UTILITY OF PHOTOGRAMMETRY USING TIME-SERIES AERIAL PHOTO FOR LANDSLIDE INVESTIGATION IN JAPAN

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JAPAN
IV-5

Abstract

Measuring and mapping comparatively the pre-(or initial stage of slow sliding) and post-(or progressed stage) landslide is the irreplaceable method for grasping the whole sliding area and its time-series phenomenon.

In view of this fact, following points are discussed.

1. Main studies and results since 1960s in Japan.
2. New knowledges concerning of this method.
3. Effective influence to the civil engineering and disaster prevention.
4. Further problems and prospect of this method.

1. Preface

From the viewpoint of disaster prevention, it is important to understand characteristics of slope movement such as landslide and slope failure and to predict its occurrence and development. However, ① many factors are involved with the occurrence of the above-mentioned slope movement. ② After its occurrence, changes in ground level, landform, hydrologic phenomena and vegetation occur like chain-phenomena. ③ In most cases, the surveys start after its occurrence. At that moment, it is too late to know the land conditions before or at the beginning of the movement. ④ Therefore, only part of the movement is known with difficulty. Qualitative analysis of the land condition related to its occurrence or non-occurrence is only partly done, too.

Among these, it is impossible to change ① and ②. Nevertheless, it is possible to acquire quantitative data by the comparing measurement of aerial photographs before and after the occurrence as far as these photographs are obtained. In this sense, ③ can be changed.

Based on this assumption, the authors so far applied time-series photogrammetry to some cases in which slope movements occurred. The authors report, in this paper, findings and problems acquired from the cases by the time-series photogrammetry and also discuss about the effectiveness of this method as well as matters that demands a special attention for application of this method.

2. Case Study

2-1. Iwatono-yama Landslide

In 1972, from Feb. to Apr., large-scale cut slope part beside the Chuo Express Way kept sliding. It was stopped by works carried out as a countermeasure. The comparing measurement of the landslide was carried out by using the aerial photographs taken at the beginning of the landslide and photographs taken when the movement was stopped due to retaining banking (Photo 1). In this case, it was possible to use the intersections of concrete frames, which provided the most advantageous as tracking points.

This made it possible to obtain an accurate image of the entire scene of the movement (Fig.1-a).

* This movement was typified as a landslide which moved as an independent land mass. Conspicuous are deformation and small failure at the neighboring part of the land mass. Both longitudinally and horizontally, characteristic is the rotation of the slided land mass (Fig.1-a,b).

* One can estimate the sliding plain through the analysis of the vectors of movement on the ground surface measured with photogrammetry. This watches an estimation by means of geologic boring (Fig.1-b).

2-2. Komoro Landslide

Part of the large-scale landslide was reactivated by a heavy rain and flood accompanied by the typhoon in August,1982. It is still active on a very small scale.

Photo 2 are the aerial photographs of the landslide site in subject taken before and after the occurrence and one taken 40 years ago. A horizontal and vertical movement vector map are shown in Fig.4-a,b and c, as a study result. On the other hand, the authors introduced Fig.4 which depicting the change in the elevation of river-bed. The decreasing tendency of the level of the river-bed and changing of river-channel of Chikugo Gawa(River) is easily understood also by stereoscopic viewing of the above-mentioned aerial photographs.

* The general process of a time-series photogrammetry applied to the Komoro landslide and Jinnosukedani landslide (2-3.) is shown in Fig.2 as a flow chart.

* Three-dimensional displacement was measured at 1125 tracking points over the the landslide-stricken area by the use of aerial photographs taken before and in the midst of the occurrence. As result, 300 points in the landslide area show their large displacements for comparing measurement.

* On the comparing measuring by analytical plotter, following processes ① to evaluate accuracy of photo-orientation in the case of adoption or rejection of each control point, ② to select minimum error condition of photo-orientation, ③ to evaluate and to select measuring points, and ④ to measure coordinate value and elevation, were carried. And the change in ground surface level by comparing contour maps at the two different periods as mentioned above are prepared.

* In the Fig.4-a,b and c, survey points with measured displacement amount of 0.3 m or more are affirmed to be located within the area of the fast moving landslide.

* On the basis of the pattern of displacement (direction ; the distribution of vertical element / horizontal element), the area of the movement is roughly divided into ① the main block around the curve of the Chikuma Gawa water channel and ② Fujimi-daira block on the northeastern small area. This matches the zoning of landslide landform by means of aerial photograph interpretation (Fig.4-d).

