

## THE GLACIERS OF THE SIERRA NEVADA DE MERIDA (VENEZUELA): A PHOTOGRAPHIC COMPARISON OF RECENT DEGLACIATION

With 7 figures and 1 table

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*Zusammenfassung:* Die Gletscher der Sierra Nevada de Mérida (Venezuela): ein photographischer Vergleich ihres rezenten Rückzugs

Gletscher sind in der Cordillera de Mérida nur im Bereich der Sierra Nevada de Mérida zu finden. Sie stellen heute Hanggletscher dar. Im Jahre 1952 bedeckten sie eine Fläche von etwa 3 km<sup>2</sup>. Dies bedeutet im Vergleich zur Ausdehnung der pleistozänen Gletscher einen Rückgang um 98,5%. Es gibt zahlreiche Hinweise auf einen starken Gletscherrückzug während der letzten 100 Jahre. Mindestens drei Gletscher sind allein seit 1972 vollkommen verschwunden (der Timoncito Gletscher in der Südostwand des Pico Bolívar Massivs, der Nuestra Señora Gletscher in der Südostwand des Humboldt-Bonpland Massivs und die Gletscher des Pico La Concha Massivs). Ein wichtiger Faktor beim beschleunigten Rückzug der Gletscher ist wahrscheinlich ihre Exposition zur morgendlichen Sonneneinstrahlung. Nachmittags ist die Sierra Nevada meistens bewölkt, was die Gletscher der Nordwestwände stärker schützt. Es muß näher untersucht werden, in welchem Umfang die von der Stadt Mérida, die etwa 25 km westlich des Pico Bolívar im engen Chamatal liegt, ausgehenden atmosphärischen Umweltbelastungen zu dem Gletscherrückzug der letzten 20 Jahre beigetragen haben.

### Introduction

The Sierra Nevada de Mérida (Fig. 1), together with the Sierra de Santo Domingo, is the largest massif of the Cordillera de Mérida (Venezuelan Andes). Its highest elevation reaches 5000 m a. s. l. in Pico Bolívar. Just as other high mountain systems in the temperate and tropical regions, the Sierra Nevada de Mérida was affected by Quaternary glaciations. The last glacial advance is locally called the Mérida Glaciation, and it culminated at approximately 20,000 years B. P. (SCHUBERT 1974, 1984, SCHUBERT a. CLAPPERTON 1990). Two stades have been recognized during the Mérida Glaciation: an Early Stade, with moraines at 2600–2800 m a. s. l., and a Late Stade, with moraines at 2900–3500 m a. s. l. Palynological studies of postglacial sediments and radiocarbon dating indicate that the Mérida Glaciation ended approximately 13,000 years B. P. (SALGADO-LABOURIAU et al. 1977). The total area of the glaciers of the late stade was estimated as approximately 200 km<sup>2</sup>, on the basis of a comparison of the weight

