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A cooling event during the Younger Dryas Chron in Costa Rica

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Abstract

A fossil pollen record from the Costa Rican Cordillera de Talamanca presents the first AMS radiocarbon-dated evidence of a temperature decrease during the Younger Dryas Chron. This cooling event is named La Chonta stadial after the bog at 2310 m altitude, located at the actual lower to upper montane forest boundary. High-resolution pollen analysis revealed that between 11,070±130 (AMS ^{14}C age) and 10,400 yr B.P. (interpolated age) vegetation comparable to present-day subalpine forest occurred about 300–400 m lower than in the previous warmer interval, and 600 to 700 m lower than at present time. The radiocarbon dates are close to the earlier estimated ages of 11,080–10,500 yr B.P. for this interval, based on interpolation and pollen concentration rates (Hooghiemstra et al., 1992). The downslope shift of the upper forest line indicates an estimated temperature drop of 2–3°C during the La Chonta stadial. The local vegetation development is indicative of a drier climate. From 10,400 to 9800±120 yr B.P. (AMS ^{14}C age) subalpine rain forest was replaced by upper montane forest, a transitional period to Holocene environmental conditions.

1. Introduction

Late Glacial climatic change has been poorly documented in Costa Rica. Only a few palaeoecological studies are available, namely Martin (1964), Hooghiemstra et al. (1992) and Horn (1993). A cold Late Glacial climatic oscillation like the one to be outlined here, was earlier reported by Hooghiemstra et al. (1992), but poor pollen recovery and lack of direct time control made the chronostratigraphical position and amplitude of this climatic oscillation tentative. More extra-regional evidence of a cooling event of Younger Dryas Chron age comes from Colombia, where the El Abra stadial is clearly evidenced in pollen records of El Abra-II (Schreve-Brinkman, 1978) and Fúquene-II (Van Geel and Van der Hammen, 1973). Younger Dryas cooling events are revealed in Greenland ice (Dansgaard et al., 1989), marine (Kennett, 1990) and terrestrial cores in different parts of the world (Peteet, 1993).

The present data originate from the La Chonta bog in the Cordillera de Talamanca, the highest mountain range of southern Central America. During the last glacial maximum (LGM) different glacier advances occurred in this mountain range, and an approximate date of 10,000 yr B.P. was suggested for the last deglaciation (Hastenrath, 1973; Horn, 1990). For these reasons the La Chonta bog may represent an optimal site to study Late Quaternary climate and vegetation changes in Costa Rica. In the tropical mountains temperature changes influence the altitudinal distribution patterns of vegetation belts, resulting in altitudinal shifts (e.g. Hooghiemstra et al., 1993), disappearance (e.g. Hooghiemstra and Van der Hammen, 1993) and/or compression of those belts (Van der Hammen, 1974). The objectives of this paper are

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to document in detail the AMS radiocarbon-dated environmental change in core La Chonta-1, to infer the sequence of climatic change (in terms of temperature and precipitation) and to correlate this sequence with the pollen record La Chonta-2 of the same bog. Hooghiemstra et al. (1992) reported insufficient pollen for pollen zone 5 of the La Chonta-2 core, interpreted to represent a cooling event at the Late Glacial to Holocene transition. Based on the available radiocarbon ages and age interpolation based on pollen concentration rates the age of the cooling event was between 11,080 and 10,500 yr B.P. Our new La Chonta-1 core correlates well to La Chonta-2 and on the basis of this correlation, pollen zones 4, 5 and 6 were easily identified.