* The major part of the main block subsides toward the dry river-bed at a dip of around 40 degrees near the scarp crown, whereas uplift tendency is dominant at the river-bed (Fig.4-c). The mechanism of this movement can not be explained by a motion of "a single circular arc sliding plane". A rational explanation about this is that, because the major part of the sliding surface was flat and deep, a squeezing phenomenon toward the river occurred at the thick soft layer underlying at the depth of several meters and this triggered a chain of phenomena, that is, the uplift on the valley side—> the transition toward the valley—> the subduction on the mountain side (Hatano et al.,1984).

* According to the Photo 2-a,b and c., the low water channel of Chikuma Gawa around its curve changed its direction extremely to the north and gave rise to a severe decrease in the level of the river-bed. As a results, the

average depth of erosion reached 3 m. As the causes of occurrence of Komoro landslide, there occur two ; that is, an increase of groundwater level due to heavy rain and the decrease of the river-bed due to flood and exploitation of bed materials from there. The data acquired suggests that the latter is more important.

2-3. Jinnosuke Dani Landslide of Hakusan

Jinnosuke Dani(Valley), dissecting the steep mountain slope of Hakusan volcano, is sliding gradually in the deep basement by itself. The sliding have been continued with several decades. The left-half of Fig.5-b indicates a huge-scale landslides landscape. The authors attempted to detect the moved distance between 18 years intervals using the aerial photos taken at 1964 and 1974. The method is same as Komoro landslide above-mentioned. Three-dimensional displacement was measured at 327 tracking points mainly in the Jinnosuke Dani and few points on the mountain slope around the valley. But as result, 84 points are available for comparing measurement.

The result is shown in Fig.5-a and b. The downward sliding along valley was measured, but the accurate image of landslide could not be ascertained, because ; 1 tracking points on the slope except on the sabo(sand arrestation) dams were not available for comparing measurement, 2 some control points are located in the wide and huge-scale landslide.

3. Effectuality of Time-Series Aerial Photogrammetry

In surveys on landslides and slope failures, it was revealed that advantageous were the comparative measurement and analysis by using photographs taken in a time-series manner.

① With regard to landslide, it enabled the understanding of the entire nature of the mass movement due to many vectors over the range of the mass movement and four-dimensional landform change to obtain aerial photographs before and at each stage of the landslide and to carry out the comparing measurement of them. Likewise, elements of the landform change and geomorphic property of slope failure can be understood and measured in a similar way.

② It is impossible to know the mass movement of the kind areally at a uniform accuracy simply by existing field reconnaissances and field surveys. By such methods, it is often difficult to differentiate the range of the movement and incidence area, to estimate the position of a major fracture and sliding plane and to determine the scale of the moving mass and geomorphic properties landforms. A method employing photogrammetry, conversely, is advantageous and cost-efficient in that areally uniform accuracy can be obtained.

③ Observations or surveys in the past were normally not started until phenomena were actualized. For this reason, it was difficult to know about conditions of an important part of a large amount of mass movement which occurred before surveys. Fortunately, there still exist aerial photographs of Japan taken by public organizations and private surveying companies after the World War II. These photographs can be used to know about conditions before the disaster. As practices in the past some years, many survey photographs were taken when occurred ground movements to be linked with serious disasters. With these photographs, the entire landform changes can be observed all through the period of mass movements.

4. Problems in Time-Series Aerial Photogrammetry

4-1. Problems when Using Ground Photographs

Most of the cameras not for surveying do not clearly indicate their inner orientation elements. Because photographs of unforeseen phenomena taken with handy cameras are very useful, these photographs can be used by applying camera calibration. When many planimetric features by which coordinates can be obtained are found in such photographs, elements such as focal length can be obtained not by calibration but by using a analytical plotter. When necessary, ground coordinates are measured on the field.

4-2. Problems when Using Aerial Photographs

On the occasion of measuring aerial photographs taken on more than two dates in a way of time-series photogrammetry, the scales must not be different too much from each other. Otherwise it becomes difficult to identify control points or movement tracking points at each photograph by aerial triangulation under a difficult condition. As a result, this becomes a factor to deteriorate relative accuracy.

Both the quantity and quality of acquired geographic information are greatly affected by the flight course of photographing, the direction and the location of slopes to be surveyed on the aerial photographs. In the case of a steep slope, in particular, it is very important to choose one in which the direction of a slope is in the direction of the principal point of a photograph.

In the case of large-scale aerial photographs, it is necessary that a immobable area is located at a position able to be orientated within a single model.

Photographs taken in the past, after World War II, are available from among those taken by GSI, the Forestry Agency, other public agencies and private surveying companies. It is necessary to choose ones with favorite conditions for understanding ground surfaces accurately (For instance, ones in defoliation).

When taking photographs, it is necessary to take the above mentioned into consideration and choose the most suitable photographing flight course, scale and time so that effective and accurate are future mapping and surveying works and the comparison with photographs taken at another time.

