ALTITUDE OF THE MODERN SNOWLINE AND PLEISTOCENE SNOWLINE IN THE ANDES

Michio NOGAMI

Previous studies

The altitudes of the modern snowline (MSL) and Pleistocene snowline (PSL) in the Andes have been observed and measured by many authors, and the data have been summarized and described by Brüggen (1950), Hermes (1955 & 1965), Lliboutry (1956), Feruglio (1957), Frenguelli (1957), Ahlfeld & Braniša (1960), Auer (1970) and Hastenrath (1967, 1971a & 1971b). The altitudinal distribution of the snowlines was shown graphically in W–E transects by Flint & Fidalgo (1964) and Hastenrath (1967, 1971a & 1971b), in meridional transects by Paschinger (1912), Klute (1928), Brüggen (1950), Lliboutry (1956), Wilhelmy (1957), Vuilleumier (1971) and Hastenrath (1967 & 1971b), and in maps of isoglacihypses by Lliboutry (1956), Feruglio (1957), Hermes (1965) and Nogami (1972).

Some of the above-mentioned surveys focused their attention on particular areas, and several which dealt with the whole Andes region were poor in basic data. Most of them are now out of date, although Hastenrath's still provides an excellent summary. In this report I intend to add new data to those of Hastenrath. The data were collected mainly from the reading of many sheets of photo-grametric maps and also from my field observations in the central Andes.

Interpretation of air-photos

Many air-photos were available for the purpose. They were utilized to distinguish glaciers from perennial snow patches and also to distinguish glacial cirques from non-glacial landforms that originated from volcanic activity, large land-slides and fluvial action. In the situation of having air-photos but no large-scaled and photo-grametric maps, there is no choice but to estimate desired local altitudes from the summit altitudes which are generally indicated rather well even on small-scaled maps. There were two difficulties in utilizing the air-photos. In some countries, the procedures of purchase from military offices are troublesome, and in general the photos are very expensive.

Map reading

Photo-grametric maps only were available for the purpose. Brief information on large-scaled maps which have been published in each country is given in Table 1.

A basic question and decision is how to select an altitude that gives a representative value for a certain quadrangle. Differences in the altitude of cirque floors are the result of many local factors, such as the aspect (cirque orientation) with respect to the sun or snow-bearing winds, the preglacial landforms, lithology and geologic structure (Unwin, 1972). The most important of these is the aspect. Cirques display a strong tendency to form on leeward slopes, particularly where long shadows provide shelter from the afternoon sun (Derbyshire, 1968). In his work, Porter (1964) considered only the lowest north-facing cirques in order to eliminate possible errors inherent in the use of cirques of varied aspect in the middle

Table 1 Photo-grametric Maps

	scale	contour interval (m)	publisher
Colombia	1: 50,000 1:100,000	20, 25 or 50 20, 25, 40 or 50	Instituto Geografico "Agustin Codazzi"
Ecuador	1: 50,000	20 or 40	Instituto Geografico Militar
Peru	1:100,000	25	————
Bolivia	1: 50,000	20 or 25	————
Chile	1: 50,000	25 or 50	————

latitudes of the northern hemisphere. In the southern hemisphere, the lowest south-facing cirques must be considered. Of what aspect are the cirques that must be considered in the tropical or subtropical Andes?

A case study on this point will be described next.

Case study of the detailed distribution of the snowline in a quardrangle of the Bolivian Andes

Area studied The quadrangle "Lago Khara Kkota" (National Map of Bolivia, sheet No. 5945IV, contour interval 20m, scale 1:50,000) was chosen. It is located in the central part of the Cordillera Real, which intersects the snow-bearing north-easterlies at right angles. In this quardrangle, there are 79 ice-free cirques, 34 cirque glaciers and 56 glacierets of hanging-glacier type.

Method The landforms of the cirques and glaciers were interpreted from streoscopic air-photos. The altitude of the outermost part of the cirque floor or threshold steeply dropping to a valley was taken as the cirque floor altitude. The altitude of the upper crevasse zone or level at which a cirque passed into a comparatively steepened tongue was taken as the altitude of the orographic snowline of the glacier. Near the level mentioned, the contour line appears almost straight, whereas it is concave in the accumulation area and convex in the ablation area.

Effect of summit altitude 113 cirque floors were identified between altitudes of 4580 m and 5300 m. 79 cirques of low altitude are free from ice today. 23 glaciers of high altitude are of cirque-glacier type with an ice tongue. 11 glaciers are emaciated and have receded from the outer parts of the cirque floor. As shown in Figure 2, the cirque floors rise in elevation in proportion to the summit altitude. The vertical distances between the summits and cirque floors ranged from 120 m to 690 m (see Figure 3). Variance in the distance decreases in proportion to the summit altitude. Variance in the snowline altitude of glacierets also decreases in proportion to the summit altitude (see Figure 4). In order to eliminate possible errors, it is thus preferable to use snowlines located around comparatively low summits.

Effect of aspect As shown in Tables 2, 3 and 4, there is a significant difference in snowline altitude with respect to glacier or cirque aspect. It is therefore necessary to utilize the

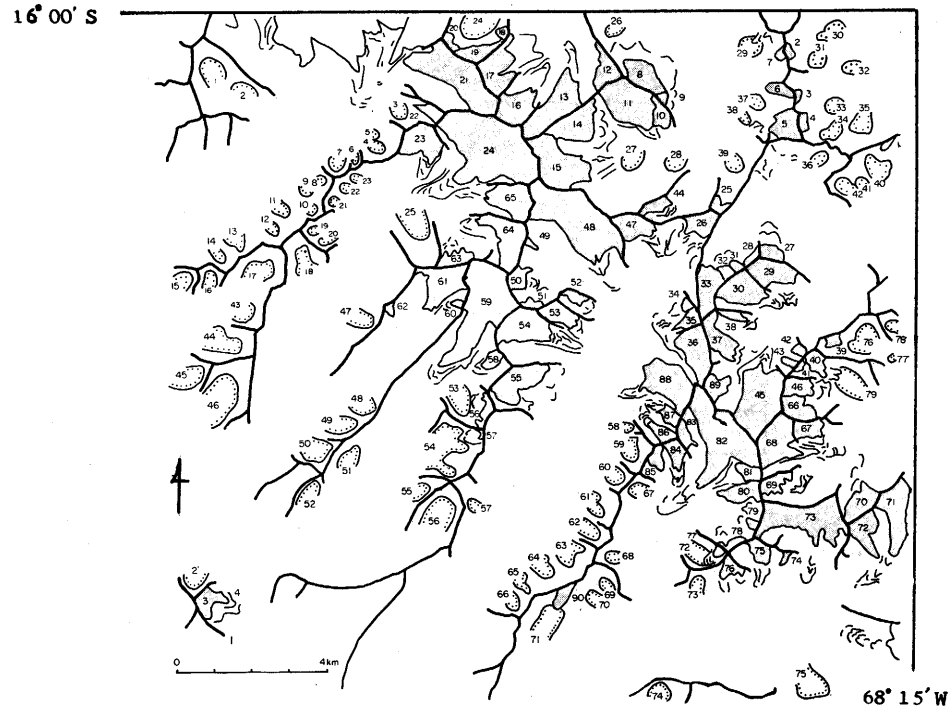

Fig. 1 Distribution of glaciers and cirques in the quadrangle "Lago Khara Kkota", Bolivia (after Nogami, 1968)
1 ridge 2 cirque wall 3 glacier 4 Neo-glacial moraines

