

*An Introduction to Periglacial or Subnival
Morphology in Japan**

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Introduction

In Central Japan there are numerous peaks with elevations of more than 2,000 m. and they assembled the so-called Japan Alps (35°20'N-36°40'N). In the Japan Alps, more than 50 past glacial cirques and U-shaped glacial valleys have been known to us. Beside these glacial morphologies numerous types of periglacial features have been found. Of course, we can not find perennially frozen ground on any higher peaks in the Japan Alps, but it is less widely known that there is an extensive development of the so-called *Strukturboden* and related forms.

However the research for the periglacial features in Japan is still less advanced than it is in other countries. Several publications referring the discoveries of some examples of flow earth, have been known. But the significances of the periglacial phenomena in Japan are becoming better understood.

Quite recently in 1955 the writer has published in a volume a treatise with some photographs and a periglacial or subnival map of the Japan Alps, which may be the first synthetic monograph that has already been published.

In this short report the writer will make an attempt to outline the periglacial or subnival⁽¹⁾ features in Japan. His own opinions and detailed

(1) The word "subnival" is used in the meaning, as was defined by C. Troll (1948).

"Indem in den höheren Breiten der humiden Zone und in größerer Höhenlage der Frost immer mehr an Wirkung gewinnt, entwickelt sich im Übergang zum arktischen bzw. zum nivalen Hochgebirgsklima die s u b n i v a l e K l i m a z o n e. Der subnivale Klimabereich mit morphologisch wirksamer Gefronnis umfasst also die subarktischen und eisfreien arktischen Gebiete und die Hochgebirge bis zur klimatischen Strukturbodengrenze."

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experimental studies will be published in the succeeding paper.

The writer has to express his sincere thanks to Dr. G. Imamura who has given opportunities to survey various publications and to Dr. M. Hoshiai from whose invaluable suggestions and opinions on climatological consideration the writer has greatly benefited.

Joining the writer, students in his institute have been making efforts to clarify the mechanical process of earth flows. Acknowledgements are also due to these young collaborators.

Historical Sketches of Periglaciological Researches

A. Tanaka and F. Hashimoto (1920) was the first who had recognised the typical hexagonal polygons on the bank of "Kamegaike" (a tarn) in the Norikura Volcanic Chain (the spot is about 2,730 m. high above M. S. L.). The diameters of hexagonal cells are 30—50 cm. and the depth of the structures are measured 10 cm. In 1928, K. Nishimura noted the occurrences of some stone polygons and stone stripes on the ridges (2,780 m.) of Mt. Shirouma, and at the top of Mt. Marishiten (2,800 m.) in the Norikura Volcanic Chain. He also sketched the soil profile beneath the stone stripes. However his illustration does not show the significant vertical microstructures. 10 years afterward in 1938, M. Nakajima published a paper on some observation of the stone polygons at the height of approximately 2,050 m. (1 km. north of Mt. Yokodake) in the Yatsugatake Volcanic Chain. The polygons are developed not only on the flat bank of "Kikkoike" (a small tarn) but also on the bottom surface of the pond.

Making use of the "hypothesis of cellular vortex in thin layer" propounded by T. Terada (1928), S. Fujiwara (1928), a meteorologist, explained the mechanism of the development of stone polygons. His idea of the explanation resembles somewhat the hypothesis produced by Nordenskjöld (1907) and Gripp (1927). However, the former hypothesis has an advantage that it provides a plain explanation for the formation of cellular structure. The writer has been accepting the hypothesis as one of the most important.

M. Schwind (1936) a German geographer, visited Japan, and he noted the occurrences of *Strukturboden* on the summits of Mt. Sugoroku (2,860m.), Mt. Nukidodake (2,812 m.), Mt. Kasadake (2,898 m.) and Minamidake (3,100 m.). Attention must be paid to his climatological opinions on various favourable conditions for solifluction on these mountain ridges. His opinion will be again discussed in the later chapter.

Tsujimura and others sent a paper on some flow earths in Japan to *Commission of Periglacial Morphology of I.G.U.* in 1952, and an extremely brief abstract was printed in the preliminary report of the Commission. S. Nishimura has been studying the phenomena of structural soils, but few of his publications has been printed, so that the writer admits of no discuss. The writer has heard of the occurrence of flow earth on Mt. Daisetsu in Hokkaido, but he has never met any detailed description.

The writer has discovered an numerous set of flow earth not only in the Japan Alps but also in the mountains east of the North Japan Alps. The most distinguished development of flow earth that has ever been found in Japan, is met with on Mt. Hachibuse of which the highest peak is the elevation of 1,928 m., Above an altitude of about 1,650 m. stone polygons, stone stripes and turf-banked terraces (Lundqvist 1944) are extensively developed (Kobayashi, 1954). The writer and his collaborators have been engaging in the experimental researches for deciphering the process of earth flowing.

