GEOLOGICAL-TECHNICAL CATASTERING OF AREAS WITH SURFACE MOVEMENT

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Received 28 May 1987

Abstract

On the humpy and hilly lands especially as a result of surface transformating constructional activities in the recent decades numerous surface movements took part, that in some cases caused gravy damages.

That is why from the seventies the detailed engineering geological-environmental geological regional investigation series had to be made. Our present study summarises the partial results of these investigations.

Research-historical outline

The surface movement belongs to the destructive phenomena of the nature. So, it is easy to understand that the experts realised soon this fact, because, in many cases quite in a small extent — even in a few square meters it should cause gravy damages — or in some cases it should ruin the technical structures.

The observation, and examination of the movements were done according to the following phases.

1. *Single movement descriptions* (the second half* of the 19th century)

A few, but in some cases very valuable observations were done by the professors of the Dept. of Mineral and Geological Studies of the BTU: J. Krenner 1877, F. Schafarzik 1882, L. Lóczy 1886.

2. *Detailed geological observations, descriptions* (1910—1936)

In the Buda part of the capital especially nearby to the clay mines of the brick factories movements have been observed in many cases. That was prof. F. Schafarzik, who first examined in details the cause of the movements, and gave proposal to eliminate them. His work was carried on by L. Lóczy and A. Vendl.

3. *Geological and soil mechanical tests* (1936—1960)

At the region of the high banks of the Balaton in the period of the heavy rainfalls of the thirties within Hungarian conditions unusually great extent movements succeed each other.

* In the international bibliography the first detailed description of surface movements were done by Collin A. 1846.

The scientific field of soil mechanics that has been developed in the twenties progressed significantly later in the thirties* so in the testing activities the engineers played more and more significant rule; J. Jáky 1936, L. Raáb 1936, Á. Kézdi 1952, 1956, 1959, L. Galli 1952, J. Domján 1953, F. Pappfalvy 1953. The geological testing procedures had a secondary importance in this time: A. Vendl 1941, F. Papp, 1952, Gy. Vigh 1959.

4. *Cooperation of the soil mechanics and engineering geology* (1960—1972)

It is an early realization, that the examination of fields subjected to surface movements requires the cooperation of well experienced geologists and civil engineers, but in our country this cooperated analysis begun only in the sixties. Most probably that was due to the balking of the previously rapidly progressing soil mechanics. Greater and greater needs arised to study the composition of the rocks from the same aspects, and, in the geology the introduction of the thermic tests on the clay mineral happened in the same period.

Detailed slope stability tests were carried out in this time on the great break of banks at Dunaújváros: Á. Kézdi 1964, 1969, 1970, J. Járay 1964, E. R. Schmidt 1966, S. Karácsonyi 1969, Gy. Scheuer 1969; the high banks of Balaton Á. Kézdi 1964, 1969, G. Bidló 1964, B. Kleb 1964, the Buda T. Paál 1962, 1968, Á. Kézdi 1970, Gy. Scheuer, 1970, I. Szilvágyi 1968, 1970, and the great extent open-cut at Visonta: Á. Kézdi 1966.

5. *The geological-technical cadastral procedure of areas subjected to surface movement* (1972—1980)

The inspection of areas that are suspective to surface movement to forecast natural disaster, and primarily determination of the extent of the endangered area are subjects of important studies in the recent years. The regional surveying, geological and technical testing and the cadastral according to country territories in Hungary has began in an organized way in 1972 by the supervision of the Central Geological Authority. Summarizing the surveying experiences the supreme authority finalized the methodological guide line and the county summations were made according to this.

Regional examination

The territory of the country geomorphologically is *hollow type*, 68.8% flat lowland, but the undulation of the other part is, also moderate, the difference between the lowest and highest point is only 936 m.

* The establishment of soil mechanics as we understand it nowadays is connected to K. Terzaghi 1925. In Hungary the first soil mechanics laboratory founded by J. Jáky 1928. at the Technical University. The worldwide advanced examination of slope stability commenced in the thirties; K. Terzaghi 1931, 1936, 1941, D. W. Taylor 1936, 1937, 1948.

According to the hollow characteristics, the geological structure is also unic. In the formations near to the surface the ratio of the young sediment is significant: 43.8% Holocene-Pleistocene river (partly moor originated) 42% aeolian deposit.

It is due to the topographic conditions and the geological structure that the possibility of the surface movements is the greatest in the variably undulating hilly areas that give 31.2% (29 025 km^2) territory of the country. It is resulting from the above circumstances, that the types of movements are related to the sedimental rocks and their extent is less than in those countries where the topography is more variable (Fig. 1).

