LATE PLEISTOCENE AND HOLOCENE CLIMATES OF VENEZUELA

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The present review accounts for the most important climatic data published until 1992 about Venezuela, and attempts to correlate them with other results from tropical South America. The evidence of climatic changes prior to the Last Glacial Maximum consists of several terrace levels, one of which representing an arid oscillation dated isotopic stage 6. Older terraces have not been dated and their meaning still remains questioned. The Late Mérida Glaciation Stage began between 19 and 16 ka, and ended around 13 ka, associated with an arid or semi-arid climate in the lowlands. The Post Glacial times (after 13 ka) were characterized by oscillations of colder and warmer climates in the mountains, correlated respectively with drier and wetter ones in the lowlands. The early Holocene is characterized by a climate similar to the present-day one, followed by a colder and drier phase around 6 ka. Present-like conditions established again until about 3 ka, when a new warm, humid phase began with a maximum at 2.5 ka. Later on, the current climate dominated. However, some minor oscillations occurred; the most notable one in the Little Ice Age (14th to 19th centuries). These climatic trends agree with those reported for the majority of the South American tropical regions, but a certain degree of heterogeneity exists in the Holocene, attributed to differences in the local climatic patterns and or to the high frequency of changes, the intensity and duration of climatic oscillations, as well as to differences in biotic responses conditioned by the internal properties of the ecological systems.

INTRODUCTION

Several fragmentary reviews about Venezuelan Quaternary climates are available. Ochsenius (1983) and Schubert (1988) concentrated on the Last Glacial, whereas Salgado-Labouriau (1984, 1989) summarized the information from the Venezuelan Andes after 13 ka. The literature about the glacials recorded in the northern Andes were compiled by Schubert (1989) and Schubert and Clapperton (1990), whereas the Holocene climatic trends of the Venezuelan Guayana were summarized by Schubert et al. (1986) and Rull (1991). Reviews on the Andean Little Ice Age include those of Rull (1987) and Rull and Schubert (1989). However, an up-to-date revision of the Venezuelan Quaternary climates (especially for the Holocene), and their correlations within the South American tropical context was not available. Consequently, the purpose of the present paper is to compile the information published until 1992 and to compare it with other results from the Tropics, in order to raise general conclusions. Multidisciplinary data (glaciology, sedimentology, palynology, palaeoecology, geochemistry, etc.) were reviewed, but only those with reliable radiometric dating were considered for correlations.

AREAS CONSIDERED AND PRESENT-DAY GEOLOGICAL AND CLIMATIC SITUATIONS

The Andean Páramos

The páramos have provided practically all the evidence about Pleistocene and Holocene climatic changes recorded in Venezuela. This area ranges between approximately 8°S and 11°N, and constitutes a particular ecological belt which dominates the Andean highlights between the upper forest limit and the permanent snowline (Lauer, 1979). In Venezuela, the páramos lie between about 2800 and 4700 m a.s.l., mainly in the periglacial zone (Monasterio, 1979; Salgado-Labouriau, 1979; Schubert, 1979), with a notably isothermal annual regime, in reference to the average monthly temperatures (5.3°C at 3500 m as.l. with a decrease of 0.6°C/100 m altitude), which strongly contrasts with notable daily oscillations, inducing soil frost every night above 3600 m altitude (Salgado-Labouriau, 1979; Schubert, 1974). Precipitation ranges from 600 to 1800 mm/year, with four dry months (December to March) and no altitudinal dependence (Monasterio and Reyes, 1980).

The Venezuelan páramos lie on metamorphic Precambrian and Paleozoic rocks, which have been modeled by glacial erosion and sedimentation (Schubert, 1979). Sculptured forms include hanging valleys, rock steps, glacial channels, cirques, aretes and horns, whereas sediments are represented by till (moraines and others) and fluvioglacial terraces (Schubert, 1974, 1975, 1979, 1982, 1984). The vegetation is open, and with two well-differentiated strata: the lower one consists of graminoid and rossette herbs, while the upper one is formed of shrubs and of the typical Espeletia (Compositae) caulirossules, which are the more conspicuous plant element of the páramos (Cuatrecasas, 1957, 1968; Vareschi, 1970; Sarmiento et al., 1971; Salgado-Labouriau, 1979; Monasterio, 1980). The páramos have been divided into three altitudinal levels by Cuatrecasas (1968): subpáramo, transition zone between the Andean forest and the páramo proper (equivalent to the páramo shrubland of Monasterio, 1980); páramo, up to the line of nightly freezing; and superpáramo, between it and the permanent snowline (the Monasterio’s desert páramo).

