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Glacial Geomorphology and Snow-Lines of Younger Quaternary around the Yari-Hotaka Mountain Range, Northern Alps, Central Japan

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Summary: The Yari-Hotaka Mountain Range is one of the most famous formerly-glaciated areas of Japan. Many glacial landforms remain in three neighbouring U-shaped valleys, named Yarisawa, Yokoo and Migimata. Moraines and outwash terraces can be classified into four groups according to their location and to the amount of glacial quartz grains contained in the deposits. A glaciation is proved for other parts of the Northern Japanese Alps before 100 000 years B. P., but not for the Yari-Hotaka Mountain Range, because the corresponding glacial landforms cannot be found here. The oldest known Ichinomata stage before and after 60 000 years B. P. corresponds to the Yokoo glacial which is proved within the whole Japanese Alps. The three younger stages, Babadaira stage (before 30 000 years B. P.), Yarisawa stage I (about 30 000 years B. P.) and Yarisawa stage II (about 15 000 years B. P.), belong to the Karasawa glacial. About 10 000 years B. P. the glaciers melted away. At all times the relief-influence was especially important for the mass-balances of Japanese glaciers. Wind-drifted snow from the west-exposed windward slopes to the slopes in eastern (lee) exposition, and a voluminous snow accumulation by avalanches from the high rocky walls onto the glacier surfaces beneath, caused very low situated glaciers as well as low equilibrium-lines. In most cases the snow-lines were situated 100 m or more above the equilibrium-lines. During the Ichinomata stage the snow-line reached an altitude of 2 400—2 450 m. It rose about 100 m to the Babadaira stage, 300 m to Yarisawa stage I and about 450 m to Yarisawa stage II. At present the snow-line is situated above the Northern Japanese Alps at over 4 000 m. Therefore only perennial snow-patches exist. If the snow-line would go down by a few hundred meters, this region would be highly interesting for studies on the beginning of mountain glaciation.

Zusammenfassung: Die bis knapp 3 200 m aufragende Yari-Hotaka-Gruppe in den Japanischen Nordalpen ist eines der klassischen Gebiete mit pleistozäner Vergletscherung in Japan. In den Nachbartälern Yarisawa, Yokoo und Migimata sind in großem Umfang glaziale und fluvioglaziale Formen erhalten. Die Moränen und Sanderterrassen können aufgrund ihrer Lage zueinander und aufgrund des glazialen Anteils an der Gesamtzahl der in den Ablagerungen enthaltenen Quarzsandkörner vier Stadien zugeordnet werden. Für andere Teile der Japanischen Nordalpen wurde eine Vergletscherung vor mehr als 100 000 Jahren B. P. nachgewiesen. Dies ist bisher für die Yari-Hotaka-Gruppe nicht möglich, weil keine entsprechenden Akkumulationsformen gefunden werden konnten. Das älteste dort bekannte Ichinomata-Stadium gehört in die Zeit vor und nach 60 000 Jahren B. P. Es entspricht dem überall in den Japanischen Alpen nachgewiesenen Yokoo-Glazial. Die drei jüngeren Stadien, das Babadaira-Stadium (vor mehr als 30 000 Jahren B. P.), das Yarisawa-Stadium I (etwa 30 000 Jahre B. P.) und das Yarisawa-Stadium II (um 15 000 Jahre B. P.), gehören zum Karasawa-Glazial. Vor etwa 10 000 Jahren verschwanden die Gletscher. Zu jeder Zeit der Vergletscherung war in Japan der Reliefeinfluß für den Gletschermassenhaushalt von großer Bedeutung. Windverdriftung von Schnee aus den westexponierten Luvhängen in die leeseitigen Osthänge und umfangreiche Schneeakkumulation auf den Gletscheroberflächen durch Lawinenabgänge aus den felsigen Gletscherumrahmungen waren für besonders tief gelegene Gletscher, aber auch für sehr tief gelegene Gleichgewichtslinien des Gletschermassenhaushalts verantwortlich. In den meisten Fällen lagen die Schneegrenzwerte um 100 m oder mehr über den Gleichgewichtslinien des Gletschermassenhaushalts. Zur Zeit des Ichinomata-Stadiums lag die Schneegrenze bei 2 400—2 450 m. Bis zum Babadaira-Stadium stieg sie um etwa 100 m an, bis zum Yarisawa-Stadium I um 300 m und bis zum jüngsten (derzeit bekannten) spätglazialen Stadium Yarisawa II um etwa 450 m. Gegenwärtig liegt die Schneegrenze über den Japanischen Nordalpen oberhalb 4 000 m. Deshalb existieren dort nur perennierende Schneeflecken. Falls jedoch die Schneegrenze einige hundert Meter sinken sollte, würde dieses Gebiet ein höchst interessantes Studienobjekt für eine beginnende Gebirgsvergletscherung sein.

1. INTRODUCTION

The Quaternary glacial topography around the Yari-Hotaka Mountain Range in the Northern Alps, Central Japan, has been studied by many authors (IMAMURA, 1940; TANAKA, 1941; SHIKI, 1952, 1969, 1974, 1975; KOBAYASHI, 1958; IOZAWA, 1962, 1963, 1966, 1972, 1979, 1980; ITO, 1982a, 1982b), as it develops most in Japan. But opinions on the distribution of glacial topography differ from each other: For example, in the Yarisawa Valley, IMAMURA (1940) and SHIKI (1969) regarded the area above 2 000 m as glacial topography, while KOBAYASHI (1958) put the elevation at above 2 300 m. On the other hand, IOZAWA (1962, etc.) placed the location of the lower terminal moraines at about 1 750 m in altitude, and clarified the existence of two glacial stages, the Yokoo and Karasawa glacials. The former stage was recognized as an older maximum stage of glacial extent at the time when the lower moraines were formed. The latter corresponds to the period when relatively fresh glacial landforms were made in the area above 2 300 m which were already recognized by KOBAYASHI (1958).

