Preliminary Report of the Patterned Ground on Ontake Volcano, Central Japan

(Contributions to Periglacial Researches in Japan, No. 4)

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Introduction

In Japan, it failed formerly to arouse much attention to periglacial phenomena until a few years ago. Since the end of World War II, researchers of our Department of Geology in Shinshu University have been making an accelerated progress of periglacial researches. Thus, up to the present day, many important discoveries in the researches for periglacial phenomena in Japan have been made in Shinshu. From researches in the field, not a few principles in periglacial agency in Japan have also been confirmed. In addition to this sort of confirmations, several environmental factors and characteristics of patterning ground in Japan have also been better understood by us (Kobayashi, 1956; p. 15–36).

The study here preliminarily reported was undertaken to search for the origination of the polygons on an old pond at Ichinoike of Ontake Volcano. Because (1) no discussion on the patterned ground of Ontake has ever been made, (2) the patterned ground at Ichinoike has been produced on the largest scale and, (3) the situation stands at the highest level in Japan. In this report, firstly we shall describe the field evidences for our purpose to search for the leading factor in patterning ground.

We had several laborious but joyous mountain climbing accompanied by Kazumi Shirasawa, Tadayuki Hatakoshi, Kazuo Yano and Mitsuo Sugiura to whom we are greatly indebted, we have to express our sincere thanks to them. We are grateful to Akira Masazuka, chief of the Matsumoto Weather Station, Itsuki Yokouchi of Kiso Biological Institute of Kyoto University and to Miss Kimiko Suzuki in our Department of Geology for much assistance with the analysis of soil samples. Finally we express our grati-

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Geographical Setting

Mount Ontake is a dormant volcano located at some 60 km south-west of Matsumoto, with the highest summit-Kengamine (3,063 m. high above M. S. L.) at 35°53.4′ north latitude and 121°45′ east longitude (Greenwich). Ontake Volcano had been active perhaps down to early Holocene and is still topographically conspicuous. In despite of the height which reaches up to 3.063m (10,051 feet) above the sea level, the highest summit shows no trace of glaciation, and the fact will sufficiently be considered in our discussion.

Ichinoike Crater is approximately circular, the crater ring is steep-walled and some 50m high above the bottom. The bottom is slightly higher than 3,000 m above M. S. L. (Fig. 1). The north-eastern part of the ring was later destroyed by the explosion of Ninoike Crater, and the crater lake of Ichinoike had almost been extinct. At present, the bottom of Ichinoike Crater is nearly horizontal and marshy, but the superficial skeletal soil bears poor vegetation (PL. III. Fig. 5). The north-eastern part of the bottom is horizontal and the other part where patterned ground is well developed shows the inclination less than 3 degrees to north-west. A very shallow rill (several centimerters in depth) flows from south-west down-stream to north-east across the north-western part of the bottom and pours into Ninoike (pond) which lies at some 50m lower level. The boulder-rows of the polygons and the stripes are saturated with flowing water, and at the margin of the patterned surface, this water is brought out to the surface.

In the autumn of 1956, we had an experience that excavated holes were soon filled with water which exuded from boulder-rows (1) and mollisolic soft sediments up to the depth of about 30cm from ground.

The forest limit of Ontake Volcano is approximately at the level of 2,200 m-2,500 m in height and the slope above *Betula Ermani* zone is sparsely vegetated. On the bottom of Ichinoike Crater, poor vegitation consisting of

(1) The word "boulder" is not used in the strict sense, it is used as compared with the stones in the central area of the polygon. It indicates the coarser stones in the border around the finer materials or merely the coarser stones in rows. At Ichinoike, the above-mentioned stones belong strictly to the fraction of boulder in size.

