

Landforms around the Lago General Carrera, Patagonia

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Yoshihiko AKAGI

Introduction

For about two weeks from March to April in 1968, the writer had the chance to survey landforms around the Lago General Carrera (Lago Buenos Aires, called in Argentina) and the Rio Blanco flowing into the lake, as a member of the third Patagonia Expedition of Hiroshima and Hokkaido Universities.

Lago General Carrera about 150 km long and 5–10 km wide, is situated at lat. $46^{\circ}30'$ S.. This lake elongates from the east of North Patagonian Glacier to Argentina. Survey areas are the vicinity of Pt. Sanchez, the Rio Blanco valley and the downstreams of the Rio San Martin and the Arroyo Pedrero (Fig. 1). Carta Preliminar: 4673 — Monte San Valentin (1:250,000 Instituto Geografico

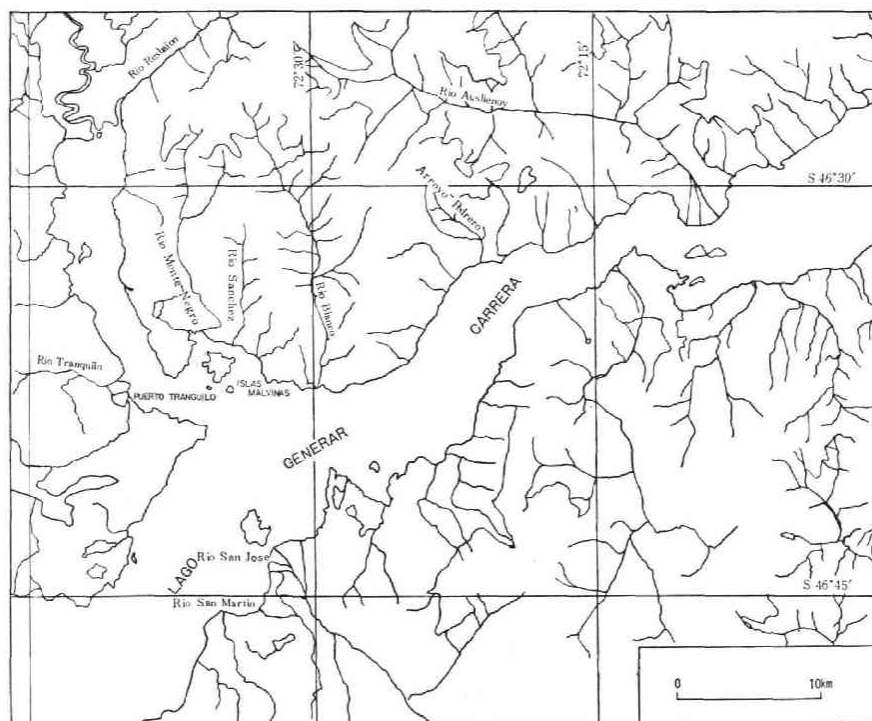


Fig. 1 Location map

Miltar 1950) is the only map of this area. This map is useless for analysis of topography by map reading, because contour-lines are not so accurate. The survey was carried out with aerial photographs on a scale of 1:40,000, Thonmen altimeter and a hand level. The lake-level is datum base for altimeter. The altitude of the lake-level is about 250 m above the sea-level. The Rio Baker rises in Lago General Carrera, crosses the Andes in the direction of north-east to south-west and flows into Canal Baker. The length of the Rio Baker from Lago General Carrera to Canal Baker is about 160 km. Copper ore mined around the Lago General Carrera is carried by boats through the Rio Baker.

I The Rio Blanco valley

The Rio Blanco that rises in Blanco Glacier which is located between the Rio Resbalon and the Rio Blanco, flows nearly southward about 20 km. This valley is a glacial trough. There are hanging glaciers, cirques and periglacial landforms at both sides (Photo 1).

1 Cirque

Many cirques can be seen on the slopes of the mountain ranges between the Rio Blanco, the Rio Sanchez (named by us), the Rio Monto Negro and the Rio Avellanos. The altitude of the cirques on the eastern slopes of these ranges is generally lower than that on the western slopes. And occasionally there is no cirque on the western slopes of these ranges. The altitude of the cirques on the western slopes of the Rio Blanco is about 1,750 m above the sea-level (Fig. 2, 3). In this area it snows hard, but it does not lie so much, for it is blown away by Westerly.

The cirque surveyed by the writer is located at the head of the tributary 3 of the Rio Blanco. This cirque is the nearest one from Lago General Carrera as remaining the glacier at the present time. The glacier of this cirque is very small in volume. This tributary runs parallel with the main river and its upper course is gentle in longitudinal profile. But at the timber line (about 1,250 m above the sea-level) this stream turns to east and becomes a hanging valley. This cirque is divided in two parts, eastern and western (Fig. 2). In the eastern part, no glacier can be seen (April 7, 1968). Inclination of the cirque wall is the steepest at the innermost where the height of the cirque wall is about 150 m.