4-3. Problems in Plotting(Mapping) and Measuring

(1) Problems in the Selection of Control Points and in the Orientation

In the case of a plotter, the number of control points for orientation and their arrangement are still limited although the used data are those from existing topographic maps or actual geodetic data. Therefore it is necessary to add points obtained by the use of planimetric features to those mentioned above in order to orient series of models or photographs taken on different dates.

There occurs a large amount of error if the arrangement of control points is improper in its relation to an area of mass movement. In this case, it is indispensable to orient so as to minimize the residual error of orientation at a group of control points which are presumably the stablest.

(2) Problems in Relation to the Selection of Tracking Points

In general case, identified are images of aerial photographs taken twice or more at different time. For this reason, it is necessary to pick up distinct and long-standing planimetric features. In this sense, a ridge between rice fields must be avoided because it changes as time goes by. Likewise, curves of a road must be avoided. For it is impossible to identify such places accurately at long interval. In the case of a river bed where no artificial structure exist, the top of a giant of boulder can be used as a standard for elevation and its outline as that for position.

It is necessary to choose as many tracking points as possible and adapt the points which were accurately measured commonly in the photographs. In the case of the analysis of survey results, on the other hand, it is necessary to differentiate tracking points where both elevations and positions are accurately measured from ones where the results are not so accurate due to factors such as halation, etc.

(3) Problems in Plotting and Measurement

When plotting and measuring mass movement phenomena in a woodland by using aerial photographs taken at different time, there often occurs an apparent difference in elevation depending on the estimation of the height of trees although no changes on the ground are occurred. Therefore, operators must pay at most attention to this matter in the case of orientation, plotting and measurement. According to this, operations by plural operators should keep out to avoid the difference in measurement between them.

Especially in the case in which comparing measurement is conducted by using photographs taken at two different times which are greatly distant from each other, it is likely to produce a big amount of error in the estimation of the ground elevation of a woodland due to the growth of trees.

In sometimes makes it difficult to identify the position and elevation of control points and tracking points under such conditions of photographing as halation, etc. An countermeasure against this includes a method in which after a stable ground feature is measured at several points, not these individual points but their centroid is used as the measuring point. It is recommended that the height of features near the ground surface be directly measured on the field.

5. Conclusion and Future View

As mentioned in 3., by applying photogrammetry in this field, it is possible to acquire such important informations that cannot be acquired solely by existing field surveys (geodetic survey and precision measurement of a mass movement and survey employing civil engineering and geological techniques). This method is not so costly compared with that of other methods. It is therefore necessary to promote the positive use of time-series aerial photogrammetry except for surveys and map making in a narrow sense.

From this viewpoint, the authors hope to improve and establish a survey method by photogrammetry in this field by experiencing many other cases of this kinds.

In addition, in the case of the mass movement of slopes, it is considered to be a key for the solution that the time-series aerial photogrammetry is positively employed from an early stage such as basic or prerecognitive survey. For this propose, it is important to combine this method with existing methods such as measurements and surveys employing civil engineering and geological techniques.

The authors wish to express hearty gratitude to Mr. Hatano S.,GSI, who discussed with the authors and gave valuable advises for this study.

[Reference]

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Hatano,S., Nagaoka,N., Mimura,K. and Saitoh,F.(1984) : Examples of application and problems of photogrammetry using time-series aerial photo on the survey of slow- and fast-moving landslide. Abstract of 38th Technical and Study Meeting--free theme and common session, 129-136. (in Japanese)