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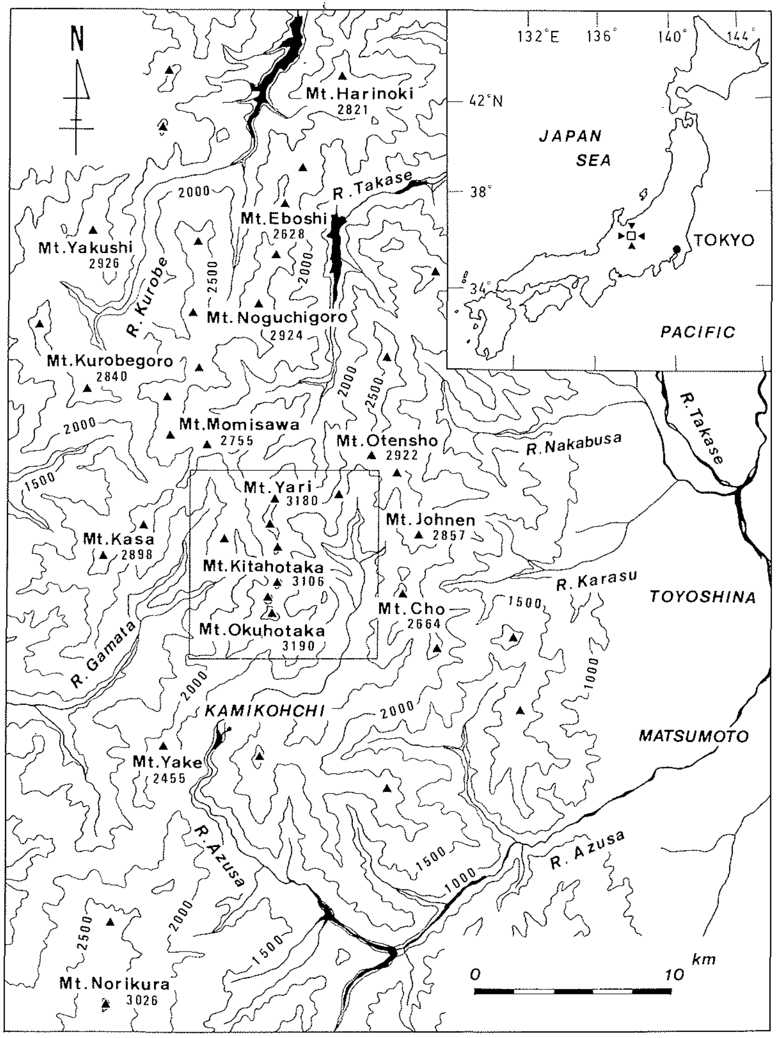

Fig. 1: Location of the study area.

Abb. 1: Lage des Untersuchungsgebiets.

The snow-line in the Northern Alps has been studied by KOBAYAŠHI & HOSHIAI (1955) and HOSHIAI & KOBAYASHI (1957). Judging from the average altitude of many cirque bottoms in the area, they located the altitude of the orographic snow-line of the last glacial at about 2 600 m. They also calculated the amount of temperature reduction, based on the meteorological data at the present time. However in these papers the difference of altitude between snow-line and equilibrium-line has not been clarified. ONO (1981) reconstructed the glacial distribution of a small cirque glacier near Mt. Kurobegoro, Northern Alps, and calculated the mass balance of this glacier from the paleoclimatological data under some assumptions. In the paper, he located the equilibrium-line at about 2 490 m in a glacial stage. However, the change of equlibrium-line in some glacial stages has not been reconstructed. And as some glacial stages have been clarified by IOZAWA (1962, etc.), KOAZE et al. (1974) and ITO (1982a, 1982b), it is necessary to clarify some altitudes of snow-line in glacial stages.

In this paper, the authors attempt to elucidate the glacial geomorphology, to clarify the ages of glacial stages by correlating with some glacial stages in other areas, to study some problems of snow-line recon-

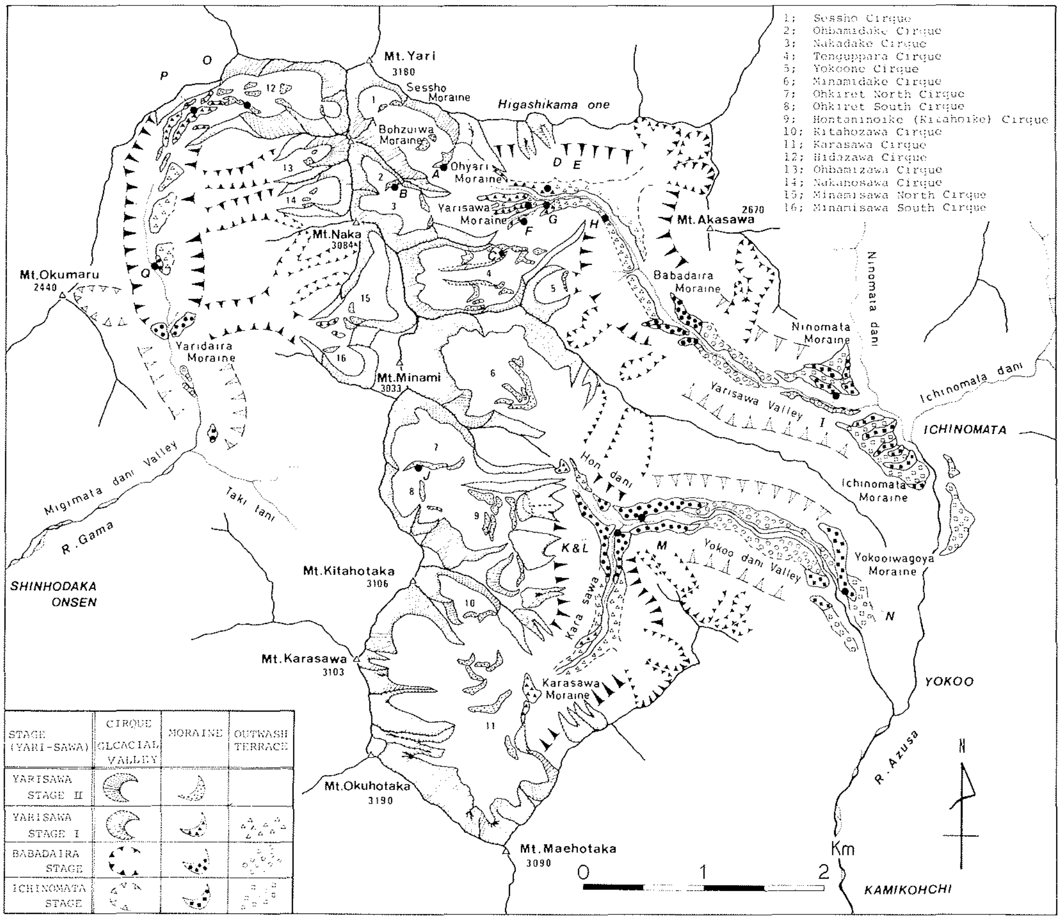

Fig. 2: Geomorphological map of the Yari-Hotaka Mountain Range. (Loc. A—Q are related to Tab. 1).

Abb. 2: Geomorphologische Karte der Yari-Hotaka-Gruppe (Japanische Nordalpen). (Die Lokalitäten A—Q beziehen sich auf Tab. 1).

struction, and to reconstruct the change of the altitude of snow-line using geomorphological and meteorological data. The studies in Yari-Hotaka Mountain Range are most important to understand the climatic change of last glacial around the high mountain area in Japan.

2. GLACIAL GEOMORPHOLOGY OF THE YARI-HOTAKA MOUNTAIN RANGE

The Yari-Hotaka Mountain Range is located in the south-central part of the Northern Japanese Alps (Fig. 1). High mountains of this region with an extension of about 26 km² are, from north to south, Mt. Yari (3 180 m), Mt. Ohbami (3 101 m), Mt. Naka (3 084 m), Mt. Minami (3 033 m), Mt. Kitahotaka (3 106 m), Mt. Okuhotaka (3 190 m) and Mt. Maehotaka (3 090 m). Although there ar no glaciers existing at the present time, many glacial landforms remain in this area (Fig. 2). There are about 11 cirques on the eastern (lee) slope (Fig. 3) and 6 cirques on the western (windward) slope (Fig. 4) of this range. Two deep U-shaped valleys, named Yarisawa and Yokoo, developed downstream on the eastern side of the range and a similar valley, named Migimata, developed on the western side of it.