2. Present environmental setting

The oval-shaped La Chonta bog (330 × 110 m, Hooghiemstra et al., 1992) is located on the boundary between lower and upper montane oak forest in the Costa Rican Cordillera de Talamanca (9°41′N, 83°57′W, 2310 m alt., Fig. 1). At present

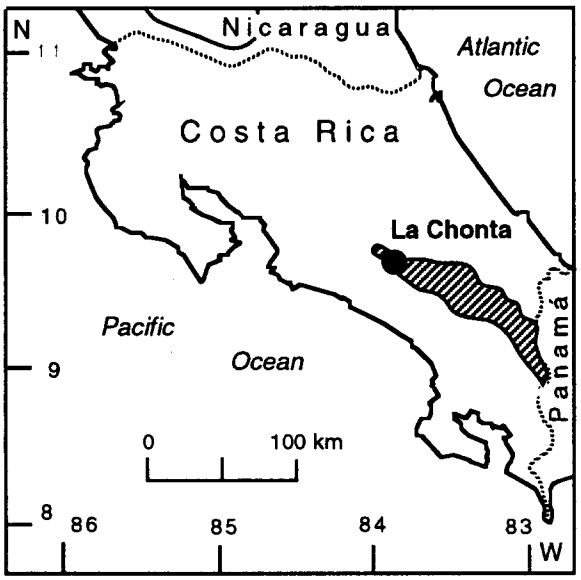

Fig. 1. Location of La Chonta bog in Costa Rica. The area covered by montane and subalpine forest and paramo vegetation in the Cordillera de Talamanca has been hatched.

the mean annual temperature near the bog site is 12–15°C, and annual rainfall is 1500–2500 mm (Herrera, 1985). Recent temperature records at nearby Mt. Chirripó show a mean lapse rate of 0.57°C per 100 m (Kappelle, unpublished data). At this mountain massif the present altitudinal vegetation zonation follows the description of Kappelle (1991): bamboo páramo (3800–3300 m), dominated by *Chusquea*; subalpine ericaceous dwarf forest (3400–3100 m), dominated by *Drimys*, *Hypericum*, *Ilex* and *Myrica*; upper montane myrsinaceous oak forest (3200–2400 m), dominated by different oak species; and lower montane lauraceous oak forest (2400–1500 m). For a more detailed account on the species composition we refer to Hooghiemstra et al. (1992) and Kappelle et al. (1991). All these vegetation belts show a greater phytogeographical affinity with their equivalents in the northern Andes than with mountains in northern Central America (Islebe and Kappelle, 1994). Today in the La Chonta bog grow four azonal plant communities along a strong soil moisture gradient (Hooghiemstra et al., 1992). Local vegetation is dominated by patches of *Hypericum*, *Eleocharis*, *Blechnum*, *Puya* and *Eriocaulon*.

3. Methods

Core La Chonta-1 was recovered in sections of 25 cm length with a Dachnovsky piston sampler. Pollen was extracted using standard acetolysis technique (Faegri and Iversen, 1975) and mounted in a glycerine gelatine medium. The fossil pollen was identified by comparison with the pollen reference collection at the Hugo de Vries laboratory (University of Amsterdam) and the morphological descriptions of Hooghiemstra (1984). Exotic spores (*Lycopodium* spores) were added as markers to determine pollen concentration and pollen counts are presented in Table 1. In Table 2 the identified pollen and spore taxa are presented. The relative proportion of each taxon was calculated on the basis of the pollen sum (arboreal pollen and herbaceous pollen types, excluding aquatics and fern spores). The results are plotted as a pollen diagram for all taxa (Fig. 2) and as a summary

Table 1
List of sample specific data used in this study

Sample no.	Depth (cm)	Pollen sum
1	405	50
2	410	37
3	415	16
4	421.5	59
5	422.5	167
6	423.5	146
7	424	103
8	424.5	116
9	425	124
10	425.5	130
11	426.5	115
12	427	140
13	427.5	144
14	428	190
15	428.5	138
16	429	179
17	429.5	151
18	430	423
19	430.5	162
20	431	146
21	432	181
22	433	155
23	434	167
24	435	147
25	436	120
26	437	160
27	438	108
28	439	289
29	440	79
30	445	154
31	450	290
32	455	352
33	460	314
34	465	198
35	470	209
36	475	396

diagram presenting the main groups (Fig. 3). Pollen analysis was carried out in samples at 1 cm intervals along the sediment column from 440 to 430 cm and at 0.5 cm intervals from 430 to 420 cm. To establish time control for the interval between 440 and 430 cm representing a climatic reversal we dated two samples of unidentified organic material at Utrecht University by accelerator mass spectrometry (AMS, Van der Borg et al., 1987). Radiocarbon ages obtained are: 9800 ± 120 yr B.P. (UTC-2925) at 415 cm depth and 11,070 ± 130 yr B.P. (UTC-2927) at 440 cm depth. These dates reveal a temporal resolution of 55 years in pollen zones 5 and 6, using a linear accumulation rate.