By the appointment of the supreme authority we accomplished a 15 734 km^2 area regional surveying (Table I, Fig. 2). The tests were made in 1978—80, these were repeated many cases or were accomplished with detailed verifications of reference areas.

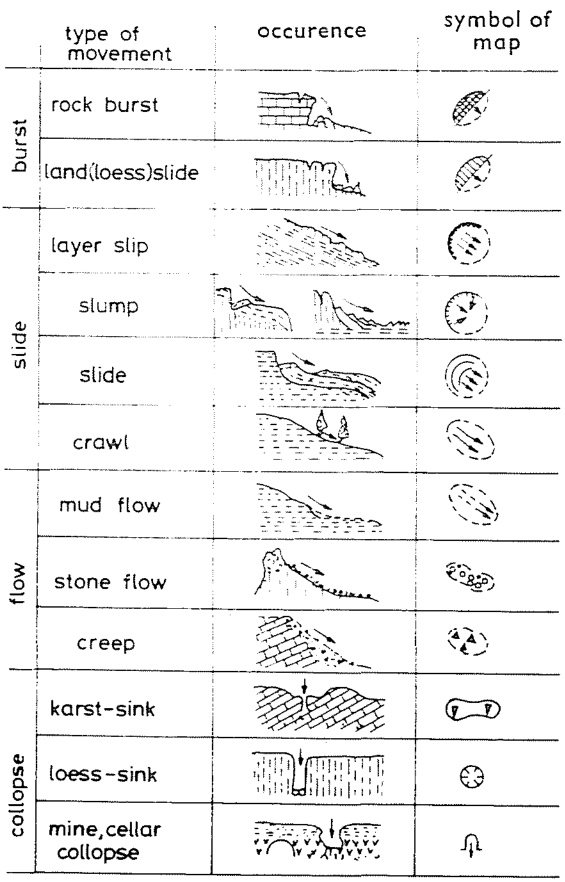

Fig. 1. The main types of surface movements at Hungary

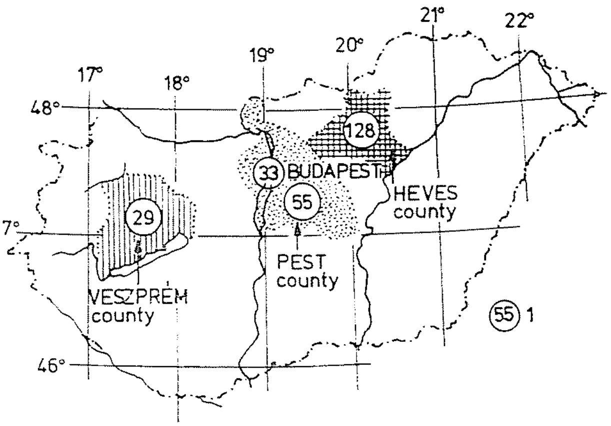

Fig. 2. The area of our regional surface movement investigation
1-registered movement pcs

Table I

The geographical characteristics of the examined area

Administrative unit	Extent of the area, km²	Highest point m. asl.	Average rainfall for 50 years mm/year	Registered movement pcs
1. Budapest	525	529	617	33
2. Pest county	6 386	865	833	55
3. Veszprém county	5 185	704	843	29
4. Heves county	3 638	1 015	784	128
Sum:	15 734			245

* The most rainy place within the examined area

The examination of different movement areas

It is well known, that the factors that result the surface movement are of many different types. Due to the interaction of the physical-chemical-biological processes, the varying geological development, the structural and morphological basis, it is very difficult to give general principles. Simplifying the question the soil mechanical experts originating the surface movement from two causes:

— the decreasement of shear-strength, and/or
— the increasement of shear-stress.

Accepting the above facts the engineering-geological research found that the following factors resulting the break down of the equilibrium;

— increasement of water content, the rise of ground water level

— distinctive morphological and structural condition
— the mineral composition and state of rocks
— the human (antropogene) interference.

The water content, the effect of the groundwater

As most of the surface movement in Hungary develop in the ambient of incoherent sedimental rock the water has a significant rule.

The relation of the distribution of the precipitation and the frequency of the surface movement should be considered as evident, and statistically can be proved, even, in the past the description of the movements were not complete (Fig. 3).