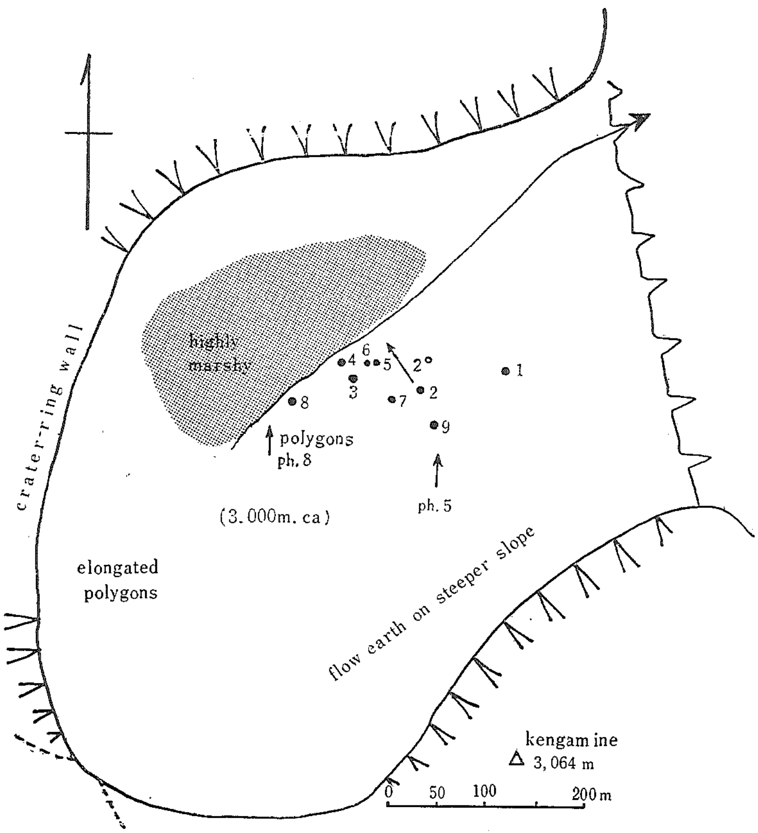

Fig. 1 A sketch-map of Ichinoike Crater of Ontake Volcano showing the distribution of patterned ground. An arrow with the sign of 2° indicates the inclination of the ground. Arrows with the sign of ph. indicate the direction towards which the photographs were taken. Black spots are the studied points.

the following plants is found.

Pleuropteropyrum Weyrichii var. *alpinum*
Carex Tolmiei var. *denticulata*
Phyllodoce aleutica
Harrimanella Stelleriana
Loiseleuria procumbens
Empetrum nigrum japonicum
Arcterica nana

Vaccinium uligonosum

Diapensia Lapponica subsp. *obobata*

Saxifraga Merkii Eisch. var. *Idzuroei*

Almost all the members are hygrophytic montane species of the wet-flushed areas and some of the above-mentioned species e. g. *Loiseleuria procumbens* (Schwarzbach, s. 48) and *Vaccinium uligonosum* (Schwarzbach, 1950; s. 48) are called "the plant of arctic tundra". At Ichinoike, most of the plants grow in the form of "turf-covered mound" which bears some resemblance to "T h u f u r". The vegetation of this type reveals a marked contrast with the vegetation upon the patterned ground on the ridge of Mt. Suisho and of Mt. Koma where such a xerophytic plant as mountain avens (*Dryas octopetala*) is found.

Air Temperature

Instrumental recordings of air temperature at higher part of Ontake Volcano have been very sparsely made and the annual march of air tempe-

Table 1 Mean air temperature at the top of Mt. Kengamine and at Kamishima for July and August in 1951; those observed in 1928 are also cited.

Observed spot	for		at 10.00 J.S.T.	daily max.	daily min.	*at 10.00 J.S.T.
Kengamine Alt. 3,050m above M.S.L.	July	Ist. decade	....	....	....	
		IInd. 〃	11.3 °C	14.2 °C	4.6 °C	
		IIIrd. 〃	13.8	16.8	7.3	12.7°C
	Aug.	Ist. 〃	10.0	12.8	6.1	12.7
		IInd. 〃	11.0	12.9	5.3	12.9
		IIIrd. 〃	11.3	12.8	7.1	11.8
Kamishima Alt. 924m above M.S.L.	July	Ist. 〃 IInd. 〃 IIIrd. 〃	21.4	26.3	15.1	Ist. dec. of Sept. 11.8
	Aug.	Ist. 〃	25.2	29.4	15.1	
		IInd. 〃	25.5	29.7	15.9	
		IIIrd. 〃	23.6	28.1	16.5	

* observed values for the summer of 1928, on the bank of Ninoike pond at the level of 2,906m in height.

rature is very incompletely known. Table 1 shows the brief observations made in 1828 and in 1951. It shows the mean air temperature at the level of 2,906m. high above M. S. L. and also the mean air temperature at the top of Kengamine (3,050m high above M. S. L) of Ontake Volcano for July and August in 1951, as compared with that at Kamishima (924 m) which is at the foot of Ontake Volcano. Table 2 shows the trend of monthly mean

Table 2 The trend of monthly mean air temperature at Kamishima of Otaki-mura (35°48′N, 137°33′E) with the altitude of 924 m. Mean values were obtained from the observation for 35 years from 1892 to 1926.

	°C	J	F	M	A	M	J	J	A	S	O	N	D	Annual mean
Monthly mean at 10.00 J.S.T.		-2.5	-1.9	3.4	10.6	15.7	19.4	23.5	24.9	19.7	13.1	6.4	0.1	11.0
Average daily maxima	Ist. decade	3.1	1.3	5.6	12.3	19.2	22.2	26.1	28.2	26.3	19.3	14.4	6.3	16.4
	IInd. 〃	1.2	2.9	9.0	14.2	19.0	23.2	26.9	28.7	22.9	17.5	11.1	4.0	
	IIIrd. 〃	1.8	3.8	9.7	15.4	20.6	24.4	27.7	26.1	21.2	15.4	9.0	4.2	
Average daily minima	Ist. decade	-8.2	-11.1	-6.7	-1.3	5.0	7.4	15.1	17.1	14.8	8.8	1.1	-2.9	3.1
	IInd. 〃	-10.4	-10.7	-4.2	-0.5	6.1	11.5	15.6	16.1	13.2	5.6	-0.6	-7.0	
	IIIrd. 〃	-8.6	-9.6	-2.8	1.9	6.1	13.5	16.5	15.8	9.3	3.1	-1.1	-6.5	
Arithmetical mean of max. & min.	Ist. decade	-2.6	-4.9	-0.6	5.5	12.1	14.8	20.6	22.7	20.6	14.1	7.8	1.7	9.8
	IInd. 〃	-4.6	-3.9	2.4	6.9	12.6	17.6	21.3	22.4	18.1	11.6	5.3	-1.5	
	IIIrd. 〃	-3.4	-2.9	3.5	8.7	13.4	19.0	22.1	21.0	15.3	9.3	4.0	-1.2	

