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Glacier variation in the Northern Patagonia Icefield, Chile, between 1985/86 and 1990/91

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Abstract

Variations of 21 outlet glaciers distributed in the Northern Patagonia Icefield, Chile, were elucidated for a period from 1985/86 to 1990/91, utilizing oblique aerial photographs taken with a hand-held 35 mm camera. It was found, in general, that most glaciers have been retreating during the last five years at much more accelerated rates of up to 300 m/a. Glaciers which do not show significant retreats in this period are mostly debris-covered. A thick cover of debris near the snout has an insulation effect on the ice underneath. Glaciers located on the western side of the icefield have retreated generally at faster rates than those located on the eastern side. San Rafael Glacier, which is the tide water glacier located at the lowest latitude in the world, has receded at very fast, accelerated rates of 190－300 m/a, as compared to a rate of 200 m/a between 1974/75 and 1985/86.

1. Introduction

The Northern Patagonia Icefield (NPI) is located in the southern part of Chile, around 47°S and 73°30'W (Fig. 1, inset). It is about 100 km long and 45 km wide and occupies an area of about 4200 km² with numerous outlet glaciers. The author had previously studied variations of 22 outlet glaciers in the NPI from 1944/45 to 1985/86 (Aniya and Enomoto, 1986 ; Aniya, 1988),

As part of the GRPP (Glacier Research Project in Patagonia) 1990, the author could successfuly fly over the NPI on December 23, 1990 and took oblique aerial photographs of the snout area of outlet glaciers with a hand-held 35 mm camera. Due to some trouble with the camera exposure system, most photographs were overexposed unfortunately ; however, they could be used for locating the snout onto topographic maps published by Instituto Geografico Militar of Chile.

It is the purpose of this study to elucidate glacier variations from 1985/86 to 1990/91 and compare them with the results of the previous studies.

2. Method

The topographic maps on which the snout position was located were produced at a scale of 1 : 50,000 with a contour interval of 50 m from the vertical aerial photographs taken in 1974. Since it was almost impossible to correlate terrain features in the oblique aerial photographs taken with a hand-held camera directly with the topographic maps, the oblique aerial photographs were first correlated with the vertical aerial photographs. In this process, the 1990 photographs were also compared with the 1986 photographs to detect any change in five years. Then the snout position was drawn onto the map, which was in turn compared with the 1986 map of snout positions.

Because the photographs were oblique and the image quality was very poor, the level of the glacier surface could not exactly be located against the valley wall for the comparison with the other years, and information on thickness changes could not be obtained. In the future we have to concern with the thickness change, from which we can derive the volume of ice lost/added. The detailed characteristics of each outlet glacier (Fig. 1) are given in a previous study (Aniya, 1988).

