On the slopes like avalanche chute and their distribution in heavily snowy regions in Japan

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Abstract

The authors define a slope like avalanche chute(SLAC) as a steep convergent slope having straight furrows which are seen like scratched patterns on aerial photographs. Slopes mentioned above are investigated by photo-interpretation,field survey,preparing large scale maps and measuring on 1:25000 topographic maps. Results obtaind are as follows;

1)In 3 sampled areas,the appearance ratio of SLAC is 77% to slopes where traces of full-depth snow avalanche(FDSA) are seen on aerial photographs taken in snowy season,and inversely the appearance ratio of traces of FDSA is 90% to SLAC.

2)The frequency distribution of inclination of SLAC are very similar to that of inclination of slopes where a FDSA occurs.

3)The appearance ratio of SLAC correlates positively to slope inclination and increases as snow depth is deeper.

4)SLAC is apt to appear on downwind slope more than on upwind slope.

1 Introduction

Slopes where full-depth snow avalanches (herinafter referred to as "FDSA") often occur have characteristic features such as poor vegetation,concave longitudinal section and so on. A straight furrow described later is one of these characteristics.

This paper defines a "slope like avalanche chute"(herinafter referred to as "SLAC") and explains the relationship between SLAC and the occurance of FDSA. Furthermore this paper shows some characteristics of SLAC derived from its distribution.

2 The definition of SLAC and some characteristics of straight furrows on SLAC

The authors define a SLAC as a steep convergent slope having straight furrows which are seen like scratched patterns on aerial photographs(See Photo 1). An example of SLAC having straight furrows are shown Fig.1.

A straight furrow mentioned above has following characteristics clarified by measuring aerial photographs and by field survey in sampled areas (See Fig. 2).

It is 2-4m in width and 2-4m in depth. Its longitudinal section is slightly concave and its cross section shows not V-letter shape but U-letter shape. Its bottom is composed of

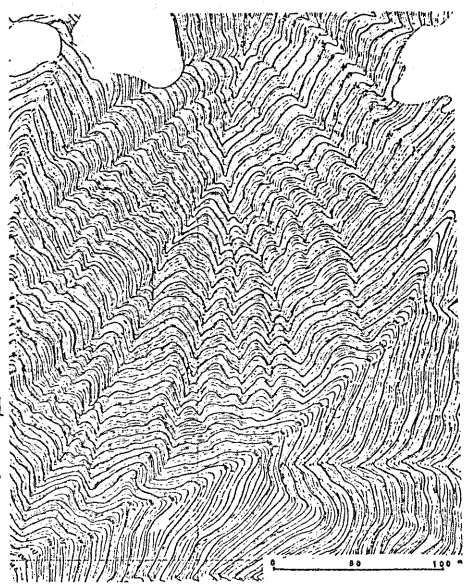

Figure 1 Contour map of SLAC

smoothed rock.

The authors can conclude from the characteristics mentioned above that this furrow differs from a gully.

3 Method

In this paper the authors investigate

a) the relationship between SLAC and occurrence of FDSA in 3 sampled areas,
b) the general distribution of SLAC in Japan,
c) the variation of appearance ratio of SLAC with slope inclination in 3 sampled areas,and
d) the variation of appearance ratio of SLAC in one section along the direction of the prevailing wind in winter

by interpretation of color aerial photographs at a scale of 1:15,000 taken in non-snow season and black-and-white aerial photographs at a scale of 1:10,000 taken when FDSA is apt to occur,and by measuring on 1:25,000 topographic maps.

4 Some characteristics of SLAC

4-1 SLAC having correlation with slopes where FDSA occurs

The following results are obtained.

a) The average appearance ratio of SLAC to slopes where traces of FDSA are seen on aerial photographs is 76.8% (See Table 1).
b) Inversely,the average appearance ratio of traces of FDSA to SLAC is 90.2% (See Table 2).