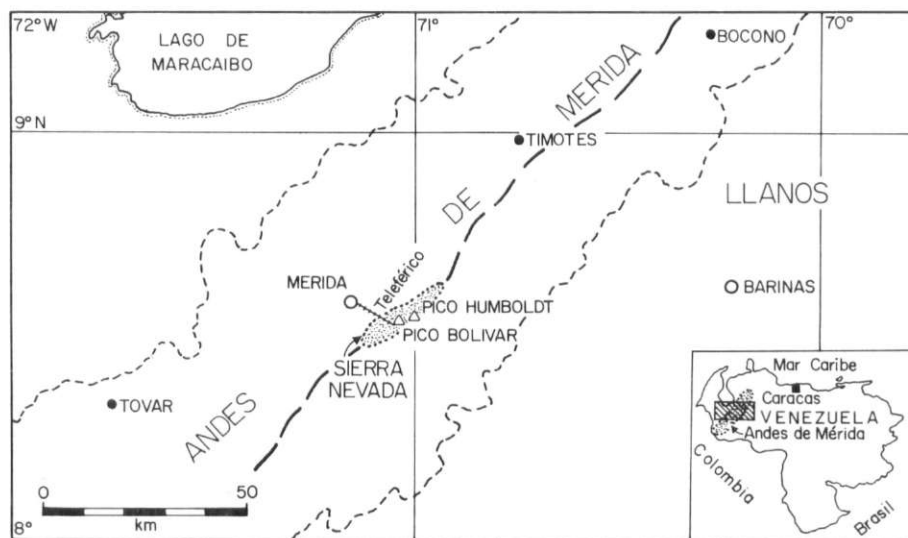


Fig. 1: Location map of the Sierra Nevada de Mérida  
Karte der Sierra Nevada de Mérida

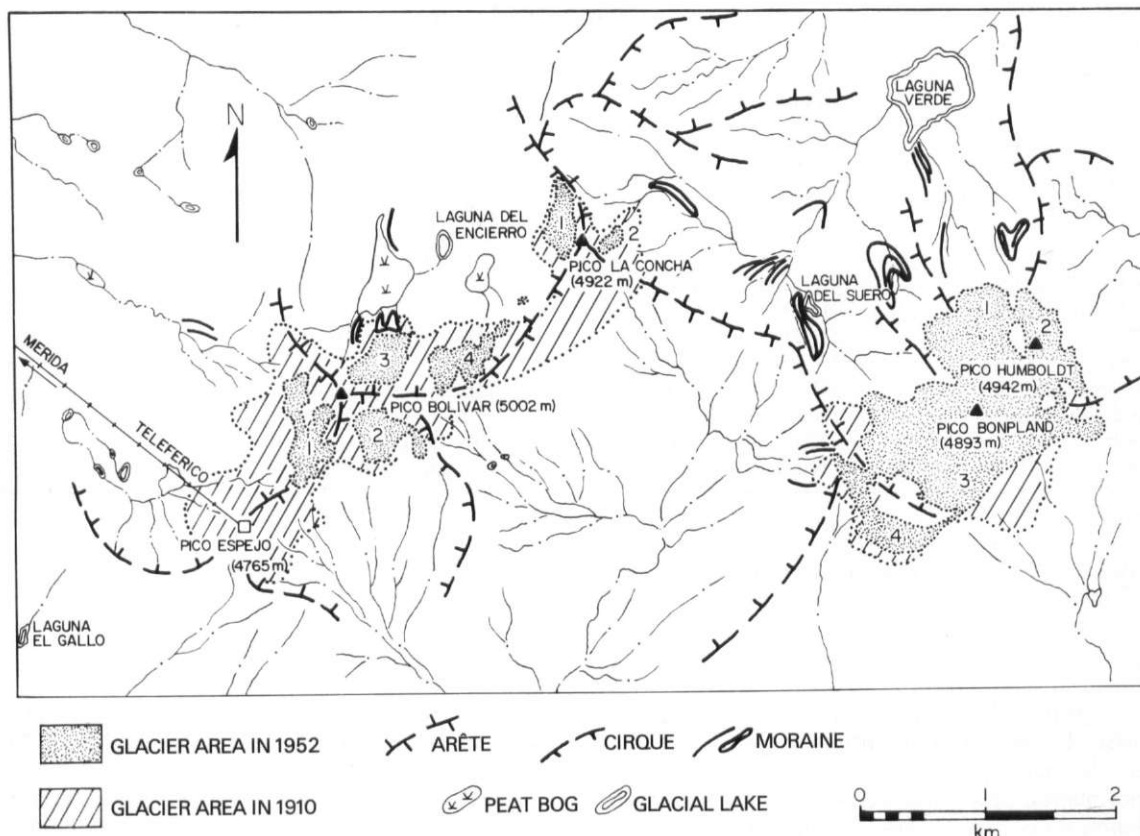


Fig. 2: Areas covered by glaciers in the Sierra Nevada de Mérida in 1910 (after JAHN 1925) and 1952 (from aerial photographs, Mission A-34, Cartografía Nacional, Caracas, no. 972-982). Note the neoglacial moraines, some of which probably were deposited during the Little Ice Age. The numbers indicate the glaciers named in Table 1

