On the Topographical Origin of some Remaining Snow Patterns, "Yukigata"

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ABSTRACT

Yukigatas are complex patterns on mountainsides formed by combinations of bright domains covered with remaining snow and dark domains of ground or trees. A positive type (bright) yukigata shows its pattern on the hillside as remaining snow and a negative type (dark) yukigata shows its pattern as ground or trees. The formation mechanism of yukigatas is closely related to snowpack, snowmelt and topography.

In this paper, I analyze two representative yukigatas, one positive and one negative, with aerial photographs and a Digital Elevation Model (DEM). Then, I examine the relation between the origin of yukigatas and topography.

The positive type yukigata called "Nichirin" (the sun) forms on landslide terrain that has an abrupt change in slope. Avalanche debris piles up below the steep slope in an area that is circular in shape. The negative type yukigata called "Hane–uma" (galloping horse) forms under a cliff on steep slopes of 35 degrees or more. Full–depth avalanches are apt to take place these denuding that slope. Thus, the formation of these two yukigatas is mainly due to topography that causes avalanche release.

1 INTRODUCTION

When seasonal snow retreats on a mountain, complex patterns appear in spring. Combinations of bright domains covered with snow and dark domains of ground or trees form these patterns. We Japanese, have looked upon some of these patterns as shapes of old farmers, animals such as oxen and horses, agricultural utensils, Chinese characters and others, and have called them "yukigata", which literally means "snow shape" (Japanese Society of Snow and Ice, 1990; Nohguchi *et al.*, in print). Yukigatas are classified into two types depending on whether the shape is bright or dark; the former are the positive type and the latter are the negative type.

Long ago, yukigatas were broadly and practically used as agricultural calendars in the snowy regions. Now, yukigatas are mostly forgotten, because modern technologies, especially weather forecasting have replaced the role of yukigatas. In Japan over three hundreds famous yukigatas have been handed down from generation to generation by oral tradition (Tabuchi, 1981) of which more than eighty are in Uuonuma County, Niigta Prefecture (Endo, private letter). Tabuchi's study of yukigatas is comparable to Wilson A. Bentley's pioneering study of snow crystals (Bentley and Humphreys, 1931). However, we cannot identify and delineate most of them. This is because, few yukigata inventories have been accumulated by natural scientist, except Tabuchi.

The formation mechanism of yukigatas is closely related to snowpack, snowmelt and topography. In this paper, I analyze two representative yukigatas, one positive and one negative, with aerial photographs and a Digital Elevation Model (DEM). Then, I examine the relation between the origin of yukigatas and topography.

2 TWO YUKIGATAS

2.1 Yukigata, "Nichirin" (the sun)

This yukigata is located on the west slope of Nomiokashira Mt. (1,843 m) south of the famous Ushiga–take Mt. (1,961.5 m) in Shimizu, Shiozawa Town, Minami–uonuma County, Niigata Prefecture (Hayashi, 1985; Yamada, 1995a; Yamada,1995b). As is expressed in its name, it is a circle–shaped, positive type yukigata (Fig. 1).

From distant views of this yukigata, I conclude that it originates because of landslide topography. By deciphering fall and winter aerial photographs and by terrain analysis, I determined the topographical origin of this yukigata and related it to snowpack phenomenon.

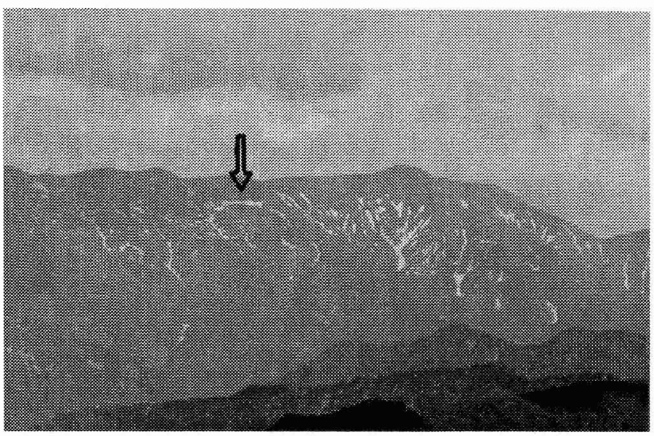


Fig 1. Yukigata, "Nichirin" (the sun) in Shimizu. Photographed by Mr. Kastuhisa Kawashima from the Uonuma Sky Line, June 6 1995.