As the result mentioned above are obtained by interpretation of aerial photographs taken only one time, the occurrence ratio of FDSA on SLAC will get larger if we are able to use aerial

Table 1 Ratio of SLAC among slopes where traces of FDSA are seen on aerial photographs

	slope			total
	A	B	C	
SLAC	368 (77)	128 (88)	277 (72)	773 (76.8)
NON-SLAC	109 (23)	18 (12)	106 (28)	233 (23.2)
total	477 (100)	146 (100)	383 (100)	1006 (100)

Note:1) Slope means a slope where a trace of FDSA is seen on aerial photographs.
2) Upper figures show number of slopes sampled.
3) Lower figures in parentheses show ratio.
4) A:Uonuma,B:Otani,C:Oguchi (See Fig.2)
5) photographs used
1:15000 color aerial photophotographs
1:12500 aerial photographs taken in late April

Table 2 Ratio of slopes where a trace of FDSA is seen on photographs among SLAC

	SLAC			total
	A	B	C	
slopes where a trace of FDSA is seen on photos	368 (91)	128 (83)	277 (93)	773 (90.2)
slopes where no trace of FDSA is seen on photos	37 (9)	27 (17)	20 (7)	84 (9.8)
total	405 (100)	155 (100)	297 (100)	857 (100)

Note: See notes of Table 1.

