Radiocarbon Ages of Peat, Guayana Highlands (Venezuela)

Some Paleoclimatic Implications

C. Schubert and P. Fritz

Instituto Venezolano de Investigaciones Científicas, Apartado 1827, Caracas 1010A, Venezuela, and Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, Canada N2L 3G1

Paleoecological studies in the Guayana Highlands revealed the presence of relatively old organic deposits. Eleven radiocarbon ages determined in four stratigraphic sections of a 1–2-m-thick layer of peat indicate that it is entirely of Holocene age. The deposits formed when humid climate succeeded Late Pleistocene glacial aridity. This observation does not support the contention that the Guayana Highlands were ecologically stable for long periods of geological time.

Late Pleistocene glacial aridity in northern South America has been well documented. The main sedimentological, paleontological, and geomorphological evidence for this aridity include: fossil dunes in the Llanos, arkosic sands on the Brazilian continental platform, palynological analyses in Venezuela and Guiana, anomalous river drainages in Venezuelan Guayana, alluvial fans and river terraces, and the presence of sula complexes, relict savannas, stone-lines, white sand (intraformational and fluvial) on divides, and ferruginous duricrusts [1]. The majority of this evidence comes from areas peripheral to the Guayana Highlands (Fig. 1).

The Guayana Highlands consist of numerous table mountains [2] cut into the Precambrian Roraima Group [3], which is mainly a sandstone sequence (approximately 2 km thick in its type section) and which overlies unconformably older Precambrian igneous and metamorphic rocks. The table mountains rise to just below 3000 m elevation at Auyán-tepui (Fig. 1) and their summit has been associated with an erosional surface (Auyán-tepui surface; [4]) of unknown age (possibly pre-Tertiary).

Recent ecological surveys of the upper Caroní river drainage area have revealed the existence of discontinuous peat deposits on the summit of most table mountains. This peat overlies directly sandstone of the Roraima Group and is drained by acid "black" water streams [5], which flow either in poorly developed beds or along fracture systems in the sandstone, forming spectacular canyons. Age determination of the peat deposits, the substrate on which most of the vegetation grows, is important to unravel the natural history of this unusual montane ecological environment.

Samples of herbaceous peat were collected at four sites following general methodology [6]: two on Churí-tepui (Chimantá Massif) and two on the Guaiquinima Massif (Fig. 1), for ra-

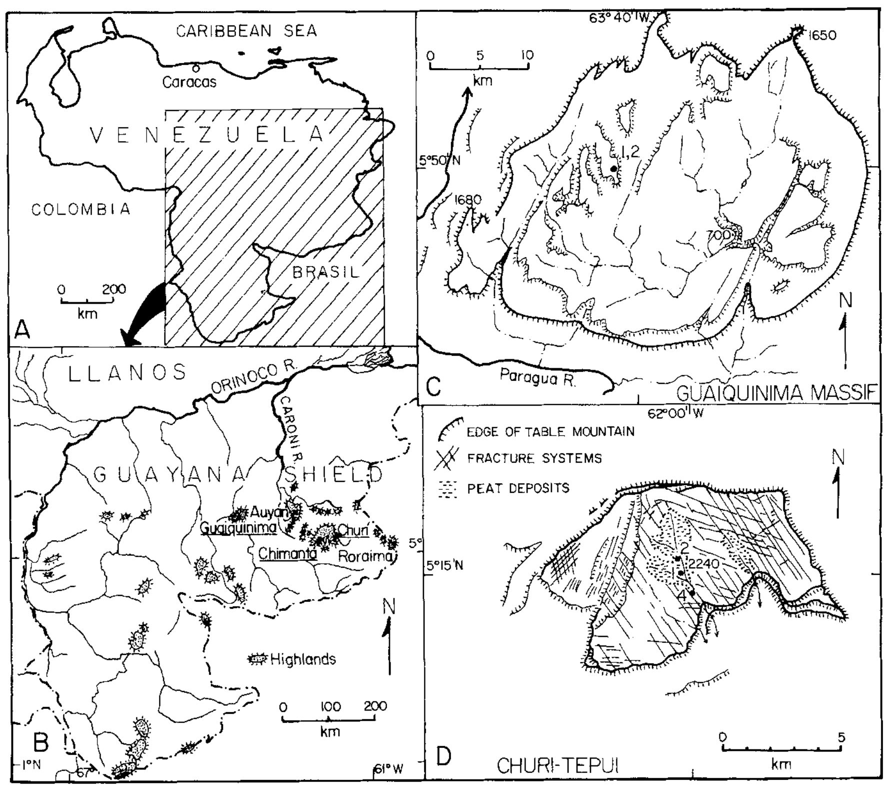

Fig. 1. A) Index map. B) Map of southeastern Venezuela showing the principal table mountain complexes of the Guayana Highlands (simplified after [13]). C) Map of Guaiquinima Massif showing location of the two coring sites (simplified after [13]). D) Photo-interpretation map of Churí-tepui (Chimantá Massif) showing peat sampling localities. Elevation in m

