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Some Geomorphic Studies of East Ongul Island; Landform Classification and Morphometry

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東オングル島の地形分類と地形計測

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要旨

目的と方法 種々の制約の多い南極地域の地学部門現地調査に側面から協力するために，第1次観測隊の撮影した1万分の1空中写真とそれから図化した5千分の1地形図を基にして，東オングル島の予察的地形分類図の作成と2,3の図上計測を行なった．地形分類は斜面の傾斜（4階級に区分）と表面物質の性状（細粒，粗粒，薄く点在，岩盤露出の4種）を規準に，これら2要素の組合せによって分類単位を設定し，2,3の微地形記号とともに類別図示した．計測は島内に無作為に配布した200地点（Fig. 1）について，高度，傾斜，方位及び地形分類単位を図上で読定し，それらの頻度分布及び相関を検討した．

結果 1）分類図及び分類単位毎の性状（面積比，地形的位置，予想される営力）は Plate 1（折込み附図）及び Table 1 に示した．微地形と表面物質の記載は一般地形図においても考慮する必要があろう．2）頻度分布その他から6つの高度帯が類別され，既に報告された発達史的知識とも対応している．（Figs. 3～5, Table 2） 3）斜面傾斜の頻度分布は対数正規型を呈している．(Figs. 6, 7）斜面傾斜と表面物質の対応関係（Fig. 9）にはかなりの幅が認められるが，斜面方位（Fig. 12），微地形的位置によって説明されよう．細粒物質及び粗粒物質の存在する傾斜の上限は大略3°及び15°である．4）傾斜別の斜面方位の頻度（Figs. 10, 11）には，氷蝕による地形配列の東西性のほかに，南北斜面の非対称（南面が急）が認められる．大陸氷後退後に，日射と卓越風向の影響によって生じたものと考えられる．5）その他，地質による制約，氷蝕後の地形変化について気づいた2,3の事項を附記した．

以上のうち 1),3),4) について現地で検討されることが望ましい．

1. Introduction

Since 1957, geomorphological investigations in the vicinity of Syowa Base have been made by the Japanese Antarctic Research Expedition and their valuable results have been published[1][2][3].

Based on the observation of aerial photographs and topographic map of East Ongul Island prepared by J.A.R.E., the writer analysed the present landforms of the island, of which informations may be useful for the investigation of geomorphology and other science or various planning in this area. This paper presents these analyses with some descriptive and suggestive notes, which would be desirable to be applied and examined in field studies and topographic mapping.

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2. Materials used

(1) Aerial photographs were taken by the first J.A.R.E. on 30 Jan. 1957, on scale of approx. 1:10,000[4].

(2) Topographic map "East Ongul Island" on scale of 1:5000, with contour interval of 2.5 m, were prepared photogrammetrically from the above photos by Geographical Survey Institute of Japan[4][5].

3. Methods of analyses

Two complementary methods, qualitative and quantitative, are used for analysis. One is a landform classification by aerial photographic interpretation[6] and another is morphometry on the topograpic map.

(1) **Landform classification** The most synthetic and systematic method of landform classification may be genetic classification according to morphogenetic factors and evolutional history. In this study, it would be desirable but difficult to achieve detailed genetic classification, only by photo-interpretation without sufficient knowledge in field or literature of genesis of the landforms in this area, which have complicated topographic features by glacial, aeolian, subnival, cryergic, fluvial and marine agencies. From this reason, the writer had to start with classification according to observable characteristics which might be related to morphological genesis. As criteria for classification are used two elements, slope inclination and surface materials, interpreted stereoscopically on aerial photographs.

a) Classes of slope inclination While many discussions have long been made on the evolution of slopes, realistic and quantitative investigation of present slope characteristics have not so progressed as to achieve standard or authorized method of slope classification according to its inclination. In this study, the writer adopted conveniently four slope classes, flat, gentle, steep and precipitous, in which slope degrees ranges approximately $0\sim5°$, $3\sim15°$, $10\sim35°$, more than $30°$ respectively. These four classes are considered to correspond to some units in landform classification survey in GSI[7][8] and their ranges are derived from our field experiences in those surveys.