The consistency of the clay sediment will change, the shear strength of it will decrease if it is thoroughly drenched by water due to precipitation. From the numerous — more then two hundred — tests we experienced, that

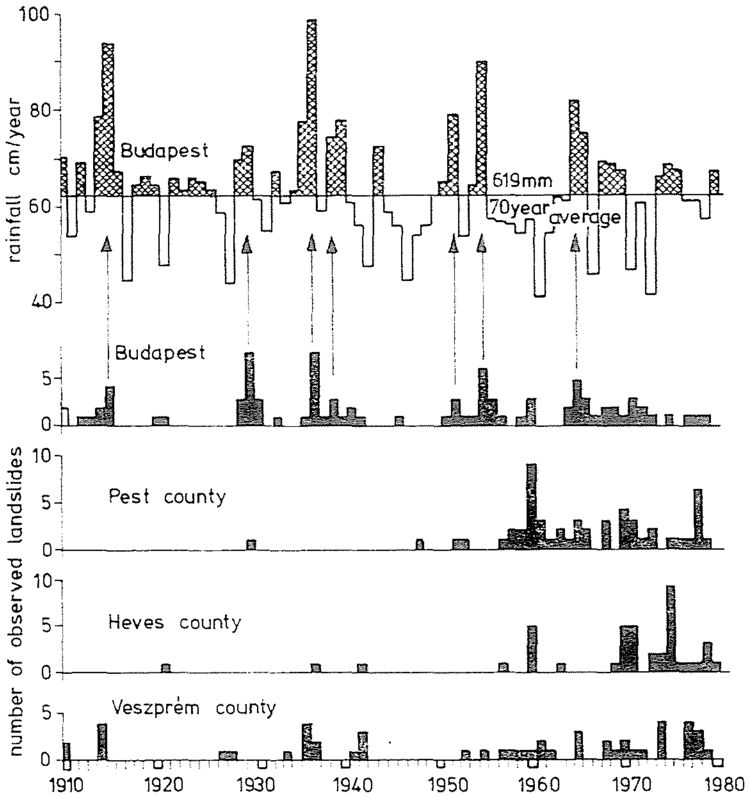

Fig. 3. The relation of the surface movement frequency and the rainfall distribution

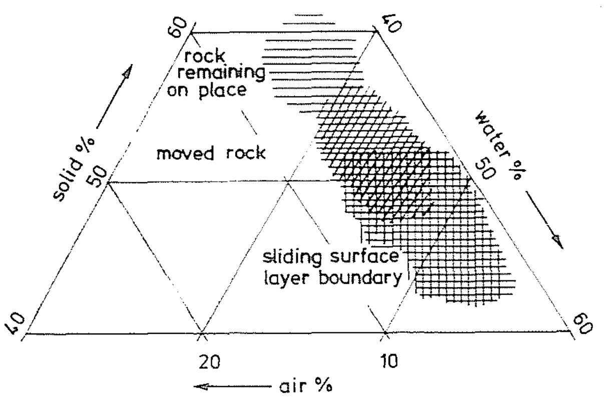

Fig. 4. The phase constitution of rockmaterial of the surface movement areas

the most thorough drench occurs on the layer boundary, that due to the lubricating effect will form a sliding surface (Fig. 4).

The thorough drenching is indicated by the fact, that the most frequent type of the surface movement is the landslide that in many cases develop to a mud flow (Fig. 5).

As the movements occur mostly in the hillocky slopes or hillsides, the groundwater level is not always continuous. The underground seepage, yet, is a general phenomenon, in rainy period the rise of the piezometric level initiates the movement.

In many cases the water gets on the surface by smaller seepages or springs. The lack of systematic and adequate drainage of this water should be a cause also of the movements. We have seen many places, that the lack of maintenance work of the drainage systems, in the recultivated former mine pits, should cause drenching and deterioration (Fig. 6).

It shows the weight of the problem, that among the preventing methods the most important task is to decrease the porewater pressure and the water content of the rock, to lower the groundwater level and due to these the shear-strength should increase and the shear-stress should decrease.

The rule of the morphological and structural conditions

The territory of the country is characterized neither by varying morphological formations nor by intricate tectonical situation. Although for the breakdown of the equilibrium in incoherent sedimental rocks there is no need for extreme conditions.

In hillocky areas based on solid rocks, the slopes are obviously steeper, and here the rockburst and the movement of the rubble is rather frequent (Fig. 7).

