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Critical Comments on Ice-Age Amazon History of Climate and Vegetation Based on New Field Evidence

By

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Kurzfassung

Die Frage, ob das letzte Hochglazial (LGM) im Amazonas-Gebiet durch eine verstärkte Aridität und/ oder durch eine markante Temperaturabsenkung charakterisiert wurde, wird in jüngster Zeit in verschiedenen Arbeiten von COLINVAUX und Mitarbeitern aufgegriffen. COLINVAUX stützt seine Aussagen auf Untersuchungen an organischen Ablagerungen (Pollen und Pflanzenresten) beim Ort Mera im östlichen Tiefland von Ecuador. Zwei ^{14}C-Daten (33,5 und 26,5 ka B.P.) sollen nach den Autoren das letztkaltzeitliche Alter der Profile belegen. Aufgrund geomorphologischer und paläopedologischer Befunde muß jedoch für die Mera-Profile ein wesentlich höheres Alter (Mittel- bis Altpleistozän) angenommen werden. Die Diskussion der letzteiszeitlichen Klima- und Vegetationsverhältnisse Amazoniens sollte daher zukünftig ohne Bezug auf die Daten der Mera-Profile vorgenommen werden. - Neue Beobachtungen zur Vergletscherungsgeschichte der Anden Ecuadors stützen zudem die Annahme größerer Aridität während des LGM.

Resumen

Acerca de la pregunta, si la región del Amazonas se caracterizó durante el último máximo de glaciación (LGM) por marcada aridez y/o significativa depresión de temperaturas, ha sido retomada por Colinvaux y colaboradores. Colinvaux apoya su tesis en investigaciones hechas en base a depósitos orgánicos (polen y restos de vegetación) en una localidad cercana a Mera en las llanuras orientales del Ecuador. Con 2 datos obtenidos por medio de C^{14} (33,5 y 26,5 ka B.P.) los autores fundamentan la edad de los perfiles. Pero, debido a investigaciones geomorfológicas y paleopedológicas, la edad de los perfiles debe suponerse mayor (Pleistoceno medio o inferior). La discusión debería entonces proseguir sin tomar en cuenta los hallazgos hechos en Mera. Recientes observaciones hechas sobre la glaciación de los Andes ecuadorianos apuntan hacia una mayor aridez durante el máximo de la última glaciación (LGM).

INTRODUCTION

What the Amazon was really like during the LGM is still unknown and is subject to some dispute (COLINVAUX 1979, 1989). A temperature depression at the LGM of about 6 °C is postulated by LIU & COLINVAUX (1985) and COLINVAUX (1987, 1989); this conflicts with the hypothesis of equatorial aridity during the LGM. If the ice-age Amazon climate was indeed different from what it is today (e.g.

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colder), then the modern rainforest communities are younger than previously thought (COLINVAUX 1989).

THE RESULTS OF COLINVAUX

In recent years COLINVAUX (1987a, b; COLINVAUX & LIU 1987; LIU & COLINVAUX 1985) reports the discovery of forest beds in the Amazon Basin radiocarbon dated to the Wisconsin/Weichsel glaciation. These are the first dates from the last glaciation determined on Amazonian samples. The locality is in Ecuador near the upper limit of the present Amazonian rain forest. With only this section from Mera available for the Amazon Basin (besides the Serra dos Carajás site in Brazil), COLINVAUX argues for a considerable temperature depression of the Amazon Basin during the LGM. COLINVAUX' conclusions on the ice-age Amazon climate contradict earlier observations in tropical South America as well as climatic modelling.

Because of the great importance of the results on ice-age climatic conditions in Amazonia made availabale by COLINVAUX, I visited the Mera site earlier in 1990 to study the morphology, sedimentology and paleopedology of the section (Fig.1).

The data published by LIU & COLINVAUX (1985), consist of fossil wood embedded in polliniferous sediments at 1100 m elevation, exposed in road cuts and radiocarbon-dated to 33,520 ± 1010 (B 9618) and 26,530 ± 270 (B 10170).

In the following I will give a short summary of the results of COLINVAUX (1987a:226f):

"The Mera site is within the altitudinal range of lowland tropical rain forest in Amazonia, though approaching the upper limit ... LIU & COLINVAUX (1985) used surface pollen samples to show that the modern rain forest near the Mera elevation of 1100 m is indeed comparable to that at elevations down to 250 m. Pollen from the fossil sections, however, differed markedly from these modern rain forest spectra. As with other pollen sections from the western Amazon lowlands, both fossil and modern pollen spectra from the Mera vicinity included numerous rare pollen taxa which could not be given botanical names. In addition, the pollen spectra are not directly comparable to any modern plant associations. But that the vegetation of Mera 33,000 to 26,000 B.P. differed markedly from modern Amazonian rain forest of the region is evident.