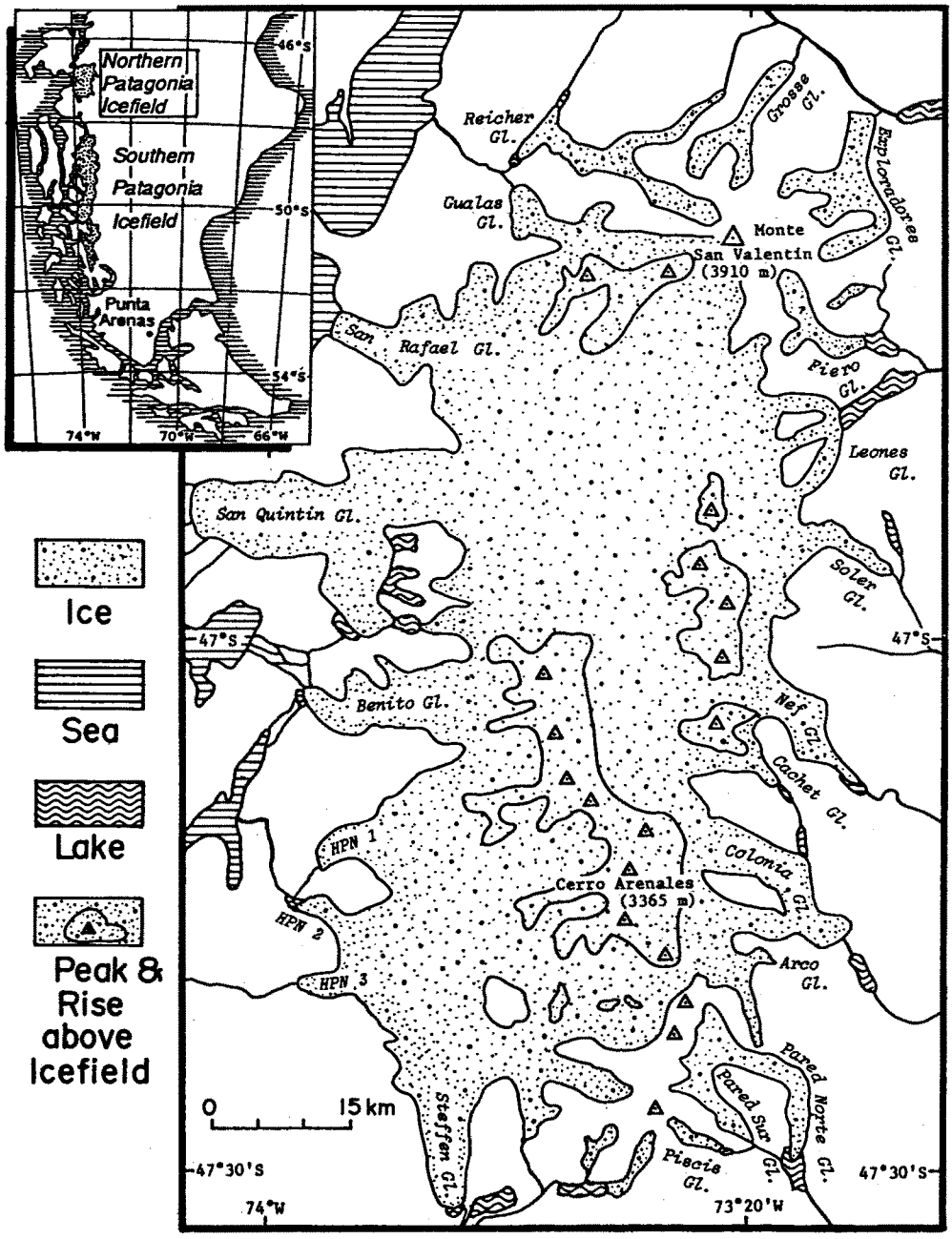


Fig. 1. The Northern Patagonia Icefield and outlet glaciers.

3. Results

Variations of 21 outlet glaciers are illustrated in Fig.2 and summarized in Table 1. The characteristics of variations of each glacier are briefly given in the following paragraphs, with the comparison to those in the previous periods, 1974/75-85/86 (11 years, hereafter written as 1974-85), 1944/45-74/75 (30 years, hereafter written as 1944-74) and/or 1944/45-85/86 (41 years, hereafter written as 1944-85).

3.1. Western side

Reicher Glacer has two tongues and both showed a considerable recession. The northeast tongue receded at rates of 60-100 m/a, which was much smaller than the rate of 195 m/a in the previous period of 1974-85. However, it showed no retreat between 1944 and 1974. The southwest tongue is unique in the NPI, in that it alone showed a net advance between 1944 and 1985, although in which period the glacier tongue retreated at a rate of 25 m/a since 1974. This time it retreated at a rate of 170 m/a and the tongue narrowed by 300 m in the proglacial lake. Gualas Glacier also has two fronts and the recession occurred at the north front with moderate rates of 20-30 m/a, while at the south front no substantial change was detected. The rate at the north front is very similar to the period of 1974-1985 (23 m/a). On the other hand, the south front receded at a rate of 32 m/a during that period.