Lake Valencia

Lake Valencia is the most important natural inland lake north of the Equator in South America, having an approximate area of 350 km², a surface elevation of 402 m above sea level, and a maximum water depth of 40 m (Binford, 1982). It lies close to the northern coast of Venezuela (10°11'N/67°52'W), in a tectonic depression between the Cordillera de la Costa and the Serranía del
The vegetation is very diverse and heterogeneous, due to the communities (Huber, 1986). Four main types with an average precipitation of 2200-4000 mm per year, defined on the basis of scarce relict formations, the tepuis or Auyan-tepui and ranging from 2000 to 2900 m altitude) was (Briceño and Schubert, 1990). The uppermost (called (Gibbs and Barton, 1983). At least six erosional peneplain underlying patches of the typical quartzitic Roraima Group from the tepuian summits and the Gran Sabana highplains. Both are on the NE sector of the Precambrian Guayana Shield, consisting of an igneous–metamorphic basement with underlying patches of the typical quartzitic Roraima Group (Gibbs and Barron, 1983). At least six erosional peneplain surfaces have been recognized on this part of the shield, of which three have been developed on Roraima sediments (Briceño and Schubert, 1990). The uppermost (called Auyan-tepui and ranging from 2000 to 2900 m altitude) was defined on the basis of scarce relict formations, the tepuis or table mountains. The intermediate one, Wonkén (900 to 1200 m) constitutes the upper, more or less continuous, surface of the Gran Sabana highplains (Schubert et al., 1986; Schubert and Briceño, 1987; Briceño and Schubert, 1990).

The climate of the tepuian summits is cool and very humid (Galán, 1984), with mean annual temperatures of 10–14°C in the highest ones, and 17–21°C in the lowest ones, with an average precipitation of 2200–4000 mm per year. The vegetation is very diverse and heterogeneous, due to the high degree of environmental diversity and temporal environmental oscillations (Huber, 1986). Four main types of plant formations can be distinguished on the tepuian summits: forests, shrublands, herbazales and pioneer communities (Huber, in press). The most important forests of the highest tepuis are the gallery forests of Bonnetia (Theaceae), restricted to the water courses; whereas on the lower table mountains of the Venezuelan Guayana, extensive and diverse mountain forests occur (Steyermark, 1966; Steyermark and Dunsterville, 1980). Shrubs are the most developed and diversified life-form on the tepui summits (Huber, 1989; Steyermark, 1986). Especially important is the so-called paramoid shrubland, dominated by the Espeletia-like, endemic genus Chimantaea (Compositae). Herbaceous formations are dominated by Stegolepis (Rapateaceae) and Xyridaceae, whereas the colonizing communities consist of algae and lichens as well as small stands of Angiospermae, growing on open-rock surfaces.

The climate of the Gran Sabana is warm and humid (mean annual temperature and precipitation around 17–24°C, and 1600–2000 mm, respectively, Galán, 1984). A mesothermic treeless savanna, dominated by Gramineae, is the prevailing vegetation type (Huber, 1986) but the majority of rivers are surrounded by very diverse gallery forests. A special type of nearly monospecific gallery forests are the Morichales, dominated by Mauritia (Arecaceae), especially well-developed in the south of the Gran Sabana region (Terán and Duno de Stefano, 1988). Several hypotheses have been proposed in order to explain the presence of such a forest–savanna mosaic, including those in which Man would have played an important role (Fölster, 1986).

QUaternary Climates

Period Prior to the Last Glacial

No direct or conclusive evidence of Quaternary climatic changes before the last Glacial have been reported in Venezuela. However, climatic factors have been suggested as important causal mechanisms to explain several sedimentological and geomorphological features.

