Paleoindian Cave Dwellers in the Amazon: The Peopling of the Americas

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A Paleoindian campsite has been uncovered in stratified prehistoric deposits in Caverna da Pedra Pintada at Monte Alegre in the Brazilian Amazon. Fifty-six radiocarbon dates on carbonized plant remains and 13 luminescence dates on lithics and sediment indicate a late Pleistocene age contemporary with North American Paleoindians. Paintings, triangular bifacial spear points, and other tools in the cave document a culture distinct from North American cultures. Carbonized tree fruits and wood and faunal remains reveal a broad-spectrum economy of humid tropical forest and riverine foraging. The existence of this and related cultures east of the Andes changes understanding of the migrations and ecological adaptations of early foragers.

For decades, there was a consensus that the earliest Americans came from Asia across the Bering Straits near the end of the Ice Age, settling first in the North American high plains, then moving into South America down the Andean chain (*1–3*). Northern Paleoindian cultures appear to begin with Clovis and Folsom, dated from ~11,200 to 10,900 and from ~10,900 to 10,200 years before the present (yr B.P.), respectively, and end in the early Holocene at ~8500 yr B.P. (*4*). Early North American Paleoindian sites contain finely chipped, fluted, bifacial spear points, other tools, and the bones of extinct large game (*5*). With these cultures as models, Paleoindians were considered to have been specialized big-game hunters adapted to open, temperate, terrestrial habitats throughout the Americas, and such habitats have been the focus of research. Pleistocene seacoasts, now mostly submerged, have not been actively investigated. The tropical rainforest was thought to have been an ecological barrier to Paleoindians because it provided only scarce resources for human subsistence, and anthropologists have theorized that people could not survive there before the development of slash and burn cultivation (*6*). The rainforests cited in the theories are more varied in climate, soil, vegetation, and food resources than is the archetype (*7, 8*), but there has been little conclusive evidence for Paleoindian foragers in tropical rainforests, due to a lack of concerted research. In this article, we present evidence for the presence of Paleoindians in the Amazon and discuss the implications of that presence for the peopling of the Americas.

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The Pre-Clovis Hypothesis

Some anthropologists have questioned the migration theory described above, suggesting that foragers with simpler tools and more generalized subsistence based on plants, smaller game, and fish spread throughout the Americas long before specialized big-game hunters did so (*9–14*). There is no undisputed evidence for foragers earlier than Clovis, however (*15*). Charcoal and megafauna associated with flaked rocks have given consistent pre-Clovis dates, but charcoal and flaked rocks can form by natural processes, and fossil bones can be dug up and used at a later date. Most pre-Clovis dates associated with human bones and undoubted cultural remains are rare inconsistent outliers, and disturbance or contamination by carbon from limestone, coal, or petroleum is likely (*16*). Conclusive evidence for an occupation requires numerous concordant dates on a range of materials such as artifacts, human skeletons, and food remains in a cultural sequence from intact stratified deposits (*17*).

South American Paleoindians

Possible Paleoindian artifacts have been identified at sites throughout South America. They range from simple flaked rocks and possibly worked bone and wood to carefully flaked bifacial and unifacial stone tools. The evidence from these sites fits neither pre-Clovis nor Clovis theories. The earliest securely dated cultures are contemporary with early North American Paleoindian complexes but have distinct subsistence patterns and tool complexes. The few assemblages of abundant biological remains are usually characterized by diverse modern species. In most cases, megafauna are rare or absent. Diagnostic tool types include fishtail points, willow-leaf points, triangular stemmed points, and limaces (slug-shaped unifacial endscrapers). The first two are considered by some archaeologists to be related to northern Paleoindian traditions, but triangular points and limaces are not. Triangular points are common in early Holocene complexes of Archaic broad-spectrum foragers in the Americas, so South American examples

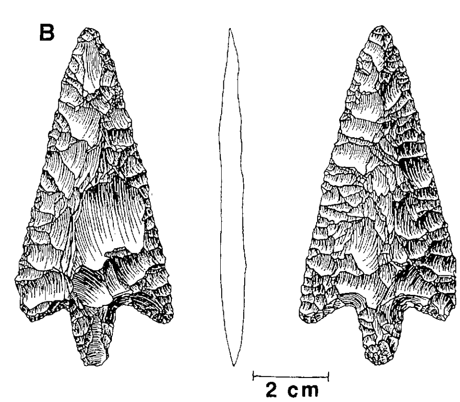

Fig. 1. Triangular, stemmed, bifacial spear points from the Tapajós river. (**A**) Quartz crystal, 25.75 g, specimen no. 1273, MPEG. (**B**) Chalcedony, 19.95 g, specimen no. 1491, MPEG.

were expected to be post-Pleistocene. However, triangular points occur in late Pleistocene Eurasia and in Alaska near the Bering Straits (*2*, *10*). Their absence from the Clovis tradition appears to be a restricted local pattern. Nonetheless, problems with dating or identification of artifacts and biological remains, or incomplete publication, have made the age, adaptations, and affiliations of many South American complexes uncertain.

Several subtropical Brazilian rock art sites and open sites with flaked stones, rock painting spalls, and possible hearths have numerous, consistent pre-Clovis radiocarbon dates going back to ~50,000 yr B.P., but human presence that early has been questioned. Later levels of these and many other sites have pressure-flaked, triangular, stemmed bifacial points and limaces; hearths; diverse modern fauna and flora; pigment; and stratigraphic relations with rock art. These assemblages have numerous dates between ~11,500 and 8000 yr B.P. but only rare inconsistent dates earlier than that (*18*).

Further south, presumed pre-Clovis complexes in Uruguay are undated surface collections (*19*). In Chile and Argentina, rare stone flakes and possible bone or wood tools occur in sites with megafauna and sometimes rock art, but pre-Clovis dates are exceptional or are associated with disturbance or contamination. Fuller assemblages with fishtail points in these and other sites have diverse modern and extinct fauna and predominantly late Pleistocene ages between ~11,000 and 9500 yr B.P. (*20*). Two widely separated wet sites in Chile and Venezuela with rare bifacial willow-leaf point fragments have barely pre-Clovis dates between ~13,500 and 11,800 and between 14,400 and 11,900 yr B.P., respectively, for megafaunal bone and plant material. However, both sites have multiple contamination agents and complex discontinuous stratigraphy affected by water action (*21*).

In Ecuador, radiocarbon dates for preceramic cultures are early Holocene; the only pre-Clovis dates are discordant and come from problematic surface assemblages (*22*). In highland Colombia, preceramic sites with rare, unifacially flaked stone tools, abundant modern fauna and flora, and rare megafauna have only two pre-Clovis radiocarbon dates, and disturbances and pre-human carbon were encountered (*23*). Fishtail points in Colombia and Panama are undated. Finely chipped, bifacial, stemmed, fluted triangular projectile points throughout Colombia also lack radiocarbon dates. In Peru, complexes with triangular and lanceolate points, other tools, and modern biota have numerous radiocarbon dates, between ~11,000 and 7100 yr B.P. in the highlands and between ~10,400 and 7700 yr B.P. on the coast. Pre-Clovis dates are rare outliers or are from levels without accepted in situ artifacts (*24*).

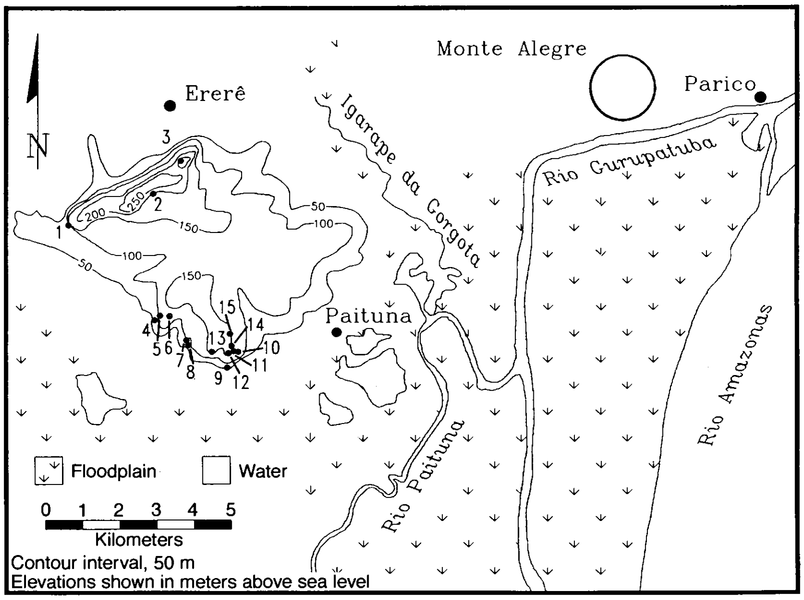

Fig. 2. Map of Monte Alegre. Coordinates: −01° 59′ 46.148″S, 54° 04′ 16.413″W, 80.18 m above sea level. Key: 1. Serra da Lua. 2. Gruta Itatupaoca. 3. Alto da Pedra Mirante. 4. Fonte do Miritiepé. 5. Gruta do Miritiepé I. 6. Gruta do Miritiepé II. 7. Gruta da Arapuã I. 8. Gruta da Arapuã II. 9. Paituna Road site I. 10. Abrigo da Curuja. 11. Gruta Quinze de Março. 12. Pedra do Pilão. 13. Gruta do Labirinto. 14. Pedra Pintada do Pilão. 15. Caverna da Pedra Pintada.

The open questions about the peopling of the Americas have implications for research strategies. Zones thought uninhabitable by Paleoindians need to be investigated, as well as presumed occupation zones. To verify age and ecological adaptation, both cultural and natural remains need to be collected from sealed stratigraphic contexts and dated. A wide range of cultural and biological material is recoverable even from humid tropical sites by flotation and total fine-screening methods. With accelerator radiocarbon and thermoluminescence techniques, diverse materials can be dated and chemical analysis can assess material composition, provenience, and contamination.

Paleoindians in the Amazon

The lower Amazon. Although parts of the Amazon are hypothesized to have been unforested savannas or subtropical forests dur-

Fig. 3. Rock paintings of concentric circles, hand prints, and an inverted figure with rayed head, Serra da Lua, Monte Alegre.

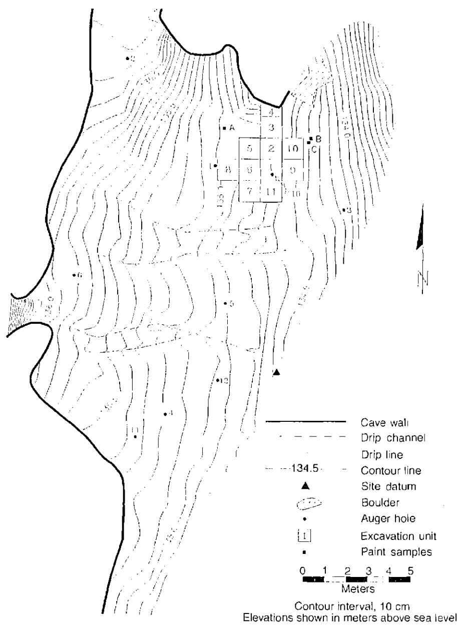

Fig. 4. Map of main chamber, Caverna da Pedra Pintada. A, snake; B, bullet-shaped winged motif; C, concentric cross.

ing Pleistocene glacials, rainforests existed along the Amazon in fertile uplands such as Monte Alegre, at the confluence of the Tapajós and Amazon rivers in the lower Amazon, Brazil (*25*).