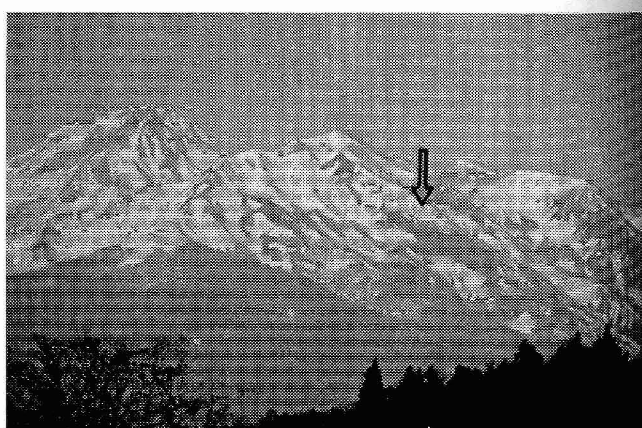


Fig 2. Yukigata, "Hane-uma" (galloping horse) in Myoukou. Photographed by Dr. Yasuaki Nohguchi from the Matsuga-mine Golf Course, May 10, 1995.

2.2 Yukigata, "Hane–uma (galloping horse)"

This yukigata is located on the west slope of Kanna–san Mt. (1,900.0 m) south of the volcano, Hiuchi–yama Mt. (2,461.8 m) in Myoukou Village, Naka–kubiki County, Niigata Prefecture (Yamada, 1996). As is expressed in its name, it is a galloping horse– shaped, negative type yukigata (Fig. 2).

In Myouko, "Hane–uma" had been used as an agricultural calender in particular, a yardstick for rice–planting. The best place to view this yukigata is in Sekiyama, Myoukou village, and the best time to see it is the middle of May (Saito, 1988). From distant views of this yukigata, I assume that its origin is also avalanche topography. By deciphering ground photographs taken in the thawing season and by terrain analysis, I determined its topographical origin and its relation to avalanches.

3 METHOD OF TERRAIN ANALYSIS

A pair of aerial photographs around yukigata, "Nichirin" were observed with a portable stereoscope. Digital elevation maps were made from reduced scale maps; 1:10,000 for "Nichirin" and 1:25,000 for "Hane–uma". Using these digital maps, contour lines and bird's–eye views were drawn and slope and its rate of change were calculated using a Digital Elevation Model (DEM) (Okimura, 1991; Richards, 1993; Iwahashi, 1994; Iwahashi and Kamiya, 1995). Then, the distinct features of the slopes, where these two yukigatas appear were determined from the view point of slope and its rate of change and their distribution.

3.1 Digital Elevation Map

I determined elevations on a 12.5 m grid in a 400 m x 400 m that included the yukigata, "Nichirin". For the yukigata, "Hane–uma", I determined elevations on a 10 m grid in a 600 m x 350 m area.

3.2 Digital Elevation Model (DEM)

In this DEM, I adopt the 3–dimensional equation of plane as an approximation of a local slope of grids. Then, I determined the regression plane by the method of least squares with two different grid systems. S Language and its graphics function (S–PLUS for Windows ver. 3.2) were used for calculating and drawing figures.