A cirque glacier partly spreads beyond the upper moraine. This glacier is thin relatively. Considerable part of the glacier is about 50 cm in thickness and nearer to the cirque wall, it becomes thicker and opaque (Photo 2). This glacier was melting at 3-4 p.m. when the writer surveyed it. The melt-water gathered at the end of the glacier and was dissecting slightly the moraine.

There are three steps of moraines in this cirque bottom. Upper and middle moraines are deposited only in the western part where the glacier can be seen at present. Both cirque bottoms are joined at the lower moraine. The upper moraine is about 60 m in length and about 40 m in width, and its surface is flat. The middle moraine is 20 m in front of the upper moraine. The relative height between upper and middle moraines is about 10 m. As mentioned above, the glacier spreads to the middle moraine, and at this part, the upper moraine overlaps on the middle moraine. The lower moraine is deposited at the outer part of the cirque bottom. The length of the moraine is about 400 m. The relative height between middle and lower moraine is about 40 m. There are two cirque lakes in the eastern part of the cirque (Photo 3, 4).

2 Periglacial landforms

At the western slope of the Rio Blanco valley, the altitude of the timber line is about 1250 m above the sea-level. Above this line, there are many types of periglacial landforms. The inclination of the slope is steeper than 30° in general, but partly, there are narrow flat slopes of 10–30 m in width. Periglacial landforms often develop on these parts. On gentle ridges among tributaries of the Rio Blanco, periglacial landforms develop, too. Geology of this area is gneiss and penetrating porphyrite according to the writer's survey. There are much slate-like debris.

On the narrow flat parts of the slopes of the Rio Blanco valley, there develop sorted circle, sorted stripe, sorted step and small-scale rock-field of which shapes are not so clear.

Sorted circle (Photo 5) Sorted circles are frequently found on slopes of which inclinations are less than 5° . Their diameters are about 1.5 m. As they are shown in Photo 5, sorting is not so clear but debris is vertical at circles.

Sorted stripe (Photo 6) Sorted stripes develop on slopes of which inclinations are about 5° . Photo 6 shows them. They comprise alternate lines of coarse stones and fine materials.

Sorted step Sorted steps develop on slopes between 5° and 10° in gradient. They have frontal bank about 20 cm and treads extending about 50 cm. But their shapes are not so clear.

Rock-field (Photo 7) There is small-scale rock-field on the slope of which gradient is about 15° near-by the tributary 3. Diameters of these rocks are less than 50 cm and the extent of rock-field is limited to small scale as 15 m \times 30 m. Origin of these rocks is the dyke of the upper part.

On the ridge extended to the Rio Blanco, there are sorted steps and tors (Photo 8, 9). The slope of the ridge is 15° – 20° in gradient. Sorted steps are mainly found on the slope of which gradient is less than 15° . The relative height

