| Environ. Sci., Hokkaido University | 12 (2) | 187~197 | Dec. 1989 |
| --- | --- | --- | --- |

# Clast-Fabric Strength in Periglacial Slope Deposits as a Function of Clast Size and Shape

Kenshiro Yamamoto
Laboratory of Fundamental Research, Division
of Environmental Structure,
Graduate School of Environmental Science, Hokkaido University,
Sapporo 060, Japan

**Abstract**

Three-dimensional fabric analysis have done to determine the process related to material transportion and to find some relations of fabric strength both to clast size and shape on a slope deposits in the Hidaka Mountains, Hokkaido, Japan. Fabrics of the slope deposits shown in logarithmic ratio plots have higher C values and K values calculated by eigenvalue method than those of deposits under non-periglacial environment. The distribution in the logarithmic plot in the study site is entirely identical with those of solifluction deposits. The results of this analysis indicate that fabrics in the study site can be regarded as solifluction fabrics. Fabric data from this solifluction deposits indicate that the clast shape and size exert a strong influence on its fabric strength. Using Zingg's shape definition, clasts of Blades and Rods have stronger clast-fabric strength than those of Discs and Spheres. Welch's statistical test for population mean of fabric strength indicate that the fabric strength of Blades and Rods were significantly different from those of Discs and Spheres. Wilcoxen's rank sum test indicates that b/a-axis ratio influences on its fabric strength, while c/b-axis ratio have no relation to the latter. The linear regression between a-axis size and its fabric strength shows strong relation among them. Thus clasts with longer a-axis and lower b/a axis -ratio have strong fabric than clasts with shorter a-axis and higher b/a-axis ratio.

**Key Words:** periglacial slope deposits, fabric strength, vector magnitude, eigenvalue method, Hidaka Mountains

## 1. Introduction

The azimuths and dips of clasts, commonly referred to as fabric, has been utilized in numerous geomorphic and sedimentological studies in order to determine flow direction of sediments and process in many sedimentary environments. Although the fabrics of fluvial and glacial sediments have been much studied, slope deposits especially under the periglacial environment have received less attention. Under the above conditions, there is considerable difference of opinion as to the significance of fabrics in viscous fluid deposits.

Drake(1974) insisted that the clast shape influence on its fabrics in viscous fluid deposits. In contrast to this, Mills(1977) indicate that there is little relation between the clast fabric and the clast size or the clast shape in viscous fluid deposits. Although many investigators (e.g., Holmes, 1941; Harrison, 1957; Anderson and King, 1968; Kruger, 1970) agreed with Drake's opinion, there seems to be no consensus among investigators as to the nature of this relationship. Existence of the different views between Drake and Mills is probably due to shortage of the number of investigated clasts. As apparent orientation preference in small samples may arise by chance, the result may be misleading.

Few studies of material transportion on slope based on fabric analysis have been done in Japan. Recently the author analysed the two-dimensional fabric of some slope deposits (Yamamoto, 1989). Nevertheless three-dimensional fabric analysis have not been done yet.

The purpose of this study is to determine the process related to material transportation on slope by three-dimensional fabric analysis and to evaluate the clast size and the clast shape influence on viscous fluid's fabrics. For this purpose, the author selected a study slope in the Hidaka Mountains, Hokkaido, Japan, and measured the orientation and the shape of clasts excaved from the slope deposits.

## 2. Regional setting

The study site is located at approximately 3km northeast of Nissho Pass in central Hokkaido(Fig. 1). Altitude of the site is 498m a.s.l.. Slope angle is 14 degree, and slope orientation (North is defined as 0 degree, and calculated in clockwise) is 3 degree which is the direction of the surface trend. Slope deposits, more than 1-5mthick, are derived from granite basement and are underlain by Ta-d pumice which falled at about 9,000y.B.P.. The

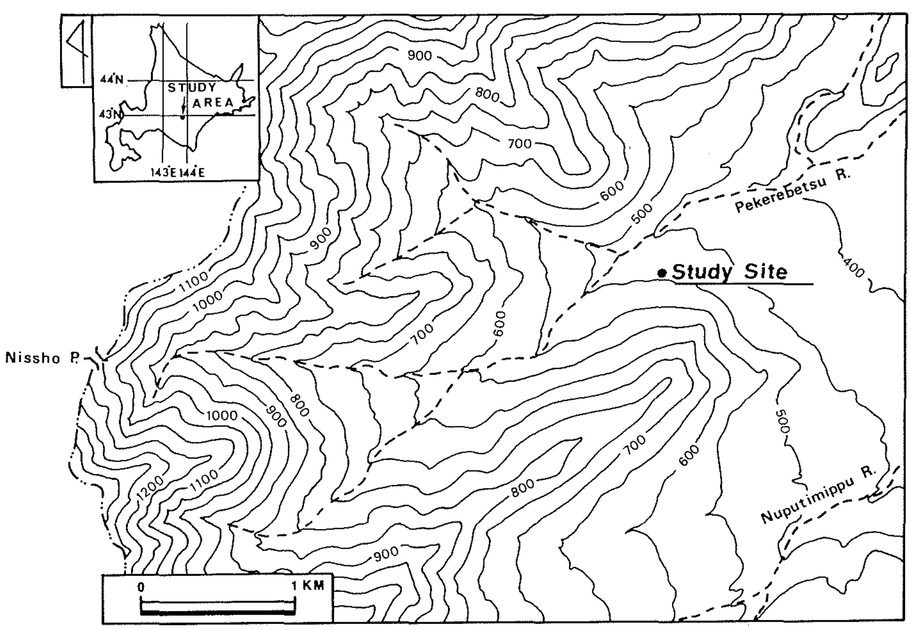


**Fig. 1** Map showing study site

slope deposits are poorly sorted and composed of angular-subangular gravels. Based on the results of two-dimensional fabric analysis of slope deposits on study site, it is estimated that the deposits is of periglacial origin, probably transported by solifluction (Yamamoto, 1989).