Recently, after completion of this operation, similar method to this are reported, in which four slope zones of α, $0\sim3°35'$, $\sim14°24'$, $\sim34°14'$, $\sim90°00'$, using four equal divisions of the function $\sqrt{\sin\alpha}$, were applied for morphological cartographic representation by MILLER and SUMMERSON[9]. This unexpected essential coincidence seems to suggest that these method of slope classification reliably reflected slope characteristics, at least, of fluvial landforms.

Geomorphic significance of these ranges of slope inclination, with reference to MILLER and SUMMERSON's note, are briefly mentioned as follows: The first class ($0\sim5°$) are correspond to almost aggraded slopes of fluvial and marine origin; the second class ($3\sim15°$) are those of small stream, debris or mudflow, landslide and solifluction, and graded slopes of piedmont gentle slope or erosion surface at high level, and relatively stable for rainwash[10], gullying and creeping for almost rock types; the third class (10~35°) are to detrital slopes below exposed bed rock cliffs and most of mountain and hill side slopes formed by rainwash, creeping and moderate mass movement erosion; and the fourth or last class (30°<) are nearly to free slope steeper than angle of repose in dry materials[11][12], on which violent mass movement erosion are in action.

On the other kinds of landforms, MILLER and SUMMERSON stated, "The upper limit of the second zone, 14°24′····marks an appropriate upward limit of····most depositional features of ice and wind."

b) Classes of surface material As criteria for analysis of surface materials are selected two properties, mode of occurence and texture, which are interpretable on airphotos and expected to hold significant clue for their origin. Mode of occurence are classified into three classes, none, thin or sparse, and covered on bed rock surface; and texture into two classes, finer and coarser.

c) Classification units and other minor features Classification units are obtained by combination of each classes of two elements, slope and surface materials. While all combinations are hypothetically possible, but some of these are not in existence in nature, because two elements are connected with close interrelation as discussed later. These units are identified by inspection in stereoscopic vision of airphotos and illustrated on base map.

Beside above classification, some other characteristic features are interpreted and mapped, as follows.

(i) Boulders or blocks more than about 2 m in diameter (more than about 0.2 mm on contact photographs of approx. 1:10,000) which are considered as glacial erratics[1][2].

(ii) Structural linear features such as apparent direction of gneissosity of bed rock[2][3], deep furrows along cross joint, and remarkable rock ridges.

These operation of photo-interpretation are fortunately facilitated with favorable conditions such as absence of vegetal cover, diagnostic structure of bed rock, use of large scale photographs and corresponding photogrammetric map.

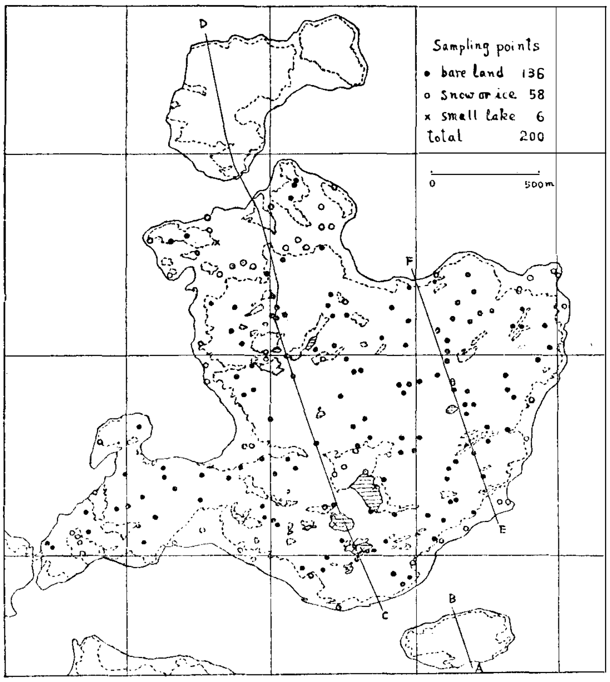

Fig. 1. Distribution of sampling points for morphometry.