The Mera fossil pollen spectra [Table 1] have several properties in common with surface spectra from the Interandean Plateau in Ecuador at elevations above 2000 m, particularly in forest taxa. Podocarpus pollen is present and Alnus is prominent, with a near absence of the rain forest Cecropia. But the fossil spectra also differ from the Andean surface samples in that the spectra lack significant contributions from taxa like Gramineae, Chenopodiaceae and Amaranthaceae, or Rumex that apparently record the arid properties of modern Interandean vegetation, situated as it is in rain shadows from both cordilleras. Prominence of Cyperaceae in several Andean surface samples can be attributed to local overrepresentation from Scirpus totora beds surrounding the small lakes from which the samples were taken. When these arid or local properties of the modern Andean samples are set aside, a clear affinity of the fossil Mera spectra with Andean forest samples remains, strongly suggesting

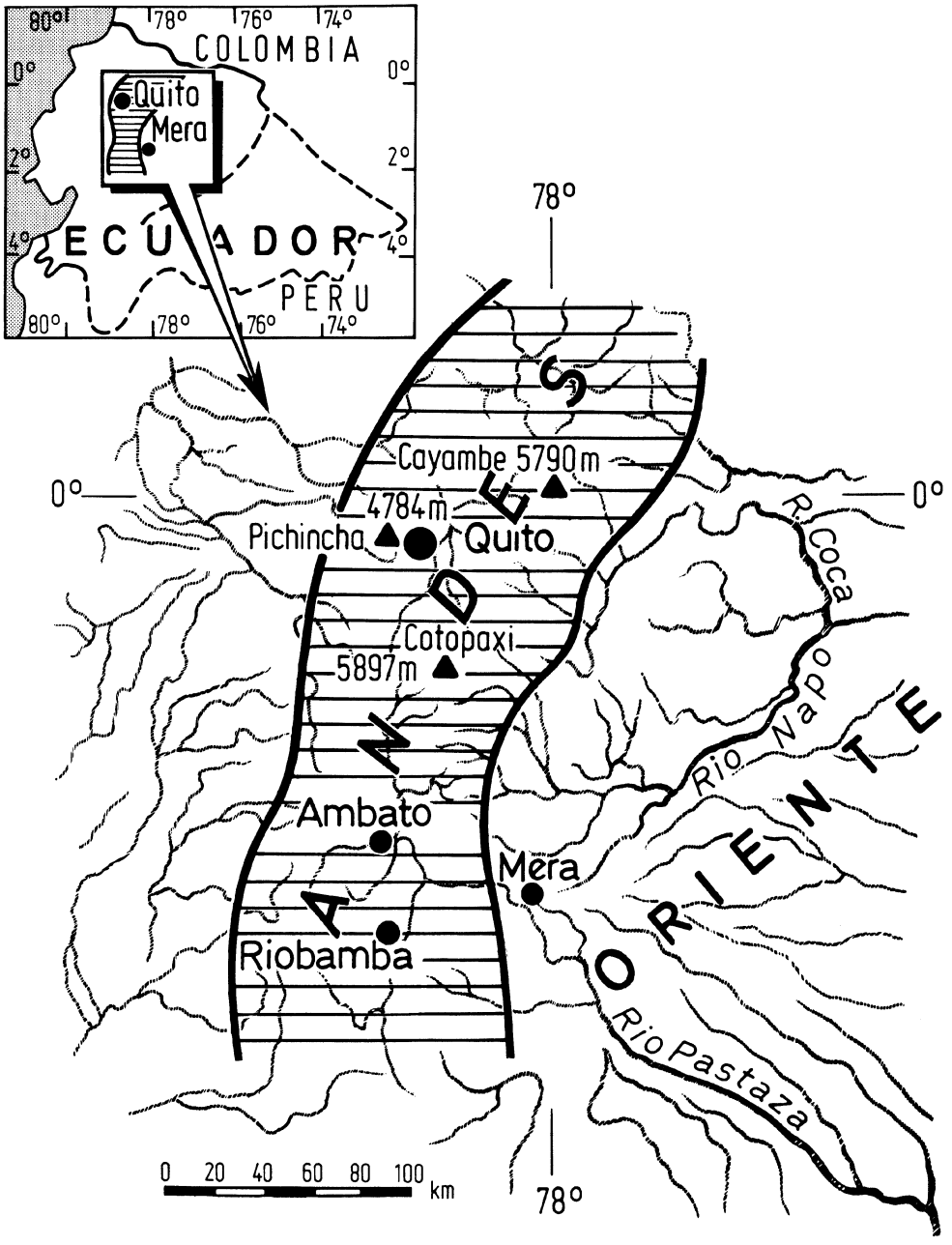

Fig.1: Index map showing the Mera site

that the Mera site was occupied by a diverse, moist, montane forest thirty thousand years ago. A forest depression of at least several hundred meters is implied ...