## 3. Procedure

Azimuths and dips of the long axis (=a-axis) of clasts were measureed in 2-3 meters depth from the bottom of Ta-d pumice, and a total of 2,350 stones was measured. The criteria of the selection was length of a-axis over 2 cm. The mean orientation and fabric strength were calculated by Krumbein's(1939) vector magnitude method, and Scheidegger's(1965) and Mark's(1973) eigenvalue method. Krumbein's method is two-dimensional analysis(dips ignored) and allows the vector mean(the resultant vector) and the vector magnitude to be calculated. Scheidegger's and Mark's method is three-dimensional analysis and produces three eigenvalues $\lambda 1 \geqq \lambda 2 \geqq \lambda 3$ and their associated mutually perpendicular eigenvectors V1, V2, and V3. The quantities S1, S2, and S3 are defined by $Si = \lambda i/N$, where N is the number of observations.

The relationship of clast shape to fabric was investigated by utilization of Drake's

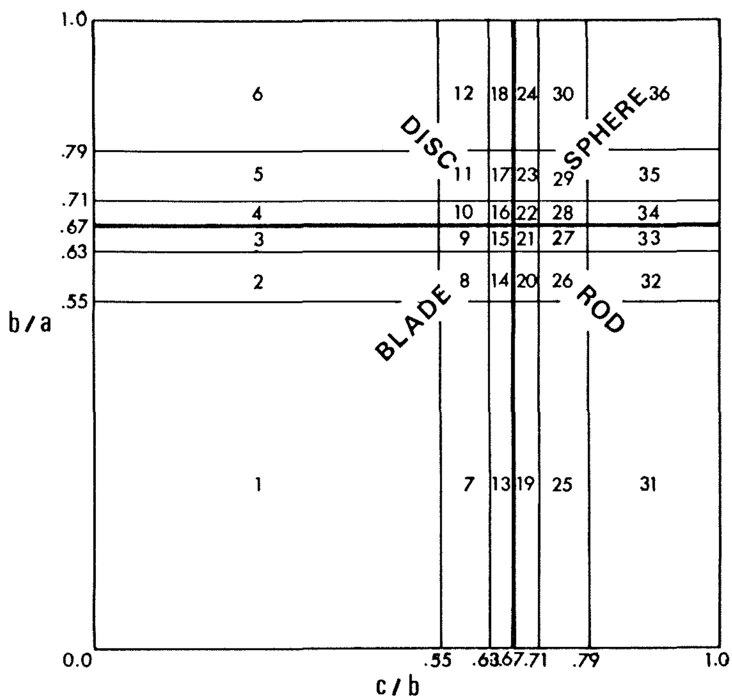


**Fig. 2** Categorical subdivisions of clast shape based on axis ratio of c/b and b/a. Blade, disc, rod, and sphere are subdivided by Zingg(1935). Numbers are category numbers proposed by Drake(1974).

(1974) method. First, clast shape was classfied by axial ratio into four types: Blade, Disc, Rod, and Sphere which are defined by Zingg(1935). Further clast shape was classfied by detailed axial ratio into Drake's 36 categories(Fig. 2) and the fabric characteristics of each category then evaluated separately.

The relationship of axial length to fabric was also investigated. Correlation between fabric and a-axis length was calculated in order to determine whether significant relationships existed. Total of 2,350 stones were classfied by length of a-axis into 20 classes and the fabric characteristics of each class then evaluated separately. Although statistically the difference of the number of stones measured in each category and class influence significance level of fabric strength value related to the null hypothesis that deposits have random fabric (=have no prefered orientation), the difference dose not influence fabric characteristics at all theoretically (Curray, 1956; Anderson and Stephens, 1972).

## 4. Results and Discussion

1) Fabric characteristics of the slope deposits in the study site

Table 1 shows fabric characteristics in each Drake's category, and it is recognized that vector magnitude ranges from 18.4 to 72.2 and S1 value from 0.858 to 0.967. Table 2 also shows fabric characteristics in each class classfied by length of a-axis, and it is recognized that the changes in vector magnitude and S1 value closely related to the increase in a-axis length.