(2) **Morphometry** Some morphometric analyses are made to clarify quantitative properties of

landforms and to examine and complement tentative results obtained by qualitative method. The procedures carried out are as follows:

a) In the area studied are distributed 200 sampling points, for measurement of landform elements, of which co-ordinates on the map are determined by statistical table of random numbers[13)14)] (Fig. 1).

b) Three elements, altitude, slope inclination, and slope direction, are measured at sampling points on the map, and kinds of landform unit, in which each point are situated, are given from the classification map.

c) Frequency distributions and correlations of these elements are calculated and illustrated in diagrams.

d) Topographic sections are made for representation of some landform characteristics, shown in Fig. 2.

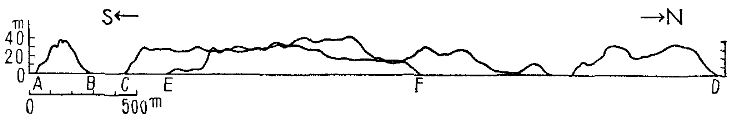

Fig. 2. Topographic sections along the line shown in Fig. 1.

4. Results and some considerations

(1) **Landform classification** Plate 1 shows reconnaissance classification map with

Table 1. Some properties of each unit of landform classification.

Landform unit		Frequency in 200 sampling points (areal extent %)	Topographic situation	General trend of external processes in action	Main kinds of agents in action
Surface material	Slope				
Exposed bed rock	Precipitous	3 (1.5)	Mainly on southern flank along E-W joint	Erosion	Wind erosion (deflation) nivation
	Steep	44 (22)	Dominant on hill flanks		
	Gentle	19 (9.5)	Predominant at upper portion of hill slope, or slope with convex contour line		
	Flat	1 (0.5)	Mainly on top of hill or ridge		
Covered with thin or sparse material	Steep	0 (0)	Restricted at upper portion of southwestern flank of hill	Intermediate or weak erosion	Wind erosion and deposition solifluction nivation
	Gentle & flat	25 (12.5)	Predominant around exposed bed rock		
Covered with coarser m.	Gentle & flat	38 (19)	Predominant at lower portion of hill slope, or slope with concave contour line	Deposition	Solifluction nivation, wash of melt water
Covered with finer m.	Flat	6 (3)	In depression of glacial overdeepening, or at foot of past sea cliffs on the upheaved marine platform		Fluvial action
Total		136 (68)			
Small lake		6 (3)	In depression of glacial overdeepening		
Ice and snow field		58 (29)	Mainly at southwestern flank or foot of hill		
Sum total		200(100)			

table of its classifing system. For each landform unit, some descriptive and morphogenetic properties measured, interpreted or deduced are listed in Table 1. These tentative results are desirable to be revised and supplemented in field studies.

From cartographic standpoint, plotting of some features, such as micro reliefs difficult to be expressed only by contour line method and kinds of surface materials represented even on hydrographic charts, should be considered in general topographic mapping in such bare land area.

(2) **Altitude zone** Frequency distribution of altitude takes trimodal histogram in Fig. 3, from which it seems appropriate for descriptive and genetic consideration to devide into six zones of altitude, three modal zones and three less frequency zone, which nearly correspond with characteristic zone of relative frequency of slope inclination and surface material in each class of altitude (Figs. 4 and 5). Moreover, these divisions are nearly consistent with morphogenetic informations reported by previous authors[1)2)] as shown in Table 2.

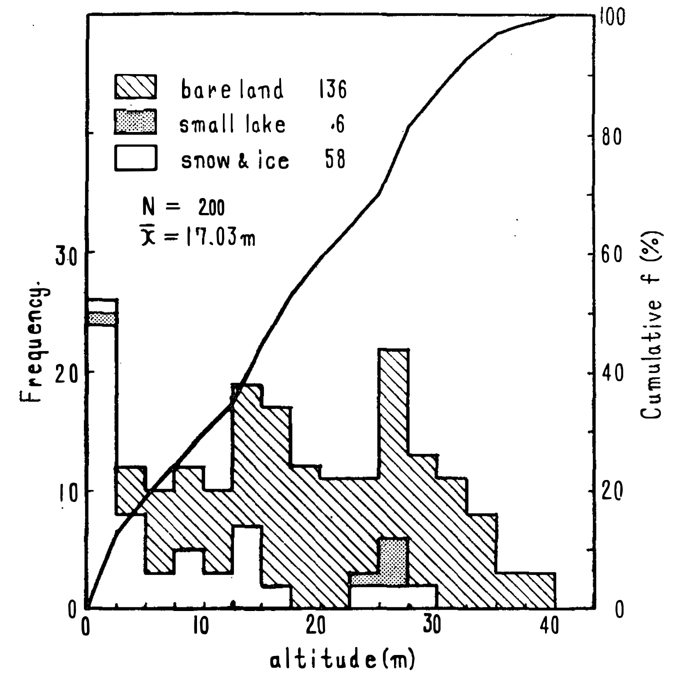

Fig. 3. Frequency distribution of altitude.