Ausdehnung der Gletscher in der Sierra Nevada de Mérida 1910 (nach JAHN 1925) und 1952 (aus Luftbildern, Mission A-34, Cartografía Nacional, Caracas, No. 972-982). Zu beachten sind die neoglazialen Moränen, von denen einige wahrscheinlich in der Kleinen Eiszeit abgelagert wurden. Die Zahlen bezeichnen die Gletscher in Tabelle 1

of paper cutouts from a map (SCHUBERT 1984). The largest glacier-covered area existed in the Pico Bolívar and Picos Humboldt-Bonpland regions, and it was estimated as about 50 km<sup>2</sup>. Numerous recessional moraines at higher elevations mark the Late Pleistocene-Holocene glacier retreat. Palynological evidence for the Little Ice Age has been found, which lasted in the Cordillera de Mérida from the 15th to the early 19th centuries A. D. It was estimated, on the basis of this palynological evidence and the elevation of the probable (so far undated) Little Ice Age moraines, that the glaciers extended to about 4200 m a. s. l. At present, the snowline is above 4700 m a. s. l.

*Modern glaciers of the Sierra Nevada de Mérida*

FRAY PEDRO AGUADO, in 1560, was probably the first to mention the existence of perennial snow in the Cordillera de Mérida (AGUADO 1963, p. 377 a. 428).

This observation was confirmed by CODAZZI (1841, p. 492), who reported the existence of glaciers in the Sierra Nevada de Mérida.

The first data on the glaciers of the Sierra, the only one that has remnants of the Pleistocene glaciers, were published by GOERING in 1896 (GOERING 1962) and SIEVERS (1886, 1888 a, 1888 b, 1908, 1911). Later, they were described in detail by JAHN (1912 a, 1912 b, 1925, 1931) and BLUMENTHAL (1923). Of these reports, the most important are those of SIEVERS and JAHN, because they represent the base for comparing the present-day extent and characteristics of the glaciers with those at the end of the 19th century. The glaciers of the Sierra Nevada are also depicted in a few paintings, such as those by FERDINAND BELLERMAN (between 1842 and 1845) and of GOERING himself in 1869. A comparison of these paintings and the present-day situation strongly supports a rapid glacier retreat during the last 100 years (SCHUBERT 1980, 1984, 1987).

Table 1: Nomenclature and area<sup>1)</sup> occupied by the glaciers of the Sierra Nevada de Mérida  
 Namensverzeichnis und Fläche<sup>1)</sup> der Gletscher der Sierra Nevada de Mérida

Region	This report <sup>2)</sup>	Jahn (1925)	Area (km <sup>2</sup> )
Glaciers of the Pico Bolívar Massif (8°33' N, 71°02.5' W)	Espejo Glacier (1)	Espejo Glacier	0.27
	Timoncito Glacier (2)	Timoncito-Hermanas Glacier	0.17
	El Encierro Glacier (3)	Bourgoin Glacier	0.17
	El Encierro Glacier (4)	Karsten Glacier	0.10
Glaciers of the Pico La Concha Massif (8°33' N, 71°01.5' W)	Ño León Glacier (1)	Garza Glacier	0.10
	Coromoto Glacier (west remnant) (2)	Mucuy Glacier	0.07
Glaciers of the Picos Humboldt-Bonpland Massif (8°33' N, 71°00' W)	Coromoto Glacier (east remnant) (1,2)	Laguna Verde and Codazzi Glaciers	2.03
	Sinigüis Glacier (3)	Sievers Glacier	
	Nuestra Señora Glacier (4)	Plazuela Glacier	
Total			2.91

<sup>1)</sup> Measured with a planimeter on aerial photographs of 1952

<sup>2)</sup> The number in parenthesis refers to the numbers of Fig. 2

The principal data about the present-day glaciers consist of personal observations in the Pico Bolívar area, the analysis and planimetric measurements on aerial photographs (Cartografía Nacional, Caracas, Mission A-34, 1952, photographs no. 972 to 982), at an approximate scale of 1:40,000, and on comparisons of photographs and paintings made during the last 100 years. Fig. 2 shows the distribution of the glaciers in 1910 and 1952. The nomenclature and measured areas are shown in Table 1. JAHN (1925) partly named them in honor of previous explorers; however, following international nomenclature rules, I have used the local geographic names of the valleys which they occupied during the Mérida Glaciation.

