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THE EL ABRA STADIAL, A YOUNGER DRYAS EQUIVALENT IN COLOMBIA

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Abstract — A survey of radiocarbon-dated palynological, stratigraphical and glacio-morphological evidence from Colombia is presented showing a cold climatic fluctuation most likely between 10,900 and 10,100 BP, immediately preceding the initiation of the Holocene. This fluctuation, called the El Abra stadial, is characterized by lower temperatures and less precipitation, and occurs after the Late-Glacial Guantiva interstadial. Average annual temperature during the Guantiva interstadial may have been 2°C lower than today, and during the El Abra stadial from 4° to 6°C lower than today. The upper forest line during the El Abra stadial was some 400 to 500 m lower than during the Guantiva interstadial and some 600 to 800 m lower than today. The Guantiva interstadial–El Abra stadial–early Holocene sequence is radiocarbon dated by some 45 dates and evidence is shown from 14 areas, mostly located at high elevations (2000–4000 m) in the Eastern and Central Cordillera and in the Sierra Nevada de Santa Marta, but some from the tropical lowlands. Although more precise dating of the boundaries is desirable, we interpret the Guantiva–El Abra climatic fluctuations as equivalents in time and climatic phenomena to the Allerød–Younger Dryas sequence in Europe.

INTRODUCTION

In 1959 a colder climatic fluctuation was reported from the tropical high Andes of Colombia, and was interpreted as probably corresponding to the European Younger Dryas stadial (Van der Hammen and González, 1959a, 1960a, 1963). The interpretation was based on an observation of the high plain of Bogotá at 2550 m altitude. Immediately below a sequence of 250 cm of Holocene sediments of which the lower part was dated 8960±400 BP with dominating arboreal pollen, there was an interval of some 20 cm with a marked rise of pollen of grasses and andean paramo herbs characteristic of high elevation; below that interval, arboreal pollen dominated again. A pollen diagram from a lake in the paramo at ca. 3600 m elevation, also showed a marked fluctuation of climate in the lower part, strongly suggesting an Older Dryas–Allerød–Younger Dryas sequence, and extrapolation and correlation of other dates from the local sequence seemed to confirm this conclusion. However, the radiocarbon date from the Dachnowsky core was early Holocene, and the interpretation remained in doubt (Van der Hammen and González, 1959b, 1960b).

In the following years evidence accumulated, partly stratigraphical and partly pollen analytical, with radiocarbon dates confirming the approximate correlation of the cold interval with the Younger Dryas, and the preceeding warmer interval with Bölling and Allerød. It was considered prudent to establish local names, so as to be able to discuss the more or less precise time-correlation of the

boundaries of these intervals; the cold phase was called the El Abra stadial, and the preceeding warmer interval the Guantiva interstadial. A high quality pollen diagram, from lake Fuquene, provided more paleoclimatic information and the total data now available strongly supports the El Abra–Younger Dryas correlation. In addition, studies of the glacial moraines in the high area of the Nevado del Cocuy and their approximate dating by means of palynology and radiocarbon dating of the sediments behind and in front of them, indicate that one very conspicuous endmoraine system (of the Bocatoma stade), is of late Lateglacial age, and most probably of El Abra (Younger Dryas) time.

Some compilation of data on the El Abra stadial in the Eastern Cordillera was previously presented by Kuhry *et al.* (1993). In the following we will present a more complete overview of the more relevant data from Colombian sites (Fig. 1 and Table 1) concerning the El Abra stadial, its dating and correlation with the Younger Dryas stadial of Europe, mostly palynological, but also stratigraphical and glacio-morphological. The climatic interpretation of these data is treated separately.

The El Abra stadial and the Guantiva interstadial are best defined in the pollen diagrams El Abra II-B3 (Schreve-Brinkman, 1978), Fuquene II (Van Geel and Van der Hammen, 1973) and Cienaga del Visitador (Van der Hammen and González, 1965). All radiocarbon ages mentioned in the text are listed in Table 2 accompanied by site-specific data. The significance of the ages is indicated and listed in Table 3.

FIG. 1. Map of Colombia showing the locations of the sites discussed in the text. Site specific data are listed in Table 1.

TABLE 1. List of sites related to Colombian El Abra evidence. Locations are plotted in Fig. 1