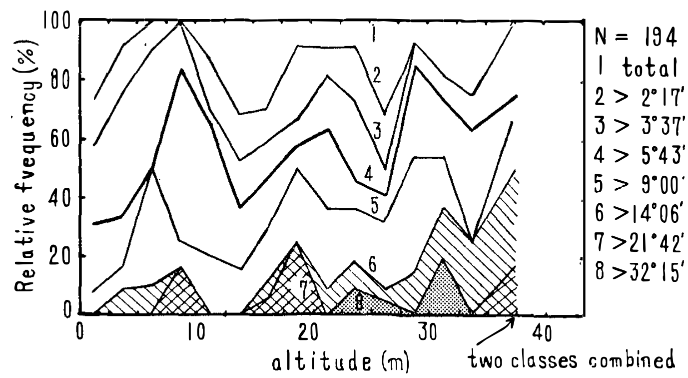

Fig. 4. Relative frequency of slope inclination in each class of altitude.

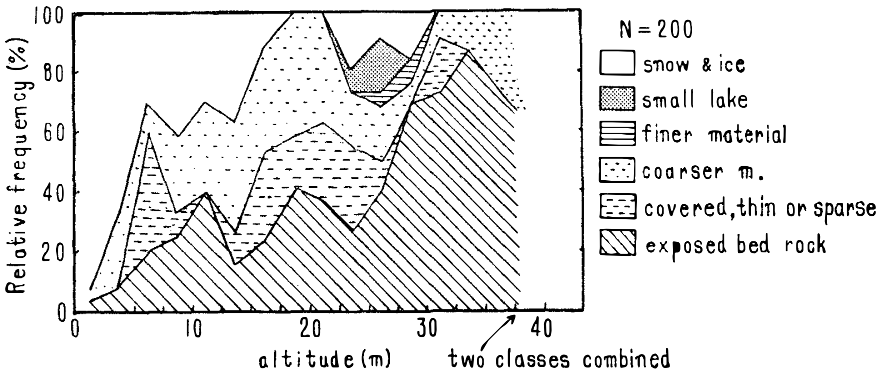

Fig. 5. Relative frequency of surface materials in each class of altitude.

Table 2. Main characteristic landforms in each altitude zone.

1.	0~ 2.5m	Flat land, formed at nearly present sea level, mostly covered by snow and ice.
2.	2.5~12.5	Relatively steep slope including nearly present sea cliffs.
3.	12.5~17.5	Upheaved marine platform-like surface developing at northern part of the island.
4.	17.5~25	Relatively steep slope including past sea cliffs.
5.	25 ~30	Small lakes and aggraded surface filling depressions in glaciated rock hills.
6.	30 ~43.4	Roches moutonnées field, or rock hills of low relief mainly composed of roches moutonnées produced by past continental glaciation.

From these frequency data, mean and median height of the island are calculated to 17.0 m and 16.5 m respectively, and hypsometric integral[15] or ratio of mean height to total height are 39.2%.

On the area above 25 m, it seems interesting that gradually diminishing exponential-like appearrance of cumulative curve in Fig. 3, and low value of 26.3% in hypsometric integral suggest to "that a roches moutonnées field is the end stage of ice erosion[16].

It may be also noticed that considerable consistency of altitude of about 40 m is seen in highest peaks or glaciated erosion surfaces in the Ongul Islands, as partly presented in Fig. 2, with possible relation to glaciated flat surface of nearly same altitude at Langhovde district in the Continent[1,2].