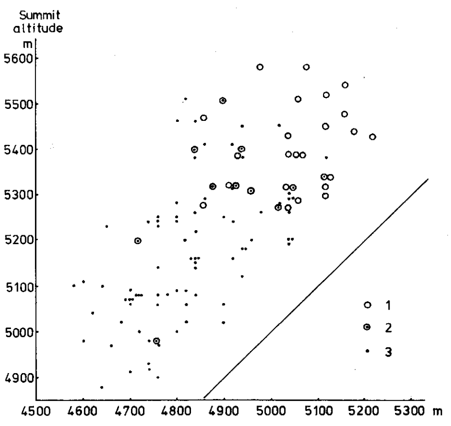

Fig. 2 Summit altitude vs. cirque floor altitude
1 cirque glacier having ice tongue
2 emaciated glacier in cirque
3 cirque free from ice

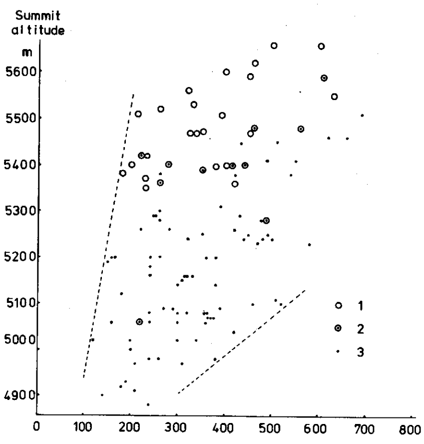

Fig. 3 Summit altitude vs. vertical distance from cirque floor to summit
1 cirque glacier having ice tongue
2 emaciated glacier in cirque
3 cirque free from ice

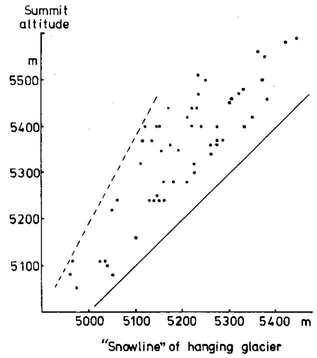

Fig. 4 Summit altitude vs. "snowline" of hanging glacier

snowlines of glaciers or cirques whose aspect is identical, even in the tropical zone.

Appropriate choice of a representative value for a certain quardrangle As shown above, both summit altitude and aspect produce local changes in snowline. Therefore, in order to eliminate errors or variations, only south-facing glaciers or cirques developed around comparatively low summits were adopted as representative. If there are several acceptable glaciers or cirques, the mean altitude of their snowlines can be considered as the representative value for the quardrangle. However, if there is only one acceptable glacier or cirque, or if there are several glaciers or cirques of obscure topographic appearence as regards their snowline, the representative value can be shown only in the form of a range or estimation.

Field observations

My field trips to the high mountain region of South America were made in 1966–67, 1970–71 and 1972–73. The area of activity extended from Bogotá to Chiloe Island, Chile. However, accessibility to snowline altitudes, even when it was of a glacial age, was very poor in general. Only in the high plateau regions of Peru and Bolivia was it possible to reach the necessary altitudes to observe glacial landforms easily and to measure the altitudes of cirque floors with a barometric altimeter. A correction value for the altitude biased by daily barometric pressure changes could be calculated without an automatic recorder, since the diurnal march of barometric pressure change maintained the same pattern for days of the

Table 2 Altitude of Snowline of Cirque Glaciers

aspect	NW	N	NE	E	SE	S	SW	W	total
n	4	2	3	3	7	7	4	4	34
mean	5274	5203	5263	5282	5256	5098	5224	5220	5217

Analysis of variance table

source of variation	sum of squares	df	V	F
between aspect	142368	7	20338	5.89
within aspect	89848	26	3456	
total	232216	33		

The F-value for the variation in altitude between different aspects is significant at the 99.5 % level as F(7, 26, 0.005) is 3.89.

same weather type at tropical or subtropical latitudes. The altitudes of the cirque floors were measured at many localities in Peru and Bolivia. Some representative values for each locality are listed in Table 6.

Summarization of data

Data collected from previous studies and arranged newly by me are also given in Table 6, and the amounts of data from each different source are specified in Table 5. Contemporary and former trend surfaces of the snowline have been reconstructed from the data in Table 6

Table 3 Altitude of Cirque Floors

aspect	NW	N	NE	E	SE	S	SW	W	total
n	22	6	6	3	13	6	14	9	79
mean	4851	4903	4827	4960	4849	4777	4732	4802	4823

Analysis of variance table

source of variation	sum of squares	df	V	F
between aspect	267579	7	38226	2.88
within aspect	941766	71	13264	
total	1209345	78		

The F-value for the variation in altitude between different aspects is significant at the 97.5 % level as F(7, 71, 0.025) is 2.47.

Table 4 Altitude of Snowline of Hanging Glaciers

aspect	NW	N	NE	E	SE	S	SW	W	total
n	6	5	4	5	12	6	9	9	56
mean	5249	5329	5275	5262	5164	5170	5136	5162	5200

Analysis of variance table

source of variation	sum of squares	df	V	F
between aspect	210558	7	30080	2.77
within aspect	521717	48	10869	
total	732275	55		

The F-value for the variation in altitude between different aspects is significant at the 97.5 % level as F(7, 48, 0.025) is 2.57.

	on MSL	on PSL	total
previous study	144	47	191
barometric measurement	1	14	15
photo-interpretation	7	18	25
map reading	89	203	292
total	241	282	523

Table 5 Data sources

Table 6 Altitude of modern snowline (MSL) and Pleistocene snowline (PSL)

Data sources are indicated by the numbers given in the REFERENCES CITED, and by the symbols "f", "m" and "b" which correspond to photo-interpretation, map reading and barometric measurement, respectively.