1.	Ciudad Universitaria, CUX (Bogotá)	4°35'N	74°05'W	2560	Van der Hammen and González, 1960a, b; Van der Hammen and González, 1963
2.	Cienaga del Visitador (Cordillera Oriental)	6°08'N	72°47'W	3300	Van der Hammen and González, 1965
3.	Naboba (Sierra Nevada de Santa Marta)	10°42'N	73°45'W	4500	Van der Hammen, 1984
4.	Valle de Lagunillas and Bocatoma Valley (Sierra Nevada del Cocuy)	6°23'N	72°18'W	3900–4000	González <i>et al.</i> , 1966; Van der Hammen <i>et al.</i> , 1980/81
5.	Mondoñedo (Mosquera)	4°40'N	74°20'W	ca. 2600	Van der Hammen, 1965
6.	El Abra (Zipaquirá)	5°00'N	73°58'W	2570	Schreve-Brinkman, 1978; Van der Hammen, 1974
7.	Laguna de Fuquene	5°27'N	73°46'W	2580	Van Geel and Van der Hammen, 1973; Van der Hammen, 1974
	Laguna de Palacio	5°16'N	73°51'W	2580	Van Geel and Van der Hammen, 1973
8.	Tequendama (Soacha)	4°35'N	74°13'W	2566	Correal and Van der Hammen, 1977; Van der Hammen, 1992
9.	Laguna Pedro Palo (Cordillera Oriental)	4°30'N	74°23'W	2000	Hooghiemstra and Van der Hammen, 1993; Van der Hammen, 1974
10.	Laguna Ciega (Sierra Nevada del Cocuy)	6°30'N	72°25'W	3510	Van der Hammen <i>et al.</i> , 1980/81
11.	Boquillas (Lower Magdalena Valley)	9°06'N	74°34'W	ca. 30	unpublished
12.	Lake Otun (Cordillera Central)	4°47'N	75°25'W	3930	Thouret and Van der Hammen, 1981, Salomons, 1986; Salomons, 1989
13.	Pico del Loro, Rio Recio (Murillo, Tolima)	4°52'N	75°27'W		
14.	El Billar (El Ruiz, Cordillera Central)	4°54'N	75°41'W	3600	Melief, 1985
15.	Lake Andabobos (Sumapaz)	4°05'N	74°15'W	3750	Melief, 1985
16.	Manacaro, Rio Caquetá (Colombian Amazonas)	1°30'S	70°11'W	ca. 150	unpublished
17.	Quinché, Rio Caquetá (Colombian Amazonas)	0°25'S	71°55'W	ca. 150	unpublished

DATA FROM THE EASTERN CORDILLERA

In section El Abra II-B3 from the El Abra corridor and rock shelters (Fig. 2) at 2570 m elevation (Van der Hammen, 1974, 1978; Schreve-Brinkman, 1978) alder pollen is replaced by pollen from open to half open vegetation of grasses, Compositae, *Geranium*, etc. This pollen is characteristic of subparamo and paramo vegetation. At the same time lake sediments are replaced by humic loam. Halfway into the rise of the herbs and shrubs, there is a radiocarbon date of 11,210±90 BP (GrN-5941). Upward, the marsh sediments pass into dark humic (andic) soil, while indicators of open water cease, and the herbs are replaced by forest (Fig. 2).

In the nearby rock-shelter Abra II, a layer with rockfall, probably related to a colder climatic interval and considered to correspond to the El Abra stadial, rendered a charcoal date of 10,720±400 BP (B-2134). The darker layer below gave a date of 12,400±160 BP (GrN-5556), and the sandy soily layer immediately above the rockfall layer gave a charcoal date of 9420±110 BP (GrN-5557). There is a good overall stratigraphic correlation between these and other sections from the site. It is concluded that the El Abra cold phase is slightly younger than 11,210 and older than 9340 BP.

In a core from Lake Fuquene (Fig. 2) at 2580 m elevation (Van Geel and Van der Hammen, 1973; Van der Hammen, 1974) pollen representing somewhat open forest of *Alnus*, *Quercus* and *Myrsine* (= *Rapanea*), with *Dodonaea*, is replaced by open vegetation of Gramineae. The transition is dated 10,820±60 BP (GrN-5839). Sixty centimeters above this transition, the forests extend again and more definitely, with a transitional phase. This rep-

resents, by correlation with other pollen diagrams, the beginning of the Holocene. Pollen diagram Fuquene I shows a very similar cold interval, correlated with the El Abra stadial. A thin volcanic ash layer marks the beginning of the Holocene forest extension, in both diagrams. From another lake in this area, Laguna de Palacio, a date of 10,550±60 BP (GrN-6100) was obtained from the middle of the interval representing the El Abra stadial (Van Geel and Van der Hammen, 1973).

Lake sediment core from mire Cienaga del Visitador (Fig. 2) at 3300 m elevation (Van der Hammen and González, 1965) shows immediately after a cold interval dated 12,770±130 (GrN-3053), a notorious extension of *Alnus*, *Quercus* and other trees, but not replacing completely the local open paramo vegetation. Arboreal pollen percentages decrease 45 cm higher in the pollen diagram, and open grass paramo elements dominate again. There is a thin volcanic ash layer, followed by a small temporary peak of *Quercus*, but conditions of open vegetation persist until the present. Shortly above the ash layer, coinciding with the small *Quercus* peak, is a radiocarbon date of 9830±140 BP (GrN-2477). The warmer interval above the 12,770 date, was called the Guantiva interstadial. The colder phase above the Guantiva interstadial is correlated with the El Abra stadial, up to the *Quercus* peak dated 9830±140 BP. Open paramo-like conditions during the Holocene are explained by the geographical position; the site is located in the rain shadow.