Since the lowest record for Podocarpus in Ecuador is at 1800 m, LIU & COLINVAUX (1985) concluded that forest types were lowered by at least 700 m at 33,000 and 26,000 yr B.P., implying a minimal temperature depression of 4.5°C during times of glacial maxima. This temperature depression is minimal, both because the data give no reason for thinking that the Mera site was at the lowest elevation of the ancient Podocarpus stands and because the dating is consistent with the fossil forests having been of interstadial rather than full glacial age..."

COLINVAUX (1987a) holds the opinion that the analysis from the Mera site is consistent with the work in the high Andes (HOOGHIEMSTRA 1989) in suggesting that temperature depression was a significant property of glacial climates at the equator, and allows extrapolation of the Andean results to low elevations.

These appear to be the only calculations of temperature at glacial maxima to have been made for anywhere in wet equatorial lowlands, and the results conflict with the widespread belief that temperature depression at low latitudes and low elevations was modest.

According to COLINVAUX the true temperature depression in the lowland Amazonian forests of Ecuador at the LGM was in the order of 6°C, the same as it was in the Colombian Andes.

THE MERA SITE REVISITED

LIU & COLINVAUX (1985) report the discovery of two forest beds near the village of Mera (Fig.2). The Mera site 2 is located in the upper part of fluvial sediments near the Rio Pastaza/Rio Alpayacu confluence in about 50 m above the floodplain of the Rio Pastaza. The Mera section 1 is located about 3 km downvalley at the eroded edge of the lower pediment gravels (Fig.2).

The geomorphologic development of the Mera region is characterized by the fluvial history of the Rio Pastaza and its tributaries (Fig.3). Near Mera the Rio Pastaza leaves the Andean mountain ranges, from which issue debris-laden rivers (Rio Pastaza, Rio Chico, Rio Alpayacu). Large alluvial fans have been built of gravels, debris, and sand by flood waters of these south-flowing rivers. By lateral planation pediment-like forms developed. After the formation of the upper pediment the streams cut down through their pediment deposit and eventually sweep most of it out of the region. During this degradation a terrace is formed that is now dissected by many small valleys. The lower pediment developed. According to our knowledge of pediment formation along the equatorial Andean mountains we suggest a relatively arid climate during the deposition of the pediment gravels. Such paleoenvironmental conditions may have occurred during the late Pliocene or early Pleistocene. With the shifting to Quaternary climatic conditions, the development of a series of alluvial river terraces started. In the vicinity of the Mera 2 section a wide terrace is formed by the degradation of the lower pediment gravels.

At the Mera 1 exposure (Fig.4), the organic bed is found in between the pediment sequences, thus documenting an age of early Pleistocene at least. The Mera 2 section may be a part of the pediment

	Conru (2,800 m)	Yambo (2,600 m)	Yaguarcocha (2,210 m)	San Marcos (3,400 m)	Rum Tum (2,392 m)	Kumpak* (700 m)	Añangucocha (230 m)	Puyo Bog (953 m)	Lago Agrio (330 m)	Sta Cecilia (330 m)	Mera (1,100 m)
Podocarpus		0.3	0.4								0.4
Palmae				0.6				0.3	0.6	1.0	
Iriartea					0.3	2.3	2.4	0.3	13.3	9.3	1.2
Cecropia	0.7	2.3	0.4			43.1	63.4	43.3	39.3	49.8	0.8
Ficus						3.4		1.2	7.2	1.0	
Urticaceae-Moraceae	5.2	10.6	4.4	1.7	2.0	10.4	4.8	17.3	14.5	14.1	4.0
Melastomaceae	1.4	3.0	1.6	1.0	1.7	1.9		1.5	0.9	0.3	7.6
Trema		0.7		0.7		0.4		1.2	2.3	2.3	
Piper						1.9	1.6	0.6	3.5	0.7	
Alnus	2.1	1.0	0.4	0.3							4.8
Hedyosmum	0.3			0.3							10.0
Acalypha						13.7		0.9	0.9	2.3	
Gramineae	36.8	27.3	14.0	37.7	70.0	1.5		6.3			0.8
Compositae	1.7	2.3	2.4	5.7	4.3		0.8	2.7	0.3	1.0	0.8
Plantago	3.8	2.0				0.4					
Rumex	8.3	1.0	1.6								
Chen-Am	1.7	8.7	7.8		0.3	0.4	0.8				
Cyperaceae	27.4	5.7	57.8	2.7	1.3		1.6	1.5			
Monolete	0.7	2.0	0.8	11.3	2.3	2.7	10.6	2.7	1.7	1.6	13.6
Trilete	0.9	3.0	2.4	5.0	0.3	2.3		1.3		2.3	2.8
'Others'	12.5	31.9	18.7	29.6	11.6	21.0	27.3	19.5	18.9	14.3	53.2