Table 1. Radiocarbon analytical data for peat and wood samples from the Chimantá and Guaiquinima Massifs. Analyses were done at the Department of Earth Sciences, University of Waterloo

Waterloo number	I.V.I.C. number	Depth [m]	Material	$\delta^{13}C$ [‰]	% Modern	^{14}C age [a]
Churí-tepui, locality *1*						
WAT-1163	CHIM-11	0.20–0.31	peat	−24.5	105.9	–
WAT-1173	CHIM-12	0.42–0.55	peat	−25.8	83.3	1450 ± 60
WAT-1164	CHIM-13	0.69–0.83	peat	−25.6	48.9	5740 ± 100
Churí-tepui, locality *2*						
WAT-1159	CHIM-9	0.39–0.45	peat	−25.3	75.0	2300 ± 60
WAT-1174	CHIM-10	0.63–0.70	peat	−24.9	74.3	2390 ± 70
WAT-1175	CHIM-10A	0.67–0.70	peat	N.A.	73.5	2480 ± 90
Churí-tepui, locality *4*						
WAT-1158	CHIM-14	0.90–1.00	wood	−23.8	82.4	1580 ± 190
Guaiquinima Massif, locality *1*						
WAT-1162	GUAIQ-1,2-3	0.20–0.30	peat	−21.9	96.6	330 ± 60
WAT-1172	GUAIQ-1,12-16	1.20–1.60	peat	−24.6	53.1	5100 ± 90
Guaiquinima Massif, locality *2*						
WAT-1171	GUAIQ-2,2-3	0.20–0.30	peat	−23.4	96.0	350 ± 60
WAT-1161	GUAIQ-2,11-15	1.10–1.50	peat	−24.2	47.4	6000 ± 80

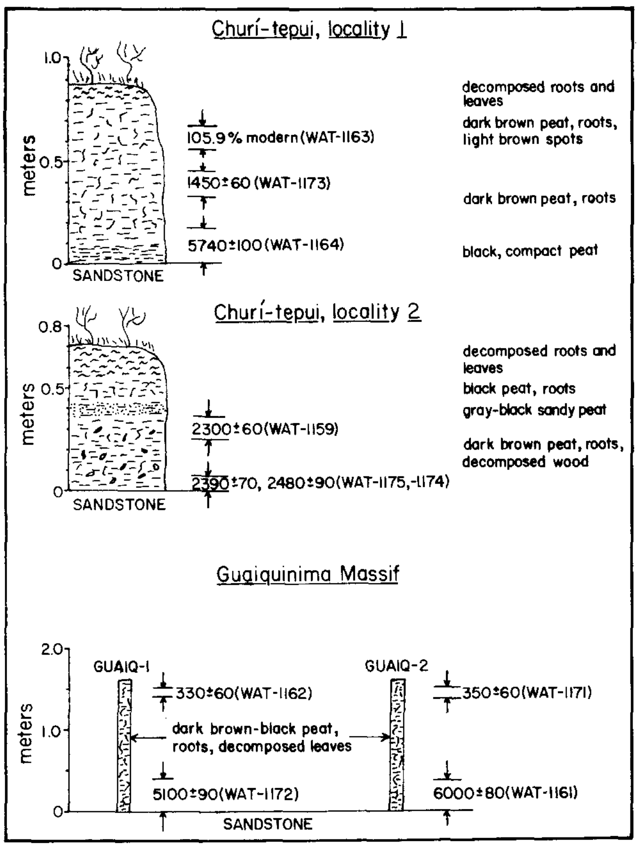

Fig. 2. Stratigraphic and cored sections at Churí-tepui and Guaiquinima Massif, with a brief description of the peats and the radiocarbon ages obtained

diocarbon dating (Table 1). Samples on Churí-tepui were collected from two peat sequences cropping out along the main stream draining the southern slope of this table mountain. Figure 2 shows the general stratigraphy of these sequences. In addition, on Churí-tepui a sample of wood fragments at the base of 1-m-thick peat sequence (locality *4*, Fig. 1 D) was radiocarbon-dated (WAT-1158, Table 1). On Guaiquinima Massif, two borings (1.6 m depth each) were made with a Hiller corer, because no peat outcrops were found, and samples were collected from two intervals (0.2–0.3 m, and 1.2–1.6 and 1.1–1.5 m) by combining several corer samples until approximately 1 kg of wet material was obtained. Roots (live and dead) were the principal contaminant, and were removed. Radiocarbon determinations were performed by liquid scintillation counting on benzene prepared by standard techniques. The preparation included combustion and an aliquot of the CO_2 produced was used for mass-spectrometer analyses of ^{13}C. Radiocarbon data are presented as conventional ages ($t_{1/2} = 5568$ years) and are expressed as percent modern (pmc), i.e., 95% of the activity of the NBS oxalic acid standard. ^{13}C-data refer to the PDB standard and are used to adjust radiocarbon ages to a $\delta^{13}C = -25‰$.