This is the case for the Andean alluvial terraces, formerly correlated with major worldwide glaciations, by analogy with similar European deposits. Schubert and Valastro (1980) offer a historical account of the study of these terraces, locally called mesas. Earlier workers invoked a tectonic origin, related with uplift events of the mountain range, but climatic interpretations were also proposed. Tricart and Milles-Lacroix (1962) developed a stratigraphical model based on geomorphology and meteorization intensity. They defined four altitudinal levels of terraces and correlated them with the four glacial periods. No isotopic dating was made. Correlations were based on the similarity of the lower Andean terrace level (TV) with the Late Pliocene/Early Pleistocene European ones. From this assumption, relative stratigraphical relationships were used to infer both age and genetic causes for the lowest levels. The terrace level called TIV was thus correlated with the Gunz alpine glacial, TIII with Mindel, TII with Riss and TI with Würm. These authors favoured the hypothesis of a climatic origin for the terraces. On the contrary, Shagam (1972a, b) and Giegengack (1977) supported that tectonics has been the decisive mechanism for the formation of these Andean deposits.

The first radiometric dates were provided by Schubert and Valastro (1980), but the time range of the 14C method
imposed serious problems for a satisfactory chronology. The ages of several successfully dated terrace levels resulted in their being younger than those assumed from mere geomorphological observations. Furthermore, these authors supported the view of Garner (1959, 1974, 1975) that arid or semi-arid climates favoured the accumulation of sediments into the valleys, whereas humid regimes determined the erosion of valley fillings, thus forming alluvial terraces.

On the other hand, thermoluminescence dating of sands and silts from level TII (formerly correlated with isotopic stage 6) gave ages between 45,000 and 47,000 BP corresponding to stage 3; whereas the level TIII (of an assumed Mindel age), was found to be around 147,000–170,000 years old (Schubert and Vaz, 1987), i.e. isotopic stage 6, which supports that valley filling occurred during glaciations, while cutting took place in interglacial epochs. The formation of the terraces would thus have been to a great extent climatically controlled.

The subjective Andean chronology of Tricart and co-workers was extrapolated to the Venezuelan lowlands, where no radiometric dates are available. In this view, Zink and Urriola (1970) recognized five alluvial terrace levels in the eastern Llanos, and deduced their ages from pedological arguments. The upper level (Mesa Formation, Q4) was assumed to be Lower Quaternary, because the existence of Oxisols and Ultisols which reflected a longer exposition to the meteorization agents. The youngest level (Q0) was dated in this way as Holocene (further studies support this assumption), and intermediate levels were considered Earlier/Middle Pleistocene (Q3), Middle/Upper Pleistocene (Q2), and Upper Pleistocene (Q1), respectively. This scheme, although it has been severely critized (Bezada and Schubert, 1987) was extrapolated to practically all the Venezuelan Llanos and to other lowlands (Vivas, 1984), even to the Guayana Shield (Guzmán, 1986). However, no objective dating supports these chronological assumptions.

The original relative chronology on which all these assumptions were founded (Tricart and Milles-Lacroix, 1962) was based on the correlation of the terrace levels with the four classical glaciations in the northern hemisphere (Zeuner, 1945). Nevertheless, further studies of both continental and marine sediments (van Donk, 1976; Fink and Kukla, 1977) showed the existence of at least 17 (and possibly more than 20) glacial/interglacial cycles, while a review of the longest continental climatic records (Kukla, 1989) reported the existence of 40 to 50 climatic oscillations of glacial/interglacial rank, during the last 2.5 million years. It seems, thus, difficult to subjectively choose the four right glacial events which contributed to the development of the Venezuelan terraces!

In spite of chronological problems, there is a general agreement about the climatic interpretation, both in the Andes and the lowlands. Accumulations are considered the product of torrential sedimentation in an arid or semi-arid climate, whereas dissection would correspond to more humid conditions, allowing the development of larger water currents, capable to erode the unconsolidated deposits. Aridity was correlated with glacial periods, and humidity with interglacial ones. However, the influence of tectonics has to be considered.