Tab.1: Pollen from Mera forest bed compared with modern pollen spectra (after LIU & COLINVAUX 1985:557). Añangucocha sample is from surface pinches of moist forest soil; Puyo bog is surface organic matter of a tropical swamp; Rum Tum is mud from a small pond; Yaguarcocha is from just below the settlement layer of a sediment core to yield pollen from the Interandean Plateau before human disturbance. Remaining samples are from mud-water interfaces of lakes. LIU & COLINVAUX distinguished >200 pollen taxa in Amazonia fossil pollen samples, although many of these cannot yet be given taxonomic names. They have included as 'others' many identifiable, but infrequent pollen types as well as a considerable number of tricolporate and tricolpate taxa yet to be identified. They have also combined subdivisions of other taxa like Moraceae and Urticaceae

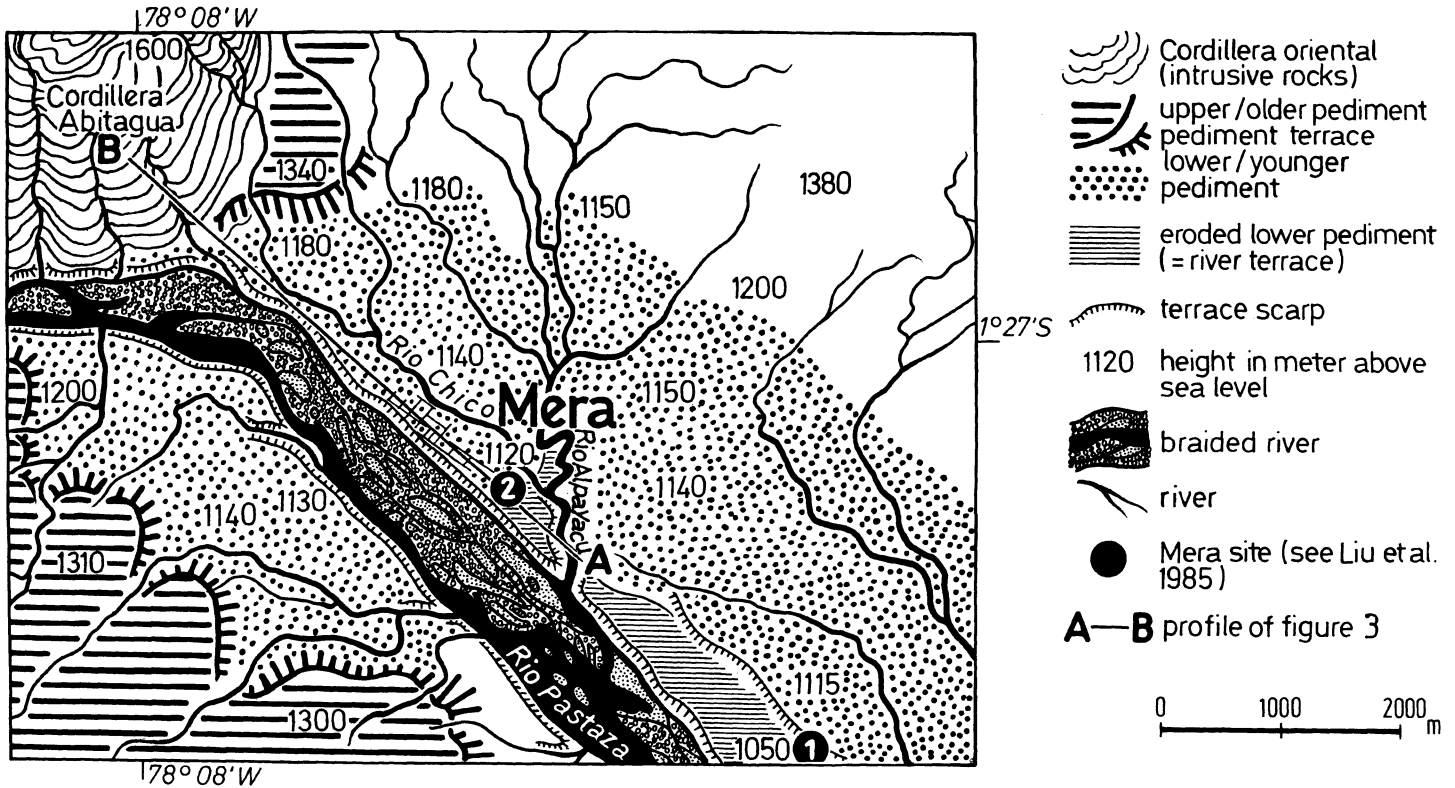

Fig. 2: Geomorphology of the Mera region

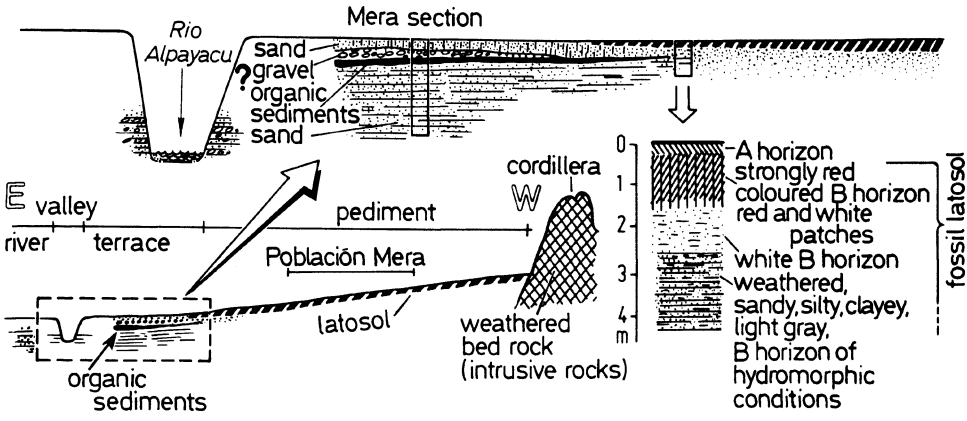

Fig.3: Schematic profile of the pediment and river terrace along a transect between the Río Alpayacu and the Cordillera Abitagua (see fig. 2)

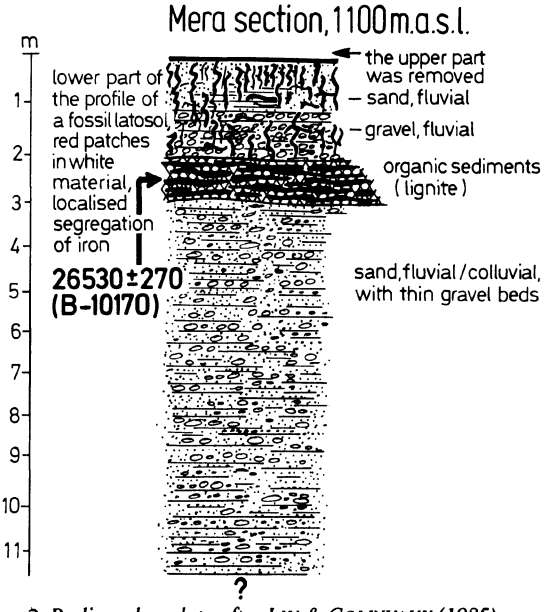

Fig.4: The Mera section 2. Radiocarbon date after LIU & COLINVAUX (1985)

sequence, too, although the overlying fluvial gravels suggest that the dark organic layers were formed after the degradation of the pediment gravels, and before the sedimentation of the river terrace that overlies the fossiliferous bed. The Mera 2 organic bed is at least of middle Pleistocene age, taking into account its geomorphologic setting.

Pedological observations give further information about the possible age of the Mera 2 forest bed. The exposure consists of deeply weathered gravelly sand at the base, overlain by sandy gravel with small rounded boulders. The organic bed is covered by fluvial coarse gravels; these are overlain by fluvial sand. The surface of the river terrace runs into the surface of the lower pediment (Fig.3+4). Relict,

strongly red coloured latosols characterize the surface of the pediment. These ferrallitic soils represent the final phase of development and weathering of soils in a hot and humid tropical climate. In the northwestern part of the exposure, the organic deposits are overlain by these latosols, whereas in the southeastern part of the section the top of the fossil soils has been eroded. Only the B horizons with their typical red and white patches marking seasonal alternations of wetting and drying during their development document that the original soil profiles were stripped. Soils comparable to these relict latosols are the product of the climate of lower elevations and of long time periods. Similar ferrallitic soils do not develop today in the vicinity of Mera nor did they develop during the Holocene. Even during the late Quaternary latosol formation was absent in comparable areas of the eastern Amazon Basin.

