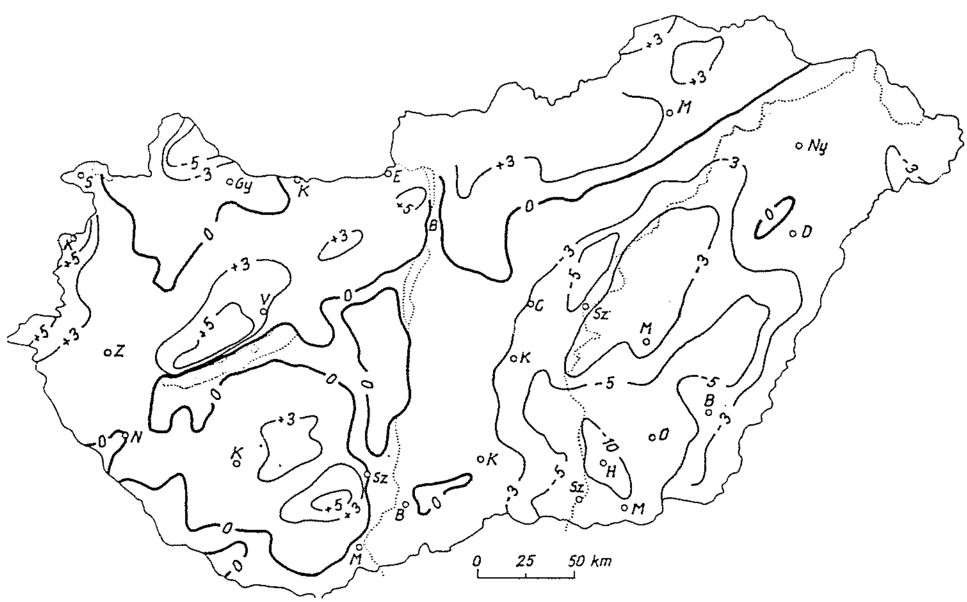

Fig. 2. Actual secular crustal movements of the solid base rock (basin floor) according to the map of A. Rónai. Movement rate in mm/25 years. Towns are indicated by initials

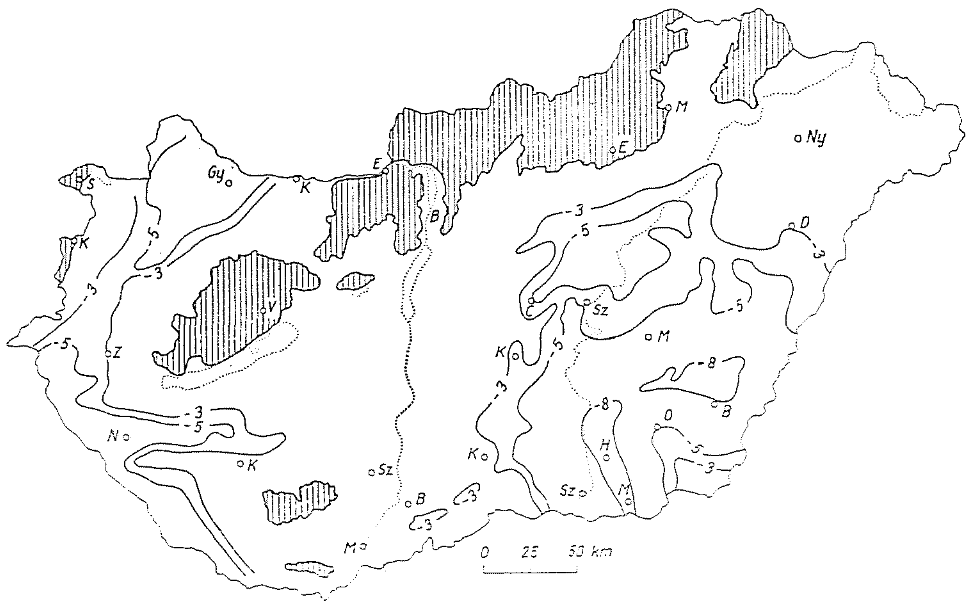

Fig. 3. Actual secular crustal movements of the solid base rock (basin floor) according to the map of L. KŐRÖSSY. Movement rate in mm/25 years. In outlined, shaded areas the solid rock is on the surface

years in the Hungarian area. This fact, however, probabilizes the assumption that the mean velocity of Quaternary secular crustal movements can be considered as about characteristic for now.

Based on the above, Fig. 2 is felt to be *the map of the velocity of the actual secular movements of the solid basic rock for a 25-year period in Hungary.* This remains, however, true for several subsequent 25-year intervals -- because of the rather constant velocity of secular movements.

Now, Fig. 2 constructed from geological-morphological data has been compared to the movement map of geodesic origin shown in Fig. 1. The contradiction is obvious.

This may be due either to the inaccuracy of one map (or both) to a degree as to become useless, or to the fact that the maps show *a priori* different phenomena, hence they cannot be directly compared.

What are the likely causes of contradiction?