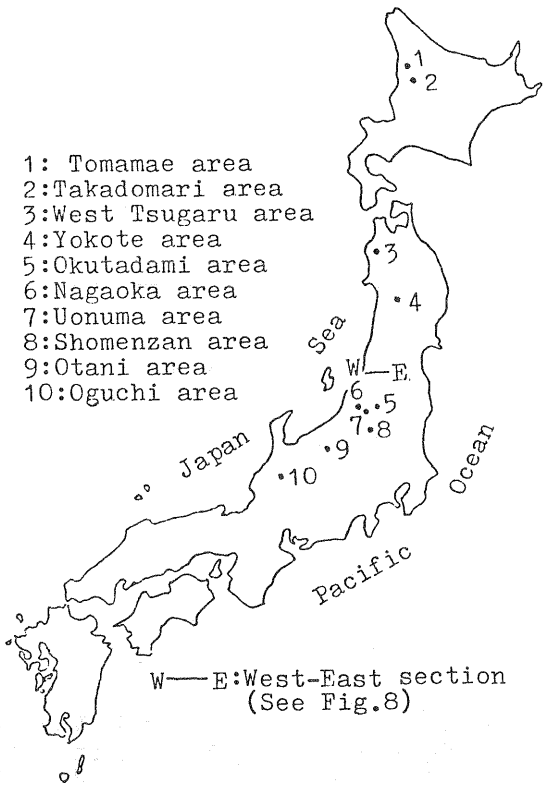

Figure 2 Location of sampled areas

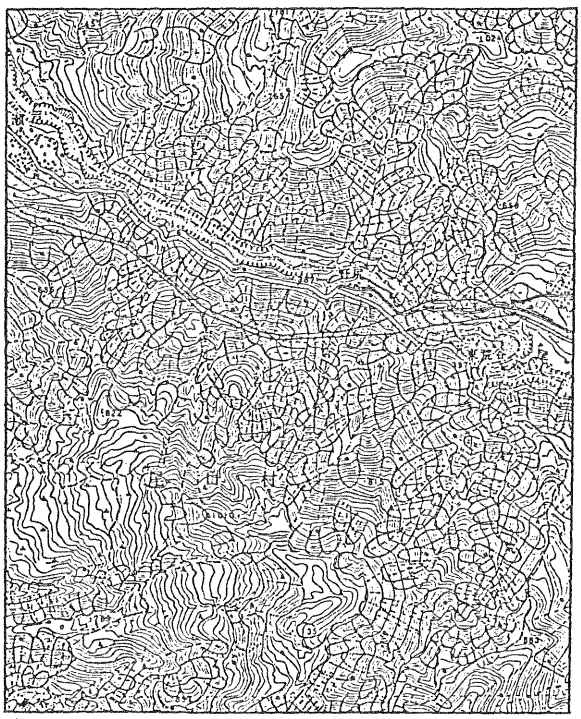

Figure 3 SLAC and slopes where FDSA occured in Oguchi area

SLAC

slope where FDSA is seen

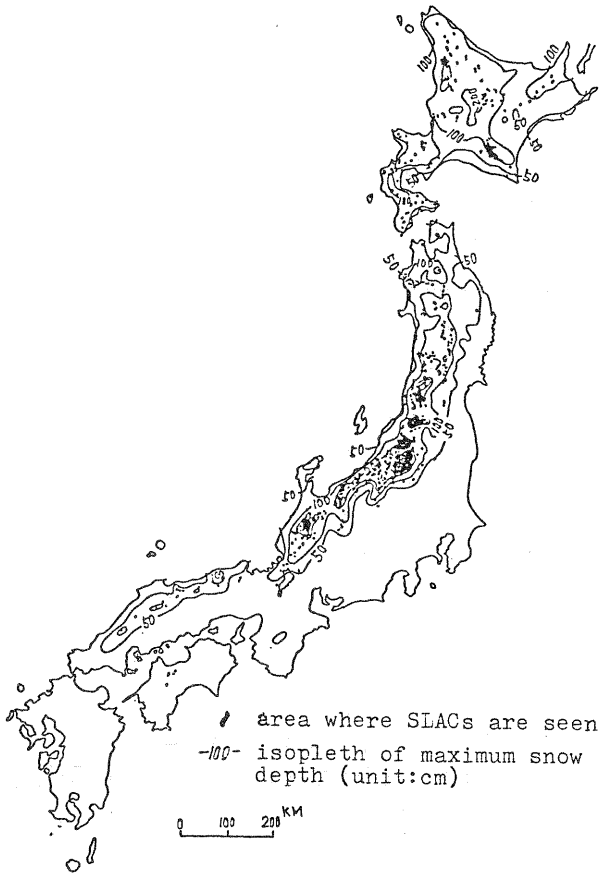

Figure 4 The general distribution of SLAC

Note: 1) The distribution of SLAC has been surveyed by photo-interpretation.
2) The isopleth of maximum snow depth is compiled from data of Meteorological Agency.

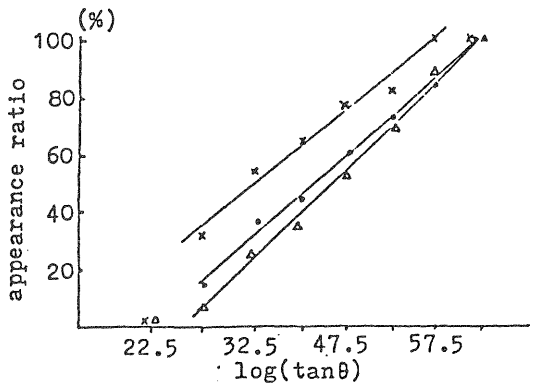

Figure 5 Variation of appearance ratio of SLAC to gradient

Note: θ:slope inclination (degree)
×:Nagaoka(461)
•:West Tsugaru(657)
△:Tomamae(395)
(Figures indicate number of slopes.)
Locations are shown in Fig.2.

photographs taken many times in snow season. However, the appearance ratio of SLAC in these 3 sampled areas is rather large from the result of survey of the general distribution of SLAC in following section. Therefore it can be concluded that FDSA occurs on a slope which is SLAC, but it cann't be insisted that FDSA doesn't occur on a slope which isn't SLAC.

Accordingly, it can be concluded that SLAC has correlation with slopes where FDSA occurs.

