Band 21 (1985), S. 97—106

ZEITSCHRIFT FÜR
GLETSCHERKUNDE
UND GLAZIALGEOLOGIE

LATE QUATERNARY PALEOENVIRONMENTAL RECONSTRUCTION USING LAKE SEDIMENTS FROM THE VENEZUELAN ANDES: PRELIMINARY RESULTS

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With 5 figures

ABSTRACT

Sediment cores from a set of lakes in the Venezuelan Andes have been recovered. The lakes range in elevation from 1100 m to 3700 m; over this elevational range, vegetation changes from montane deciduous dry forest to páramo, and mean annual temperature declines by °16 C. Lake water chemistry is strongly related to elevation. Geochemical, sedimentological and palynological studies are underway to relate modern climatic conditions to near-surface sediment characteristics. The relationships will be used to interpret down-core variations in longer sedimentary records. Two cores (from 3450 m and 1100 m) span most of the Holocene; a third core (from 2300 m) goes back to 16,840±310 BP to the time of the Mérida glaciation. Climatic fluctuations in northern South America over the last 30,000 years are reviewed.

REKONSTRUKTION SPÄTQUARTÄRER UMWELTBEDINGUNGEN ANHAND VON SEESEDIMENTEN AUS DEN VENEZOLANISCHEN ANDEN (VORLÄUFIGE ERGEBNISSE)

ZUSAMMENFASSUNG

Sedimentkerne aus einer Reihe von Seen in den venezolanischen Anden wurden analysiert. Die Seen liegen zwischen 1100 und 3700 m über dem Meer, in diesem Höhenbereich wechselt die Vegetation von trockenem, montanem Laubwald zum Páramo, und das Jahresmittel der Temperatur fällt um 16° C. Die Chemie des Seewassers ist stark höhenabhängig. Geochemische, sedimentologische und palynologische Analysen geben Aufschluß über die heutige Beziehung zwischen Klima und Sedimenten, mit der längere Sedimentkerne untersucht werden. Zwei Kerne aus 1100 und 3450 m Höhe umspannen fast das ganze Holozän, ein dritter aus 2300 m geht bis 16.840±310 BP, der Zeit der Mérida-Vereisung. Schwankungen des Klimas der letzten 30.000 Jahre im nördlichen Südamerika werden behandelt.

1. INTRODUCTION

Lake sediments from a wide altitudinal range have been sampled from a limited area of the Venezuelan Andes (fig. 1). The sediments have been deposited in environments which currently range from sub-tropical to high alpine. Analysis of surface sediments is underway to identify characteristic modern palynological, sedimentological and geochemical signals in the sediments from different elevations. We hypothesize

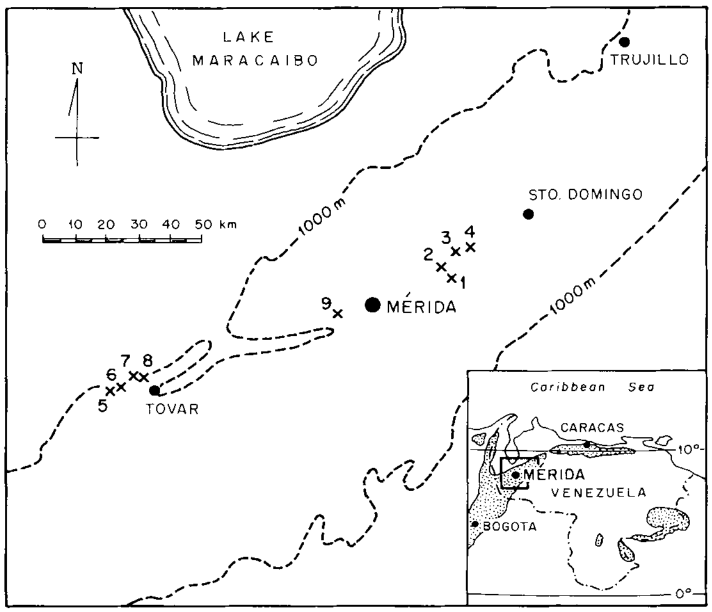

Fig.1: Location of study area. Lakes studies are numbered 1 to 9, as in table 1. Insert shows general location with areas above 1000 m shaded