air temperature at Kamishima for 35 years. Diurnal fluctuation of air temperature was observed by Dr. Tanaka and others (Tanaka, 1930; p. 995–996), the results are put in Fig. 2. The spot where the observation was made, is on the bank of Ninoike.

On the north-west bank of the pond, there is a permanent snow-bed which has been called "Mannenyuki", the word means "permanent snow". Fig. 12 in Plate V shows the snow-bed at minimum on 30 Sept. 1956. The first heavy snowfall would come approximately during the first decade of October every year.

According to aerological sounding for recent four years, the average air temperature for January and February is about 13.6°C at the level of 3,050m in height in free atmosphere. It may, therefore, be said that the average value for above-mentioned two months at the same height is approximately below −15°C. Theoretically, the lapse rate for these months should take a value larger than 4.5°C/100m, then we can obtain a value

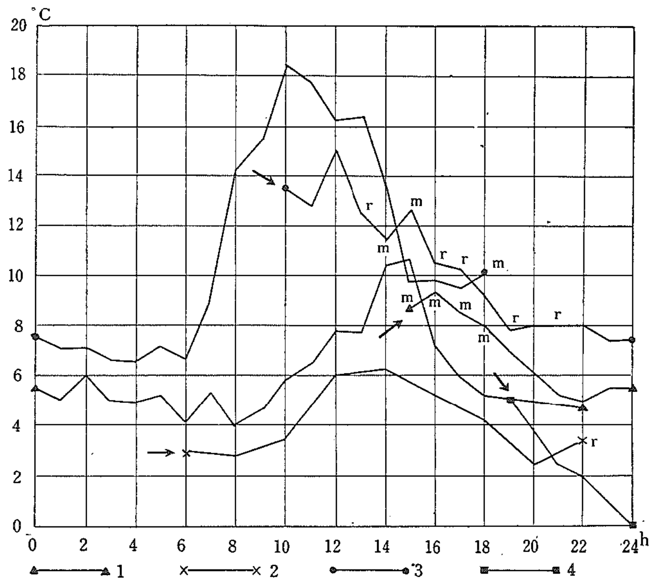

Fig. 2 Diurnal fluctuations of air temperature at the level of Ninoike (2,906m high above M.S.L.) of Ontake Volcano.

1 Obsevation from 14 Sept. to 15 Sept. in 1927 (Tanaka and his co-wokers)
2 Observation made at 16 Sept. 1927 (〃)
3 Observation from 14 July to 15 July in 1928 (〃)
4 Observation from 29 Sept. to 30 Sept. in 1956 (Kobayashi)
r: indicates rainy weather, m: indicates misty weather

larger than —13.1°C for the same months. Hence, daily freezing and thawing would be active in autumn, because snowaccumulation would interrupt the action in spring.

Surface Patterns of the Ground

The forms of patterned ground at Ichinoike are essentially those of stone polygon. They are, however, often intermediate even upon the horizontal surface. Sometimes they are tongue-like forms known as stone garland, and sometimes they bear a resemblance to those of the stripes (Fig. 3) upon the slope of 2 degrees. The polygons at Ichinoike scarcely exhibit a hexagonal form. As was discussed by Boyé (1950 p. 141), if polygonal form might be produced by the combination of each cell in which less coarser material is bordered by a row of coaser boulders, hexagonal form is essentially of no importance to obtain a clue to solve the riddle

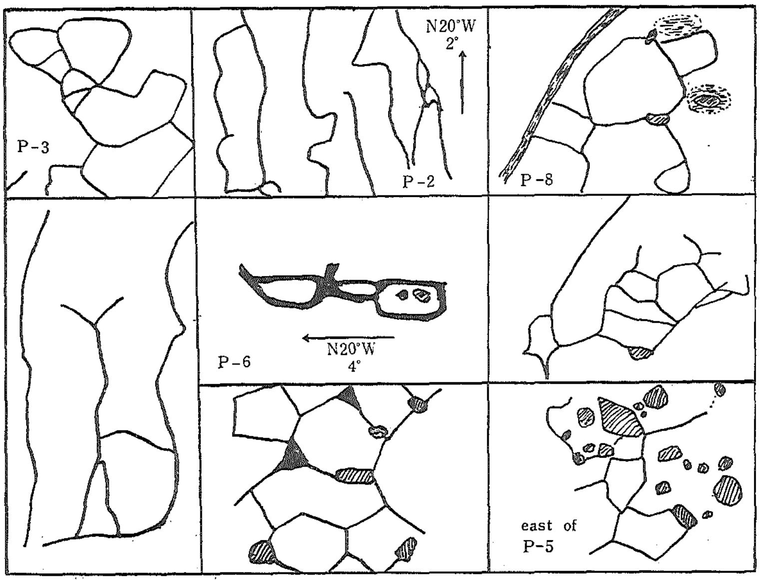

Fig. 3 Schematically drawned patterns of the polygons and the stripes at Ichinoike. Black lines indicate the boulder-rows.