Logarithmic ratio plots of eigenvalue of which were developed byWoodcook(1977) is usefull to clear fabric characteristics by using three-dimensional fabric data. Fig. 3 shows logarithmic ratio plots which were derived from data listed on Table 1. All plots shown in Fig. 3 are in a range with $C>2$ and distribute in clusters. In this logarithmic ratio plots, C is a fabric strength which equals $\ln(S1/S3)$. When the term "stronger" fabric is used to mean larger vector magnitude, S1 value, or C value, and "weaker" fabric to mean smaller values of those variables, fabric strength varies from weaker fabric in close proximity to the orign of graph to stronger fabric as values of C increase. Fig. 3 indicates that Blade and Rods have stronger fabric than Discs and spheres, resulted from difference of C values. Further fabric shape is subdivided into cluster and girdle by using K, which is defined as $\ln(S1/S2)$ / $\ln(S2/S3)$. Girdle plots within $0<K<1$ and cluster within $1<K=\infty$ and the transition of girdle and cluster occurs at $K=1$. Values close to the x-axis, uniaxial girdles, occur when two eigenvalues are large and one is small. If the large values are apporoximately equal, the distribution is a symmetrical girdle. Values near the y-axis, uniaxial clusters, occur when one eigenvalue is large and two are small.

Fig. 4 shows logarithmic ratio plots which were derived from data listed on Table 2. Plots shown in Fig. 4 vary from the axial cluster to the transition girdle and cluster, and distribute in a range with $C>2$. Plots indicate that class with the longer a-axis length have higher C value.

Nelson(1985) summarized the fabrics that have been observed in various types of deposits. In solifluction deposits, fabrics have higher C values than those of deposits under different environment, and plots distribute in clusters. The distribution of logarithmic ratio plot in the study site is entirely identical with those of solifluction deposits. As a result of this, it can be stated that fabrics in the study site can be regarded as solifluction clast fabrics.

2) Relation of fabric to clast shape and size

Fig. 5 shows population mean and range both of vector magnitude and S1 value in each clast shape. Range of Blades' vector magnitude and S1 value do not overlap those of Discs' and Spheres' at 90% confidence interval. Mean of Rods' vector magnitude and S1 value are

**Table 1** Characteristics of the fabrics separated by each Drake's category.

| Drake's category number | N | Clast size | | Clast fabric | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | length of a-axis | | two-dimensional analysis | | three-dimensional analysis | | | | |
| | | Av. (cm) | Sd. (cm) | V.Mg. (%) | V.Me. (°) | S1 | S2 | S3 | ln(S1/S2) | ln(S2/S3) |
| 1 | 56 | 14.7 | 9.37 | 59.7 | 6.5 | .927 | .053 | .020 | 2.862 | 0.975 |
| 2 | 82 | 10.3 | 8.28 | 45.3 | 358.7 | .952 | .031 | .017 | 3.426 | 0.601 |
| 3 | 57 | 9.9 | 6.59 | 48.0 | 0.8 | .937 | .042 | .021 | 3.105 | 0.693 |
| 4 | 72 | 7.8 | 4.11 | 37.1 | 5.8 | .916 | .057 | .027 | 2.777 | 0.747 |
| 5 | 167 | 8.1 | 6.09 | 42.8 | 4.1 | .912 | .056 | .032 | 2.790 | 0.560 |
| 6 | 370 | 7.5 | 4.91 | 33.8 | 2.0 | .901 | .062 | .037 | 2.676 | 0.516 |
| 7 | 35 | 21.3 | 28.40 | 50.0 | 5.9 | .919 | .065 | .016 | 2.649 | 1.402 |
| 8 | 52 | 10.0 | 11.15 | 45.1 | 356.0 | .948 | .033 | .019 | 3.358 | 0.552 |
| 9 | 37 | 7.7 | 4.08 | 50.3 | 355.5 | .925 | .054 | .021 | 2.841 | 0.944 |
| 10 | 48 | 8.1 | 4.86 | 37.5 | 359.4 | .902 | .057 | .041 | 2.762 | 0.329 |
| 11 | 94 | 6.1 | 4.23 | 44.4 | 356.7 | .922 | .055 | .023 | 2.819 | 0.872 |
| 12 | 150 | 5.7 | 4.71 | 19.9 | 5.3 | .860 | .082 | .058 | 2.350 | 0.346 |
| 13 | 17 | 13.8 | 21.50 | 72.2 | 13.8 | .967 | .028 | .005 | 3.542 | 1.723 |
| 14 | 32 | 7.4 | 4.32 | 60.9 | 11.8 | .942 | .040 | .018 | 3.159 | 0.799 |
| 15 | 25 | 12.8 | 16.82 | 61.3 | 3.0 | .934 | .049 | .017 | 2.948 | 1.059 |
| 16 | 22 | 6.2 | 2.87 | 41.0 | 350.1 | .900 | .074 | .026 | 2.498 | 1.046 |
| 17 | 35 | 6.4 | 5.70 | 28.7 | 5.6 | .927 | .040 | .033 | 3.143 | 0.192 |
| 18 | 46 | 5.6 | 2.80 | 40.0 | 4.6 | .909 | .073 | .018 | 2.522 | 1.400 |
| 19 | 19 | 13.2 | 10.06 | 68.9 | 357.3 | .940 | .050 | .010 | 2.934 | 1.609 |
| 20 | 25 | 6.3 | 3.99 | 32.4 | 11.7 | .915 | .052 | .033 | 2.868 | 0.455 |
| 21 | 19 | 7.4 | 6.90 | 57.7 | 3.2 | .964 | .028 | .008 | 3.539 | 1.253 |
| 22 | 17 | 6.3 | 2.90 | 52.4 | 10.3 | .935 | .052 | .013 | 2.889 | 1.386 |
| 23 | 33 | 6.6 | 6.42 | 48.1 | 1.1 | .924 | .060 | .016 | 2.734 | 1.322 |
| 24 | 55 | 5.5 | 3.18 | 38.5 | 357.3 | .863 | .087 | .050 | 2.295 | 0.554 |
| 25 | 46 | 11.0 | 7.26 | 44.5 | 7.0 | .933 | .046 | .021 | 3.010 | 0.784 |
| 26 | 69 | 9.8 | 22.61 | 51.8 | 357.1 | .896 | .072 | .032 | 2.521 | 0.811 |
| 27 | 43 | 6.2 | 3.84 | 36.3 | 355.7 | .891 | .065 | .044 | 2.618 | 0.390 |
| 28 | 36 | 5.7 | 2.68 | 21.8 | 3.8 | .949 | .030 | .021 | 3.454 | 0.357 |
| 29 | 60 | 5.6 | 2.47 | 47.3 | 359.2 | .917 | .055 | .028 | 2.814 | 0.675 |
| 30 | 53 | 4.9 | 2.15 | 32.3 | 359.7 | .904 | .055 | .041 | 2.799 | 0.294 |
| 31 | 112 | 10.5 | 7.78 | 56.9 | 3.3 | .929 | .051 | .020 | 2.902 | 0.936 |
| 32 | 105 | 6.5 | 3.65 | 41.0 | 5.3 | .922 | .058 | .020 | 2.766 | 1.065 |
| 33 | 66 | 6.6 | 3.40 | 40.8 | 351.2 | .921 | .050 | .029 | 2.913 | 0.545 |
| 34 | 39 | 5.5 | 2.11 | 18.4 | 9.0 | .880 | .073 | .047 | 2.489 | 0.440 |
| 35 | 70 | 6.0 | 3.83 | 27.9 | 3.2 | .918 | .057 | .025 | 2.779 | 0.824 |
| 36 | 86 | 4.6 | 1.75 | 31.2 | 8.2 | .858 | .093 | .049 | 2.222 | 0.641 |