Climatic Conditions and Vegetations

(1) "WALDGRENZE"

In the Japan Alps the *Pinus pumila* zone has approximately an altitude of about 2,500 m. above M. S. L. Strictly speaking, it is to be said that in the South Japan Alps the *Pinus pumila* zone is slightly higher and often it rises up to the height of 2,900 m. However, it is also widely accepted that the actual upper limit of the *Pinus pumila* zone is by no means the natural vegetation limit of the shrubs. The reason for this aspect is as follows. Because of the steep slope near the ridges or summits, the soil does not maintain water enough to support the life of this huge shrub. Thus the meager vegetation consists of dwarf shrubs and herbs, covers the soil above the *Pinus pumila* zone and bare soil surface is extended here and there. These bare soil surfaces is the main part favourable for frost action or cryoturbation.

A large majority of the peaks in the Japan Alps has an elevation of less than 3,000 m., and flat-topped crest and even-crested ridges are so well-developed that the level and lowly inclined soil surfaces afford a good condition for preserving the forms of earth flow free from the destruction of fluvial actions. Accordingly it appears that on the highly inclined slope nivation is more active than solifluction.

Waldgrenze is represented by the limit line of the *Betula Ermani* var.

Communis zone. This floral zone is accompanied by some other plants, *Rubus vernus*, *Sorbus Matsumurana*. The average temperature of the warmest 2 months (July–August) at *Waldgrenze* on Mt. Norikuradake (36°5′N) is 10°–11°C and that of Tateyama (36°34.5′N) is 12°C. Mean temperature of July at *Waldgrenze* on Mt. Norikura is 6–7°C. Of course it may be questionable that *Waldgrenze* is corresponding to the mean isotherm of the warm months. However, it is accepted by some researchers that *Waldgrenze* may be controlled by the duration of vegetation period.

(2) AIR TEMPERATURE

The climate on the mountains in Japan is so incompletely known that at present it is not possible to rate climatic factors. Recently it became possible to obtain the data of aerological radiosonde sounding in free atmosphere. Fig. 1 shows the mean cross section of the temperature through free atmosphere along the 8 radiosonde stations in Japan. The mean value is obtained from the data for only 4 years sounding from 1950 to 1953. But the mean temperature for these 4 years shows that it is of normal year.

It is worth noting that every isotherm through free atmosphere reduces its height when it is in contact with the slope of mountain (Kobayashi & Hoshiai, 1955). The lapse rate on the mountain slope will be shown in Table 1. The monthly mean lapse rate is obtained from the relation between the monthly mean value at Mt. Fuji Observatory (3,772 m. above M. S. L.) and that at Mishima Observatory (22 m. above M. S. L.).

Table 1 Lapse rate on the mountain slope.

Monthly Mean Air Temperature	Locality	J	F	M	A	M	J	J	A	S	O	N	D	Annual Mean
	Mt. Fuji (3772 m.)	80.0	81.4	85.1	90.9	95.7	0.6	5.5	5.7	2.7	96.8	90.3	84.5	93.3
Mishima (22 m.)	4.1	4.5	7.8	12.6	17.0	20.9	24.9	25.4	22.1	16.4	11.6	6.7	14.5	
Lapse rate °C/100 m.	0.64	0.62	0.60	0.58	0.57	0.54	0.52	0.53	0.52	0.53	0.57	0.59	0.57	

It is also noticeable that the value of lapse rate along the mountain slope, usually takes larger value than that through free atmosphere.

(3) WIND DIRECTION AND ITS EFFECTS.

All the main ridges of the Japan Alps have almost the trend of NS-direction, and the most glacial cirques are situated on the eastern slope of the ridges. M. Schwind (1936) called the eastern slope in the North Japan