First, the eight–neighborhoods square grid system uses all the nine grid elevations (Z_j=1, •••9) within 3 x 3 square grids (Fig. 3). Secondly, four–neighborhoods square half– grid system uses all the four grid elevations (Z_j=1, •••4) within 2 x 2 square grids. Here, the half–grid means that the center of the square grid, at which slope gradient is calculated, does not coincide with the existing grid, but with a point between the existing grids. For simplicity, I used the center of grids as the origin of the coordinate, with the East–West direction as the X–coordinate and the North–South direction as the Y–coordinate.

The regression plane using these two square grid systems is easily calculated. The slope gradient θ (i.e., the inclination of the slope) at the center of the grid can be expressed by vector analysis as follows:

8–neighborhoods: $\theta = \tan^{-1}(a^2+b^2)^{1/2} = \tan^{-1}\{(H^2+V^2)^{1/2}\}/6D$, (1)

4–neighborhoods: $\theta = \tan^{-1}\{(H^2+V^2)^{1/2}\}/2D$, (2)

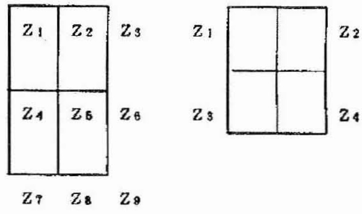


Fig. 3 Eight-neighbourhoods square grid system (left) and four-neighbourhood square halfgrid system (right). Z_j is an elevation and the center of grids is taken as the origin of the coordinate system

where a and b are coefficients of x, y in the plane equation Z=f(x, y)=ax+by+c, respectively, and D is the grid interval. The slope gradient θ, obtained from the eight–neighborhoods square grid system, is equal to a trend surface, which was obtained by algebra (Okimura, 1991). H and V are expressed by grid elevation values:

8–neighborhoods: $H=z_3+z_6+z_9-z_1-z_4-z_7$,
$V=z_1+z_2+z_3-z_7-z_8-z_9$. (3)

And, 4–neighborhoods: $H=z_2+z_4-z_1-z_3$,
$V=z_1+z_2-z_3-z_4$. (4)

The space second derivative (i.e., the rate of change of slope, the Laplacian), expresses the unevenness of the topography. Positive values indicate that the terrain is convex, and negative values indicate concave terrain. The calculated discrete Laplacian $\nabla f(x, y)$ is the relative value (Grid interval D=1), which is widely used in the field of remote sensing image analysis and its application to terrain classification (Richards, 1993; Iwahashi, 1994; Iwahashi and Kamiya, 1995):

$$\nabla f(x, y)=4z_5-z_2-z_4-z_6-z_8. \qquad (5)$$

4 RESULTS

I confirmed that the contour lines calculated by DEM check with those of the original analog map for both yukigata topographies. Also, both frequency distributions of slope gradient obtained from the eight–neighborhoods square grids system and the four–neighborhoods square half–grid system were approximately identical. For the two study areas, the grid interval of about 10 m had sufficient accuracy for a primary survey.

4.1 Nichirin

The fall and winter season aerial photographs (Fig. 4 and Fig. 5) show the morphological characteristics of landslide terrain, the track they leave on the hillside, a curved scarp at the head, and the hummocky mass of debris on their surfaces. Contour lines and an oblique bird's–eye view drawn from the digital elevation map including yukigata, "Nichirin" are shown in Fig. 6 and 7. The upper abrupt scarp and the lower hummocky mass of debris can be dimly recognized in both figures.

From the isopleth of the calculated slope gradient (Fig. 8), the angle of the abrupt slopes above "Nichirin" caused by a landslide ranges from 40 to 45 degrees. Slopes from 40 to 45 degrees are the sites where surface avalanches occur frequently. This topography suggests that the yukigata, "Nichirin" is mainly formed by the accumulation of debris piled up on a circle by avalanches. The circle–shaped remaining snow persists longer than the surrounding snowpack. Therefore, I conclude that the topographical origin of this positive type yukigata is landslide terrain where avalanches are apt to occur.