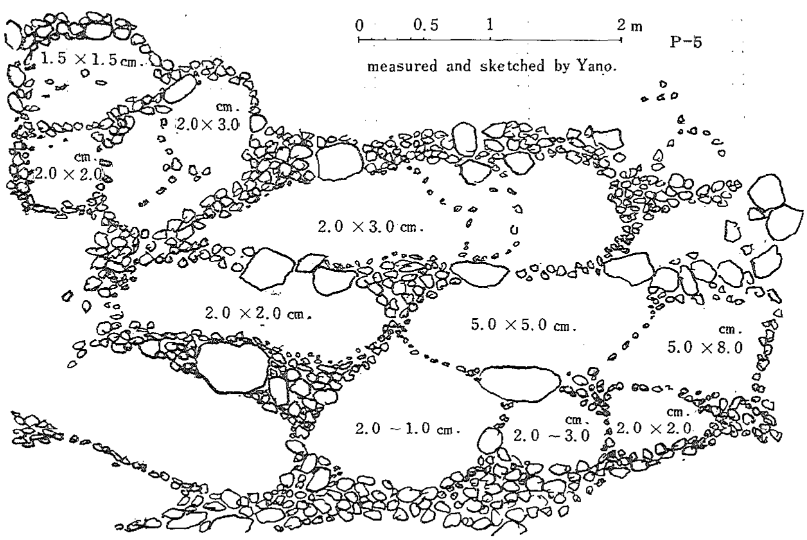

Fig. 4 Surface patterns of the patterned ground at Ichinoike of Ontake Volcano. Black lines show the distribution of boulder-rows. Numerical values in the picture show the average size of the stones in the central area of polygons. P-5 means the sudied point which is shown in Fig. 1.

of genesis.

The petrological character of the stone at the place is a kind of non-porous two-pyroxene-andesite. Upon the surface, boulders with a length of about 1 m are often met with. These huge boulders are quite often surrounded by rings of stones (Pl. Ⅳ, Fig. 8). The size of boulders in boulder-rows have averagely the length of 15cm and the width of 10cm, and the particles in the central areas are averagely 2 or 3cm in diameter (Fig 4.). Some measured values are tabulated in Tabe 3.

Table 3 The relations between the size of the polygons and that of the stones in boulder-rows and in the central areas.

size of mesh	in boulder-row		in central area	
	max.	min.	max.	mean.
400×100cm	35×35cm	12×10cm	10×10cm	3×2 cm
250×200	50×45	10×7	5×5	2×1
200×200	45×45	15×10	15×10	3×2
200×150	60×35	15×10	10×8	2×2
200×100	30×20	10×10	8×5	2×1
180×70	50×30	3×3	5×5	2×2
120×100	35×25	8×8	5×5	3×2
115×52	20×15	7×5	5×5	2×1
150×95	40×25	10×10	15×10	5×5
100×50	40×25	15×10	6×5	3×2

Subsurface Structures

As was already stressed by Kobayashi (1956; p. 30), in any stone polygons and stone stripes, the profiles of patterned grounds are quite similar to each other. The subsoil structure beneath the patterned ground at Ichinoike is shown in Fig. 5. The brown fine-grained subsoil which is drenched with water and very unstable like porridge or soft paste, is a kind of "mollisol" which was designated by Bryan (1949. pp. 101-104). The thickness of mollisol at Ichinoike is seemed to be more than 50cm. Because of the softness and unstableness, excavation was always obliged to be ceased. On 30 Sept. 1956, the central surfaces of the polygons were often depressed to a considerable depth (10cm or more) by the weight of our bodies. On the contrary, the boulder-rows in which interstitial water flows with a soft noise were stable enough to support the weight.

In the preceding papers, the senior author (Kobayashi; 1955, 1956) pointed out the fact that the polygon and the stripes bore the "2 or 3 layered profile". At every point of patterned ground, the downward size-decreasing of particles from the surface is seen. The intermediate particles are on the surface of the central area of boulder-row, and they are also beneath the boulder-row (Fig. 5 A1, A2, B). The surface of the lowest layer of fine particles is undulated. It is noticeable that even on the dry striped slope, the surface of the mollisolic layer shows undulation and the boulder-row occupies the depressed surface of mollisol. The undulation of the surface of mollisol has been found by us in every case on Mt. Mitsudake, Mt. Suisho and Mt. Cho in the North Japan Alps and also on Mt. Hachibuse. This layer of fine particles or mollisol will be the leading actor that performs the patterning ground.