Until very recently (at least 1972), there were three areas with glaciers: the Pico Bolívar Massif, the Pico La Concha Massif, and the Picos Humboldt-Bonpland Massif. All of these glaciers are cirque or hanging glaciers. The extent of the glaciers in 1952 was estimated at approximately 3 km<sup>2</sup> (Table 1). Other data on Venezuelan glaciers can be found in SCHUBERT (1989; in press).

#### Recent deglaciation

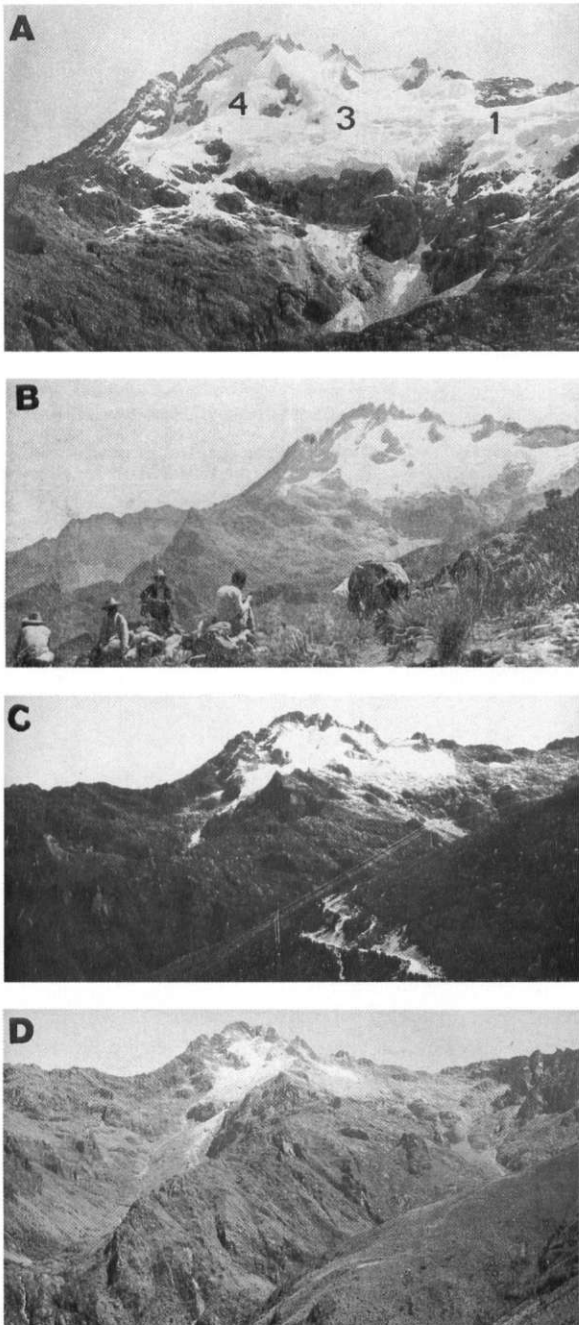
The principal evidences of recent glacier retreat in the Sierra Nevada de Mérida are the comparison of ancient and present-day snowlines and the comparison of paintings and photographs.

