Report 18

Reconnaissance survey of some glaciers in the Southern Icefield

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Abstract. Presented are reviews of history of explorations and scientific researches in the Patagonia Southern Icefield (HPS), and also of two glaciological topics in HPS, i.e. climatic and glacial variations, and catastrophic runoff (probably, *Jökulhlaup*) in the Paine River.

Reconnaissance field surveys were carried out in the southern region of HPS in January, 1984. Brief comments on the conditions and features of glaciers are also given as to Grey and Pingo Glaciers in the Paine region to the east of HPS, and Amalia and unnamed glaciers in Peel and Calvo Fjords to the west of HPS.

1. Introduction

The most common designation for Patagonian Glaciers, in Chile, is Hielo Patagónico (Patagonian Ice), which includes both the icefield (campo de hielo, used on Chilean maps) and is outlet glaciers. The term Hielo Patagónico was first used by Kuhn (KÖLLIKER et al., 1917), REICHERT (1915) and STEFFEN (1947), and later adopted by LLIBOUTRY (1956). It is often abbreviated to HPN and HPS, for North (Norte) and South (Sur). Hielo Continental (continental ice or ice sheet) is also used officially in Argentina. However, at the present the use of word ice sheet may be confined to the Antarctica and the Greenland (e.g. ARMSTRONG et al., 1969). As mentioned in Editorial Notes (front page), we will use the term Patagonia Southern Icefield to indicate Hielo Patagónico Sur (HPS) as well as Campo de Hielo Sur.

The Southern Icefield stretches for 350 km from 48°20'S to 51°30'S. The area of the icefield is 13,500 km^2; the size ranks third in the world following the Antarctic and Greenland Ice Sheets. The HPS has a mean elevation between 1500 and 2000 m a.s.l. from which many nunataks emerge to the additional height of 1000 to 1500 m. From the accumulation area of HPS a number of outlet glaciers calve into fjords on the western side and into proglacial lakes on the eastern side (Fig. 1). The three largest lakes are Lagos San Martín (named O' Higgins in Chile), Viedma and Argentino. It is known that climatic conditions are different between HPS and HPN. Differences of glaciological characteristics are also considered to exist between the two regions. Very little knowledge has, however, been obtained on glaciology from the icefield and glaciers around it.

Although the Glaciological Research Project in Patagonia, 1983–84 has concentrated its field work on the Northern Icefield (HPN), it should be more interesting to carry out researches in HPS and to compare glaciological and meteorological characteristics between HPN and HPS. In order to collect many kinds of information on glacier conditions, observation sites and transportation for prospective research, reconnaissance surveys were carried out