Both, the morphology (river terrace and pediments) and the paleosols (type and weathering thickness of the relict latosols, see SEMMEL 1985), suggest that the organic layers were not deposited during the LGM (33.5 and 26.5 ka B.P.) as is concluded by LIU & COLINVAUX (1985) and COLINVAUX (1987a, b, 1989). The organic sediments must be of at least middle or lower Pleistocene age. Until now we have no information about the paleoenvironmental history of the eastern Amazon basin and the equatorial Andes, therefore we do not know under what circumstances the pediments of the Mera region were formed.

There is strong evidence that the radiocarbon dates mentioned by LIU & COLINVAUX (1985) do not represent the true ages of the deposition of the organic layers. The dates of 26.5 and 33.5 ka B.P. suggest that the samples were contaminated with modern ^{14}C.

Without doubt, pollen data are the most important source of information with respect to Quaternary vegetation and climate history. The assemblages of species that LIU & COLINVAUX (1985) report from the Mera forest beds reveal an Andean pollen spectra that is not closely comparable to pollen from any modern facies of the Andean forests (Table 1). 53.2 % of the pollen from the Mera forest bed is unidentifiable; only when taxa like Gramineae, Chenopodiaceae, Amaranthaceae, or *Rumex* were set aside, a clear affinity of the Mera spectra with the Andean forest samples remains (COLINVAUX 1987a). The bad preservation of the wood fragments in the Mera beds, the high amount of unidentifiable pollen, and the weak resemblance with modern pollen spectra from Ecuador may be a hint that the Mera forest beds are not of Weichsel/Wisconsin age, but of middle or early Pleistocene age.

Our preliminary results give no reason to expect a climate of the LGM so much colder than the present as to exclude ice-age rain forest from the Mera site. The Mera site is not suitable for LGM climatic reconstructions of the Amazon Basin because the sedimentology, geomorphology, and paleopedology of the sections were studied incompletely by LIU & COLINVAUX (1985), and because the chronostratigraphic setting is not clear.

Hence, for the Amazon Basin, reconstruction of ice-age conditions from empirical data still must be based on meagre evidence from lowland sites and on studies of lake sediments (HOOGHIEMSTRA 1989; MARKGRAF 1989), fluvial series (CAMPBELL & FRAILEY 1984; SHOWERS & BEVIS 1988), and glacial histories from the equatorial Andes (CLAPPERTON 1987; SCHUBERT & CLAPPERTON 1990; SELTZER 1990; VAN DER HAMMEN 1987).