that with increasing elevation, changes in pollen deposition and sediment characteristics should reflect the altitudinal climatic zonation and enable diagnostic signals to be identified for each zone (cf. Salgado-Labouriau 1979, Andrews et al. 1982). These signals, or "climatic signatures" in the modern sediments may then be used as a key to interpreting paleoclimatic and paleoenvironmental conditions during Late Pleistocene and Holocene time in longer lacustrine sedimentary records. As climatic and vegetation zones changed elevation in the past, so sediment composition and pollen deposition (i. e., the climatic signal) would have changed accordingly (Salgado-Labouriau and Schubert 1976, Salgado-Labouriau et al. 1977). Our objective is thus to determine if a strong altitudinally-dependent climatic signature can be identified in the lake sediments today, and if so, to apply this to the interpretation of longer sedimentary records. By utilizing both palynological and geochemical analyses, two independet paleoclimatic reconstructions can be developed and used as an internal check on the paleoclimatic interpretation.

2. LATE QUATERNARY CLIMATIC FLUCTUATIONS OF TROPICAL AND EQUATORIAL SOUTH AMERICA

Information on Late Quaternary climatic fluctuations of tropical and equatorial South America has been derived primarily from palynological studies of a few continuous peat or lacustrine records or from geomorphological studies of glacial, periglacial and alluvial deposits (e. g. van der Hammen and Gonzales 1960a, 1960b; van der Hammen 1974; Tricart 1974; Schubert 1970, 1975; Schubert and Valastro 1974; Salgado-Labouriau and Schubert 1976). Only peat and lacustrine sediments provide a continuous record of paleoclimate and the most comprehensive examples of such studies are those of van der Hammen and associates in Colombia. Based on several sequences, a fairly consistent picture of altitudinal fluctuations in vegetation zones has emerged, primarily as a result of changes in mean annual temperature, but also, at times, due to precipitation changes. These variations have been summarized by van der Hammen (1974) and by Flenley (1979) who also noted broad similarities with paleoclimatic records from other tropical regions of the world. In Colombia, a glacial advance prior to 30,000 BP was associated with mean annual temperatures 5—6° C below modern conditions and increased precipitation. At that time, the páramo vegetation zone in eastern Colombia (Sabana de Bogotá) may have been extremely reduced in area, and in places glaciers may have been locally in contact with the montane forest (van der Hammen et al. 1981). The Fuquenian glacial period (21,000—14,000 BP) (equivalent to the Mérida glaciation of the Venezuelan Andes; Schubert 1974) comprised two distinct stades. During these glacial episodes, the upper montane forest limit was 1500 m lower than today and an extensively dry páramo vegetation zone developed. Mean annual temperatures may have been 10—12° C cooler than contemporary climate (van Geel and van der Hammen 1973). At this time glaciers advanced down to ~3500 m in the Venezuelan Andes (Schubert 1970, 1972, 1974, 1982). At a later stage during the mid-Holocene, vegetation zones migrated upward in elevation 300 to 400 m above present levels, reflecting a significant warming trend (van der Hammen and Gonzales 1960b). A similar history has been suggested for the central Venezuelan Andes, based on short peat sections and interstratified peat and alluvial deposits (Salgado-Labouriau and Schubert 1977, Salgado-Labouriau et al. 1977, Salgado-Labouriau 1980).