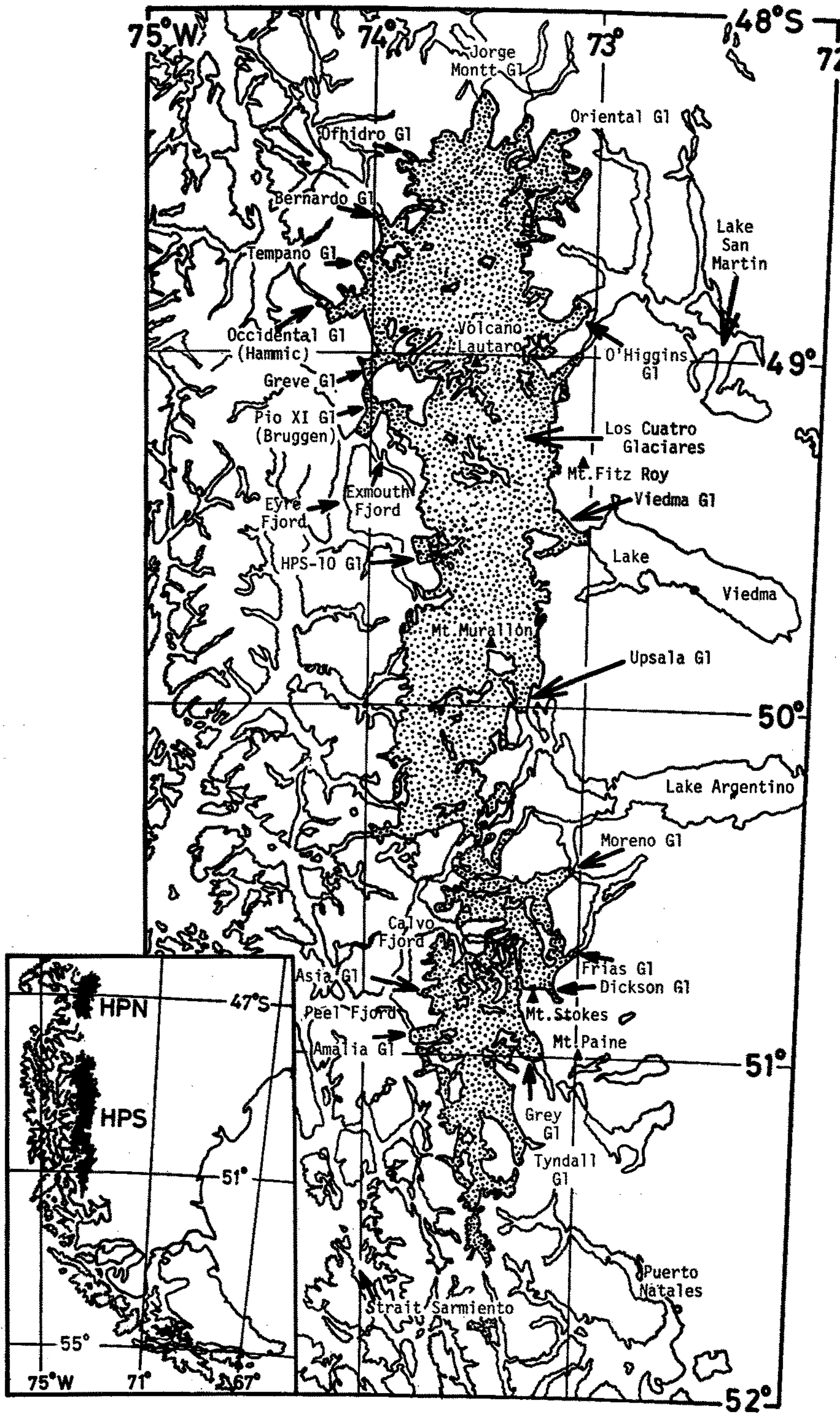

Fig. 1. The Patagonia Southern Icefield (Hielo Patagónico Sur: HPS).
Compiled from maps of Dirección de Vialidad, Ministerio de Obras Públicas, Chile (1982), and Hielo Patagónico Sur (Lliboutry, 1956).

during January 5 to 11, 1984, in the southern regions of HPS. The present paper aims firstly to summarize history of explorations and scientific (mainly glaciological) researches made in HPS (Section 2), secondly to give review of works on climatic and glacial variations in HPS, and on the phenomenon of glacial floods (Sections 3 and 4) in the Paine region, and thirdly to describe the results of reconnaissance field trips in 1984 and give some comments on current glaciological problems in HPS (Section 5).

2. History of exploration and scientific research in HPS

The first non-native exploration in the HPS area was done in 1557 by the order of Chile's Spanish Governor G.H. de Mendoza, who sent two vessels in charge of Captains (Cpt.) J. F. Ladrillero and C. de Ojeda, to explore the western entrance to the Straits of Magellan. They made separate reconnaissances of a large part of the channels and fjords of the western side of HPS. For the next two and a half centuries no navigator explored the area to the same extent. The first foreign reconnaissance from the eastern side of HPS took place in 1782, when Spanish Cpt. A. de Viedma explored the origin of the Río (River) Santa Cruz, discovering the lake which bears his name, and seeing for the first time the Fitz Roy Massif to the west. In 1831 Lt. J. Kirke reached the end of Eyre Fjord as part of a hydrographic expeditionary group led by British Cpt. P. King.

During the mid 19th century border disputes in Patagonia arose between Chile and Argentina. From 1876 to 1902 border surveys were made in the region to the south of the 41st parallel. Argentine and Chilean explorers visited HPS from both sides, the most active Argentine party being led by F. P. Moreno, leader of the Comisión Argentina de Límites (CAL), who made many trips and determined to some extent the toponymy of the area. On behalf of Chile, work was improved and completed by the German geographer H. Steffen who made nine explorations to western Patagonia between 1892 and 1902, six of them appointed by the Chilean Government. He also explored the northern area from Puerto Montt to Jorge Montt Glacier of HPS. Important scientific knowledge was obtained by R. Hauthal, a German geologist who worked for CAL. Hauthal (1899) was the first explorer to penetrate HPS and make glaciological studies in the area of Lake Argentino. The border problem came to an end with the Laudo Arbitral, independent arbitration by His Majesty Edward VII in 1902, which determined the entire Patagonian frontier. In particular, in the area of HPS the border was defined by the summits of Mt. Fitz Roy in the north, Mt. Murallón in the center and Mt. Stokes in the south. Today two tentative border lines cut, in slightly different way, several eastern outlet glaciers of HPS and a part of the icefield to connect the above mountains; most part of the icefield lies in Chile.