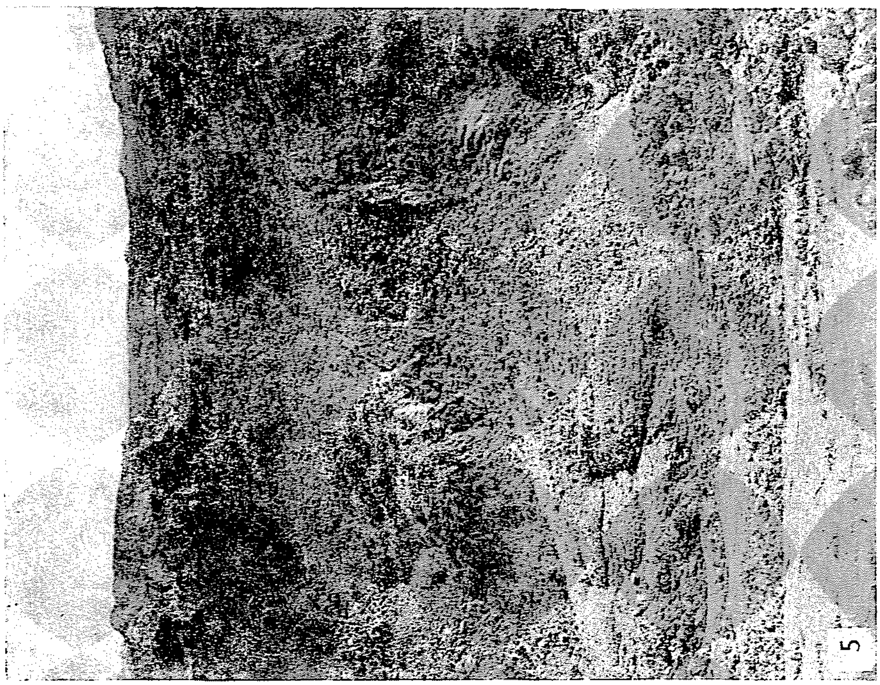

Fig. 5. A landslide that developed to mudflow (claymine at Pilisborosjenő)

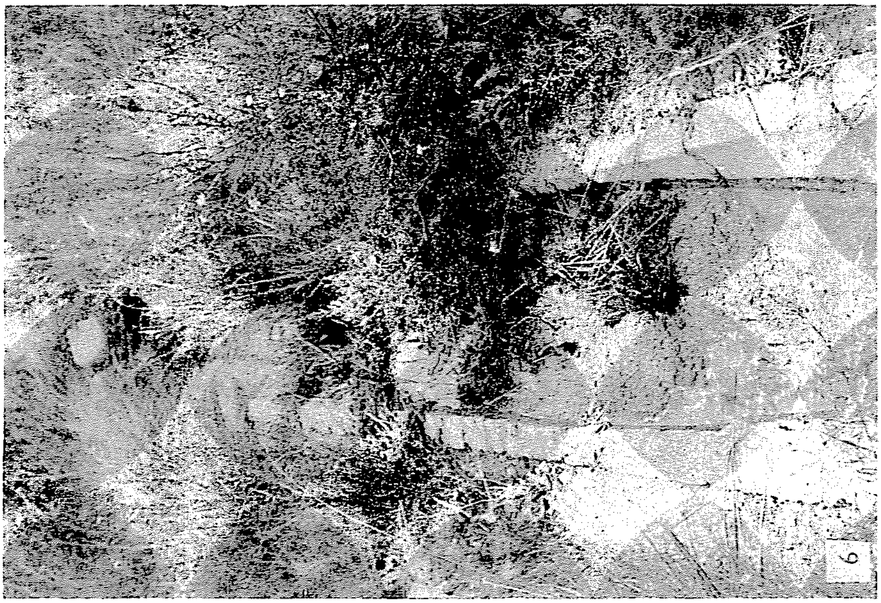

Fig. 6. An infilled catch-water drain, out of use

Fig. 7. Stoneflow on a deep volcanic slope (Börzsöny-hills)

Fig. 8. Slump of ruptured rhiodacit tuff with cellar collapse (Ostoros)

In this type of rock ambient, at the sides of the hills the tectonical slashing is conspicious and that should result the burst of steep walls (Fig. 8).

In the areas that are based on loose sedimental rocks, the morphology is less variable. yet, the bedding of the impervious layers is important. Early at the beginning of this century it was found, that in the Buda side of the capital in the frequent movement areas the Oligocene "kiscelli clay" stratum that forms a sliding plane is bedding with slight downhill slope.

From the analysis of more than sixhundred movements it has been found, that in most of the cases of surface movement the sliding plane is bedded with 10—15 degree of downhill gradient.

That is why, the formation and the more and more frequent disruption of the slope require special care. Among the preventing methods the supporting structures are important; with sustaining wall, with piles, with ironing, resistance improved with soil mars; and the other geometrical methods that are less frequently applied because of the high prices: reducing the slope gradient, formation of bermes.

The state and mineral composition of the rocks

The solid rocks in their original bedding situation, are generally stable. The movements should be resulted by the technical and climatical effects in loosed weathered rock materials on the steep slopes, especially in cases, where the strength of materials bedded on each-other, are different, and some parts of them are abutting. In rigid, strongly fissured structural dolomites and weathering volcanic tuffs the movement should happen in smaller depth but in large area; for the first we can see examples in the "Dunántúli Középhegység" for the latter in the "Északi Középhegység". Among the loose sediments the movement of clay areas and the so-called Danube and Balaton high banks composed mainly of loess, has got special significance.