4-2 The general distribution of SLAC in Japan

The general distribution of SLAC in Japan shown in Fig.4 has following characteristics.

a) Distributed areas of the SLAC correspond to heavily snowy regions.

b) In Pacific coast side, SLAC is scarecely distributed except for high mountainous regions where it snows.

c) In Hokkaido district and in western part of Honshu from Hakusan area appearance ratio of SLAC is rather smaller comparing with that of slope where FDSA is expected to occur judging from slope inclination and vegetation.

d) SLAC tends to appear in some areas composed of special geological composition, such as effusive rocks (andesite, rhyolite, tuff), plutonic rocks (granite), metamorphic rocks, tertiary rocks and so on. In densely distributed areas, however, SLAC appears in an area composed of any geological composition in spite of its tendency. The fact mentioned above has been derived from comparing the general distribution of SLAC with 1:200,000 geological maps prepared by Land Agency.

It is the important point whether SLAC can be correctly extracted in order to preparing a map of the general distribution of SLAC in Japan. There is similar topography which is hardly distinguished only by photo-interpretation in volcanoes. Volcanic areas where topography like SLAC is and which SLAC is not seen near are excluded from Fig.4.

Interpreting photographs, some SLACs which seem to be invaded by vegetation are seen. Moreover there are some SLACs whose furrows are obscure.

4-3 The variation of appearance ratio of SLAC with slope inclination in 3 sampled areas

The variation of appearance ratio of SLAC with slope inclination is shown in Fig.5 in 3 sampled areas (See Fig.2). Frequency distribution of SLAC to slope inclination and also that of FDSA are shown in Fig.6 and Fig.7 respectively. Comparing Fig.6 with Fig.7, frequency distribution of SLAC is very similar to that of FDSA. As shown in Fig.5, appearance ratio of SLAC increases as slope

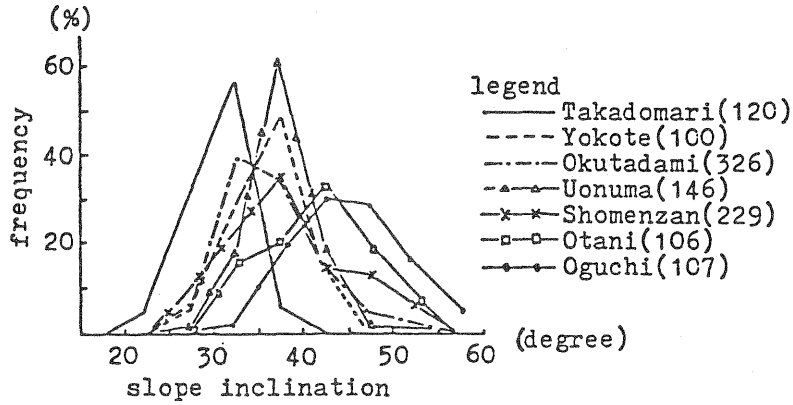

Figure 6 Frequency distribution of SLAC

Note: 1) Locations are shown in Fig.2.
2) Figures indicate number of slopes.

inclination is larger. In 3 sampled areas, appearance ratio of SLAC relates linearly to logarithm of gradient of slope inclination. And it can be expected that appearance ratio of SLAC grows larger as snow is deeper from Fig.5 and 6.

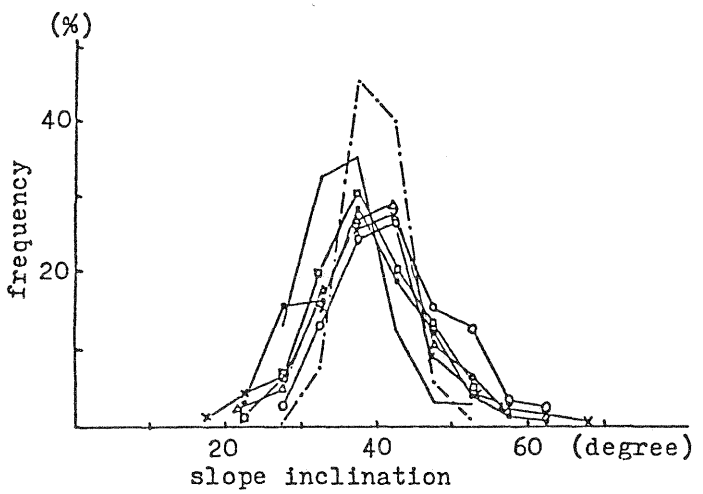

Figure 7 Frequency distribution of FDSA (after Highway Research Committee)

