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VARIATIONS OF SOME PATAGONIAN GLACIERS SINCE THE LATE-GLACIAL*

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ABSTRACT. After a Late-Glacial readvance, the glaciers in Argentine Patagonia receded quickly, and by 10,000 B.P. at least one glacier was little larger than it is today. Three episodes of Postglacial readvance followed, the first culminating about 4600 B.P. during early Sub-Boreal time, the second about 2000 B.P. during the Sub-Atlantic, and the third during recent centuries. In contrast to most other parts of the world, no glacier, so far as is known, reached its maximum Postglacial extent in recent centuries.

INTRODUCTION

The Late-Glacial/Postglacial transition is not a precise boundary and is to some extent arbitrary. Using the same criteria, it was perhaps not simultaneous everywhere. The end of the Patagonian Late-Glacial is defined herein as the culmination of the last general readvance of the ice when the extent of the ice was still such that the present glaciers were not individually recognizable. Postglacial time began as the ice started to recede after the Late-Glacial readvance.

The two Patagonian ice fields extend south along the main cordillera, the northern ice field from lat 46°30′ S to 47° 30′ S, and the southern ice field from lat 48°20′ S to 51°30′ S. They lie across the prevailing westerly winds, so that their western slopes have a highly maritime climate while a more continental climate prevails on the eastern slopes and on the precordillera. On the west, precipitation is heavy and fairly evenly distributed throughout the year, but on the east, most falls in autumn and winter. Aerial photographs taken in 1945 indicate a great contrast in the behavior of the glaciers at that time: most of those on the west, particularly of the southern ice field, were close to the forest, whereas those on the east, with one known exception, had all shrunk greatly from recent end moraines.

The 100 kilometer gap between the two ice fields is occupied by the complex ramifications of the Canal Baker (fig. 1). Between these branches of the Pacific Ocean and the Argentine plains to the east are several mountain groups; moisture-bearing westerly winds penetrate the gap to these massifs which, therefore, have a much heavier ice cover than do the precordillera of similar height that lie in the lee of the main range.

During 1966, two outlet glaciers on the eastern side of the southern ice field were studied: the advancing Moreno Glacier and the receding Frias. These glaciers were confluent in the Late-Glacial and formed end moraines which were also investigated. Farther north, glaciers in two massifs to the east of the gap between the ice fields were studied: the Cerro San Lorenzo group, and the Sierra de Sangra (fig. 1). Some details of the glacial geology of these several areas are shown on figures 2 to 5;

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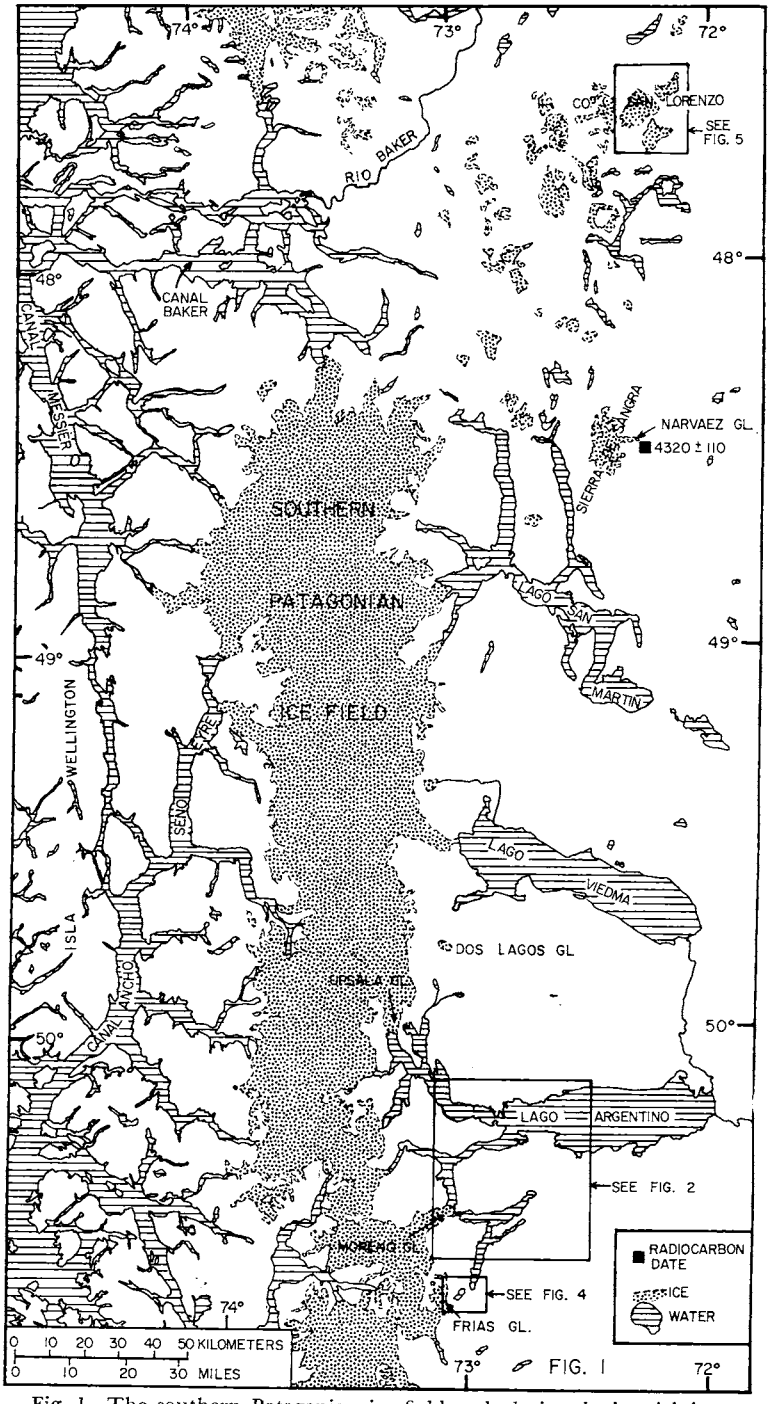


Fig. 1. The southern Patagonian ice field and glaciers in its vicinity.