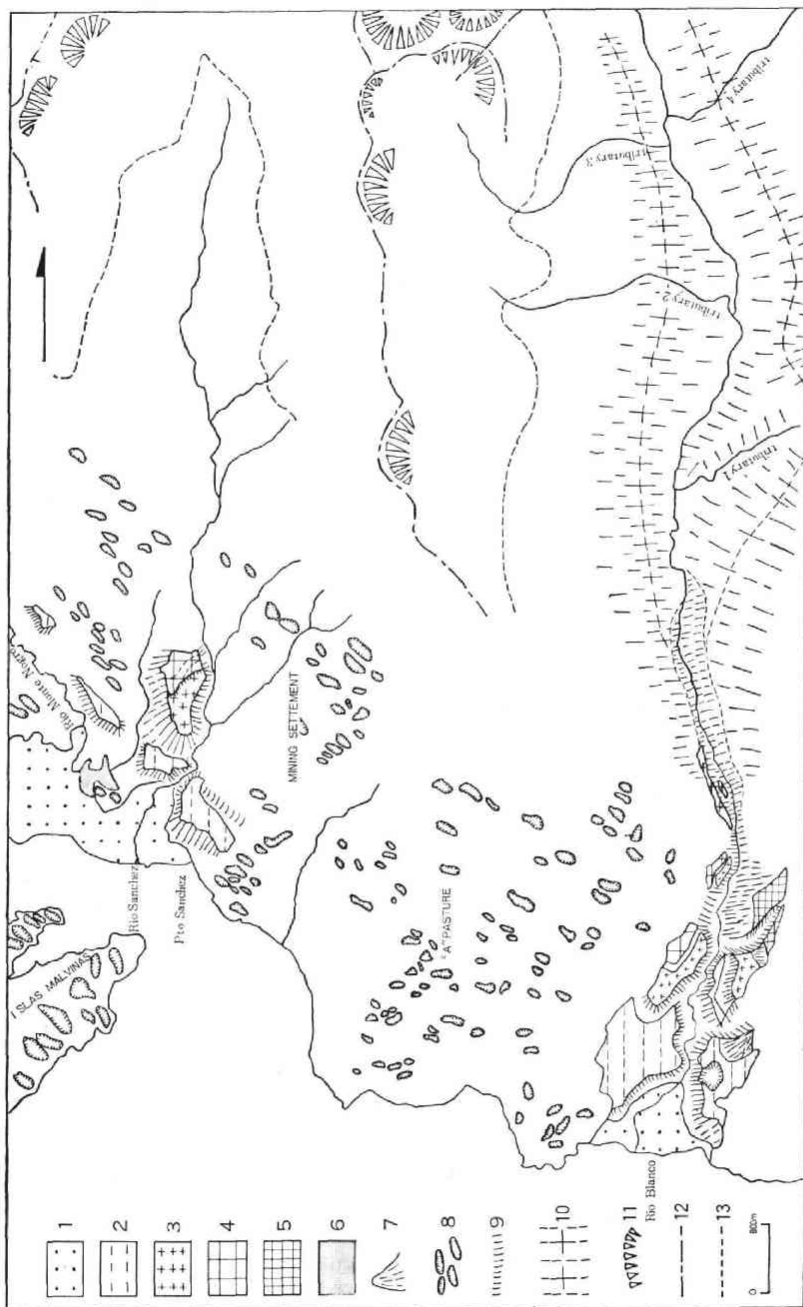


Fig. 2 Geomorphological map of the vicinity of Pt. Sanchez and lower part of the Rio Blanco

- 1: Delta 2: Lower terrace 3: Middle terrace 4: Upper terrace 5: Dissected fan 6: Marsh 7: Talus 8: Main rundhoeker 9: Steep slope 10: Glacial trough 11: Cirque 12: Sharp ridge 13: Timber line

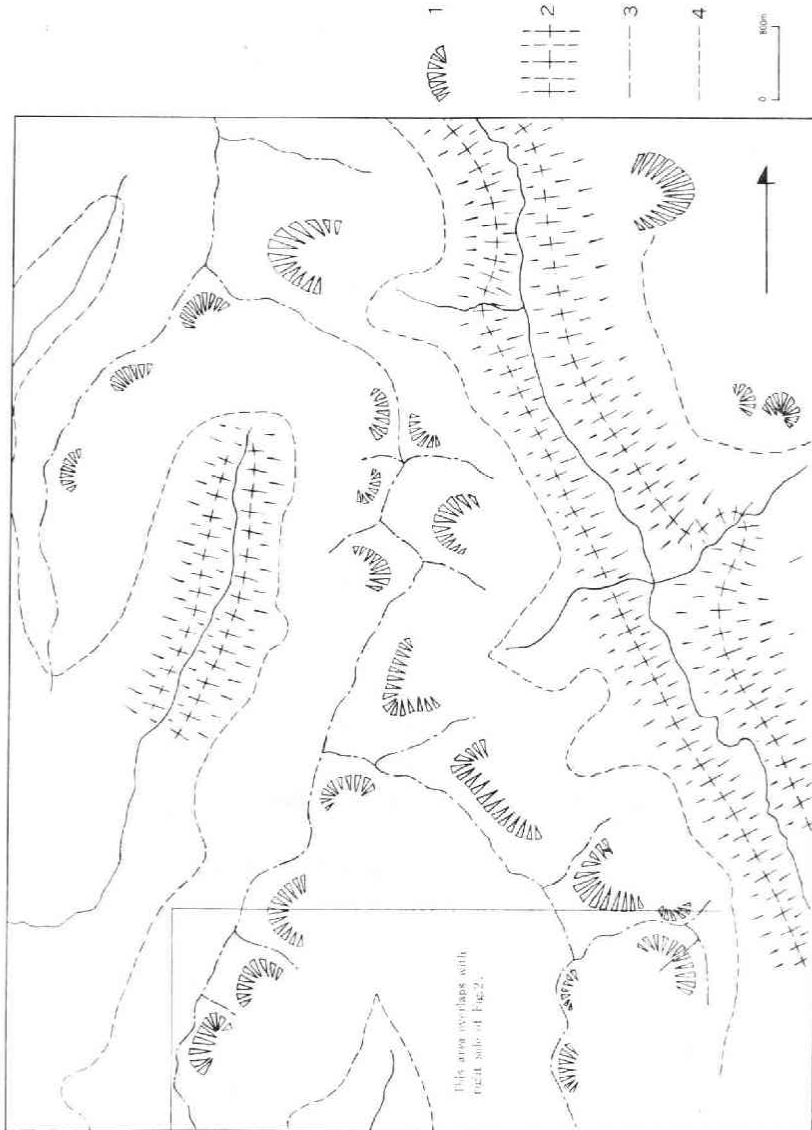


Fig. 3 Geomorphological map of upper parts of the Rio Blanco and the Rio Monte Negro
1: Cirque 2: Glacial trough 3: Sharp ridge 4: Timber line

of frontal banks, which are often covered with vegetation, is about 20–30 cm. Treads of the steps extend 50 cm–1 m in width and less than 10 m in length. The height of the tors is lower than 3 m and some of tors have been almost destroyed. It is recognized that these tors are formed clearly by frost splitting and at their bases slate-like debris are much accumulated.