4-4 The variation of appearance ratio of SLAC in a section roughly along the direction of the prevailing wind in winter

A variation of appearance ratio of SLAC is shown in Fig.8a in west-east section expeced roughly the direction of the prevailing wind in winter (See Fig.2) and a profile along the section is shown in Fig.8b. In this survey, each sampled unit is normally 2km in north-south side and 1km in west-east side respectively. As shown in Fig.5, distribution of slope inclination has an effect on appearance ratio of SLAC. Therefore, appearance ratio is reduced in case of average distribution of slope inclination in sampled areas in order to take off the influence of distribution of slope inclination.

It is expected that the appearance ratio of SLAC increases as average altitude becomes higher in a sampled area and that appearance ratio of SLAC in downwind side becomes larger than that in upwind side.

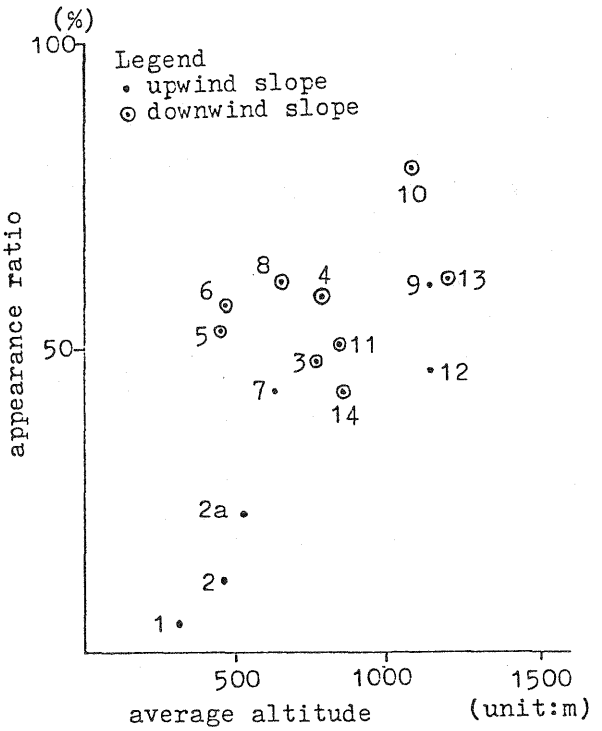

Figure 8a Variation of appearance ratio of SLAC
Note:1)Figure indicates sample no.
2)Location of sample is shown in Fig.8b.

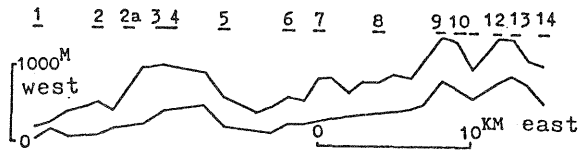

Figure 8b Profile of a west-east section
Note:1)Figure indicates location of sample shown in Fig.8a.
2)Location of this section is shown as W-E section in Fig.2.
3)The prevailing wind is from west in this region in winter.

5 Discussion

The general distribution of SLAC is clarified as shown in Fig.4. And an example of distribution of SLAC is shown in Fig.3 and 8a. From these figures, it is inevitable to conclude that SLAC has something to do with snow and that rainfall doesn't play an

important role in forming of SLAC. It is important to be free from mistakes in case of interpreting whether a slope is SLAC. As explaining in Section 4-2, few samples are hardly distinguished from SLAC by photo-interpretation in some volcanoes such as Kirishima. However, it is not necessary to change the aforementioned conclusion.