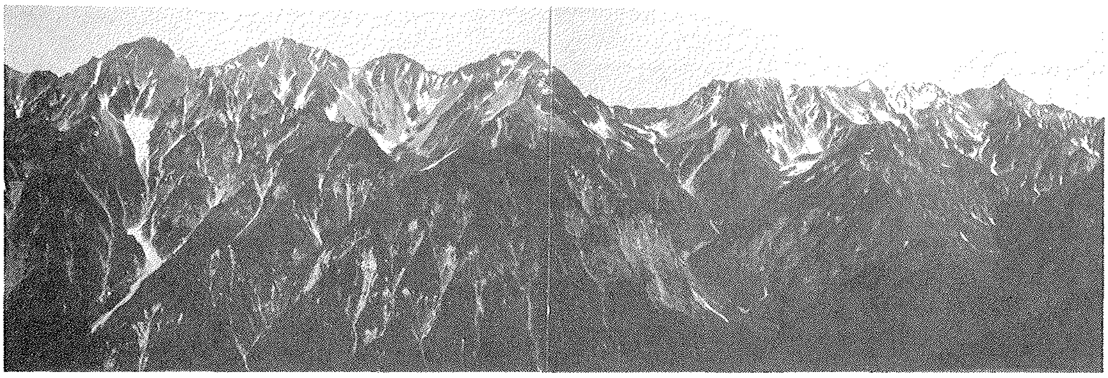

Fig. 3: Eastern slope of Yari-Hotaka Mountain Range (from Mt. Chogatake).

Abb. 3: Ostabdachung der Yari-Hotaka-Gruppe (mit Mt. Yari rechts im N; Aufnahme ITO im Aug. 1977 vom Mt. Chogatake).

There are many accumulation landforms along the three valleys, consisting of moraines, outwash terraces and taluses. In the case of not being able to judge from the topography, the authors used a method based on the use of a scanning electron microscope (S. E. M.) as shown by KRINSLEY & DONAHUE (1958), KRINSLEY & TAKAHASHI (1962), BIEDERMAN (1962), PORTER (1962), KRINSLEY & DOORNCAMP (1973), KOAZE et al. (1978) and SHIMIZU (1980). If one ovserves the surface texture of many quartz sands with this method, one can evaluate the formative history of the deposits because many characteristic textures develop on such sand surfaces, under the original environments. The results from the study area are indicated in Tab. 1.

2.1. *The Yarisawa Valley*

Upstream, there are 5 cirques facing to the east. These are Sessho (the level of cirque floor is 2 860 m), Ohbamidake (2 850 m), Nakadake (2 650 m), Tenguppara (2 650 m) and Yokoone (2 490 m) cirques. Some ridges of terminal moraines and some roches moutonnées develop around the end of these cirque floors. Also, some small fossil rock glaciers, protalus ramparts and rock streams can be observed. There are glacial ponds at the bottom of the Tenguppara Cirque.

Fig. 4: Western slope of Yari-Hotaka Mountain Range (from around Mt. Momisawa; ITO, 1982a).

Abb. 4: Westabdachung der Yari-Hotaka-Gruppe (mit Mt. Yari links im N; Aufnahme ITO im Aug. 1979 vom Mt. Momisawa).

Area	No.	Altitude (m)	Quartz Sand (total)	(glacial)	Glacial (%)	Name of Moraine
Yarisawa Valley	A	2620	20	11	55	Ohyari.
	B	2850	20	9	45	———
	C	2550	20	12	60	Tenguppara.
	D	2290	20	11	55	Yarisawa.
	E	2230	20	13	65	———
	F	2240	20	14	70	———
	G	2210	20	13	65	———
	H	2130	20	14	70	———
	I	1770	20	13	65	Ninomata.
Yokoo Valley	J	2560	20	11	55	———
	K	1930	20	12	60	Yokoohondani -deai.
	L	1910	20	13	65	Yokoohondani -deai.
	M	1880	20	14	70	Yokoohondani -deai.
	N	1680	20	11	55	Yokooiwagoya.
Migimata Valley	O	2610	20	9	45	———
	P	2440	20	13	65	Hidazawa.
	Q	2030	20	14	70	———

Tab. 1: Proportion of glacial quartz grains contained in the deposits (observation of quartz sand surface texture with the help of a scanning electron microscope). Loc. A—Q are indicated Fig. 2.

Tab. 1: Glazialer Anteil an der Gesamtzahl der Quarzsandkörner in den Ablagerungen (Analyse der Quarzsand-Oberflächenbeschaffenheit mit Hilfe eines Rasterelektronenmikroskops). Die Lage der Entnahmestellen A—Q ist in Abb. 2 ersichtlich.

Downstream, the U-shaped Yarisawa Valley develops up to Ichinomata (1 700 m). Along this U-shaped valley, there are many moraines and outwash terraces. The former can be classified into four groups according to their location (Figs. 2 and 5) as follows:

a) The lowest group of moraines developed at an altitude from 1 700 m to 1 850 m around Ichinomata. These moraines, named Ichinomata and Ninomata, consist of seven ridges of terminal moraine and two ridges of lateral moraine. These topographies, first studied by IOZAWA (1962, etc.), were doubted to be moraines by SHIKI (1969) and YOSHIKAWA et al. (1973). However, we can recognize them as terminal moraines, judging from the features of topography and sedimentary facies, and from the result of observation by S. E. M. (Loc. [I]: Tab. 1, Fig. 2).

Further downstream, some outwash terraces which continue up to the height of these moraines occur along the river. These accumulation features were dissected by fluvial erosion of 70 m. The glacial stage when these glacial landforms were developed should correspond to the maximum glacial extent of this valley, for there seem to be no glacial landforms downstream.

b) Around 2 000 m, a second group called Babadaira terminal moraine exists. Upstream, a valley bottom plain develops through the accumulation of outwash and fluvial deposits, due to the damming effect of this moraine (Fig. 5). The valley floor and wall are more heavily dissected downstream than upstream. The outwash terraces formed in this period, when the Babadaira moraine accumulated, do not continue up to the height of the Ichinomata and Ninomata moraines (Fig. 5).

c) Moraines of the third group include the Yarisawa terminal moraine (2 350 m). These moraines are found at some distance below many of the cirque bottoms, formed by small glacier tongues which stretched downward from the cirques. Outwash terraces developing downstream from these moraines extend to the Babadaira moraine. The deposit of Loc. [H] is judged to be an outwash, though the glacial quartz content of the sample at Loc. [H] is 70% (Tab. 1). The reasons are that many marks, formed under the subaqueous environment, are recognized on many quartz sand surfaces, and that the deposit forms the terrace topography.

d) The highest moraine group is located around each cirque bottom. This group includes the Ohyari (2 610 m), Bohzuiwa (2 690 m) and Sessho (2 860 m) moraines, which are all terminal moraines. These moraines develop near to each other, around the cirque floors. The outwash terraces and the fluvioglacial deposits of this period can not be easily observed. This phenomenon would indicate that the glacial advance was short in time and that these moraines were formed by small glaciers.