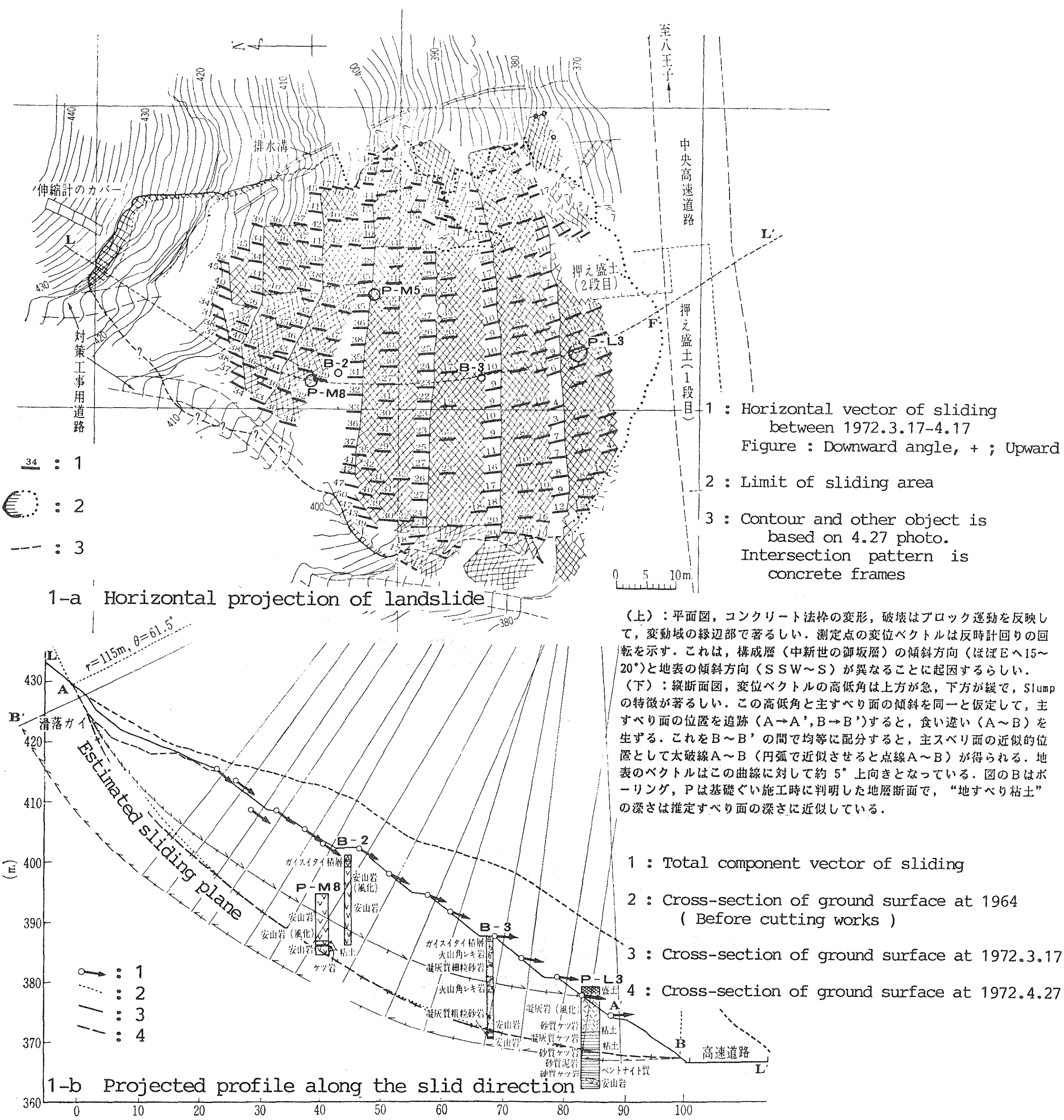


Fig.1 Accurate sliding image of Iwatonoyama landslide along the sliding direction by the comparative measurement with the 1972.3.17 aerial photo and 4.27 photo (Hatano,1984)

Photo 1 Stereo-view of Iwatonoyama landslide, after the retaining banking (Photo by S.Sekine, 1972.4.27)

