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TECHNICAL-GEOLOGICAL INTERPRETATION OF THE PHENOMENA HAVING OCCURRED IN THE CASE OF A LAND SLIDING

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A b s t r a c t

The studied land sliding affected an area of 70 ha, having a length of 2 km and a width varying between 110 m and 600 m. Three available aerial photographs (black and white): one taken immediately after the land sliding and two taken twelve years and respectively one year before, have confirmed the hypotheses a geologist established in field by employing conventional mappings.

The hypotheses referred to the size of the sliding, to the sliding directions, to the thickness of the mass of slid earth in some points, as well as to the development of phenomena all along the process. With that end in view, a comparative photo-interpretation of some field elements recorded on the three aerial photographs was performed, and there were used metrical determinations (levelling, coordinates, linear and angle measurements) made by stereo plotting devices on the aerial and terrestrial photograms taken after the land sliding.

I n t r o d u c t i o n

During the last decade, a great number of more or less important land slidings took place in Romania, some of which stabilized, others which reoccurred; part of them threaten to start again.

Moreover, in some zones considered not to be favourable for land slidings, such phenomena have nevertheless occurred.

The situation led to the necessity of performing various studies, both in order to find out the potential land sliding places and the measures to be taken so as to prevent the damages that such phenomena cause to human amd material goods.

The geologist's activity is of a great importance in this kind of studies ; a geologist is the first called to account for the phenomena produced and to recommend the measures to be taken, in collaboration with many other experts ; these measures are conditioned by a series of objective elements. That is why , in case of a large or relatively large land sliding, the geologists are directly (as a professional task) or indirectly (by mere curiosity) interested to see and to analyze the cause of the respective land sliding , to state their own opinions and to find the best solutions , so as to limit the sliding and to consolidate the land , in order to avoid another sliding .

The geologist called to express his opinion in connection with the land sliding can reckon on a valuable help if he has at his disposal photogrammetric records of the slid zones ,taken before and after the sliding has occured , because one may rely on such records when establishing the causes of the slope's instability , as well as the most economical and most adequate consolidation means and systems , the measures to be applied so as to eliminate the causes which had led to the instability , to prevent it and to control the future efficiency of the applied consolidation measures.

The authors of this paper , a photogrammetrist and a geotechnician , have proposed to transpose the data a geologist had in connection with a recent sliding in the basin of the Dîmboviţa River and to suggest ideas concerning the necessary methodology for finding out the potential sliding zones, by aerial photograms .

We should mention from the very beginning the fact that the data concerning the respective zone , acquired by conventional methods , have not only been confirmed by the photograms , but they have been completed ; they have suggested new points of view , which could not have been apparent through the traditional methods.

Record of problems

Starting from an initial analysis made directly an the aerial photographs taken in June 1979 , immediately after the land sliding , and then considering also two older aerial photo - graphs taken in 1978 and in 1967 , the authors of the present study have concluded that photogrammetry offers certain possibilities to obtain more easily data connected with :

1. the morphology of the considered area ;
2. the inter-relation between the morphology and the geology of the deposits (rocks) of the respective ground (rock resistance to the external agent action , their nature - structural areas a.s.o.);
3. the measurement of the position of structural surfaces (direction and inclination) ;
4. the measurement of the position of rock stratification in that zone ;
5. the correlation between the position of structural surfaces and the rock position (a very important factor in determining whether water may penetrate through the end of the layer) ;
6. the slopes' microhydrography (the water network and flowing system on the slope) ;
7. the areas of the slopes showing a moisture excess (slopes and counter-slopes retaining the water, springs, emergence places of the water) ;
8. the zones favourable for phenomena of instability (areas affected by old land slidings being in a state of doubtful equilibrium - non-active zones , but which are potentially adequate for sliding ;
9. parameters of active sliding (a) - an affected area ; b)- the failure pitch ; c) - earth mass movement ; d) - delivering zones) ;
10. the establishment of the sliding direction of the earth mass ;
11. the development of sliding phenomena ;
12. the efficiency of the measures of consolidation .

In figures 1-3 an example of the above is given , indicating the phenomenon or element shown by the photographic image or which can be determined by means of photographs.