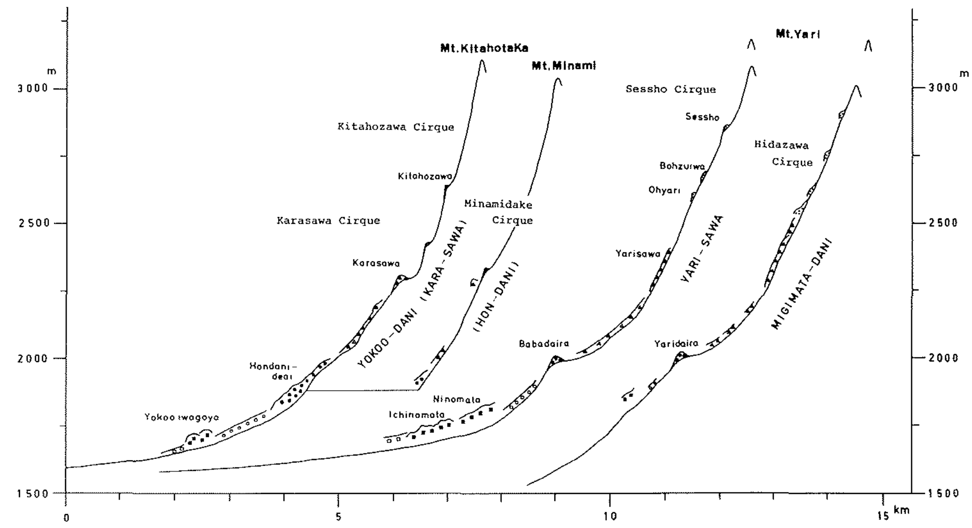

Fig. 5: Profiles of the valley bottoms of Yarisawa, Yokoo and Migimata Valleys. (Legend as indicated on Fig. 2).

Abb. 5: Tiefenlinienprofile der Täler Yarisawa, Yokoo und Migimata (Legende vgl. Abb. 2).

It is evident that the four groups of moraines represent four stages of glacial extensions for the following reasons:

1. These four groups are terminal moraines, and developed at different altitudes.
2. The outwash terraces of the first, second and third stages are formed in different areas along the valley.
3. The glacial topography of each stage is dissected to a different degree, and the degree of vegetation cover and the soil genesis of each deposit are different.

The authors name the four glacial advances from older to younger as follows: 1) Ichinomata stage, 2) Babadaira stage, 3) Yarisawa stage I and 4) Yarisawa stage II.

Judging from these glacial landforms, the distribution of glaciers in these four stages was gradually reduced since the Ichinomata stage, the maximum glacial extent. The interval between the Ichinomata stage and the Babadaira stage should be one of relatively longer time, as the glacial landforms in the Ichinomata stage are much more dissected than those of the Babadaira stage. The Yarisawa stage II should be classified as a recessional one after the glacial extent of the Yarisawa stage I.

2.2. *The Yokoo Valley*

There are many cirques facing east. They are, from north to south, Minamidake, Ohkiretto North, Ohkiretto South, Kitahoike, Kitahozawa and Karasawa cirques (Fig. 2). The bottoms of these cirques are situated at nearly the same altitudes (2 300—2 600 m) as those of the Yarisawa Valley mentioned above. The Karasawa cirque is a large compound one, and the altitude of the cirque floor is at a relatively low height (2 300 m). Downstream of the Karasawa cirque, a U-shaped valley developed up to Yokoo. In comparison with this U-shaped valley, a V-shaped valley and a hanging valley developed in the downstream area of the Ohkiretto and Minamidake cirques.

There are also many terminal moraines and outwash terraces, which can be classified into four groups (four stages) by their locations and difference of degree of dissection, as in the case along the Yarisawa Valley (Figs. 2 and 5).

a) The Yokoo-iwagoya terminal moraine (IOZAWA, 1962, etc.), which develops at an altitude from 1 670 m to 1 820 m around Yokoo, is the lowest group of moraines. The moraine was verified by the method based on the S. E. M., as in the case of the Ichinomata and Ninomata moraines (Tab. 1, Fig. 2).

b) Moraines of the second group develop at 1 950 m in elevation. [K] (upper part) and [L] (lower part) in Fig. 2 and Tab. 1 show the same location of one of these moraines. Using the S. E. M. method, the resultant value of [K] is smaller than of [L] in Tab. 1. This difference indicates that the deposits of Loc. [K] developed as ablation-till and the deposits of Loc. [L] developed as lodgement-till, because the latter was more affected than the former by glacial actions.

These moraines do not have the typical topography of terminal moraine ridges. This is because three glaciers, from the Karasawa Valley, the Hontani Valley and the Kitahozawa cirque, flowed together in this area, and some parts of these moraines were eroded away by their fluvio-glacial processes. Upstream, a valley bottom plain did not develop, in contrast to the case of the Yarisawa Valley.

c) Moraines of the third group include the Karasawa terminal moraine (2 300 m) at the end of the floor of the Karasawa cirque. Around the Hondani Valley, it can be seen that two small valley glaciers developed, judging from the location of moraines. Outwash terraces developing downstream from these moraines extend to the moraines of the third group.

d) On the floor of many cirques, many typical terminal moraines of the highest group of moraines developed at an altitude from 2 330 m to 2 650 m. Outwash terraces of this period cannot be easily observed, as in the case along the Yarisawa Valley.

These four stages can be correlated to the four stages, Ichinomata stage, Babadaira stage, Yarisawa stage I and Yarisawa stage II, in the Yarisawa Valley.

2.3. *The Migimata Valley*

The Hidazawa, Ohbamisawa, Nakanosawa, Minamisawa North and Minamisawa South cirques are on the western (windward) slope, and a U-shaped valley streches downstream from 2 400 m to 1 850 m.

The glacial geomorphology in this area was studied in detail by ITO (1982a) who classified it into four stages, namely the Takitani (correlated to the Ichinomata stage), the Yaridaira (correlated to the Babadaira stage), the Hidazawa I (correlated to the Yarisawa stage I) and the Hidazawa II (correlated to the Yarisawa stage II), according to both the locations of terminal moraines and outwash terraces, and the differences in the degree of dissection (Figs. 2 and 5).

Primary features of the glacial geomorphology described in that paper are as follows:

1) The Yaridaira terminal moraine developed about 2 000 m high in this valley, forming a valley bottom plain above the moraine ridge as in the case of the Babadaira moraine in the Yarisawa Valley (Figs. 2 and 5).

2) The lowest moraine at about 1 850 m was dissected by fluvial erosion in the same way as in the case of the Ichinomata and the Ninomata moraines (Fig. 5).