latitude (N or S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
11°05'–10°45'	73°00'–73°30'	Magdalena y Guajira		3700	m
11°05'–10°45'	73°30'–74°05'	Magdalena		3500±	m
11°00'–10°45'	73°15'–73°30'	Maruamaque		3600	m
11°00'–10°45'	73°30'–73°45'	Pico Bolivar		3800±	m
11°00'–10°45'	73°45'–74°00'	Don Diego		3300–3500	m
11°	74°	Santa Marta		3700–3800	38
10°50'	73°40'	Santa Marta (N. slope)	5000±		m
10°50'	73°40'	Santa Marta (S. slope)	5400±		m
10°50'	73°40'	Santa Marta	4600–4700		18
10°45'–10°30'	73°30'–73°45'	San Sebastin de Rabago		3700	m
10°45'–10°30'	73°45'–74°00'	Cerro Arucina		3700	m
10°45'–10°25'	73°30'–74°05'	Depto. del Magdalena		3700	m
9° – 8°	71°	Cord. Merida	4500–4600		18
8°50'– 8°43'	70°58'–71°06'	Páramo de La Culata	4700	3500	32 & 33
7°50'– 7°30'	72°35'–73°00'	Durania		3400–3500	,m
7°30'– 7°10'	72°35'–73°00'	Pamplona		3700	m
7°00'– 6°45'	72°35'–73°00'	Cerrito		3500–3700	m
6°30'	72°20'	Cocuy	4500–4700		18
6°30'	72°20'	Cocuy	4580		5
6°25'– 6°05'	72°35'–73°00'	Soata		3700	m
6°00'– 5°45'	72°35'–73°00'	Paz del Pio		3500–3600	m
6°00'– 5°45'	73°00'–73°15'	Duitama		3600	m
5°45'– 5°30'	72°45'–73°00'	Sogamoso		3650	m
4°39'	75°20'	Tolima	4800		38
4° – 5°	76°	Central Cordillera	4700–4800		18
4°	76°	El Nevado	4560±		m
3°00'	76°00'	Huila	4600–4700		18
1°00' N	77°53'	Cumbal	4790–		18
0°10'–0°30' S		western Ecuador		3700	16
0°20'– 0°30'	78°15'–78°30'	Pintag		3800±	m
0°20'– 0°30'	78°30'–78°45'	Amaguaña		4000–4200	m
0°30'– 0°40'	78°15'–78°30'	Sincholagua		4000	m
0°30'– 0°40'	78°30'–78°45'	Machachi		3900	m
0°40'– 0°50'	78°15'–78°30'	Cotopaxi		3800–4000	m
0°40'	78°28'	Cotopaxi	4750		18
0°50'– 1°00'	78°15'–78°30'	Laguna de Anteojos		3500–3600	m
1°00'– 1°10'	78°15'–78°30'	San Jose de Poalo		3500–3600	m
1°00'– 1°10'	78°30'–78°45'	Salcedo		3900–4000	m
1°10'– 1°20'	78°15'–78°30'	Sucre		3200	m
1°10'– 1°20'	78°45'–79°00'	Simiatug		4000	m
1°20'– 1°30'	78°30'–78°45'	Quero	4800±	4000	m
1°20'– 1°30'	78°45'–79°00'	Chimborazo	4900–5000	4000	m
1°29'	78°50'	Chimborazo	4800		18
1°30'– 1°40'	78°30'–78°45'	Guano		4200±	m
1°30'– 1°40'	78°45'–79°00'	Guaranda		4000±	m
1°40'– 1°50'	78°30'–78°45'	Riobamba		4100	m
1°40'– 1°50'	78°45'–79°00'	Sicalpa		4000	m
1°50'– 2°00'	78°30'–78°45'	Guamote		4100±	m
1°50'– 2°00'	78°45'–79°00'	Pallatanga		4100±	m
2°00'– 2°10'	78°30'–78°45'	Palmira		3900–4000	m

latitude (S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
2°10′– 2°20′	78°30′–78°45′	Totoras		3900	m
2°10′– 2°20′	78°45′–79°00′	Alausi		3900±	m
2°20′– 2°30′	78°30′–78°45′	Huangra		3700–3800	m
2°20′– 2°30′	78°45′–79°00′	Juncal		4100	m
2°50′– 3°00′	79°00′–79°15′	Cuenca		3700–3800	m
3°00′– 3°10′	79°00′–79°15′	Girón		3800±	m
3°00′– 3°10′	79°15′–79°30′	San Fernando		3700–3800	m
3°30′– 3°40′	79°15′–79°30′	Selva Alegre		3600–3700	m
4°00′– 4°10′	79°00′–79°15′	Rio Sabanilla		3300±	m
4°10′– 4°20′	79°00′–79°15′	Vilcabamba		3200	m
4°20′– 4°30′	79°00′–79°15′	Yangana		3440	m
4°30′– 4°40′	79°00′–79°15′	Valladolid		3300–3400	m
4°30′– 4°40′	79°15′–79°30′	Amaluza		3300–3400	m
4°40′– 4°50′	79°15′–79°30′	Laguna Cox		3400–3500	m
5°30′– 6°00′	79°00′–79°30′	Pomahuaca		3350–3500	m
6°00′– 6°30′	79°00′–79°30′	Incahuasi		3400–3700	m
6°30′– 7°00′	78°00′–78°30′	Celendin		3900	m
6°30′– 7°00′	78°30′–79°00′	Chota		3950	m
6°45′	78°30′	Hualgayoc		3650–3700	35
7°00′– 7°30′	78°00′–78°30′	San Marcos		3800±	m
7°00′– 7°30′	78°30′–79°00′	Cajamarca		3950	m
7°30′– 8°00′	78°00′–78°30′	Cajabamba		3950±	m
7°30′– 8°00′	78°30′–79°00′	Otuzco		4100±	m
8°00′– 8°30′	77°30′–78°00′	Pallasca		4300–4500	m
8°45′– 9°35′	77°00′	Cord. Oriental	4700–4800		18
8°45′– 9°35′	77°30′	Cord. Blanca	4900–5000		18
8°45′– 9°35′	77°50′	Cord. Negra	5100–5200		18
8°45′– 9°35′	77°30′	Cord. Blanca	4900	4100–4300	21
8°45′– 9°35′	77°50′	Cord. Negra	5200	4300–4400	21
8°48′	75°54′	Acrotambo	4750		16
9°00′– 9°30′	77°00′–77°30′	Huari	5000–5200		m
9°08′	77°36′	Huascaran	5000–5100		m
9°12′	77°46′	Pelegatos	4800	4000	17
9°30′–10°00′	77°00′–77°30′	Recuay	4800–5000	4200–4400	m
9°30′–10°00′	77°30′–78°00′	Huaraz		4300–4400	m
9°35′	77°40′	Cord. Negra		4100	b
10°00′–10°30′	76°00′–76°30′	Ambo	4800+	4000–4100	m
10°00′	76°00′	Valle Malconga		4000	24
10°00′–10°30′	76°30′–77°00′	Yanahuanca	5300±	4400–4700	m
10°00′–10°30′	77°00′–77°30′	Chiquian	4900+	4400–4600	m
10°00′	77°25′	Conococha		4100±	b
10°16′	76°55′	Yerupaja	5200		18
10°30′–11°00′	76°00′–76°30′	Cerro de Pasco		4200±	m
10°30′–11°00′	76°30′–77°00′	Oyon	4950–5150	4700±	m
10°30′–10°50′	76°30′	Cord. Huayhaush	4900–5200		18
10°30′–11°00′	77°00′–77°30′	Ambar	5100±	4600–4750	m
11°00′–11°30′	76°00′–76°30′	Ondores	5000–5200	4600±	m
11°00′–11°30′	76°30′–77°00′	Canta	5050–5100	4700±	m
12°	75°		5000		14
12°15′	75°00′	Pampas		4000±	b