Archaeologists had suggested the possibility of Pleistocene colonizations in the Amazon, either by foragers from Asia or incipient farmers from tropical Africa, but early sites were expected to be invisible because of poor preservation and lack of rock for lithics (*26*). Suitable rock is widely available, however, and finely flaked bifacial stone points have been recorded in several Amazonian regions, including the lower Amazon region, from the mouth of the Tapajós river to Belém, Brazil, and to Guyana. Of quartz crystal or chalcedonic rock, the lower Amazon points are up to 12 cm long and thin, with down-turned wings and contracting stems or concave bases (Fig. 1) (*27*). Edges are finely retouched with regular, continuous pressure flaking.

Although without dates or stratigraphic context, the lower Amazon points were assumed to be early Holocene Archaic (*27*). However, neither the points nor flakes from making them had been found in lower Amazon early Holocene sites (*28*). Further, they differed morphologically and technically from documented South American lowland Archaic points, which are thick and percussion-flaked, lacking the continuous pressure retouching, well-articulated stems, and down-turned wings (*29*). The shape and technique of lower Amazon points linked them, instead, to late Pleistocene triangular points of eastern South America, cited above.

Caves and rockshelters at Monte Alegre. To investigate the age of the points, it was necessary to excavate a stratified occupation site where they were made. We surveyed caves where deposits would have been protected from Holocene erosion and sedimentation. Numerous caves and rockshelters had been recorded in the Paleozoic sandstones of Monte Alegre by 19th-century naturalists and 20th-century speleologists, geologists, and archaeologists (Fig. 2) (*30–32*). Many bore evidence of human activity in the form of stylized rock paintings (Fig. 3). The red and occasionally yellow designs (~20 cm to 2 m long) include geometric motifs, anthropomorphic figures, animals (modern taxa, apparently), and handprints of adults and children. Because North American Paleoindians are not known for rock painting, the art was thought to be Holocene but no sites had been excavated and dated.

Monte Alegre lies between Manaus and Belém on the Amazon north bank opposite Taperinha. The much-faulted uplands (terra firme), 50 to 300 m above sea level, have crystalline Precambrian basement, Paleozoic and Tertiary sediments, Mesozoic diabase dikes, hot springs, and quartz veins. Broad river floodplains (várzea) are Quaternary alluvium. The humid tropical monsoon climate (Köppen Am climate type) is characterized by ~2000 mm of annual rainfall. Tall evergreen forest grows on fine, nutrient-rich soils, and seasonal forest and savanna woodland grow on nutrient-poor sandy or rocky soils. Widespread deforestation from more than two centuries of ranching and agriculture has created dense secondary forests and shrubby pastures (*25*, p. 32; *32*).

Surveys and excavations in Monte Alegre. As part of the Lower Amazon project (*33*), we surveyed 21 caves, rockshelters, and open sites and satellite-located them to global coordinates. To test for the presence of archaeological deposits, sites [site numbers 2, 5 through 10, and 15 (Fig. 2)] were augered in levels of ~10 cm and were mapped with electronic distance-measuring devices.

At Caverna da Pedra Pintada, a painted sandstone cave near Monte Alegre, we found stratified Paleoindian deposits (Fig. 4). The well-lit, airy main chamber is 15 m from north to south, 10 m from east to west, and 6.5 m high. Although the cave is dry in the dry season, moisture drips down the center in the rainy season. There is a perennial spring nearby (Fig. 2, site 4). About 130 m below and 3 km away are floodplain lakes and streams. The Amazon main channel lies about 10 km away. During the late Pleistocene, river levels were lower and floodplains less extensive.

The 12 auger cores inside and outside the cave revealed two areas of deep, well-preserved, stratified archaeological refuse on the north and south sides just inside the mouth. Under the paintings on the north ceiling, we excavated 11 contiguous meter-sized squares to a maximum depth of ~2.25

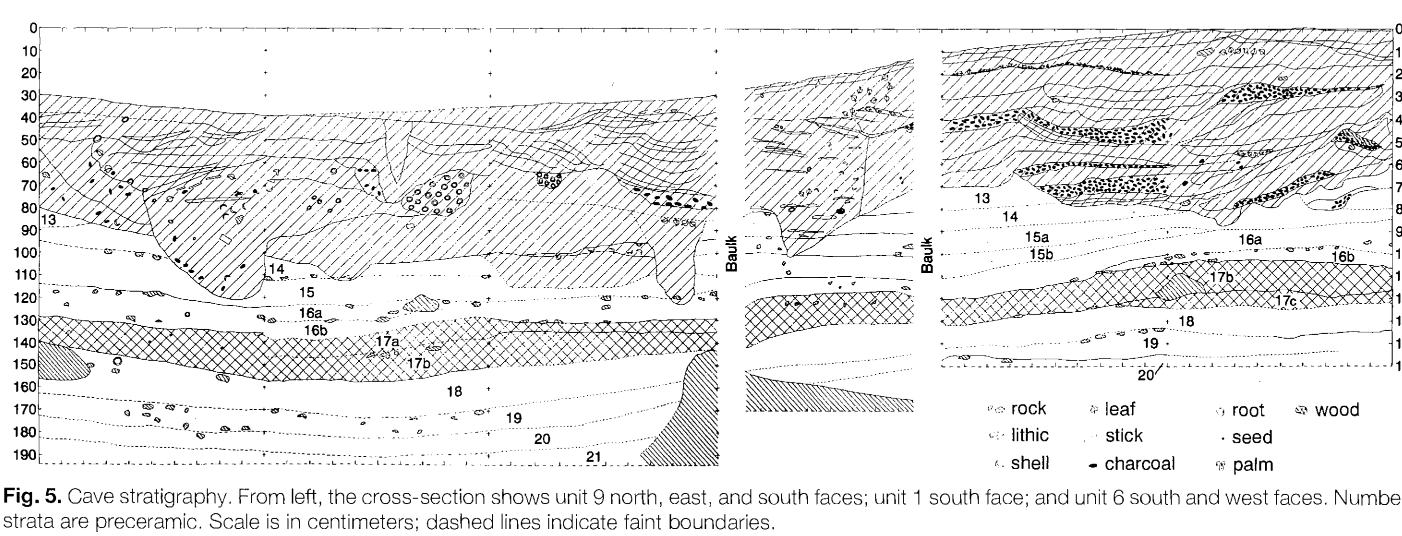

Fig. 5. Cave stratigraphy. From left, the cross-section shows unit 9 north, east, and south faces; unit 1 south face; and unit 6 south and west faces. Numbered strata are preceramic. Scale is in centimeters; dashed lines indicate faint boundaries.

m from surface to bedrock (34). The stratigraphic column (Fig. 5) included 20 main archaeological strata in four groups from bedrock to surface: ~50 cm of sterile sand and sandstone boulders (strata 18 through 21), 30 cm of late Pleistocene preceramic Paleoindian midden (strata 16 and 17), 30 cm of culturally sterile soil (strata 13 through 15), and 65 cm of Holocene pottery-age midden (strata 1 through 12).

Disturbance and preservation in the dry sandy soil diminished with depth. Late prehistoric layers contained faunal bone, shell, dry and carbonized plant remains, small root intrusions, burrows, cattle wallows, and a post structure. Early and middle Holocene strata contained faunal bone, shell, carbonized plants, middle Holocene burials, and the post intrusions. Culturally sterile strata below covered the Paleoindian deposit, which contained abundant carbonized plants, lithics, pigment, rare faunal remains, and only a few post intrusions and one burrow. The sand and sandstone underneath were sterile.

Pleistocene Occupation

Paleoindian strata. There were two main strata in the Paleoindian deposit. The lower was stratum 17, a blackish sand layer 10 to 25 cm thick. Above was stratum 16, a dark gray sand layer 5 to 20 cm thick. Occupation features were shallow hearths and concentrations of carbonized seeds but no pits or post holes. Strata subdivisions could be excavated in only a few locations. Four main Paleoindian periods could be discerned from substantial changes through time in the proportions of lithic materials. Initial, early, and middle periods were concentrated in stratum 17, and stratum 16 contained the rest of the middle period and the late period. Because of uneven bedrock and the loose soil, the different Paleoindian strata were merged in some areas. The distribution of lithic material showed that intensity of occupation increased greatly with

Table 1. Distribution of lithic materials in Paleoindian levels. N, S, E, W, and C refer to horizontal subdivisions of levels. Counts in parentheses are less than 75 total specimens and have statistically unreliable percentages. Unit 5 float screen samples (except level 13) and unit 7 screen samples were lost.