San Rafael Glacier, a tide water glacier and one of the two largest in the NPI, has retreated at rates of 190-300 m/a between 1985-90, which is by far the fastest in this area. The glacier had retreated from 1974 to 1985 at a rate of 200 m/a which was also the fastest rate in the NPI during that period. These

Table 1. Glacier variations in the Northern Patagonia Icefield between 1985/86 and 1990/91.

Glacier Name	Retreat (m)
Northern Side	
Grosse	No substantial frontal change, but thinning
Western Side	
Reicher : NE	300-500 (60-100)
: SW	850 (170). Tongue narrowed by 300 (60)
Gualas : N	100-150 (20-30)
: S	No substantial change.
San Rafael	900-1500 (190-300)
San Quintin : front	200 (40) and considerable thinning
: side	300 (60)
Benito	450 (90)
HPN1	600-1200 (120-240)
HPN2	1350 (270)
HPN3	750-950 (150-190)
Southern Side	
Steffen : front	350 (70)
: side (E)	400 (80)
Eastern Side	
Pared Sur	No substantial change
Pared Norte	400 (80)
Piscis	No substantial change
Arco	No substantial change
Colonia	500 (100)
Cachet	400-950 (80-190)
Nef	Probably no substantial frontal retreat, but calving front is breaking away. Narrowed by about 600 (120).
Soler	130-240 (26-48)
León	120-200 (24-40)
Fiero	400 (80)
Exploradores	No substantial frontal change, but considerable thinning

The number in parentheses indicates an average annual rate.