3) Many cirques are located between 2 500—2 800 m high and show no clear development, since most of the snow was been blown out by the strong winds over this western (windward) slope.

4) Many hanging glaciers should have developed in the Takitani and the Yaridaira stages, as there are some steep valleys below these cirques.

3. AGES OF THE GLACIAL STAGES IN YARI-HOTAKA MOUNTAIN RANGE

3.1. *Tentative correlation*

Only correlations based upon the locations of terminal moraines and the difference of the degree of dissected glacial landforms are possible at the present, as the absolute ages of the four stages mentioned above have not been determined by key tephra and ^{14}C data.

KOAZE et al. (1974) have clarified five glacial stages, named Yoshihara, Iwatake, Akakurazawa, Kanayamazawa and Shiroumazawa from older to younger, along River Matsukawa, around Mt. Shirouma in the Northern Japanese Alps. As the ^{14}C age of 25 150±210 years B. P. was obtained from wood fragments in the Akakurazawa terminal moraine, the ages of these five glacial stages were estimated as follows:

Yoshihara stage: much older than 30 000 years B. P.
Iwatake stage: befor 30 000 years B. P. (at least)
Akakurazawa stage: about 25 000 years B. P.
Kanayamazawa stage: about 20 000 years B. P.
Shiroumazawa stage: after 20 000 years B. P.

Comparing glacial extents of each stage around the Yari-Hotaka mountain range and around Mt. Shirouma, they can be classified as follows:

Ichinomata (Takitani) stage — Iwatake stage
Babadaira (Yarisawa) stage — Akakurazawa stage
Yarisawa (Hidazawa) stage I — Kanayamazawa stage
Yarisawa (Hidazawa) stage II — Shiroumazawa stage.

There is no stage in the Yari-Hotaka area corresponding to the Yoshihara.

Around Mt. Chogatake in the Northern Japanese Alps, the oldest glacial stage (Chogatake stage) before 100 000 years B. P. and the periglacial stage before and after 60 000 years B. P. were identified by ITO (1983), using tephrachronology. In the latter stage, there was almost no glacial activity around Mt. Chogatake. It was judged that the former stage correlates with the Yoshihara stage, and the latter stage correlates with the Iwatake stage. Therefore the ages of the Ichinomata and Takitani stages are estimated to be about 60 000 years B. P.

In the Hidaka Mountain Range in Hokkaido, the northernmost main island of Japan, ONO & HIRAKAWA (1975) recognized two glacial stages which were called Poroshiri and Tottabetsu, from older to younger. They concluded that the Poroshiri stage should antedate 40 000 years B. P., while the Tottabetsu is evidently between 30 000 and 10 000 years B. P., based upon tephrachronology. It can be said, therefore, that the Iwatake stage correlates with the Poroshiri, and the Akakurazawa, Kanayamazawa and Shiroumazawa stages with the Tottabetsu (ONO, 1980a).

IOZAWA (1962, 1963, 1966, 1972, 1979, 1980) has clarified the existence of two glacial stages, the Yokoo and Karasawa glacials mentioned above, throughout the high mountains of Japan. The former glacial can be correlated with the Ichinomata (Takitani) stage, and the latter glacial can be divided into three stages based on the Babadaira (Yaridaira) stage, based on IOZAWA's geomorphological map.

3.2. *Reconstruction of the glacial stages*

The results mentioned above are shown in Tab. 2 and indicate the following. Before the Ichinomata stage: A glacial extent at this period like the Chogataka glacial before 100 000 years B. P. was not clarified because glacial landforms were not recognized. The Ichinomata stage: This stage is presumed to be a cold climatic period before and after 60 000 years B. P., and there was a maximum glacial extent period in this area. Three valley glaciers developed and flowed down to about 1 700 m. The Babadaira stage: After the Ichinomata stage the glaciers reduced upstream and fluvial erosion acted effectively. In the Babadaira stage, valley glaciers developed again and flowed down to about 2 000 m. This stage is thought to have occurred before 30 000 years B. P. The Yarisawa stage I: Though the glaciers, which developed

Absolute Age $\times 10^4$ yr. B.P.	Japanese Alps (whole)	Northern Japanese Alps					Central J. A.	Hokkaido
		Yari-Hotaka Mountain Range (eastern slope)	Yari-Hotaka Mountain Range (western slope)	Mt. Chogatake	Mt. Shirouma	Mt. Tateyama	Mt. Kumazawa	Hidaka Range
1	Karasawa Glacial	Yarisawa II	Hidazawa II		Shiroumazawa	Tateyama	Koma	Tottabetsu
2		Yarisawa I	Hidazawa I		Kanayamazawa			
3		Babadaira	Yaridaira		Akakurazawa			
4								
5, 6	Yokoo Glacial	Ichinomata	Takitani		Iwatake	Murodo	Kumazawa	Poroshiri
7, 8				Chogatake	Yoshihara			
References	Iozawa (1962, etc.)	*This Report*	Ito (1982a)	Ito (1983)	Koaze et al (1974)	Fukai (1974)	Kobayashi and Shimizu (1966)	Ono and Hirakawa (1975)

Tab. 2: Tentative correlation of glacial stages in Japanese high mountains, based on ONO (1980a).

Tab. 2: Vorläufige Korrelation der Gletscherstände in den Gebirgen Japans unter Zugrundelegung der Arbeit von ONO (1980a).

about 30 000 years B. P., reduced upstream, they flowed down to about 2 300 m around 20 000 years B. P. The Yarisawa stage II: After about 15 000 years B. P., a reduction stage of glaciers began. Finally it is concluded that the glaciers melted away after about 10 000 years B. P.

4. PROBLEMS OF SNOW-LINE RECONSTRUCTION

In spite of numerous methods for snow-line reconstruction, for example from glacier extension or from climatic data, most of them cannot be adapted to the case of pleistocene glaciers of the Japanese Alps. There are neither detailed data about the situation of the glacier surfaces nor ice- and snow-ablation data or climatic data, e. g. mass of snow precipitation at the time of the maximum glaciation of the four existing glacial stages.

Snow-line values for mountain glaciers always reflect the climatic conditions which, modified by the relief influence, determine the mass-budget of the glacier. Studies on mass balances of mountain glaciers, especially within the European Alps, demonstrate that the equlibrium-line divides the glacier surface with an accumulation area/ablation area ratio of about 2:1 (GROSS et al., 1977). The Japanese areas of glaciation show, however, that such a result can only be accepted as a real height value of the snow-line in case of large glaciers with high situated accumulation areas. Snow accumulation has to be gained almost entirely by snow precipitation.

All former Japanese glaciers were surrounded by rocky walls, often rising some hundred meters above the glacier surfaces. Therefore the relief influence is especially important, not only concerning radiation and wind exposition, but also for snow accumulation by way of snow avalanches. In these cases an equilibrium-line with an accumulation area/ablation area ratio of $S_{ac}:S_{ab} = 2:1$ is not identical to the snow-line altitude. The summed-up snow accumulation by precipitation onto the glacier surfaces and by avalanche-snow from the surrounding rocky walls causes an equilibrium-line decisively lower in height than the snow-line.