Excavation information					Rock types						
Period	Level	Prov. no.	Strata	Depth (cm)	Chalcedonic rock *n*	Chalcedonic rock %	Quartz breccia *n*	Quartz breccia %	Quartz crystal *n*	Quartz crystal %	Totals
				Unit 1							
Late	8	8208	Base 15/16	102–106 to 115–123	(64	98	1	1	0	0	65)
Middle/Early	9	8209	17	115–123 to 136–138	217	54	154	38	27	6	398
	10	8210	18	136–138 to 149–154	(2	1	0	0	0	0	2)
Totals					283		155		27		465
				Unit 2							
Middle	10	8227	Base 15, top 16	98–104 to 100–112	(23	76	3	10	4	13	30)
Middle/Early	11AC	8228, -9	Base 16, top 17	104–112 to 108–120	171	75	21	9	35	15	227
Early	12	8230	Top 17	108–120 to 114–120	107	74	11	7	26	18	144
Initial	13E	8231	Base 17	119–120 to 120–132	102	42	62	25	75	31	239
	13W	8231	Base 17	114–120 to 119–127	127	31	95	23	184	45	406
Totals					530		192		324		1046
				Unit 5							
Early	11	8311	Base 16, top 17	94–95 to 98–93	(17	56	9	30	4	13	30)
	12	8312, -3	17	98–99 to 102–104	(33	54	10	16	18	29	61)
Initial	13	8314–6	17	102–104 to 106–109	53	39	36	27	44	33	133
	14	8317, -9	Base 17, top 18	106–109 to 110–120	(4	20	8	40	8	40	20)
Totals					107		63		74		244
				Unit 6							
Middle/Late	8AB	8342, -3	16	85–97 to 101–108	133	88	10	6	7	4	150
Early	9	8344	Top 17	101–108 to 108–113	229	57	93	23	77	19	399
Initial	10	8345	17	108–113 to ~110–120	242	41	114	19	224	38	580
	11	8346	Base 17	110–120 to 113–125	242	33	160	22	316	44	718
	12	8347	Base 17, top 18	113–125 to 124–134	(14	31	12	26	19	42	45)
Totals					860		389		643		1892
				Unit 7							
Late	12	9141	15/16	73–80 to 88–93	153	95	0	0	7	4	160
	13AB	9142	15/16	88–93 to 95–98	590	95	8	1	21	3	619
	14A S	9143	16	95–98 to 97–102	93	96	0	0	3	3	96
Middle/Early	14BC N	9143	16/17	95–98 to 97–102	228	85	6	2	33	12	267
Early	15A NE	9144	17	102–103 to 102–113	177	68	9	3	73	28	259
Initial/Early	16 NE	9145	17	102–113 to 111–118	103	53	12	6	79	40	194
	17 AB	9146–9	17	111–118 to 114–122	104	24	33	7	286	67	423
	18 NE	9147	17	114–122 to 118–125	36	13	23	8	201	77	260
	19	9148	17/18	114–125 to 123–137	22	22	11	11	64	65	97
	20	9150	17/18	123–137 to 126–138	(1	50	0	0	1	50	2)
Totals					1507		102		768		2377
				Unit 8							
Late	14	9201	16	68–70 to 80–81	(26	89	1	3	3	10	30)
	15	9202	16	80–81 to 88–94	182	94	8	4	2	1	192
Middle	16A E	9203	17	88–94 to 96–98	118	76	15	9	21	13	154
Early	16B W	9204	17	88–92 to 94–98	86	61	26	18	27	19	139
	17AB	9205, -6	17	94–98 to 100–108	129	57	65	28	32	14	226
Initial	19–20	9207–9	17/18	100–108 to 102–130	(4	33	2	16	6	50	12)
Totals					545		117		91		753

time and that camping location shifted slightly. Units 3 and 4 at the slope of the cave wall lacked Paleoindian strata.

Lithic tools. In all, we counted 24 formal tools and more than 30,000 flakes from toolmaking in the Paleoindian strata. In contrast, there were fewer than 150 lithics in the other layers.

As identified by thin sections and petrographic microscopy correlated with x-ray diffraction, the primary rocks were chalcedonic rock (35), quartz crystal, and quartz breccia (fault- or shear-zone polycrystalline quartz from recrystallized sandstone). Shale, volcanic rock, granodiorite, microdiorite, and granite made up less than 0.001%. All the rocks occur in the municipality but none are from the cave, whose friable sandstone is composed of silt and subrounded quartz grains joined by microparticles of clays and iron oxyhydroxides. The proportions of the main rock types changed steadily over time (Table 1). Chalcedony, the most abundant, made up ~30 to 40% during the initial period, 40 to 70% in the early period, 70 to 90% in the middle period, and 90 to 98% in the late period. Quartz crystal made up ~50 to 30% of the lithics during the initial period, 30 to 15% in the early period, 15 to 5% in the middle period, and was rare or absent in the late period. Quartz breccia varied irregularly, often being high in the initial period, high to moderate in the early and middle periods, and rare in late-period deposits.

The lithics show that Paleoindians made triangular, stemmed bifacial points, as well as other tools (Fig. 6). Techniques of manufacture resemble those of other Paleoindian and upper Paleolithic complexes (36). In all the periods, there were percussion and pressure flaking, bifacial and unifacial flaking, heat treating, and isolated platforms prepared with pecking and grinding. Broad bifacial thinning flakes and fine, narrow, regular retouching flakes are common in all periods.

Among the tools, 10 bifacial and 14 unifacial tools were identified. The bifaces included four points (Fig. 6, A through D), two chalcedony point preforms [Fig. 6E and provenience (prov.) number 8209], one quartz crystal biface (prov. 9295), one bifacially retouched chalcedony blade (prov. 9243), and two chalcedonic rock plaques made on cobbles (prov. 8314 and 9203). No bifaces showed wear from use, and all but the plaques had broken during manufacture. Among unifaces were a chalcedony stemmed graver (Fig. 6G), four limaces (Fig. 6, H and I; prov. 8230, of chalcedony; and prov. 8314, of quartz crystal), five unifacially retouched flakes or blades of various materials (prov. 8208, 8231, 8314, 9147, and 9270), and four unretouched blades (Fig. 6F and prov. 9123, 9272, and 9287–8), all of chalcedony. The largest limace (Fig. 6I), blades, and flake tools had blunted edges, and the graver bore gloss on its upper and lower surfaces.

With only a few whole tools, the range

Table 1. (continued)

Excavation information					Rock types						
Period	Level	Prov. no.	Strata	Depth (cm)	Chalcedonic rock		Quartz breccia		Quartz crystal		Totals
					n	%	*n*	%	*n*	%	
				Unit 9							
Late	10AB	9237, -8	Top 16	97–108 to 111–117	(39	97	0	0	1	2	40)
	11AB	9239, -40	Top 16	111–117 to 117–124	332	95	8	2	7	2	347
	12A C/NW	9241	16	108–117 to 121–126	561	91	31	5	18	2	610
Middle	12B E	9242	16	117–126 to 126–135	638	82	84	10	54	6	776
	13	9243	16/17	121–135 to 123.5–137	1258	68	488	26	96	5	1842
	14	9244	17	123.5–137 to 127–138	762	71	213	19	93	8	1068
Early	15	9245	17	127–138 to 129–146.5	806	45	820	46	135	7	1761
	16	9246	17	129–147 to 132–147	114	37	158	51	35	11	307
Initial	17	9248	17	132–147 to 138–156	26	27	45	47	24	25	95
	18/20	9249, -50	Base 17 to 20	138–156 to 176–183	(56	83	4	5	7	10	67)
Totals					4592		1851		470		6913
				Unit 10							
Late	3AB	9259, -60	15/16	108–116 to 118–123	(15	88	2	11	0	0	17)
	4	9261	15/16	118–123 to 120–130	133	93	4	2	5	3	142
	5	9265	Top 16	120–130 to 126–136	190	94	0	0	12	5	202
	7B SW	9269	16	127 to 136	287	95	10	3	5	1	302
	6A C/E	9266	16	129–136 to 136–142	128	89	11	7	4	2	143
Middle	7A C/E	9268	16	136–142 to 140–150	486	88	22	4	41	7	549
	8A C/E	9270	Top 17	140–150 to 143–158	634	81	65	8	78	10	777
	9A C	9271	17	143–158 to 146–158	656	79	102	12	63	7	821
Early	10AB	9272, -3	17	136–158 to 145–162	482	57	182	21	171	20	835
Initial	11AB	9274, -5	17	145–162 to 146–166	148	41	84	23	125	35	357
Totals					3159		482		504		4145
				Unit 11							
Late	5ABC	9281–3	16	83–97 to 104–110	868	97	12	1	13	1	893
	6ABC	9284–6	16	104–110 to 108–118	1852	97	12	0.6	29	1	1893
	7AB	9287, -8	16	108–118 to 112–125	2413	94	75	2	62	2	2550
	8B C/NE	9290	16	116–125 to 120–128	2583	96	67	2	37	1	2687
	9B C/NE	9292	16/17	120–128 to 124–130	2001	90	138	6	67	3	2206
Middle	8A NW	9289	17	112 to 117	157	76	20	9	29	14	206
	9A NW	9291	17	117 to 119	(33	80	3	7	5	12	41)
Early	10 AB	9293, -4	17	119–128 to 122–132	764	69	209	18	128	11	110
	11AB	9295, -6	17	122–123 to 130–139	565	56	290	28	153	15	1008
Totals					11,236		826		523		12,585
Grand totals					22,819		4177		3424		30,420

of types at any time is uncertain and functions can be classifed only tentatively. The stemmed points and limaces occurred only in the initial and early periods. The bifacial points could have been knives or spear, dart, or harpoon points, which in Amazonia today are usually socket-hafted and barbed. The unifaces would be suitable for woodcutting, digging, or hide-working.

Paintings and pigment. Stylistic variation and superpositions in the paintings suggested that more than one period was represented (30). The red wall paint was iron oxide, which cannot be dated directly, but the stratigraphy and chemical composition of the paint gave relative chronological information. The Paleoindian strata contained hundreds of lumps and drops of red pigment, as well as two small spalls of painted wall (prov. 9242). In contrast, only one pigment rock was identified in Holocene layers: a late prehistoric faceted red rock. In addition, several late prehistoric pottery sherds bore unfired red paint. There was no overlap of strata on paintings, due to the slope of the walls, but the lowest paintings were waist- to eye-level for Paleoindians and knee- to ankle-level for Holocene people.

To ascertain if the excavated pigments could have been used to paint the walls, 20 samples were analyzed (37) (Table 2): 6 of red paint from wall paintings (5 above the excavation block and 1 in a secondary chamber); 10 of pigment from Paleoindian layers; and 4 control samples from Paleoindian layers, the late prehistoric pigment rock, and red paint from a sherd. A silica layer over the paintings made them difficult to sample but presumably was responsible for their preservation.

Under the scanning electron microscope, all pigment samples were physically similar: a fine red powder composed primarily of quartz 1 to 200 μm in size and of ferruginous laterite rich in hematite, a common iron-rich material also present in the lithics and cave rocks. No concentrations of laterite that could have served as pigment were observed in the cave rock, but fossil laterite is common in the region. The cave pigment was variable in composition even within a design (see the different results on sample 1/1, Table 2). Secondary components included illite, kaolinite, goethite, gibbsite, and gypsum.