The end of the conflict gave rise to a period of scientific activity in HPS, including reconnaissance of the glacial periphery. Two facts stimulated this interest: evidence of volcanic activity, and the search for a possible water channel between Lake Argentino and Peel Fjord. Between 1895 and 1897, O. Nordenskjöld (1907), leader of a Swedish expedition, explored the east side completing hydrographic knowledge of the area. He planned the first ice crossing from Dickson Glacier to Peel Fjord, but failed due to the difficulties involved. From 1907 to 1909, Swedish geologist P. Quensel (1910) discovered the existence of an active volcano on the icefield to the west of Peel Fjord. Photographic work was also done during this expedition.

Scientific climbing expeditions began in 1914 when German naturalist F. Reichert (1917) organized an expedition to Moreno Glacier. It was the first time anyone succeeded in reaching the ice divide. This 1914 reconnaissance made possible the strong 1916 German Scientific Society of Buenos Aires expedition: A. KÖLLIKER et al. (1917) made the first reconnaissance of glaciers to the west of Lake Viedma, reaching a col which they named Paso de los Cuatro Glaciares. They obtained very interesting meteorological and glaciological results. The period between 1920 and 1940 was characterized by the expeditions of the great explorers F. Reichert and Father de Agostini. De AGOSTINI (1945), an Italian Salesian, made several expeditions up to 1944, from both sides of HPS. Usually accompanied by mountain guides, he climbed various peaks, taking complete sets of photographs of the area. The geologist E. Feruglio occasionally accompanied him, doing studies in glacial geology. In 1933 Reichert led a Sociedad Argentina de Estudios Geográficos expedition to search for the volcano discovered by P. Quensel. He reached the base of the volcano (as well as the ice divide) though he did not name it or locate it on a map. Reichert and de Agostini virtually closed the circle of great explorers to this region of Patagonia. Their work completed a general knowledge of geographic features of HPS. In 1944 and 1945, at the request of the Chilean Government, the United States Air Force made a complete aerial survey of HPS.

In 1947 H. Gianolini and J. Mercer attempted to cross HPS following Kölliker's route of 1916. They reached a point near the Paso de los Cuatro Glaciares. This expediton stimulated the scientific interest of Mercer in the area. He made important studies on glacial geology on HPS in the sixties and seventies. Several attempts had also been made during this period to climb Mt. Fitz Roy, but it was not until 1952 that a strong French team reached the summit. The French glaciologist L. Lliboutry accompanied the expedition and made important scientific observations which were published in a monograph (LLIBOUTRY, 1956), one of the best writings to that date on Patagonian glaciology.

At the same time, transverse crossings of HPS were being attempted. In 1952 an Argentine scientific-climbing expedition which included E. Huerta and M. Bertone completed the first traverse to join the two sides of HPS (HUERTA, 1954). They penetrated from Lake Viedma across Paso Marconi, on to the accumulation area of Pio XI Glacier, reaching the ice-free soil in the western part of this glacier, before returning, in all 120 km. This expedition was of great importance and led to the creation of the Instituto Nacional (Argentino) del Hielo Continental Patagónico. Since then, the Instituto sponsored several expeditions to HPS and published two books on general glaciological features (BERTONE, 1960; 1972). In 1953 the Instituto Geográfico Militar de Chile published 1:250,000 maps (Carta Preliminar) covering HPN, HPS and Tierra del Fuego. These maps are based on trimetrogon aerial photographs taken by the USAF in 1944/45, and are still the best maps available on HPS. In 1956 H. W. Tilman led an expedition to Peel Fjord, sailing from England in his boat Mischief. Together with Chilean J. Quinteros he completed the first transverse traverse of HPS, from Calvo Fjord to Lake Argentino, a 60 km round trip (TILMAN, 1957). The late fifties saw many scientific climbing expeditions, principally from Argentina, but others from Italy and Japan. In 1960, J. Mercer from the Institute of Polar Studies, Ohio State Univ., U.S.A., led a scientific expedition to the eastern side of HPS, on the 50th parallel. This was the first in a series of expeditions by Mercer to HPS, which covered many outlet glaciers flowing to both sides.

Special mention must be made of E. Shipton who, in 1958, began a series of climbing-scientific expeditions to HPS. In 1960, with J. Ewer he located the elusive volcano reached by Reichert in 1933, later called Volcán Lautaro. In 1961, Shipton, García, Ewer and Marangunić completed the first successful longitudinal traverse, from Jorge Montt Glacier southward to Upsala Glacier, 260 km (SHIPTON, 1963). This feat, among other expeditions to the area, makes Shipton one of the great explorers of HPS. Also in 1961 the first winter expedition took place in the Fitz Roy area. Since this time many traverses, climbs and scientific expeditions have succeeded from both Chilean and Argentine sides.