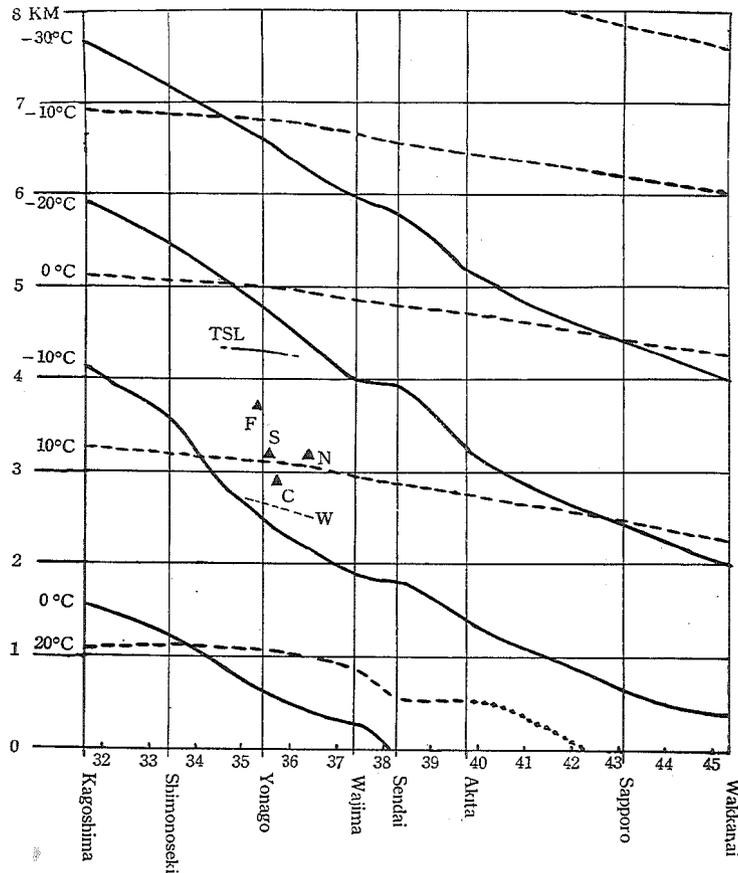


Fig.1; Isotherm distribution with height along the Japanese Islands in Summer (July and Aug.) and Winter (Jan. and Feb.)

Arithmetic mean in the period of 1950-1953, only the night observations made at about 0000 J.S.T. were used. (Calculated by M.Hoshiai)

F: Mt. Fuji, TSL: Assumed topographical snowline, W: Waldgrenze, S, C, and N indicates each highest summit of the South, Central and North Japan Alps.

Alps *Karseite* and the western slope *Solifluktionseite*. The reason for this characteristic feature may be as follows :

- 1) At the heights of main ridges, prevailing westerlies are active throughout a year.
- 2) The air which brings much snowfalls comes from west in winter season and snow falls much more on the eastern side than on the western side.
- 3) During the summer day the eastern side of the ridges is generally more

cloudy than the western side, as a consequence the total insolation on the eastern side becomes less intensified than that on another side.

According to H. U. Sverdrup (1935), total amount of ablation for a day H (depth in cm.) is expressed as

$$80\rho H = (1-A)I - R + 24\beta[\theta + m(e - 4.58)]v$$

where ρ : density of snow or ice, I : radiation income, A : albedo of snow or ice, R : heat loss by long wave radiation, β : some const., θ : temperature, m : const., e : vapour tension, v : wind velocity.

When each θ , I , and e takes same value one another on each side of the ridges, because there is no reason to evaluate that each takes different value; wind velocity toward western side is far larger than toward eastern side. Therefore total ablation of snow or ice on western side during the melting season may be far larger than that of eastern side, and this may be one of the essential reasons for the development of glacier on eastern side.

If we apply the name *Strukturbodengrenze* for the actual lower limit of flow earth, it will be corresponding to *Waldgrenze*. The most favourable condition for frost action may require that the soil surface is poor in vegetation.

Under certain favourable circumstances, when soil is not covered with vegetation frost action may be able to produce flow earth phenomena. Y. Sasa (1954) recently described an occurrence of polygons and stripes on Mt. Kampuzan which is less than 350 m. high above M. S. L. This fact leads a critical conclusion that *Strukturbodengrenze* does not corresponding to any mean air temperature, because so many variable factors are effective to produce flow earth structure.

In fact, even at the highest summit in the Japan Alps, heavy snow falls in winter and heavy rain falls in warm season and the fact affords an unfavourable condition for the formation of flow earth.

Some Observations on the Polygons and the Stripes

(1) **STONE POLYGONS** (Polygons, Polygonböden, stone rings, Steinringe, Steinnetze, Rautenböden, sols polygonaux, Cercles de pierre)

Typical polygon is hexagonal and in Japan it is called *Kikkorekita* or *Kikkosareki* (each of which means Carapace shaped gravels). In this respect, Woldstedt (1954) noted that typical polygon shows circular and often octagonal form, but we have never met with octagonal form

in Japan (PL. I, Fig. 2, 3).

The polygons are known to us from :

<i>locality</i>	<i>height (m.)</i>	<i>rock species</i>	<i>diameter (cm.)</i>
1) Kamegaike } Norikuradake	2,730 ca.	andesite	30-50
2) Tsurugaike }	"	"	30
3) Kikkoike-Yokodake	2,050 ca.	"	30-150
4) Utsukushigahara	1,900 ca.	granophyric rock	30(-)
5) Kaminodake	2,660	Mesozoic sandstone	20-40
6) Kasadake	2,800 ca.	quartz-porphry	
7) Hachibuseyama	1,650-1,900 ca.	Tertiary sandy shale	30 ca.
8) Kampuzan (39° 59'N)	340	andesite	10 ca.

Tsujimura (1940) noted that M. Schwind had published a map showing the distribution of flow earth in the North and South Japan Alps. But it is regrettable that the writer has never read that publication.

The polygons are generally on the horizontal surface of the even-crested ridges. Sometimes, when the inclination of the slope is small, the intermediate forms appear. No doubt stone stripes are deformed types of stone polygons as was discussed by E. Antevs (1932).