Among elemental components, Fe/Ti ratios may be diagnostic of pigment sources (38) (Table 2). Most paints and pigments had Fe/Ti ratios above 50. These [2/2, 2/3, 2/4, 1/4 (prov. 8231), 2/5 (prov. 9214), 2/7

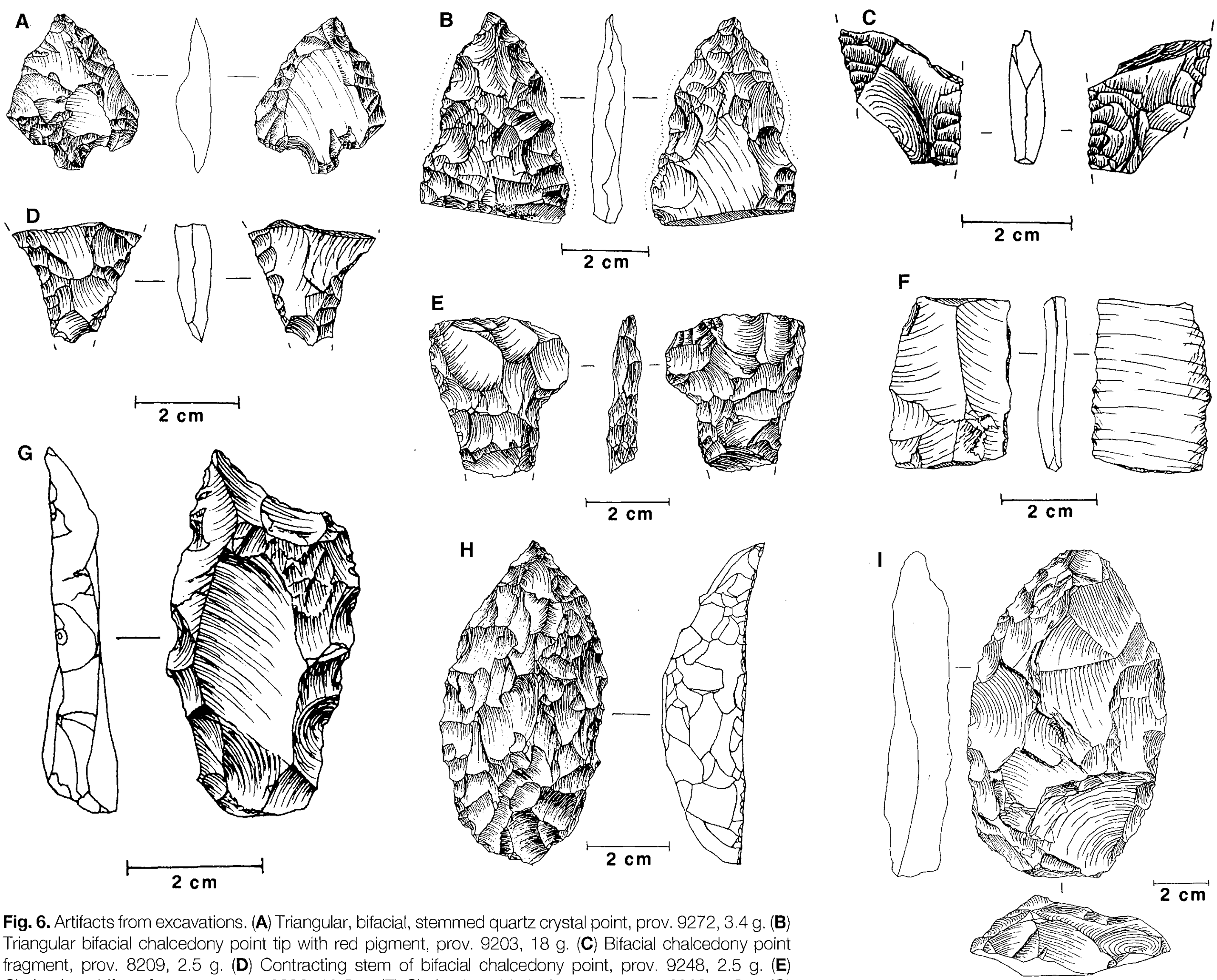

Fig. 6. Artifacts from excavations. (**A**) Triangular, bifacial, stemmed quartz crystal point, prov. 9272, 3.4 g. (**B**) Triangular bifacial chalcedony point tip with red pigment, prov. 9203, 18 g. (**C**) Bifacial chalcedony point fragment, prov. 8209, 2.5 g. (**D**) Contracting stem of bifacial chalcedony point, prov. 9248, 2.5 g. (**E**) Chalcedony biface fragment, prov. 9206, 12.5 g. (**F**) Chalcedony blade fragment, prov. 9290, 5.5 g. (**G**) Chalcedony unifacial graver, prov. 9145, 16 g. (**H**) Chalcedony limace with graver tip and red pigment, prov. 8344, 72 g. (**I**) Quartz breccia limace, prov. 9290, 250 g. See Table 1 for excavation units, levels, depths, strata, and periods for provenience numbers.

(prov. 8314), 2/9 (prov. 8345), 2/11 (prov. 8314), and 2/14 (prov. 8313) (Table 2)] include all but one wall paint, all but two Paleoindian pigments, and the late prehistoric stone, but not the control samples or pottery paint. This source appears to have been used comparatively frequently by Paleoindians and cave painters but rarely by late prehistoric cave dwellers. A smaller group of samples had Fe/Ti ratios below 50. These [1/2, 1/3 (prov. 8344), 2/6 (prov. 8202), 2/10 (prov. 9290), 2/13 (prov. 8345), 2/15 (prov. 8345), and 2/16 (prov. 8345) (Table 2)] included the controls, two pigments from Paleoindian levels, and the pottery paint, but no cave paint. This source was used occasionally by both Paleoindians and late prehistoric cave dwellers. Four samples [1/1, 2/1 (prov. 9203), 2/8 (prov. 8344), and 2/12 (prov. 8345) (Table 2)] had Ti levels below 0.5%, in contrast to the other samples. They included two pigment chunks and the pigment on the chalcedony point tip from Paleoindian levels. In the fourth sample, cave wall paint (1/1, Table 2), the low iron content could be the cause for the low ratio.

Because pigment was abundant in the Paleoindian layers and was similar physically, chemically, and in Munsell color codes to the wall paint, it seems likely that Paleoindians made many of the paintings. Because one pigment rock of similar material was found in the late prehistoric deposit, some paintings could possibly be of that age, but the lack of any dropped or spattered pigment in those layers suggests that these are not numerous. As no pigment was recovered from early Holocene contexts, it is unlikely that the paintings were Archaic.

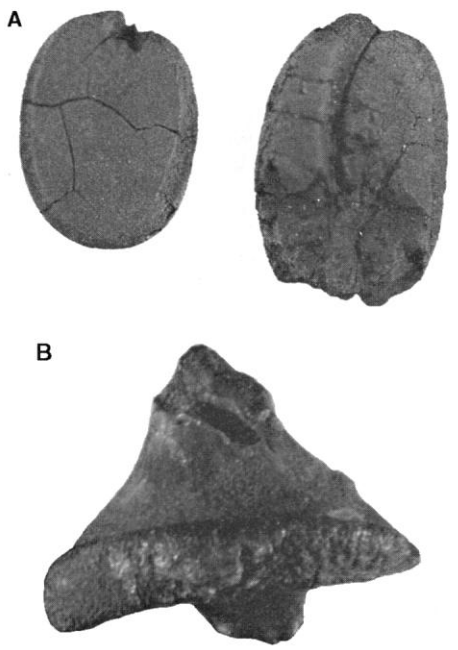

Fig. 7. (**A**) Carbonized seeds of *Hymenaea* cf. *parvifolia* and *oblongifolia*. Left, prov. 9290. Right, prov. 9272. Seed at right is about 10.8 mm long and each seed is about 5 mm wide. (**B**) Otolith of large fish, prov. 8347. Otolith is about 5 mm wide.

Biological remains. The Paleoindian deposit contained thousands of carbonized fruits and wood fragments from common tropical forest trees (39). Jutaí [*Hymenaea* cf. *parvifolia* and *oblongifolia* (Leg. Caesalpinioideae)] (Fig. 7A), achuá [*Sacoglottis guianensis* (Humiriaceae)], and pitomba [*Talisia esculenta* (Sapindaceae)] occurred in many levels. Brazil nut (castanha do Pará) [*Bertholetia excelsa* (Lecythidaceae)], muruci da mata [*Byrsonima crispa* (Malpighiaceae)], apiranga [*Mouriri apiranga* (Melastomataceae)], and tarumã [*Vitex* cf. *cymosa* (Verbeaceae)] occurred in several levels.

Jutaí is a leguminous tree of terra firme forests, high várzea, and woodland along the Amazon, valued for flour from the aril around the seeds and for medicine, varnish, and wood. Growing up to 30 m in moisture-retentive soils, it is shorter on droughty soils. Achuá is a common lower Amazon rainforest tree 18 to 20 m tall that bears edible starchy fruits. Pitomba is a 6- to 12-m-tall fruit tree of the eastern Amazon and Atlantic tropical rainforests. Brazil nut is a large, 30- to 50-m-tall rainforest tree native to Amazonia. Its nutritious seeds are important in local and export markets. Muruci da mata, a 12- to 18-m-tall tree thought indigenous to lower Amazon terra firme forests, has small fruits that can be preserved for months in water. Apiranga is a small Amazonian fruit tree of sandy floodplains and secondary forests, and tarumã is a várzea tree whose fruits are used for fish bait.

Table 2. Ratios of weight percents of iron and titanium in paint, pigment, and control samples as determined by SEM-EDS.

Sample description (group/sample no.)	Fe/Ti
Samples of paint from the cave wall	
Concentric crosses design (1/1);	17.6*
second sample from concentric crosses design	8.6*
Linear design, north chamber (2/2)	90.8
Snake design, north wall; main chamber (2/3)	77.2
Spiral-winged bullet-shaped design (2/4)	60.1
Samples of pigment on artifacts from excavation	
Biface tip (2/1)	299.1*
Pottery sherd (2/6)	11.6
Chalcedony chip (2/14)	64.1
Pigment rocks from excavation	
Red laterite (1/2)	10.6
Red laterite (1/4)	102.9
Faceted red laterite rock (2/5)	60.5
Red laterite (2/7)	126.7
Red laterite (2/8)	530.8*
Red laterite (2/9)	60.9
Red laterite (2/10)	29.0
Conglomerate with patches of red laterite (2/11)	64.9
Laminar red laterite (2/12)	182.2*
Control rock samples	
Quartz chip (1/3)	8.5
Cave sandstone (2/13)	12.8
Chalcedony chip (2/15)	7.0
Chalcedony chip (2/16)	21.9

*Titanium not dependably quantified (below 0.5 weight %).

The common palms were sacurí (*Attalea microcarpa*), tucumã (*Astrocaryum vulgare*), and curuá (*Attalea spectabilis*) (all Arecoideae), which are all native to the Amazon. These palms proliferate in sandy soils and conditions of disturbance in areas of high rainfall. Sacurí was common in all levels; the others were present in about half the levels. All are valued for fruit and raw materials and are cooked for food.

The plant remains show that tree fruits were important in subsistence, at least in the rainy season. Most of the trees fruit from December through February; sacurí and curuá fruit throughout the year. All the fruits are eaten by animals. But because the fruits did not occur in prehuman strata and because the palm seeds were cracked, not gnawed, they are probably human food remains. Although palm endocarps were the most common, these inedible parts survive disproportionately.

The species harvested by Paleoindians in the late Pleistocene are still to be found in the relict tropical forests of Monte Alegre. The plant remains included no examples of crops or of plants specially adapted to dry tropical climates or cool climates. The many species adapted to disturbance suggest some alteration to the forest from Paleoindian woodcutting and burning.