N : the number of observations  Av. : the average of length of a-axis in each category
Sd. : the standard deviation of length of a-axis in each category
V.Mg. : Vector Magnitude  V.Me. : Vector Mean

**Table 2** Characteristics of the fabrics in each class of a-axis length.

| Clast size | | N | Clast shape | | | | Clast fabric | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Length of a-axis(cm) | class mark(cm) | | Clast shape B(%) | D(%) | R(%) | S(%) | two-dimensional analysis V.Mg. (%) | V.Me. (°) | three-dimensional analysis S1 | S2 | S3 | ln(S1/S2) | ln(S2/S3) |
| 2 ≦ a < 3 | 2.5 | 111 | 6.3 | 41.4 | 12.6 | 39.6 | 29.5 | 1.9 | .898 | .061 | .041 | 2.689 | 0.397 |
| 3 ≦ a < 4 | 3.5 | 437 | 11.4 | 41.2 | 18.8 | 28.6 | 33.9 | 2.1 | .910 | .060 | .030 | 2.719 | 0.693 |
| 4 ≦ a < 5 | 4.5 | 412 | 11.4 | 45.0 | 22.5 | 21.1 | 33.6 | 359.1 | .906 | .058 | .036 | 2.749 | 0.477 |
| 5 ≦ a < 6 | 5.5 | 331 | 15.7 | 45.0 | 19.0 | 20.2 | 33.3 | 3.0 | .896 | .064 | .040 | 2.639 | 0.470 |
| 6 ≦ a < 7 | 6.5 | 199 | 13.1 | 46.2 | 19.6 | 21.1 | 26.8 | 358.0 | .893 | .064 | .043 | 2.636 | 0.398 |
| 7 ≦ a < 8 | 7.5 | 172 | 11.6 | 45.9 | 26.7 | 15.7 | 30.5 | 357.6 | .890 | .070 | .040 | 2.543 | 0.560 |
| 8 ≦ a < 9 | 8.5 | 123 | 13.0 | 52.0 | 22.0 | 13.0 | 48.6 | 5.6 | .923 | .055 | .022 | 2.820 | 0.916 |
| 9 ≦ a < 10 | 9.5 | 103 | 20.4 | 38.8 | 29.1 | 11.7 | 41.3 | 4.6 | .913 | .052 | .035 | 2.865 | 0.396 |
| 10≦ a < 11 | 10.5 | 64 | 23.4 | 35.9 | 29.7 | 10.9 | 56.2 | 4.1 | .915 | .048 | .037 | 2.948 | 0.260 |
| 11≦ a < 12 | 11.5 | 61 | 27.9 | 45.9 | 16.4 | 9.8 | 56.3 | 359.2 | .888 | .067 | .045 | 2.584 | 0.398 |
| 12≦ a < 13 | 12.5 | 49 | 26.5 | 49.0 | 16.3 | 8.2 | 62.5 | 2.0 | .913 | .074 | .013 | 2.513 | 1.739 |
| 13≦ a < 14 | 13.5 | 43 | 32.6 | 34.9 | 30.2 | 2.3 | 60.1 | 0.5 | .917 | .061 | .022 | 2.710 | 1.020 |
| 14≦ a < 15 | 14.5 | 31 | 25.8 | 38.7 | 19.4 | 16.1 | 60.4 | 357.3 | .899 | .086 | .015 | 2.347 | 1.746 |
| 15≦ a < 16 | 15.5 | 31 | 32.3 | 41.9 | 19.4 | 6.5 | 70.6 | 356.5 | .941 | .045 | .014 | 3.040 | 1.168 |
| 16≦ a < 18 | 17.0 | 49 | 32.7 | 44.9 | 20.4 | 2.0 | 50.7 | 2.3 | .941 | .042 | .017 | 3.109 | 0.904 |
| 18≦ a < 20 | 19.0 | 31 | 38.7 | 29.0 | 29.0 | 3.2 | 54.8 | 12.9 | .949 | .039 | .012 | 3.192 | 1.179 |
| 20≦ a < 24 | 22.0 | 30 | 36.7 | 30.0 | 30.0 | 3.3 | 78.7 | 16.9 | .952 | .046 | .002 | 3.030 | 3.136 |
| 24≦ a < 28 | 26.0 | 26 | 57.7 | 11.5 | 30.8 | 0.0 | 59.3 | 4.3 | .936 | .050 | .014 | 2.930 | 1.273 |
| 28≦ a < 32 | 30.0 | 21 | 52.4 | 28.6 | 19.0 | 0.0 | 72.3 | 10.5 | .960 | .033 | .007 | 3.370 | 1.551 |
| 32≦ a | 58.8 | 26 | 46.2 | 19.2 | 30.8 | 3.8 | 89.4 | 5.1 | .972 | .025 | .003 | 3.660 | 2.120 |