In brief, evidence of climatic changes prior to stage 2 in Venezuela consists in the existence of several terrace levels, of which only one (TIII) has been dated as isotopic stage 6, probably characterized by arid or semi-arid climates. The
palaeontological data are available at present. Andean and lowland terrace levels (lack of radiometric ages) remain unknown. For the same reason, correlation between defined, the first one presented by a moraine at 2600 to 2700 m, the second by a morainic complex at 3000 to 3500 m. The last glacial event observed in the Venezuelan Andes, directly related with the Mrrida moraines (Salgado-Labouriau and Schubert, 1976; Salgado-Labouriau et al., 1977). Two main glacial stages within the Mrrida Glaciation have been defined, the first one presented by a moraine at 2600 to 2700 m, the second by a morainic complex at 3000 to 3500 m. The radiometric ages which support this chronology were obtained from peat sediments accumulated after the formation of the upper morainic level, so only a minimum age of 13 ka may be given for the moraines. This minimum age for the Late Mrrida Stage increased when Schubert and Rinaldi (1987) dated 16 to 19 ka fluvio-glacial sediments of a glacial outwash plain, derived from moraines of the upper altitudinal complex. Therefore, the upper morainic level corresponds to the Last Glacial Maximum (CLIMAP, 1976), whereas the lower one, although younger, is of unknown age. An eventual correlation with the Andean TII terrace level, TL dated about 45 to 47 ka (Schubert and Vaz, 1987), would equate the Earlier Mrrida Stage with the Middle Würm/Wisconsin of the northern hemisphere (Bowen et al., 1981; Schubert, 1989). On the contrary, a refuge was tentatively postulated by Salgado-Labouriau (1984), on the basis of radiocarbon dating and pollen analysis. In the base of the Tuñame Andean terrace, some organic layers could be successfully dated, giving ages between about 34 and 50 ka (Schubert and Valastro, 1980). The pollen assemblages of these sediments were dominated by trees (mainly Alnus and Podocarpus), indicating that a humid gallery forest existed at the site during the Mrrida Glaciation. Moranic complexes, which presumably developed during this cold interval, lie a few hundreds of metres above, so the páramo could have been compressed. Another possibility, as pointed out by Salgado-Labouriau (1984), is that the Tuñame region constituted a forest refuge area.

Consistent evidence of aridity was found around the Andes, during the Mrrida Glaciation (Schubert, 1988; Tricart, 1985). A multidisciplinary study of Lake Valencia showed that aridity prevailed from 13 to about 10.5 ka, coinciding with the Late Mrrida Stage (Binford, 1982; Bradbury, 1978; Bradbury et al., 1981; Leyden, 1985; Salgado-Labouriau, 1980). The same is true for Lake Maracaibo, which covered a very small portion of the present lake at the end of stage 2. According to sedimentological studies and radiocarbon dates (Sarmiento and Kirby, 1962), the ancient lake area probably consisted of swamps and dry areas. Extensive dune fields, also indicative of past arid climates, were found in the Llanos and radiocarbon + TL dated about 11 to 12 ka (Roá, 1979; Vaz and García-Miragaya, 1989). Another TL age of 36 ka was obtained for one of these dunes (Vaz and García-Miragaya, 1989) but, unfortunately, the lack of sampling information and suitable palaeoecological context does not allow its inclusion in the discussion. Other alluvial terraces were found on the northern Coastal Range (Schubert, 1985), associated to the Guayana tepuis (Schubert, 1986), and tentatively correlated with the last glacial event, but no radiometric dating is available.

Palaeontological evidence of an assumed humid climate (mainly fossils of mastodons) were found and dated ca. 13 ka in Falcón (review in Schubert, 1988). This evidence is not conclusive, because the large mammals from which the fossils probably derived could also live in savanna or arid environments, and because no palaeoclimatic inference could be found in the original reports of these fossil findings (Bryan, 1973; Bryan et al., 1978). In consequence, these data cannot be used as correlation units.

From a biogeographic point of view, it is noteworthy that some of the localities which provided palaeoecological evidence of aridity (especially the Lake Valencia region and Guayana), were previously postulated as Pleistocene biological refuges (Haffer, 1982; Prance, 1982). However, after the quoted results and others (review in Schubert, 1988), this hypothesis had progressively lost reliability (Bradbury et al., 1981; Schubert, 1989). On the contrary, a refuge was tentatively postulated by Salgado-Labouriau (1984), on the basis of radiocarbon dating and pollen analysis. In the base of the Tuñame Andean terrace, some organic layers could be successfully dated, giving ages between about 34 and 50 ka (Schubert and Valastro, 1980). The pollen assemblages of these sediments were dominated by trees (mainly Alnus and Podocarpus), indicating that a humid gallery forest existed at the site during the Mrrida Glaciation. Moranic complexes, which presumably developed during this cold interval, lie a few hundreds of metres above, so the páramo could have been compressed. Another possibility, as pointed out by Salgado-Labouriau (1984), is that the Tuñame region constituted a forest refuge area.