The pollen diagram of core Sabana de Bogotá CUX (Fig. 3) at 2560 m elevation (Van der Hammen and González, 1960a) shows an interval of dominating trees (*Alnus* and *Myrica*), followed by a marked decrease of trees (especially of *Alnus*), and a marked extension of

TABLE 2. Radiocarbon dates discussed in the text listed with increasing age. Sediment-specific data are indicated. An account of the relevance of the samples is given in Table 3 (cross references are given in Column 4)

Laboratory number	Locality, section	Stratigraphic position and material	Reference to Table 3	Publication	Age (BP)
GrN-9809 (Col 283)	Lake Otun Central Cordillera	115 cm paleosoil	(1)	Thouret and Van der Hammen, 1983	7440±70
GrN-3598	Valle de Lagunillas	198–206 cm		González <i>et al.</i> , 1966	8190±100
GrN-4003 (Col 53)	(S.N. del Cocuy)-VL-V	peat	(2)		8200±100
GrN-4358 (Col 43a)	Naboba (S.N. de Santa Marta-SN-VII)	115–120 cm peaty clay	(3)	Van der Hammen, 1984	8485±70
K-561 (Col 10)	Bogotá, Ciudad Universitaria-CUX	235–265 cm charcoal	(4)	Van der Hammen and González, 1960a (uncorrected)	8960±400
GrN-11331 (Col 353)	Pico del Loro, Rio Recio, Murillo (Tolima)	110–120 cm charcoal	(1)	Thouret <i>et al.</i> , 1995	8960±140
GrN-12494 (Col 443)	El Billar II East flank El Ruiz	260–264 cm peat	(5)	Melief, 1985	9020±50
GrN-5557 (Col 86)	El Abra II Zipaquirá	level 8 charcoal	(6)	Correal <i>et al.</i> , 1970; Van der Hammen, 1978	9420±110
GrN-7115 (Col 171)	Tequendama I Soacha	240–290 cm charcoal	(7)	Correal and Van der Hammen, 1977	9740±135
GrN-16689 (Col 685)	Quinché, Caquetá R., Amazonia	ca. 645 cm organic clay	(8)	Van der Hammen <i>et al.</i> , 1992	9810±70
GrN-2477 (Col 32)	Cienaga del Visitador Boyacá, Susacá	270–300 cm dark lake sediment	(9)	Van der Hammen and González, 1965	9830±140
GrN-6730 (Col 174)	Tequendama I Soacha	155–160 cm charcoal	(10)	Correal and Van der Hammen, 1977	9990±100
GrN-6210 (Col 165)	Tequendama I Soacha	120–130 cm charcoal	(11)	Correal and Van der Hammen, 1977	10,025±95
GrN-4141 (Col 52)	Valle de Lagunillas	232–252 cm	(12)	González <i>et al.</i> , 1966	10,030±90
GrN-6732 (Col 176) (incl. 177)	Tequendama I Soacha	FL-160–170 cm charcoal	(11)	Correal and Van der Hammen, 1977	10,130±150
GrN-7113 (Col 168)	Tequendama I Soacha	L-305–320 cm charcoal	(11)	Correal and Van der Hammen, 1977	10,140±100
GrN-7114 (Col 175)	Tequendama I Soacha	150–160 cm charcoal	(11)	Correal and Van der Hammen, 1977	10,150±150
GrN-12499 (Col 449)	El Billar II East flank El Ruiz	11–14 cm peat	(13)	Melief, 1985	10,240±50
GrN-6733 (Col 190)	Laguna Pedro Palo V West flank Cord. Oriental	125–150 cm peaty lake sediment	(14)	Hooghiemstra and Van der Hammen, 1993	10,280±90
GrN-6734 (Col 191)	Pedro Palo V West flank Cord. Oriental	275–300 cm peaty lake sediment	(15)	Hooghiemstra and Van der Hammen, 1993	10,380±90
GrN-4140 (Col 51)	Valle de Lagunillas S.N. Cocuy, VL-V	275–300 cm peat	(16)	González <i>et al.</i> , 1966	10,400±120
GrN-6731 (Col 169)	Tequendama I Soacha	L-320–350 cm charcoal	(17)	Correal and Van der Hammen, 1977	10,460±130
GrN-12978 (Col 499)	Andabobos Sumapaz area	305–330 cm peat	(18)	Melief, 1985	10,530±90
GrN-6100 (Col 117)	Laguna de Palacio Valle de Ubaté	827–848 cm (organic) lake-clay	(19)	Van Geel and Van der Hammen, 1973	10,550±60
B-2134 (Col 120)	El Abra II Zipaquirá	148 cm charcoal	(20)	Van der Hammen, 1978	10,720±400
GrN-6270 (Col 166)	Tequendama I Soacha	200–220 cm charcoal	(17)	Correal and Van der Hammen, 1977	10,730±105
GrN-4210 (Col 59)	Mondoñedo II Mosquera	ca. 700 cm charcoal	(21)	Van der Hammen, 1965	10,760±160
GrN-5839 (Col 115)	Laguna de Fuquene II Valle de Ubaté	478–497 cm peaty lake sediment	(22)	Van der Hammen, 1965	10,820±60
GrN-4209 (Col 58)	Mondoñedo I Mosquera	ca. 350 cm charcoal	(21)	Van der Hammen, 1965	10,840±110
GrN-6539 (Col 170)	Tequendama I Soacha	ca. 330–360 cm charcoal	(23)	Correal and Van der Hammen, 1977	10,920±260
GrN-7394 (Col 241)	Boquillas Lower Magdalena	2845–2900 cm peaty clay	(24)	unpublished	11,170±170
GrN-5941 (Col 123)	El Abra II-B3 Zipaquirá	185–190 cm black humic clay	(25)	Schreve-Brinkman, 1978; Van der Hammen, 1978	11,210±90
GrN-4083 (Col 50)	Valle de Lagunillas S.N. del Cocuy VL-V	326–350 cm peat	(26)	González <i>et al.</i> , 1966	11,350±140
GrN-6758 (Col 193a)	Pedro Palo III West flank Cord. Oriental	180–200 cm (organic) lake sediment	(27)	Hooghiemstra and Van der Hammen, 1993	11,380±130
GrN-4036 (Col 49)	Valle de Lagunillas S.N. del Cocuy VL-V	372–378 cm peat	(28)	González <i>et al.</i> , 1966	11,900±120
GrN-12498 (Col 448)	El Billar II East flank El Ruiz	31–34 cm peat	(29)	Melief, 1985	11,910±70
GrN-4002 (Col 48)	Pedro Palo III West flank Cord. Oriental	350–400 cm (organic) lake sediment	(30)	Hooghiemstra and Van der Hammen, 1993	11,950±100
GrN-4037 (Col 47)	Valle de Lagunillas S.N. de Cocuy VL-V	472–486 cm peat	(31)	González <i>et al.</i> , 1966	12,140±120
GrN-12493 (Col 442)	El Billar II East flank El Ruiz	547–564 cm wood	(32)	González <i>et al.</i> , 1966	12,310±160
GrN-5556 (Col 85)	El Abra II Zipaquirá	322–326 cm peat	(33)	Melief, 1985	12,330±70
GrN-16672 (Col 647)	Manacaro I Caquetá R., Amazonia	150–175 cm charcoal	(34)	Correal <i>et al.</i> , 1970; Van der Hammen, 1978	12,400±160
GrN-16594 (Col 646)	Manacaro I Caquetá R., Amazonia	290 cm wood in organic clay	(35)	Van der Hammen <i>et al.</i> , 1992	12,530±45
GrN-3053 (Col 24)	Cienaga del Visitador Susacá, Boyacá	330 cm wood in organic clay	(35)	Van der Hammen <i>et al.</i> , 1992	12,560±45
GrN-7553 (Col 240)	Boquillas Lower Magdalena	370–390 cm dark lake sediment	(36)	Van der Hammen and González, 1965	12,770±130
GrN-7066 (Col 201)	Laguna Ciega III S.N. del Cocuy	2240 cm peaty clay	(24)	unpublished	12,800±180
		367.5–378 cm clayey peat	(37)	Van der Hammen <i>et al.</i> , 1980/81	12,830±80