The most abundant information concerns the Pico Bolívar Massif. Probably the oldest paintings indicating with precision the existence of glaciers at a

lower elevation than today are those by GOERING, who visited the region between 1864 and 1874. One painting in particular (GOERING 1962, Plate IX), called "La Concha, Sierra Nevada and Quebrada San Jacinto", shows a massive glacier (Espejo Glacier) filling the main western cirque below Picos Bolívar and Espejo, whose floor is at about 4000 m a. s. l. (approximately 700 m below the present-day glacier termini). In an engraving (GOERING 1962, p. 155), he shows glacier tongues on the floor of the Pico Espejo cirque. In a report on his ascent to the Sierra Nevada, ENGEL (1869) mentioned the possible existence of perennial snow in this cirque. From this position, the Espejo Glacier retreated rapidly; in 1910 (JAHN 1925) it still covered Pico Espejo, the ice was thick and stratified, and it terminated at approximately 4500 m a. s. l. BLUMENTHAL (1923) reported that in 1922 only a small glacier remained, and in 1936, only small remnants were left (ROMERO 1980, p. 43). Since then, Espejo Glacier has melted completely (Figs. 3 a. 4).

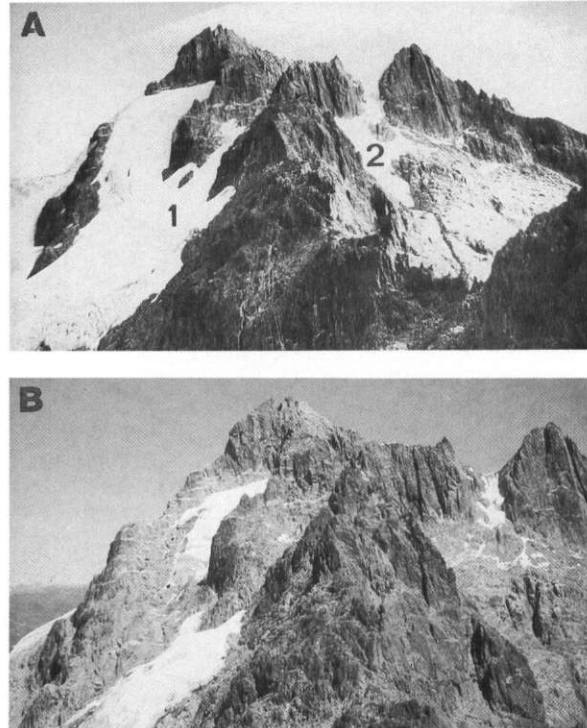
In 1868, BOURGOIN (in: JAHN 1925) reported the existence of ice thicknesses between 8 and 16 m on the flanks of Pico El Toro, 5 km southwest of Pico Bolívar. In 1915, a small remnant still existed, and by 1931 it had disappeared completely (JAHN 1931). FÉBRES-CORDERO (1890) wrote about the deglaciation of the Sierra Nevada, in particular of Pico El Toro, on which, by 1890 he observed rock patches emerging as the ice melted.

The snowline has risen from approximately 4100 m to more than 4700 m a. s. l. since 1885 (SIEVERS 1885/86, 1886, 1888 a; JAHN 1912 a; SCHUBERT 1972). JAHN (1925) measured an ice thickness of 25 m in the glaciers of Pico Bolívar in 1910; SCHUBERT (1972)



**Fig. 3:** Photographic sequence of the glaciers of the north face of the Pico Bolívar Massif (glaciers 1, 3, a. 4 of Fig. 2). Note that glaciers 1 and 4 (Espejo and El Encierro Glaciers) had completely disappeared by 1991  
 Photographs: A: A. JAHN, January 1910 (JAHN 1912b); B: K. JAGENBERG, February 1936 (in: ROMERO 1980, p. 43); C: C. SCHUBERT, February 1972; D: C. SCHUBERT, January 1991

Photosequenz der Gletscher der Nordwand des Pico Bolívar Massivs (Gletscher 1, 3 u. 4 in Abb. 2). Zu beachten ist, daß die Gletscher 1 und 4 (Espejo und Encierro Gletscher) 1991 vollkommen verschwunden sind



**Fig. 4:** Photographs of the glaciers of the south face of the Pico Bolívar Massif (glaciers 1 a. 2 of Fig. 2). Note that Timoncito Glacier (2) has practically disappeared between 1972 and 1991. Glacier 1 has melted and consists now of two small firn patches  
 Photographs: A: C. SCHUBERT, February 1972; B: C. SCHUBERT, January 1991