Evidence of drier conditions over a wide area of tropical and equatorial South America during glacial periods has also been reported by Damuth and Fairbridge (1970). Tricart (1974) and Roa (1979) described "Wisconsin Age" dunes in the Amazon Basin and Venezuelan Llanos and thick Pleistocene alluvial sediments deposited in the Andes during (or following) an arid period have been described (Tricart and Millies-Lacroix 1962, Schubert and Valastro 1980). Much biogeographical research also points to extensive savanna-type vegetation in the Amazon and Orinoco basins during the Late Wisconsin glaciation of North America (Vuilleumier 1971, Haffer 1974, Vanzolini and Williams 1970, Brown and Ab'saber 1979). Bradbury et al. (1981) noted a late Pleistocene arid episode based on studies of lake sediments from Lake Valencia, Venezuela and studies of lake levels in Colombia also indicate a late Pleistocene dry episode (van Geel and van der Hammen 1973, van der Hammen et al. 1981).

In short, the record of climatic fluctuations in northern South America clearly indicates that very large changes in climate have occurred in the Andes during the late Pleistocene. In the Andes, these changes were amplified by the sharp altitudinal zonation of climate and associated vegetation. However, at the present time, the paleoclimatic record of the Venezuelan Andes is based primarily on episodic information (principally glacial deposits and alluvial sediments); relatively few detailed studies of continuous sedimentary records have been carried out.

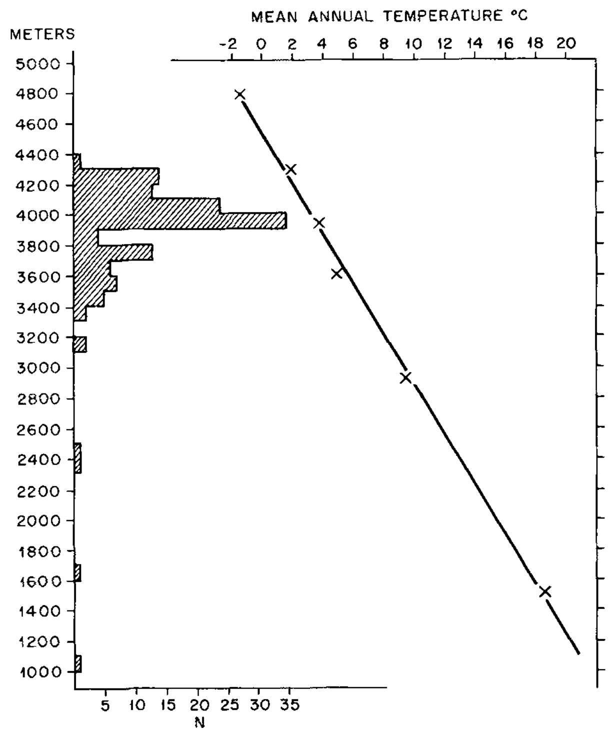

Fig. 2: Number of lakes (N) at various elevations in the Mérida area and mean annual temperature