One of the few scientific reports covering the accumulation area is by C. MARANGUNIC (1964) who made several expeditions into the area in the early sixties. Scientific expeditions have been reduced mainly to observation of outlet glaciers on the eastern side, and some to a lesser extent in the west. Moreno Glacier has been studied extensively as it calves into Lake Argentino. Of note are the damming and subsequent flooding demonstrated in the late sixties (e.g. LLIBOUTRY, 1953; LISS, 1970). Another interesting phenomenon is the very active advances and retreats which Pio XI (or Brüggen) Glacier has shown since 1925 (LLIBOUTRY, 1956; MERCER, 1964; IWATA, 1983), as described in the following Section.

From the late 1960's to the early 1970's, several Japanese parties carried out geological, botanical and glaciological researches in Patagonia. SAKAGAMI et al. (1970) accomplished an oversnow traverse from Pio XI Glacier to Upsala Glacier in 1969, and obtained some periglacial and meteorological information in HPS. INOUE (1983) made a preliminary heat balance measurement on HPS-10 Glacier in 1969. Reconnaissance studies were made of meteorology and glaciology in Jorge Montt Glacier in 1981–1982 (ENOMOTO and ABE, 1983).

3. Climatic and glacial variations in HPS

Glacial geology has been the most highly developed field of research in Patagonia, partly because investigators need only to reach the area of the glacier terminus, not the accumulation area. The first intensive study was made by CALDENIUS (1932) between 1925 and 1928. In the late 1930's, Salmi, from ash and pollen analyses, interpreted the stratigraphy. Auer, in the mid 1950's, extended this work, using radiocarbon dating. In the 1930's Feruglio studied glacier deposits, in the course of general geological work. In 1949, Nichols and Miller investigated the glacial geology of Ameghino Valley on the eastern side of HPS.

To date, not much detailed knowledge has been obtained on Quaternary glaciation in the Patagonian region. CALDENIUS (1932) proposed several stages of glaciation. MERCER (1967) described the glaciation of Chile and Argentina between Lat. 46°S and the Strait of Magellan. MINATO and NISHIMURA (1982) have an opinion that nearly all of Patagonia was once covered by a continental ice sheet and the earliest stage of glaciation belongs to the Late Pliocene—Early Pleistocene, which may be nearly equivalent to Nebraskan Glaciation in U.S.A.

Mercer carried out extensive radiocarbon dating of organic matter obtained from moraines, and also tree-ring analyses. Mercer and Heusser also made determinations of glacial chronology in the lake region of Chile (Lat. 40–41°30'). From these data and those of southern Patagonia, MERCER (1976) conducted global comparisons of the last glaciation between the northern hemisphere and southern South America (SSA: south of Lat. 40°S), reaching the following conclusions as to the regions SSA:

1) Interhemispheric comparisons of events before about 25,000 ^{14}C years ago (B.P.) cannot be made, as insufficient data are available in SSA. Chronology after 25,000 B.P. is in many respects similar to that in North America and Europe, but important differences are evident during deglaciation.

2) No equivalent of the widespread North American advance about 14,500 B.P. has yet been identified.

3) The final full late glacial advance was probably about 13,000 B.P. at the time as the Port Huron advance in eastern North America.

4) After 13,000 B.P., a warming trend began, confining glaciers to present margins by 11,000 B.P.

5) There is no evidence of glacier advances equivalent to the European Younger Dryas Stade (11,000–10,000 B.P.) or the North American Cochrane-Cockburn advance (8,200–8,000 BP.).

6) The following three Neoglaciations took place: (a) 4,500–4,200 B.P. (largest advances), (b) 2,500 B.P. (smaller advances), (c) during recent centuries. Between these Neoglacial advances, glaciers receded to within their present margins.

As for the recent climatic change in the 20th century, NAKAJIMA and SATO (1970) did tree-ring analyses near HPS-10 Glacier, and showed the tendencies of the lower temperature in the periods around 1925 and 1945, and the higher temperature around 1920, 1940 and 1955.

Glacial fluctuations have been recognized in some glaciers in Patagonia (e.g. LLIBOUTRY, 1956; MERCER, 1964). By comparing a Landsat image taken in February 1976 with the Carta Preliminar published in 1945, IWATA (1983) examined the fluctuations of the frontal positions of glaciers in HPS, which are summarized as follows:

During the last three decades, Pio XI Glacier advanced about 10 km; many glaciers on the Pacific side of HPS such as Ofhidro, Bernardo, Témpano and Hammic Glaciers are almost in equilibrium. Whereas, Greve Glacier retreated nearly 5 km and O'Higgins Glacier retreated about 10 km.

Amalia Glacier on the western side of HPS has shown a retreat as reported in Section 5. However, the frontal position of a calving glacier tends to vary remarkably, by not instantaneous but indirect response of climatic change, as discussed by Naruse (Report 10).