FINSTERWALDER (1953) reconstructed mass-balance curves based on climatic data for glaciers of the eastern part of the European Alps. Fig. 6a shows an example for an altitude to be situated between h_l = 2 000 m and $(G)h_u$ = 3 500 m. The accumulation rate ac, which almost entirely refers to snow precipitation, amounts to about 2 m at the altitude of 3 500 m. The ablation curve ab shows that the mean ablation rate at the altitude of 2 000 m amounts to about —11 m and that it comes near zero at the altitude of 3 500 m. This means that in the altitude belt higher than 3 500 m only snow accumulation is relevant for the glacier mass balance. The curve a, which represents the sum of ac and ab, cuts the ordinate a = O at S = E. In this case the result is acceptable for the altitude of the snow-line S as well as for the altitude of the equilibrium-line E.

Fig. 6b shows another theoretical example. Only the lower part between h_l = 2 000 m and Gh_u = 2 750 m is glaciated area. The upper parts are the rocky walls surrounding the glacier, which supply snow in the form of avalanches (— av) onto the glacier surface (+ av). Because the ablation rate ab during summer and autumn is not higher than assumed in the first example in Fig. 6a, the mass-balance curve cuts the ordinate in E, which is situated far below the snow-line S. For both examples the altitude S remains the same, of course. Fig. 6b is representative of the situation of the pleistocene glaciers of the Northern Japanese Alps. That means the area-ratio method for the glacier surface S_{ac}:S_{ab} = 2:1 is not acceptable for snow-line reconstruction in the Yari-Hotaka Mountain Range. Better results are shown by the method of FINSTERWALDER (1953) in a modified form which includes the surrounding rock walls (VORNDRAN, 1970). Unfortunately the necessary climatic data are not sufficiently well-known for the four periods of glaciation that have been identified in the Yari-Hotaka Mountain Range. First very welcome attempts to reconstruct climatic data were made by ONO (1981) in order to estimate the ablation rate of

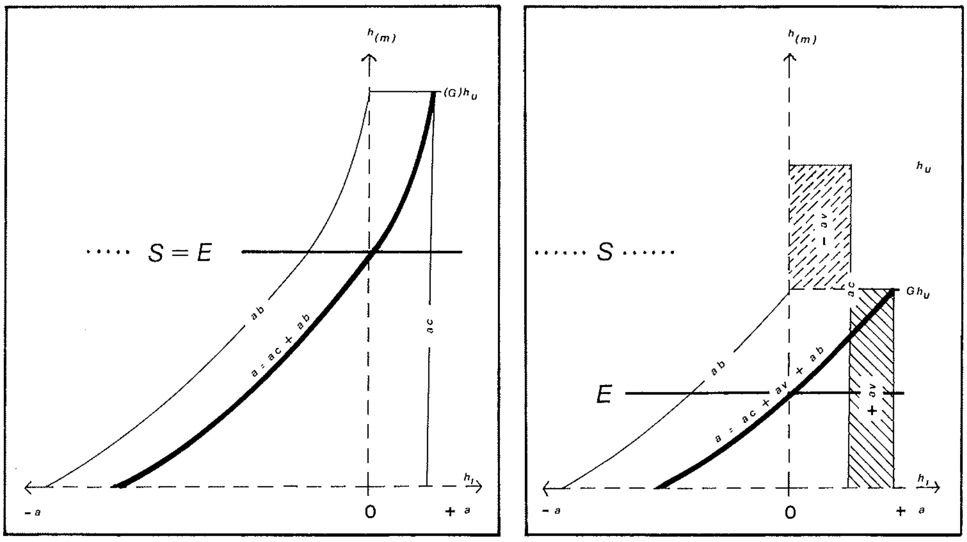

Fig. 6: a) Mass-balance curves for glaciers with snow-accumulation primarily in form of snow-precipitation (from FINSTERWALDER, 1953).
b) Mass-balance curves for glaciers with snow-accumulation both by snow-precipitation and by snow-avalanches out of the rocky walls which are surrounding the glacier surfaces.
S = snow-line, E = equilibrium-line, $h_{(m)}$ = altitude (in meters), h_u = highest top of the rocky glacier surroundings, Gh_u = highest point of the glacier, h_l = lowest point of the glacier end, + a = accumulation dominates, — a = ablation dominates, ab = ablation, ac = accumulation by snow-precipitation, av = avalanche-snow.

Abb. 6: a) Massenhaushaltskurven für Gletscher, die primär durch Schnee-Niederschlag ernährt werden (vgl. FINSTERWALDER 1953).
b) Massenhaushaltskurven für Gletscher, die sowohl durch Schnee-Niederschlag als auch durch Schneelawinenabgang aus der Felsumrahmung auf die Gletscheroberfläche ernährt werden.
S = Schneegrenze, E = Gleichgewichtslinie des Gletschermassenhaushalts, $h_{(m)}$ = Höhe (in Metern), h_u = höchster Punkt der Gletscherumrahmung, Gh_u = höchster Punkt des Gletschers, h_l = tiefster Punkt des Gletschers, + a = Schneeauftrag überwiegt, — a = Schneeablation überwiegt, ab = Ablation, ac = Auftrag durch Schnee-Niederschlag, av = Lawinenschnee.

Kurobegoro Glacier. Concerning this stage of knowledge it would be more problematic to make any assumptions than to use simple methods like those suggested by LOUIS (1955) or by KUROWSKI (1891) to reconstruct the snow-lines.

The method published by LOUIS (1955) only needs knowledge of the altitude of the lowest point h_l of the lower glacier end and of the highest top h_u of the rocky surroundings of the glacier. The approximate altitude of the snow-line S then is calculated as follows:

$$S = \frac{h_u + h_l}{2}$$

KUROWSKI (1891) considered not only the relative height of the glacier extension, but also the changing areas of glacier surface between different altitudes. The snow-line S here is identical with the mean height of the glacier surface. It may be a disadvantage of KUROWSKI's method to take the ablation curve ab represented by a straight line and not by a parabolic curve as with FINSTERWALDER's method. If we include the rocky glacier surroundings, however, which contribute to the mass-balance of the glacier below, this disadvantage ist acceptable as long as no detailed climatic data are known.

The mean heights of the glacier areas including the surrounding walls as calculated from the modified KUROWSKI method, will be taken in Section 5 as representave for the required snow-lines. These values will be compared with the values calculated by the LOUIS method and also by the area-ratio method for the glacier surface $S_{ac}:S_{ab} = 2:1$.

5. SNOW-LINES OF THE GLACIAL STAGES

All the cirques in Migimata Valley are exposed to the west, whereas most of the cirques und U-shaped valleys in Yarisawa Valley and Yokoo Valley show eastern exposition. Therefore the snow-lines of the Migimata Valley glaciers can be taken as representative of the western (windward) exposition and those of the other two large valleys of the opposite eastern (lee) exposition. The results of the snow-line calculations are shown in Tab. 3.