(2) **STONE STRIPES** (Streifenböden, Sols striés)

Stone stripes are more common than stone polygons. The stripes are elongated in the direction of slope which usually inclines less than 20 degrees. Soil profile beneath the stripes and the polygons, shows apparently the same stratification. The stripes are known from the following localities (PL. I, Fig. 1, 4, PL. II, Fig. 5)

<i>locality</i>	<i>height(m.)</i>	<i>rock species</i>	<i>width of fine grained belt(cm.)</i>
1) Yakushidake	2,962	quartz-porphry	
2) Kaminodake	2,660	Mesozoic sandstone	20
3) Utsugidake	2,800(-)ca.	granite	7
4) Minamikomagatake	2,800 ca.	"	7
5) Gokurakudaira	2,850 ca.	"	
6) Minamidake	2,650	porphyrite	
7) Chogatake	2,640	palaeozoic slate	20
8) Hachibuse	1,650-1,900 ca.	Tertiary sandy shale	30
9) Suishodake	2,900 ca.	granite	
10) Shiroumadake	2,900	phyllite	
11) Tengu-one	2,780 ca.	phyllite & diabase	
12) Marishiten	2,820	andesite	30
13) Rengedake	2,700 ca.	porphyrite	

- | | | | |
|------------------------|-----------|----------------|-----|
| 14) Kampuzan(39° 56'N) | 250-280 | andesite | 100 |
| 15) Kasadake | 2,800 ca. | quartz-porphry | |

(3) PROCESS OF EARTH MOVEMENT

The stripes are usually developed on the western and southern slope. The fact makes us to conclude that insolation is necessary for the development of flow earth, that is solifluction. It is worth noting that flaggy boulders are always orientated vertically on the boulder front or on the boulder line. Moreover, flaggy boulders are orientated parallel in the direction of the stripes. The fact that has been recognized on Mt. Suishodake, Mt. Hachibuseyama and Mt. Chogatake, was also clearly shown in a photograph illustrated by Boyé (1950, PL. XXV).

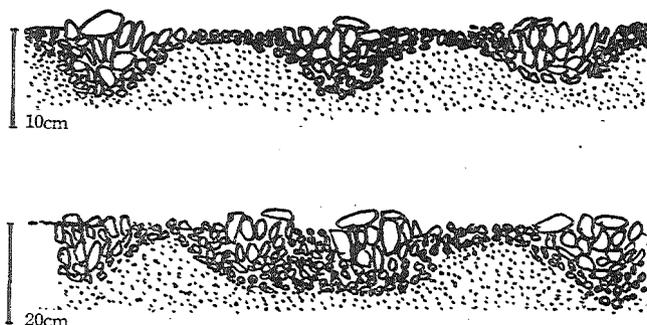


Fig. 2; Soil profiles of stone stripes on Mt. Suisho (upper) and Mt. Hachibuse (lower), which show the stratification and the orientation of boulders.

Until quite recently soil profile of flow earth including stone polygons and stone stripes has not been elaborately observed. However many examples afford a conclusion that they bear a characteristic stratification. Flow earth is frequent on the surface where aeolian loam had once deposited. The so-called loam is fine-grained volcanic ash (K. Kobayashi, 1954), and it is widely known that the bed of loamy material affords a good condition for frost action. The writer once observed that frosting was very active only over the loamy surface on Mt. Komagatake (2,900 m. ca.).

It is hardly said that we find no loamy layer beneath the flow earth structure. On the high mountain ridges, boulders and gravels are scattered to form somewhat like a block field. However beneath the layer of boulders there are usually fine-grained sand or loamy materials. It may be said that

boulders in soil are upheaved by normal frost action, as was discussed by Lundqvist (1949). Thus the stratification by size-decreasing from the surface downward will appear (Fig. 3). Apart from the prevailing aspects (for

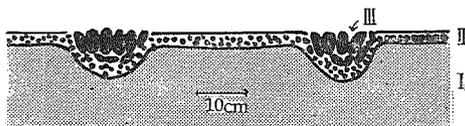


Fig. 3; Schematic Soil profile of stone polygon on Mt. Hachibuse (Locality Hachibuse-D, 1850 m.) I: loamy sand, II: gravels of about 0.5 cm. in diameter, III boulders of about 4-5 cm. in diameter)

instance Flint, 1947; p.461), it may be an important fact that in many cases flow earth in the Japan Alps is associated with this fine loamy materials.

The writer has observed that the soil profile of the polygons and the stripes showed undoubtedly the similar stratification. Schematic soil profile of flow earth structure is presented in Fig. 3. Beneath the belt of fine grains between the boulder line, surface of the finest soil (I) is higher than that beneath the boulder line. When the inclination of slope is slightly more than 20 degrees, boulders flow down at the rate of some 1 m. per year, and at last boulders slip down together at the foot of the slope, resulting the disappearance of flow earth structure in a few years.

In the writer's experiment, the flaggy boulders put horizontally side by side show the tendency that they produce an imbrication (Fig. 4).