N : the number of observations B=Blade, D=Disc, R=Rod, and S=Sphere

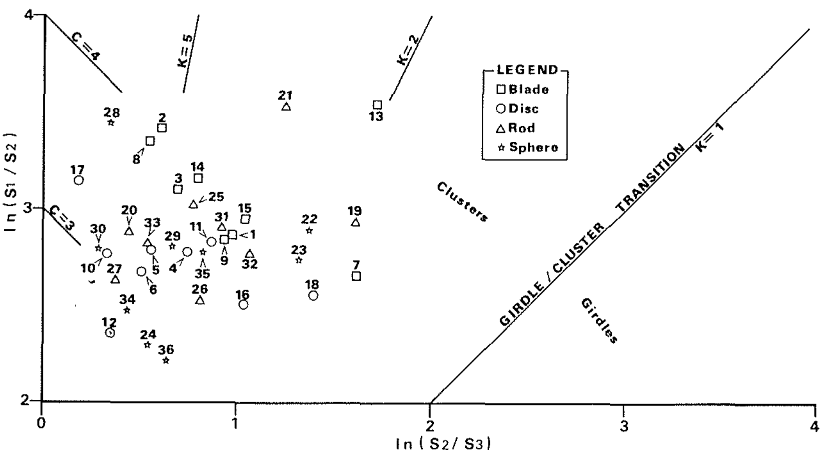


**Fig. 3** Logarithmic ratio plot of eigenvalues for each data group subdivided into Zingg's category. Number beside the symbol means Drake's number shown in Fig. 2.

higher than those of Discs' and Spheres', and resembled those of Blades'.

Some statistical tests were done in order to evaluate clast shape influence on the fabric strength. Table 3 shows results of Welch's statistical test which is to test the difference among the above population mean. The null hypothesis —no significant difference— was

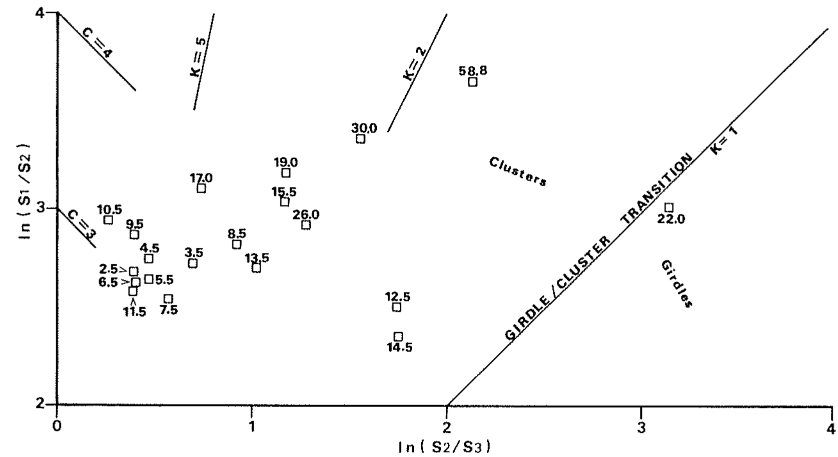


**Fig. 4** Logarithmic ratio plot of eigenvalues of each data in classes classified by a-axis length. Figure beside the symbol means class mark of a-axis length.