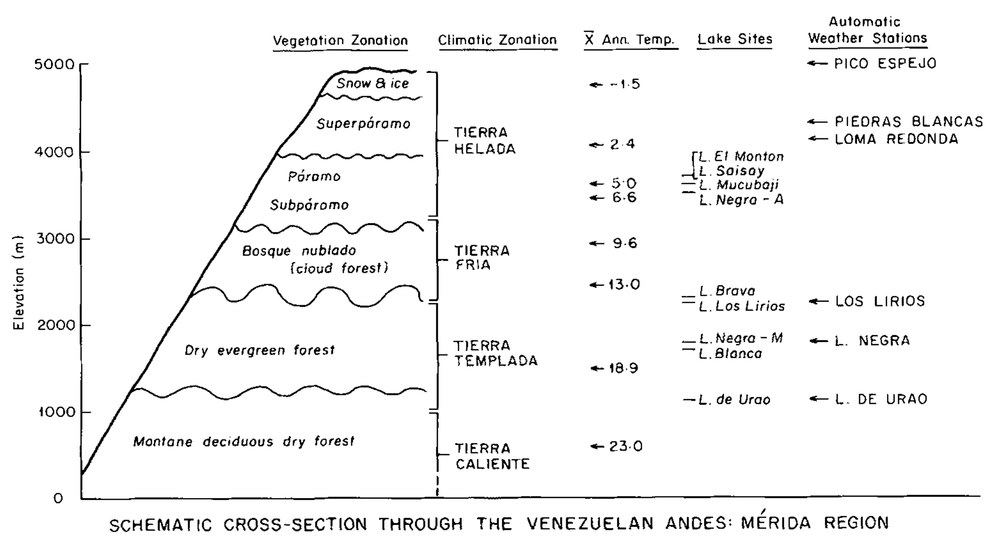

Fig. 3: Schematic cross-section through the field area. Vegetation zones are shown in relation to sites of lake sediment studies; location of automatic weather stations are also given (Vegetation zonation after Walter 1977)

3. FIELD AREA

In the area around Mérida, numerous small lakes can be found, ranging in elevation from 1100 to >4000 m (fig. 2). Over this elevational range, vegetation changes from thornbush and deciduous woodland *(tierra caliente)* through evergreen woodland *(tierra templada)* and cloud forest *(tierra fria)* to páramo and superpáramo *(tierra helada)* (fig. 3). Mean annual temperature is closely related to elevation, ranging from ~21° C at 1100 m, to ~1° C at 4200 m. Precipitation varies widely from <500 mm at the lowest lake site, to >1500 mm in the wetter páramo sites. Geologically, most lakes (with the exception of Lago de Urao) occur within similar rock types, metamorphic rocks of Upper Palaeozoic age, either the Sierra Nevada Formation (a banded gneiss) or the Mucuchachí Formation (schists and phyllites). The lakes are generally small (10—40 ha), with through-flow at higher elevations but generally closed (or only periodically open) systems at lower elevations.

Climatic records have been kept at many sites in the area for a number of years. To supplement these records, automatic weather stations have been installed at six sites in the area (fig. 3). Daily air and ground temperature, relative humidity, soil moisture and precipitation are being recorded to provide precise data from the lake study areas.

4. PRELIMINARY RESULTS

4.1 LIMNOLOGY

Limnological characteristics of nine lakes, ranging in elevation from 1100 m to 3700 m, have been determined (table 1). In spite of the limited number of samples, it is clear that pH values and conductivity of the surface waters decrease with increasing elevation. Individual cation concentrations (fig. 4) demonstrate a pronounced altitudinal dependency. These differences are presumably related to changes in evaporation

Table 1: Limnological Characteristics of Lakes Studied in Venezuelan Andes (October 1983)

Lake	Open/ Closed	Elevation (m)	Maximum Depth (m)	Water Temperature (° C)		Surface Water		pH[1]
				Surface	Bottom	Conductivity (μmhos)	Dissolved Oxygen (ppm)	
1. Saisay	Open	3700	43.40	11.0	8.0	8	7.5	6.2
2. El Monton	Open	3700	38.10	10.0	7.5	1	4.4	6.4
3. Mucubaji	Open	3540	15.80	9.5	8.0	10	6.4	6.7
4. Negra (A)[2]	Open	3460	23.75	8.0	6.9	10	5.0	7.0
5. Brava	Closed	2380	14.75	16.5	15.0	38	6.2	7.2
6. Lirios	Closed	2300	8.30	15.0	13.9	49	7.0	7.0
7. Negra (T)[2]	Closed	1700	3.85	15.5	15.5	20	1.2	7.4
8. Blanca	Closed	1620	4.75	20.0	19.1	72	7.0	7.0
9. Urao	Closed	1100	2.55	28.0	27.0	1700	—	10.0

[1] pH values are ±0.2.
[2] Negra (A) is near Apartaderos, between Mérida and Santo Domingo; Negra (T) is near Tovar (see fig. 1).