3 *Glacial trough*

The valley course of the Rio Blanco upstream to midstream is NWW-SEE in direction almost like a straight line (Photo 1, Fig. 2, 3) and turns to the south drawing the shape of "S" midstream to downstream. The gradient of the longitudinal profile of the glacial trough is 3:200 between the mouth and the junction of the tributary 2. Upstream from the junction the gradient could not be measured but might be almost same as the lower part.

According to the interpretation of aerial photographs, the origin of this glacial trough is surrounded with glacial tongues, cirque glaciers and hanging glaciers which spread from small ice caps. The relative height between the glacier snout and the trough bottom may be about 500 m. In front of glacial tongues and cirque glaciers, there are moraines which are covered with forest. And some parts of forest are buried with new moraines.

As measured the slope of this glacial trough at the junction of the tributary 1, the slope is composed of four parts from the river channel up to the ridge. 1) 3°–10°, 2) 10°–20°, 3) 20°–30°, and 4) 25°–20°. But the boundaries of these parts are transitional. The moraine deposited near the boundary between slope 1) and 2) is shown in Photo 10 & 11. The thickness of the moraine at this part is 3–4 meters. The moraine is deposited up to the boundary between slope 2) and 3), and gets thinner upward. At the part 4), gentler than the part 3), knolls are scattered (Photo 10).

The glacial trough narrows at the valley end (Fig. 2, Photo 12). Downstream from this narrow develop two levels of terraces 320 meters and 290 meters above the lake-level. These terraces are intermittent and correlated to the upper and middle terraces of 270 m and 230 m above the lake-level at the river mouth. (As mentioned later, lacustrine terraces (dissected deltas) are found at all mouths of rivers flowing into Lago General Carrera. The heights of these terraces are 270 m, 230 m and 110 m above the lake level.) The upper terrace continues up to the flat bottom of the glacial trough. The middle terrace is correlated to the base of gentle slope between glaciated floor and V-shaped valley cutting the floor. The knickpoint of the longitudinal profile of the valley is between the junction 1 and 2. The V-shaped valley is cut downstream from the junction 1 (Photo 13).

II Landforms of the vicinity of Pt. Sanchez

There are three levels of glaciated surfaces and three lacustrine terraces (dissected delta) in this area.

1 *Glaciated surface*

The heights of these three levels of glaciated surfaces are 750 m–550 m, 350 m–250 m and lower than 100 m above the lake-level (Fig. 2 and Photo 14, 19). There are many rundhockers on these glaciated surfaces. But some of them are also formed on the slopes between these surfaces. The back slope of these surfaces is as steep as one of the Rio Blanco. Basement rock of this area is metamorphic rock N 20°–30° E in strike.

The upper glaciated surface develops most widely behind a mining settlement, and partly at the right side of the Rio Monte Negro and behind "A" pasture. Many rundhockers with steep slope on the west side are formed on this surface (Photo 16) and the direction of striation is N 80° W.

The middle surface develops most widely near "A" pasture and partly at the left side of the Rio Monte Negro and the Rio Blanco. The extent of the middle surface at "A" pasture is about 2000 m × 2500 m. On this surface many rundhockers develop at the margin. These rundhockers also have steeper slopes on the west side as on the upper glaciated surface. The direction of striation on the surface of exposed rock is N 70° W. There is a landform regarded as esker on the west end of this middle glaciated surface. This is composed of gravel and sand weakly sorted. The relative height of esker is about 10 m and its direction is almost east to west (Photo 17, 18).

The ridge located at the east of Pt. Sanchez, is 250 m above the lake-level and has the same direction as the strike (NNE-SSW) in geological structure connecting Islas Malvinas (Photo 15). This ridge is scraped almost vertically in some places and the scraped face is N 80° W in direction.

The rundhockers on the lower glaciated surface are remained above the delta accumulations, though they are not so many. The rundhocker on the marsh between the Rio Sanchez and the Rio Monte Negro is 25 m in height. The rundhocker shown in photo 19 has been remained above the lower lacustrine terrace accumulation.

2 *Lacustrine terrace*

On both sides of the Rio Sanchez and the Rio Monte Negro, there are terraces which are considered as dissected delta (Fig. 2). On the left side of the Rio Sanchez is only a terrace 110 m high above the lake-level. Two ridges are

observed on this terrace surface (Photo 20). One of the ridges, partly broken, is situated at the margin of the surface and its height is 1.5 m. The other is situated at the center of the surface and extends on the surface of the terrace at the right side of the Rio Sanchez. This ridge is 20 m high.

Six levels of terraces are formed on the right side of the Rio Sanchez. The heights of them are 105 m, 210 m, 225 m, 235 m, 245 m and 270 m. Among them terraces of 105 m, 235 m and 270 m are relatively broad.