In brief, reliable dating exists for the Late Mrrida Glaciation Stage, which seems to have been in progress between at least 19 and 16 ka, and ended before ca. 13 ka. It has also been reasonably proved that lowlands were characterized by arid or semi-arid climates during this time. Other analytical data seem to favour the existence of a Middle Mrrida Stage, at ca. 45–47 ka, but it depends in great extent on the truthfulness of the correlations among undated moraines and dated alluvial deposits.

### The Last Glacial

The most firmly supported data about Late Pleistocene
climates proceed from the Andes, but several reliable suggestions can be derived from Lake Valencia and Guayana.

Since 13 ka, the oldest measured date on postglacial deposits (peat accumulations favoured by the existence of a terminal moraine at Mucubají (Salgado-Labouriau et al., 1977), a general deglaciation trend is registered (Salgado-Labouriau et al., 1988). However, some minor stadial and interstadial oscillations are recorded by pollen analysis and radiocarbon dating. Salgado-Labouriau et al. (1977) found a cold interval between ca. 12.6 and 12.2 ka, during which the tree line was 400 m below its present position, suggesting a decrease of about 3°C in mean annual temperature. A subsequent increase of temperature (Mucubají Warm Phase) of probably more than 5°C occurred, and lasted until about 11.9 ka, when another cold interval (Mucubají Cold Phase) started. The end of this last event was situated at about 11.1 ka (Salgado-Labouriau et al., 1988) or 9.3 ka (Salgado-Labouriau, 1989), whereas the estimated temperature decrease was of about 2° to 3°C below the present averages.

A detailed study of the Pleistocene/Holocene boundary was carried out by Salgado-Labouriau (1980) on Lake Valencia sediments. A dry period was recorded between ca. 13.4 and 11.5 ka. Some chronological confusion exists in later deposits, probably on account of the reworking of lake sediments (Salgado-Labouriau, 1980). Bradbury et al. (1981) extended the arid phase until 10.5 ka, which fits the younger Dryas.

It seems clear that around 10 ka the climate became wetter. The late Valencia dry event (13.4–11.5 ka) started at the end of the Mérida Glaciation and ended at the beginning of the Mucubají Phase. Radiocarbon and TL ages of lowland dunes and associated sediments, also indicating arid climates, show good chronological agreement (ca. 12.3 to 11.1 ka, Roa, 1979; Vaz and García-Miragaya, 1989). On the other hand, indications of a more humid climate coincide with the former signs of deglaciation, at ca. 10 ka.

As a consequence, it seems that during the Pleistocene/Holocene transition colder events in the highlands can be correlated with drier phases in the lowlands, whereas Andean interstadials coincided with wetter lowland climates.

The Holocene

The Pleistocene/Holocene boundary was found at ca. 10 ka in both the Andes (Salgado-Labouriau et al., 1988) and Lake Valencia (Salgado-Labouriau, 1989), showing good agreement with the Earth’s global scheme (Fairbridge, 1983). We shall sum up briefly the recorded Holocene climatic oscillations, based on pollen analysis of peat and lacustrine sediments, considering only the radiocarbon dated records.

In the Andes, both postglacial vegetation and climate were similar to the present-day ones from 10 to 6.3 ka. However, the high mountain belt páramo seemed to be poorer in species than today (Salgado-Labouriau, 1989), probably due to the slow colonization processes (Salgado-Labouriau et al., 1988) which began with poor and fluctuating herbaceous communities, showing a subsequent diversity trend which was not saturated until about 3 ka (Rull, 1990).

A climatic phase, cooler and drier than at present (La Culata dry phase), was found in the páramos at ca. 6 ka (Salgado-Labouriau and Schubert, 1976), but conditions similar to the present ones returned and remained until 3–3.5 ka, when a warm and humid phase (the Miranda Warm Phase) started (Salgado-Labouriau et al., 1988). This represents the maximum of recorded mean Holocene temperatures until the present. Estimations based on the position of the tree line provided values of around 1.2°C above the present-day mean temperatures. This phase is represented by a rich páramo vegetation, and occurred at the point in which the diversity spectrum stabilized, producing a little variation on successional trends (modulated succession of Rull, 1990). Late Holocene climates were similar to the present, except for a short glacial phase which will be discussed later on.