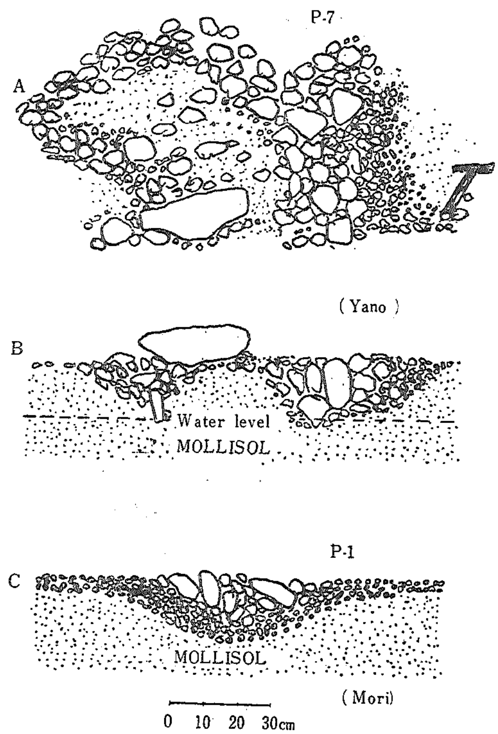

Fig. 5 Subsurface structure of the polygons at P-1 and P-7.
A 1 : Surface pattern at P-7.
A 2 : Subsuface structure of the above-shown polygon. See also Pl. 5, Fig. 11.
B : Subsuface structure of the polygon at P-1.

Some samples were collected from mollisol to analyse mechanically and determine the particle-size distribution. The larger particles than 0.06 mm were analysed by wet sieving and the analysis of the finer particles was made by the pipette method as described by Krumbein (1932. p. 140-149). The material from mollisol contains much less silty part than the so-called "loam" in Japan. The senior author (Kobayashi, 1955 and 1956) once noted that the subsoil beneath the stripes and the polygons were usually rather fine and often loamy. The so-called "loam" originated from volcanic ash, however, contains usually much silty material (sometimes 80-90%), while the material (Fig. 6) contains only 20-15% silt. The so-called "loam" has much of volcanic glass fragments and that of monomineral grains as shown in Table 4. With respect to this

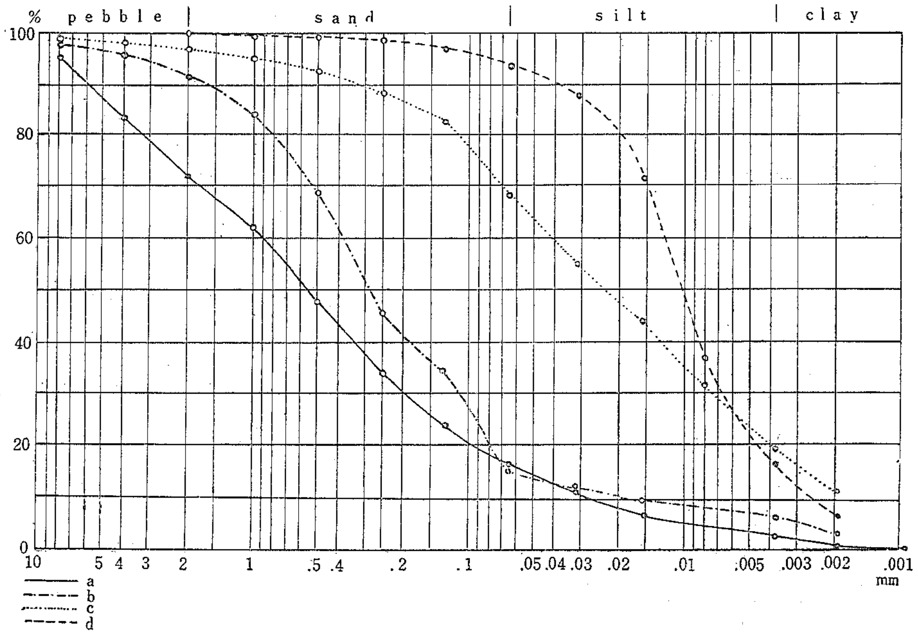

Fig. 6 Size-composition of the samples from Mollisol and volcanic ash represented as cummulative curves.
a : samples from Mollisol beneath the polygon north of P-7
b : samples from Mollisol beneath the polygon at P-7
c : sample from white clayey layer in the subsoil beneath the "turf-covered mound" at P-9
d : sample from the so-called "loam" in the depth of 20 cm from ground at Koyashiki, north-east of Ontake Volcano.

characteristics, the present sample contains a few of volcanic glass fragments and much of weathered rock fragments in grain-size fraction 1/8–1/16 mm. Hence, the finer particles of mollisol might have been the weathered product of rocks under periglacial climate, though the process of periglacial weathering has not yet been confirmed.

Some questions will be noted here. Notwithstanding that the mollisol may at least have the depth of more than 50cm, and the length and width of the polygon reach roughly up to 100 or 200cm, the boulder-rows are not so deep as 30 cm.