FIG. 2. Summary pollen diagrams and stratigraphical sections of the El Abra corridor and rock-shelters (2570 m), Lake Fuquene (2580 m), and the peat-lake sediment sequence Cienaga del Visitador in the paramo de Guantiva (3300 m). Redrawn after Van der Hammen (1974) and Van der Hammen (1978).

grasses and some paramo elements (*Geranium* and *Jamesonia*). Later, *Myrica* extends again to dominate completely around 8960 ± 400 BP (uncorrected; K-561). The extension of paramo is correlated with the El Abra stadial, the preceding forest phase with the Guantiva interstadial, and the following forest phase with the Holocene.

The stratigraphic sequence in the Tequendama rock-shelter (Fig. 3) at approximately 2570 m elevation (Correal and Van der Hammen, 1977; Van der Hammen, 1992) is similar to that in the El Abra rock-shelters (see above). Above a somewhat darker layer (layer 5a) there is an interval of lighter colour with rockfall (layer 5b) attributed to colder climatic conditions. The rockfall layer is covered by a yellowish layer with volcanic ash without rockfall (layer 6). The boundary of layers 5a and 5b was dated $10,920 \pm 260$ BP (GrN-6539), layer 5b rendered dates of $10,730 \pm 105$ BP (GrN-6270) and $10,460 \pm 130$ BP (GrN-6731), the boundary of 5b and 6 rendered dates of $10,150 \pm 150$ BP (GrN-7114), $10,140 \pm 100$ BP (GrN-7113), $10,130 \pm 150$ BP (GrN-6732), $10,025 \pm 95$ BP (GrN-6210) and 9990 ± 100 BP (GrN-6730), with an average of approximately 10,000 BP. Layer 6 gave a date of 9740 ± 135 BP (GrN-7115). It was concluded that the rockfall layer 5b corresponds to the El Abra stadial.