All terraces are fill terraces. At the base of the terrace scarp on the left side of the Rio Sanchez terrace deposits are composed of alternations of gravels 10–15 cm in diameter and the mixture of sand and gravels about 2 cm in diameter. The thickness of the alternations of these deposits is about 50 cm. The strike of these alternations is N 80°W and the dip is 30°S. These alternations become thinner and their gravels become smaller upward. And at 80 m above the lake-level, terrace deposits are composed of the alternations of gravels about 2 cm in diameter and sand. Their thickness is 5 cm–10 cm (Photo 21). Judging from the facies, these deposits seem to be foreset beds of the older Rio Sanchez delta.

3 Varved clays

Along the Rio Monte Negro varved clays are found. The varved clays are composed of pairs of dark-brown and gray materials. Generally dark-brown material is thicker than gray one. The thickness of one pair is about 1–2 cm. The base of these varved clays is under the lake-level at the mouth of the Rio Monte Negro. Upward the river the thickness of varved clays becomes about 60 m and clay shifts to gravel.

4 Alluvial plain

At the mouths of the Rio Sanchez and the Rio Monte Negro deltas are developing and there is a marsh between these deltas. At the right side of the mouth of the Rio Monte Negro there is a plain slightly higher than the delta plain. This plain deposit is composed of clay, peat, volcanic ash and pumice.

III Terrace along the Rio San Jose and the Rio San Martin

Both the Rio San Jose and Rio San Martin flow almost parallel to each other into the lake. There are three levels of terraces and developing deltas downstream of these rivers (Fig. 4). Judging from shapes and facies of the deposits, these terraces are considered as dissected deltas. Downstream of the Rio San Jose, the radius of the middle terrace surface is about 2,000 m, the lower terrace surface about 3,500 m and developing delta about 2,500 m. Along the Rio San Martin each radius is 1,200 m, 2,000 m and 1,200 m.

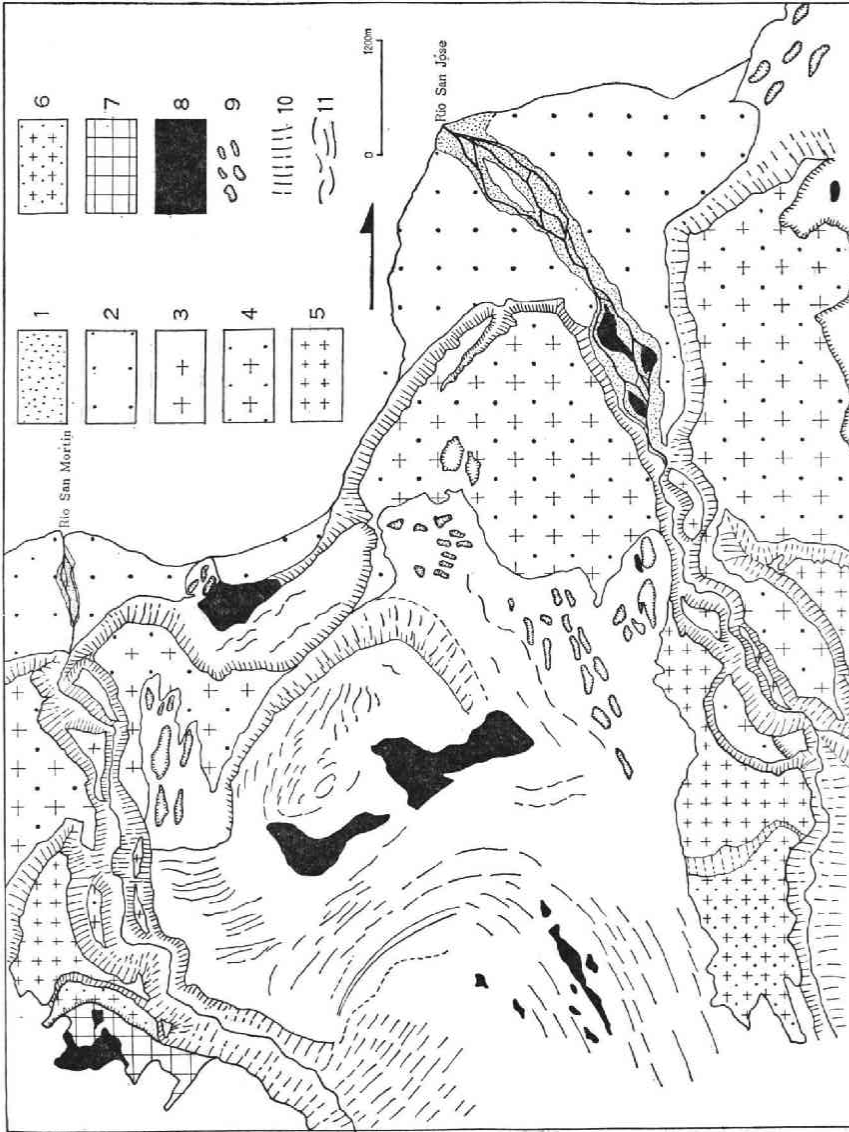


Fig. 4 Geomorphological map of lower parts of the Rio San Martin and the Rio San Jose
 1: Dry river bed 2: Delta 3: Lower terrace I 4: Lower terrace II 5: Middle terrace 6: Upper terrace I 7: Upper terrace II 8: Marsh and swamp 9: Main rundhocker 10: Steep slope 11: Bench-like topography and linear depression on the basement rock