4. Results and discussion

4.1. Brief description of the pollen zones

Pollen zone 4. Poaceae percentages vary from 6 to 30%, Asteraceae and Ericaceae from 0.6 to 2%. *Podocarpus* is present up to 1%. *Alnus* varies from 11 to 77% and *Quercus* reaches up to 55%. Monolete spores have percentages from 1 to 6%. *Isoetes* spores (excluded from pollen sum) found up to 108%. Upper montane forest (up to c. 2700 m) dominated by *Quercus* was characteristic during this period.

Pollen zone 5. This zone is characterised by Poaceae percentages between 20 and 35%, somewhat higher than before. Percentages for the total of subalpine taxa (Ericaceae, *Ilex*, *Viburnum*, *Drimys*, *Myrica*) are also higher and reach 5%. Percentages for *Podocarpus* and *Hedyosmum* vary from 0.3% to 1%. *Alnus* shows percentages up to 18% and *Quercus* varies from 30 to 55%. *Antidaphne*, a parasitic Loranthaceae on oak and some other trees, is present with percentages from 0.5 to 5%. Urticales, Umbelliferae, Rubiaceae, Solanaceae and *Salix* have percentages from 0.3 to 0.7%. Monolete spores (verrucate and psilate) are substantially higher than before with percentages up to 50%. Cyatheaceae spores show a single peak of nearly 70%. *Isoetes* percentages are markedly lower and vary from 0.5 to 35%. Hooghiemstra et al. (1992) described pollen zone 5 of core La Chonta-2 as a zone mainly characterized by relatively high percentages of *Alnus* (up to 75%) and relatively low percentages of *Quercus* (up to 40%). However, most samples lacked pollen.

Pollen zone 6. In this zone Poaceae percentages are reduced and vary from 5 to 22%. Melastomataceae are represented with percentages from 1 to 3%. Subalpine taxa have percentages of less than 1%. *Alnus* varies from 7 to 94%, *Quercus* from 30 to 70%. Monolete spores show percentages up to 20%. *Isoetes* is present with percentages from

Table 2
Identified pollen taxa in core La Chonta-1, listed according to altitudinal zonation and ecological preference

Paramo	Subalpine Rain Forest	Upper Montane Rain Forest	Oak	Lower Montane Rain Forest	Pteridophytes	Aquatics
Poaceae	Asteraceae	*Weinmannia*	*Quercus*	Urticales	monolete verrucate spores*	Cyperaceae*
Valeriana	*Hypericum*	*Podocarpus*		*Antidaphne*	monolete psilate spores*	*Isoetes**
Caryophyllacea	Ericaceae	*Rapanea*		*Ulmus*	Cyathea bac.*	
Gentianaceae		Melastomataceae		Rubiaceae	Cyatheacea*	
Ranunculus		*Ilex*		Solanaceae	*Hymenophyllum**	
Cruciferae		*Viburnum*		*Salix*	*Jamesonia**	
		Drimys			*Lophosoria**	
		Myrica			*Lycopodium reticulate**	
		Hedyosmum			*Lycopodium foveolate**	
		Myrtaceae				
		Alnus				

Taxa marked with an asterisk are not included in the pollen sum.

10 to 150%. Oak dominated montane forest is shifting up in this zone.