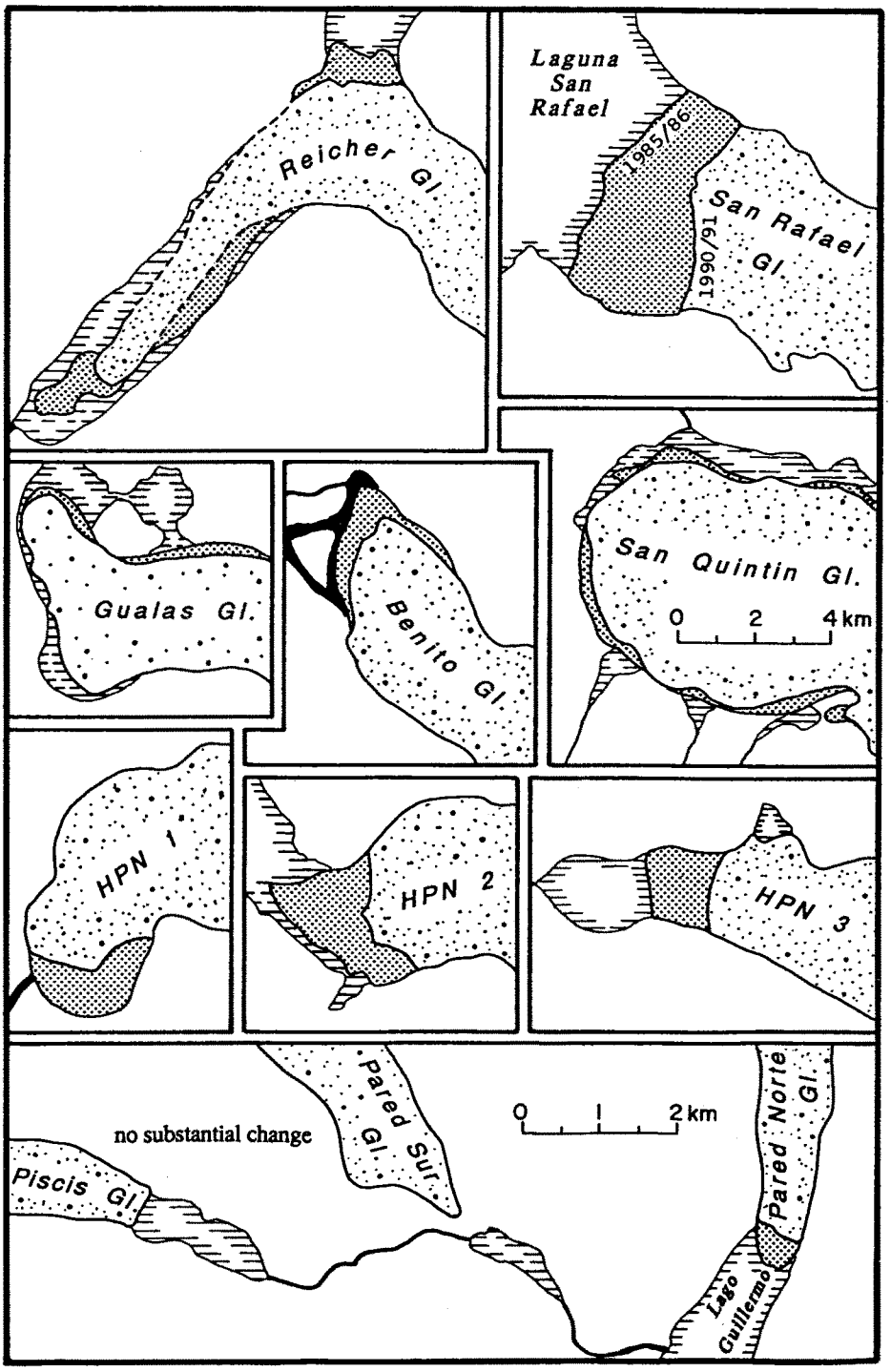