For such complex topography a graphic display of the slope gradient (i.e., the derivative of elevation), especially its bird's–eye view (Fig.8b) is more informative than a display of elevations. The area between the scarp and the hummocky mass of debreis is arc–shaped. The rate of change of slope (i.e., the Laplacian) was negative here and thus it is concave terrain.

A cross section of "Nichirin" was made from 1:10,000 scale. Elevations were determined every 10m along the WNW–direction fall line that goes through the center of the landslide with the origin of x–axis chosen at elevation 1,600 m. The top elevation of the scarp of the landslide was about 1,750 m and its length was about 80 m.

Comparing the ground photograph (Fig. 1) and aerial photographs (Figs. 4, 5) with the contour lines, slopes and cross section in Figures 6–9, the radius of "Nichirin" is about 150 m and the topmost edge of "Nichirin" (1,700 m) coincided with the hummocky mass of debris of past landslides. Furthermore, the lowest border of the landslide was estimated to be at least 1,650 m from the rate of change of the cross section.

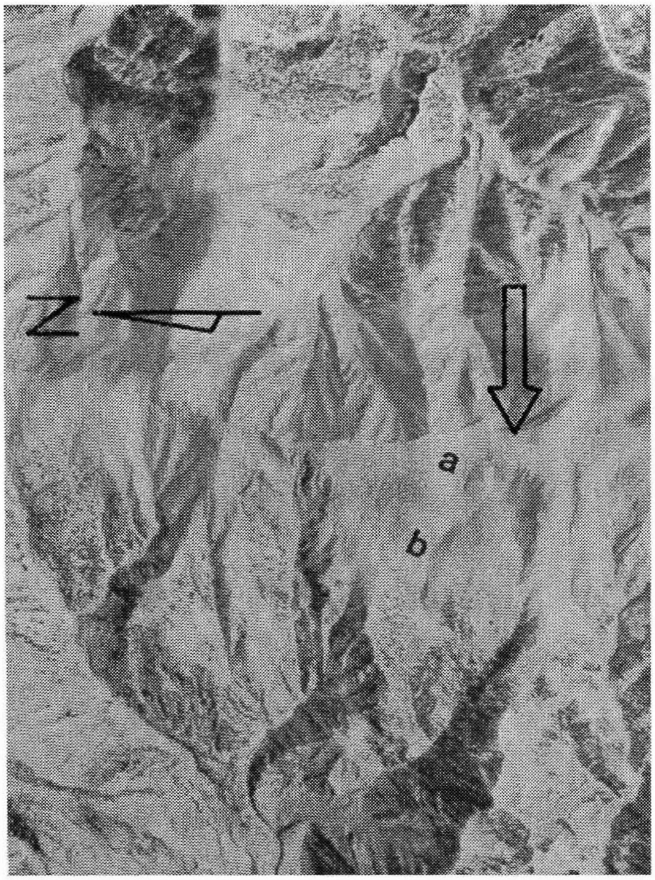


Fig. 4 Winter aerial photograph of the Yukigata, "Nichirin" (the sun) in Shimizu. Photographed by National Research Institute for Earth Science and Disaster Prevention, March 1 1964. A curved scarp is at (a) and hummocky mass of debris is at (b).

4.2 Hane–uma

From the photograph of yukigata, "Hane–uma" taken in the spring (Fig. 2), we can recognize many tracks of remaining snow at his mane, where snow blocks spilled and dropped down, and several slipover tracks on the remaining snow below his abdomen. On the contour map drawn from the digital elevation map (Fig. 10), there is a blank area at the cliff that correspond to the mane of the horse.

From the bird's–eye view of slope gradient near "Hane–uma" (Fig. 11), the body of the horse is on slopes of more than 35 degrees, and in the circumference gentle slope spreads. This topography suggests that the yukigata "Hane–uma" is mainly formed by the denudation of snowpack by avalanches. Small amounts of remaining snow melt away earlier than the surrounding snowpack.