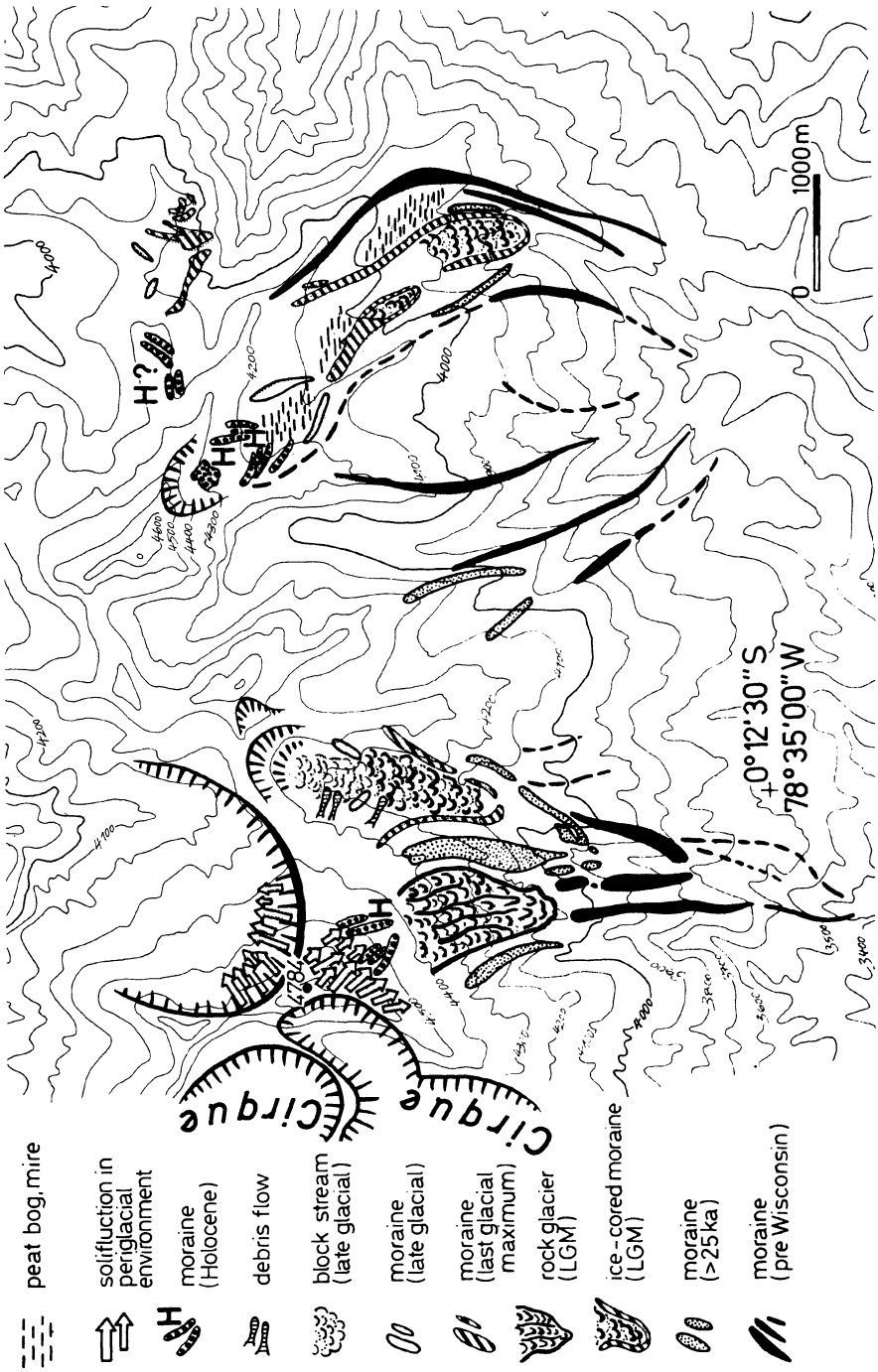

Fig.5: Map of glacial features on Pichincha volcano

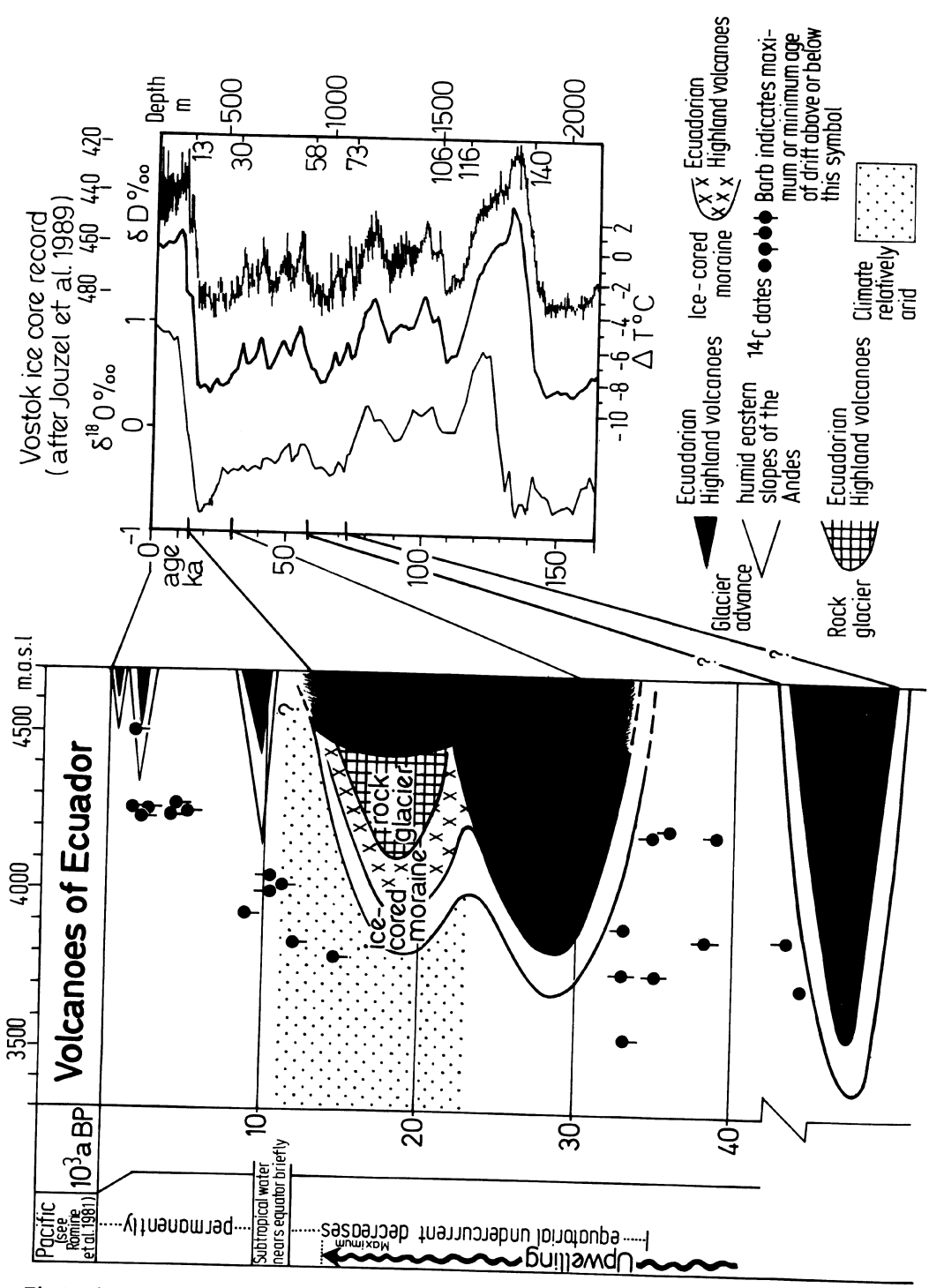

Fig.6: The Weichselian/Wisconsinian glaciations of the Ecuadorian Andes (after different sources and own investigations)

GLACIAL HISTORY AND PALEOCLIMATE (ECUADORIAN ANDES)

My own observations on the ice-age glacial history of the Ecuadorian Andes support the concept of greater aridity during the LGM documenting relatively severe aridity in the equatorial Andes. Radiocarbon dates are used to fit the observed intervals of glaciation in a chronological framework (Fig.6). A chronostratigraphic sequence of late Quaternary moraines, ice-cored moraines, and rock glaciers is shown in Figure 5. The LGM is represented by rock glaciers and ice-cored moraines that document a relatively cool and arid climate compared with the intervals between about 33 and 28 ka B.P. and 10.6 - 9.3 ka B.P. Note that the formation of rock glaciers and ice-cored moraines fall within the LGM (Fig.6), suggesting that less moisture was transported from the eastern Amazon lowlands to the high Andes. This, together with the conclusions of temperature depression of 6-9 °C and lessened precipitation in the Colombian Andes during the LGM points to an increased ice-age aridity and it seems likely that the Amazon lowlands could have been sufficiently arid to destroy the rain forest (see also WRIGHT et al. 1989). Therefore, the hypothesis to explain the high species richness of Amazonia by the refugial theory and intermediate disturbance cannot be excluded by the Mera results (see also NELSON et al. 1990).

CONCLUSIONS

1. No evidence of last glacial age has been found for the Mera fossil forest beds that are reported to be of last glacial age and to give evidence of relatively cold temperatures even in Amazonian lowlands during the last ice-age (see LIU et al. 1985).
2. The Mera forest beds seem to be of at least middle or early Pleistocene age according to the geomorphologic and paleopedologic setting.
3. New observations from the Ecuadorian Andes suggest that rock glaciers and ice-cored moraines were formed during the LGM, thus indicating more arid and colder climatic conditions.