Results of the radiocarbon analyses are shown in Table 1 and Fig. 2. The peat sequences of Churí-tepui (locality *1*) and Guaiquinima Massif (localities *1* and *2*) show radiocarbon age sequences which range from ultramodern or recent to 6000 ± 80 ^{14}C years B.P. (distribution of radiocarbon ages in the profiles suggests significant post-depositional compaction).

Locality *2* on Churí-tepui gave anomalous ages in that the middle and lower parts of the sequence have the same radiocarbon ages within the standard deviations; this may be the result of an erosional-depositional event (shown by the intercalated sandy interval) and/or erosion by the adjacent stream and re-deposition of peat (peat erosion by streams was observed at many localities, marked by leached sandstone at localities previously covered by peat). From the sample descriptions, it is evident that contamination by contemporary material (mainly roots) was inevitable; however, applying a correction for a contamination as high as 30% would give maximum radiocarbon ages between 6250 and 7300 years for the bottom of the stratigraphic sections [7]. The fact that three localities on two different table mountains gave approximately similar maximum ages for peat deposition suggests that present-day peat deposition began long after the beginning of the Holocene.

Forest refuges have been postulated in the Amazon basin and surrounding areas during Pleistocene glacial periods (see [8] for reviews), in order to explain the biological evolution of this region. However, very few paleoecological studies have been published within these refuge areas. So far, they show that even in these areas, significant climatic changes (mainly widespread aridity) occurred during the Late Pleistocene glaciation (for example, in the Lake Valencia region, Venezuela, in areas of Guiana, and Brazil [9]). Recently, evidence for a Late Holocene age of the Amazonian drainage system has been found [10]. The Venezuelan Guayana Highlands have been postulated as the Pantepui refuge area or as a long-existent habitat [11]. Our radiocarbon data suggest that the last peat-forming event began in the Middle Holocene; previous to that, the summits of the table mountains must have had a much drier climate with sparse vegetation cover and predominance of mechanical weathering and erosion [12]. Radiocarbon dates on wood fragments from alluvial sequences near the middle Caroní river suggest that the products of this erosion were deposited beginning at about 8000 ^{14}C years B.P. [4]. The "surprisingly low endemicity" of the generic flora on the table mountain summits observed by Steyermark ([11], p. 205) may be explained by the relatively modern occupation of the highlands (Salgado-Labouriau, pers. comm.). In conclusion, we suggest that the table mountains were not a Pleistocene or early Holocene refuge for the modern summit flora; peat deposition on the summit characterizes the present interglacial period, while relative aridity characterized the last glacial period. The existence of a long geological period of ecological stability (particularly during the Quaternary), at least in the Guayana Highlands, is not supported by our data or by other geological-geomorphological data [1].

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Accumulation of Linear Alkylbenzenesulphonate Surfactants in Sewage Sludges

J. McEvoy and W. Giger
Swiss Federal Institute for Water Resources and Water Pollution Control (EAWAG), Federal Institute of Technology, CH-8600 Dübendorf

Linear alkylbenzenesulphonates (LAS) are the major synthetic surfactants currently manufactured. Their global production in 1982 was estimated at 1.1×10^6 metric tons which accounted for 28% of all synthetically produced surfactants [1]. Commercial LAS surfactants are characteristically complex mixtures [2] which are composed of components having alkyl chains of C_{10} to C_{15} with C_{11}, C_{12}, and C_{13} usually predominant. LAS are extensively employed in both household and industry as cleaning agents, and have wide application in textile, paper, pulp and paint processing. The heavy usage of these surfactants and their subsequent release into the wastewater system prompted this study into the occurrence of LAS in sewage sludges and their behaviour and fate during sewage sludge treatment. In Switzerland approximately 70% of the sewage sludge (corresponding to 110000 metric tons of dry sludge year^{-1}) is applied to agricultural land. Hence the report that LAS can make up 5% of the fulvic acid fraction in sewage sludge [3] is of considerable concern.

For this study, sludge samples (Table 1) were collected from eight Swiss sewage treatment plants which have