latitude (S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
12°30′		Vilca and Yauricocha	5200	4300	17
13°00′–13°30′	74°00′–74°30′	Ayacucho		4200±	m
13°08′–13°14′	73°02′–73°09′	Panta	4800		m
13°20′	74°10′	Ayacucho		4100±	b
13°30′	71°00′	Cord. Carabaya	4800		18
13°30′	71°30′	Vilcanota	5000		18
13°30′	71°30′	Vilcanota	4900		26
13°30′–14°00′	73°30′–74°00′	Chincheros		4200±	m
13°30′–14°00′	74°00′–74°30′	Huancapi		4200±	m
13°30′–14°00′	74°30′–75°00′	Paras		4300–4400	m
13°30′–14°00′	75°00′–75°30′	Santiago de Chocorvos		4200±	m
13°40′	73°00′	Huancarama		3750±	b
13°40′	73°30′	Andahuaylas		4000±	b
14°00′–14°30′	73°30′–74°00′	Querobamba		4400	m
14°00′–14°30′	74°00′–74°30′	Santa Ana		4300±	m
14°00′–14°30′	74°30′–75°00′	Laramate		4200–4400	m
14°30′	70°45′	Santa Rosa		4600	14
14°30′	71°00′	Sicuani		4250±	b
14°30′–15°00′	71°00′–71°30′	Yauri		4500–4600	m
14°30′–15°00′	71°30′–72°00′	Velille		4500–4700	m
14°30′–15°00′	73°30′–74°00′	Chaviña		4500	m
14°30′–15°00′	74°00′–74°30′	Puquio		4200±	m
14°30′	74°30′	Pulhuanga		4300–4400	35
15°00′–15°10′	69°00′–69°15′	Kkata	5200±	4200–4800	m
15°00′–15°30′	70°00′–70°30′	Juliaca		4600	m
15°00′–15°30′	70°30′–71°00′	Ocuviri	5400±	4600	m
15°00′–15°30′	71°00′–71°30′	Condoroma		4800	m
15°00′–15°30′	71°30′–72°00′	Cailloma		4900±	m
15°00′–15°30′	72°00′–72°30′	Orcopampa		4700±	m
15°00′–15°30′	72°30′–73°00′	Cotahuasi (Solimana)	5498–	4800±	m
15°00′–15°30′	73°00′–73°30′	Pausa (Sora Sora)	5505–	4700±	m
15°10′–15°20′	69°00′–69°15′	Villa General Gonzales	4800+	4300–4500	m
15°10′–15°21′	69°31′–69°44′	Huancané and Moho		4200	26
15°20′–15°30′	69°00′–69°15′	Italaque		4300±	m
15°30′–15°40′	69°00′–69°15′	Escoma		4100–4200	m
15°30′–16°00′	70°00′–70°30′	Puno		4500±	m
15°30′–16°00′	70°30′–71°00′	Lagunillas		4700	m
15°30′–16°00′	71°00′–71°30′	Callalli		4700±	m
15°30′–16°00′	71°30′–72°00′	Chivay (Amapato)	5400±	4800	m
15°30′–16°00′	72°00′–72°30′	Huambo	5300+	4800–4900	m
15°30′–16°00′	72°30′–73°00′	Chuquibamba (Coropuna)	5800±	4850±	m
15°30′	72°40′	Corupuna	5300		18
15°40′–15°50′	69°00′–69°15′	Puerto Carabuco		4400±	m
15°50′–16°40′	67°50′–68°30′	Cord. Real	4900–5150		26
15°50′–16°40′	67°50′–68°30′	Cord. Real	5300–5400		1
15°50′–16°40′	67°50′–68°30′	Cord. Real	5450		18
15°50′	68°30′	Illampu	5300–5400		18
15°50′–16°00′	68°45′–69°00′	Ancoraimes		4250	m
15°54′	68°34′	Chearcollo		4900	16
15°55′	68°30′	Achacachi		4100	b