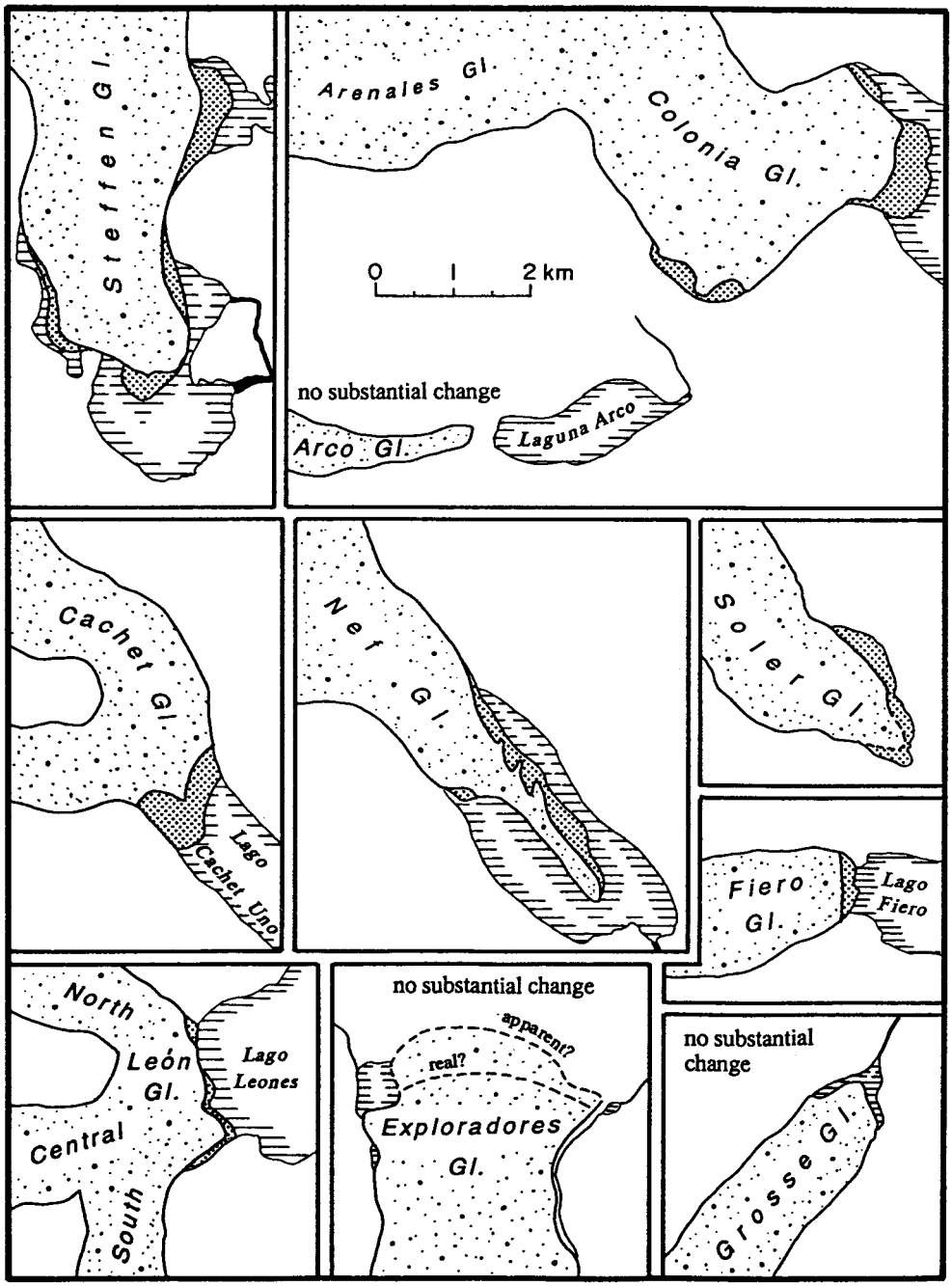