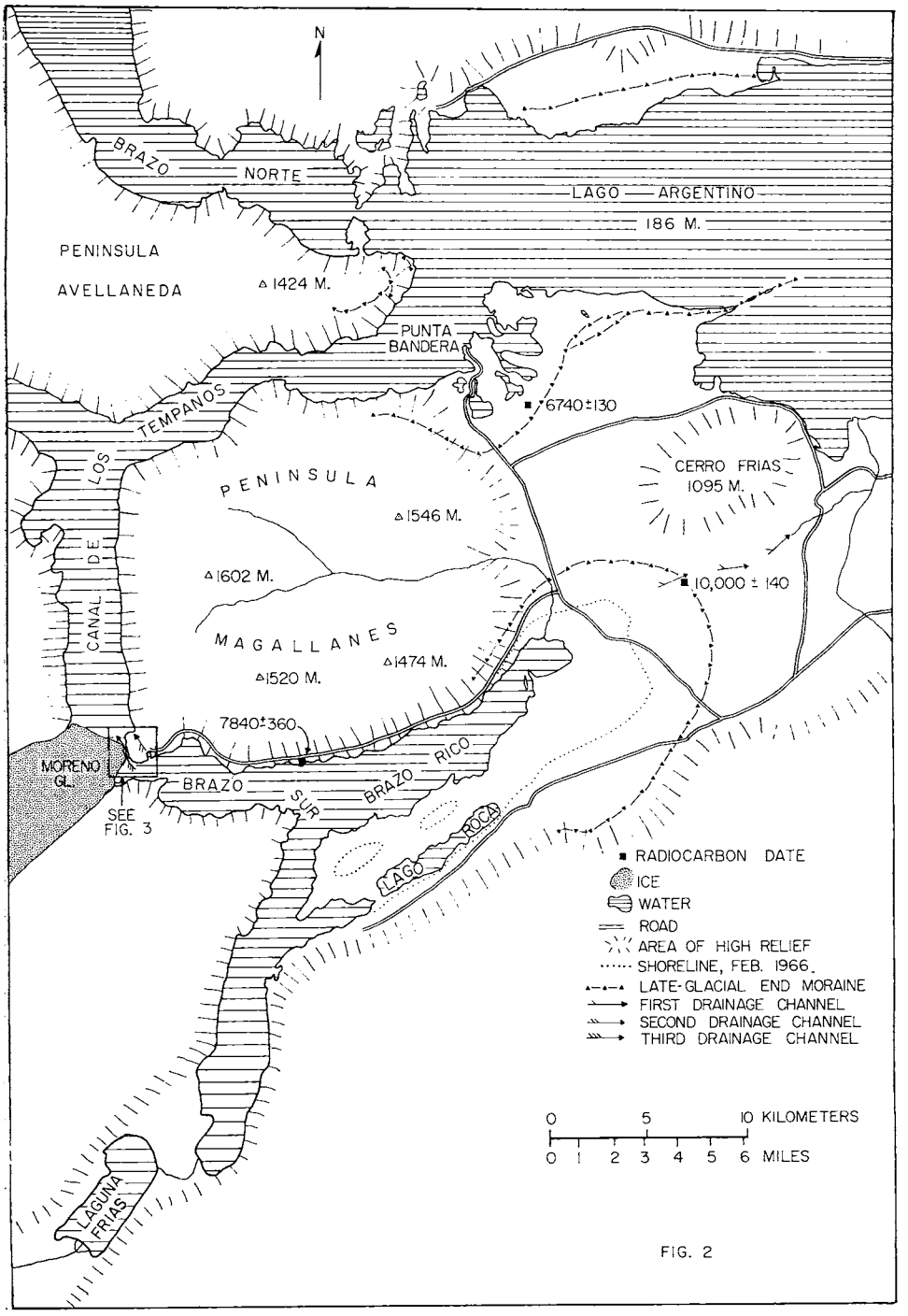


Fig. 2. Península Magallanes and vicinity.

TABLE 1

Radiocarbon dates, 1966 field work

Sample no.	Age: years B.P.	
I-2200	(6740 ± 130)	Peat on blue clay, 1 kilometer inside the Late-Glacial moraines near Punta Bandera. Gives minimum age of end moraine. Apparently there was a long interval before peat formation began: see sample I-2201. The site is east of the moisture-controlled tree limit, and peat does not appear to be forming today.
I-2201	(3830 ± 115)	Basal peat in drainage channel 42 meters above Lago Argentino. Moreno Glacier is advancing and periodically dams the Brazo Sur. Ice-dam now breaks when the water level has risen 18 meters. Channel was used only when glacier was between about 100 and 1000 meters farther forward than today. Sample gives minimum date for the abandonment of the channel which had previously been used about 10,000 B.P. (see sample I-2209).
I-2202	(210 ± 90)	Thin compressed peat on bedrock, 5 kilometers from Moreno Glacier, which was believed when collected to be below Late-Glacial till and perhaps to be of Allerød age. Young age shows that this is not so; covering material may be till reworked by mudflow or sheet wash following a forest fire.
I-2203	(7840 ± 360)	Peat on till 8 kilometers from the Moreno Glacier. Gives minimum date for recession of ice past this point. Sample I-2209 indicates that this happened before 10,000 B.P.
I-2204	(4320 ± 110)	Basal peat on till, in bog on outermost end moraine of the Narvaez Glacier. Gives minimum age for the formation of moraine. Agrees well with sample I-2208.
I-2205	(1980 ± 100)	Peat, thought to have begun to form after the Moreno Glacier ceased to form an ice dam; that is, it gives a minimum age for a recession after an earlier advance.
I-2206	(2170 ± 105)	Great numbers of trees have recently been drowned around the shores of ice-dammed Brazo Sur of Lago Argentino, and a bog was covered by water-transported tree trunks after the ice dam burst in March 1966. Two buried layers of peat containing tree trunks were expected to record similar events in the past. Date of a tree in the lower layer agrees well with sample I-2205 and suggests advance of Moreno Glacier to about its present position, but the stratigraphic relation to sample I-2207 is not clear.
I-2207	(3860 ± 115)	Wood from upper buried layer in front of Moreno Glacier. Date agrees well with sample I-2201 which suggests an advance of the Moreno to slightly beyond its present position so that the ice dam did not break. Stratigraphic position above sample I-2206 is unexpected and suggests that the wood is not in its primary position; this detracts from its significance.
I-2208	(4590 ± 115)	Rooted tree stump 1 meter below water level of lagoon dammed by the outermost end moraine of the San Lorenzo Este Glacier. Agrees well with sample I-2204.