The shapes of boulder at Ichinoike are not flaggy, the orientation of boulder were not able to be measured, somewhat flaggy boulders, however, were found to exhibit an appearance of imbrication (Kobayashi, 1955 and

1956) round a huge boulder.

Table 4 Mineral composition of the samples from the loam and the mollisol in percentage numbers. (in grain-size fraction 1/8–1/16 mm)

	1	2	3
volcanic glass groundmass flake	36.7%	% (23.1)	% (19.1)
quartz	0.7	8.6	......
orthocl. & albite	4.4	7.0	......
plagioclase	18.4	21.0	16.5
clayed mineral	14.8	16.4	59.0
biotite	0.7	1.2	0.7
hornblende	1.0	0.7	......
augite	2.9	1.9	0.7
hypersthene	14.7	14.4	3.3
olivine	0.6	......	0.7
titano-magnet	2.5	3.8	......
hematite	0.1	......	0.7
limonite	1.3	......	......
opaque mineral	1.9	......	......
unidentified min	......	1.5	......
total sum	100.7	99.6	100.7

1. Sample from the loam in the depth of 20 cm from ground, at Koyasiki remains, at the foot of Ontake Volcano.
2. Sample from the loam in the depth of 1 m from ground at Atsusa mura, near Matsumoto.
3. Sample from the top of mollisol at Ichinoike.

"Turf-Covered Mound"

Short description of "turf-covered mound" will be made here. As is shown in Fig. 7 and 5 & 6 in Pl. Ⅲ, ther are many turf-covered mounds upon the skeletal soil of the bottom of Ichinoike Crater. They bear a some resemblance to "T h u f u r" in apparence. The vegetation consists of rather such non-hygrophytic plants as *Arcterica nana*, *Carex stenantha* and *Diapensia Lapponica* L. var. *obovata*. Besides these, *Loiseleuria procumbens* is also found.

The soil profile of the mound, as is shown in Fig 7 and Fig. 10 in Pl. Ⅴ is not so peculiar, and well-stratified layers beneath the ground are shown. The soil of upper layers contains much plant remains. The white clay is embedded between the brownish fine grained sand (Fig. 6). Beneath the mound, stone is scarcely found. Turf-covered mound is often surrounded by many boulders as is shown in Fig. 6 in Pl. III, it might, therefore, have a close relation to the development of the polygon.

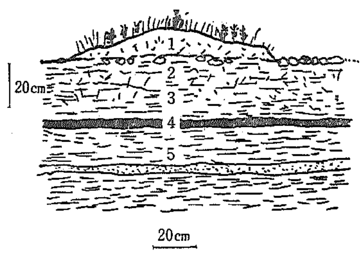

Fig. 7 Subsurface structure of the "Turf-covered mound" at P-9 30m south of P-5.
1 : humussic dark brown sand
2 : brown silt with plant remains
3 : brown clayey sand with plant remains
4 : white clay. See also Textfig. 6 and Fig. 10 in Pl. V
5 : yellowish brown clayey sand

Geological Considerations

Now we must refer to the time, when the patterned ground at Ichinoike had originated. It is, however, a hard problem. At present, it is evident that there is a favourable condition in which patterned ground is able to be formed. The development of a thick mollisol, the height of the situation and the annual march of air temperature at this level, afford a necessary condition for the agency of solifluction to be active.

Of course, the so-called "Shinshu loam" would have been originated from the volcanisms of various volcano, e. g. Ontake, Norikura and other volcanoes. Although, we have studied the loam at several places, our knowledge on the geological significances of the loam has been meagre. There is an extensive sheet of volcanic ash which has hitherto been called "loam" around Ontake volcano. We are not certain, however, when the deposition of the so-called "loam" took place with respect to the known lavas of Ontake Volcano.

The sequence of volcanism of Ontake was studied by Kozu (1908) and it is tabulated in Table 5. On the other hand, we have some knowledges on the stratigraphical and mineralogical features of the loam in our area.

Table 5 History of volcanism of Ontake Volcano. After Kozu (1908)

Mikasa Komikasa flank volcano	Marishiten volcano (lava)	San'noike volcano	Shinoike volcano	Gonoike volcano	Central cone	Explosion
	type 10					
lava	type 11					
	type 12	lava	lava			
		Explosion				
				lava		
					Ichinoike lava	
						Ninoike Shirakawa Jigokudani Explosion

(1) Quite recently, Koyashiki remain of Kaida-mura at the north-eastern foot of Ontake Volcano, was excavated by Dr. Makoto Suzuki, Mr. Sohei Fujisawa and other researchers. As a member of the group, the senior author studied the upper part of so-called "loam" which contains a few blades and not a few bifaced points. The occupation of the palaeolithic people of Koyashiki must have been later than the Komaglacial (Würm 1-2) in age and the date of deposition of the so-called "loam" would be the event since these glacial maxima. (Kobayashi and others 1957).

(2) With respect to the mineral composition of the so-called "loam" at Koyashiki (Table 4), hypersthenic pyroxene is pretty dominant in numbers from the top to the depth of about 70 cm. It contains more than 30% shard-type volcanic glass in numbers (Table 4).