All values of the four glacial stages show that the snow-lines in western exposition are about 50 m to 100 m higher than those on the eastern side. The mean altitude of the snow-lines for the whole Yari-Hotaka Mountain Range can be calculated by summing up the total glaciation of Migimata Valley, Yarisawa Valley and Yokoo Valley (Tab. 4). In these values the influence of wind-exposition and radiation-exposition is very much reduced.

The values of the snow-line altitudes estimated by the LOUIS method do not differ from the values in Tab. 4. Therefore we may say that the altitude of the snow-line rose from the oldest known Ichinomata stage to the following Babadaira stage by about 100 m, to Yarisawa stage I by about 300 m and to the youngest Yarisawa stage II by about 450 m.

Even if the snow-line of Yari-Hotaka Mountain Range rose more than about 200—250 m after Yarisawa stage II and reached the altitude of the highest mountains tops, the highly situated cirques did not necessarily have to be free of glaciers. Small glaciers still could exist although the snow-line rose above the highest summits of the watersheds, because accumulation by snow avalanches is very important. Therefore there might have existed a still younger glacial stage after the Yarisawa stage II at the end of pleistocene.

6. PRESENT SNOW-LINE

While the area-ratio method with an accumulation area/ablation area ratio of 2:1 can be used as long as a

a) *Valleys in eastern exposition detailled* [1])

Glacial Stages	Altitudes of snow-lines in Yarisawa Valley K	Yarisawa Valley L	Yokoo Valley K	Yokoo Valley L
Yarisawa st. II	2900 m	2850—2900 m	2850 m	2850 m
Yarisawa st. I	2700—2750 m	2700m	2650—2700 m	2650 m
Babadaira st.	2500 m	2550 m	2500—2550 m	2500 m
Ichinimata st.	2350—2400 m	2400—2450 m	2400—2450 m	2400—2450 m

b) *Valleys in western and in eastern exposition* [1])

Glacial Stages	Altitudes of snow-lines in western exposition (Migimata Valley) K	western exposition (Migimata Valley) L	eastern exposition (Yarisawa and Yokoo Valley; mean value of Tab. 3a) K	eastern exposition L
Yarisawa st. II	2900 m	2900 m	2850—2900 m	2850—2900 m
Yarisawa st I	2750—2800 m	2750 m	2650—2750 m	2650—2700 m
Babadaira st.	2550—2600 m	2550 m	2500—2550 m	2500—2550 m
Ichinomata st.	2450—2500 m	2400—2450 m	2350—2450 m	2400—2450 m

in comparison

Glacial Stages	Altitudes of equilibrium-lines (S_{ac}:S_{ab} = 2:1) western exposition	eastern exposition
Yarisawa st. II	2900 m	2700—2750 m [2])
Yarisawa st. I	2800 m	2500 m [2])
Babadaira st.	2300 m [2])	2200—2250 m [2])
Ichinomata st.	2200 m [2])	2100 m [2])

[1]) values calculated by NADLER-LÖSCH (1982) with K = modified KUROWSKI-method or L = LOUIS-method
[2]) The equilibrium-line is situated more than 100 m below the snow-line

Tab. 3: Altitudes of snow-lines in Migimata Valley, Yarisawa Valleey and Yokoo Valley for four glacial stages during younger pleistocene.

Tab. 3: Schneegrenzhöhen für vier jungpleiostzäne Gletscherstände in den Tälern Migimata, Yarisawa und Yokoo.

glacier exists, those methods of snow-line calculation that are based on data on the relief, especially of the glacier-extension including the rocky surroundings, can only be used as long as the snow-line does not rise above the summits, even if small glaciers do exist. In that case the snow-line can be gained by way of climatic data only.

This is the recent situation in the formerly glaciated areas of the Japanese Alps. There are no glaciers now, but numerous perennial snow-patches by way of additional snow accumulation in form of avalanches. The best example within the Yari-Hotaka Mountain Range is the avalanche snow-patch in Karasawa Cirque, a north exposed cirque-bottom in a height of about 2 300 m, where sometimes summer-skiing is possible (Fig. 7). The sum of snow precipitation during winter time plus accumulating avalanche-snow from surrounding rocky walls is not enough to modify the deeper parts of firn to glacier-ice. For this process the present rate of snow ablation is too high in altitudes of 2 300—3 000 m of the Northern Japanese

Glacial Stages	Altitudes of snow-lines*
Yarisawa stage II	2850—2900 m
Yarisawa stage I	2700—2750 m
Babdaira stage	2500—2550 m
Ichinomata stage	2400—2450 m

* mean-values calculated by NADLER-LÖSCH (1982) with modified KUROWSKI-method

Tab. 4: Altitudes of snow-lines for the glacial stages of the Yari-Hotaka Mountain Range.

Tab. 4: Schneegrenzhöhen für die Gletscherstände in der Yari-Hotaka Gruppe.

Fig. 7: Karasawa Cirque with snow-patch (from Mt. Otensho-dake).

Abb. 7: Karasawa-Kar mit prennierendem Schneefeld (Aufnahme ITO im Juni 1978 vom Mt. Otensho-dake).

Alps. But if the present snow-line would go some hundred meters lower, this region might become highly interesting for studies on the beginning of mountain glaciation.

At present the snow-line above the region of the Northern Japanese Alps must be situated at a height of little more than 4 000 m (HOSHIAI & KOBAYASHI, 1957; KAIZUKA, 1976; SCHWIND, 1967). This is proved by the fact that Mt. Fuji, the volcano situated 175 km south-east of the Yari-Hotaka Mountain Range, is not glaciated in spite of its height of 3 776 m.

The method based on the mean altitude of the 0° C air temperature measured in the free atmosphere during the months of July, August and September for calculating the present snow-line is problematic if the results are compared with heights of snowlines calculated by other methods especially because relief influence is not included. This is shown by the example of Wajima, a radiosonde station 160 km northwest of Mt. Yari. During the years 1974—1976 the mean 0° C summer-temperature was found in a height of 4 600—4 650 m. This value measured in the free atmosphere and neglecting relief influence is some hundred meters higher than the actual snow-line in Northern Japanese Alps. The importance of relief and snow avalanche influence is impressively demonstrated by numerous perennial snow-patches.

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References

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Biederman, E. (1962): Distinction of shoreline environment in New Jersey. — J. Sed. Petrol. 32: 181—200.

Finsterwalder, R. (1953): Die zahlenmäßige Erfassung des Gletscherrückgangs an Ostalpengletschern. — Z. Gletscherkde. Glazialgeol. II (2): 189—239.

Fukai, S. (1974): The glacial landform and its formation stage at Mt. Tateyama in the Japanese Alps. — Memoir Faculty of Education, Toyama Univ. 22: 119—133 (J/E).

Gross, G. et al. (1977): Methodische Untersuchungen über die Schneegrenze in alpinen Gletschergebieten. — Z. Gletscherkde. Glazialgeol. XII (2): 223—251.

Hoshiai, M. & K. Kobayashi (1957): A theoretical discussion on the so-called "snow line", with reference to the temperature reduction during the last glacial age in Japan. — Japn. J. Geol. Geogr. 28: 61—75.