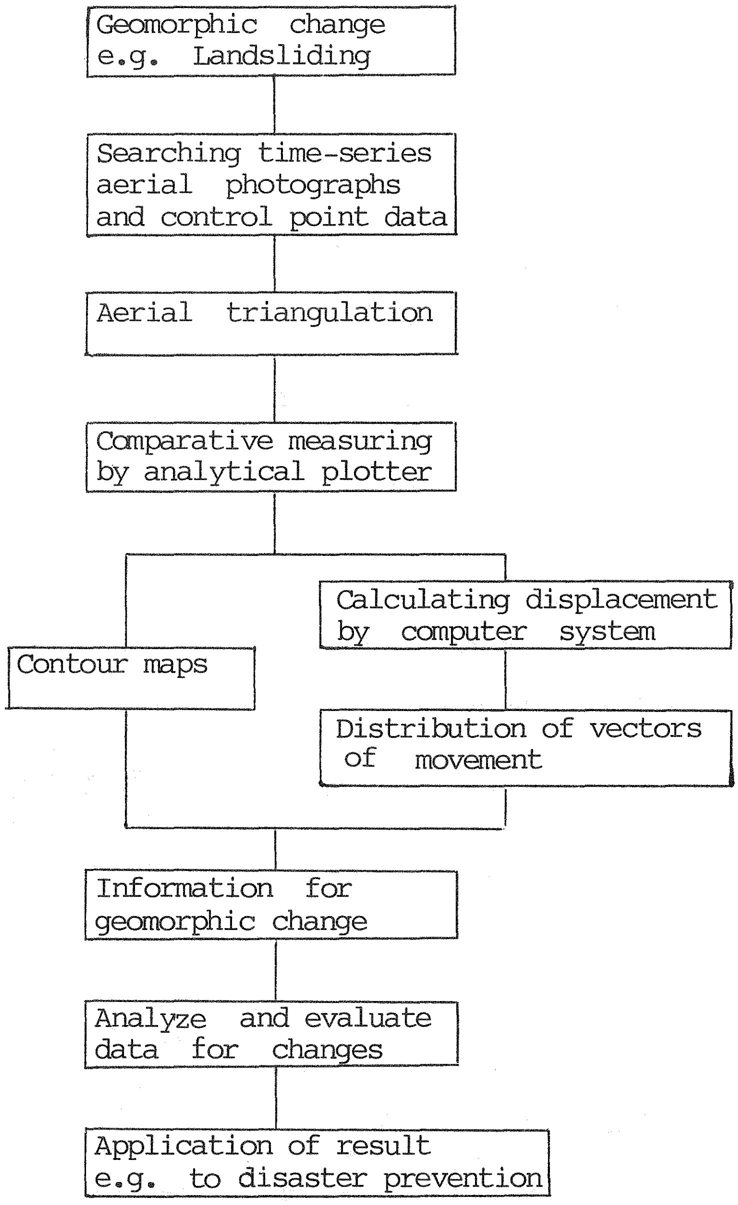
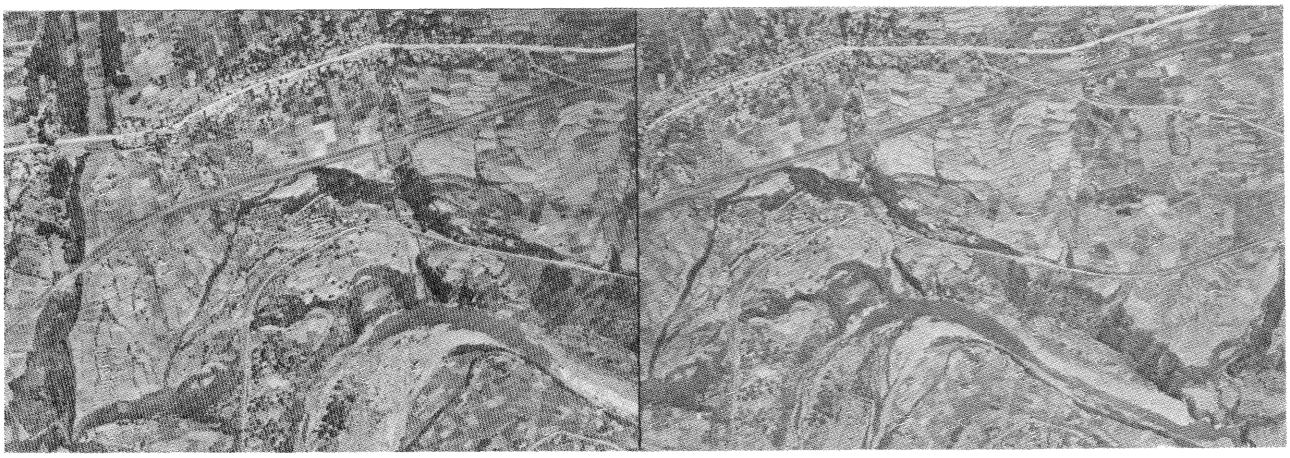
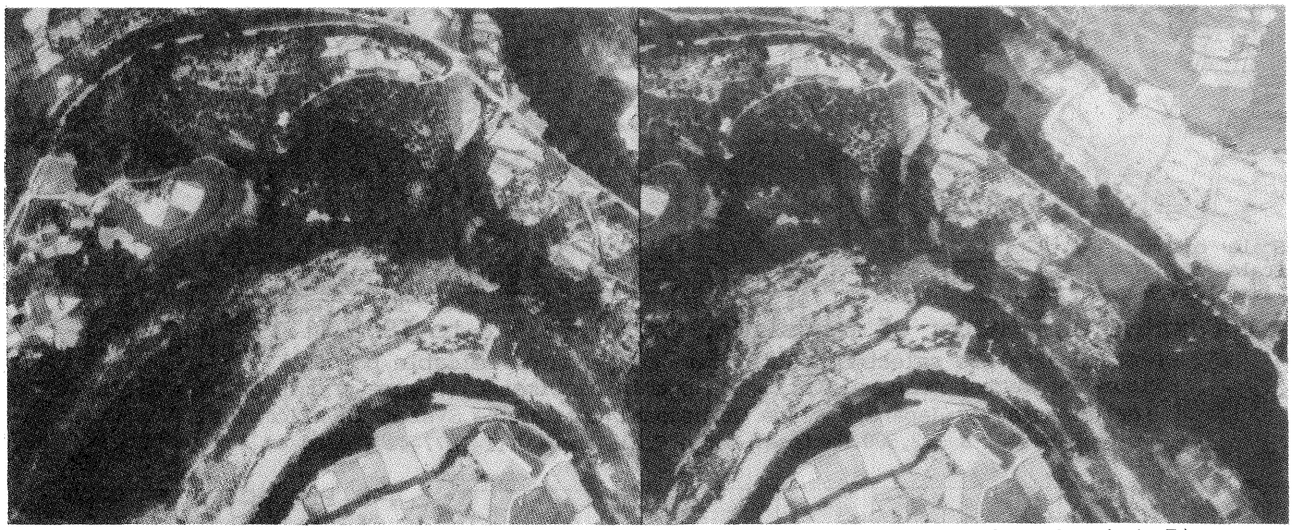