Photos der Gletscher der Südwand des Pico Bolívar Massivs (Gletscher 1 u. 2 in Abb. 2). Zu beachten ist, daß der Timoncito Gletscher (2) zwischen 1972 und 1991 praktisch geschmolzen ist. Gletscher 1 ist ebenfalls geschmolzen und besteht zur Zeit nur noch aus zwei kleinen Firnflecken

measured 20 m in the terminal zone of Timoncito Glacier in 1972, and its thickness must have been larger in the central part (Fig. 5C). The vertical retreat of the glaciers is approximately 80 m between 1885 and 1910 (JAHN 1925), and between 100 and 150 m since then (SCHUBERT 1972), that is, a total of 180 to 230 m since 1885. A recent reconstruction of the glacier system of the Sierra Nevada de Mérida and the Sierra de Santo Domingo during the Late Pleistocene suggests that these glaciers occupied a total area of about 200 km<sup>2</sup>; by 1952, the total area was about 3 km<sup>2</sup> (SCHUBERT 1984; in press). During a visit to Pico Espejo on 30 January 1991, it was determined that Timoncito Glacier had totally disappeared (Figs. 4 a. 5), and also the glaciers of the Pico La Concha Massif. Since 1885, the rate of vertical glacier retreat has been estimated as 6 m/year. VARESCHI (1970) published an analysis of the development of



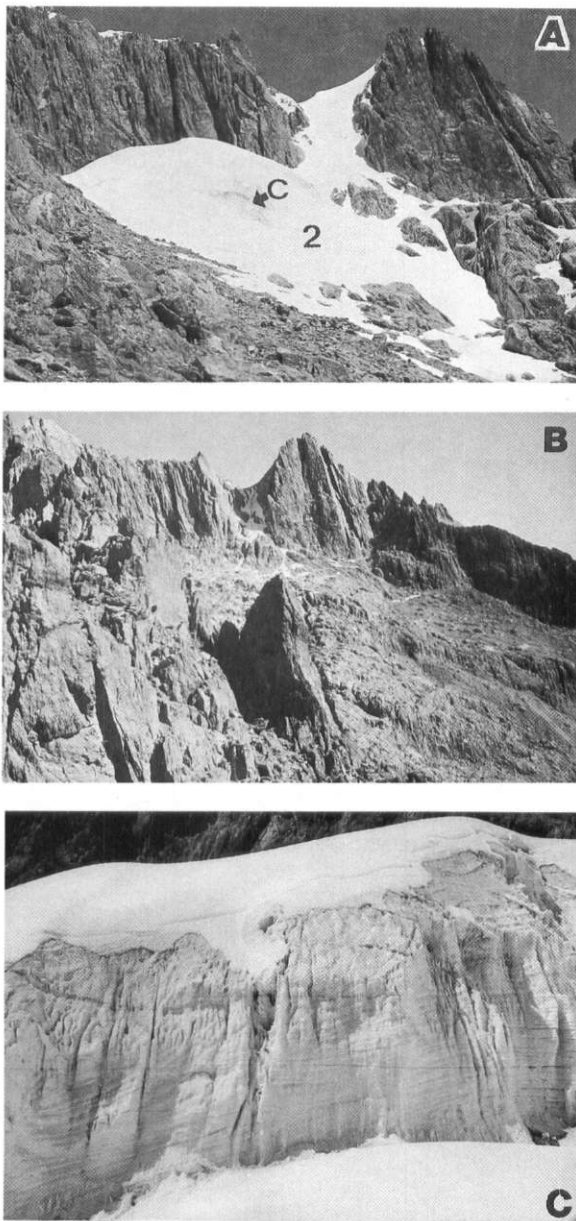


Fig. 5: Timoncito Glacier (no. 2 in Fig. 2) on the south face of Pico Bolívar, in February 1972 (A) and January 1991 (B). C: Crevasse in Timoncito Glacier showing approximately 20 m of ice thickness in 1972 (see location in A). All photographs taken by C. SCHUBERT