1. Relative inaccuracy of levelling data applied for geodesic examination.
2. A much lower line density of levelling net supplying movement control data than needed.
3. Incertainty of geological-geomorphological test results in connection with the establishment of Quaternary movement rates (layer thicknesses or terrace heights).

4. Incertainty in the determination of the time factor belonging to the Quaternary level variations.
5. Eventually, an actual, significant change of the movement tendencies of the geological recent past.

Likely effects of the listed causes have been examined in detail in a different connection [8]. These examinations (not to be detailed here) led us to the assumption that — although their effect is by no means negligible — other causes are responsible for the mentioned contradictions such as:

6. The map in Fig. 1 on the results of geodesic movement tests represents other than, or better, also other than secular crustal movements.

Since — as it has been stated — our geodesic measurements are bound to the earth surface, secular crustal movements cannot be directly measured but on bench marks built in solid rocks on the surface. In Hungary, there is little possibility for it, and even the existing possibilities have little been made use of in constructing the former levelling nets. In sediment-coated areas (hence, in most of the territory), measurement results combine secular (regional) and relatively short-time (local) crustal movements. What is more, secular crustal movements in these areas have two appearances: movement of the solid base rock (basin floor), and compaction subsidence of the sediment layer. Also local (short-time) crustal movements may appear in different forms. For instance, these include technogen crustal movements (meaning no new kind of movement but only a new category and denomination).

The two types of movement maps (Figs 1 and 2) are seen not to be uniform, making their direct comparison meaningless. First, the movement values as resultants of different movement forms demonstrated by levelling results had to be decomposed into components and their relative shares. Now, a special map of secular crustal movements of the solid base rock could be constructed, to be compared to Fig. 2 deduced from Rónai's map.

Actually, however, the problem of decomposing movement values to components is not yet solved although it is not an unsolvable problem. This is confirmed by the following consideration. Movement values (resultant from different movements at the same spot) could be decomposed in the following steps:

a) Outlining the areas exposed to local (e. g. technogen) movements and determining their rate at the given spot. Such examinations are going on actually: for instance, the program of the international geo-science organization of socialist countries (KAPG) involves the examination of technogen movements as a separate scope. This would partly permit to specially construct the map of local movements, and partly, to exempt the resultant movement values from their effect.

b) Determining the rate of compaction subsidences at the given areas by the method of L. STEGENA [9]. Rather than to describe this method, it is simply stated to lend itself to assess the sediment compaction rate from the density frequency distribution on depth and the sediment deposit time. This would result in the possibility of specially constructing the map of compaction subsidences, and exempting the resultant movement value from its effect, not to reflect other than the combined effect of the secular movement of the base rock, and the measurement errors.

c) Finally, measurement errors ought to be detached, for instance by D. CSATKAI's method [10]. Neither this method will be presented but simply noted that starting from the assumption of constant secular movement rate — if three measurement results are available — CSATKAI attempts to screen out measurement errors from contradictions between movement diagrams constructed from the first and second, as well as from the second and third measurement. This last step would result in the possibility to construct the velocity map of the secular movements of the base rock (basin floor).

Although the outlined train of thought is in need of improvement in several of its particulars, it offers a possibility of scientific analysis of movement rates determined by geodesic means, likely to offer a better insight into the actual vertical crustal movements, their causes and consequences.

7. Referring to the contradictions of the presented movement maps, these may decisively result from the change of the height of the reference surface in the interval between two levellings. This is not understood as the eventual movement of some national reference point itself, it being irrelevant for the relative movement pattern and causing only a certain reference level difference. Movement test results may be affected in a much more complex manner by the fact that because of the secular variation of the gravity field in the interval between two levellings, the reference level surface passing through the origin may not only be displaced vertically but may become skew or undergo irregular deformation [11]. According to P. BIRÓ, this phenomenon may have an effect of the same order as the vertical crustal movements expected in the same interval. This circumstance could explain for much of the observed contradictions. A method likely to numerically reckon with the effect of the phenomenon is recently under development [12].

Finally, it may be stated that in view of the last quoted two facts, at the actual level of our research methods, Figs 1 and 2 *need not coincide*, with other words, decisive facts would be ignored by expecting the given research results to coincide. At the same time this observation hints to caution towards similar comparisons.

Obviously, however, test methods are to be improved, developed, until results deduced in different ways for the same phenomenon are reassuringly coincident. In this case, there is a special need to elaborate the method of decomposing the movement values deduced by geodesic means to their components, as well as to observe the effect of the secular variation of the gravity field on the movement rate deduced from precise levellings. Of course, to solve these problems requires the common effort of several geo-sciences.

Summary

Importance of the co-operation between different geo-sciences in examining the actual vertical crustal movements is pointed out. Movement maps constructed from geodesic measurements (precise levellings) and from geological-geomorphological data are compared. Possible causes of the contradictions are analyzed and the effect of primordial causes demonstrated. Research scopes likely of help for continuing the examination of the actual vertical crustal movements are indicated.

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* In Hungarian.

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