Fig.2 Flow-chart of time-series photogrammetry



2-a 1946.6.14 ; Photo by US Army, M165-A-6, 106,106, 1:10,000. (×0.7)



2-b 1982.6.8 ; Photo by Komoro city, K4866, C8-6,7, 1:8,000. (×1.5)

2-c 1983.11.19 ;Photo by Kyodo-sokuryosha, C1-3528,3527, 1:4,000. (×0.66)

Photo 2 Landform change at the foot of Komoro landslide. ; Changes of water channel and it height in riverbed should be notice (Stereo view is possible for Photo 2-a,b and c, but the direction of each photo is different according to the flight course.)

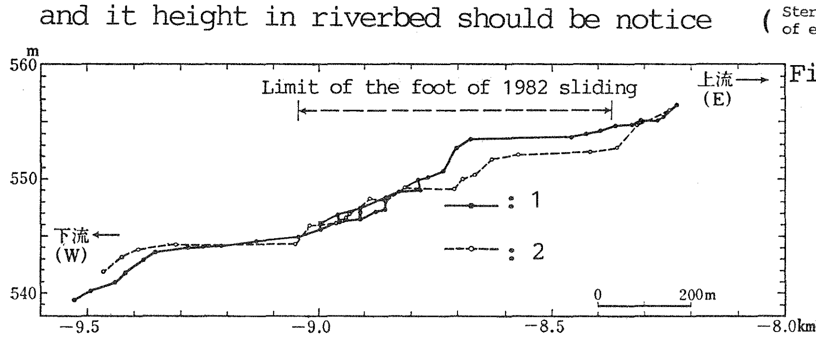


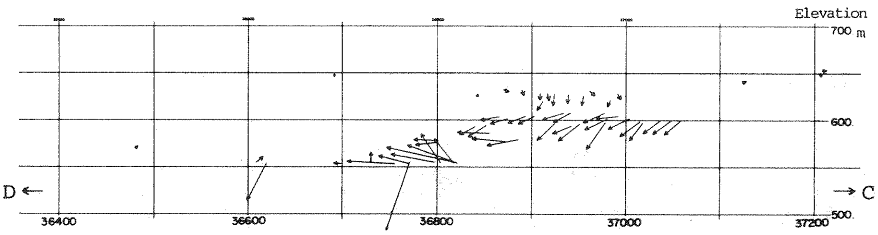
Fig.3 Vertical change of riverbed of Chikuma Gawa (River), by comparative measurement using aerial photos of pre- and post-1982 sliding (Hatano,1983)

1 : Height of river-water level at 1981.6.8

2 : Height of riverwater level at 1982.10.13

4-a Horizontal vector of landslide, from 1982.6.8 to 1983.11.19

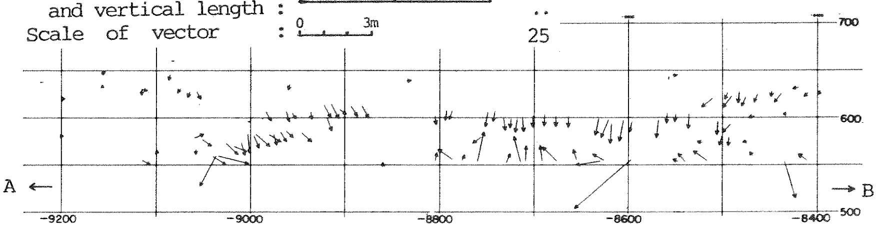
Plotted data are selected points from 300 measured reliable points.
Figure of vector means elevation change in centimeter, figure on map grid is distance from datum point of Japanese Plane Orthogonal Coordinate System in kilometer.
Base map by GSI's 1:2,500 National Large Scale Map "VIII-ID77-42"(based on 1981 aerial photo). (x0.35)



4-b Projected vectors to N-S plain (C-D line shown in 4-a)