TABLE 1 (Continued)

Sample no.	Age: years B.P.	
I-2209	(10,000 ± 140)	Basal peat on clay covering cobbles in drainage channel through Late-Glacial moraines. Gives minimum age for abandonment of drainage channel, which would have been occupied from the time the moraines were formed until the ice had receded 30 kilometers, only 1 kilometer in front of today's position. The water of the Brazo Sur could then have escaped via the channel mentioned in connection with sample I-2201.
I-2273	(370 ± 90)	Sample, which came from a similar situation 1 kilometer away, was submitted as check on sample I-2202. Date shows that both are young.

11 radiocarbon dates obtained from samples of peat or wood are given in table 1. This field study was a continuation of work begun in 1963 (Mercer, 1965).

THE LATE-GLACIAL SUBSTAGE IN LAGO ARGENTINO

Massive closely spaced end moraines extend a considerable distance east of Lago Argentino down the valley of the Río Santa Cruz. Their ages are unknown, but most are thought to date from full-glacial time of the last glaciation. Ice evidently occupied the basin of Lago Argentino for a long time, but once it had begun to withdraw from the eastern shore, it receded uninterruptedly until, 40 kilometers to the west, a readvance took place, forming what are here referred to as the Punta Bandera moraines. Caldenius (1932, p. 142) thinks they correspond to the Fennoscandian moraines of Europe, since dated by radiocarbon at between 10,850 and 10,050 B.P. (Nilsson, 1964, p. 170), but Feruglio (1944, p. 151) believes they are Postglacial.

The Punta Bandera moraines were formed by two ice tongues, a Lago Argentino glacier most of which ended in a calving front and a Brazo Rico glacier which ended entirely on land. For much of their extent, they are double-crested. The moraines of the Brazo Rico ice lobe are breached by an abandoned water course (fig. 3); a pit dug through the channel fill showed the following section:

mud 15 centimeters (probably the result of trampling by domestic animals)
peat 15 centimeters
sand 30 centimeters
peat 150 centimeters; basal peat 10,000 ± 140 B.P. (I-2209)
clay 30 centimeters
cobbles and boulders.

THE RECESSION FROM THE LATE-GLACIAL END MORAINES

From the Punta Bandera end moraines the ice receded up the complex channels of Lago Argentino and separated into the several present-day valley glaciers at or close to lake level. When the Brazo Rico glacier

had receded the full length of the Brazo Rico, it split into two branches, which, with continued recession, eventually became the Frias Glacier and part of the Moreno (fig. 2.)

The Moreno Glacier since the Late-Glacial.—As the Brazo Rico ice lobe withdrew from the Punta Bandera moraines, its meltwater continued to occupy the channel through the moraines until a lower outlet was open when the proto-Moreno Glacier had receded to Bahía Catalán at the western extremity of the mountainous Península Magallanes (fig. 2).

The promontory that forms the western extremity of the Península Magallanes is connected to the peninsula by a saddle immediately north of Bahía Catalán believed to be an old spillway; it is 42 meters above lake level and is estimated by the writer to be about 5 meters below the channel through the Punta Bandera moraines (fig. 3 and pl. 1). There