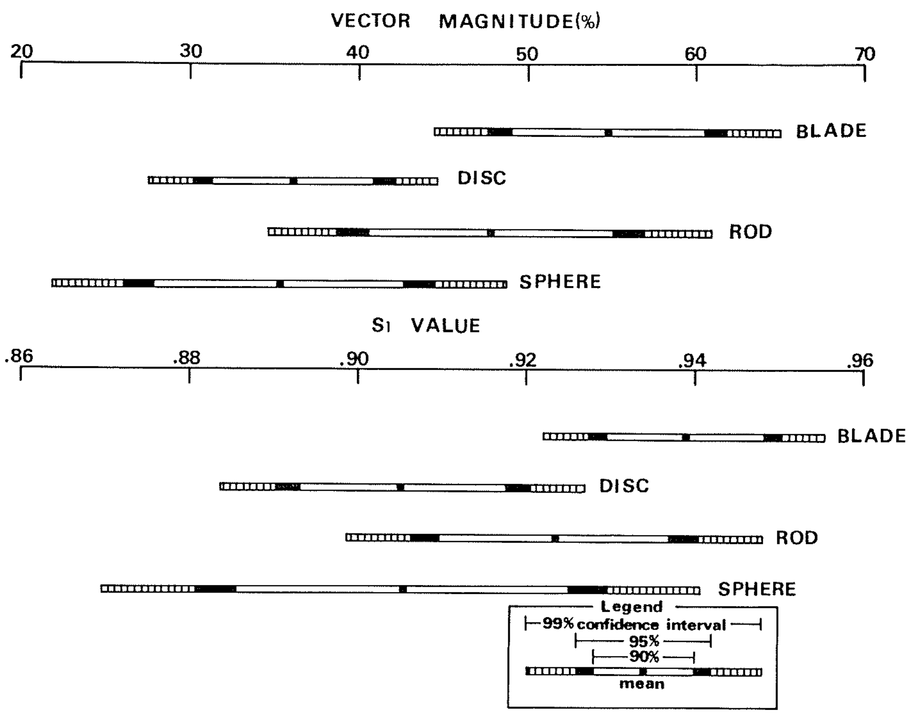


**Fig. 5** Population mean and range both of vector magnitude and S1 value in each clast shape at different confidence interval.

rejected in each statistical test. Therefore Blades and Rods have stronger fabric than Discs and Spheres. As the clasts of Blades and Rods have lower b/a-axis ratio, it may be inferred that clasts with lower b/a-axis ratio have stronger fabric than clast with higher one. This

**Table 3** Welch's statistical test among population mean bnth of vector magnitude and $S_1$ value separated by each Zingg's diagram

| Vector magnitude | $S_1$ value |
|---|---|
| (1) $H_0$ : Blade = Disc $H_1$ : Blade > Disc<br>T = 4.462 with DF = 16<br>$t_{16}(.005) = 2.921$ ∴ reject $H_0$ | (5) $H_0$ : Blade = Disc $H_1$ : Blade > Disc<br>T = 2.999 with DF = 13<br>$t_{13}(.01) = 2.650$ ∴ reject $H_0$ |
| (2) $H_0$ : Blade = Sphere $H_1$ : Blade > Sphere<br>T = 3.844 with DF = 15<br>$t_{15}(.005) = 2.947$ ∴ reject $H_0$ | (6) $H_0$ : Blade = Sphere $H_1$ : Blade > Sphere<br>T = 2.871 with DF = 18<br>$t_{18}(.01) = 2.552$ ∴ reject $H_0$ |
| (3) $H_0$ : Rod = Disc $H_1$ : Rod > Disc<br>T = 2.481 with DF = 14<br>$t_{14}(.05) = 1.761$ ∴ reject $H_0$ | (7) $H_0$ : Rod = Disc $H_1$ : Rod > Disc<br>T = 1.831 with DF = 15<br>$t_{15}(.05) = 1.753$ ∴ reject $H_0$ |
| (4) $H_0$ : Rod = Sphere $H_1$ : Rod > Sphere<br>T = 2.221 with DF = 16<br>$t_{16}(.05) = 1.746$ ∴ reject $H_0$ | (8) $H_0$ : Rod = Sphere $H_1$ : Rod > Sphere<br>T = 1.400 with DF = 27<br>$t_{27}(.1) = 1.314$ ∴ reject $H_0$ |

$H_0$ : statistical hypothesis $H_1$ : alternative hypothesis T : calculated statistical testing value in each case DF : degree of freedom $t_{15}(.05)$ : statistical testing value with degree of freedom = 15, level of significance = 0.05
The null hypothesis was rejected in each test as the value of Blade and Rod were significantly different from the value of Disc and Sphere.

hypothesis was tested by Wilcoxen's rank sum test and its results are listed on Table 4. All null hypothesis were rejected in each test composed of clast shape separated by b/a-axis ratio and were significant in each test composed of those separated by c/b-axis ratio. This result supports the above hypothesis, and it has been pointed out that c/b-axis ratio cannot influence on its fabric strength. This relationship may be explained that the clasts like Blades and Rods have more sufficient elongation to force the a-axis into strong parallelism with flow direction in viscous fluids than clasts like Discs and Spheres.