The height of the lower terrace surface of the Rio San Martin is 110 m. The pattern of vegetation indicates former drainage and wave action. On the lower terrace surface of the right side of the Rio San Martin, there are deposits of ancient sand dune whose thickness is about 2 m. Volcanic ash is banded in this sand dune. Around Lago General Carrera, the deposits of volcanic ash were found only at this place and in the alluvial plain deposit, mentioned above. The ancient sand dune is the only deposit in this place. Deposits of the lower terrace are alternations of gravels 20–30 cm in diameter and the mixture of the sand and gravels less than 5 cm in diameter. The thickness of the alternation is about 80 cm–100 cm. The strike of the layer is E-W and the dip is 32°N.

The writer could not survey the upper and middle terrace surfaces. Judging from aerial photographs, there are however considerable differences in landforms between right and left sides of the Rio San Martin. On the left side the middle and upper terraces are clear deltaic forms, whereas on the right side there are six levels of bench-like bedrock surface behind the lower terrace surface (Fig. 4, Photo 22, 23).

IV Landforms at the mouth of Arroyo Pedrero

At the mouth of the Arroyo Pedrero there are three levels of terraces which are considered as dissected delta fans, and their heights are 270 m, 230 m and 110 m at each lower rim. These heights are accordant with the lacustrine terraces above-mentioned. The surfaces of these terraces are sloping gently as the Arroyo Pedrero flows into the lake with considerable gradient (Photo 24).

Conclusion

1) There are three small glaciated surfaces with many rundhockers in the vicinity of Pt. Sanchez. Their heights are 750–550 m, 350–250 m and lower than 100 m. These rundhockers are gentle in their east side, and steep in west side. The direction of striations is about N 80°W and accordant with the direction of Lago General Carrera.

2) At the mouths of all rivers flowing into Lago General Carrera, there are three levels of lacustrine terraces of which heights are 270 m, 230 m and 110 m above the lake-level. The upper lacustrine terraces are correlated to the bottom of the glacial trough of the Rio Blanco. It is supposed that the lowering of lake-level is due to the reduction of glacier. A knickpoint forming V-shaped valley in the longitudinal profile of the Rio Blanco has been retreating to the point about 8 km from the mouth. While the knickpoint retreated about 8 km, the lake-level has lowered 270 m with twice stable periods.

3) The height of the snow line is about 1,750 m above sea-level and the timber line is about 1,250 m above sea-level at the Rio Blanco. It is supposed that these lines have fluctuated recently.

The author should like to express his sincere gratitude to members of the third Patagonia Expedition of Hiroshima and Hokkaido Universities, especially Dr. Kiyoshi Hasegawa, the leader of the members, for their helpful suggestions in the field. He is greatly indebted to Prof. Kasuke Nishimura of Tohoku University and Prof. Yoshio Yoshida of Hiroshima University for critical reading of this manuscript.



Photo 1 The glacial trough of the Rio Blanco



Photo 2 The cirque glacier at the head of the tributary 3 of the Rio Blanco



Photo 3 Terminal moraines of the cirque glacier in the photo 2; upper moraine, in center; cirque lake, in right;