Fauna were poorly preserved in the sandy soil but highly diverse (40). The remains were small (1 to 20 mm), often carbonized fragments of bone and shell. Remains include teeth, jaws, cranial fragments, otoliths, spines, vertebrae, ribs, pelvises, long bones, phalanges, claws, carapace and plastron fragments, and shells. The faunas include fishes, rodents, bats, bivalve and univalve mollusks, tortoises, turtles, snakes, amphibians, birds, and large land mammals (over 65 kg, possibly ungulates). Bats and small rodents were probably owl prey. Among the large rodents were many juveniles. The amphibians were small toads (Bufonidae). The tortoises (s.o. Cryptodira, Testudinidae) and aquatic turtles (s.o. Pleurodira) were often juvenile. Bivalves were freshwater pearly mussels. Fish, the most abundant fauna, include pirarucú (*Arapaima gigas*), traíra (*Hoplias malabaricus*), unidentified pimelodids, doradids, and other catfishes, cichilds, and characins. Size varied from very small (~5 cm) to very large (~1.5 m) (Fig. 7B). Today, water fauna are mainly sought during the dry season or seasonal fish runs. Men often hunt the large fish with spears or harpoons from boats in open water; the small fish are shot with arrows or caught in nets, traps, by hand, and with poison by work groups including women and children. Women and children also catch the smaller faunal species and juveniles. Paleoindian subsistence thus appears to have been broad-spectrum tropical forest and river foraging.

Dating. To date the preceramic occupation, we used several different methods at different labs on biological and cultural material from controlled stratigraphic contexts. A total of 56 carbonized plant specimens from Paleoindian strata were radiocarbon-dated, 49 by accelerator mass spectrometry (AMS) and 7 by conventional dating (*41*). To avoid the imprecision of dates from combined samples, we dated single specimens separately, for the most part. Wood charcoal from the inner rings of large trees can be several hundred years earlier than the time of cutting and burning. Therefore, most dates were run on fruits. The two materials, however, gave equivalent results. Samples were rigorously cleaned and tested for possible contamination by dating of split samples of solid and soluble carbon.

The radiocarbon dates (Table 3) fell in a narrow span in the late Pleistocene. 1σ terms were $<\sim300$ for conventional dates and <80 for AMS dates. The means are from ~11,200 to 10,000 radiocarbon yr B.P., and 2σ ranges are from 11,730 to 9880 yr B.P. The dates are consistent with stratigraphy and the periodization of lithic materials. Levels where strata merged had wider date ranges than others, as expected. On the basis of the large suite of dates, we estimate that the site was first occupied during the long initial period, from ~11,200 to 10,500 yr B.P. The arrival of humans is marked by a cluster of four dates between 11,145 ± 135 and 10,875 ± 295 at the base of the deposit. The early period lasted from ~10,500 to 10,200 yr B.P., the middle period from ~10,200 to 10,100 yr B.P., and the late period from ~10,100 to 9800 yr B.P.

To check the radiocarbon results and verify the contemporaneity of cultural and biological remains, three sediment samples were dated by optically stimulated luminescene (OSL) at the University of Washington, and 10 burned Paleoindian lithic artifacts were dated by thermoluminescence (TL) at the Centre des Faibles Radioactivités (CNRS-CEA) without knowledge of the results of the radiocarbon or OSL dating. Luminescence dating usually has larger technical error terms than radiocarbon dating but has the advantage of being able to date the nonorganic cultural remains common in early archaeological sites (*42*).

The OSL and TL ages obtained and the key data used in their calculations are presented in Table 4. The luminescence dates, ~16,000 to 9500 yr B.P., overlap the possible range of calendar dates estimated for the radiocarbon dates, ~14,200 to 10,500 yr B.P. (*43*), but have a somewhat wider spread, as expected. The OSL and TL dates are quite consistent, considering the wide range of materials dated, and they support the late Pleistocene radiocarbon age of the preceramic culture.

Summary. The results from the analysis of the preceramic component at Caverna da Pedra Pintada reveal a long-term occupation by foragers in the late Pleistocene. The Paleoindian culture, named Monte Alegre, had bifacially and unifacially chipped stone tools, stylized rock art, and an economy of tropical forest and floodplain foraging. The assemblage indicates that Paleoindians visited the cave periodically for more than 1200 years. While there, people ate tree fruits and a wide variety of river and land game, painted the cave, made stone tools, and cut wood. From ethnographic analogy, possible ritual reasons for rock-painting and fruit-eating include defining ancestral territory and celebrating initiations.

Holocene Occupations

Immediately after the Paleoindian occupation, the cave was abandoned and the deposit became covered by sand containing bits of charcoal blown from hearths outside the cave (strata 13, 14, and 15). The subsequent reoccupation is represented by a thin gray layer containing abundant remains of mussels, snails, turtles, fish, shell disc beads, rare carbonized wood and seeds, and pottery. The pottery consisted of red-brown to gray-brown bowl sherds with sand or shell temper and deep, rounded incisions and punctations. The culture, named Paituna, is dated by six early Archaic radiocarbon dates between 7580 and 6625 yr B.P. on a turtle bone, shells, and shell temper in a sherd, and by one TL date of 4710 ± 375 on a late Archaic sherd. These dates overlap those from nine other Lower Amazon early pottery shell middens and extend a few hundred years earlier (*44*). The deposit confirms specialized exploitation of river fauna by the early pottery cultures, which are the oldest in the Americas. The deposit

Table 3. Paleoindian accelerator mass spectrometric and conventional radiocarbon dates.* Carb., carbonized; frag., fragment; B, Beta Analytic.

Material	Prov. no.	Date (yr. B.P.)	$\delta^{13}C$ (per mil)	Lab no.
		Unit 2		
Initial period				
Wood char. frag.	8231	10,450 ± 60	−23.5	B76952CAMS
Carb. *Attalea microcarpa* seed	8231	10,560 ± 60	−21.2	B76953CAMS†
Carb. *Astrocaryum vulgare* seeds	8231	10,905 ± 295	−20.7	GX17407
Carb. *A. vulgare* seeds	8231	11,110 ± 310	−23.2	GX17406
		Unit 5		
Initial period				
Carb. *Attalea microcarpa* seed	8314	10,392 ± 78	−23.6	GX17400CAMS
Carb. *Astrocaryum vulgare* seeds	8314	10,875 ± 295	−22.5	GX17414
Carb. *Attalea microcarpa* seeds	8314	11,145 ± 135	−21.6	GX17413
		Unit 6		
Initial period				
Carb. *A. microcarpa* seeds	8345	10,275 ± 275	−21.7	GX17421
Carb. *Astrocaryum vulgare* seeds	8345	10,655 ± 285	−22.8	GX17420
Carb. *Attalea microcarpa* seeds	8346	10,305 ± 275	−22.7	GX17422
		Unit 7		
Late period				
Carb. *A. microcarpa* seed	9142	10.230 ± 60	−26.8	B75001CAMS
Initial/early period				
Carb. palm seed	9147	10,260 ± 60	−25.8	B75002CAMS
Wood char. frag.	9147	10,290 ± 80	−27.6	B75007CAMS
Wood char. frag.	9147	10,300 ± 60	−27.7	B75004CAMS
Carb. *A. microcarpa* palm seed	9147	10,320 ± 70	−23.1	B75006CAMS
Carb. *A. microcarpa* seed	9147	10,390 ± 70	−22.1	B75003CAMS
Carb. *A. spectabilis* seed frag.	9147	10,450 ± 60	−23.3	B75005CAMS
Wood char. frag.	9148	10,280 ± 70	−16.6	B75008CAMS
Carb. *A. spectabilis* seed	9148	10,330 ± 60	−22.5	B75009CAMS
		Unit 8		
Early period				
Wood char. frag.	9204	10,370 ± 70	−26.6	GX19525CAMS
Humate from same	9204	10,330 ± 70	−27.8	GX19525CAMS
Carb. *A. microcarpa* seed	9204	10,380 ± 60	−25.8	GX19524CAMS
Humate from same	9204	10,510 ± 60	−25.0	GX19524CAMS
Wood char. frag.	9204	10,480 ± 70	−24.8	GX19526CAMS
Humate from same	9204	10,570 ± 70	−25.2	GX19526CAMS

appears to represent a temporary camp visited briefly from main camps near the floodplain.

Above and intruding into the Archaic deposit was material of the Aroxí culture. The material included reddish-orange pottery sherds, carbonized tree fruits, remains of turtles and fish, and about five poorly preserved human burials. Bowls and thick griddles, used today for cooking manioc, were present. The pottery had grit temper and rare shallow, broad incisions. It relates to lowland South American Formative horizons, ~4000 to 2000 yr B.P., thought to represent the spread of pottery and root horticulture (45). Radiocarbon dates on a carbonized curuá seed, a human molar, and a human cranium were 3603, 3410, and 3230 yr B.P.

Above that layer was a substantial midden of gray-brown soil with dried and carbonized plants; faunal remains; numerous gray, sponge-tempered pottery sherds; rare lithics; and cordage. More than 30 posts of an oval structure were still in place. Dried cobs of maize related to Coroico and decorated gourd fragments directly document prehistoric agriculture (46). Broad-spectrum year-round hunting, fishing, and gathering are indicated by the wide variety of common species. In addition to the fruit trees in Paleoindian levels, late prehistoric levels had cultivated species, dry season fruiting species, and naturalized species, such as cashew (*Anacardium occidentale*), which appear to have spread into the area as increased clearing opened forests and reduced precipitation (47).

The pottery, occasionally decorated with red paint or incisions, relates to the incised and punctate horizon associated with the spread of lowland South American complex chiefdoms, A.D. ~1000 to 1600; a few bark ash– or sherd-tempered sherds in the midden are related to the Polychrome horizon of the Amazon, associated with earlier ranked societies, A.D. ~400 to 1100 (33, 48). Rare percussion-flaked lithics were quartz breccia, chalcedony, mafic volcanic rock, and granite. There were no points or point fragments, but two ground-stone axe fragments and a faceted pigment rock were found. The culture, Pariçó, has two radiocarbon dates on charcoal and a wood post, 675 and 430 yr B.P.