The continuous and well-dated Holocene record from Lake Valencia provided important information on Late Pleistocene aridity, as well as Holocene palaeolimnological features. According to Binford (1982) and Leyden (1985), their climatic inferences also showed good agreement with those found elsewhere; however, these environmental deductions arose from lake-level and salinity fluctuations, and climatic forcing is not guaranteed in all cases (Bradbury et al., 1981).

The Holocene climatic trends of Guayana agree very well with those of the Andes, but they consist mainly in humidity variations, due to both latitude and altitude (the summit of the highest tepui, the Roraima, is below the Andean páramo belt, where all geomorphological evidence of Mérida Glaciation were found).

The last peat-forming event on the tepui summits began in the Middle-Holocene; drier climates were thus assumed for the Late Pleistocene–Early Holocene (Schubert and Fritz, 1983; Schubert et al., 1986). This conclusion is based on the ages of the older tepuian peat deposits (ca. 7 ka), and also of lower altitude alluvial sediments (8 ka), interpreted as the products of mechanical erosion in arid or semi-arid climates (Briceño, 1985). Rull et al. (1988a, b) suggested that the beginning of peat formation is older, because the pollen assemblages from the base of all peat sections reflect plant communities with a certain degree of complexity not to be expected in early stages of colonization. On the other hand, the bottom of a peat bog from the Gran Sabana (Mapauri) as dated at 8.9 ka (Rinaldi et al., 1990).

Subsequent climates were similar to the present on the majority of the tepui summits, but several minor local oscillations were recorded (Rull, 1991), with a certain degree of spatio-temporal heterogeneity. For example, a Bonnetia forest retreat was recorded in Amur bi about 5.5 and 4.4 ka, when a probable lowering of vegetational belts occurred in Churi. This would indicate a decrease of both temperature and humidity, but no signs of this event was found on the other tepuis studied (Acopán, Toronó, Guaiquinima and Auyán).

In the Gran Sabana, however, the situation is more homogeneous. An Early-Holocene phase, drier than today,
extending until about 6.5 ka, was recorded at Mapaurú (Rinaldi et al., 1990), but it cannot be correlated with other sequences, due to the lack of peat bogs of similar ages. Nevertheless, this drier phase occurred approximately at the same time as the Andean La Culata Dry Phase. This reconstruction being based on peat analyses, the climate was not arid or semi-arid, but only indicates a decrease of the precipitation/evaporation (P/E) ratio. A more humid interval extended probably until about 4 ka, followed by another decrease of P/E, ending around 3 ka.

From this period, the more intense Holocene oscillation was recorded in all the tepui summits and the Gran Sabana sections studied. Between about 3.2 and 1.5 ka, both temperature and humidity slightly increased, coinciding with the Andean Miranda Warm Phase, showing that it was a very wide climatic event. The increase of humidity was reflected in both the expansion of Bonnetia forests (tepui summits) and lake levels rise (Gran Sabana), whereas the temperature increase was based on altitudinal displacements of ecological belts from Churi (Rull, 1991, 1992).

In the Venezuelan part of the Amazon Basin, Sandford et al. (1985) and Saldarriaga and West (1986) found significant amounts of soil charcoal, with radiocarbon ages ranging from about 6 ka to the present. Several of these charcoal-forming events (interpreted as fire events) coincided with dry phases recorded in other places of Amazonia, but it is not still clear if these fires were related with climatic droughts or human disturbance. In brief, the existence of an Early-Holocene arid or semi-arid phase on the lowlands is evidenced. However, we only have minimum ages (those corresponding to the base of the sedimentary sections analyzed) for this dry event, and a correlation with some episode of the Mérida Glaciation cannot be discarded. A subsequent interval of climate similar to the present was followed by a cold and dry event at about 6 ka, and returned again before a warm–humid phase initiated at ca. 3–3.5 ka. A general glacier retreat took place, confirmed by the observation of a spectacular glacier retreat in the Andes during the last 100 years (Schubert, 1984).