The correlation between vector magnitude and length of a-axis(by class mark, see Table 2) is shown in Fig. 6, and also the correlation between S1 value and length of a-axis is shown in Fig. 7. Length of a-axis correlates with both vector magnitude and S1 value. As a result of this, it can be stated that fabric strength increase as a function of length of a-axis. This finding may be attributed to the difference of clasts' movement velocity in viscous fluids. Since it is inferred that movement velocity of clasts with shorter a-axis is faster than those of clasts with longer a-axis, the former should move through openings which are made by the latter, and change its flow direction easier. Thus the reason why clasts with shorter a-axis have weaker fabric is probably due to obstruction by clasts with longer a-axis.

Although effects of clast size and clast shape on fabrics were discussed respectively, size and shape of clasts are mutually correlated each other as shown in Table 2 that clasts with long a-axis reveal high content of Blades and Rods. At present it is hard to define which of them more strongly affects to clast fabrics.

**Table 4** Wilcoxen's rank sum test to assess the effect of axis ratio
Wilcoxen's rank sum test

| Vector magnitude | $S_1$ value |
|---|---|
| effect of b/a | |
| (1)-a $H_0$ :Blade+Rod=Disc+Sphere<br>$H_1$ : Blade+Rod≠Disc+ Sphere<br>$W=217,\ 252<W_{18,18}(.01)<414$<br>∴reject $H_0$ | (1)-b $H_0$ : Blade+Rod=Disc+Sphere<br>$H_1$ : Blade+Rod≠Disc+Sphere<br>$W=236,\ 252<W_{18,18}(.01)<414$<br>∴reject $H_0$ |
| (2)-a $H_0$ : Blade=Disc $H_1$ : Blade≠ Disc<br>$W=45,\ 56<W_{9,9}(.01)<115$<br>∴reject $H_0$ | (2)-b $H_0$ : Blade=Disc $H_1$ : Blade≠ Disc<br>$W=48,\ 56<W_{9,9}(.01)<115$<br>∴reject $H_0$ |
| (3)-a $H_0$ : Rod=Sphere $H_1$ : Rod≠Sphere<br>$W=63,\ 66<W_{9,9}(.1)<105$<br>∴reject $H_0$ | (3)-b $H_0$ : Rod=Sphere $H_1$ : Rod≠Sphere<br>$W=58,\ 62<W_{9,9}(.05)<109$<br>∴reject $H_0$ |
| effect of c/b | |
| (4)-a $H_0$ : Blade+Disc=Rod+Sphere<br>$H_1$ : Blade+Disc≠Rod+Sphere<br>$W=304,\ 280<W_{18,18}(.1)<386$<br>∴significant $H_0$ | (4)-b $H_0$ : Blade+Rod=Disc+Sphere<br>$H_1$ : Blade+Disc≠Rod+Sphere<br>$W=308,\ 280<W_{18,18}(.1)<386$<br>∴significant $H_0$ |
| (5)-a $H_0$ : Blade=Rod $H_1$ : Blade≠Rod<br>$W=68,\ 66<W_{9,9}(.1)<105$<br>∴significant $H_0$ | (5)-b $H_0$ : Blade=Rod $H_1$ : Blade≠Rod<br>$W=66,\ 66<W_{9,9}(.1)<105$<br>∴significant $H_0$ |
| (6)-a $H_0$ : Disc=Sphere $H_1$ : Disc≠Sphere<br>$W=83,\ 66<W_{9,9}(.1)<105$<br>∴significant $H_0$ | (6)-b $H_0$ : Disc=Sphere $H_1$ : Disc≠Sphere<br>$W=91,\ 66<W_{9,9}(.1)<105$<br>∴significant $H_0$ |

W : calculated statistical testing value in each case
$W_{18,18}(.01)$ : statistical testing value with level of significance=0.01, 18 reveal the number of samples

## 5. Conclusion

In the logarithmic ratio plots by three-dimensional fabric analysis, fabrics of the slope deposits in the study site have higher C value and plots distribute in cluster. These facts indicate that this slope deposits is of periglacial origin, probably transported by solifluction.

In the results from the statistical test, fabric strength of periglacial slope deposits shows strong relation to length of a-axis and b/a-axis ratio. Accumulated data in this study indicate that clasts with longer a-axis and lower b/a-axis ratio have stronger fabric than clasts with shorter a-axis and higher b/a-axis ratio. These findings may simply be additional affirmative evidence for the existence of a relation between orientation and clast properties. Comparision of fabric data in different study sites should require of us to