With respect to the glacier inventory, BERTONE (1960) has listed some characteristics of 356 glaciers on the eastern side of HPS between 47°30'S and 51°S. However, the inventory in all of Patagonia has not yet been completed.

4. Glacial flood in the Paine region

In every summer since 1982, the Paine River has shown a sudden increase in discharge, which lasted for about 20 days. It has occurred once or twice a year: January 1982, December 1982, March 1983, December 1983 and December 1984. The water was found to be released from Dickson Glacier. The peak runoff was about 350 m^3/s and the total volume of water released in one outburst was estimated as about 250×10^6 m^3 (PEÑA and ESCOBAR, 1983). These catastrophic outflows caused floods in the Paine region and much damage was inflicted on facilities in Paine Park.

The Paine River originates from Lake Dickson at the terminus of Dickson Glacier which lies in the southeastern part of HPS. Dickson Glacier is an outlet glacier from HPS flowing eastward and calving into the lake. The Paine River flows from Lake Dickson, through Lake Paine, to Lakes Nordenskjöld, Pehoé and Toro (see Fig. 2). Due to the increased outflow, Lake Pehoé showed an increase in water level of 1.9 m. A fluviometric station immediately upriver from Lake Nordenskjöld has evaluated the outflow, after eliminating the regulating effect of Lake Paine, Lake Dickson and runoffs from other sources. According to previous data and historic testimony, the anomalous outflow in 1982 was the first time that this phenomenon has been recorded.