In the Buda part of the capital the Oligocene so-called "kiscelli clay" was a widely used rough ceramic raw material from the Roman time up to nowadays. In the area of the mine pits that were used by numerous brickyards the movements caused damages on built up areas, on roads and on public works.

The original clay has got blue-grayish colour, is well consolidated, appears as clayey marl. Although the surface layers are oxidized and loosed. The lime has partly dissolved, the illit-montmorillonit content increased, and due to these the rock became water-sensitive and easily moveable (Figs 9—10). The superficial layer of it is rough slope chippings and Pleistocene loess which is permeable, and so, the clay is quickly drenched. The movements used to be repeated even in well drained areas.

In the Miocene sediments, similarly to the original "kiscelli clay" the lime content is significant, so their plasticity and water sensitivity is lower (Fig. 11).

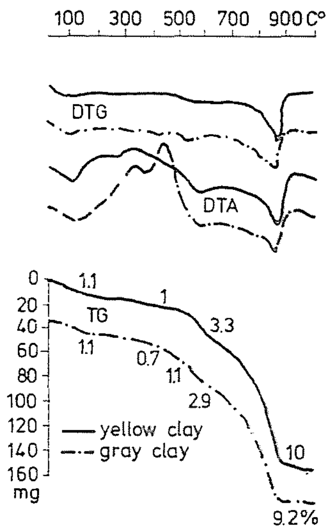

Fig. 9. Derivatogram of gray and oxidated yellow "kiscelli clay"

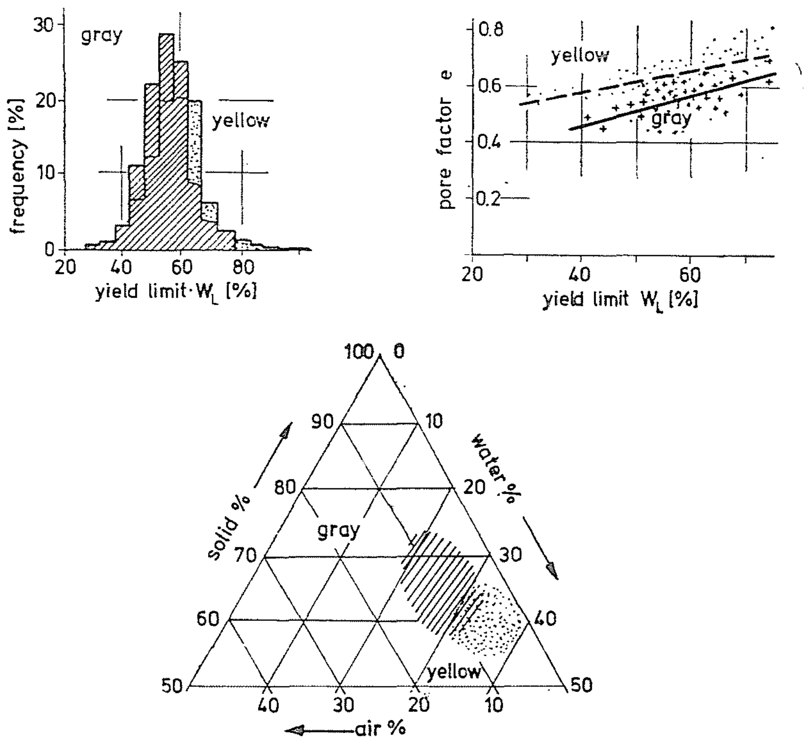

Fig. 10. Phase constitution, yield point and pore factor of gray and yellow "kiscelli clay"

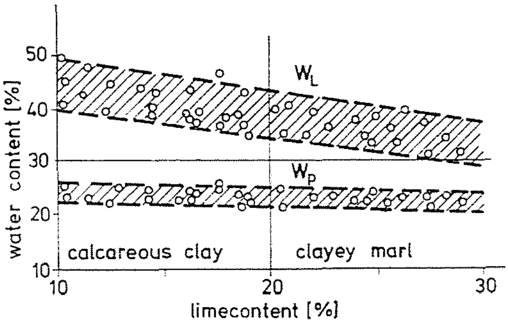

Fig. 11. The decreasement of the Miocene clay plasticity due to the increasement of lime content