It is clarified that FDSA occurs frequently on SLAC as shown in Table 1. Therefore, SLAC is considered to be a indicator of a slope where FDSA will occur. Inversely, however, it is not right that FDSA doesn't occur on a slope which is not SLAC. Because distribution of SLAC is sparse in Hokkaido and in west part of Honshu Island. The reason of this couldn't be made clear. It is a problem to solve this.

It is hardly considered that a furrow is eroded only by running water because cross section of a furrow shows a U-letter shape. However, it is not expected that FDSA make SLAC because FDSA frequently covers some furrows at once and because SLAC is sparsely distributed in Hokkaido and in west part of Honshu. SLAC couldn't be traced to its origins in this investigation. It remains a question to clarify in the future.

There are following topographic features referred to when we cosider how SLAC has been formed.

a) avalanche chute defined by Shimokawa (1980)
This avalanche chute is frequently steeper than SLAC and is eroded more severely than SLAC. Shimokawa insisted in his paper that the main agent making avalanche chute is snow avalanche.

b) slope without furrows where FDSA is expected to occur
There are some slopes without furrow where FDSA is interpreted to occur because of poor vegetation, steep inclination and so on. Inclination of these slopes is mostly less steeper than that of SLAC.

Therefore, a group of eroded slopes are expected in snowy regions. Avalanche chute, SLAC, and slope without furrow can be arraged in order of severity of erosion which they have suffered.

There are SLAC where furrows become indistinct because of invasion of vegetation to them. This fact raises the following question. When was such furrow mainly formed?

One of ways how to procure materials which are needed to solve the remained question is to investigate distribution of SLAC in complete detail and to compare its distribution with distribution of many kinds of factors such as snow depth, occurrence of FDSA, and so on.

6 Conclusion

The result procured in this survey are as follows;

a) SLAC appears in heavily snowy region and doesn't appear in the Pacific Coast side except for high mountain.

b) FDSA occurs on almost all SLACs. Inversely, however, FDSA doesn't always occur on a slope wich is neither SLAC nor "avalanche chute".

c) Appearance ratio of SLAC relates to slope inclination and snow depth.

d) Frequency distribution of inclination of SLAC is very similar to that of inclination of slopes where FDSA occurs.

And following questions remain.

a) What is the forming agent of SLAC?

b) When was SLAC mainly formed? Or ,has SLAC been forming now?