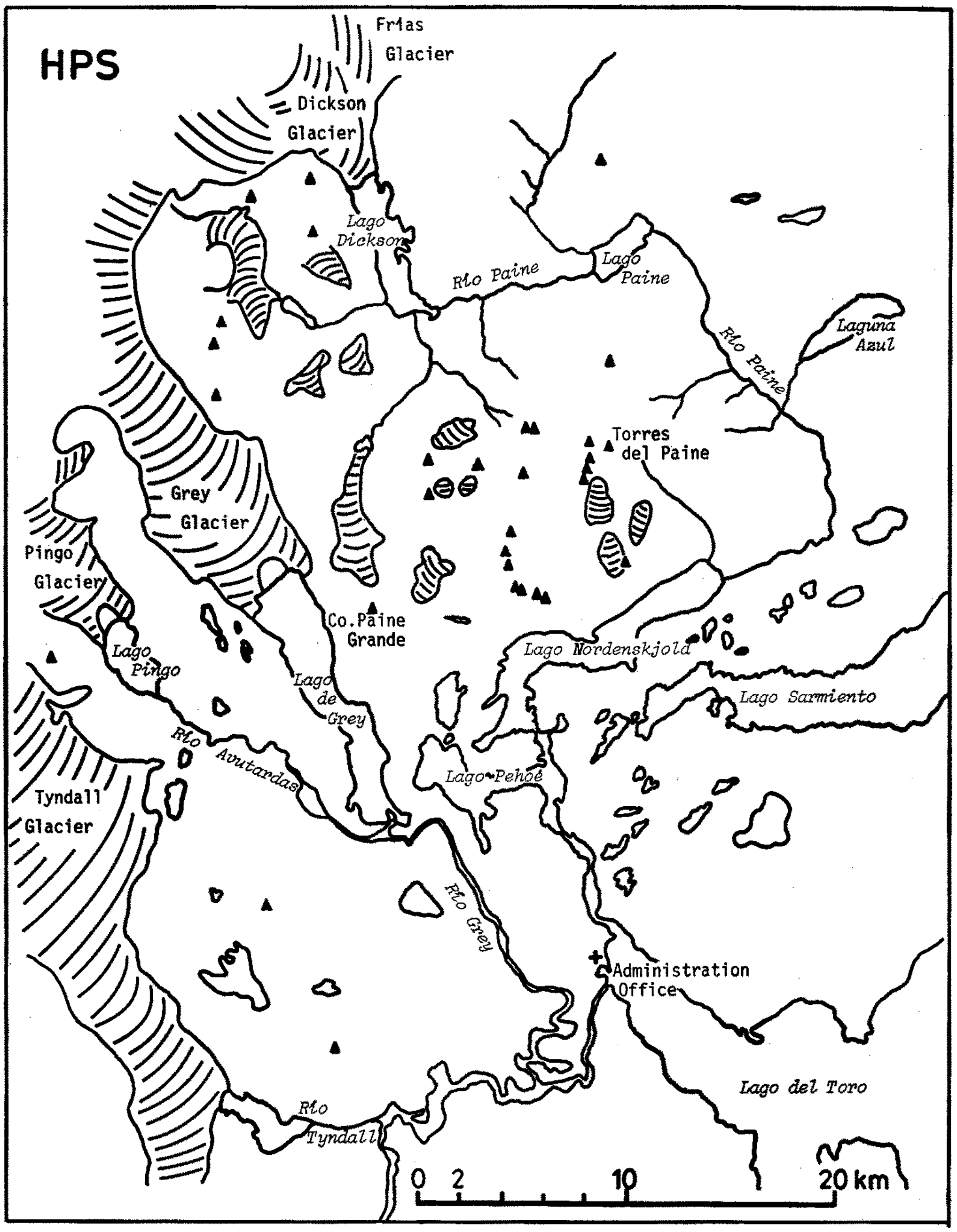

Fig. 2. The Paine region in the southeastern part of HPS.
Redrawn from Parque Nacional Torres del Paine (CONAF, 1980).

Peña and Escobar (1983), from the Dirección General de Aguas, Chile, analyzed the hydrological and meteorological data, and also did field researches. Then they proposed a hypothesis that the great outflow is caused by the discharge of a superglacial lake formed over the confluence of a secondary tongue of Dickson Glacier with a tongue of Frías Glacier, which is located to the east of Dickson Glacier and drains to Lakes Frías and Argentino. Field trips and photographs showed that there were water masses and ice blocks near the boundary of two glacier tongues. Here, part of the runoff to Lake Frías was blocked, though the precise mechanism is yet unknown. Possible explanations include landslide, glacial slide and glacial advance. Peña and Escobar believe that this superglacial lake, possibly together with subglacial water masses, drained through subglacial tunnels under the eastern margin of Dickson Glacier down to Lake Dickson. The hydrograph was studied according to Nye's equation (1976), and a simplified solution by means of iterative computations was proposed. It has been demonstrated in the report that this model can reproduce quite accurately the hydrograph of the Paine River outflow.

Such a catastrophic outflow as above has been reported in various glacial regions of the world, and is known as *Jökulhlaup* (the term originates from Iceland). The phenomenon results from the sudden and rapid draining of a glacier-dammed lake, or from sudden release of water stored in cavities within a glacier or in a sub-glacial lake (Paterson, 1981).

We now examine other possible causes for the large outflow in the Paine River.

1) Climatic changes (or abnormal weather conditions)

Increases in outflow have not been observed in neighboring drainage systems. The Grey River, for example, drains water from an area including the icefield immediately to the west of Dickson Glacier, yet there is no corresponding outflow increase, making it unlikely that the phenomenon results from climatic change.

2) Geothermal heat

There is no evidence of an increase of melt water due to increase of geothermal heat, such as, for example, from volcanic activity, though volcanoes exist in the area (e.g. Volcán Aguilera lies 60 km to the northwest).

3) Sudden glacial advance over Lake Dickson

Although a sudden glacial advance over Lake Dickson would result in increased outflow, the field reconnaissance shows no indication of such event. Additionally, there is no evidence to indicate that icebergs had been blocking the outflow from Lake Dickson.

4) Discharge of englacial and sub-glacial water

This is the most probable cause, in addition to draining of superglacial water as stated by Peña and Escobar. Furthermore, water may have flowed not only from the ablation area but also from the accumulation area of Dickson Glacier. In mid-summer, much melting of snow occurs even on the icefield, then the meltwater is probably stored within and/or beneath the icefield.

To date no detailed reconnaissance over the upper part of Dickson Glacier has been made, so the precise cause cannot yet be ascertained. There remains another problem, as to why the phenomenon has started to occur in 1982.

5. Reconnaissance surveys in the southern part of HPS in 1984

Reconnaissance surveys were carried out from January 5th to 11th, 1984, in the south-eastern and the southwestern parts of HPS, namely 1) the Paine region and 2) the Peel and

Calvo Fjords region. The field trips were made by Naruse, accompanied by journalist K. Matsui of the Asahi Shimbun.

5.1. The Paine region

The region assigned for Parque Nacional Torres del Paine (National Park Towers of Paine) has a large number of glacial lakes and fully glaciated rock *towers* of which the highest mountain is Co. Paine Grande, 3050 m a.s.l., as shown in Figure 2. Into the region, four outlet glaciers discharge from HPS: Tyndall, Pingo, Grey and Dickson Glaciers. Many visitors come, especially in summer, to the Park for sightseeing, trekking or climbing. Roads for vehicles are established from Puerto Natales to Lakes Grey, Pehoé and Azul. There are also lodgings and *refugios* (shelter huts), and an administration office, ranger's stations and a meteorological station controlled by CONAF (Corporación Nacional Forestal, Chile).