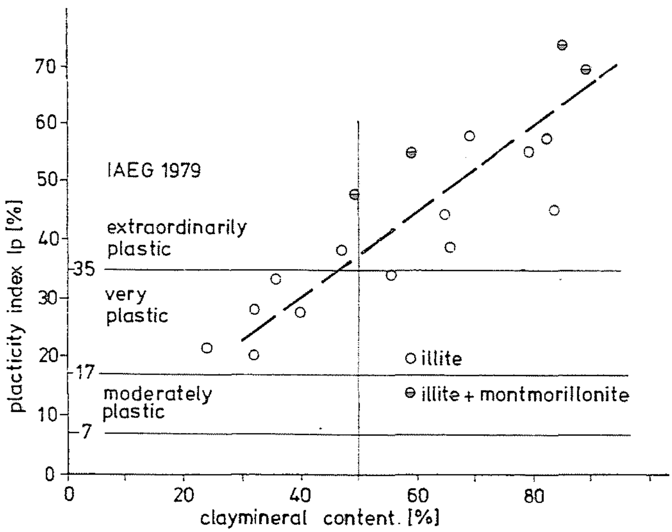

Fig. 12. The plasticity of Pannon clay as function of clay-mineral content

In the Pannon and Pleistocene materials the illit-montmorillonit content is higher, so they should be more plastic (Fig. 12). The texture of the Pleistocene materials is characteristically terrestrial, of mosaic-bulb type, so they are highly sensitive to water.

The stability of the Balaton and Danube 15—30 m high banks, composed of the variable Pannon sand-clay layer series, and Pleistocene loess layers, is an other difficult problem.

The previous break down with great extent movements due to the drenching caused by the groundwater, under pressure, and the partial public works construction. The water sensitivity of the loess banks is well known. Due to the

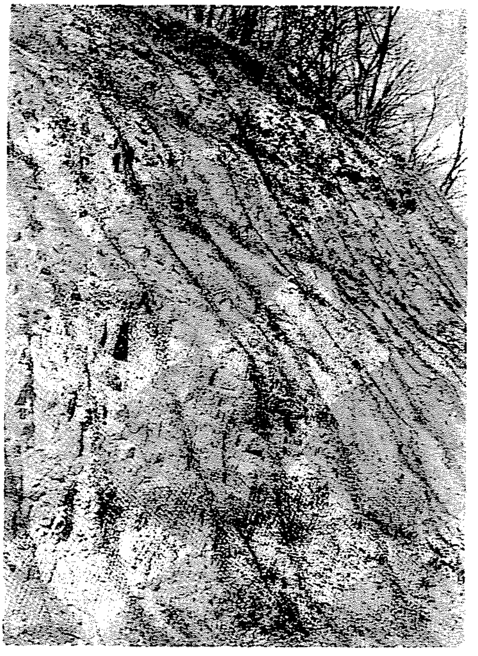

Fig. 13. An andezit surface broken with a deep slope of a road cut and protected with "nettlon" net

high permeability the precipitate, or other water, dissolve the lime content of the rock causing great extent landslip.

To eliminate the problems originated from material characteristics preferable the so-called mechanical preventing methods should be applied, these are: chemical materials, ion changes, injecting, compression that inrease the shear-strength of the rock, these methods are, however, rather expensive.

The effect of the human interference

The human activities as construction, exploitation of raw-materials in greater and greater areas influence the equilibrium of the nature, and the effect of it is very complex. Partly, with the great extent open excavation, with mines, with road and railway cuttings break down the natural slope equilibrium. On the other hand, building up the areas, partial public works construction, drenching the superficial layers change the state of the rocks, so becoming one of the decisive factors in the development of surface movements.

The breakdown of the equilibrium may cause problems even in the originally stable, solid rock ambient (Fig. 13).

In Hungary, in the recent decades, at more and more settlements, causes gravy situation the sinking, that belongs to the special type of the surface

Fig. 14. Collapse-on entire collapse of a tuf-cellar in terrace gravel and clay

movements, which should be considered as the surface projection, of the break of cellar roof, cutted in the rocks (Fig. 14). A detailed investigation of these is described in a separate study.

The above described pernicious effect of human activities causes significant problem in the environment protection. The opencast minepits and the orderless waste stockpiles defract the townscape and cause continuous danger of accidents.

Their recultivation up to now is not free of problems. At one part the drainage systems was not working properly due to some of them spoiled. On the other hand, a great amount of waste material were mixed into the backfilling material. In the following years after the backfilling the groundwater level arised, and seeping through the waste material conveyed the pollution.