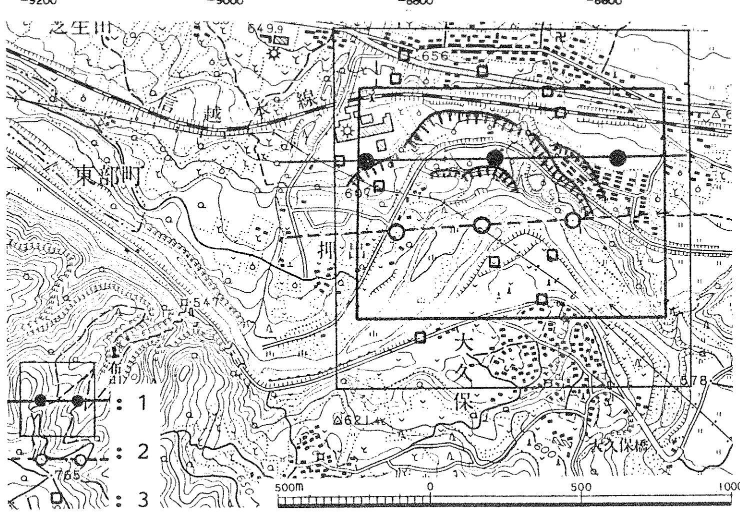
(Plotted vectors are different on each Figure by the reason of drafting.)

Scale of horizontal and vertical length : 0 100 200m 1 : 25
Scale of vector : 0 3m



4-c Projected vectors to E-W plain (A-B line shown in 4-a)

Upward vectors are mostly on river bed.
Downward vectors are mostly on slope or plain.



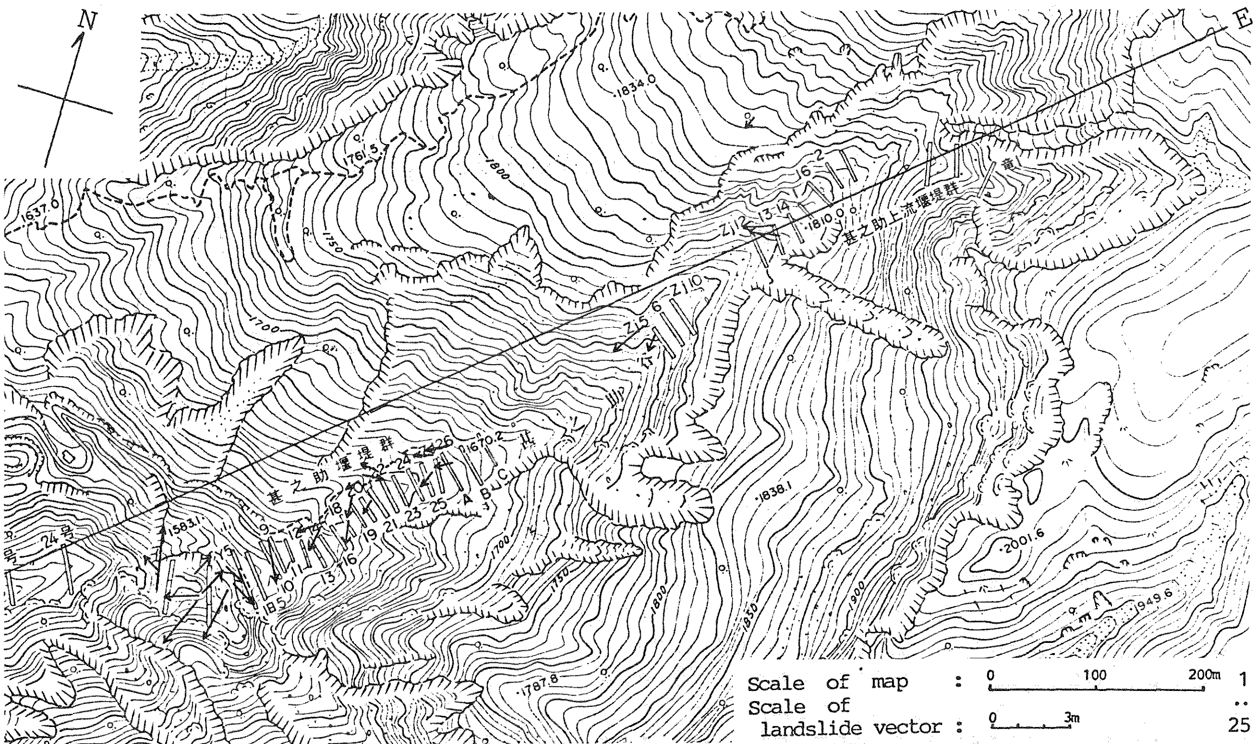
4-d Location of the study area(□)

1 : 1983.11.19 aerial photo ; course, principal point, angular field
2 : 1982.6.8 aerial photo ; -- ditto --
3 : Main control point