Combining slope contour lines of more than 35 degrees and the cliff, the resulted outline (Fig.12) is similar to that of yukigata "Hane–uma" (Fig.13). Therefore, I conclude that the topographical origin of this negative type yukigata is cliff terrain and steep slopes where full–depth avalanches are apt to take place. The total length of Hane–uama was about 600 m and its width was about 200 m.

The white part between the tail and the rear leg (Fig. 13) is a gentle inclination ranging from 20 to 25 degrees (Fig. 12). Dotted lines in Fig. 12 do not follow the drawing rule stated above. This is because, in addition to slopes of the avalanche site, plants, trees and runout distances of avalanches are important issues.

5 CONCLUDING REMARKS

Yukigatas are strongly associated with accumulation and melting of snowpack and micro topography. In the case of the positive type yukigata, "Nichirin", land slide terrain and avalanche release due to abrupt terrain created by

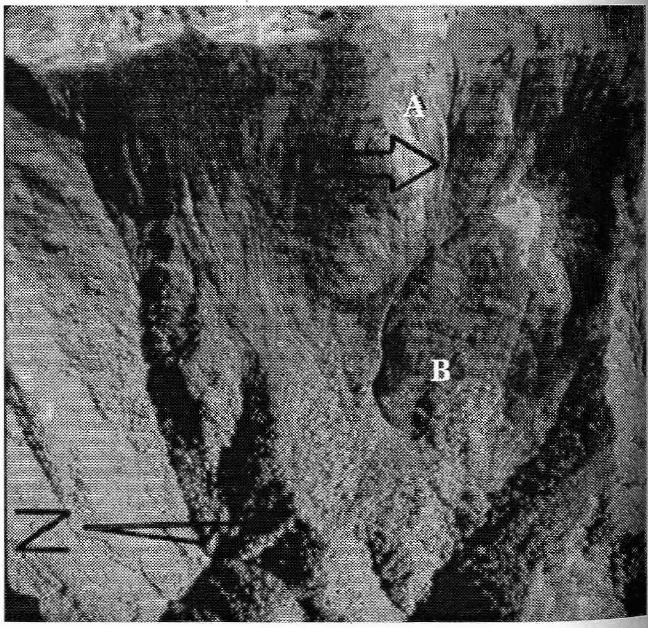


Fig. 5 Fall Aerial photograph of the Yukigata, "Nichirin" (the sun) in Shimizu. Photographed by Agriculture and Forestry Section, Shiowa Town Office, Fall, 1994. Trucks and curved scarp are at (A) and hummocky mass of debis is at (B).

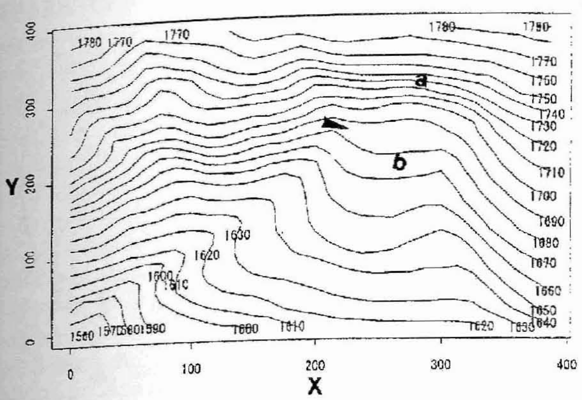


Fig. 6 Contour lines around, "Nichirin" in Shimizu. Positive direction of X-coordinate is south and positive direction of Y-coordinate is East. All units are meters.