M e t r i c   d e t e r m i n a t i o n s

In order to obtain some of the geometrical elements characteristic of the land sliding , orthophotographs have been carried out based on the photographs derived from the three successive aerial photographs taken at the same scale, as well as from maps at the plotting scale of 1/2000 with 1m of eq, using the photographs of the last two photographs taken .
In the process of stereo plotting for each aerial photograph , there were recorded the model coordinates and levels for the significant details chosen together with the geotechnician.
At the same time , the terrestrial photographs taken on the separation zone were processed by an instrument of the stecometer type, and the coordinates (x,y,z) of some characteristic or fictitious points were obtained .

1. Determination of the sliding plane position (direction and inclination) .
Two procedures were used - one relying on terrestrial photographs and the other , on aerial photographs .
The terrestrial photographs were employed for the places where the layer along which the sliding had taken place had remained discovered (fig.4a and b) .
By exploiting the terrestrial photographs and by calculations, we established the co-ordinates of some A,B,C.type groups of points in ab geodesic system (x , y , z) ; these groups are selected so that the straight lines AB and BC may approximately form an angle of 100^g , according to which the plane inclination was determined on the directions AB and BC , as well as the general inclination and direction of the sliding plane , settled by composing the vectors that define the two components .
The aerial photographs were used to determine the successive inclination of the slopes affected by sliding in the apparently motionless areas . In this respect there were established the co-ordinates (x , y , z) of some details (three at least) identified on the photographs derived from the three aerial photographs , and thus the inclinations were deduced as above ; these data supported the further interpretations of

the position of the sliding plane on large areas.

2. Determination of the position of geological formations (direction and inclination).

When taking over the terrestrial photographs, we noticed portions where geological formations outcropped in two directions (fig. 4 "c") in the separation zones, where the geological deposits were not affected by the sliding, and , by photogrammetric processing, the co-ordinates (x , y , z) of points A, B , C , D were determined ; so , the layer direction and inclination were deduced in a way similar to the above mentioned one . It is preferable to make both direction measurements against reference horizons .

3. Determination of the earth mass thickness affected by sliding.

An orientative image of the earth mass thickness affected by sliding was obtained by comparing the position of the sliding plane with that of the land surface plane obtained by stereo ploting device , with levels in the falling zones and in the upsetting zones (fig.1-4) ; these data serve to estimate the depths necessary for prospection works (bore-holes, wells) as well as in the stability calculations .

4. Determination of the slide earth mass movement .

A first estimate of the apparent size of earth mass movement in various sliding points was obtained by means of linear measurements made on orthophotographs derived from photograms taken after the land sliding. The measurements were made in the falling , upsetting and fragmentation zones , according to certain planimetrical details (fig.1-3).

In order to determine the actual size of the earth movement, accurate planimetric details were identified on the photographs taken from the three available aerial photogrphs for which the geodetic co-ordinates (x , y , z) were determined within the same reference system by an instrument of stereo - plotting, as well as on the orthophotograms .

The dimensions and direction of the movement having occurred at the surface of the land were deduced from the differences between the co-ordinates values . The above data served to establish the evolution of the phenomenon in time , as well as the order in which the different earth masses started moving and the causes of the sliding .

Conclusions

This study shows the possibilities offered by the photogrammetric recordings and processing through an interdisciplinary co-operation , in obtaining qualitative and quantitative elements concerning the geotechnical interpretation of the slope instability phenomena .

The advantage of the adopted method is that it allows :
a) - the rapid attainment of a general estimate of the sliding dimensions ; b) - an accurate determination of the parameters required so as to know the causes of the sliding , its evolution and the necessary consolidation measures ; c) - a retroactive examination of the zone where the sliding has occured by a comparative analysis of the photogrmmetric recordings made before the sliding ; d) - the location of the consolidation measures on a suggestive material .
The method adopted permits the working out of an accurate and complete study , with less technical and economic expense than in the case of conventional investigations - and in a shorter period of time.
It has resulted from the study carried out that a previous analysis made by an experienced researcher (preferably by a team made up of a photogrammetrist and a geotechnician) on the photographs and aerial photographs taken in 1967 and in 1978 would have led to the forecast of an eventual activation of the zone , because the old lines of falling and upsetting are evident on them . The fact shows that it is necessary to improve and extend this method in all cases where there are photogrammetric materials available and that it is most useful to perform some special photogrammetric recordings for the zones with land sliding potentials , remote sensing included.