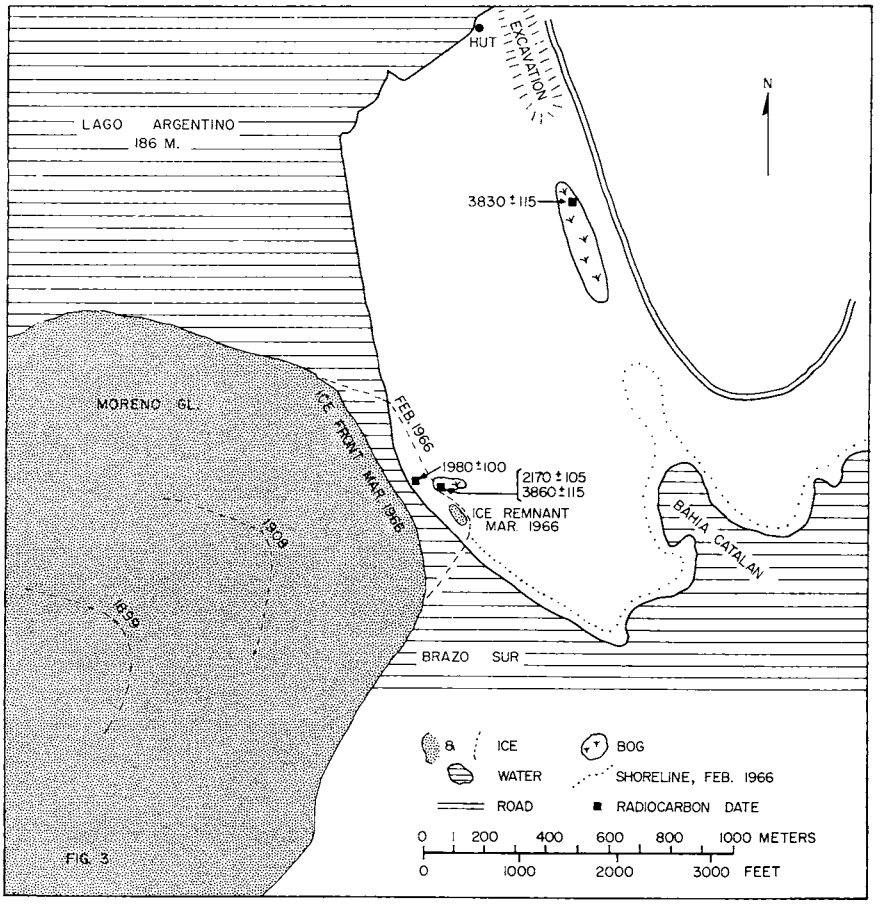


Fig. 3. Moreno Glacier terminus and vicinity.

PLATE I

Moreno Glacier terminus, February 1966, view southwest. Brazo Sur and Bahía Catalan on left.

is, however, some doubt about the difference in elevation between these two channels because no accurate levelling has been carried out by any of the workers who have been in the area. Raffo, Colqui, and Madejski (1953, p. 338) conclude from measurements they have made that the channel through the moraines is only 31 meters above lake level, but Heinsheimer (1956, p. 332) thinks that the Bahía Catalán saddle, measured at 42 meters above lake level, is the lower. In 1966, when the impounded Brazo Sur had reached 27 meters above Lago Argentino and was only 15 meters below the Bahía Catalán saddle, it was estimated by the writer to be still at least 20 meters below the channel through the moraines. A long, narrow peat bog that now occupies the spillway was excavated (fig. 3); the basal peat of 110 centimeters of peat overlying sand is 3830 ± 115 C-14 years old (I-2201).

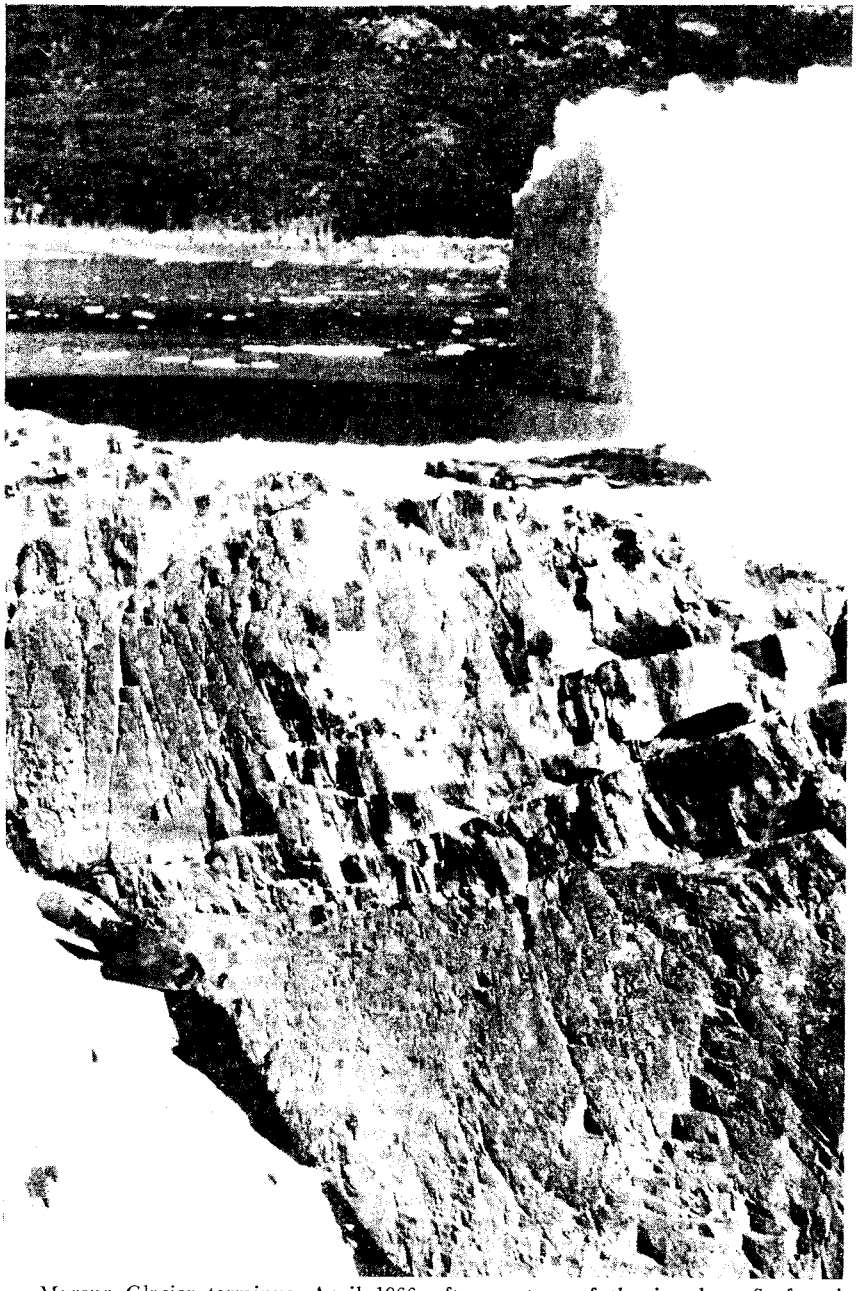
Recently, the Moreno Glacier has been slowly advancing and impounding the Brazo Sur (pl. 1). The ice dam repeatedly gives way, at increasing intervals, and released floodwaters pour past the terminus. The vicinity of the ice dam was visited a month after it had broken in February, 1966, and sections cut in the superficial deposits by the released floodwaters were studied. The torrent had removed all superficial material from the previously ice-covered surface except for some compact peat in fissures (pl. 2). This peat, which had survived several other recent outbreaks of the Brazo Sur, is 1980 ± 100 C-14 years old (I-2205).