The process suggests that in the later stage these boulders will take vertical orientation in the boulders line. This movement is undoubtedly affected by a sort of convection current and the boulder line may be the subsiding belt of one cellular convection system.

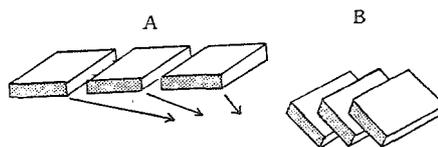


Fig. 4; Schematic diagram showing the movement of flaggy boulders.

A; when put horizontally side by side (arrow shows the movement of each boulder vectorically), B; boulders move toward the boulder line and make an imbrication.

Various Types of Periglacial and Subnival Features

(1) STONE STREAMS (Lundqvist, 1944)

Stone streams adopted here may not be the same feature as Blockströme or stone rivers (Darwin, 1834; A. Heim, 1936) Turf covers the line of boulders and less coarser stones between the boulder line are now moving down. This type of stone streams may be said as the stone stripe of older stage.

Stone streams are clearly exhibited on the western slope of Mt. Shirouma (2,933 m.), and on the slope of *Doppelgrate* (2,800 m.) on Mt. Warimodake (PL. III, Fig. 10).

(2) **TURF-BANKED TERRACES** (Lundqvist, 1944; Terrasses de cryoplanation, stone terraces)

This type of feature is formed on ground rich in gravels and poor in boulders.

1) Northern slope of Misayama (1,650 m. ca.) on Mt. Kirigamine

2) Western slope (1,800 m. ca.) on Mt. Hachibuseyama (PL. III, Fig. 9)

(3) **STONE PAVEMENTS** (Dallages de pierres)

This form is usually developed where snow falls heavily in winter and until midsummer it does not melt away. An example is seen on the northern slope (2,700 m. ca.) of Mt. Mitsumata-Rengedake.

(4) **ROCK GLACIERS** (Glaciers rocheux)

When glacial ice began to waning, detritus might be washed out under periglacial condition. Although solifluction is not so severe in the cirques at present, the action during the early postglacial age would be more active and prevailed more extensively.

In cirques we can find such a detritus like rock glaciers and a sort of lacustrine deposit (originated from morainic lake) under periglacial condition.

1) Rock glaciers in the cirques of Mt. Yakushidake

2) Stratified lacustrine deposits in the cirques of Mt. Komagatake and Mt. Minamikomagatake.

It has been said that most cirques have level and flat bottom surfaces, however according to the writer's inspection the recognition is not true to nature. The level and flat surfaces of the bottom have originated from the postglacial or periglacial deposition of detritus (PL. II, Fig. 6).

(5) **NIVAL CIRQUES** (Cirques périglaciaires, periglacial cirques)

Even in the midsummer, there often remain small snow-patches on the eastern or northern slope. They almost melt away before the beginning of autumn, and small hollowlike cirques appear. This form may be produced by the snow-patch erosion which has been discussed by W.V. Lewis (1939). At the bottoms there are pits without soil (Coulées de blocailles sans limon) and meltwater by ablation of snow escapes from. Sometimes this kind of pits also can be seen at the bottom of *Doppelgrate*.

The formations of nival cirques may have started from the time when the frosting was active during the glacial or the postglacial age. Thus nival