The description and documentation of different movements

In the framework of the surveying extended to the humpy and hilly areas of the country, the processing of the different movement areas in uniform system has been done as follows:

1. the location and situation of the movement area: description of geographical location and situation according to cordinal points
2. Morphological conditions:
   surface conditions, built up density of the area, plantation percentage will be determined

3. Geological conditions:
first of all the depth of surface movement effected area must be introduced

4. Hydrogeological conditions:
the introduction of the surface- and ground water, to the depth of movement boundaries

5. Characteristics of the danger of movement of the slope:
recording the surface movement signals

6. The duration of the surface movement:
a question with many uncertainties, the inhabitants should give some information, results of previous testing should be used, the velocity of the movement

7. The extent of the movement:
length, width, depth of the moved mass of rock, direction of the movement

8. The causes of the surface movement:
natural conditions, the role of human interferences

9. Accidents and damages:
visible damage, damages described in studies

10. Rehabilitation and protectional works:
accomplished technical orders, introduction and documentation of the constructed protectional works

11. Observation after the movements:
technical reports made in different phases procession of the in-situ observation in chronological order detailed descriptions of the observations with soil tests

12. Type of movement:
denomination of the movement, phase of development, active, potential accomplished

13. Boundaries of the area according to real-estates:
on the basis of cadastral register on maps with scale 1: 2 000 or 1: 5 000

Appendix: plans, profiles, research and soil test documentations, photos.
Summation register cards.

These detailed uniform system processions are the bases of the county or regional summation.

County summation cadastral

The county summation data that are related to the public administration system serve as geological basis of the development of settlements. The construction of this material follows the traditional system of geological map series, with the evaluation of the natural conditions, morphological, geological, hydrogeological, and engineering geological characteristics of the region. The detailed summation of the movement area in tabular and mapping forms were done as follows:

1. The location of the area:
   built up area, agricultural area etc.
2. The geologic age and formation:
   in the grouping rocks taking part in the movement, and those being in stillstand are separately evaluated
3. Duration of the movement:
   grouping of available data according to single or repetitive movements
4. The extent of the movement:
   according to the horizontal and vertical extent
5. The cause of the movement:
   separately detailed natural conditions, and results of human interferences
6. The type of the resulted damage:
   the construction is destroyed, broken, cracked, swung out, etc.
7. The estimated costs of reconditioning:
   considered both the accomplished or proposed technical work
8. The efficiency of the work:
   the accomplished work was efficient or further corrections are needed
9. Further testing proposal:
   detailed soil test is necessary, technical interference or only periodical observation or no any further action is needed
10. The type of movement:
    grouping, registration, in certain cases at one movement area there may occur different types of movement
11. Development of the movement:
    covered or open area, active, potential or accomplished movement.

On the bases of summarized data the endangered areas should be determined for each county, and necessary measures should be proposed.

It is clearly seen that in the surface movement most frequently the Pleistocene formations took part, (272 cases in the examined areas) and within

Table II

The distribution of surface movement according to their type

Type of movement	Budapest	Pest county	Veszprém county	Heves county	Total
Rock burst	3	7	9	5	24
Landslide	4	9	6	12	31
Layer slip	9	11	15	7	42
Slump	5	17	5	12	39
Slide	18	10	99	4	131
Crawl	19	1	6	5	31
Mud flow	7	4	12	—	23
Stone flow	1	2	2	2	7
Creep	—	1	9	4	14
Slope flake	1	2	4	2	9
Cellar collapse	—	3	4*	—	7
Mine plough	—	2	—	—	2
Sum:	67	69	171	53	360

* The entirely collapsed cellars are registered only

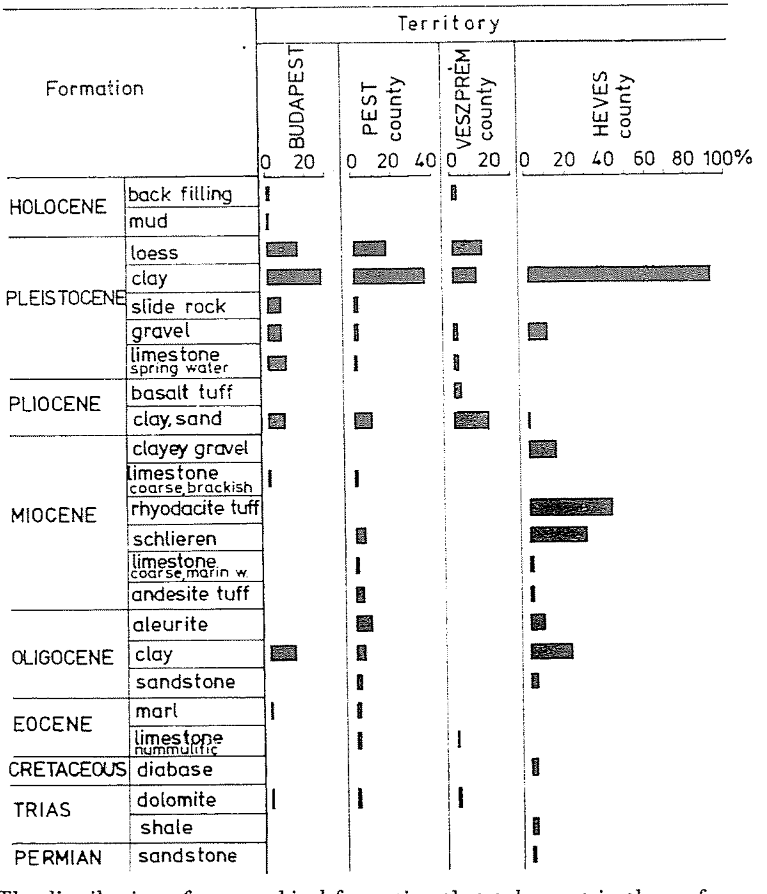

Fig. 15. The distribution of geographical formation that take part in the surface movements according to the age and type of rock