latitude (S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
16°00′–16°10′	68°00′–68°15′	Zongo	5000–5200	3900–4500	m
16°00′–16°10′	68°15′–68°30′	Lago Khara Kkota	5100–5150	4750	m
16°00′–16°10′	68°15′–68°30′	Lago Khara Kkota	5100	4600	27 & 28
16°00′–16°30′	69°30′–70°00′	Ilave		4700	m
16°00′–16°30′	70°00′–70°30′	Pichacane		4700	m
16°00′–16°30′	70°30′–71°00′	Ichuña (Ubinas)	5400+	4900±	m
16°00′–16°30′	71°00′–71°30′	Characato (Misti)	5822±	4700±	m
16°00′	71°00′	Alto de Torola		4550	b
16°00′–16°30′	71°20′	Arequipa region		4500	14
16°00′–16°30′	71°30′–72°00′	Arequipa (Chachani)	5784–6056	5000–5200	m
16°10′–16°20′	67°45′–68°00′	Unduavi		4000–4400	m
16°10′–16°20′	68°00′–68°15′	Milluni	5100	4000–4700	m
16°11′	71°31′	Chachani	5800+		16
16°11′	71°31′	Chachani	6000		18
16°15′	68°15′	Cumbre	5100	4450±	b
16°19′	71°23′	Misti	5855+		18
16°19′	71°23′	Misti	5800+		16
16°20′–16°30′	67°30′–67°45′	Chulumani		4100–4250	m
16°20′–16°30′	67°45′–68°00′	Chojlla		4250–4800	m
16°30′–16°40′	67°30′–67°45′	Lambate		3500–4050	m
16°30′–16°40′	67°45′–68°00′	Palca (Mururata)	5200–5700	4400–4600	m
16°30′–17°00′	69°30′–70°00′	Mazo Cruz	5200+	4600±	m
16°30′–17°00′	70°00′–70°30′	Huitire	5400–5600	4800–4900	m
16°30′–17°00′	70°30′–71°00′	Omate		4600±	m
16°30′–17°00′	71°00′–71°30′	Puquina		4500±	m
16°40′–16°50′	67°30′–67°45′	Araca	4850–5150	4650	m
16°40′–16°50′	67°45′–68°00′	Cohoni	5100	4700–4800	m
16°40′–16°50′	68°30′–68°45′	Sacacani	4750+	4500–4600	m
17°00′–17°10′	66°45′–67°00′	Independencia		4000–4100	m
17°00′–17°10′	67°00′–67°15′	Ichoca		4050–4500	m
17°00′–17°10′	67°15′–67°30′	Yaco		4700	m
17°	67°30′	Quinsa Cruz	5300–5400		18
17°00′–17°30′	70°00′–70°30′	Tarata (Chuquiananta)		4600–4700	m
17°00′–17°30′	70°30′–71°00′	Moquegua (Arunane)		4800±	m
17°10′–17°20′	67°45′–66°00′	Corani		3850–4040	m
17°10′–17°20′	66°30′–66°45′	Morochata		4150–4250	m
17°10′–17°20′	66°45′–67°00′	Cavicavini		4150±	m
17°10′–17°20′	67°00′–67°15′	Luruhuta		4050–4300	m
17°17′	66°23′	Tunari	5180		3
17°20′–17°30′	65°45′–66°00′	Colomi		3900–4000	m
17°20′–17°30′	66°45′–67°00′	Kami		4300	m
17°20′–17°30′	67°00′–67°15′	Colquiri		4400±	m
17°20′–17°30′	69°15′–69°30′	Tambo Mauri		4700–4800	m
17°30′–17°40′	66°45′–67°00′	Leque		4300	m
17°30′–17°40′	67°00′–67°15′	Caracollo		4500	m
17°43′	69°45′	Tacora	5910+	5000	4
17°43′	69°45′	Tacora	5988+		f
17°45′	69°38′	Caracani		4950	f
17°50′–18°00′	68°45′–69°00′	Okoruro		4600–4700	m
17°50′–18°00′	69°00′–69°15′	Rio Blanco	5400+		m

latitude (S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
17°48′	68°58′	Sunicagua		4800	f
17°48′	69°09′	Grazani Azul		4800–4900	f
17°51′	69°24′	peak of 5370m		4800–4900	f
17°53′	69°27′	Cosapilla		4850–4950	f
18°00′–18°10′	66°30′–66°45′	Huayna Chaca		4700±	m
18°00′–18°10′	68°15′–68°30′	Estancia Marcarani		4700–4800	m
18°00′–18°10′	68°45′–69°00′	Nevado Sajama		4700–4800	m
18°00′–18°10′	69°00′–69°15′	Nevados Payachata		4900–5000	m
18°06′	69°05′	Larancahue	5530+	4900–5000	f
18°06′	69°30′	Taapaca	5815+		f
18°07′	68°55′	Sajama	5900–6000		1
18°07′	69°07′	Pomerape	6000±		f
18°10′–18°20′	66°00′–66°15′	Coakari		4100	m
18°10′–18°20′	68°30′–68°45′	Estancia Agua Rica		4700–4800	m
18°10′–18°20′	68°45′–69°00′	Estancia Laguna		4700±	m
18°10′–18°20′	69°00′–69°15′	Cerro Quisi Quisini		4800–4900	m
18°10′	69°10′	Payachata	5900–6000		1
18°16′	69°29′	Milagro		4750	f
18°20′–18°30′	66°00′–66°15′	Arroz Pata		4200	m
18°20′–18°30′	66°30′–66°45′	Uncia	4800+	4400–4500	m
18°20′	66°50′	Huanuni		4250	b
18°20′–18°30′	69°00′–69°15′	Nevado Quinsa Chata		4700–4800	m
18°23′	69°03′	Acotango	5900±		f
18°24′	69°29′	Chapiquina		4900	f
18°25′	69°10′	Huallatari	6000–		4
18°30′	69°26′	Belén		5000	f
18°30′–18°40′	65°45′–66°00′	Chayata		4500–4700	m
18°40′–18°50′	65°45′–66°00′	Chairapata		4500	m
18°40′–18°50′	68°45′–69°00′	Jolo		4700–4800	m
18°45′	65°50′	Ocuri		4050	f
18°45′	69°03′	Arintica	5590+		f
18°46′	65°40′	Ravelo		4000	b
18°46′	69°15′	Anocariri		4850	f
18°50′–19°00′	65°30′–65°45′	Marcoma		3950–4000	m
18°50′–19°00′	66°15′–66°30′	Japo	5200+	4600–4700	m
18°50′–19°00′	66°30′–66°45′	Azanaques	5100+	4600–4700	m
18°50′–19°00′	68°45′–69°00′	Capitan		4700–5100	m
18°58′	69°08′	Mulluri		4800–4900	f
19°00′–19°10′	65°45′–66°00′	Ajtara		4500±	m
19°00′–19°10′	66°15′–66°30′	Estancia Calacota		4600–4700	m
19°10′–19°20′	65°45′–66°00′	Tinguipaya		4600–4700	m
19°10′–19°20′	66°30′–66°45′	Urmiri		4500±	m
19°15′–19°30′	68°45′–69°00′	Mauque		4600±	m
19°20′–19°30′	65°30′–65°45′	Don Diego		4400–4500	m
19°20′–19°30′	65°45′–66°00′	Yocalla		4500–4700	m
19°20′–19°30′	66°15′–66°30′	Rio Castilla Maju		4600	m
19°30′–19°40′	65°30′–65°45′	Posití (Este)		4640	m
19°30′–19°45′	68°45′–69°00′	Lagunas Chuncara		4900–5000	m
19°40′	65°45′	Potosí		4300±	b
19°40′–19°50′	65°30′–65°45′	Puna		4600	m