Table 3. *(continued)*

Material	Prov. no.	Date (yr. B.P.)	$\delta^{13}C$ (per mil)	Lab no.
		Unit 9		
Early period				
Wood char. frag.	9245	10,260 ± 70	−27.5	GX19530CAMS
Humate from same	9245	10,210 ± 60	−27.4	GX19530CAMS
Carb. *A. microcarpa* seed	9245	10,420 ± 70	−26.2	GX19529CAMS
Humate from same	9245	10,250 ± 70	−25.7	GX19529CAMS
Carb. *A. microcarpa* palm seed	9246	10,370 ± 60	−24.8	GX19531CAMS
Humate from same	9246	10,180 ± 60	−24.3	GX19531CAMS
		Unit 10		
Early period				
Carb. *A. microcarpa* seed	9272	10,110 ± 60	−24.7	GX19532CAMS
Humate from same	9272	10,190 ± 60	−25.2	GX19532CAMS
Humate from *A. microcarpa* seed	9272	10,190 ± 50	−27.8	GX19534CAMS
Carb. *A. microcarpa* seed	9272	10,290 ± 70	−25.7	GX19527CAMS
Humate from same	9272	10,330 ± 70	−25.4	GX19527CAMS
Carb. *A. microcarpa* seed frag.	9272	10,290 ± 70	−24.0	GX19528CAMS
Humate from same	9272	10,120 ± 70	−25.8	GX19528CAMS
Wood char. frag.	9272	10,310 ± 70	−29.9	GX19535CAMS
Humate from same	9272	10,210 ± 70	−28.6	GX19535CAMS
Wood char. frag.	9272	10,360 ± 60	−23.9	GX19533CAMS
Humate from same	9272	10,220 ± 60	−26.0	GX19533CAMS
Initial period				
Carb. *A. microcarpa* seed	9274	10,250 ± 70	−29.9	GX19537CAMS
Humate from same	9274	10,470 ± 70	−24.9	GX19537CAMS
Humate from carb. *A. microcarpa* seeds	9274	10,350 ± 70	−25.4	GX19536CAMS
Carb. *A. microcarpa* seed	9274	10,410 ± 60	−24.3	GX19538CAMS
Humate from same	9274	10,390 ± 70	−24.9	GX19538CAMS
		Unit 11		
Late period				
Carb. *A. spectabilis* palm seed	9290	10,210 ± 60	−27.6	B76955CAMS
Carb. wood frag.	9290	10,360 ± 50	−12.3	B76954CAMS
Early period				
Carb. *A. microcarpa* seed	9294	10,450 ± 60	−29.9	GX19523CAMS
Humate from same	9294	10,000 ± 60	−30	GX19523CAMS
Wood char. frag.	9296	10,390 ± 60	−26.3	GX19540CAMS
Humate from same	9296	10,230 ± 60	−25.2	GX19540CAMS
Wood char. frag.	9296	10,470 ± 70	−28.1	GX19539CAMS
Humate from same	9296	10,000 ± 60	−28.9	GX19539CAMS
Humate from *A. microcarpa* seed	9296	10,490 ± 80	−23.7	GX19541CAMS

*Uncalibrated, $\delta^{13}C$ corrected, in radiocarbon years before the present. †CAMS refers to the accelerator at Lawrence Livermore Laboratory, University of California.

Conclusion

The human presence in Caverna da Pedra Pintada during the late Pleistocene is established by numerous artifacts of rocks exotic to the cave. A humid tropical environment is documented by abundant carbonized plants, the $\delta^{13}C$ ratios, and remains of fauna. The age is established by a large series of dates that are comparable in age regardless of laboratory, technique, and type of material used. The dated materials are associated in stratigraphic context at the beginning of a long cultural sequence. There is no prehuman biological material that could have mixed with the cultural remains, which are stratigraphically separated from later Holocene assemblages by a culturally sterile layer.

The conclusion to be drawn from the excavations and analyses is that the Monte Alegre Paleoindians were rock-painting tropical forest and river foragers contemporary with North American Paleoindian cultures but with a distinct tradition of finely chipped bifacial and unifacial lithic tools. Earlier hypotheses that the paintings and bifacial points were Holocene were not supported by the evidence.

The discovery of Paleoindians along the Amazon confirms earlier evidence that the Paleoindian radiation was more complex than current theories provide for. Paleoindians traveled far and developed diverse cultures. Although Amazonians shared some lithic technology with North American Paleoindian cultures, they had different formal tools, art styles, and subsistence practices. The existence of a distinct cultural tradition contemporary with the Clovis tradition but more than 5000 miles to the south does not fit the notion that the North American big-game hunters were the sole source of migration into South America. Clovis is evidently just one of several regional traditions. Clearly, Paleoindians were able to adapt to a broad range of habitats. In the Amazon, they developed a long-term adaptation to the humid tropical forest. Although some points in the cave were presumably used for hunting larger fauna, the biological remains reflect not specialized big-game hunting but generalized foraging. Recent research suggests that North American Paleoindians may have had broader economies, as well (49).

The cultural sequence exemplified by Caverna da Pedra Pintada and other Ama-

Table 4. Luminescence age estimates and radioactivity data for lithics and sediment from Paleoindian levels in calendar years before the present.

Samples	U* (ppm)	Th* (ppm)	K* (%)	Internal dose rate†	External dose rate‡ (μGy/year)	Annual dose	Paleodose (Gy)	Age (years)
Brecciated quartz flake with percussion platform (prov. 9270)	0.27	1.97	0.02	180.6 ± 9.6	337 ± 22.6	517.6 ± 24.6	5 ± 0.3	9,530 ± 780
Pressure-retouched tool fragment of chalcedony, heat-spalled (prov. 9270)	0.85	4.46	0.31	931.5 ± 67.2	337 ± 22.6	1268.5 ± 70.9	13 ± 1.2	9,860 ± 1,080
Chalcedony flake (prov. 8344)	1.34	10.25	0.95	2044.0 ± 130.2	321 ± 21.0	2365.0 ± 131.9	24 ± 1.6	10,140 ± 890
Flake of chalcedony with cortex (prov. 9290)	1.20	4.43	0.79	1485.7 ± 87.5	321 ± 21.0	1806.7 ± 90.0	19 ± 1.9	10,400 ± 700
Chalcedony bifacial reduction flake, heat-spalled (prov. 8344)	1.54	4.87	0.96	1735.6 ± 98.1	332 ± 21.0	2057.6 ± 100.4	22 ± 1.9	10,860 ± 690
Chalcedony bifacial reduction flake, heat-spalled (prov. 8344)	1.19	4.90	0.94	1681.2 ± 95.3	322 ± 21.0	2003.2 ± 97.6	22 ± 1.2	10,940 ± 800
Brecciated quartz flake (prov. 8231)	0.20	0.72	0.03	104.6 ± 5.4	331 ± 21.0	435.6 ± 21.7	5 ± 0.2	11,880 ± 760
Sediment (prov. 8231)	0.60	3.80	0.10	–	–	550 ± 42	7 ± 0.6	12,491 ± 1409
Heavy fraction from screened sediment (prov. 8231)	0.56	3.92	0.28	–	–	686 ± 208	9 ± 1.1	12,536 ± 4125
Sediment (prov. 8231)	0.60	4.06	0.06	–	–	528 ± 42	7 ± 0.7	13,106 ± 1628
Chalcedony bifacial reduction flake, heat-spalled (prov. 9292)	1.41	4.23	0.98	1553.7 ± 82.1	325 ± 21.0	1878.7 ± 84.8	27 ± 1.0	14,250 ± 850
Chalcedony bifacial reduction flake, with heat-spalling (prov. 8346)	0.84	4.06	0.66	1029.9 ± 55.6	341 ± 23.6	1370.9 ± 60.5	21 ± 1.8	15,330 ± 900
Chalcedony bifacial reduction flake (prov. 8231)	1.38	3.81	0.75	1325.4 ± 76.0	342 ± 23.6	1667.4 ± 79.6	27 ± 1.9	16,190 ± 930

*The U, Th, and K contents of the dated lithic samples were measured by neutron activation analysis at the Institut Pierre Süe (CEN, Saclay, France) and each has an error of ±10% (*57*). †The internal dose rate was calculated with the specific values given in (*58*). The α contribution was deduced from fine-grain measurements (*59*). ‡The external dose rate was deduced from sediment samples analyzed by high-purity spectrometry, which made it possible to check the steady-state equilibrium of the U series. It includes a cosmic dose rate contribution of 85 μGy/year (*60*). The γ dose rate was calculated with the assumption of a mean water value of 19% per weight.

zonian sites shows that early human evolution was not severely limited in humid tropical environments as compared with others. Rather than a single archetypal human adaptation to the tropical forest for all time, we see a dynamic trajectory (*48, 50*). Pleistocene foraging bands gave way to fishing villages along waterways in the early Holocene. Horticulture was then adopted and the use of pottery spread. During the Christian era, populous agricultural societies with complex organization appeared in several areas. The European conquest disrupted and decimated native societies, which were relegated to the peripheries, often to poorer land, where they live today by shifting cultivation and foraging, surrounded by outsiders. Present-day native lifeways thus reflect adaptation not only to the environment but also to life in post-colonial nations.

The great contrasts between ancient and modern lifeways in Amazonia create problems for research on human evolution that relies primarily on modern tropical forest Indians as models for Paleolithic adaptations (*51*). The evidence from actual developmental sequences shows that tropical forest people in South America are not primary hunter-gatherers and do not descend directly from the ancient hunter-gatherers (*6, 8, 52*). Where primary foraging was supplanted by staple cropping thousands of years ago in this way, early prehistoric cultures offer evidence for its role in human behavior (*53*).

Amazon archaeology also offers evidence for the role of humans in tropical forests. Despite the theoretical importance of the history of Amazonian forests, comprehensive, well-dated paleoecological sequences are lacking for most regions (*54*). From the late Pleistocene on, however, there exist archaeological sites containing diverse biota that people gathered from wide territories and deposited in stratified cultural deposits. Like paleontological and palynological assemblages, archaeological remains hold only a subset of the total biological community of the time, but they include a broader range of identifiable, datable specimens than do nonhuman deposits. Amazonian archaeology thus holds potential evidence concerning the history of tropical habitats.

Archaeological and ethnobotanical evidence shows that Amazonian forests once thought to be virgin were settled, cut, burned, and cultivated repeatedly during prehistoric and historic times, and that human activities widely altered topography, soil, and water quality (*7, 8, 48, 50, 55*). Substantial biodiversity patterning appears to be associated with such human activities (*56*). Given the nature of the human occupation, it seems reasonable to acknowledge a human role in the development of landforms and biotic communities in Amazonia over the millennia. Research on tropical forests can benefit by taking into account the long-term effects of both past and present human activities.