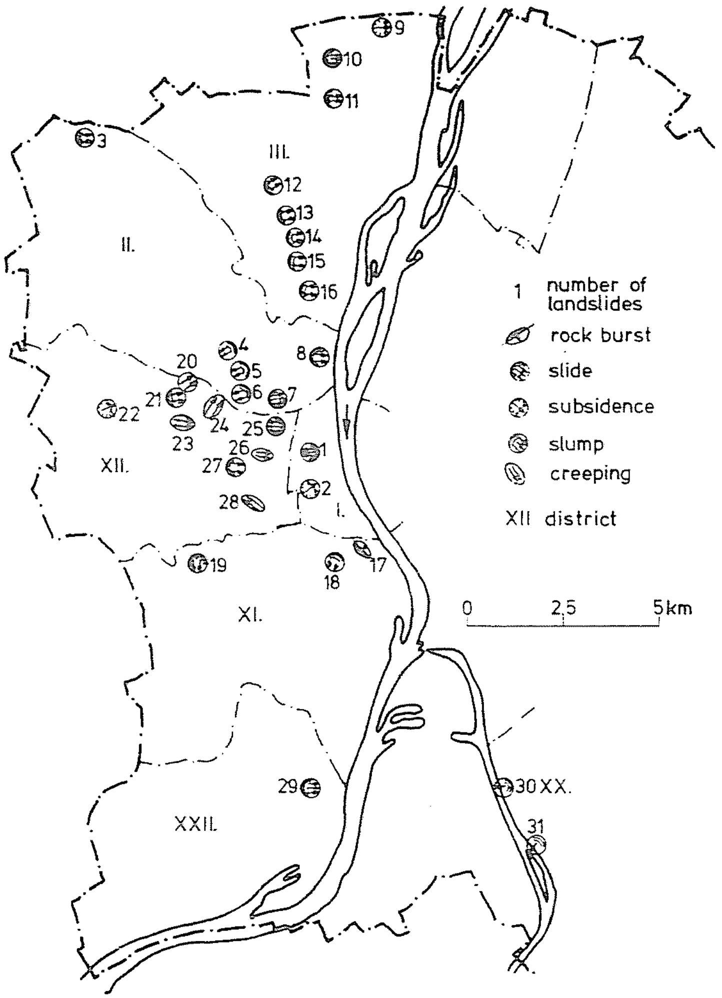

Fig. 16. Grouping of surface movements registered in the Buda part of the capital according to their type

this the materials of the slope (Fig. 15). It is similarly reasonable that in the type of the movements is predominating the landslide, and the layers slipping (Fig. 16).

It resulted from the above that among the causes the water has got primary role, but the number of movements, initiated by human interferences are also significant (Table III).

The extent of the movements compared with some other examples of different counties is smaller, in the Balaton and Danube high banks there were deeper breakes (Table IV).

Table III

The grouping of the surface movements according to initiative causes

Cause	Budapest	Pest county	Veszprém county	Heves county	Total
Natural factor					
drenching	26	39	15	99	179
undermined slope	1	7	4	1	11
morphological character	5	13	13	71	102
structural position	1	13	8	9	31
Human interferences					
drenching	4	3	10	8	25
open cut	13	14	7	18	52
road-railway cut	3	12	15	59	89
undermining	—	2	—	6	8
cellar	2	2	1	2	7

Table IV

Grouping of the surface movements according to their extent

Extent / depth	Budapest	Pest county	Veszprém county	Heves county	Total
Insignificant					
< 10 m²					
< 5 m	—	4	—	2	6
Small range					
10—50 m²					
< 5 m	2	4	3	17	26
5—10 m	1	2	—	1	4
Medium range					
50—250 m²					
< 5 m	6	2	3	40	51
5—10 m	1	2	4	8	15
10—20 m	—	1	1	—	2
Great extent					
>250 m²					
< 5 m	17	26	8	56	107
5—10 m	6	11	2	4	23
10—20 m	—	3	8	—	11
Total:	33	55	29	128	245

The cadastral work by county territories helped the cognition of the regions, and the selection of the reference areas. These examinations are under process, in different places.

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