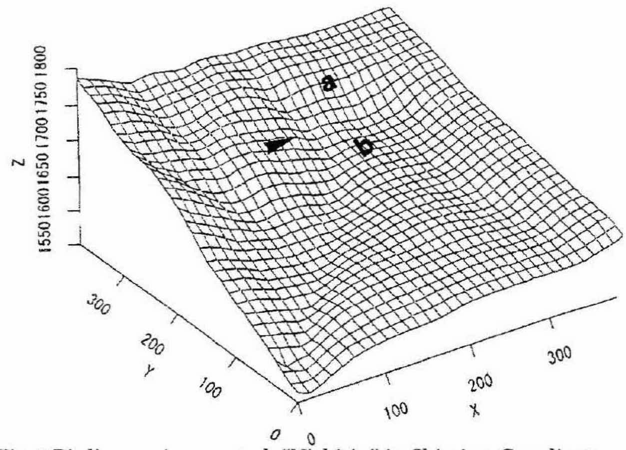
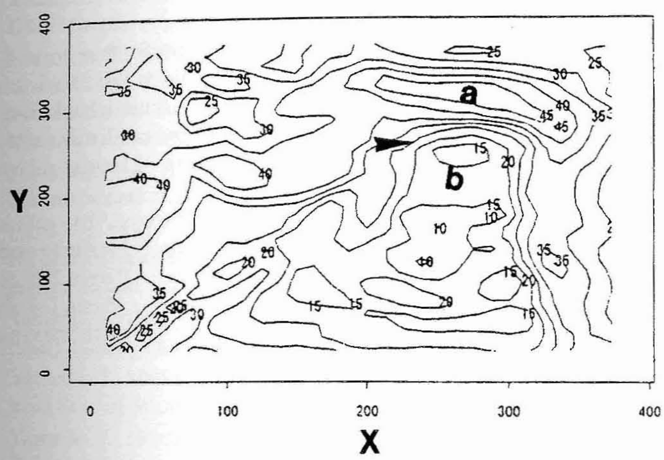
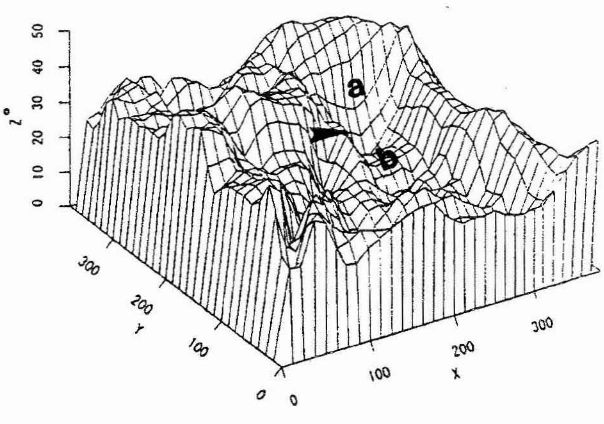


Fig. 7 Bird's-eye view around, "Nichirin" in Shimizu. Coordinate direction and units are the same as Fig. 6



a. Contour Lines



b. Obique, "bird's-eye view"

Fig. 8 Isopleth of slope gradient (left figure) and its bird's-eye view (right figure) around, "Nichirin" in Shimizu.