(3) **Slope inclination and surface material** a) Frequency distribution of slope inclination appears to take log normal type on the whole area, snow and ice field, and barren land free from them, respectively, as shown in Figs. 6 and 7. This is of interest but would not be asserted as one of general or essential facts, because slope frequency data, measured for unified natural area, comparable to this case are rare, while some examples for erosional slope of maturelly dissected fluvial landforms are reported as normal distribution[13,14], which might be possible to be considered as a small part of log normal one.

b) Fig. 8 presents to compare two sets of data for slope inclination by inspection in stereovision of aerial photographs and by measurement of space of successive contour lines on the map. In this figure, slope data by measurement in each class by inspection take fairly proper distribution, but their ranges are overlapping each

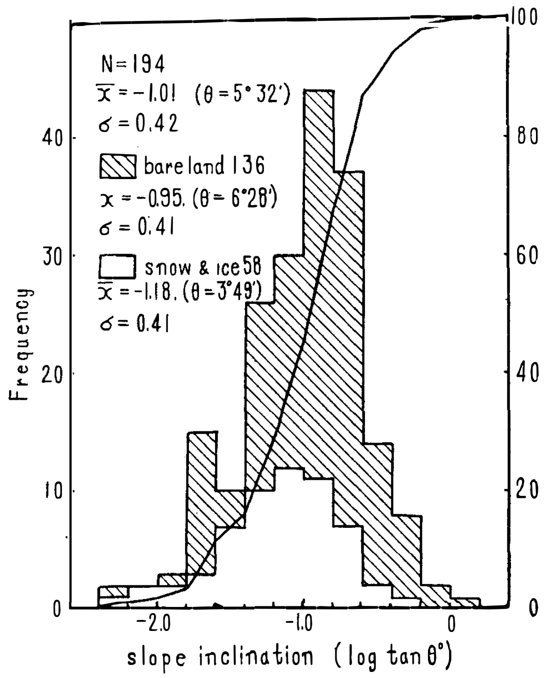

Fig. 6. Frequency distribution of slope inclination.

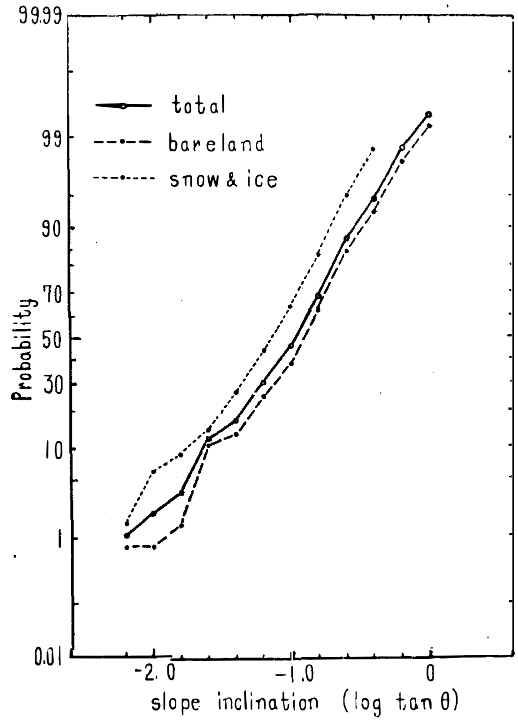

Fig. 7. Frequency distribution of slope inclination plotted in probability paper.

other in considerable degree. These inconsistencies are considered, with critical examination, neither mainly due to various kinds of errors in measurement and inspection in this study, nor in plotting and drawing of contour lines, but rather due to occurrence of micro relief or remarkable change of slope inclination within small extent not sufficiently expressed with contour line. Steroscopic perception of slope inclination is rather fairly consistent in experience, and theoretically invariable for different flying altitude or photo scale, if focal length and base-height ratio or overlap are equal.

c) Frequency of each kind of surface materials, shown in Table 1, are considered

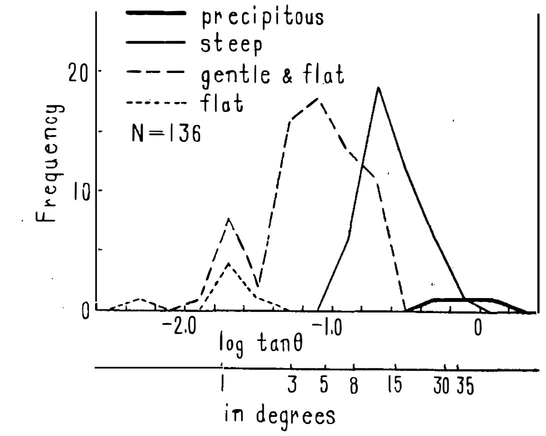

Fig. 8. Frequency distribution of slope inclination by measurement on topographic map in each slope class by inspection of air photos.