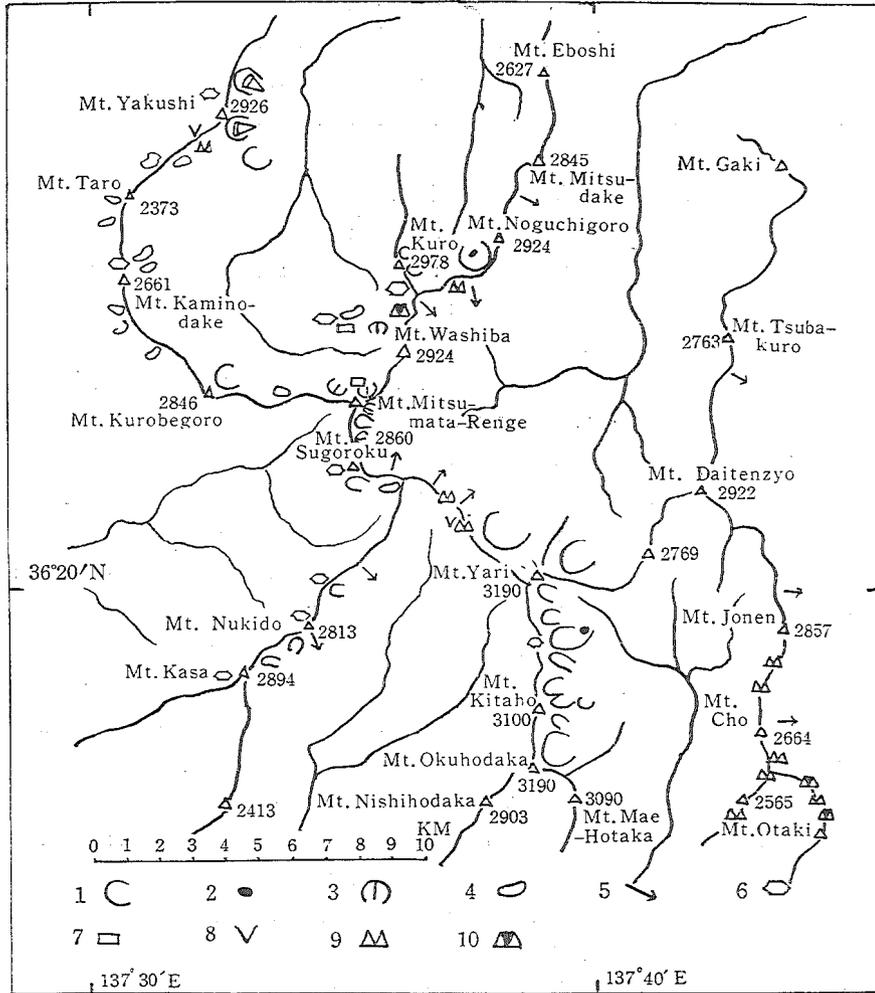


Fig. 5; Map showing the glacial, periglacial and subnival features in the North Japan Alps. Unfortunately the writer is not able to adopt all from the international legends proposed by Dr. H. W. Ahlmann in 1952.

1: glacial cirques, 2: morainic lakes, 3: nival cirques, 4: ponds of various origin, 5: Asymmetrical ridges (arrow indicates the slope which inclines abruptly) 6: polygons, stripes and stone streams, 7: stone pavements, 8: Draining pits consist of boulders only, 9: Double ridges, 10: Ponds originated from double ridges.

cirques in the Japan Alps have been originated (PL. III, Fig. 12).

(6) **BLOCKMEERE** (Felsenmeere)

Sometimes enormous numbers of blocks appear in midsummer beneath snow-patches. The bottom of the shallow basin without soils shows that the surface beneath the snow-patches is subjected to severe "Abspülung"⁽²⁾.

This type of *Blockmeer* is found everywhere and examples at Kumonotaira (2,500 m. ca.), Mitsumata-Rengedake and Tateshinayama are distinguished.

(7) **COULÉES DE BLOCAILLES SAN LIMON**

As has been above noted this feature can be seen at the bottom of *Doppelgrat* or nival cirque and at a spot within *Blockmeer*, in another case it is found on the surface poor in vegetation.

(8) **DOPPELGRATE** (Double ridges, Ponds on the ridges)

It is a problem that this type of feature is really of periglacial or of some other processes. There are numerous *Doppelgrate* in the Japan Alps. The writer has already discussed what process they came into being through (Kobayashi, 1955). According to the writer's opinion this form may be produced under the cool climatic condition with rather high precipitation. In case when *Abspülung* is now going on, the forms are funnel-shaped or cradle-shaped, and in Japan they are called "Funakubo" (the word means a bottom of a ship). But as soon as the draining pit at the bottom choked with clayish soil, a pool appears. Funakubo and the small ponds of this origination are distributing at many places on even-crested ridges and cols on the ridges.

It is also worth noting that not a few funnel-shaped hollows and the ponds that might be produced through above-mentioned process are found on even-crested ridges and cols in the *Mittelgebirge* with an elevation of about 1,000 m. On *Doppelgrate* the writer will go into details at another opportunity (PL. II, Fig. 7 & 8).

(9) **ASYMMETRICAL RIDGES** (Ungleichseitiger Grate, Asymmetrie der Kammbildung)

This type of ridge-form may not be the feature like periglacial asymmetrical valley (Vallée dissymétriques périglaciaires), because the formation of this form might not be affected by solifluction only. It may be originated from the thickly accumulated snow on eastern slope influenced by climatic factors. Asymmetry of ridges is one of the most characteristic features in the Japan Alps, as was discussed by M. Schwind (1936). As was

(2) Nishimura read a paper before the annual meeting of Geogr. Soc. Japan in 1955; Snow-patch erosion in Kirigamine volcano.

above discussed, eastern slope of ridges is more snowy until the beginning of autumn than western slope, erosive power of solid water and meltwater is more active, and as the result slope of eastern side becomes to incline abruptly. Of course in many cases eastern slopes are steep owing to the occurrences of cirque walls.

Significances of Periglacial and Subnival Features in the Pleistocene History.

Deposits in the cirques show that after the glacial ice began to waning, vast amount of detritus were supplied under periglacial conditions as has been reported from the Hidaka Ranges (Hashimoto & Kumano, 1955). At present the supply of detritus has been extremely diminished in quantity, because of the richer vegetation.

Although such microstructures of flow earth as stone polygons and stone stripes are forming to-day and we have never found apparent fossil flow earth, detritus on the cirque bottom, turf-banked terraces, stone streams and other related forms began to develop in times past. However we are not able to date that time.