Der Timoncito Gletscher (Nr. 2 in Abb. 2) an der Südwanndes Pico Bolívar im Februar 1972 (A) und im Januar 1991 (B). C: Gletscherspalte im Timoncito Gletscher mit einer Eismächtigkeit von etwa 20 m im Jahr 1972 (siehe Lage in A)

lichens on moraines of the Pico Bolívar Massif, and calculated rates of growth of 20 and 60 mm/year, respectively, for *Rhizocarpon geographicum* and *Aspicilia cinerea*. Using these values, it can be estimated that the

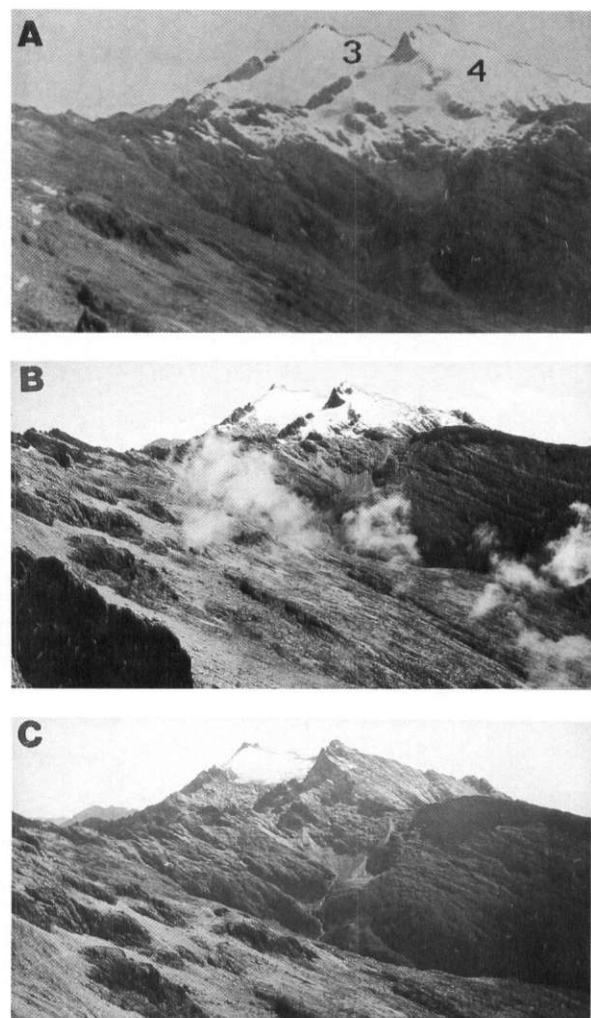


Fig. 6: Photographic sequence of the glaciers of the south face of Pico Bonpland (middle ground) and Pico Humboldt (background) (no. 3 a. 4 of Fig. 2). Note that glacier 4 (Nuestra Señora Glacier) has disappeared between 1972 and 1991

Photographs: A: A. JAHN, January 1910 (JAHN 1912b); B: C. SCHUBERT, February 1972; C: C. SCHUBERT, January 1991

Photosequenz der Gletscher an der Südwanndes Pico Bonpland (Mittelgrund) und Pico Humboldt (Hintergrund) (Nr. 3 u. 4 in Abb. 2). Zu beachten ist, daß Gletscher 4 (Nuestra Señora Gletscher) zwischen 1972 und 1991 vollkommen geschmolzen ist

rate of glacier retreat in the region is 1.5 to 5 m/year, based on morainic levels between 4000 and 4300 m a. s. l.

The melting of Timoncito Glacier implies an acceleration of the rate of deglaciation since 1972. This compares favorably with the vertical retreat of 150 and 200 m, respectively, of glaciers in Ecuador and Perú between 1870 and 1909 (SIEVERS 1911).