4.2. Palaeoenvironmental reconstruction

Whereas at present the bog area is surrounded by montane forest dominated by the oak species *Quercus costaricensis*, *Q. copeyensis* and *Q. seemannii* (Kappelle, 1991), during the Pleniglacial it was situated in the páramo belt, which is the humid alpine vegetation of the Neotropics (Hooghiemstra et al., 1992; Martin, 1964). During the Late Glacial the upper forest line, which corresponds to the 9–10°C annual isotherm, rapidly shifted upslope to 2700–2800 m altitude. For the first time since the LGM, the bog became surrounded by montane oak forest (Fig. 3). This episode was followed by an interval with a marked lowering of the upper forest line, suggesting a climatic cooling. We name this interval the La Chonta stadial (after the bog). This lowering of the upper forest line follows the initial temperature rise in pollen zone 4, interpreted from an increase of elements from the uppermost montane rain forest (*Ilex*, *Viburnum* and *Drimys*) and from the subalpine forest belt. Today, this moist subalpine dwarf forest is located between 3100 and 3400 m in the Cordillera de Talamanca area (Islebe and Kappelle, 1994). The Poaceae record indicates a downslope extension of the páramo vegetation in pollen zone 5. *Quercus* pollen is represented by values less than 50% in the early stage of the La Chonta stadial (pollen zone 5), while later in pollen zone 6 values rise steadily to over 50%. Changes at the transition from pollen zone 5 to 6 reflect an upward migration of the montane forest belt. The base of the La Chonta stadial is radiocarbon dated 11,070±130 yr B.P. and using a linear interpolation between the two AMS radiocarbon ages, the top has an estimated age of 10,400 yr B.P. These ages are close to the previously estimated ages of this cooling event in core La Chonta-2, of 11,080–10,500 yr B.P. (Hooghiemstra et al., 1992: pp. 223–224). A transition to Holocene conditions is shown between 430 and 415 cm and is dated between 10,400 and 9800 yr B.P. In Colombian records a comparable transitional period is documented and dated c. 10,100–9600 yr B.P. (Van der Hammen and Hooghiemstra, submitted). Horn (1993) pointed out that *Isoetes* occurs in the Cordillera de Talamanca especially on lake shores. A drop in lake level provides new habitats and brings *Isoetes* populations closer to the core site. Therefore in our study area higher percentages of *Isoetes* are most probably related to a lowering of the lake level, permitting abundant presence of *Isoetes* on lake shores. In according to this, the La Chonta stadial reflects a moist phase and the subsequent pollen zone 6 reflects a drier phase. Colombian *Isoetes* taxa are mainly subaquatic (Cleef, 1981) and a rise in *Isoetes* in Colombian records indicates higher lake levels (Hooghiemstra, 1989). Taxa