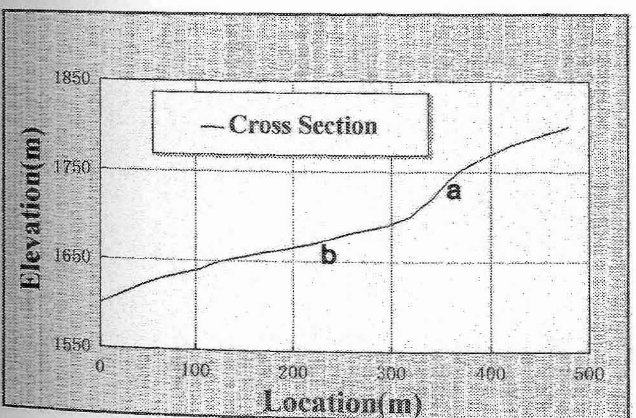


Fig. 9 Cross section around the yukigata, "Nichirin" in Shimizu

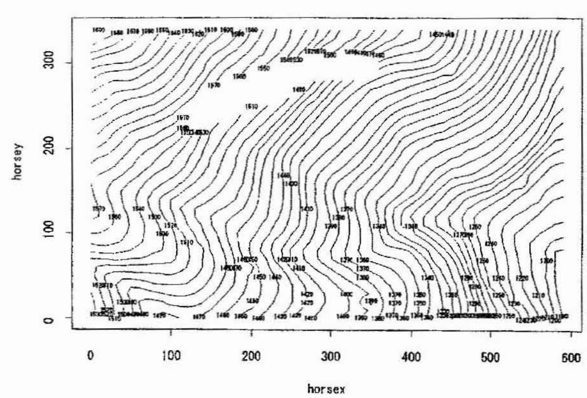


Fig. 10 Contour lines near trhe yukigata "(Hane-uma)." Positive direction of X-coordinate is north and positive direction of Y-coordinate is East. All units are meters.

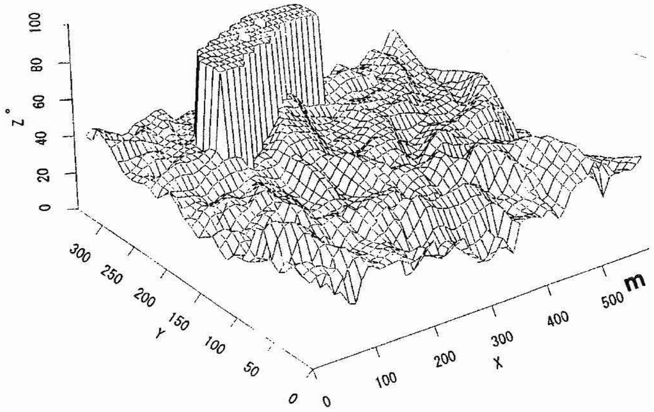


Fig. 11 Bird's-eye view of slope gradient by the eight-neighbourhoods square grid system near the yukigata, "Hane-uma".

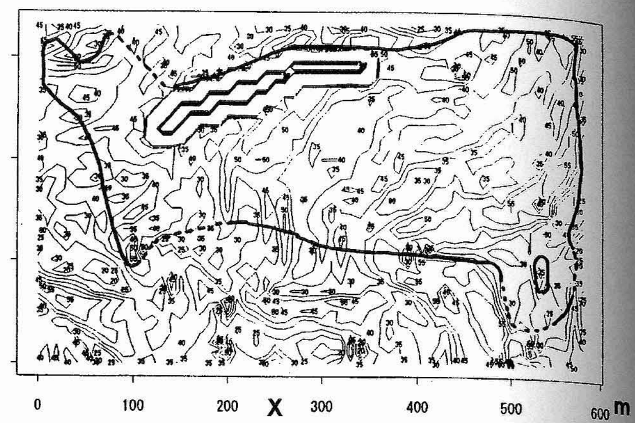


Fig. 12 Domain combining contour lines of more than 35 degrees and the cliff near "Hane-uma". The slope gradient was calculated by the four-neighbourhoods square half grid system.

landslides caused huge snow accumulations. In the case of the negative type yukigata, "Hane–uma", cliffs and steep slopes and full–depth avalanches caused denudation.

In order to confirm the formation mechanism, on–the–spot investigations and more detailed terrain analysis should be done by experts. The occurrence and disappearance of yukigatas should be observed and the mechanism of accumulation, melt and reaccumulation by avalanche and snow drift investigated.

Yukigatas, which had been valuable as the agricultural calenders in the past, will be useful not only for avalanche education but for better understanding of the avalanche phenomenon. Further, yukigatas are one of the best teaching materials for understanding nature and the connection of nature and human beings.

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Fig 13 Sketch of the yukigata, "Hane-uma" (galloping horse). Realistically designed from Fig.12 by Ms. Kanae Hirama.

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