REFERENCES AND NOTES

1. B. M. Fagan, *The Great Journey* (Thames and Hudson, London, 1987).
2. J. F. Hoffecker, W. R. Powers, T. Goebel, *Science* **259**, 46 (1993).
3. T. C. Lynch, in *Early South Americans*, J. E. Jennings, Ed. (Freeman, San Francisco, CA, 1983), pp. 87–139.
4. The Clovis tradition was thought to have begun 12,000 to 11,500 years ago, but dates that early are no longer considered valid [C. V. Haynes Jr., in *14C Dating and the Peopling of the New World*, R. E. Taylor, A. Long, R. S. Kra, Eds. (Springer-Verlag, New York, 1992), pp. 355–374]. Dates earlier than 11,200 yr B.P. are outliers or are associated with disturbance or possible contamination from old carbon, such as lignite coal [for example, G. Frison, in *Clovis: Origins and Adaptations*, R. Bonnischen and K. L. Turnmise, Eds. (Center for the Study of the First Americans, Corvallis, OR, 1993), p. 135]. Most Clovis and Folsom dates were run on combined samples of wood charcoal.
5. Common in the Clovis tradition tool complex are fluted and unfluted lanceolate bifaces, blades and flakes, scrapers made on blades and flakes, perforators, and in some sites, cobble tools.
6. R. C. Bailey *et al.*, *Am. Anthropol.* **91**, 59 (1989); T. N. Headland, *Hum. Ecol.* **15**, 463 (1987); R. C. Bailey and T. N. Headlund, *ibid.* **19**, 261 (1991).
7. A. C. Roosevelt and A. Haller, organizers, *Amazonia: A Dynamic Habitat, Past, Present, and Future* (taped symposium no. 25-2, AAAS, Washington, DC, 1990); S. Beckerman, *Am. Anthropol.* **81**, 533 (1979).
8. A. C. Roosevelt, *Adv. Econ. Bot.* **7**, 31 (1989), and in *Advances in Historical Ecology*, W. Balee, Ed. (Columbia Univ. Press, New York, in press).
9. G. R. Willey, *An Introduction to American Archaeology: Vol. 1: South America* (Prentice-Hall, Englewood Cliffs, NJ, 1971); I. Rouse, *Quat. Res.* **6**, 567 (1976).
10. A. L. Bryan, Ed., *Early Man in America from a Circum-Pacific Perspective* (Archaeological Researches International, Edmonton, Alberta, Canada, 1978).
11. A. L Bryan, Ed., *New Evidence for the Pleistocene Peopling of the Americas* (Center for the Study of Early Man, Orono, ME, 1986).
12. R. G. Bednarik, *Antiquity* **81**, 101 (1989).
13. T. D. Dillehay, G. A. Calderon, G. Politis, M. Beltrao, *J. World Prehist.* **6**, 145 (1992).
14. N. Guidon and A. Delibrias, *Anthropologie* (*Paris*) **89**,

385 (1986); R. S. MacNeish, *Am. Sci.* **64**, 316 (1976).
15. D. F. Dincauze, *Adv. World Archaeol.* **3**, 275 (1984); C. V. Haynes Jr., *Am. Antiq.* **45**, 583 (1980); T. E. Lynch, *ibid.* **55**, 12 (1991).
16. S. Bowman, *Radiocarbon Dating* (Univ. of California Press/British Museum, Berkeley, CA, 1990), pp. 27–30; R. E. Taylor, Ed., *Radiocarbon Dating: An Archaeological Perspective* (Academic Press, Orlando, FL, 1987); J. A. J. Gowlett and R. E. M. Hedges, Eds., *Archaeological Results from Accelerator Dating* (Oxford University Committee for Archaeology, Monograph 11, Institute of Archaeology, Oxford, 1986).
17. N. Toth, in *The First Americans*, T. D. Dillehay and D. J. Meltzer, Eds. (CRC Press, Boca Raton, FL, 1991), pp. 53–76.
18. The painted rockshelter Caverna da Pedra Furada has 42 consistent charcoal dates ~50,000 to 17,000 yr B.P. [N. Guidon and A. Delibrias, *Nature* **321**, 769 (1986)]. Rare, flaked stones from lower levels of the Alice Boer site are undated. Higher levels contained the triangular points and other tools. A small charcoal sample with the deepest point was 14,200 ± 1150 yr B.P., but three dates just above were ~6000 yr B.P. Five TL dates between ~11,000 and 3000 yr B.P. on flint fit radiocarbon ages of ~10,500 yr B.P. and younger [M. Beltrão, C. R. Enriquez, J. Danon, E. Zuleta, G. Poupeau, in (*11*), pp. 203–213; W. Hurt, *ibid.*, pp. 215–219]. Highly disturbed limestone caves around Lagoa Santa contained human bones, megafauna, modern biota, stone flakes, and pigment. Radiocarbon dates of ~25,000 to 10,200 yr B.P. on scarce charcoal ranged much earlier than those on human bone mineral, dated ~10,000 to 7000 yr B.P. [A. Prous, *Anthropologie (Paris)* **90**, 257 (1986); in (*11*), pp. 173–182]. Other sites with rare, triangular, stemmed bifacial points; numerous limaces; modern biota; human skeletons; and pigment have nine radiocarbon dates between 10,700 and 9000 yr B.P. Three pre-Clovis dates between 21,000 and 16,000 yr B.P. have uncertain associations [P. I. Schmitz, *Estud. Atacameños* **8**, 16 (1987); *J. World Prehist.* **1**, 53 (1987)]. Ibiqui sites have two dates of 12,770 and 12,690 yr B.P. on plant remains with flakes that are near but not with megafauna, but the sites had prehuman carbon dated 12,690 to 33,600 yr B.P.. Eighteen dates between 11,500 and 9500 yr B.P. came from Uruguai sites with hearths, triangular stemmed points, and modern biota. Abrigo do Sol, a sandstone shelter with petroglyphs, stone flakes, modern flora, and disturbed stratigraphy had three questionable pre-Clovis radiocarbon dates of 12,300, 14,470 (a small sample), and 14,700 yr B.P. distributed discordantly among 24 dates between circa (ca.) 11,600 and 6000 yr B.P. [E. Miller, *Estud. Atacameños* **8**, 37 (1987)].
19. A. Taddei, *Estud. Atacameños* **8**, 62 (1987).
20. Tagua Tagua and Quereo, which are ancient lake sites, contained possibly cut megafauna bones, bone tools, and mollusks, and had six radiocarbon dates between 11,600 and 10,925 yr B.P. on plant remains. Tagua Tagua also had several lithic flakes [L. Nunez, J. Varela, R. Casamiquela, in *Estud. Atacameños* **8**, 142 (1987)]. Carbonates may have affected the dates, which at Quereo were the same over several meters of depth rather than in a sequence. Lower levels of La Moderna had rare flaked rocks, megafauna, one discordant date of 12,330 yr B.P., and several dates between 7000 and 6550 yr B.P. Levels with extinct fauna in Mylodon Cave gave 18 discordant dates between 13,500 and 5000 yr B.P. and no evidence for humans in pre-Clovis levels [G. L. Mengoni Gonalons, in (*11*), pp. 271–279]. Las Buitreras contained 16 flaked rocks with possibly butchered megafauna dated 7670 yr B.P. [S. E. Caviglia, H. D. Yacobaccio, L. A. Borrero, in (*11*), pp. 295–313]. Lower levels of a painted cave at Los Toldos had 48 flaked rocks, pigment, abundant guanaco, rare megafauna, and a single date of 12,600 yr B.P. Higher levels had several dates between ca. 11,000 and 7500 yr B.P., associated with subtriangular, stemmed bifacial points; other tools; and modern game [A. Cardich, L. A. Cardich, A. Hajduk, *Relac. Soc. Argent. Antrop. N.S.* **7**, 85 (1973); in (*13*), pp. 169–170]. Fishtail points and one date of 12,390 yr. B.P. came from Cueva del Medio, but seven others from the same hearth were 10,550 to 9595 yr B.P. [C. Gnecco, *Lithic Technology* **19**, 35, (1994)]. Fishtail point sites are summarized in (*13*), pp. 168–172. Human skeletons from two sites [J. B. Bird, M. Bird, J. Hyslop, *Travels and Archaeology in South Chile* (Univ. of Iowa Press, Iowa City, IA, 1988)] gave collagen radiocarbon dates in the middle Holocene and appear to be intrusive [R. A. Housley, *Archaeometry* **34**, 337 (1992)].
21. Monte Verde is a habitation site in a stream, and Taima Taima is a kill site in a spring [T. Dillehay, Ed., *Monte Verde: A Late Pleistocene Settlement in Chile* (Smithsonian Institution, Washington, DC, 1989), pp. 1–22 and pp. 132–145; C. Ochsenius and R. Gruhn, Eds., *Taima-Taima: A Late Pleistocene Paleoindian Kill Site in Northernmost South America—Final Reports of 1976 Excavations* (CIPICS/South American Quaternary Documentation Program, Saarbrucken, Federal Republic of Germany, 1979)]. Nineteen dates on soil, wood, and mastodon bone collagen from Taima Taima are ca. 14,440 to 11,860 yr B.P., with an outlier at 7590 yr B.P. Nine dates on mastodon bone, plants, and possibly worked wood from Monte Verde range from 13,565 to 11,790 yr B.P. Potential carbon contaminants are bitumin, redeposited volcanic ash, and modern pollutants at Monte Verde and petroleum, Miocene limestone, and 41,000- to 36,000-year-old lignite at Taima Taima. The two point fragments from Monte Verde were near but not in the dated site, which held no debris from point manufacture among the approximately 10 possible lithics. Stones with the 33,000-year-old dates have not yet been shown to be artifacts.
22. Surface sites in the Ecuadorian highlands have points with 47 obsidian hydration dates between 27,000 and 3000 yr B.P., but all 23 radiocarbon dates (on soil) are Holocene, 9080 to 4000 yr B.P. [W. J. Mayer-Oakes, in (*11*), pp. 133–156]. An unassociated skull 20,000 to 30,000 years old by TL and radiocarbon dates on limestone concretions and amino acid racemization of collagen was only 2000 yr B.P. by collagen radiocarbon dates [D. M. Davies, in (*10*), p. 279].
23. W. R. Hurt, T. van der Hammen, G. Correal Urrego, *The El Abra Rockshelters, Sabana de Bogotá, Colombia, South America* (Occasional Paper and Monograph No. 2, Indiana Univ. Museum, Bloomington, IN, 1976); G. Correal Urrego, *Evidencias culturales y megafauna pleistocenica en Colombia* (Publicacion 12, Fundacion de Investigaciones Arqueologicas Nacional, Banco de La Republica, Bogotá, Colombia, 1981). Undated stemmed, fluted triangular bifacial points include "Restrepo" and "El Inga broad-stemmed" [C. Gnecco, *Lithic Technol.* **19**, 35 (1994)].
24. In highland Peru, Pikimachay, a carbonate-rich shelter with flaked rocks and megafauna under rockfall, had five consistent radiocarbon dates between ca. 20,000 and 14,000 yr B.P. on bone and small charcoal samples [R. S. MacNeish *et al.*, *Prehistory of the Ayacucho Basin, Peru, Vol. II* (Univ. of Michigan Press, Ann Arbor, MI, 1981)], but the artifacts are questioned. Higher levels with triangular points, modern fauna, and bone tools had six radiocarbon dates between 11,000 and 7100 yr B.P. Guiterrero cave had triangular points, leaf-shaped points, a single pre-Clovis charcoal date of 12,560, and numerous dates between 10,585 and 7575 yr B.P. [T. F. Lynch, Ed., *Guitarrero Cave* (Academic Press, NY, 1980)]. Early Holocene sites contain modern camelids and points like Guitarrero's [J. Rick, *Prehistoric Hunters of the High Andes* (Academic Press, NY, 1980)]. On the coast, surface sites with large, triangular, stemmed bifacial points and limaces of the Paijan culture contained charcoal and megafauna dated 12,795 and 12,360 yr B.P., but 21 other dates on human bone, charcoal, and modern fauna fell from 10,430 to 7740 yr B.P. [P. Ossa and M. Moseley, *Nawpa Pacha* **9**, 1 (1971); C. Chauchat, *Prehistoire de la Cote Mort du Perou: Le Paijanien de Cupisnique* (Cahiers du Quaternaire No. 18, CNRS Editions, Paris, 1992)]. Surface flake scatters at Talara tar seeps had two discordant dates of 11,200 and 8125 yr B.P. on marine shell [J. Richardson in (*10*), pp. 274–289].
25. T. C. Whitmore and G. T. Prance, Eds., *Biogeography and Quaternary History in Tropical America* (Oxford Monographs on Biogeography No. 3, Oxford Univ. Press, Oxford, 1987).
26. B. J. Meggers, in *Amazonia*, G. T. Prance and T. C. Lovejoy, Eds. (Pergamon, Oxford, 1985), pp. 307–327; D. W. Lathrap, in *Origins of Agriculture*, C. Reed, Ed. (Mouton, The Hague, 1977), pp. 713–751.
27. A. Boomert, *Niew West-Indische Gids* **54**, 94 (1980); *Museu Paraense Emilio Goeldi* (Banco Safra, São Paulo, Brazil, 1986), pp. 114–117; M. Simoes, *Bol. Mus. Para. Emilio Goeldi* **62**, 1 (1976); private collections, Monte Alegre. The Lower Amazon points differ from undated Rio Negro basin bifacial points, which are large (up to 20 cm), triangular, elongated, chalcedony points with broad fluted stems (*8*), similar to Restrepo points (*23*).
28. A. C. Roosevelt, R. A. Housley, M. Imazio da Silveira, S. Maranca, R. Johnson, *Science* **254**, 1621 (1991); M. Magalhães, *Archaeology of Carajás: The Pre-Historic Presence of Man in Amazonia* (Companhia Vale do Rio Doce, Rio de Janeiro, Brazil, 1994).
29. I. Rouse and J. Cruxent, *Venezuelan Archaeology* (Yale Univ. Press, New Haven, CT, 1963); W. P. Barse, *Science* **250**, 1388 (1990).
30. M. Consens, *Dedalo* **1**, 265 (1989).
31. C. F. Hartt, *Am. Nat.* **5**, 139 (1871); E. Perreira, personal communication, 1991; A. R. Wallace, *A Narrative of Travels on the Amazon and Rio Negro* (Ward, Lock; London, 1889), pp. 100–107. N. N. Sadeck led the research team to Caverna da Pedra Pintada. Outside the cave, a tourist path had destroyed the deposit.
32. L. T. Silveira, R. V. Lima Pinheiro, S. V. Lima Pinheiro, Roteiro Espeleológico das Serras do Ererê Paituna (Monte Alegre, Pará); Projeto Radambrazil: Mapa Geológico, 1976, Santarém, Folha SA.21, Min. das Minas, Departamento Nacional de Produção Mineral. The Am climate with ~2000 mm of rain is the most widespread in Amazonia.
33. A. C. Roosevelt, *The Developmental Sequence at Santarém on the Lower Amazon, Brazil* (Report to NEH, Washington, DC, 1990) and *Moundbuilders of the Amazon: Geophysical Archaeology on Marajó Island, Brazil* (Academic Press, San Diego, CA, 1991).
34. Excavation was carried out with hand tools, following stratigraphy. Objects were piece-plotted. Soil was Munsell color-coded and screened through 1.5-mm mesh. For each level, 8 to 32 liters of soil were floated through filters, 1-liter samples were collected for microfloral analysis, and 8-liter samples were collected for TL dosimetry.
35. B. E. Luedtke, *An Archaeologist's Guide to Chert and Flint* (Archaeological Research Tools, vol. 7, Institute of Archaeology, Univ. of California, Los Angeles, 1992).
36. M.-L. Inizan, H. Roche, J. Tixier, *Technology of Knapped Stone* (Cercle de Recherche et d'Etudes Prehistoriques and CNRS, Meudon, France, 1992).
37. The samples were analyzed at the American Museum of Natural History by scanning electron microscopy with energy-dispersive x-ray spectroscopy (SEM-EDS) to assess micromorphological features and identify major inorganic elemental components and secondary components. Semiquantitative EDS analysis was carried out for four principal elements (Al, Si, K, and Fe). The samples were also studied with optical petrography for mineral and organic components. At the University of Pará, five additional excavated pigment samples were analyzed by x-ray diffraction and two were thin-sectioned. SEM-EDS samples were mounted on half-inch aluminum stubs directly on conductive carbon tape and coated with 100 Å of evaporated carbon to improve electron conductivity. SEM-EDS was carried out on a Zeiss DSM 950 scanning electron microscope with a Link Analytical AN10000 energy-dispersive system under identical conditions for all samples (15 kV for 100 live seconds with an 18-mm working distance). For optical petrography, samples 1/2 and 1/4 were analyzed as grain mounts in refractive-index oils.
38. H. Blatt, G. Middleton, R. Murray, *Origin of Sedimentary Rocks* (Prentice-Hall, Englewood Cliffs, NJ, ed. 2, 1979), p. 315.
39. Identifications were made by comparison of carbonized plants with project collections from the region and with MPEG and New York Botanical Garden (NYBG) herbar-