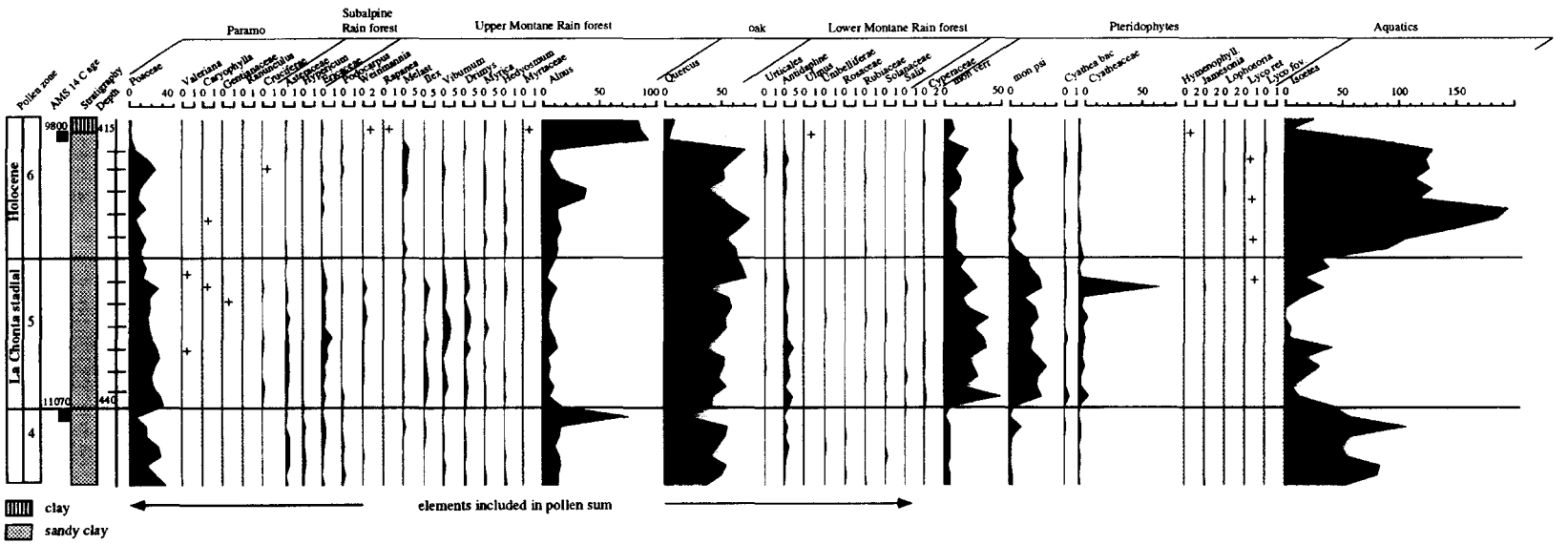

Fig. 2. Pollen percentage diagram of the interval of 450–415 cm of section La Chonta-1 (2310 m alt.), Costa Rica. Pollen spectra marked with a "+" mean less than 0.3%.