The Mondoñedo area, east of Mosquera at ca. 2600 m elevation, at the westernmost part of the high plain of Bogotá (in the rain shadow), is an area of erosion and

colluvial sedimentation. A deep paleo-erosion gully, filled with colluvial sediments, presented a well defined dark soil horizon (Fig. 3). In the higher part of this soil complex, a charcoal horizon was present. The charcoal of this horizon was sampled at two different sites; the corresponding dates are: $10,840 \pm 110$ BP (GrN-4209) and $10,760 \pm 160$ BP (GrN-4210). The soil complex in this Mondoñedo sequence (Van der Hammen, 1965; Van der Hammen *et al.*, 1980) probably represents the Guantiva interstadial and the transition to the El Abra stadial, the charcoal level coinciding with the deterioration of climate, leading to the death of the local forests (see above). It is interesting to note that the charcoal (of pine) in the European Allerød soil ('Usselo-layer') gave dates like these in many places, indicating the climatic deterioration of the beginning of the Younger Dryas.

In the area of the Paramo de Sumapaz (Melief, 1985) the pollen records of lake sediments of Alsacia (3100 m), La Primavera (3525 m), Andabobos (3750 m), El Gobernador (3815 m) and somewhat less clear La Guitarra (3400 m) show substantial evidence of a colder phase. This colder climatic phase is characterized by a decrease of arboreal pollen, an increase of pollen of grasses and other paramo herbs, and situated between warmer intervals below and above. Radiocarbon dates, or interpolated estimated dates based on radiocarbon dates and the interpolation method based on pollen density (Middelorp, 1986), correspond to the El Abra chrono-

TABLE 3. Account of the relevance of the samples listed in Table 2 with respect to the El Abra chronozone and cooling event

Reference to Table 2	Dating number	Relevance of the dated sample
(1)	Col 283, Col 353	Dates lowermost Holocene soil of a soil-tephra sequence on top of the Late Otun moraine, considered to be of El Abra age (Bocatoma stade).
(2)	Col 53	Dates peat correlated with the early Holocene.
(3)	Col 43a	Dates basal part of peat layer covering the Naboba moraine, correlated with the Bocatoma stade.
(4)	Col 10	Dates early climatic amelioration (increase of <i>Myrica</i>) after interval of high grass pollen values, correlated with the El Abra stadial.
(5)	Col 443	Dates lower part of the present day warmer period, immediately above a cold interval correlated with the El Abra stadial.
(6)	Col 86	Dates darker humid layer immediately above rockfall layer.
(7)	Col 171	Dates the lower part of sediment covering the rockfall layer (considered to be of early Holocene age).
(8)	Col 685	Dates transition of sand to dark silty clay, related to open water conditions correlated with the beginning of the Holocene.
(9)	Col 32	Dates interval of higher grass percentages above the Guantiva interstadial (El Abra and at the beginning of the Holocene).
(10)	Col 174	Dates sediments at the top of layer with exfoliation in rock-shelter (exfoliation correlated with the El Abra stadial).
(11)	Col 165, Col 168, Col 175 Col 176	Dates transition of rockfall layer in rock shelter considered to be of El Abra stadial age, to overlying layer without rockfall, considered to be from the beginning of the Holocene. (Col 174)
(12)	Col 52	Dates peat immediately above the sandy interval considered to be deposited during the Bocatoma glacial stade (Col. 51).
(13)	Col 449	Dates top of warmer interval (Guantiva interstadial) immediately below the colder interval correlated with El Abra.
(14)	Col 190	Dates lower part of pollen diagram interval correlated with the Holocene.
(15)	Col 191	Dates upper part of pollen diagram interval correlated with the El Abra stadial.
(16)	Col 51	Dates peat in the middle of sandy horizon, considered to be deposited during the Bocatoma glacial stade.
(17)	Col 169, Col 166	Dates rockfall layer in rock shelter, considered to be of El Abra age.
(18)	Col 499	Dates lower part of colder pollen diagram interval correlated with the El Abra stadial (above a warmer interval correlated with the Guantiva interstadial).
(19)	Col 117	Dates El Abra stadial interval in pollen diagram.
(20)	Col 120	Dates lower part of rockfall layer in rock shelter, correlated with the El Abra stadial.
(21)	Col 59, Col 58	Dates charcoal in higher part of darker soil, considered to be of Guantiva age, covered with colluvial material (considered to be of El Abra age).
(22)	Col 115	Dates transition of Guantiva interstadial and El Abra stadial in pollen diagram.
(23)	Col 170	Dates the base of the rockfall layer of Col 166 and 169 (17).
(24)	Col 241, Col 240	Dates first sequence of peat and clays deposited in the valley of the lower Magdalena River after glacial phase of erosion.
(25)	Col 123	Dates uppermost part of Guantiva interstadial, at the transition to the El Abra stadial in type pollen diagram.
(26)	Col 50	Dates peat considered of Guantiva interstadial age.
(27)	Col 193a	Dates upper part of pollen diagram interval correlated with the Guantiva interstadial.
(28)	Col 49	Dates beginning of peat formation in Lagunillas sequence.
(29)	Col 448	Dates lower part of warmer interval (Guantiva interstadial) below the colder interval correlated with El Abra.
(30)	Col 194c	Dates lower part of pollen diagram interval correlated with the Guantiva interstadial.
(31)	Col 48	Short cold spell in Guantiva interstadial.
(32)	Col 47	Dates first extension of vegetation in the area, after retreat of glacier, and amelioration of climate (early Guantiva interstadial).
(33)	Col 442	Dates lower part of pollen diagram interval correlated with the Guantiva interstadial.
(34)	Col 85	Dates darker humic layer, correlated with the Guantiva interstadial.
(35)	Col 647, Col 646	Dates a layer of organic clay with wood, being part of the first sediments deposited in the Caquetá River valley after glacial time erosion.
(36)	Col 24	Dates short cold interval immediately below the Guantiva interstadial interval.
(37)	Col 201	Dates base of cold interval between intervals correlated with respectively the Susacá interstadial (immediately below) and the Guantiva interstadial (above).