From the administration office at the west side of Lake Toro, one can approach the terminus of Grey Glacier in about two days on foot. We rode horseback along the east side of Lake Grey and reached the left-hand bank of the terminus of Grey Glacier, guided by ranger J. Alarcón. Grey Glacier (51°00'S, 73°15'W) is one of the large outlet glaciers, which flows southeastward to calve into Lake Grey. A large ice-free rock is exposed in the central part of the glacier terminus separating the glacier into two ice flows. There are many crevasses and seracs on the glacier surface near the terminus. It seems difficult to reach the glacier directly from the terminus. We arrived at the middle part of the ablation area of the glacier, about 5 km from the terminus, by traversing the left-hand bank. Although numerous crevasses run in the area, it should be possible to find routes for research work and a flat place adequate for setting up an observational station on the glacier. Also it may be possible to approach the accumulation area on HPS through Grey Glacier.

We again traveled the Avutardas River from the south side of Lake Grey, and reached the lower stream side of a lake called Pingo. A small but beautiful calving glacier discharges from HPS to the lake. The Glacier (51°00'S, 73°20'W) is not named either on the map of CONAF or on that of LLIBOUTRY (1956), but is called Pingo Glacier by the locals. Because both the left and right banks of the lake have very steep slopes, it seems impossible to reach the glacier on foot. A small boat will be necessary to make surveys in the proglacial area. Due to its small size, the lake may be appropriate for hydrological research.

From the river side of Avutardas near Lake Pingo, the middle part of the ablation area of Tyndall Glacier was seen at a very close distance. The glacier is one of the largest outlets from HPS; it flows southeastward. It should be easier to reach the glacier from the Avutardas River than from the Tyndall River.

5.2. The Peel and Calvo Fjords region

The only means to approach glaciers on the western side of HPS is a boat. We made a round trip with a chartered boat from Puerto Natales, through the Strait Sarmiento and Peel Fjord, to Calvo Fjord. It took about 24 hours to travel from P. Natales to Amalia Glacier (50°55'S, 73°40'W) at the eastern end of Peel Fjord. The glacier is also an outlet glacier which flows westward from HPS and calves into the fjord. An ice-free rock island exists at the central part in the fjord, not isolated from the glacier terminus. The island is not located on the Lliboutry's map which was compiled on the basis of the trimetrogon in 1947. By comparing the present frontal position of the glacier with that shown on the map, it was found that Amalia Glacier retreated about 3 km during the last 37 years. We observed very fresh and clear glacial striae on the rock walls of the island.

Although many crevasses and seracs exist on the glacier surface near the terminus, we could reach the glacier via the island with ease. It seems possible to install a meteorological station either on the glacier or on the island. However, it may be too difficult to approach the accumulation area in HPS from this glacier.

Next, we traveled by boat to the vicinity of Asia Glacier and to the inlet of Calvo Fjord. Since the pack ice was very concentrated in the fjord, we could not approach any glaciers. The pack ice was mostly composed of glacier-ice blocks smaller than 1 m in diameter.

The required or suitable conditions of a glacier for future researches on glaciology and meteorology should be:

a) An outlet glacier from HPS; not a cirque or a hanging glacier on an isolated mountain.

b) Easy approach and convenient transportation to the glacier.

c) Existence of places appropriate for camping and setting up observation stations on and around the glacier.

d) Surface condition of the glacier appropriate to research surveys.

Taking account of the above conditions, the most suitable glaciers may be Grey Glacier on the eastern side of HPS and Amalia Glacier on the western side. In addition, Dickson Glacier, presenting an interesting problem of the periodic outburst, satisfies almost the above conditions.

6. Concluding remarks

A large number of challenging problems have not been tackled in Patagonian glaciers and icefields, both north and south. To make clear the characteristics of Patagonian glaciers in comparison with those in other regions of the world, more sufficient knowledge is needed not only in glaciology but also in a wide variety of interdisciplinary fields related to glaciology.

At the same time, urgent work includes a compilation of basic data from Patagonia on meteorology, glaciology, and related fields. Especially, we point out here the following:

1) Distribution of glaciers, their shapes and structures, and dynamical behavior (i.e. glacier flows and variations). And, insofar as possible, the delimitation of the ice divides on the icefields.

2) Annual amount of precipitation or annual net accumulation of snow, especially on the icefields.

3) Annual amount of ablation, that is the total amount of melting of ice and the amount of calving into fjords and lakes.

These data and information should contribute to the study of the effect of recent climatic change on the behavior of snow and ice on the earth, and also to the evaluation of properties of Patagonian ice as a water resource. There is awareness of the importance of conserving the area of HPS, which has already been declared national parks, both in Argentina and in Chile. In addition, UNESCO has entered the National Park Los Glaciares (Argentina) to the list of World Heritage, and has declared Parque Nacional Torres del Paine as a World Biosphere Reserve.