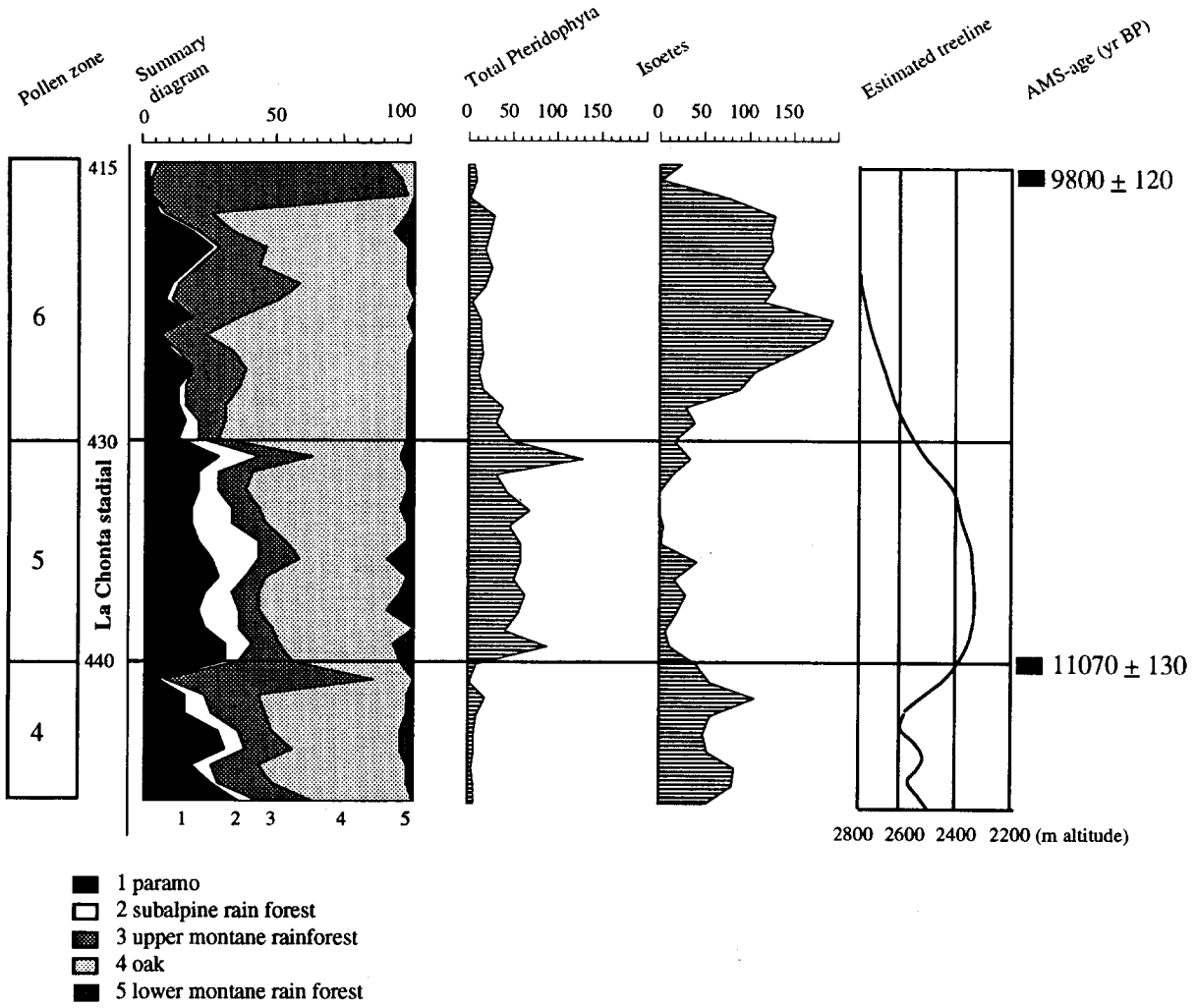

Fig. 3. Main pollen diagram of five major ecological groups, the total Pteridophyta record and the *Isoetes* curve as well as the estimated altitudinal position of the upper forest line.

indicating cool-moist conditions, such as monolete fern spores (Fig. 2), decrease in number during the latest stage of the La Chonta stadial. It is noteworthy that other aquatics, such as *Myriophyllum*, are not recorded in this interval. The record of total Pteridophyta in Fig. 3 includes also the Cyatheaceae, which are indicative of strong forest gap dynamics. The Cyatheaceae peaks at the end of the cold event showing the transition phase to early Holocene oak forest.

The altitudinal downslope shift of the upper forest line is estimated at 300–400 m. A temperature drop of 2–3°C is inferred using the locally calculated lapse rate of 0.57°C/100 m. The transition to early Holocene conditions is marked by the formation of local swamp forest of *Alnus acuminata*, the only alder species of Costa Rica. This is a sign of rapid vegetational change after which the bog became again completely surrounded by oak forest.

As earlier mentioned, regional palaeoecological evidence of a cooling event of Younger Dryas age has also been forthcoming from Colombia, where this climatic oscillation is locally known as the El

Abra stadial. Evidence from the Eastern Cordillera was summarized in Kuhry et al. (1993) and a summary of all Colombian evidence, including a list of relevant radiocarbon ages, is presented by Van der Hammen and Hooghiemstra (submitted). From the Colombian Lake Fúquene pollen record (Van Geel and Van der Hammen, 1973) high percentages of Cyperaceae are reported for this interval. This indicates shallow water conditions and a relatively dry climate. In our Costa Rican site almost no Cyperaceae were found during the La Chonta stadial. The Colombian El Abra stadial was interpreted to reflect a lowering of the upper forest line by c. 400 m, which is equivalent to the here estimated 300–400 m. Presently, Central America is dominated by the trade wind circulation associated with the Azores High and the Intertropical Convergence Zone (ITCZ; Portig, 1976). Seasonal southward displacement during cooling events of the ITCZ results in reduced precipitation in the area. The regional trend of drier Pleistocene climates is further supported by evidence from Guatemala (Leyden, 1984) and Panama (Markgraf, 1989; Bush et al., 1992).

5. Conclusions

Two pollen records from La Chonta bog in Costa Rica (La Chonta-2, Hooghiemstra et al., 1992 and La Chonta-1, this paper), show a cold climatic oscillation during the Late Glacial. The age of this cold oscillation is dated by AMS radiocarbon dates from 11,070±130 to 10,400 yr B.P. (interpolation between two AMS ^{14}C ages) and corresponds to the Younger Dryas Chron. It is named here the La Chonta stadial. Palynological data indicate that temperature dropped by 2–3°C during the La Chonta stadial. The transition to Holocene environmental conditions occurred in Costa Rica and Colombia through a transitional phase. More data and additional time control from mountainous and lowland Costa Rica is needed to substantiate the observed climatic oscillation.

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