FIG. 3. Summary pollen diagram Sabana de Bogotá CUX and stratigraphical sections from the Tequendama rock shelter and Mondoñedo at ca. 2600 m elevation. Redrawn after Van der Hammen and González (1960a, b); Correal and Van der Hammen (1977); Van der Hammen (1965).

FIG. 4. Summary pollen diagrams from Lake Pedro Palo (ca. 2000 m), La Primavera (3525 m), Andabobos (3750 m) and Alsacia (3100 m). Redrawn after Hooghiemstra and Van der Hammen (1993); Melief (1985).

FIG. 5. Summary pollen diagrams of cores El Billar-II and El Billar-II 1 (3600 m). Redrawn after Melief (1985).

Lake Alsacia	Calculated interpolated age of local zone ALS 3 f (Melief, 1985) correlated with the El Abra stadial: ca. 10,800–9700 BP (Fig. 4).
Lake La Guitarra	Calculated interpolated age of boundary of local zones GUI 2 and GUI 3 (Melief, 1985), considered to be the base of the El Abra stadial: ca. 11,000 BP.
Lake La Primavera	Calculated interpolated age of local zone PRI 1 (Melief, 1985), considered to correspond to the El Abra stadial and the beginning of the Holocene: base ca. 11,200 BP and the top ca. 9600 BP (Fig. 4).
Lake Andabobos	Calculated interpolated age of local zone AND 2 b (Melief, 1985), considered to represent the El Abra stadial and the beginning of the Holocene: base ca. 11,000 BP; radiocarbon date from this zone: 10,530±90 BP (GrN-12978) (Fig. 4).
Lake El Gobernador	Calculated extrapolated age of lower-most local zone GOB 1 (Melief, 1985), considered to be El Abra stadial: from >10,500 to ca. 10,000 BP.

The pollen diagram of core Pedro Palo-III (Fig. 4) from lake Pedro Palo at ca. 2000 m elevation shows the period of the transition of cold climatic conditions to the warmer Guantiva interstadial (pollen zone 2) (Van der Hammen, 1974; Hooghiemstra and Van der Hammen, 1993). The lower and upper boundary of the Guantiva interstadial is radiocarbon-dated 11,950±100 BP (GrN-6759) and 11,380±130 BP (GrN-6758) and the sediments of this interval consist of silty peaty material. It is followed by a hiatus-horizon and the remaining part of the core is of Holocene age.

Pollen diagram Pedro Palo-V starts in the Guantiva interstadial (pollen zone 2) and shows between 480 and 190 cm (pollen zone 3) a period of colder climatic conditions, correlated with the El Abra stadial. This cold interval of the core includes lacustrine clays changing into silty peaty sediment during the coldest part of pollen zone 3 which is indicative of a lowering of the lake level. The base of the silty peaty sediment of Late El Abra age is

radiocarbon-dated 10,380±90 BP (GrN-6734). This cold interval is followed by a clear transition to warmer (early) Holocene conditions. The lower part of this Holocene pollen zone includes a radiocarbon date of 10,280±90 BP (GrN-6733) and according to our interpretation this date is possibly slightly too old (Hooghiemstra and Van der Hammen, 1993). Comparing the Pedro Palo records with other important records from this area (e.g. El Abra) the temperature decrease suggested by the vegetational change in pollen zone 3 is not very marked. This seems to be caused by the fact that the upper forest limit was, after 12,000 BP well above 2000 m altitude, and the local alder swamp forest may have partly veiled the effects of regional change in the pollen record.

THE SIERRA NEVADA DEL COCUY AREA

The pollen diagrams Laguna Ciega-I and Laguna Ciega-II at 3510 m elevation (Van der Hammen *et al.*, 1980/81) show a cold phase (dominating paramo elements) dated 12,830±80 BP (GrN-7066), followed by an interval of extension of arboreal pollen, correlated with the Guantiva interstadial. This interval is followed by a renewed extension of paramo elements, that ends with an increase of subparamo elements, and is correlated with the El Abra stadial.