(3) The material in the depth of 1 m from the top of the loam at Atsusamura near Matsumoto contains more than 20% shard-type volcanic glass fragments in numbers, and also far lager numbers of hypersthenic pyroxene than augitic one are contained. In this respect, both samples bear a similarity to one another (Table 4).

(4) Mineral composition of the above-mentioned samples have a resemblance to the lavas of Type 6, 7, 8 and 11 extruded from Marishiten Volcano of Ontake and so to those from Kengamine volcano of Norikura. Ontake Volcano is only 20 km apart from Norikura Volcano.

(5) In grain-size fraction 1/8-1/16mm, the material of mollisol at Ichinoike crater contains 19.1% glass fragments. In contrast with the typical loam, the majority of glass fragment of mollisol consists of the fragments of the glassy groundmass of andesite. It contains also abundant numbers of clayed minerals and far lager numbers of hypersthenic pyroxenes than augites. Considering only these facts, we are apt to believe that the apparent loam-like materials of the mollisol have not originated from the volcanism which produced the extensive sheet of the so-called "loam".

(6) Beneath the upper soft loam, hard and rather heterogeneous loamy materials are often met with at various places of lower altitudes. The loam proper may have a polygenetic origination derived from various volcanisms.

As was already noted, no trace of probable glaciation during the Würm glacial age is seemed to show that the latest eruption might have happened during the Würm 4 or since the Würm 4. In this respect, Kano (1937; p. 93～112) committed a mistake in which he supposed the craters of Ichinoike and Ninoike the glaciated features. Though, we have not any certain proof, so far as our experiences go, the eruption of Ichinoike Crater would be later than the deposition of the loam.

The lava erupted during the volcanism of Ichinoike Crater, is petrographically oliv.-bearing-hypers.-aug.-andesite, and the feature is not similar to the upper part of the "loam" at Koyashiki, and so to the mineral composition of the upper part of the mollisol at Ichinoike.

The question is that our present knowledges (Kozu, 1908) on the petrographical features deny the occurrence of younger lava which contains so much hypersthenic pyroxenes as the lava which has supplied the material to the mollisol at Ichinoike. In any case, it is possibly said that deposition of the loam might originate earlier than the eruption of Ninoike. Hence, the date of the drying up of Ichinoike caused by the explosion of Ninoike would certainly be postglacial in age.

The patterned grounds produced possibly by freezing and thawing of water in soils might have been formed during the postglacial or the Holocene. Although the size of the patterned ground of Ichinoike Crater is approximately five or ten times the size of the normal magnitude of active patterned grounds in Japan, it can be said that they have been formed under the present periglacial climatic conditions.

In this respect, the condition that produces this magnitude should be attributed to the ground condition and not to the climate.

Conclusion

At the ordinary field of patterned ground in Japan, water is supplied by thawing of frost or by melting of snow, and usually the subsoil is pretty dry in summer and early autumn. While, the ground at Ichinoike, Norikura and Tateshinayama bears much water and thick mollisol is well developed in favour of their situation on the banks of ponds. With regard to the size of patterned ground, it is still questionable if it is affected by coldness in winter, or daily or seasonal freezing and thawing of frost. It should, however, be stressed that the degree of dryness or wetness and the total thickness of mollisol would not fail to affect the size of the polygons.

Generally speaking, in the Japan Alps, the stripes are dominantly developed on the western cryoplanated gentle slope where only xerophytic plants are poorly vegetating. In contrast with this fact, the patterned ground at Ichinoike Crater of Ontake Volcano is upon nearly horizontal wet ground where only hygrophytic plants are met with.

In principle, we are inclined to believe that ordinary patterned ground in Japan is developing on dry ground, and each boulder-row is only 20cm or 30cm apart. While, that at Ichinoike is developing on far larger scale, sometimes the width and the diameter reach up to 200cm or more.

According to Woldstedt (1954; s. 65) and Washburn (1956; p. 853), it is said that the convection hypothesis is now in disfavour. As was noted by the senior author (Kobayashi, 1955; p. 23–38), we have not yet found any obstacle in our opinion that a sort of convective movement of mollisol was once active in the processes of patterning ground, although the factors and mechanisms have not yet been little understood.

In spite of vast amount of publications on patterned ground, our knowledge on their genesis has been still very insufficient. However, so far as we are to analyse their genesis, (1) we should make a close inspection to the subsoil structure of patterned ground and (2) although mechanical application should be avoid, experimental study is necessary for the better understanding of the nature.