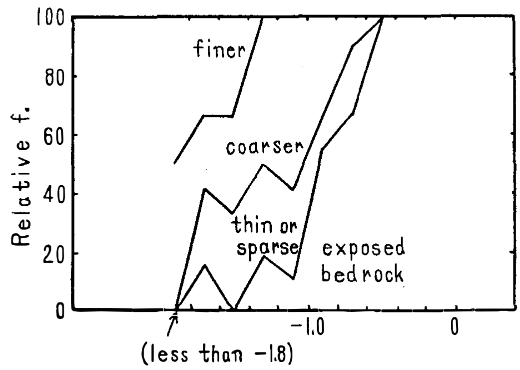

Fig. 9. Relative frequency of surface materials in each class of inclination (N=136).

to reflect characteristic environment of this area as follows:

i) Large extent of exposed bed rock surface, more than a thirds of whole area, are produced by vigorous glacial erosion at near past, and to the present by various agents prevailing in polar climate of severely cold and dry conditions, while, in humid temperate region as our country, soil or detrital mantle are usually remains even on steep slope of less than repose angle.

ii) Superiority of coaser materials than finer one in areal extent may be due to that of mechanical weathering than chemical and biological one, uplifting of weathered coaser material by frost action and selective transportation by wind of finer material to the sea, as pointed out by previous authors[2].

d) Mode of occurrence or texture of surface material and slope inclination have generally close interrelations, according to its proper morphogenetic factor. These interrelations are recognized considerably in this case as shown in Fig. 9 and Table for classifing system in Plate 1.

The incompleteness of their interrelations or co-existence of verious kinds of surface materials in each class of slope inclination are considered to be caused by some other factors such as direction, situation and form of slopes, besides same factor as discussed in above b).

Effects of direction, or exposure, are partly presented in Fig. 12, in which occurrence of surface materials and snow cover are mostly restricted in S–W–N directions, namely lee side of prevailing wind[2][18], for gentle slope or class between 5°43′–14°06′.

On the other hand, influence of topographic situation and slope form are clearly seen in Plate 1. Even for slopes of equal inclination, shallow depression or furrows, expressed with contour line of concave forward, tend to be aggraded and covered with materials, while swells or spurs with convex contour to be eroded and exposed to bed rock surface. These factors might be possible to be expressed quantitatively by measures such as catchment area or distance from divide, and reciprocal of radius of contour line curvature. But these analyses will be given in further study.

In Fig. 9, it is noted that the upper limit of covered slope with finer and coarser materials are approximately 2°17′ and 14°06′ respectively, which are nearly correspond to our experience or MILLER and SUMMERSON's note.

(4) **Orientation and asymmetry of slopes** Characteristic orientation and asymmetry of slopes are shown in Figs. 10 and 11. The first mode is found in N–NW direction, the second in S–E, and less frequency in NE and SW on the whole samples. This tendency appears same on steeper slope than 5°43′, while, on steeper than 14°06′, maximum frequency occur in S or SE and second in N. These facts are considered to reflect E–W orientation of hill topography conformable with direction of glaciation from E to W[1][2], and asymmetric form with the south-facing slope steeper, which are probably due to the differencial influence, in each exposure, of climatic factors such as insolation and prevailing wind[1],[18].