Fig. 2. Glacier variations between 1985/86 and 1990/91 (from summer to summer, five year period). Scale is the same for all glaciers to accommodate easy comparisons of the changes, except for San Quintin Glacier which is two times smaller than the rest. The stippled pattern denotes the area diminished in five years, and the horizontal stripes indicate a lake except for Laguna San Rafael which is actually sea, the head of a fjord.


Steffen Gl.
Arenales Gl.
Colonia Gl.
0 1 2 km
no substantial change
Arco Gl.
Laguna Arco
Cachet Gl.
Lago Cachet Uno
Nef Gl.
Soler Gl.
Fiero Gl.
Lago Fiero
North León Gl.
Central
South
Lago Leones
no substantial change
apparent?
real?
Exploradores Gl.
no substantial change
Grosse Gl.

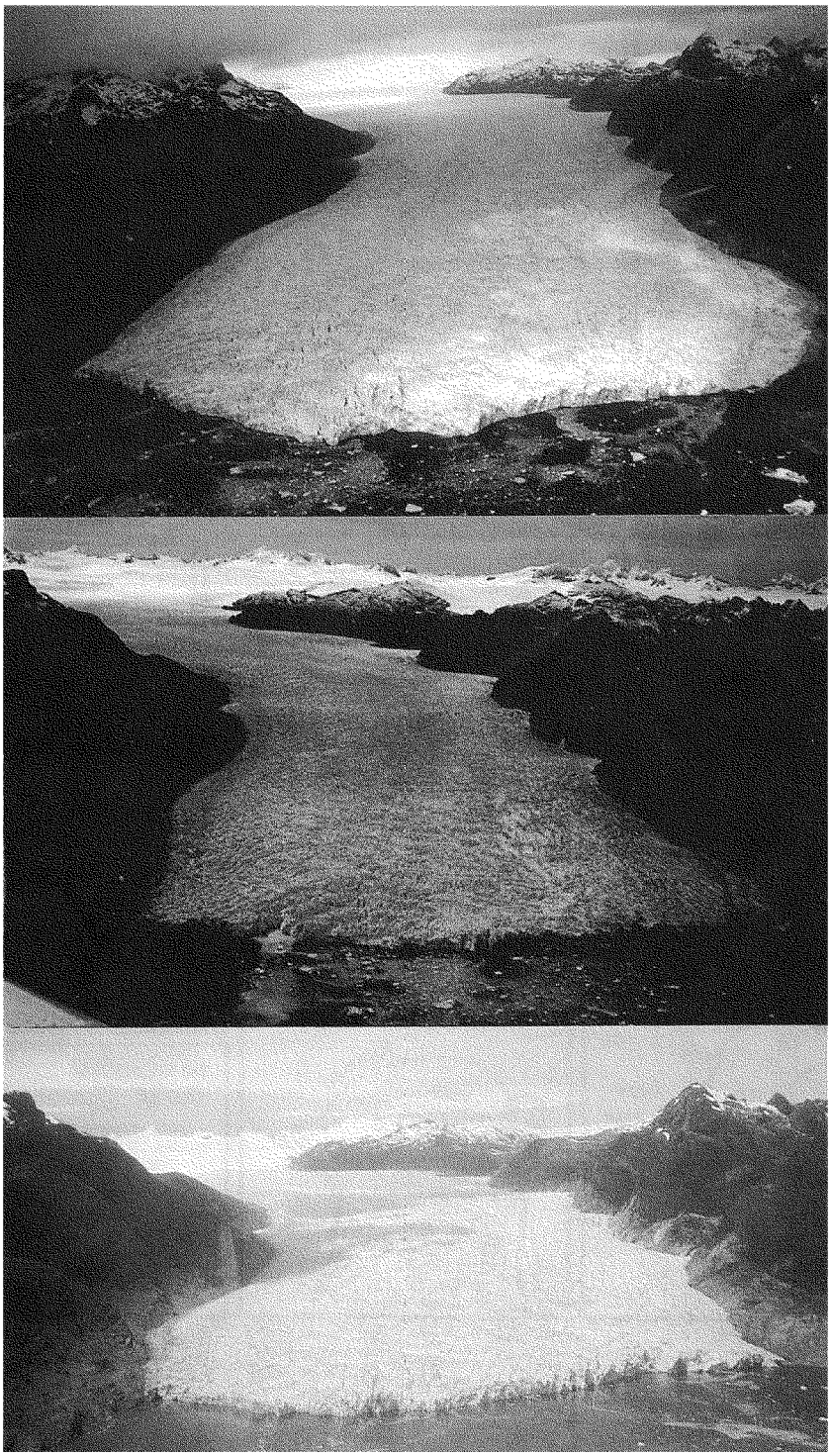


Fig. 3. Photographs showing the large recession of San Rafael Glacier. Top ; November 15, 1983 : middle ; January 13, 1986 : bottom ; December 23, 1990. Note the change of the snout at the left margin : in 1983, there was a dirt band ; in 1986 the length of the dirt band became about three-forth ; and in 1990 it was gone.

data indicate that the rate of the retreat has accelerated significantly in recent years. Fig. 3 shows the snout condition at three periods since 1983. If this trend continues in the future, the glacier will cease to terminate in the Laguna (Lagoon) San Rafael. San Quintin Glacier, the other of the two largest and located immediately south of San Rafael Glacier, showed a little retreat at the front and northern and southern sides. Although thinning away seems more prominent than the snout retreating from aerial survellance, it is impossible to quantitatively assess the surface lowering without precise ground surveys, because it terminates on a flat area near the sea level without valley-confining. The snout area was thinly covered with debris and the surface was slushy with abundant water in December 1990.

Benito, HPN1, HPN2, and HPN3 are located at the lower western side of the NPI and all showed strongly accelerated recession rates ranging from 90 m/a to 270 m/a. These glaciers had receded in the previous periods (1944-74 and 1974-85) at rates ranging from very slight to a maximum of 77 m/a. Steffen Glacier shows large accelerated recession rates of 70 m/a at the front and 80 m/a at the eastern side. Its recession rates at the front were 14 m/a for 1974-85 and 30 m/a for 1944-74.