Fig. 1 Aerial photograph showing the situation of the area in 1967 (before the sliding)

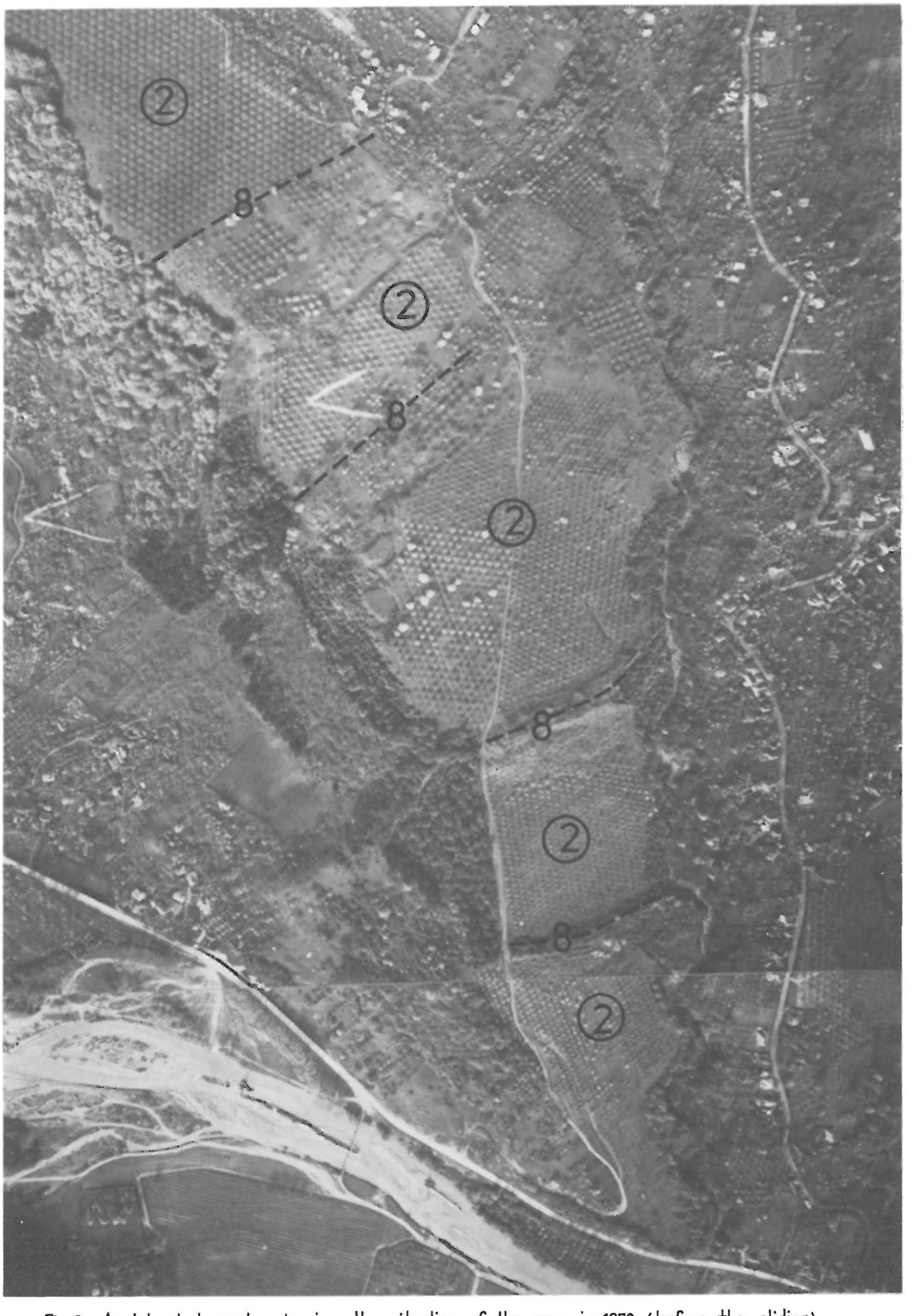

Fig.2 Aerial photograph showing the situation of the area in 1978 (before the sliding)