**The Last Centuries**

Short-term processes interrupted this general warming: Schubert (1972, 1975) and Schubert and Valastro (1974) described an upper complex of minor moraines on the Venezuelan Andes, at about 4000 m altitude, and hypothesized about the possibility of recent glacial readvances. Pollen analysis and radiocarbon dating of a peat bog, situated near the altitudinal level of the quoted minor morainic level, allow to report a lowering of about 1.8–2°C in the mean temperatures (the Piedras Blancas Cold Phase, Salgado-Labouriau, 1989), beginning approximately in the 14th century (Rull et al., 1987) and thus correlated with the Little Ice Age. It was assumed to be responsible for the formation of these upper moraines (Rull and Schubert, 1989). Radiocarbon dates indicated that a subsequent episode of deglaciation started at about the end of 19th century, showing good agreement with the mentioned historical records summarized by Schubert (1984).

A previous paleoecological work on Laguna Victoria sediments (Salgado-Labouriau and Schubert, 1977) detected a recent forest retreat and attributed it to human action, on account of the presence of Rumex pollen, a weed introduced by the Europeans. Too little evidence is available to correlate this retreat with the Piedras Blancas Cold Phase, although this relationship has been suggested (Rull, 1987; Rull et al., 1987), based on a reinterpretation of the data from Laguna Victoria, showing that the forest retreat began before the appearance of Rumex. Furthermore, it is known that Europeans reached the Venezuelan Andes in 1560 AD and developed cattle raising after 1570 (Wagner, 1967, 1979), prior to which, the pdramos were not used by the autochthonous Andean cultures either as permanent establishment sites or for agricultural purposes (Wagner, 1978, 1979). Human practices could be important factors to avoid a return to the former ecosystems, but they could hardly be a triggering mechanism for the detected disturbance which began in the 14th century (Rull, 1987).

The only detailed record of this period beyond the Andes proceeds from the Urué valley (Gran Sabana), and is also founded on palynological analysis and radiocarbon dating (Rull, 1991, 1992). In that area, a minimal plant cover was recorded around 1300 AD. The increase of Gramineae pollen at the expense of Mauritia was interpreted as a reflection of a decrease in P/E. This trend was maintained until about 1750 A.D., when the P/E ratio increased. According to these results, the Andean last glacial episode could be correlated with this Gran Sabana dry event.

**CORRELATIONS WITH TROPICAL SOUTH AMERICA**

The main body of data about pre-LGM climates in tropical South America proceeds from the Andean Range, and was reviewed by Clapperton (1983) and Schubert and Clapperton (1990). They show a lack of unequivocal evidence of glacial deposits in the northern Andes (Venezuela, Colombia and Ecuador) earlier than isotopic stage 2. However, fifteen Quaternary glacial/interglacial cycles could be recognized on Funza, Bogotá and Fiquene long cores in the Colombian highplains (Hooghiemstra, 1984, 1988, 1989; Hooghiemstra and Sarmiento, 1991; van der Hammen, 1979, 1988). The terrace levels TII and TIII from the Venezuelan Andes match the Funza pollen zones 2 and 4, respectively, which are characterized by lowerings of altitudinal belts implying a temperature decrease during isotopic stages 2 and 6.

The last glacial was recorded in many South American tropical regions (Clapperton, 1983; Schubert, 1988, 1989; Schubert and Clapperton, 1990). Two main episodes could be recorded; the first one from 43 to about 33 ka, roughly coinciding with the Venezuelan terrace level TII, the last one 28 to 18 ka (van der Hammen et al., 1981; Helmens, 1988; Herd, 1982; Clapperton, 1983, 1987; Hastenrath, 1981), which allows its correlation with the second advance of the Mérida glaciation. These glacial advances correspond with aridity or semi-aridity in the lowlands of tropical South America (Damuth and Fairbridge, 1970; Schubert, 1988; van der Hammen, 1988) and with the sea-level changes (Bard et al., 1990).

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(Mucubaji climatic phases) between 13 and 10 ka probably relate with the general regional and global trends: they coincide with similar oscillations in Colombia (González et al., 1965; van der Hammen and González, 1960a; b; van der Hammen, 1978; van der Hammen et al., 1981; Helmens, 1988), Ecuador (Clapperton and McEwan, 1985; Clapperton, 1987), and Perú (Mercer, 1983; Mercer and Palacios, 1977) and with the global younger Dryas episode.

Markgraf and Bradbury (1982) summarized the data available on Holocene climates until the earlier 80s. A phase as humid as or more humid than today expanded from 10 to 8 ka (and possibly until 6 ka), whereas the interval 6 to 4 ka was drier and cooler. From about 4 ka to the present, significant regional differences existed and no general climatic trends could be derived.