Photo 4 Cirque lakes and lower moraine



Photo 5 The sorted circle on the right side slope of the Rio Blanco



Photo 6 Sorted stripes on the right side slope of the Rio Blanco



Photo 7 The small-scale rock-field on the right side slope of the Rio Blanco

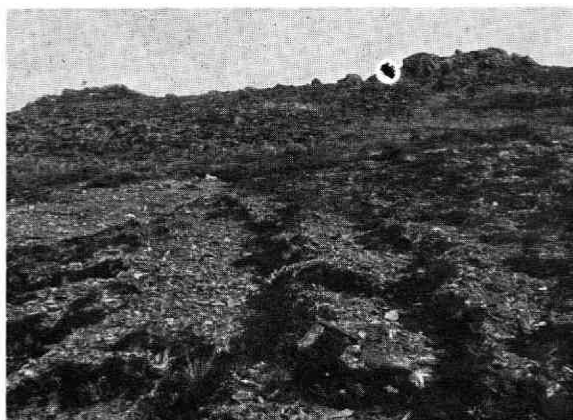


Photo 8 Tors and sorted steps on the spur stretched to the Rio Blanco



Photo 9 Plucking on the tor in the photo 8

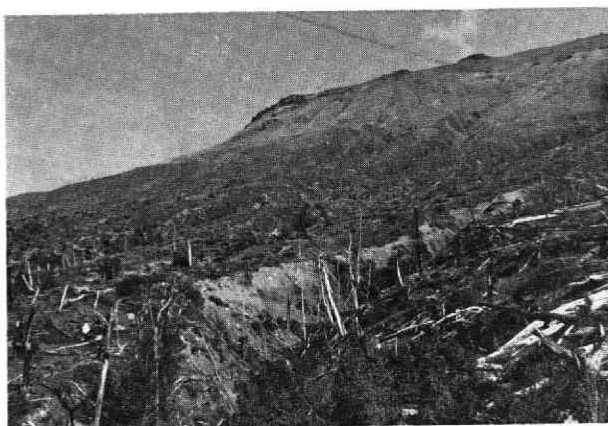


Photo 10 The side wall of the glacial trough of the Rio Blanco



Photo 11 The lateral moraine in the photo 10

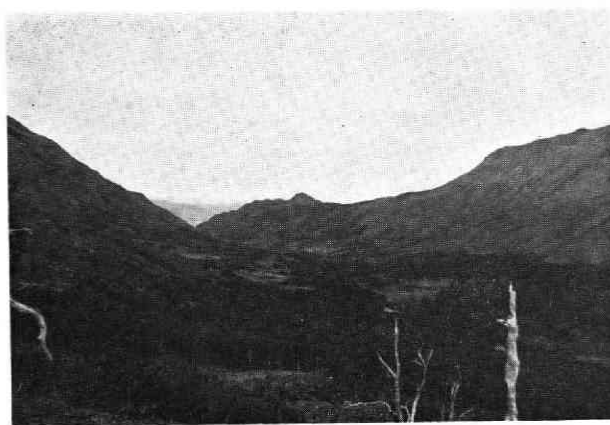


Photo 12 The lower course of the Rio Blanco, photographed from the same point of photo 1. Sharp ridge of the right side end at the knickpoint of skyline.



Photo 13 V-shaped valley near the junction 1 of the Rio Blanco

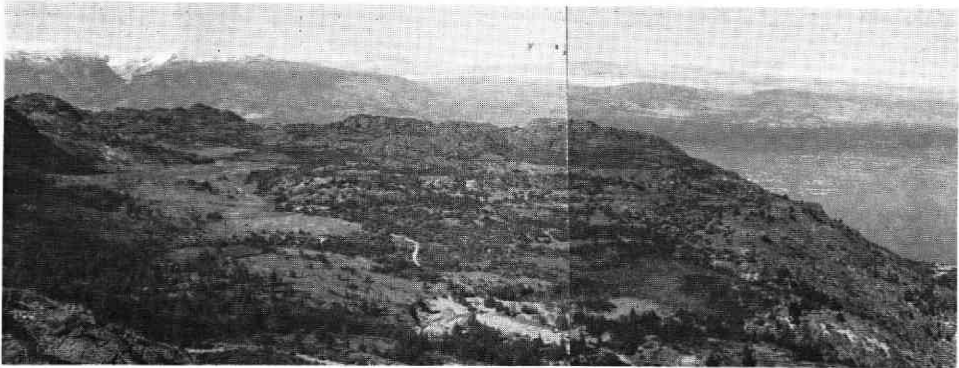


Photo 14 The middle glaciated surface near "A" pasture



Photo 15 The ridge located at the east of Pt. Sanchez and Islas Malvinas. This photo continues to photo 14.