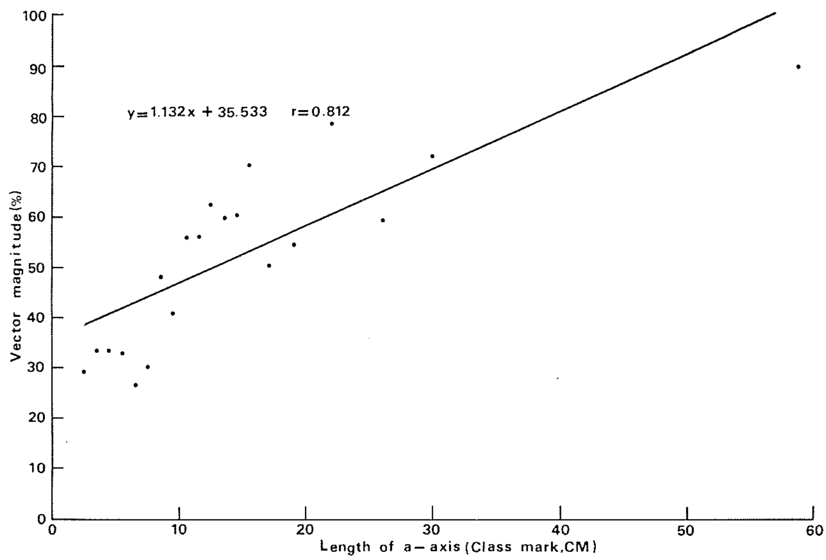


**Fig. 6** Plots of vector magnitude as a function of a-axis length.

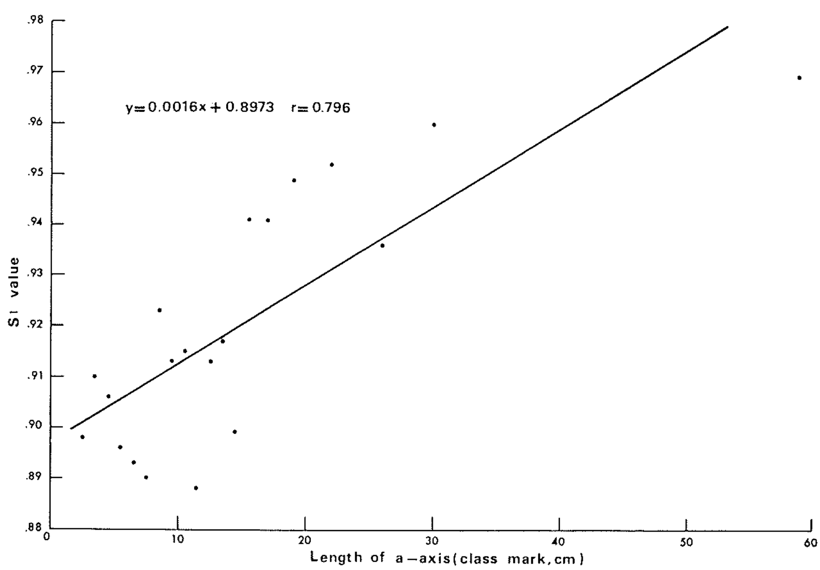


**Fig. 7** Plots of S1 value as a function of a-axis length.

measure clast with longer a-axis and lower b/a-axis ratio in order to gain the strongest fabric.

**Acknowledgements**

The author would like to thank Professor Yugo Ono and Assistant Hiroshi Yamamoto of Hokkaido University for help during the corse of this study. The auther also thanks Mr. Takashi Moriyama and the Moriyamas for their help with the field survey.

## References

Anderson, J. W. and Stephens, M. A.(1972): Test for randomness of directions against equatorial and bimodal alternatives. *Biometrika,* **59**, 613－621.

Andrews, J. T. and King, C. A. M.(1968): Comparative till fabrics and till fabric variability in a till sheet and a drumlin: A small scall study. *Yorkshire Geol. Soc. Proc.,* **36**, 435－461.

Curray, J. R. (1956): The analysis of two-dimentional orientation data. *Jour. Geol.,* **64**, 117－131.

Drake, L. D. (1974): Tills fabric control by clast shape. *Geol. Soc. America Bull.,* **85**, 247－250.

Harrison, P. W. (1957): A clay-till fabric: its character and origin. *Jour. Geology,* **65**, 275－308.

Holmes, C. D. (1941): Till fabric. *Geol. Soc. America Bull.,* **52**, 1299－1354.

Krumbein, W. C. (1939): Prefered orientation of pebbles in sedimentary deposits. *Jour. Geol.,* **47**, 673－706.

Kruger, J. (1970): Till fabric in relation to direction of ice movement. *Geogl Tidsskr.,* **69**, 133－170.

Mark, D. M. (1974): On the interpretation of till fabrics. *Geology,* **2**, 101－104.

Mills, H. H. (1977): Basal till fabrics of modern alpine glaciers. *Geol. Soc. America Bull.,* 88, 824－828.

Mills, H. H. (1983): Clast-fabric strength in hill slope colluvium as function of slope angle. *Geografikca Annaler,* **65(A)**, 255－262.

Nelson, F. E. (1985): A preliminary investigation of solifluction macrofabrics. *Catena,* **12**, 21－33.

Scheidegger, A. E. (1965): On the statistics of the orientation of bedding planes, grain axes, and similar sedimentological data. *U. S. Geol. Survey Prof. Paper,* **525-c**, 164－167.

Woodcock, N. H. (1977): Specification of fabric shapes using an eigenvalue method. *Geol. Soc. America Bull.,* **70**, 1231－1236.

Yamamoto, K. (1989): Chronology of Holocene periglacial slope deposits in the Northern Hidaka Mountains, Hokkaido, Japan. *The Quarternary Research* ,**28-(3)**, 139－158.

Zingg, Th. (1935): Beitrag zur Schotteranalyse. *Schweizer. Mineralog. u. Petrog. Mitt.,* **15**, 38－140.