Immediately in front of the ice margin of February 1966, a small peat bog occupied a depression. Many dead tree trunks lay on the surface, some having fallen into the bog, and others having been stranded by the surge of water that accompanied the breaking of the dam. The torrent also truncated the bog at its western end and cut a section 3 meters deep and 6 meters wide, revealing two layers of peat and wood separated by sand below the modern peat and wood layer. The lower peat layer rested directly on bedrock. The layers were variable in thickness and were much distorted. The C-14 age of wood from the lowest layer is 2170 ± 105 years and from the middle layer is 3860 ± 115 years (I-2206 and I-2207).

This evidence enables some conclusions to be drawn about the history of the Moreno Glacier during the last 10,000 years. The C-14 age of 10,000 ± 140 years for the basal peat in the drainage channel through the Punta Bandera moraines gives a minimum date, not only for the abandonment of the moraines, but also for the recession of the ice to the Bahía Catalán spillway, 30 kilometers to the west. By 10,000 B.P., therefore, the Moreno Glacier was little bigger than it is today.

The Bahía Catalán spillway was used only when the terminus of the Moreno Glacier stood between the Bahía Catalán and its present position, a distance of no more than 1 kilometer (fig. 3 and pl. 1). It was first occupied about 10,000 B.P., but the age of the channel fill suggests it was also used 6000 years later. It is unlikely that the glacier was virtually in equilibrium for almost 6000 years; probably it receded clear of the Península Magallanes after 10,000 B.P., resulting in abandonment of the

PLATE 2



Moreno Glacier terminus, April 1966, after rupture of the ice dam. Surface in forground was ice-covered in February 1966 and was afterward scoured by released waters of Brazo Sur, in background; note high water mark. Basal peat near trowel is 1980 ± 100 C-14 years old.

Bahía Catalán spillway. The young age of the channel fill is believed to be evidence for a later readvance of the ice of not more than 1 kilometer beyond its present position, causing reoccupation of the spillway. The date of the maximum of this readvance is not known, but by 3830 B.P. the spillway was no longer in use, indicating that the ice had receded again to near its present position.

This readvance of the Moreno Glacier resulted in the flooding of about 70 km^2 of land at the east end of the Brazo Rico as the water level rose 42 meters to the level of the spillway. When the glacier receded again and the ice dam broke, this surface, its vegetation cover gone, was exposed to deflation by the strong winds. The channel through the Punta Bandera moraines is situated adjacent to and downwind of this area, and the sand layer interrupting the peat is believed to have been wind-deposited at that time. A similar sudden lowering of lake level had taken place in the early Postglacial, and the clay underlying the peat, and therefore more than 10,000 C-14 years old, perhaps had a similar origin. The difference in composition reflects difference in source material: much glacial lake clay had accumulated in pro-glacial Brazo Rico, whereas during the later inundation caused by the advance of the Moreno to the Bahía Catalán, the ice was much further away and little clay was deposited. The waters covered a surface that had been long exposed to weathering and soil formation, and when they receded, it was this material that the wind eroded.

Because the Bahía Catalán spillway has not been used since at least 4000 B.P., the Moreno Glacier cannot have been much further forward than it is today during that interval. However, the age of the basal peat recently overridden by the glacier, 1980 ± 100 C-14 years, suggests that this peat had perhaps begun to form after a previous episode of repeated outbreaks of impounded water, when the glacier had advanced to about the same position as that of today: ice dams of less than three years duration were being breached before the waters of the Brazo Sur had risen to the level of the Bahía Catalán spillway.

A tentative field interpretation of the section exposed by the torrent was that the sand layers had been deposited on the bog by flood waters at a time when the glacier was repeatedly damming the channel and that the peat and wood layers had accumulated when the channel was clear. However, the apparent transposition of the two organic layers is unexpected and unexplained; perhaps bulldozing by advancing ice after 2170 B.P. overturned the deposit, but this does not seem likely from field observation. No conclusion can be drawn except that the bog was not ice-covered in either 3860 B.P. or 2170 B.P.

Since the beginning of the 20th century and probably earlier, the Moreno Glacier has been advancing, and in this respect it is unique among the glaciers on the eastern side of the southern ice field. According to Hauthal (1910, p. 140), local information indicates that the glacier almost closed the channel in 1880, but the reliability of this report is un-

certain. When first surveyed in 1899 the terminus was 1000 meters from the shore and has since been advancing, although with pauses and some slight recessions. By 1908 it had advanced 500 meters and by 1914 another 350 meters, so that the channel was then only 150 meters wide (Reichert, 1917, p. 229). In 1917 the channel was closed for the first time. Thus, between 1899 and 1917, the glacier apparently advanced at a nearly constant annual rate of about 55 meters. After 1917, however, the advance appears to have stopped for nearly 20 years, and the ice dam did not form again until 1935 (Raffo, Colqui, and Madejski, 1953, p. 333). Since then, the Brazo Sur has been impounded about a dozen times, always for less than a year until 1954. Since 1954 the ice dam has lasted more than 2 years on at least three occasions; before the most recent rupture of the dam in February, 1966, the Brazo Sur had reached a record level of about 27 meters above the remainder of Lago Argentino and 15 meters below the Bahía Catalán drainage channel. If the ice dam remained unbreached for 3 years, the Bahía Catalán channel would again be occupied; to prevent the loss of farm land that this would cause, an artificial cut has been begun (fig. 3).