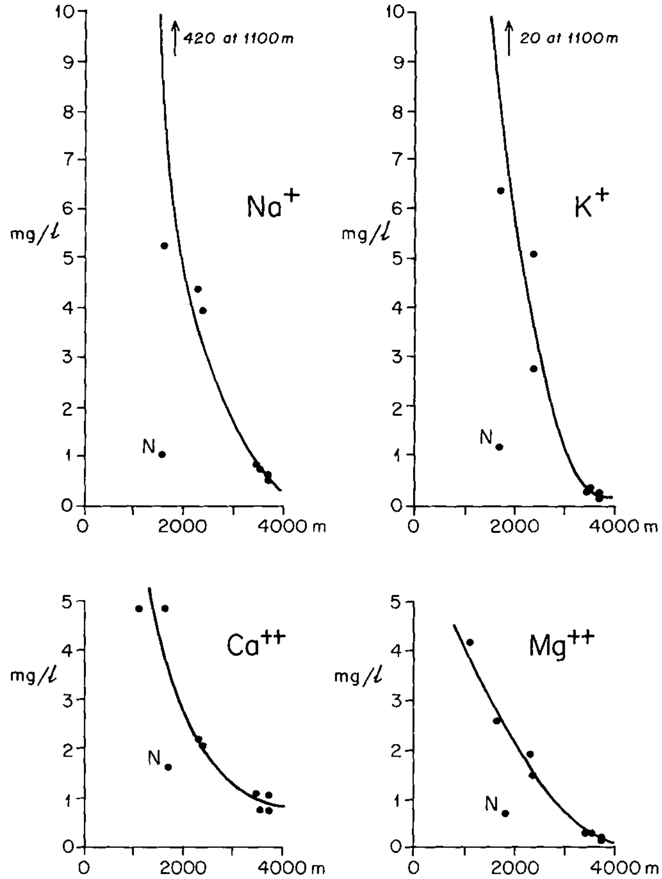

Fig. 4: Surface water cation concentration in relation to lake elevation. "Best fit" lines have been estimated by eye. Data from Laguna Negra (near Tovar) (marked N) are anomalous (see text)

rate with elevation and to the lake being within an open or closed basin. Cluster analysis of both surface and sub-surface limnological data (not shown) results in good discrimination of the samples by elevation, with potassium ion concentrations as the primary discriminant parameter. However, Laguna Negra (near Tovar) is anomalous (fig. 4); the reasons are unclear at present, but might be due to relatively rapid groundwater throughflow which would reduce evaporative concentration of the cations.

Of the lakes sampled so far, Lago de Urao is the most extreme case with the Na^+ concentrations two orders of magnitude higher than in any other lake sampled. This is most probably due to the fact that the drainage basin in which Lago de Urao is situated includes sedimentary rocks of Triassic and Cretaceous age. Lago de Urao is also the lowest lake studied and is in the most arid location ($\sim$400 mm precipitation per year). It is extremely shallow (generally $\sim$2 m deep) and sediments beneath the lake contain gaylussite (a hydrated sodium calcium carbonate [$Na_2Ca(CO_3)_2 5 H_2O$]).

4.2 SHORT CORES

Short cores ($\sim$ 1 m) have been recovered from the deepest parts of the lakes shown in table 1. These will be used to determine modern relationships between climate and sediment geochemistry, sedimentology and pollen content. Diatom studies of sediments are also planned. Initial analysis of the short cores from lakes above 3400 m indicate that carbonate carbon content of the sediments has steadily declined over the last 2000—2400 years (estimated age). Whether this reflects an increased sedimentation rate over the interval (and a steady carbonate production) is not clear; further ^{14}C analyses may resolve this question.

4.3 LONG CORES

Longer cores have been recovered from three lakes (table 2). Sedimentation rates (fig. 5) obviously decrease with elevation. A ^{14}C date of 6300 ± 215 a from the base of the shorter core from Lago de Urao suggests that the records of both cores are entirely