Such asymmetric form seems to be generally found in the Continent through recon-

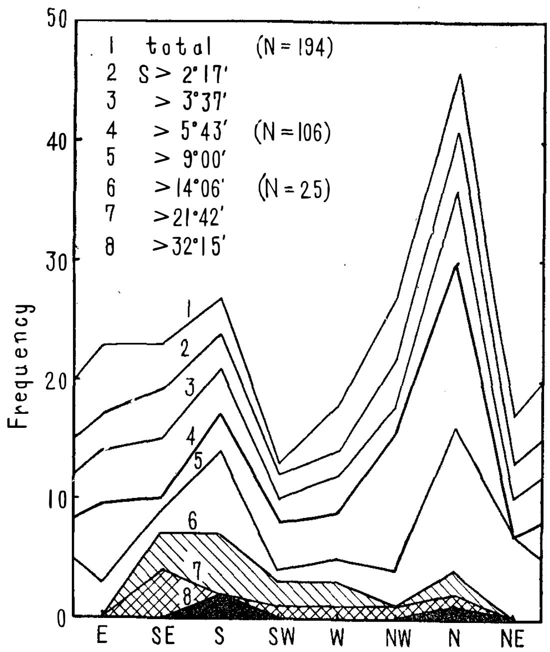

Fig. 10. Frequency of slope direction in steeper slopes more than each inclination class.

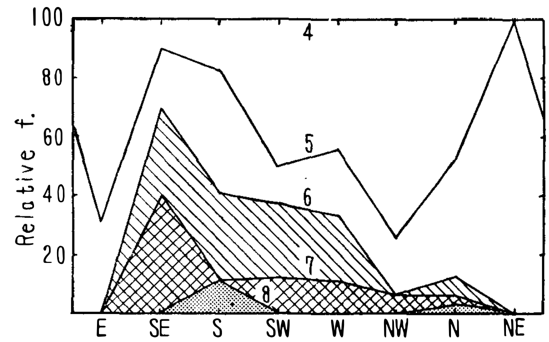

Fig. 11. Relative frequency of slope inclination steeper than 5°43′, in each class of slope direction (N=106) (Denote numbers are same as shown in Fig. 10).

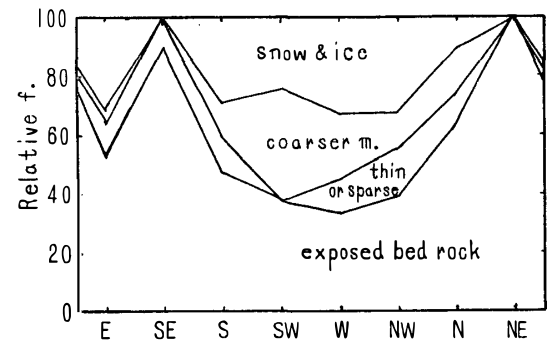

Fig. 12. Relative frequency of surface materials in each class of slope direction for steeper slopes more than 5°43′ (N=106).

naissance observation of aerial photographs and also terrestrial photographs printed in Antarctic Records.

The forming processes of such asymmetric slope may be one of the interesting and important problems in climatic geomorphology[16) 17) 19) 20) 21)].

(5) Some other notes on morphogenetic factors and processes

a) Rock and structural control

In East Ongul island, there are three rock types classified and mapped by TATSUMI and KIKUCHI[2)]. Correspondance of landforms to these rock types are as follows:

i) Basic metamorphic rock, banded in the central part with nearly N–S direction may be resistent to erosion and generally makes ridges and hillocks, including the highest summit of the island.

ii) Dioritic gneiss, occured in the western neck of the island, seems weak to erosion and form gentle slope almost covered with drift materials.

iii) Granodioritic gneiss, distributed in almost part besides the above, include various kinds of landforms.

Structural control, especially, by E–W joints are notably facilitated with its coinsidence with direction of glaciation and nearly of prevailing wind.

b) Modification of landforms after the glaciation

Previous authors[1,2] pointed out strong intensity of various external agents acting in the present, mainly from the evidence of micro features such as exfoliated surface, cellular holes, facetted pebbles and stone-polygons.

This consideration may be also supported by some facts that eastern side of the island presents not so smooth slope as stoss side of glaciation but rugged and precipitous sea cliffs with deep furrows along joints, and occurrence of asymmetric slopes, as above-mentioned, not reliable to be caused by glaciation.

The writer would like to express my hearty thanks to senior staff and colleagues in GSI for their kind considerations for this study, especially to Mr. K. NISHIMURA and Mr. Y. KITANI, and also acknowledge to Dr. T. YOSHIKAWA of Tokyo University and Dr. T. NAKANO of our Institute for their critical advise to this manuscript.

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