The Frias Glacier since the Late-Glacial.—The Frias Glacier flows south from the main cordillera and ends at the foot of the Cordillera des los Baguales (fig. 4). The left portion of the front curves to the east and

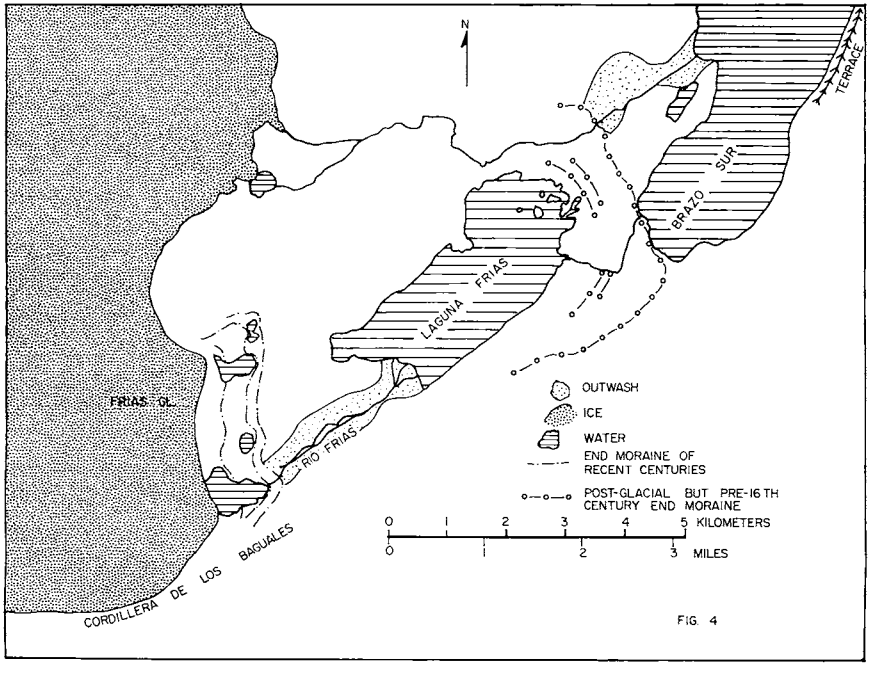


Fig. 4. Frias Glacier and Laguna Frias.

extends a short distance into the valley of the Rio Frias. Within 1 kilometer of the ice front are three principal moraine ridges, beyond which mature forest is growing with trees at least 400 years old. On deposits left by the first advance, trees at least 200 years old are growing (by field count of growth rings in cores). Deposits of the second advance, which was nearly as extensive, have almost no trees, but some of the few that occur are about 50 years old (by field count of growth rings in cross sections). The third moraine ridge is bare.

During the Argentine-Chilean boundary survey at the end of the 19th century, a photograph was taken from the Brazo Sur of part of the Frias Glacier and its steep tributaries on the mountains to the west (Argentine Government, 1900, p. 962). The terminus of the glacier is not visible in the photograph, but rock windows in the steep tributaries were not noticeably different in 1966.

Formerly, a tongue of ice extended down the valley of the Río Frias 9 kilometers beyond the present ice margin and reached the shore of the Brazo Sur of Lago Argentino, forming the massive end moraines that now enclose the 5 kilometer-long Laguna Frias (fig. 4). Raffo, Colqui, and Madejski (1953, p. 339) and Lliboutry (1956, p. 401) think that the moraines date only from the beginning of the present century and cite the Frias Glacier as having suffered greater recent recession than any other glacier in the area. They believe that the great recession of the Frias and the advance of the Moreno were contemporary and were both caused by the Moreno's capture of part of the drainage of the Frias. However, this is certainly incorrect because mature forest with trees at least 400 years old is growing on the moraines. Hauthal (1904, p. 46) believes that the moraines are Late-Glacial. No organic matter that could have dated these moraines was obtained during the field study, and an estimate of their age depends upon indirect evidence. A terrace cut in drift extends for about 3 kilometers along the east side of the Brazo Sur to within 4 kilometers of its southwest extremity (fig. 4), ending where the surface is bedrock. This terrace is approximately accordant with the Bahía Catalán spillway and is believed to have been cut when the Moreno Glacier was in an advanced position. The Laguna Frias moraines show no trace of the terrace nor any signs of having been formed at or before a time of higher water level than in 1966. Therefore, they are probably less than 3830 C-14 years old and more than 400 calendar years old.

Glaciers of the Cerro San Lorenzo Area since the Late-Glacial.— Glaciers radiate in all directions from the pyramidal peak of Cerro San Lorenzo, and ice lies on the adjacent northeast-trending ridge of Cerro Hermoso (fig. 5). The open sea is 160 kilometers away, and maritime influences are much reduced. Aerial photographs taken in 1956 (on file at the Instituto Geográfico Militar, Buenos Aires) give evidence of great recent recession of all the glaciers. The shrinkage has been most marked on the north side of Cerro Hermoso where some glaciers, formerly about