: Main landslide scarp and erosion scarp

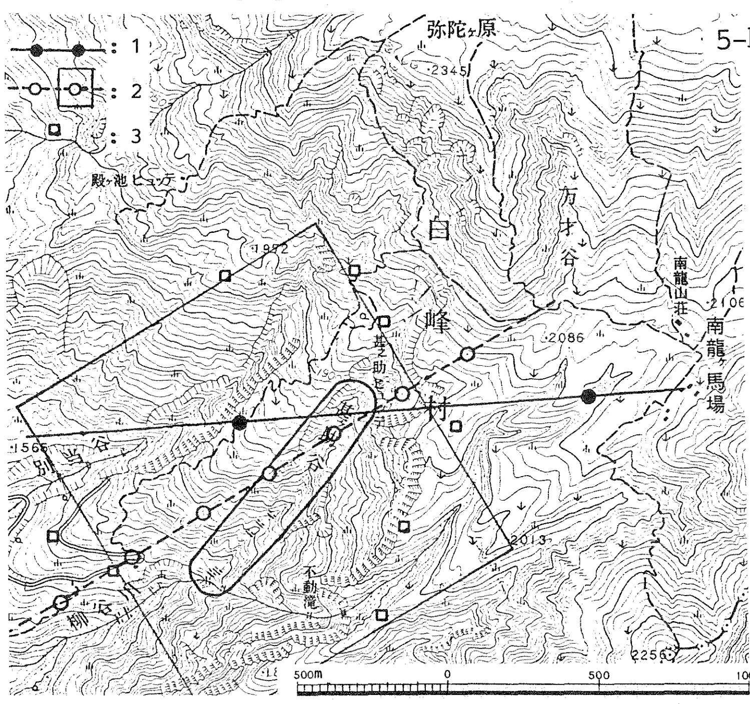
Base map by GSI's 1:25,000 Topographic Map "Kurumasaka Toge" and "Komoro"

Fig.4 Study result of Komoro landslide



5-a Horizontal vector of landslide, from 1964 to 1979

Plotted data are selected points from 84 measured reliable points.
Figure of vector means elevation change in centimeter.
Base map by 1:5,000 map of Kanazawa Const.Office of MOC (based on 1972 aerial photo). (x0.7)



5-b Location of the study area( )

1 : 1964 aerial photo,
Forestry Agency, Yama-357, 1/20,000 ;
course, principal point, angler field.
2 : 1979 aerial photo,
Kanazawa Const.Office of MOC, 1/3,000 ;
-- ditto --
3 : Main control point

Base map by GSI's 1:25,000 Topographic Map "Hakusan"

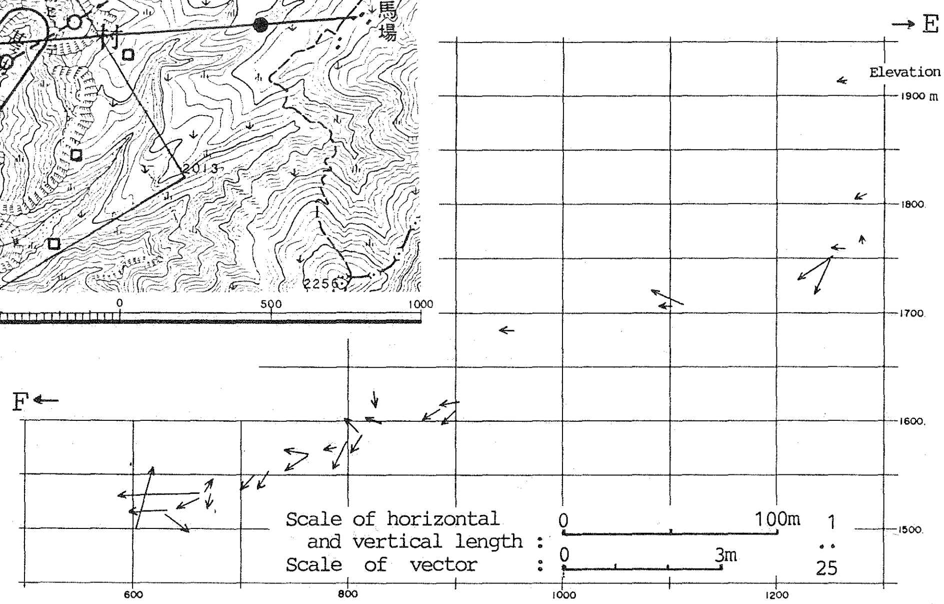


Fig.5 Study result of Jinnosuke Dani landslide

5-c Projected vectors to valley line (E-F, shown in 5-a)

Plotted data are different between on Fig.5-a and c by the reason of drafting.