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Explanation of Plates

Pl. I

Fig. 1 : Stone polygons at Ichinoike (Photo. by Kobayashi)

Fig. 2 : Stone polygons at P-3 of Ichinoike (Photo. by Kobayashi)

Pl. II

Fig. 3 : Stone polygons at Ichinoike. A measure in the picture is 1 m long. (Photo. by Kobayashi)

Fig. 4 : Stone polygons south of P-8. The helve of a shovel in the picture is 50 cm long. (Photo. by Shirasawa)

Pl. III

Fig. 5 : Turf-covered mounds and the view of Ichinoike. See also Ph. 5 in Textfig. 1 (Photo. by Kobayashi)

Fig. 6 : Close up of a turf-covered mound (Photo. by Kobayashi)

Pl. IV

Fig. 7 : Close up of a boulder-row. A measure is 50 cm long. (Photo. by Kobayashi)

Fig. 8 : Stone polygon around a huge boulder at P-8. The helve of a shovel is 50 cm long. (Photo. by Shirasawa)

Pl. V

Fig. 9 : Stone stripe. The stripe is subparallel to the direction of N 20° W towards which the ground inclines approximately 3 degrees. (Photo. by Kobayashi)

Fig. 10 : Subsoil structure of turf-covered mound at P-9. A measure is 1 m long. See also Textfig. 7 (Photo by Shirasawa)

Fig. 11 : Subsoil structure of the polygon at P-7. (Photo. by Kobayashi)

Fig. 12 : Permanent snow-bed at minimum on 30 Sept. 1956 on the bank of Ninoike pond (Photo. by Kobayashi)

No. 6

Plate I

Fig. 1

Fig. 2

No. 6

Plate Ⅱ

Fig. 3

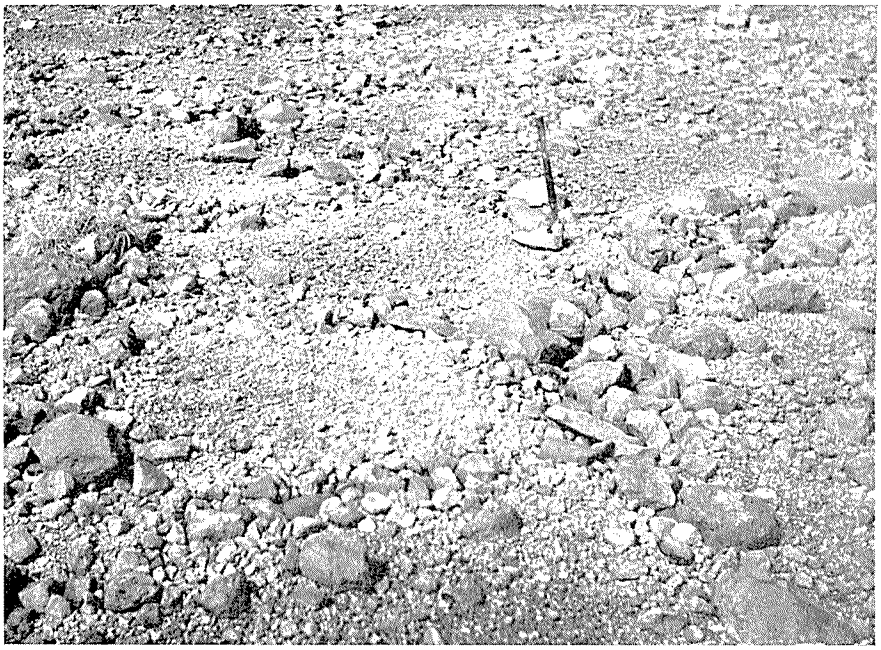

Fig. 4

No. 6

Plate III

Fig. 5

Fig. 6

No. 6

Plate Ⅳ

Fig. 7

Fig. 8

No. 6

Plate V

Fig. 9

Fig. 11

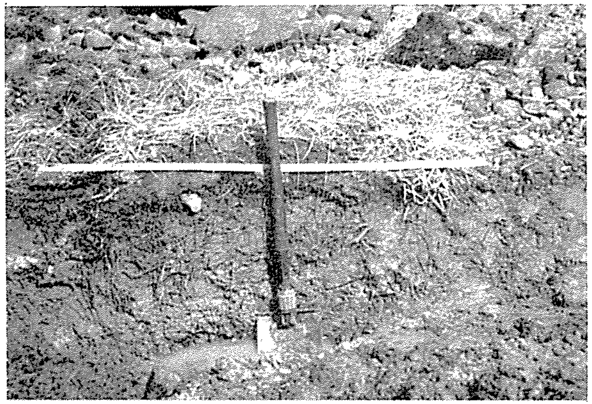

Fig. 10

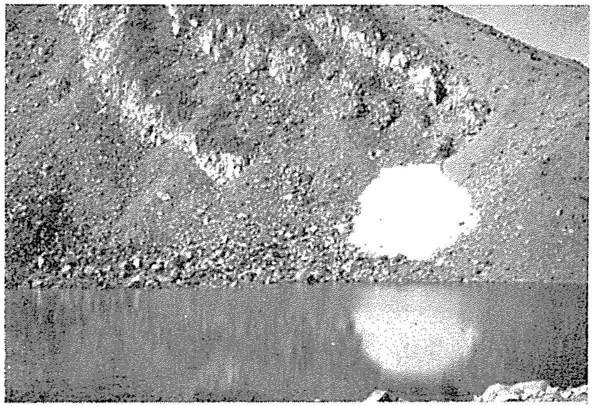

Fig. 12