From the Lagunillas Valley at ca. 3900–4000 m elevation the pollen diagrams VL-III, V and XI are relevant (González *et al.*, 1966; Van der Hammen *et al.*, 1980/81). The pollen diagram of lake section VL-III was interpreted as containing a rather long Lateglacial part, and a zone III (El Abra stadial) that shows a rise of grasses as compared to the lower zone II that has higher arboreal pollen percentages. No radiocarbon dates are available, but a correlation seems possible with dated diagram VL-V. Pollen diagram VL-V shows a long Lateglacial and Holocene sequence, dated with nine radiocarbon dates, between 12,320 and 8190 BP. Around 12,310±160 BP (GrN-4037) there is a considerable increase of arboreal pollen percentage. Grass pollen percentages increase again in an interval between 12,140±120 BP (GrN-4002) and 11,900±120 BP (GrN-4036), followed by a renewed increase of arboreal pollen percentage. The complete interval from >12,310 to <11,350 corresponds to the Guantiva interstadial. After

11,350±140 BP (GrN-4083) the grass pollen percentages reach 95% and a sequence of peat alternating with sand and gravel seems to indicate that the ice-border is near the site. This sequence has radiocarbon dates of 10,400±120 BP (GrN-4140) and 10,030±90 BP (GrN-4141). A *Plantago rigida* bog then develops, replacing the 'colder' *Distichia* bog, with dates of 8200±100 BP (GrN-4003) and 8190±100 BP (GrN-3598). Grass pollen percentages, however, remain the same (like in the Cienaga del Visitador diagram), probably related to the local presence of peat-bog vegetation and a locally relatively drier climate. Section VL-III is situated immediately in front of the large Bocatoma moraines, that should be younger than 12,320 BP, and could have the age of the peat-sand-gravel interval of El Abra stadial age, just mentioned.

Pollen diagram VL-XI is from lake sediments inside the Bocatoma moraines. The lake must have dried up in the beginning of the Holocene. The sediments start with high grass pollen percentages and low pollen densities in varved loamy sand (apparently the ice was still very near). Then there is a considerable increase of arboreal pollen percentage (mainly *Alnus*) and of pollen density. There was no material to be dated, but the pollen diagram shows the transition of a colder to a warmer period, most probably from the El Abra stadial to the Holocene. The Bocatoma moraine is of Lateglacial age, and most probably from El Abra stadial time, although it cannot be excluded that ice was present at this end-moraine complex at a somewhat earlier phase of the Lateglacial.

DATA FROM THE CENTRAL CORDILLERA

The lower part of peat core El Billar-II (Fig. 5) from 3600 m elevation (Melief, 1985) is dated by two radiocarbon ages: 12,330±70 BP (GrN-12493) and 9020±50 BP (GrN-12494). The lower part of this interval has relatively high arboreal pollen values, in the middle there is a quite well marked increase of grasses, and finally a return to higher arboreal pollen values. The base of the colder paramo interval has, according to interpolation, a date of ca. 11,000 BP. A parallel section El Billar-II 1, has a radiocarbon date of 11,910±70 BP (GrN-12498) in the interval with higher arboreal pollen percentages, and a date of 10,240±50 BP (GrN-12499) in the higher grass pollen interval, confirming the interpretation as respectively Guantiva interstadial and El Abra stadial.

Salomons (1986, 1989) used pollen analysis to investigate many soils from both the west and east flank of the Parque los Nevados transect in the Central Cordillera. They are mostly paleosol sequences of Andosols (volcanic ash soils), and several of them reach back into the Last Glacial. Radiocarbon dates enabled him to recognize the base of the Holocene soils, and with further dates and comparison with pollen diagrams of lake sequences (Melief, 1985), he could correlate the diagrams with the paleo-vegetational and paleo-climatic sequences. Diagram TPN-13 from a site on the west flank at 3725 m elevation, shows a Lateglacial sequence, with a well marked warmer interval (local zone U) with higher per-

centages of arboreal pollen (*Hesperomeles*, *Myrsine* (= *Rapanea*) and Melastomataceae etc.), correlated with the Guantiva interstadial, and a colder interval with very high percentages of grasses (local zone V), correlated with the El Abra stadial (ca. 11,000–10,000 BP), followed by definitely higher arboreal pollen percentages during the following interval of Holocene age.

The Late Otun moraines at ca. 4000 m elevation of the Central Cordillera are covered with a sequence of paleosols of ca. 200 cm, that represent the entire Holocene (Thouret and Van der Hammen, 1981; Thouret *et al.*, 1995; Salomons, 1986, 1989). A radiocarbon date at a depth of 115 cm is 7440±70 BP (GrN-9809), while the base, through correlation with the dated San Carlos section (Melief, 1985), should have an age of ca. 10,000 BP. Radiocarbon dates from the lower part of the soil sequence are between 8000 and 9000 BP (8960±140 BP; GrN-11331), confirming this correlation. The older Early Otun moraines are covered by a longer sequence of paleosols and tephra, going back to ca. 12,400 BP. The Late Otun moraines may therefore most probably be correlated with the more important cold phase in the interval 12,000–10,000 BP, the El Abra stadial, and with the Bocatoma moraines of the Sierra Nevada del Cocuy.