Table 2 Late Pleistocene history in relation to glacial topography in the Japan Alps. (K. Kobayashi, 1955)

Geol. Age		Climatic conditions	The Central Japan Alps	The North Japan Alps
Holocene	Holocene	Weak solifluction Vegetation in cirques	Structural soils Vegetation in cirques	Structural soils Vegetation on moraines
	?			
Late glacial	Postglacial in Japan	Rather dominant periglacial condition	Detritus at Suriba-chikubo & Senjojiki cirque, nival cirques	Nival cirques at Mt. Norikura, Rock glaciers at Mt. Yakushi
		Aeolian "loam"	Aeolian "loam"	Aeolian "loam"
		Rather dominant periglacial condition	Morainic lake deposit in cirque during deglaciation	
W2	Hida-glacial-II	Glacial and dominant periglacial condition	2 Moraines at Senjojiki	2 Moraines at Yakushidake
W1	(Koma-glacial)		& Nogaie cirque	Upper moraines in Yarisawa Valley
W/R	Interglacial			
R	Hidaglacial-I	?	? (fluvio-periglacial fan)	Yarisawa lowest moraine (fluvio-periglacial fan)

Of course features on a large scale might have begun to develop during the glacial or early postglacial age.

The degree of refrigeration during the last glacial age in Japan was estimated by Hoshiai and the writer (1955), further researches on this problem have made the authors to conclude that the degrees of the summer temperature reduction might be about 6°C, and the mean temperature for the season of ablation at the height of cirque bottom 3.5°C (unpublished manuscript).

Table 2 shows the late Pleistocene history and the correlation between the North, and Central Japan Alps.

The writer wishes to meet another opportunity to discuss the data in this chronological table. Although in the studies of late Pleistocene chronology, estimated years must be given, the measurement by radiocarbon dating has not yet become available in Japan.

As the climate during the Pleistocene might have been fluctuating on a worldwide scale, international correlation is possible. Hida glacial age I may be referred to Porosiri glacial and Riss glacial; Hida glacial II to Tottabetsu glacial and Würm glacial.

References will be presented including the bibliography on periglacial morphology in Japan (literatures treat nothing but the polygons and the stripes).

References

- Boyé, M. (1950) Glaciaire et périglaciaire de l'ata sund nord-oriental Groenland. Expéditions polaires Francaises; Actualités Scientifiques Industrielles, 1111 (Paris).
- Black, R. F. (1950) Permafrost, in Trask's Applied Sedimentation (New York).
- Commission de morphologie périglaciaire (1952): Rapports préliminaires pour la 8^e Assemblée Générale et le 17^e Congrès International, U.G.I.
- Flint, R. F. (1947) Glacial geology and the Pleistocene epoch (New York).
- Fujiwara, S. (1928) On the stone polygons at Kamegaike, on Norikuradake; Geogr. Rev. Japan, 4, 8.-in Japanese
- Hashimoto, S. & Kumano, S. (1955) Zur Gletschertopographie im Hidaka-Gebirge, Hokkaido, Japan, J. Geol. Soc. Japan. 61. 716.-in Japanese
- Imamura, G. (1937) Past glaciers and the present topography of the Japanese Alps. Sci. Rep. Tokyo Bunrika Daigaku; 2, 7.
- (1940) The Japanese Alps and the Past Glaciers (Tokyo) -in Japanese
- Kleibelsberg, R. V. (1948-9) Handbuch der Gletscherkunde und Glazialgeologie. 2 Bde. (Wien)
- Kobayashi, K. (1954) A short report on the history and the Pleistocene Geology