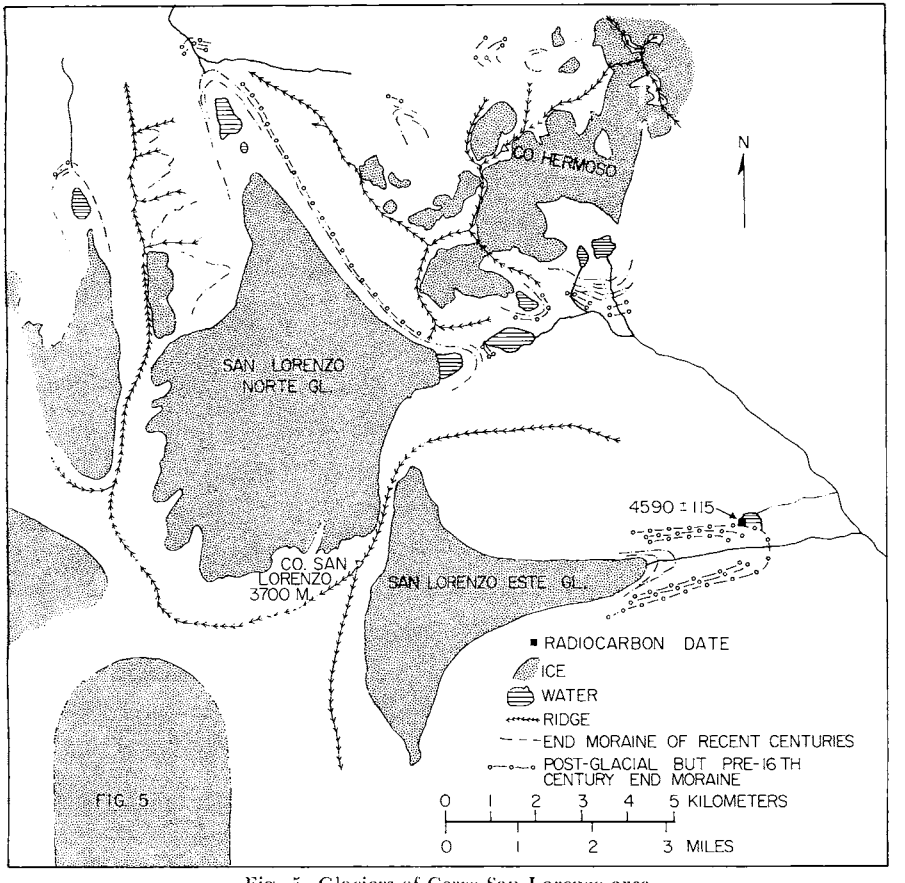


Fig. 5. Glaciers of Cerro San Lorenzo area.

2 kilometers long, have virtually disappeared. The glaciers studied by the writer were those on the south side of Cerro Hermoso, the eastern distributary lobe of the San Lorenzo Norte Glacier, and the San Lorenzo Este Glacier.

The three glaciers on the south side of Cerro Hermoso end at about 800 meters above sealevel, 200 meters below tree line, but trees are confined to the valley sides and do not grow on the moraine ridges and outwash. The eastern and central glaciers were formerly combined, and an older and a younger set of end moraines formed by the joint glacier lie respectively 1 to 1.5 kilometers and 1.5 to 2 kilometers ahead of the present termini. The older moraines, of which four can be distinguished, have a long-established vegetation cover, and soils and turf have developed on the more favorable ground between the ridges. The outermost of the younger set of moraines has sparse vegetation mats and no turf or soil, and the inner moraine is bare. A photograph taken in 1940 (Agostini, 1945, p. 293) shows that the tongues of the glaciers were then

farther forward than they are today, but that rock windows in the middle and upper parts of the glacier were similar.

The western glacier carries a heavy load of rock waste and has receded and thinned from a massive compound moraine, composed of unvegetated debris partly covering much older material.

All meltwater from the San Lorenzo Norte Glacier today flows to the Pacific Ocean. On at least two occasions in the past, a distributary lobe with Atlantic drainage extended about 1 kilometer into the valley between Cerro San Lorenzo and Cerro Hermoso. A massive, bare moraine ridge has partly overwhelmed the innermost of three much older moraines that impound a lake. The ice has since thinned an estimated 80 meters and receded behind a proglacial lagoon.

The San Lorenzo Este Glacier ends at about 700 meters above sea-level. It has recently thinned greatly, but rock debris covering the lower 2 kilometers of the tongue has inhibited terminal recession. A fresh, bare end moraine lies within 100 meters of the ice front, and an older moraine with sparse vegetation cover and no trees lies within 200 meters. Beyond these moraines are three much older ones, the outermost being 2.5 kilometers downvalley. The inner two are poorly developed, especially on the valley floor, and are perhaps only recessional moraines. The outermost moraine impounds a small lagoon (fig. 5 and pl. 3), which drains from its far end over bedrock so that its level has not changed, except seasonally, since it was formed. In a pit dug at the edge of the lagoon, below 1 meter of clay and nearly 1 meter below the late summer water level, was a layer of peat with rooted stumps of small trees (probably *Nothofagus antarctica*). A sample of wood is 4590 ± 115 C-14 years old (I-2208) and is presumed to date the maximum extent of the glacier.

The Narvaez Glacier, Sierra de Sangra, since the Late-Glacial.—The Sierra de Sangra lies 100 kilometers south of Cerro San Lorenzo and 50 kilometers east of the northern end of the southern icefield. It contains a complex of transection glaciers extending about 20 kilometers north to south (fig. 1).

The Narvaez Glacier, the largest on the eastern side of the mountains, has receded from a bare moraine, and a 2-kilometer-long proglacial lake has formed. Beyond the bare moraine are at least two others on which vegetation has not reached environmental equilibrium. Trees about 200 years old grow on the outer moraine. When the glacier was first visited and photographed by the Princeton University Expedition in 1897, the proglacial lake was just starting to form (Hatcher, 1903, p. 141). The bare moraine was, therefore, probably formed about A.D. 1880, and the outer moraine during the 17th century.

Two massive moraines with mature forest cover lie about 700 and 1000 meters beyond those of recent centuries; on the outermost, a pit was dug in a small peat bog consisting of 1 meter of peat on till. A C-14 age of 4320 ± 110 years (I-2204) for the basal peat give a minimum age for this moraine.

End Moraines of San Lorenzo Este Glacier, view southwest. Light-colored moraines on valley floor date from recent centuries. Upper limit of vegetation on hillside in background is moraine that is continuous with that in foreground, impounding lagoon. Tree drowned by lagoon is 4590 ± 115 C-14 years old. Two lower moraine ridges faintly visible on hillside in background.

THE CHRONOLOGY

Field evidence indicates one Late-Glacial and three Postglacial readvances of the glaciers on the east side of the southern Patagonian ice field.