DATA FROM THE SIERRA NEVADA DE SANTA MARTA

The Naboba moraine at 4500 m elevation (Van der Hammen, 1984) is covered, in a lower part, by a sequence of 160 cm of sediment, first 40 cm of sandy loam, then 120 cm of peat. There are two radiocarbon dates from the peat section from ca. 4500 m elevation, the one from the base is 8485±70 BP (GrN-4358). Extrapolation suggests a date of ca. 10,000 BP for the base of the sediments, while the pollen diagram does not show a fundamental difference between the loam and the peat. It seems therefore probable that the Naboba moraine is of the same age as the Bocatoma and Late Otun moraines and of El Abra stadial age.

DATA FROM THE TROPICAL LOWLANDS

Data from the tropical lowlands are still very scarce and difficult to interpret. Nevertheless it seems useful to mention the presence of peat layers intercalated in minerogene river sediments, in the lower Magdalena River, as yet mainly unpublished, with six dates between 12,800±180 BP (GrN-7553) and 11,170±170 (GrN-7394). The peat layers and associated minerogene sediments are therefore of Guantiva interstadial age, and might represent a period of increasing river discharge.

From tropical lowland Amazonia (middle Caquetá River) we report a few dates on wood from a peaty layer, intercalated in a low terrace that belongs to the present inundation valley. The dates are 12,530±45 BP (GrN-16672) and 12,560±45 BP (GrN-16594). The peat is covered by some 290 cm of clay; the little terrace was then eroded, and the earliest dated sediments of the new cycle of river deposition have an age of 9810±70 BP (GrN-

16689). If the Holocene rate of sedimentation is applied to the sediments of the little terrace, the top could have an age of ca. 11,000 years; if that is right, the river would have cut itself into the Guantiva interstadial age sediments, during the El Abra stadial.

THE CLIMATIC CHANGE OF THE EL ABRA STADIAL

The dates presented in this paper and in the corresponding original publications, may be interpreted in terms of changes in average annual temperature and relative changes of rainfall. Both in the El Abra II-B 3 diagram, as in the Fuquene II diagram, lake level dropped at the beginning of the El Abra stadial, leading to (the extension of) marshy zones, and lake sediments being replaced partially by marshy shore sediments. In Fuquene, the extended marshy zone is again occupied by the lake at the beginning of the Holocene. All this suggests that the El Abra stadial was not only colder, but also drier than before and after.

The available pollen diagrams from the Eastern and Central Cordillera, may be interpreted as altitudinal movements of the upper forest line, and of the boundary between the Andean and subAndean forest belts (under modern conditions at ca. 2300 m). Average annual temperature during the Guantiva interstadial may have been 2°C lower than today, and during the El Abra stadial from 4–6°C lower than today. The upper forest line during the El Abra stadial was some 400–500 m lower than during the Guantiva interstadial and some 600–800 m lower than today.

DISCUSSION AND CONCLUSIONS

From the data of the Eastern Cordillera of Colombia (e.g. Figs 2–4), it is clear that in the higher part of this area, there is significant evidence of the existence of a Lateglacial interstadial (Guantiva interstadial) followed by a Lateglacial stadial, the El Abra stadial, whose age is between approximately 11,000 and 10,000 BP (probably between ca. 10,900 and 10,100 BP). There may be a transitional phase from ca. 10,000 to 9500 BP. The dates are sufficiently precise to accept a time correlation between the El Abra stadial and the Younger Dryas stadial of Europe. Data from the Central Cordillera equally confirm the existence of the El Abra cold interval, while the presence of a late Lateglacial moraine system in both the Eastern and Central Cordillera (the Bocatomá and Late Otún moraines, respectively) and possibly also in the Sierra Nevada de Santa Marta, is proved, and an El Abra stadial age is most probable.

A re-evaluation of the El Abra evidence is part of our current study. Additional radiocarbon dates of some of the original cores on which the El Abra climatic oscillation was based (El Abra II-B3 and Fuquene II) as well as newly recovered cores from Lake Fuquene are in progress (Van 't Veer and Islebe, *in preparation*). We expect to eliminate uncertainties (Heine, 1993) and to improve the interpretation of the pollen records in terms

of local environmental and regional climatic change.

Of special importance is to obtain more information on the tropical lowland equivalent of the El Abra stadial, in terms of vegetation, climate, stratigraphy and geomorphology.

Colombia was probably the first country outside Europe where Allerød–Younger Dryas equivalents were found and dated. Since then a considerable amount of evidence has accumulated. One of the main tasks will certainly be to extend the knowledge from the highlands to the lowlands, so as to understand better the global climatic change and impact of the El Abra–Younger Dryas stadial.

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