- of the Matsumoto basin and its adjoining mountains; *J. Shinshu Univ.*, 4.
- Kobayashi, K. & Hoshiai, M. (1955) Late Pleistocene and modern snowlines in Japan; *Earth Science (Chikyu Kagaku)*, 21. -in Japanese
- Kobayashi, K. (1955) *Nature in the Japan Alps (Tokyo)*. -in Japanese
- Lewis, W. V. (1939) Snow-patch erosion in Iceland; *Geogr. J.* 94.
- Lundqvist, G. (1944) *De svenska fjällens natur; STF : s handböcker om det svenska fjället (Stockholm)*
- (1949) The orientation of the block material in certain species of flow earth; *Geogr. Annal.*, 31, 1-4.
- Nakajima, M. (1938) On the stone polygons at Kikkoike on Mt. Tadeshinayama; *Jour. Geogr.*, 50, 588. -in Japanese
- Nishimura, K. (1928) A new discovery of structure earth in the Hida Range; *Chikyu*, 9, 6. -in Japanese
- Sasa, Y. (1954) Stone polygons and stone stripes found in the Samukaze (Kampu) volcano, Northern Japan, *J. Geol. Soc. Japan*, 60, 711. -in Japanese
- Schwind, M. (1935) *Eiszeitforschung in Japan*, *Geogr. Zeitschr.*, 41.
- (1936 a) *Meine Reise durch die Japanischen Nordalpen*, *Zeitsch. für Erdk.*, 4
- (1936 b) The Extension of the diluvial Glaciers in the Japanese North-Alps, *Journ. Geol. Soc. Japan*, 43
- (1936 c) Die Kasa-Dake-Kette und die Entdeckung des Rundhöckergebietes am Nukedo-Dake, *Geogr. Rev. Japan*, 12
- (1937 a) Beobachtungen auf meinen Reisen durch die Zentral-und Südalpen im Sommer 1936, *Geogr. Rev. Japan*, 13
- (1937 b) Glazialformen und Strukturböden in den Japanischen Nordalpen, *Geogr. Zeitsch.*, 43
- Sverdrup, H. U. (1935) The Ablation on Isachsen Plateau on the Fourteenth of July Glacier in relation to radiation and meteorological conditions; *Scientific Results of the Norwegian-Swedish Spitzbergen Expedition 1934, Part, IV*; *Geogr. Annal.*, 17
- Terada, T. (1928) Some experiments of periodic columnar forms of vortices caused by convection; *Rep. Aeronaut. Res. Inst.*, 3.
- Troll, C. (1948) *Der subnivale oder periglaziale Zyklus der Denudation*, *Erdkunde*, Bd. II.
- Tsujimura, T. (1923) *Alpine landforms in Japan*; *J. Geogr.* 35, 416, 418.
- Popular scientific writings: *Mountains*, p. 115-117 (1940); *The story of landforms*, p. 370-1 (1949) -in Japanese
- Woldstedt, P. (1954) *Das Eiszeitalter*, Bd. 1 (Stuttgart)

Explanation of Plates

- PL. I; Fig. 1: Soil profile of the stripes on Mt. Hachibuse showing the loamy layer downward (1,650 m.).
- Fig. 2: Soil profile of the polygons on Mt. Hachibuse showing the loamy layer downward (1,850 m.).
- Fig. 3: The polygons on Mt. Hachibuse (1,850 m.).
- Fig. 4: The stripes on Mt. Chogatake (2,640 m.).
- PL. II; Fig. 5: The stripes on Mt. Hachibuse (1,650 m.).
- Fig. 6: Postglacial detritus covering the granite base in the Suribachikubo-cirque (2,530 m.).
- Fig. 7: Double ridges (Doppelgrate) on the ridge of Mt. Otakiyama (2,650 m. ca.).
- Fig. 8: The pond of Mt. Otakiyama originated from double ridge (2,560 m. ca.).
- PL. III; Fig. 9: Turf-banked terraces on Mt. Hachibuse (1,800 m. ca.).
- Fig. 10: Stone streams in the double ridge near Mt. Warimo-dake.
- Fig. 11: The pond of Sugoroku situated at the cols near Sugoroku hut (2,500 m.).
- Fig. 12: Nival cirque near Mt. Washibadake.



Fig.1



Fig.2

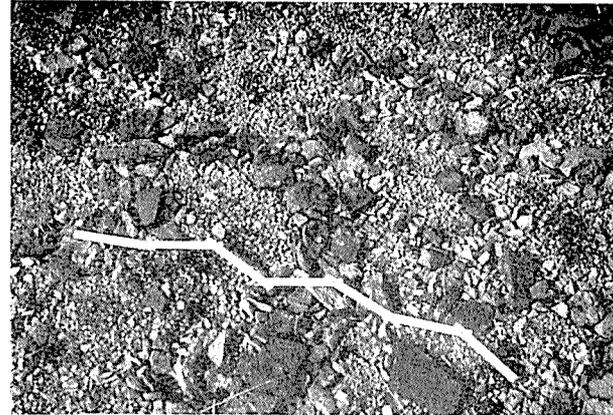


Fig.3



Fig.4

PL. I

No.5



Fig. 5



Fig. 6

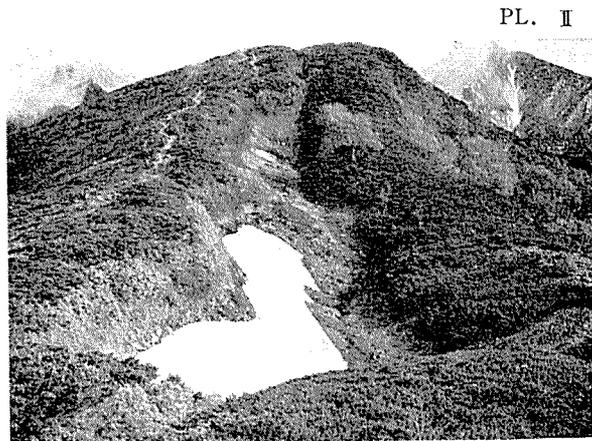


Fig. 7



Fig. 8



Fig. 9



Fig. 10



Fig. 11



Fig. 12