latitude (S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
19°40′–19°50′	66°00′–66°15′	Rio San Juan		4400±	m
19°40′–19°50′	66°15′–66°30′	Estacion Yura		4400–4500	m
19°40′–19°50′	66°30′–66°45′	Opoco		4800±	m
19°42′	68°40′	Chapire		5000	4
19°42′	68°40′	Chapire	5995+		m
19°50′–20°00′	66°30′–66°45′	Lagunas Huancarani		4700–4800	m
20°59′	66°05′	Chorolque	5600		18
21°00′–21°10′	67°45′–68°00′	Chiguana	5300+	4800	m
21°00′–21°15′	68°15′–68°30′	Ollagüe	6180–	5200±	m
21°00′–21°15′	68°30′–68°45′	Volcan Miño	5300–5600		m
21°10′–21°20′	67°45′–68°00′	Cerro Tomasamil	5900+	4800–4900	m
21°10′–21°20′	68°00′–68°15′	Volcan Ollagüe	5865+		m
21°10′	68°30′	Aucaquilcha	6180+		1
21°10′–21°20′	68°30′	Aucaquilcha–Ollague	6180+	4800–5200	15 & 16
21°15′–21°30′	68°00′–68°15′	Volcan Ollaque	5870+	5400	m
21°15′–21°30′	68°15′–68°30′	Salar de San Martin	5600±		m
21°15′–21°30′	68°30′–68°45′	Chela		4800	m
21°20′–21°30′	67°45′–68°00′	Cerro Inti Pasto	5950+	5000–5400	m
21°20′–21°30′	68°00′–68°15′	Cerros de Cañapa	5900+		m
21°20′	68°09′	Ollague	5870+		15 & 16
21°30′–21°40′	67°45′–68°00′	Mina Corina	5800+		m
21°30′–21°40′	68°00′–68°15′	Cerro Araral	5700+		m
21°30′–21°45′	68°15′–68°30′	Ascotan	5700–5900	4900–5000	m
21°30′–21°45′	68°30′–68°45′	Cerro Palpana	5900–6000		m
21°40′–21°50′	66°15′–66°30′	La Cienega		4800–5000	m
21°40′–21°50′	66°30′–66°45′	San Pablo de Lipez	5300+	4900±	m
21°40′–21°50′	67°45′–68°00′	Cerro Cachi Laguna	5800+		m
21°40′–21°50′	68°00′–68°15′	Cerro del Inca	5650+		m
21°45′–22°00′	68°15′–68°30′	Volcan San Pedro	5800±		m
21°50′–22°00′	66°45′–67°00′	San Antonio de Lipez	6000+	5200	m
21°50′–22°00′	68°00′–68°15′	Cerro Incaliri	5600+		m
21°53′	66°53′	Lipez	5850–		1
22°00′	67°15′	Sonequera	5855–		m
22°05′	68°	Apagado	5600+		m
22°12′	68°12′	Toconce		5000	4 & 20
22°15′	67°10′	Uturunco	5900–		1
22°50′	67°55′	Licancabur	6190+		m
23°15′–23°30′	67°30′–67°45′	Volcan Lascar	6050+		
23°30′–23°45′	67°30′–67°45′	Cerro Miscanti	5750+		m
23°30′–23°45′	67°45′–68°00′	Socaire	5800–		m
23°45′–24°00′	67°30′–67°45′	Tuyajto	5600+		m
23°45′–24°00′	67°45′–68°00′	Cerro Miñiques	5900+		m
24°03′	65°45′	Chañi	5800–5900	4560	13
24°03′	65°45′	Chañi	5900–6000		10
24°03′	65°45′	Chañi		5200–5300	13
24°03′	65°45′	Chañi	5800	4500	2
24°10′	68°05′	Pullar	6225+		m
24°25′	66°10′	Acay		5000	10
24°25′	66°10′	Acay	5950–		m
24°43′	68°30′	Llullaillaco	6620+		18

latitude (S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
24°43′	68°30′	Llullaillaco	6723±		10
24°43′	68°30′	Llullaillaco	5600–6500	5000	16
24°48′	66°30′	Cachi	5900–6000	4650	10
24°48′	66°30′	Cachi	6200–6300		18
25°36′	67°55′	Antofalla	6100+		m
26°30′	68°35′	peak of 6120m	6120–		m
26°35′	68°40′	unnamed peak	5910+		m
26°50′	68°40′	Peña Blanca	6020–		m
27°05′	68°35′	Ojo del Salado	5400+		15
27°06′	68°45′	Tres Cruces	6300–	4300+	4
27°15′–27°30	69°00′–69°15′	Laguna del Negro Francisco	6050+	4900±	m
27°30′	66°00′	Aconquija	5000–5200	3800–4200	13
27°30′	66°00′	Aconquija	5000–5200		10
27°30′	66°00′	Aconquija	5200	3800	2
27°30′	66°00′	Aconquija	5100–5200		18
27°55′	68°41′	Bonete	6000	5400	18
28°23′	69°40′	Potro	5830–		4
28°23′	69°40′	Potro	5500		18
28°58′	67°45′	Famatina	5800		13
28°58′	67°45′	Famatina	5700–5800		10
29°00′	67°50′	Mejicana		5200–5400	2
29°45′	70°07′	Doña Anna	5690–	4300	10
29°56′	69°54′	Tórtolas	5600+		15
29°57′	70°21′	Infiernillo		4200	f
30°07′	69°57′	Los Bañados	5700		f
30°10′	70°	Rio Turbio (Elqui)		4300	4
30°10′	70°	Cord. Elqui	5000		18
30°15′–30°30′	70°30′–70°45′	Hurtado		3700	m & f
30°30′–30°45′	70°30′–70°45′	Central Los Molles		3600	m & f
30°45′–31°00′	70°30′–70°45′	El Maqui		3450	m & f
31°01′	70°25′	peak of 4040m and 4024m		3900	f
31°15′	70°35′	Rio Tascadero		3400	4
31°32′	70°42′	Burras		3600	f
31°45′–32°00′	70°30′–70°45′	Cuncumen		3450	m & f
31°58′	70°10′	Mercedario	4800		10
32°00′	70°15′	international border	4800		10
32°00′–32°15′	70°30′–70°45′	Tranquilla		3200	f
32°03′	70°10′	Ramada	4800		18
32°10′–32°30′	69°40′	Cord. Tigre	4800–5000	4050–4200	10
32°15′–32°30′	70°30′–70°45′	Estero Alicahue		3000	f
32°30′–32°45′	70°15′–70°30′	Rio Colorado		3500	m & f
32°39′	70°01′	Aconcagua	4600		10
33° –34°	70°00′	Maipo	4250		18
32°45′	69°50′	Portillo		2800	b
33°05′	70°08′	Juncal	4400		23
33°05′	70°08′	Juncal	4500		4
33°05′	70°05′	Plomo	4500		10
33°10′	69°30′	Cordon Plata		3600–4000	15
33°20′	69°50′	Polleras (Tupungato)	3600+		10
33°20′	69°50′	Tupungato	4400		18