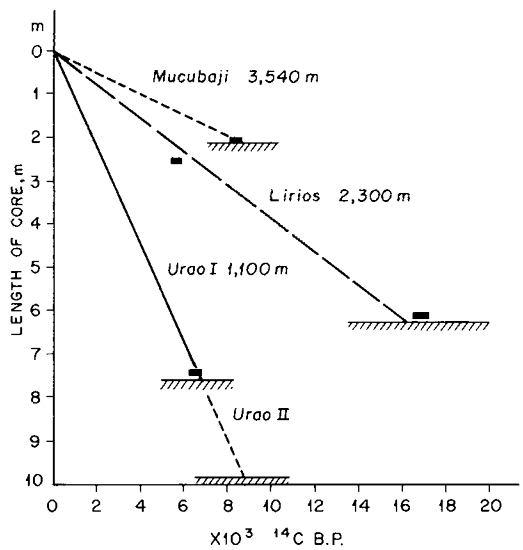

Fig. 5: Preliminary chronology for 3 long cores obtained in 1983—84. Two cores from L. de Urao are shown (see table 2). Sedimentation rate varies with basin elevation. The L. Los Lirios record extends back to the time of the Mérida glaciation

of Holocene age (the deeper sediments in core II are primarily clay and silts and do not contain enough organic material for conventional ^{14}C analysis). In view of the high sedimentation rate in this lake a fairly detailed reconstruction of Holocene paleoclimate should be possible. We interpret a thick layer of gaylussite crystals ($Na_2Ca[CO_3]_2 \cdot 5H_2O$) at the base of core I to indicate that the lake was at least partially desiccated immediately prior to 6300 BP. This may also be related to a marked change in stratigraphy of the sediments in Laguna Los Lirios (2300 m) at 2.5 m depth; at this level, sediments change from predominately gray inorganic to dark organic-rich material. A ^{14}C analysis above this transition gave a date of 5590 ± 170 a. The base of the Los Lirios core dated $16{,}840 \pm 310$ a, which means the record extends back into the time of the Mérida glaciation. According to Schubert (1980) the periglacial zone at that time would have extended down to approximately the elevation of the lake; at the present time, the lake is near the lower boundary of the cloud forest zone (fig. 3) so the sediments should document pronounced changes in vegetation and climate since the last glacial maximum. This core may also help resolve the controversy surrounding the occurence of a late glacial interstadial episode equivalent to the Allerød of western Europe (Mercer 1969, Clapperton 1984).

Table 2: Long Core Lacustrine Sedimentary Records and Dating Control

Site	Elevation (m)	Water Depth (cm)	Core Length (cm)	Sample Depth (cm)	Age (^{14}C Years BP)*	^{13}C (‰ PDB)	Sample I. D.
L. Mucubaji	3540	240	210	200—210	8,300 ± 255	−23.6	GX 9987
L. Los Lirios	2300	723	620	253—258	5,590 ± 170	−29.4	GX 10364
				610—620	16,840 ± 310	−26.9	GX −10326
L. de Urao I	1100	140	762	737—745	6,300 ± 215	−20.7	GX −10325
L. de Urao II	1100	124	962		**		

* ^{13}C corrected; ½ life = 5570.
** ^{14}C analysis not yet available.

Finally, sediments recovered from Lago Mucubaji (3600 m) gave a basal date of 8300 ± 255 a. In addition, short cores (≤ 1 m) from this and other lakes nearby should provide detailed records of climatic fluctuations in the late Holocene and provide valuable insight into Neoglacial events in the northern Andes.

5. SUMMARY

Short sediment cores (≤ 1 m) have been recovered from nine lakes in the Venezuelan Andes (ranging in elevation from 1100 m to 3700 m) with a view to interpreting their palynological, geochemical and sedimentological characteristics in terms of modern climatic conditions. Cation concentration in lake surface waters is inversely related to elevation. At the present time, mean annual temperature in the lake basins differs by 16° C, and vegetation zones change from páramo down to deciduous dry forests. Long cores have also been recovered from three lakes. The longest record (from 2300 m) spans the last 17,000 years; two other cores (from 1100 m and 3540 m) extend to early Holocene times.

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Paper presented at the Symposium on Climate and Paleoclimate of Lakes, Rivers and Glaciers in Igls, Austria, 4—7 June 1984. Revised 17 April 1985.

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