Imamura, G. (1940): Japanese Alps and glaciers of glacial age. — 1—162, Tokyo: Iwanami-shoten (J).

Iozawa, T. (1962): On the lowest moraine around the Yari-Hotaka Range. — Geogr. Rev. Japan 35: 652—653 (J).

Iozawa, T. (1963): Glacial landforms in the Japanese Alps by photo-interpretation. — Geogr. Rev. Japan 36: 743 (J).

Iozawa, T. (1966): Glacial geomorphology in Japan. — Chiri (Geography) 11 (3): 24—30 (J).

Iozawa, T. (1972): The book of geomorphological map for mountain climber. — 1—190, Tokyo: Yama-to-keikoku-sha (J).

Iozawa, T. (1979): Japanese Alps (Atlas of bird's eye view). — 1—191, Tokyo: Kodan-sha (J).

Iozawa, T. (1980): Japan Alps. — Excursion Guide-Book, 3rd Meeting of IGU Commission in Field Experiments in Geomorphology, 157—161, Kyoto.

Ito, M. (1982a): Glacial geomorphology around the Migimata, Gamata Valley, Northern Japanese Alps. — J. Geography 91: 88—103 (J/E).

Ito, M. (1982b): Glacial geomorphology around the Yari-Hotaka Mountain Range, northern Japanese Alps. — Chiri (Geography) 27 (4): 62—63 (J).

Ito, M. (1983): Glacial geomorphology and accumulation terraces around Mt. Chogatake, northern Japanese Alps. — Geogr. Rev. Japan 56: 35—49 (J/E).

Kobayashi, K. (1958): Quaternary glaciation of the Japan Alps. — J. Faculty of Science, Shinshu Univ. 8: 13—67.

Kobayashi, K. & M. Hoshiai (1955): Snow line of the glacial stage and the present time in Japan. — Chikyu-kagaku (Earth Science) 21: 1—7 (J).

Kobayashi, K. & H. Shimizu (1966): Significance of the Ikenotaira Interglacial indicated by moraines on Mt. Kumazawa of the Kiso Mountain Range. — J. Faculty of Science, Shinshu Univ. 1: 97—113.

Koaze, T., Sugihara, S., Shimizu, F., Utsunomiya, Y., Iwata, S. & S. Okazawa (1974): Geomorphological studies of Mt. Shirouma. — Sundai-shigaku, Meiji Univ. 35: 1—86 (J/E).

Koaze, T., Sugihara, S., Shimizu, F. & K. Shimokawa (1978): The surface texture of quartz grains from glacial deposits. — J. Research Institute of Cultural Science, Meiji Univ. 17: 1—10 (J/E).

Krinsley, D. (1973): Surface features of sand grains from LEG of the deep sea drilling project. — Initial Reports of the Deep Sea Drilling Project, 925—933, Washinton.

Krinsley, D. & T. Takahashi (1962): Surface features of sand grains; an application of electron microscopy. — Science 135: 923—925.

Krinsley, D. & J. Donahue (1968): Evironmental interpretation of sand grain surface textures by electron microscopy. — Bull. Geol. Soc. Am. 79: 743—748.

Krinsley, D. & J. Doornkamp (1973): Atlas of quartz sand surface texture. — 1—91, Cambridge.

Kurowski, L. (1891): Die Höhe der Schneegrenze mit besonderer Berücksichtigung der Finsteraarhorngruppe. — Geogr. Abh. V (1): 115—160, Wien.

Louis, H. (1955): Schneegrenze und Schneegrenzbestimmung — Geogr. Taschenbuch 1954/55: 414—418.

Louis, H. & K. Fischer (⁴1979): Allgemeine Geomorphologie. — Lehrbuch der Allg. Geographie I, Berlin—New York.

Margolis, S. & J. Kennett (1971): Antarctic glaciation during Tertiary recorded in sub-Antarctic deep sea cores. — Am. J. Sci. 271: 1—36.

Nadler-Lösch, C. (1982): Jungquartäre Gletscherstände und Schneegrenzhöhen in den Japanischen Nordalpen (Mt. Yari-Gebiet). — Wiss. Zulassungsarbeit, 1—83, Augsburg.

Ono, Y. (1980a): Glacial and periglacial geomorphology in Japan. — Progress in Phys. Geogr. 4 (2): 149—160, London.

Ono, Y. (1980b): Glaciation of the Japanese Alps. — Guidebook for the Excursion E-16 of 24th IGC: 21—23, Tokyo.

Ono, Y. (1981): Mass balance of the Pleistocene alpine glacier in the Japanese Alps. — Ann. Rept., Institute of Geoscience, Univ. of Tsukuba 7: 35—38.

Ono, Y. & K. Hirakawa (1975): Glacial and periglacial morphogenetic environments around the Hidaka Range in the Würm glacial age. — Georgr. Rev. Japan 48: 1—26 (J/E).

Porter, J. (1962): Electron microscopy of sand surface texture. — J. Sed. Pet. 32: 124—135.

Schwind, M. (1967): Das Japanische Inselreich. — Bd. 1: Die Naturlandschaft, Berlin.

S h i k i , M. (1952): Glacial landforms on the northern slopes of Mt. Kita-hotaka. — Geogr. Rev. Japan 25: 448—457 (J/E).

S h i k i , M. (1969): Recent alpine geomorphological studies in Japan. — Ochanomizu Univ., Studies in Arts and Culture 22: 69—81.

S h i k i , M. (1974): Accumulation terraces of the Quaternary Ice Age in the mountains of central Japan. — Daiyonki-Kenkyu (Quaternary Research of Japan) 12: 203—210 (J/E).

S h i k i , M. (1975): Topographic characteristics of rock glaciers and climatic terraces and their significance. — In: M. Shiki, ed., Problems of ice age in Japan, 57—71, Tokyo: Kokon-shoin (J).

S h i m i z u , F. (1980): Chemical weathering on quartz grains in the glacial deposits of the Europe Alps, the Nepal Himalaya and the Japan Alps. — Rev. Research for Disaster Prevention 50: 1—29, Tsukuba (J/E).

T a n a k a , K. (1941): Glaciated landforms around the Yari-Hotaka Mountain Range. — Geogr. Rev. Japan 17: 609—626 (J).

V o r n d r a n , G. (1970): Die Höhe der Schneegrenze in der Silvrettagruppe. — Mitt. Geogr. Ges. München 55: 155—167, München.

W i l h e l m , F. (1975): Schnee- und Gletscherkunde. — Lehrbuch der Allg. Geographie III/3. Berlin—New York.

Y o s h i d a , Y. (1980): Some aspects of glaciological studies. — In: Recent Trends of Geographical Study in Japan. Repr. from: Recent Progress of Natural Sciences in Japan 5: 21—26, Tokyo.

Y o s h i k a w a , T. , S u g i m u r a , A. , K a i z u k a , S. , O t a , Y. & Y. S a k a g u c h i (1973): Geomorphology of Japan, New Edition. — 1—415, Tokyo (J).