Photo 16 The rundhocker on the upper glaciated surface

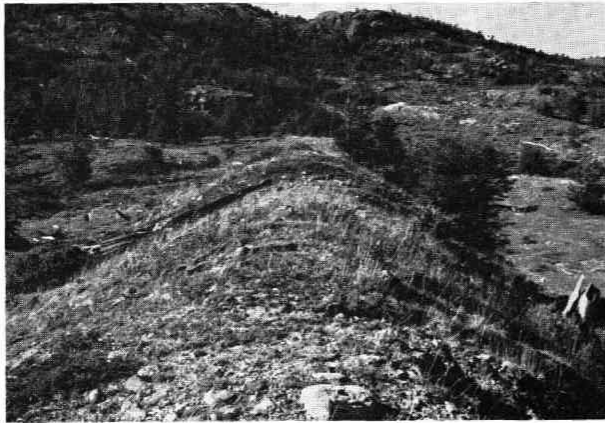


Photo 17 The landform regarded as esker

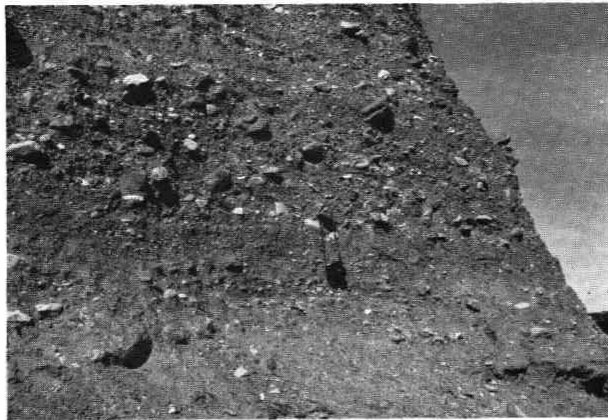


Photo 18 The facies of the esker in photo 17

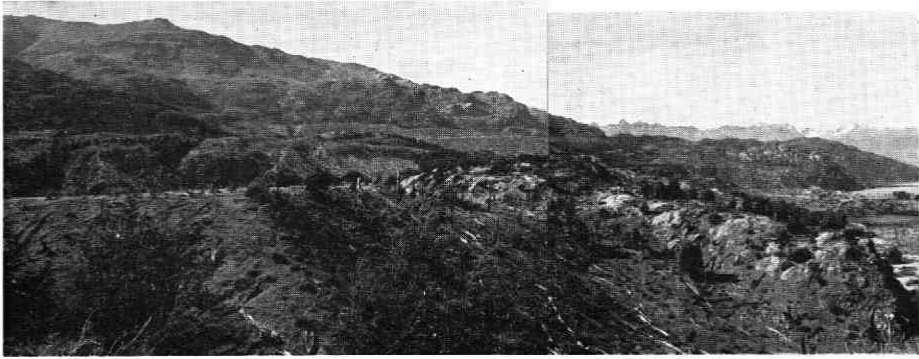


Photo 19 Landscape between the Rio Monte Negro and Pt. Sanchez, rundhockers remained above accumulation, in right front; the middle glaciated surface and the lower lacustrine terrace along the Rio Sanchez, in right behind; upper and middle lacustrine terraces along the Rio Sanchez and the Upper glaciated surface, in center; the lower lacustrine terrace on the left side of the Rio Monte Negro, in left; (photographed from the right side of the Rio Monte Negro)

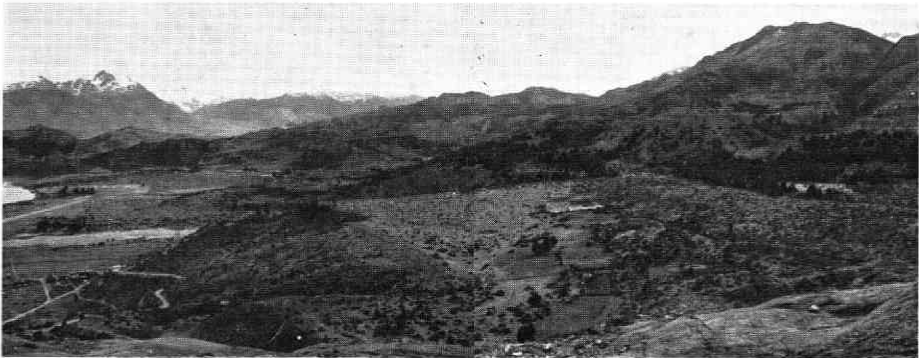


Photo 20 Lacustrine terraces along the Rio Sanchez and the Rio Monte Negro, the terrace on the left side of the Rio Sanchez, in foreground; terraces on the right side of the Rio Sanchez, in right behind; terraces on the right side of the Rio Monte Negro, in central behind

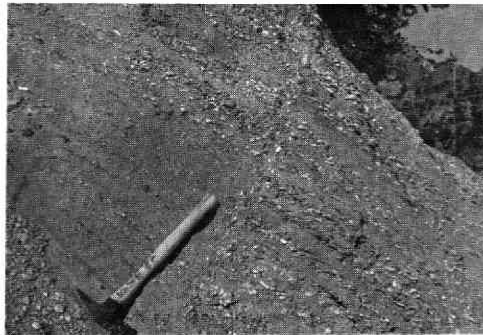


Photo 21 The foreset-bed of the lacustrine terrace at the Rio Sanchez



Photo 22 Terrace surfaces along the Rio San Martin

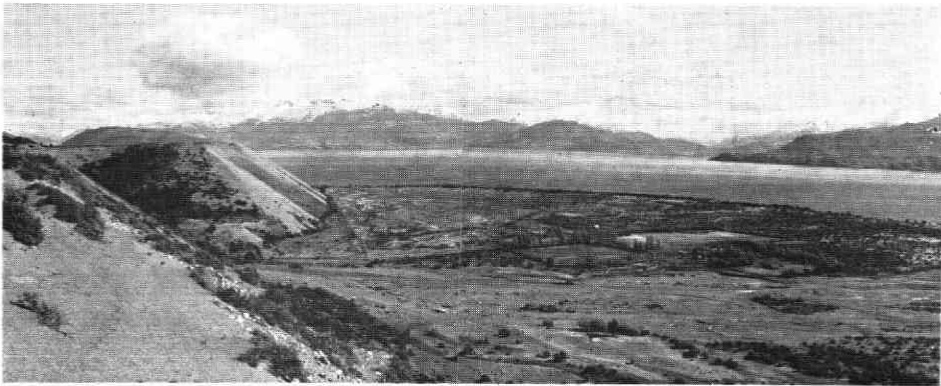


Photo 23 Lower terrace and delta at the mouth of the Rio San Martin



Photo 24 Middle and lower terraces along the Arroyo Pedrero