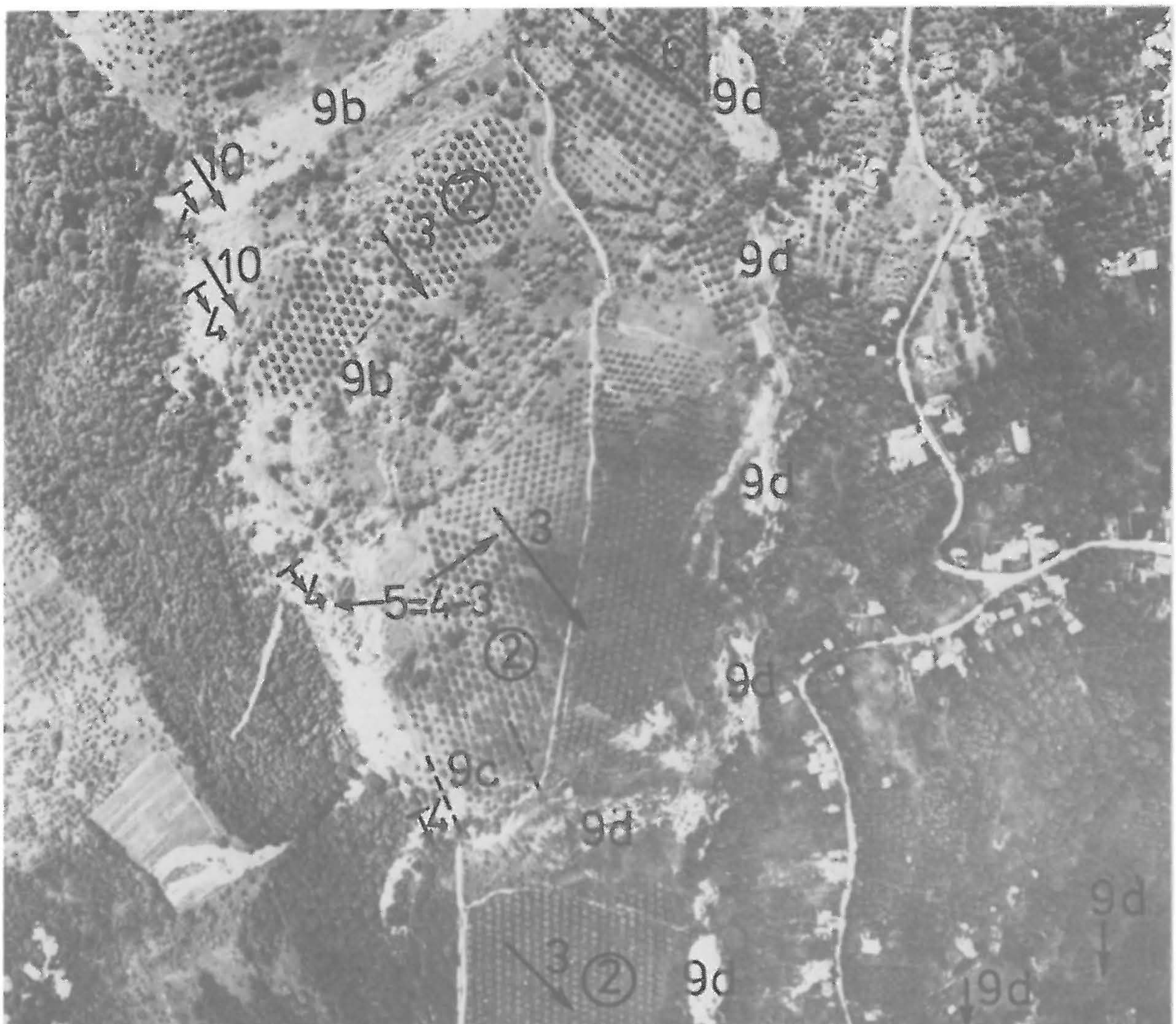

Fig. 3 Aerial photograph showing the situation of the area in 1979 (after the sliding)

Fig. 4 Terrestrial photograph showing the situation of the area (after the sliding)

a, b – the points selected for the determination of the position of the sliding plane ;
c – the points selected for the determination of the position of the geologic structure.