This general picture agrees with the Venezuelan climatic trends until about 6 ka (La Culata Dry Phase). However, further research revealed different climatic trends: Campbell and Frailey (1984) proposed that a wet climate dominated the Amazon Basin between 11 and 5 ka, Graf (1981) claimed for a climate favourable to peat growth from 7 to 5.5 ka, in the Peruvian/Bolivian Andes. In contrast, other studies agree with the conclusions of Markgraf and Bradbury (1982), and the Venezuelan findings. Noteworthy are the record of a drastic lowering of the Andean Lake Titicaca (Bolivia) level between about 7.7 and 3.6 ka (Wirman and de Oliveira, 1987), and the inferred dryness from about 7 to 6 ka in nearby places (Servant and Fontes, 1984). A glacier readvance was recorded in the Colombian Andes just before 6 ka (van der Hammen et al., 1991).

Before the Miranda Warm–Humid Phase (3.3–1.4 ka), when a climate similar to the present-day one existed in the Venezuelan Andes, several dry phases occurred in the American Tropics. Examples were found on the Brazilian and Ecuadorian parts of the Amazon Basin (Absy, 1982, 1985; Colinvaux, 1987; Colinvaux et al., 1988; Liu and Colinvaux, 1988); and in the Colombian and Guyana plains (Wymstra and van der Hammen, 1966). This contrasts with the occurrence of the relatively moist period found in Ecuadorian lowlands between about 5 and 3.4 ka (Servant et al., 1981). The Miranda Warm-Humid phase was paralleled by a general glacier retreat in the northern Andes, between about 2.7 and 1.6 ka (Markgraf and Bradbury, 1982), although some discrepancies exist, for example a rainfall decrease in the Brazilian Amazon Basin (Absy, 1982, 1985), and a glacial readvance in the Colombian Andes, between about 4.7 and 2.6 ka (van der Hammen et al., 1981).

Contrasting with this very heterogeneous Holocene picture, remarkably good agreement exists in both chronology and intensity of the cold and dry phase correlated with the Little Ice Age, at least in the Colombian (van der Hammen, 1974; van der Hammen et al., 1981), and the Peruvian (Thompson et al., 1986) Andes.

One of the most conspicuous facts in the Holocene is the high degree of heterogeneity observed in both dates and palaeoclimates. According to Markgraf and Bradbury (1982), this could be due to the variability of climatic patterns or to a high frequency of changes. But, despite sampling and statistical errors, both the intensity and the duration of those climatic oscillations (Rull, 1991), as well as medium-scale features like, for example, latitude and local mesoclimatic factors, would be important. Short and low-intensity variations could produce slight vegetational changes in sensitive communities, but not in the more tolerant ones, while extended and stronger oscillations probably determined more intense ecological reorganizations. Between these extreme cases, a wide range of possibilities and a gradient of ecological responses exist. Furthermore, the responses vary because they depend on the ecological characteristics of the involved ecosystems. Properties such as resilience, response time (lags), successional maturity, and other internal ecosystem features (the so-called ecological noise, Rull, in preparation) are important at the moment in which the environment changes. The same climatic disturbance acting on different ecosystems or on different serial stages of the same successional process may produce different responses.

Besides, climatic features are not necessarily homogeneous at the scale of tropical South America. At present, a very high variability of temperatures, precipitation regimes, aridity, and other climatic characteristics can be found in this region. Both deserts and hyperhumid zones, as well as hot and glacial areas coexist. Since palaeoecological data are largely based on punctual reconstructions from different places, a certain degree of heterogeneity is not surprising, but is logical. Local phenomena must be considered in the interpretation of past climates. For instance, a present climatic record based on the Andean glacier retreat, the aridity of northwestern Venezuela and the extremely humid Amazon climate, would be very difficult to interpret in terms of a tropical South American characterization. If we accept that the present is a key to the past, the acceptance of a more dynamic point of view, which considers the implicit heterogeneity, is necessary. The rule is a succession of regional, large-scale trends, spiked with more small-scale, heterogeneous oscillations. We have to separate those two scales in the records of the past. Climatic and ecological variations seem not to be discrete, but gradational and overlapping phenomena. Of course, regional and intense variations can be found and correlated, but minor, punctual variations may obscure the picture if a correlation with the former is attempted.

REFERENCES


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