4. The new findings support the hypothesis of greater aridity of the Amazon Basin during times of glacial maxima, with the rainforest reduced to refugia in regions of high rainfall.

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NOTE ADDED IN PROOF

In a recent article BUSH et al. (1990)[1] again report on late Pleistocene temperature depression and vegetation change in Ecuadorian Amazonia. Beside the Mera sites another exposure (San Juan Bosco, 3°3'45"S, 78°27'20"W) at the western edge of the Amazon basin is mentioned. I cannot comment the latter site, but some remarks to the Mera exposures with regard to the interpretation by the authors should be presented.

(1) The second Mera site is characterized in different ways, namely as road-cut (Nature 1985) and as Río Pastaza cliff (Quat. Res. 1990). The geographic situation is 1°28'S (Nature 1985) and 1°29'S (Quat. Res. 1990).

(2) On the one hand I agree that there is no doubt that the pollen and wood samples from Mera represent plants that grew locally and that the hypothesis of long-distance transport must be rejected. On the other hand according to BUSH et al. (1990: 336) the inclination of the present-day river valley is too steep to accommodate the old depositional systems indicated by the stratigraphy, and between 33 and 26 ka B.P. the localities must have had a much-less-incised topography that allowed lower energy streams than are seen today. To explain the late Quaternary change in topography the authors suggest local tectonic activity. I cannot agree with this explanation, because of the deep weathering of fluvial sediments. The stream down-cutting is not restricted to the late Quaternary, on the contrary, the down-cutting is an indispensable condition for the formation of the soils without the influence of groundwater as indicated by the fossil soils of the Mera sites.

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1 BUSH, M.B., P.A. COLINVAUX, M.C. WIEMANN, D.R. PIPERNO & K.-B. LIU (1990): Late Pleistocene Temperature Depression and Vegetation Change in Ecuadorian Amazonia. - Quaternary Research 34 (3): 330-345.