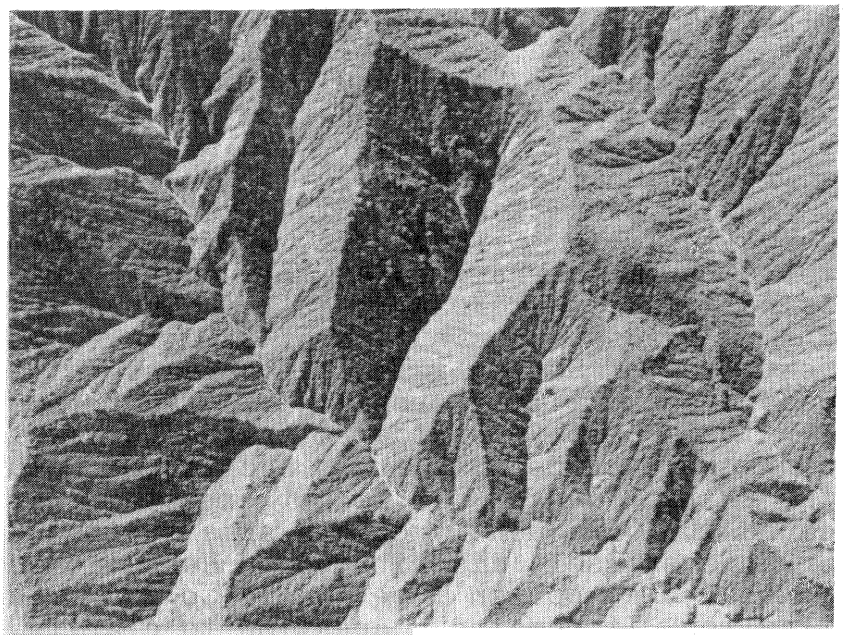

Photo 1a
A sample of SLAC in Hokuriku District

Note:
photo scale 1:15000
place Yunotani Mura

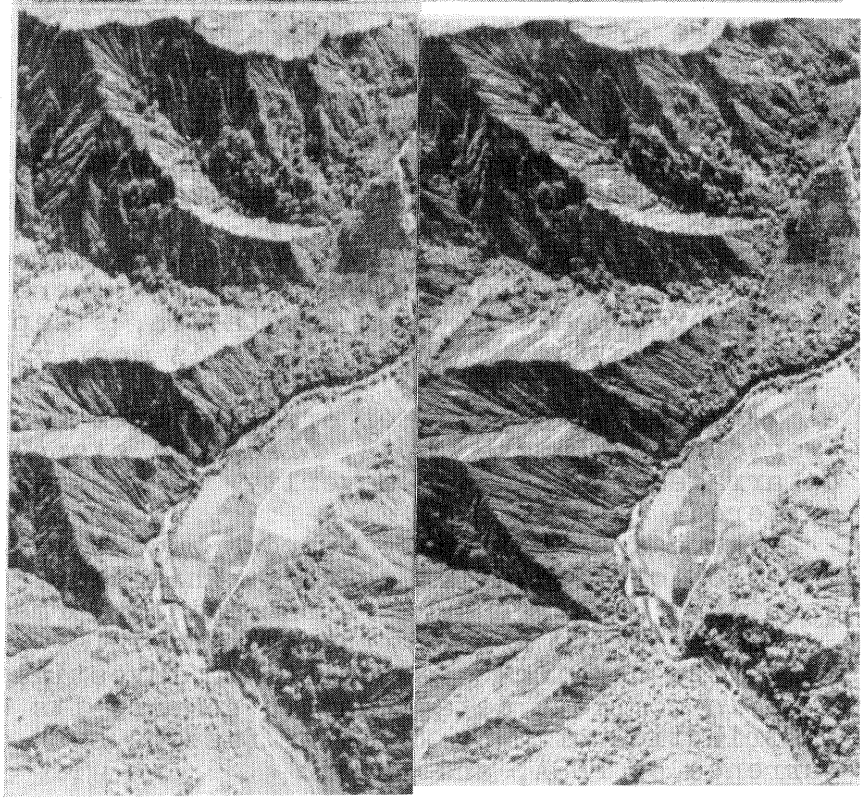

Photo 1b
Stereo photographs of SLAC

Note:
Photo scale 1:15000
place Hakusan area

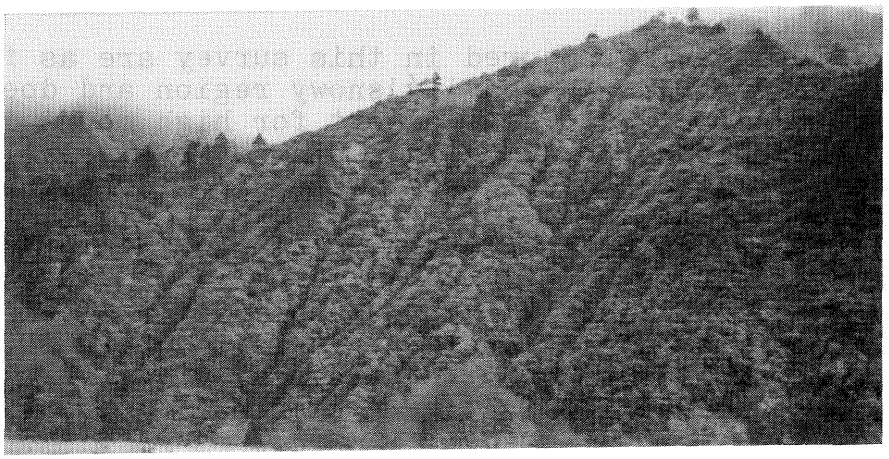

Photo 1c
Terrestrial photograph of SLAC