The Late-Glacial readvance.—Caldenius (1932, p. 142) believes that the Punta Bandera substage corresponds to the Finiglacial (Younger *Dryas*) substage of Scandinavia, which lasted about 800 years, from 10,850 to 10,050 C-14 years ago (Nilsson, 1964, p. 170). Heusser (1966a, p. 297) has studied the pollen content of bogs in Chile at about lat 41°31′ S, in the vicinity of Lago Llanquihue near Puerto Montt, and concludes that the climatic sequence closely followed that in Europe. He notes a Late-Glacial climatic oscillation similar to the Allerød oscillation and believes that the glaciers readvanced in Younger *Dryas* time, although he found no end moraines of that age. He thinks that, based on C-14 dating, Postglacial time in southern Chile began about 10,000 B.P.

By 10,000 B.P., the ice in the Brazo Sur of Lago Argentino had receded at least 97 percent of the distance from the Late-Glacial moraines to the present ice margin, about 30 centimeters of clay had then accumulated on the cobbles of the abandoned drainage channel, and peat had begun to accumulate on the clay. How long the clay took to accumulate is not known, but if it was wind-transported as suggested, it may have been only a few years. The 30 kilometer recession of the ice may also have been rapid: the environment is similar in many ways to Glacier Bay, Alaska, where the ice has receded 100 kilometers in the last 200 years (Goldthwait, 1963, p. 45). Therefore, the Punta Bandera substage may be contemporary with the Younger *Dryas* in Europe; if so, the amelioration of climate, from Late-Glacial to approximately present conditions, must have taken place in only a few centuries. Some slight evidence in favor of this interpretation is that the two ridges of the Punta Bandera end moraines indicate that a lesser readvance followed the maximum extent of the Late-Glacial; Nilsson (1964, p. 165) also notes two cold phases in the Younger *Dryas* of Sweden, the earlier being the colder. The Punta Bandera substage may be older, however, and perhaps the same age as the Valders substage in North America; the Two Creeks forest bed, drowned earlier in the Valders advance, is 11,850 ± 100 C-14 years old (Broecker and Farrand, 1963, p. 797). A third possibility is that the Punta Bandera substage is older than either the Younger *Dryas* or the Valders.

The first Postglacial readvance.—Dates of about 4600 B.P. for wood killed at the maximum Postglacial extent of the San Lorenzo Este Glacier and about 4300 B.P. for peat formed after the maximum postglacial extent of the Narvaez Glacier suggest that these two glaciers reached a maximum at about the same time. Undated ancient moraines in front of other glaciers in the vicinity are perhaps of similar ages. The Moreno Glacier probably reached a maximum a few centuries later. However, the

behavior of the Moreno is not typical of the area: it is now anomalously still advancing about 300 years after other glaciers reached their maxima.

The date that the San Lorenzo Este and the Narvaez glaciers reached their greatest postglacial extent is usually considered to fall within the Hypsithermal Interval. However, some glaciers in Switzerland and North America advanced at about the same time (B-254, Gfeller, Oeschger, and Schwarz, 1961; W-1030, Ives and others, 1964; Heusser, 1966b, p. 139), suggesting that all these advances were climatically caused and were not surges. Botanists hold conflicting views about the climate at that time, and some find evidence of a cool episode; the problem is summarized and discussed by Frenzel (1966). If an interval of glacier advance was indeed worldwide, there is much evidence that it was separated from the glacier advances of about 3000 B.P. by renewed Hypsithermal conditions (for example, Faegri, 1945, p. 117; Hammen and Gonzalez, 1960, p. 745; Heusser, 1966b, p. 137); therefore, it should not be considered part of Neoglaciation.

The second Postglacial readvance.—Evidence had earlier been found of a maximum Postglacial extent of the Upsala Glacier about 2000 B.P. with some doubtful evidence of an earlier advance of similar extent before 3600 B.P. and of the Dos Lagos Glacier about 1600 B.P. (Mercer, 1965, p. 400 and 408). These glaciers are 60 and 80 kilometers north of the Moreno. Sub-Atlantic glacier advances are also known from Alaska and elsewhere in the northern hemisphere (Porter and Denton, 1967). In 1966 only indirect evidence was found for glacier advances at that time: on the bedrock surface now being covered alternately by the Moreno Glacier and its glacial lake outlet, peat began to form about 1980 B.P., perhaps soon after an earlier scouring of the surface. The maximum extent of the Frias Glacier, more than 400 calendar years old but probably less than 3830 radiocarbon years, may also be Sub-Atlantic in age.

The San Lorenzo Este and the Narvaez glaciers with Sub-Boreal maxima have two or three moraines outside those formed in recent centuries of which only the outermost have been dated. Possibly, therefore, they all advanced on both occasions, but the San Lorenzo Este and the Narvaez did not extend so far in the Sub-Atlantic as during the Sub-Boreal.

The third Postglacial readvance.—All the glaciers studied, except for the Moreno, have receded from recent end moraines. No ice-tilted trees were found that could have precisely dated any of these moraines (see Lawrence, 1950, p. 245). However, no trees more than 200 years old were growing on the oldest moraines, suggesting that the readvances have all taken place within the past 3 centuries. This most recent episode of glacier expansion has, therefore, been contemporary with that in all other parts of the world, outside some high polar regions, and which has been best recorded in the Alps (see Kinzl, 1932, p. 396). It has differed in one important respect, however: in no case, so far as is known, has a glacier reached its greatest Postglacial extent in recent centuries.

CONCLUSIONS

Late-Glacial and Postglacial glacier fluctuations in Argentine Patagonia have been broadly in phase with those in the northern hemisphere. The maximum reached by two glaciers about 4600 B.P. in the early Sub-Boreal greatly strengthens the northern hemisphere evidence of an advance at that time and suggests that it was worldwide. An important difference between Argentine Patagonia and the northern hemisphere is that the advance of recent centuries has been weak compared to those in the Sub-Atlantic and early Sub-Boreal. The reason is not clear, but perhaps the climatic deterioration that accompanied the two earlier advances was caused by some event in the southern hemisphere—a northward migration of the Antarctic Convergence, for instance—which had less effect in the northern hemisphere, and the deterioration in recent centuries had its origin in the northern hemisphere.

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