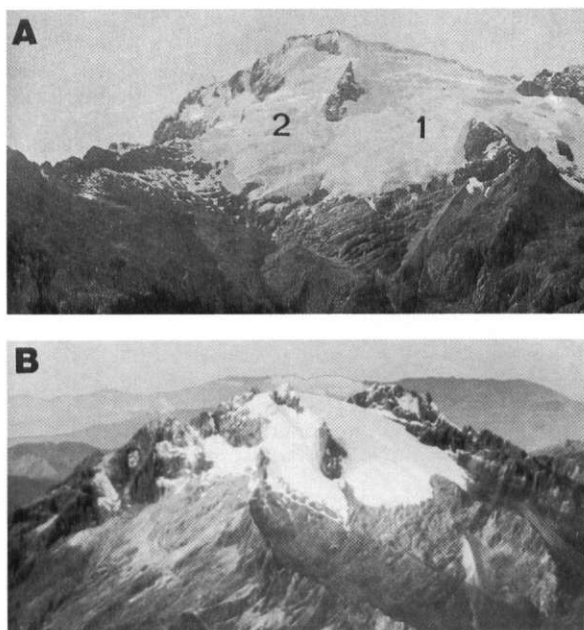


Fig. 7: Photographs of the glaciers of the north face of Pico Humboldt (no. 1 a. 2 of Fig. 2).

Photographs: A: A. JAHN, January 1910 (JAHN 1912b); B: R. HERRERA 1973 (personal communication)

Photos der Gletscher an der Nordwand des Pico Humboldt (Nr. 1 u. 2 in Abb. 2)

HASTENRATH (1981, p. 60) documented a significant glacier retreat in Ecuador during the last few centuries; the area reduction during this time interval was approximately 50%. A rapid retreat between 1938 and 1977 was documented photographically in the Sierra Nevada del Cocuy (Colombia) by VAN DER HAMMEN et al. (1981). The same was documented in the Sierra Nevada de Santa Marta (Colombia) by WOOD (1970), who estimated that at least one third of the glacier cover disappeared between 1939 and 1969. A spectacular retreat of several hundreds of meters in altitude was observed during the last 100 years in Perú (BROGGI 1943). Between 1944 and 1968, quantitative measurements on the Yanasinga Glacier (central Perú) suggest rates of glacier retreat between 3.2 and 4.6 m/year (PETERSON et al. 1969).

On the Picos Humboldt-Bonpland Massif the information is scarce. A rapid recent retreat of the glaciers is suggested by the existence of fresh, bare rock surfaces just below the glacier terminal zones, partially covered by fresh till (HANBURY-TRACY 1945, GIEGENGACK a. GRAUCH 1975). By January 1991, the glacier cover of the southeastern flank of Pico Bonpland (Nuestra Señora Glacier) had disappeared (Fig. 6). The glacier cover on the northwestern flank of Pico Humboldt (Coromoto Glacier) also diminished significantly between 1910 and 1973 (Fig. 7).

### Conclusions

In the Cordillera de Mérida, glaciers are only found on the highest peaks of the Sierra Nevada de Mérida. The total area occupied by the glaciers in 1952 was approximately 3 km<sup>2</sup>, and represents a reduction of approximately 98.5% in relation to the extent of Pleistocene glaciers. At present, these are hanging glaciers and there is ample evidence of rapid deglaciation during the last 100 years. At least three glaciers have totally disappeared since 1972 (Timoncito Glacier, the glaciers of the Pico La Concha Massif, and Nuestra Señora Glacier). To quantify this process, it is suggested that an urgent surveying program be initiated, together with periodic aerial and satellite surveys. The two principal glaciers that have melted since 1972 (Timoncito and Nuestra Señora Glaciers) were located on the southeastern flanks of their respective massifs. One factor that probably was significant in their accelerated melting was their exposure to the morning sun; in the afternoon, the Sierra Nevada is commonly covered with clouds, offering protection to the northwest-facing glaciers. At the same time, it should be investigated to what degree the atmospheric pollution produced by the city of Mérida, located in the narrow, deep Chama River valley about 25 km west of Pico Bolívar, is contributing to the accelerated melting of the glaciers observed during the last 20 years.

### Acknowledgments

I thank two anonymous referees for reviewing and improving the manuscript. The figures were processed by the Photography Department of I. V. I. C. (Caracas).

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