Acknowledgements

We would like to express our appreciation to Sr. Director Mauricio Rosenfeld, Sr. Sergio Gallardo, Sr. Julio Vera and Sr. José Alarcón of Corporación Nacional Forestal, XII Región, Chile, for their assistance given to us on the field trip.

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Resumen. Reconocimiento de algunos glaciares en el Hielo Patagónico Sur

La designación usual en Chile para los Glaciares Patagónicos es Hielo Patagónico, que incluye tanto el campo de hielo (nombre oficial en los mapas de Chile) como los glaciares de descarga. A menudo se abrevia como HPN y HPS, designando los glaciares Norte y Sur respectivamente. El término Hielo Continental se usa oficialmente en Argentina. Sin embargo, los hielos continentales actuales pueden confinarse solamente a la Antártica y Groenlandia. Como se menciona en la nota editorial (primera página), usaremos el término Patagonia Southern Icefield (Campo de Hielo Patagónico Sur) para referirnos al Hielo Patagónico Sur (HPS) como también al Campo de Hielo Sur.

El Campo de Hielo Sur se extiende longitudinalmente por 350 km, desde los 48°20'S hasta los 51°30'S. El área total del Campo de Hielo Sur es de 13500 km². Es la tercera mayor área de hielo del mundo, después de los Hielos Continentales de la Antártica y Groenlandia. HPS tiene una altura media entre 1500 y 2000 m sobre el nivel del mar, a partir de la cual numerosos nunataks emergen una altura adicional de 1000 a 1500 m. Desde el área de acumulación de HPS, numerosos glaciares descargan hacia fiordos al occidente y hacia lagos pedemontanos al oriente. Se sabe que las condiciones climáticas son diferentes entre HPN y HPS. Entonces se supone que también son diferentes las características glaciológicas entre ambas regiones. Sin embargo, se ha obtenido muy poco conocimiento glaciológico sobre el campo de hielo y sus glaciares.

A pesar que el Proyecto de Investigación Glaciológica en Patagonia 1983–84 ha concentrado su trabajo de terreno en el Campo de Hielo Norte (HPN), sería más interesante llevar a cabo investigaciones en HPS y comparar características glaciológicas y meteorológicas entre HPN y HPS. Para obtener variada información sobre la condición de los glaciares se llevó a cabo observación de lugares, transporte para futuras investigaciones, y reconocimientos durante el 5 al 11 de Enero de 1984 en el sector sur de HPS: la región del Parque Nacional Torres del Paine y el área del Fiordo Calvo y Peel. El presente artículo tiene por objeto en primer lugar resumir la historia de exploraciones e investigaciones científicas (principalmente glaciológicas) realizadas en HPS desde el siglo 16 (capítulo 2), en segundo lugar entregar antecedentes de trabajos sobre variaciones climáticas y glaciales en HPS (cap. 3), y sobre las crecidas glaciares (cap. 4) en la región del Paine, que se considera es un fenó-

meno llamado *Jökulhlaup*, y en tercer lugar describir las resultados de viajes de reconocimiento en 1984 con algunos comentarios sobre problemas glaciológicos actuales en HPS (cap. 5).

Condiciones necesarias o adecuadas de un glaciar para futuras investigaciones en glaciología y meteorología deberían ser:

(a) glaciar de descarga de HPS
(b) Fácil aproximación y transporte
(c) Existencia de lugares adecuados para instalar campamentos y estaciones de observación para medir condiciones de superficie.

Tomando en cuenta las mencionadas condiciones para el sector sur de HPS, el glaciar más aconsejable sería el Glaciar Grey en la vertiente oriental de HPS y el Glaciar Amalia en la vertiente occidental. Además, el Glaciar Dickson, el cual muestra un interesante problema de inundación glaciar, satisface prácticamente todas las condiciones mencionadas.

Un gran número de problemas de los glaciares y campos de hielo de la Patagonia plantean un desafío aún no afrontado, en relación a otros en otras regiones del mundo. Es imperiosa la necesidad de mayor conocimiento, no sólo glaciológico sino también que abarque un vasto campo de estudios interdisciplinados relacionados con glaciología. Al mismo tiempo, una labor urgente a realizar es una compilación de datos básicos sobre Patagonia en meteorología, glaciología, etc. En especial:

1) Distribución de glaciares, su forma, estructura y comportamiento dinámico y la delimitación del divortium glatiarum sobre los campos de hielo.
2) Acumulación neta anual de nieve.
3) Ablación neta anual, eso es, el derretimiento y desprendimiento hacia fiordos y lagos.

Estos datos e información debieran contribuir al estudio del efecto de cambios climáticos recientes sobre el comportamiento de hielo y nieve en la Tierra, y tambien a la evaluación de propiedades del hielo Patagónico como recurso de agua.