latitude (S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
33°30′	70°27′	Punta de Damas		2900	f
34°30′	70°	Negro Overo	4000		18
34°36′	70°10′	Rio Atuel	3300		10
34°40′	70°20′	Palomo	3100–3300		4
34°49′	70°20′	Rio Tinguiririca	2700+		10
35°00′	70°05′	Risco Plateado	3800		10
35°00′	70°15′	Paso de Las Damas	3500		10
35°13′	70°36′	Planchón	3200		23
35°16′	70°35′	Peteroa	2700–3200		10
35°16′	70°35′	Peteroa–Azufre	2500–4000		9
35°30′	68°30′	Co. Nevado	3810–		m
35°30′–35°45′	71°00′–71°15′	Vilches		2000–2100	m
35°31′	70°37′	Descabezado Chico	2800–3250		9
35°45′–36°00′	71°00′–71°15′	Melado	2500±	1700–2000	m
35°59′	71°10′	Lástimas	2700		23
36° –37°	70°30′	Cord. Viento		2200	10
36°00′	70°51′	San Pedro	2700+		9
36°	71°	Chilean Andes	2600		18
36°	71°	Argentine Andes	3000+		18
36°00′–36°15′	71°00′–71°15′	Nevado de Longaví	2800±	1800–1900	m
36°00′–36°15′	71°15′–71°30′	Achibueno		1500	m
36°12′	71°10′	Nevado de Longaví	2700		23
36°15′–36°30′	71°15′–71°30′	Bullileo		1250–1600	m
36°28′–36°35′	69°15′	Payun Matru	3750+		10
36°30′–36°45′	71°15′–73°30′	Lara		1500±	10
36°36′	70°25′	Domuyo	3800	2400–2500	10
36°45′–37°00′	71°15′–71°30′	Nevado Chillán	2800±		m
36°50′	71°25′	Nevado Chillán	2800		23
37°	71°10′	Chilean Andes	2400–2500		18
37°10′	71°10′	Donaire	3130+		10
37°12′	70°00′	Pum Mahuida	3979–		10
37°25′	71°25′	Antuco	2100		10
37°55′	71°25′	Callaquén	2700		10
38°23′	71°35′	Lonquimai	2400		10 & 23
38°42′	71°45′	Llaima	2500		4
38°42′	71°45′	Llaima	2400		23
38°55′	71°55′	Rio Allipen		700	m & f
39°15′	72°15′	Villarrica	1800–1900		18
39°38′	71°30′	Lanín	2100		23
39°38′	71°30′	Lanín	1800–2000		10
39°30′–39°45′	72°00′–72°15′	Pullingue		900–1000	m
39°45′–40°00′	72°00′–72°15′	Choshuenco (El Mocho)	1900–2000	900–1000	m
39°45′–40°00′	72°15′–72°30′	Riñihue		900–1000	m
39°00′–39°20′	71°30′	Argentine Andes (W to E)		1550–1950	11
39°20′–39°40′	71°30′	Argentine Andes (W to E)		1400–1750	11
39°40′–40°00′	71°30′	Argentine Andes (W to E)		1300–2000	11
40°00′–40°20′	71°20′–71°50′	Argentine Andes (W to E)		1300–1800	11
40°20′–40°40′	71°30′	Argentine Andes (W to E)		1200–1700	11
40°40′–41°00′	71°30′	Argentine Andes (W to E)		1200–1700	11
41°00′–41°20′	71°30′	Argentine Andes (W to E)	2000	1200–1800	11

latitude (S)	longitude (W)	locality	MSL (m)	PSL (m)	data source
40°		Argentine Andes	2000		18
40°30′	71°30′	Falkner	2250		11
40°30′	72°10′	Riñihue	1600		18
40°58′	72°20′	Puntiagudo	1200+		10
41°06′	72°30′	Osorno	1400–1500		18
41°10′	71°30′	Lopez	2012+		10
41°10′	71°30′	Catedral	2409+		10
41°10′	71°55′	Tronador	1500		23
41°12′	71°49′	Gl. Río Manso	1360–2100		7
41°19′	72°40′	Calbuco	1400		23
41°30′	73°00′	Fiord topography to South (Pacific coast)			
41°45′–42°00′	72°15′–72°30′	Hornopiren	1400–1600	800–1000	m
41°45′	72°30′	Yate	1200–1600		23
41°45′–42°00′	72°30′–72°45′	Volcan Apagado	1200+	700–800	m
41°53′–42°02′	72°00′	Cordon Norte	800+		23
42°00′–42°15′	72°15′–72°30′	Cholgo	1300	600–700	m
42°00′–42°15′	72°30′–72°45′	Llancahue		500–700	m
42°08′	72°	Pico Alto	1000+		23
42°15′–42°30′	72°15′–72°30′	Huinay	1300–1400	650–800	m
42°15′–42°30′	72°30′–72°45′	Buill	1100–1200	600–700	m
42°24′	72°	Pico Amunátegui	1300+		23
42°30′	72°	Rio Turbio	800+		10
42°30′–42°45′	72°15′–72°30′	Pillan	1300–1400	500–700	m
42°30′–42°45′	72°30′–72°45′	Fiordo Reñihue	1300	500–600	m
42°39′	72°00′	Torrencillas	1700		23
42°39′	71°56′	Gl. Torrencillas	1800		7
42°45′–43°00′	72°15′–72°30′	Michinmahuida	1200–1300	600±	m
42°45′–43°00′	72°30′–72°45′	Chaiten	1300±	500–700	m
43°	72°	Argentine Andes		1100–1600	12
45° –46°	73°	western slope of Andes	1400		13
45°10′	73°10′	Maca	2400–		10
46°30′	73°00′–74°00′	North Patagonian ice sheet to South			
46°40′	73°	Lago Buenos Aires	1400–1500		18
46°33′	73°20′	San Valentín	1050		23
46°33′	73°20′	San Valentin	1300–1500		10
46°40′	74°	Gl. San Rafael	1050		23
46°50′	73°45′	Ofqui	1000		4
47°	73°45′	western slope of Andes	1320		13
47°13′	73°30′	Arenales	1300		34
48°15′	73°00′–74°00′	South Patagonian ice sheet to South			
49°30′	73°10′	Gl. Viedoma	1200		4
50°10′	73°10′	Lago Argentino	1500–1600		10
51°40′	59°00′	East Falkland	710+	385	6
51°40′	60°00′	West Falkland		300	6
52°00′	69°00′	Fiord topography to South (Atlantic coast)			
53°	73°	Estrecho de Magallanes	900		18
55°	67°	Beagle Canal	900–1000		18
55°	67°	Cord. Alvear	900–1200		10
55°	70°	Beagle Canal	400–500		18
63°20′	57°54′	Base O'Higgins	0–100		25

and mapped as contour lines for isoglacihypses. Based on a comparison of these two maps for the contemporary and former snowlines, the general circulation in the last glaciation can be discussed. A part of the result has been reported already (Nogami, 1972). The final result and its implications will be reported separately in the near future.

Acknowledgement

This study received financial support from the Itoh Science Foundation, and the field work was financed by a grant from the Ministry of Education. This article is dedicated with sincere thanks to Professor Taiji Yazawa, who encouraged me through his constant guidance regarding the essential nature of climatic geomorphology.