3.2. Eastern side

Pared Norte Glacier has retreated at a rate of 80 m/a, although it had retreated only slightly between 1974 and 1985, and at a rate of 43 m/a between 1944 and 1974. Piscis Glacier shows no substantial change in the five year period. So did in the previous period of 1974-85. However, it had retreated at a rate of 25 m/a between 1944 and 1974. Colonia Glacier retreated at a considerably fast rate of 100 m/a during the study period, compared to the period of 1974-85 when it retreated very little. Before, the edge of the snout was cliff in a proglacial lake, but in December 1990 it was slope and gave an appearance of disintegration. Nef Glacier terminates in a proglacial lake and the snout has been steadily wasting away, by retreating and narrowing. This time, however, wasting was effected primarily by narrowing. Cachet Glacier has been retreating at a very fast rate of 64 m/a since 1944, which is only second to that of San Rafael Glacier, and continues to recede at accelerated rates of 80-190 m/a since 1985.

Soler Glacier has retreated at rates of 26-48 m during the study period and the position of the front has receded to the arcuate line of shear moraines which was formed sometime between 1983 and 1985 due to the stagnation of ice (Aniya, 1987). The heavily debris-covered area between the 1985 front and 1990 front has become pitted due to slow differential decay of the ice. This glacier has retreated at rates of 5-15 m for the period of 1974-85 and 3-10 m for the period between 1944 and 1974. Thus the retreat rate has been significantly increased in recent years. León Glacier receded 120-200 m in the period of five years since 1985-86, whereas it had retreated only 200 m between 1944 and 1985. Near the center of the snout, we can now see some bedrocks between the proglacial lake. Fiero Glacier has retreated 400 m between 1985 and 1990, whereas it had retreated only 300 m between 1944 and 1985, of which no retreat was observed between 1974 and 1985.

Those glaciers with extensive debris cover near the snout do not appear to have changed substantially during the study period. To begin with, it is very difficult to locate the real front on the debris-covered surface. For exmaple, at Exploradores Glacier, the supposedly-real snout (front of active ice) was located between the areas with the pitted topography and the smooth surface. The pitted topography was supposed to be caused by differential melting of the stagnant ice under the debris cover. The similar situation can be found for Grosse Glacier, located east of Exploradores Glacier, Arco Glacier which has shown no significant retreat since 1944, and Pared Sur Glacier. For this reason, at these glaciers the frontal recession is not apparent ; but ice has been slowly wasting away by surface lowering.

4. Discussion

It is distinctively clear now that as a whole the outlet glaciers in the NPI have been retreating at much faster rates during the period of 1985-90 than the previous periods of 1974-85 and 1944-74. Those glaciers which did not show significant recession during this period are heavily covered with debris near the snout area, which insulates the ice underneath. Only exception is Piscis Glacier, which did not retreat significantly although its surface is debris-free.

In general, glaciers located on the western side of the NPI have receded at faster rates than those located on the eastern side, as with the previous periods of 1974/75-85/86 (Aniya, 1988). This tendency is

contrary to the trend found for major outlet glaciers in the Southern Patagonia Icefield (SPI, see Fig. 1 inset), where glaciers on the western side have retreated less than those on the eastern side or even advanced (Aniya and Naruse, 1991). Due to rapid recessions in recent years, proglacial lakes have been formed at some glaciers and calving has started, which probably accelerates ablation (Colonia, HPN1, south side of San Quintin, Benito, Grosse). On the other hand, some glaciers which used to terminate in a proglacial lake or on the valley train have retreated to such an extent that the bedrock underneath had emerged and some parts of the glacier now terminate on the bedrock (León, HPN1).

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