REFERENCES CITED

1 Ahlfeld, F. & Braniša, L. (1960): *Geología de Bolivia.* Instituto Boliviano del Petróleo, La Paz, 245 p.

2 Auer, V. (1970): The Pleistocene of Fuego-Patagonia. Part V: Quaternary problems of southern South America. *Annal. Acad. Sci. Fennicae,* series A, III, Geologica-Geographica, 100, 194p.

3 Bowman, I. (1968): *The Andes of southern Peru* (reprint ed.). Greenwood Press, New York, 336p.

4 Brüggen, J. (1950): *Fundamentos de la geología de Chile.* Inst. Geogr. Militar, Santiago de Chile, 374p.

5 Celeman, A. P. (1935): Pleistocene glaciation in the Andes of Colombia. *Geogr. Jour.,* 86, p. 330–334.

6 Clapperton, C. M. (1971): Evidence of cirque glaciation in the Falkland Island. *Jour. of Glaciol.,* 10, p. 121–125.

7 Colqui, B. (1965): Repertorio actualizado sobre imformación recogida en glaciares Argentinos. *Acta Geol. Lilloana,* 7, p. 63–78.

8 Derbyshire, E. (1968): Cirque. p. 120 in *the Encyclopedia of Geomorphology,* 1295p. ed. by R. W. Fairbridge.

9 Ferrán, O.G. & Martínez, M. V. (1962): Reconocimiento geológico de la Cordillera de los Andes entre los paralelos 35° y 38° latitud sur. *Anales de la Fac. Ciencias Físicas y Matemáticas,* Univ. Chile, Santiago vol. 19.

10 Feruglio, E. (1957): Los glaciares de la Cordillera Argentina. *Geografía de la República Argentina,* T. 7, p. 5–86, GAEA.

11 Flint, R. F. & Fidalgo, F. (1964): Glacial geology of the east flank of the Argentine Andes between latitude 39°10′ S and latitude 41°20′ S. *Bull. Geol. Soc. Amer.,* 75, p. 335–352.

12 Flint, R. F. & Fidalgo, F. (1969): Glacial drift in the eastern Argentine Andes between latitude 41°10′ S and latitude 43°10′ S. *Bull. Geol. Soc. Amer.,* 80, p. 1043–1053.

13 Frenguelli, J. (1957): El glaciarismo cuaternario. *Geografía de la República Argentina,* T. 2, p. 117–218, GAEA.

14 Hastenrath, S. (1967): Observations on the snow line in the Peruvian Andes. *Jour. of Glaciol.,* 6, p. 541–550.

15 —— (1971a): On the Pleistocene snow line depression in the arid regions of the South American Andes. *Jour. of Glaciol.,* 10, p. 255–267.

16 —— (1971b): On snow line depression and atmospheric circulation in the tropical Americas during the Pleistocene. *South African Geogr. Jour.,* 53, p. 53–69.

17 Heim, A. (1948): *Wunderland Peru.* Verlag Hans Huber, Bern, 301p.

18 Hermes, K. (1955): Die Lage der oberen Waldgrenze in den Gebirgen der Erde und ihr Abstand zur Schneegrenze. *Kölner Geogr. Arbeiten,* 5.

19 —— (1965): Der Verlauf der Schneegrenze. *Geogr. Taschenbuch, 1964–65,* p. 58–71.

20 Hollingworth, S.E. & Guest, J.E. (1967): Pleistocene glaciation in the Atacama desert, Northern Chile.

Jour. of Glaciol., 6, p. 749–751.
21 Kinzl, H. (1968): La glaciación actual y pleistocénica en los Andes centrales. *Colloquium Geographicum,* Univ. Bonn, 9, p. 77–90.
22 Klute, F. (1928): Die Bedeutung der Depression der Schneegrenze fur eiszeitliche Probleme. *Zeitschr. für Gletscherkunde,* 16, p. 70–93.
23 Lliboutry, L. (1956): *Nieves y glaciares de Chile,* Ediciones de Univ. de Chile, Santiago, 471p.
24 Mabire, B. (1961): Morfologias glaciares y no glaciares en la región de Huanuco (Andes del Peru), Valle de Malconga y valle de Llicua. *Bol. Soc. Geol. del Peru,* 36, p. 139–145.
25 Miller, H. (1965): Observaciones glaciologicas en las cercanias de la Base General Bernardo O'Higgins, Peninsula, Antártica. *Comunicaciones de la Escuela de Geología,* 8, Univ. de Chile, Santiago.
26 Newell, N. D. (1949): *Geology of the Lake Titicaca region, Peru and Bolivia.* Memoir 36, Geol. Soc. Amer.
27 Nogami, M. (1968): Statistical analysis of the altitudinal distribution of glaciation in the Cordillera Real, Bolivia. (in Japanese with English summary) *Jour. of Geogr.*, 77, p. 125–140.
28 — (1970): El retroceso de los glaciares en la Cordillera Real, Bolivia. (in Japanese with Spanish summary) *Geogr. Review of Japan,* 43, p. 338–346.
29 —— (1972): The snow line and climate during the last glacial period in the Andes mountains. (in Japanese with English summary) *The Quaternary Research (Japan),* 11, p. 71–80.
30 Paschinger, V. (1912): Die Schneegrenze in verscheiden Klimaten. *Peterm. Geogr. Mitt.*, Erg. Heft, 173.
31 Porter, S. C. (1964): Composite Pleistocene snow line of Olympic mountains and Cascade range, Washington. *Bull. Geol. Soc. Amer.*, 75, p. 477–482.
32 Schubert, C. (1974): Late Pleistocene Merida Glaciation, Venezuelan Andes. *Boreas,* 3, p. 147–152.
33 Schubert, C. & Valastro, S. (1974): Late Pleistocene glaciation of Paramo de La Culata, north-central Venezuelan Andes. *Geol. Rundschau,* 63, p. 517–538.
34 Tanaka, K. (1961): Note on the periglacial morphology of the "Hielo Patagonico Norte" and adjacent areas of Chile. (in Japanese with English sammary) *Geographical Studies presented to Prof. Taro Tsujimura in honour of his 70th birthday,* p. 239–257.
35 Tricart, J. (1965): Observations on the Quaternary firn line in Peru. *Jour. of Glaciol.*, 5, p. 857–863.
36 Unwin, D. J. (1973): The distribution and orientation of corries in northern Snowdonia, Wales. *Transactions Publ.* 58, p. 85–97, Inst. British Geographers.
37 Vuilleumier, B. S. (1971): Pleistocene changes in the fauna and flora of South America. *Science,* 173, p. 771–780.
38 Wilhelmy, H. (1957): Eiszeitklima in den feuchttropischen Anden. *Peterm. Geogr. Mitt.*, Erg. Heft, 262, p. 281–310.