ium specimens. Preliminary identifications were by M. L. Ribeiro, Monte Alegre. Information about tarumã was contributed by N. Smith and W. Balee. Brazil nut was identified by S. Mori, NYBG. Jutaí was identified by L. Kaplan and J. H. Langenheim.
40. Identification of mammals was done by J. Pokines and J. Flynn of the Field Museum (FM). Identification of birds was done by J. Bates and D. Stotz, FM.
41. Samples were cleaned mechanically and treated with a succession of acid and basic baths to remove possible contaminants. To test for anachronistic carbon, the base-soluble carbon of 19 seeds and charcoal samples was extracted and dated separately from the solids by AMS, at the suggestion of C. V. Haynes Jr. The soluble carbon dates were statistically equivalent to the solid carbon dates from the same specimens, eliminating the likelihood of contamination. In three of the palm seeds, the solids were too small to date after the intensive pretreatment. No ancient carbon contamination agents are known to occur in the cave sandstone and none were found. White nodules and clear crystals in the layers were shown by x-ray diffraction and petrography to be gypsum (calcium sulfate), not calcium carbonate. Stable isotope ratios for the dates fell in the ranges of closed-canopy tropical rainforest trees, except for one with a ratio characteristic of local CAM forest epiphytes and rock-dwelling succulents.
42. Luminescence dating is based on stored energy that accumulates in a sample over time through the effects of natural radioactivity from within the sample and its immediate environs. This energy is released by heat or light to produce a luminescence signal proportional to the time since the last exposure to heat or light. The age is derived by determination of the paleodose or equivalent dose and the amount of radiation necessary to produce the natural luminescence signal, and dividing that by the annual dose, which is the amount of radiation received by the sample in 1 year [J. M. Aitken and H. Valladas, *Philos. Trans. R. Soc. London Ser. B* **337**, 139 (1992)]. The lithics were dated to their last exposure to heat (at least 400°C); the sediments were dated to their last exposure to light before deposition. The lithics were protected from heat and sun to prevent resetting but could not be kept in the dark. The chalcedony is protected from resetting by opacity but the quartz breccia is translucent. Material for dating was taken from interiors to minimize resetting. Environmental dose rates were estimated from soil samples because dosimeters could not be placed. The OSL analysis was performed on 90- to 125-μm quartz grains prepared in a standard fashion [M. J. Aitken, *Thermoluminescence Dating*, Academic Press, Orlando, FL (1985)]. Luminescence in quartz is known to have a rapidly bleaching component and a slowly bleaching component when exposed to light [N. Spooner, J. R. Prescott, J. T. Hutton, *Quat. Sci. Rev.* **7**, 325 (1988)]. OSL measures only the rapidly bleaching component, which only takes a few minutes to drop to background levels, usually ensuring sufficient light exposure for resetting in antiquity. The OSL signal was stimulated by green light and the emission was collected through ultraviolet filters. The light was produced by a high-intensity quartz-tungsten halogen lamp, whose beam was collimated, passed through 550 20-nm interference filters, and directed to the sample via fiber optics. The paleodose was evaluated by combination of additive and regeneration growth curves, constructed from single aliquot analyses [G. A. T. Duller, *Nucl. Tracks Radiat. Meas.* **18**, 371 (1991); J. R. Prescott, D. J. Huntley, J. T. Hutton, *Ancient TL* **11**, 1 (1993)]. The annual radioactivity was measured on the sediment samples by high-resolution gamma spectroscopy. No disequilibrium was detected in the decay chains. These results agreed with the external doses obtained for the lithics at the Gif lab, CERNS-CEA. The experimental procedure for TL sample preparation and dating for lithics has been described elsewhere [H. Valladas, *Quat. Sci. Rev.* **11**, 1 (1992)]. A fission-track study of spatial distribution of uranium in the lithic samples, used to estimate dose rates, revealed relatively homogeneous distribution of radioisotopes. Moreover, there was good agreement between the mean external dose rate computed from gamma spectrometric measurements on sediment samples, 32.6 ± 22 μGy/y, and the one extrapolated from isochron analysis.
43. There is no secure tree-ring calibration curve for radiocarbon dates in the period extending from 11,200 to 10,000 yr B.P.; tentative sea coral intercalibration between ^{14}C and uranium-thorium dates and comparison of radiocarbon and TL dates for the French Magdelenian suggest that radiocarbon years before the present range from 500 to 3000 years younger than calendar years [B. Becker, B. Kromer, P. Trimborn, *Nature* **353**, 647 (1991); E. Bard, B. Hamelin, R. G. Fairbanks, A. Zindler, *ibid.* **354**, 405 (1990); F. Audouze, in *The Pleistocene Old World*, O. Soffer, Ed. (Plenum, New York, 1987), p. 185; K. Tankersley, personal communication].
44. The dates were run at Oxford University and Geochron Laboratories. See table 1 in A. C. Roosevelt, in *The Emergence of Pottery*, J. Hoopes and W. Barnett, Eds. (Smithsonian Press, Washington, DC, 1995), pp. 115–132.
45. D. W. Lathrap, *The Upper Amazon* (Praeger, New York, 1970); A. C. Roosevelt, *Parmana: Prehistoric Maize and Manioc Subsistence along the Amazon and Orinoco* (Academic Press, New York, 1980).
46. Corn was identified by W. Galinat and L. Kaplan.
47. P. B. Cavalcante, *Frutas Comestíveis da Amazônia* (MPEG and Editora CEJUP, Belém, Brazil, 1991), pp. 68–71 and pp. 158–163
48. A. C. Roosevelt, *L'Homme* **33**, 255 (1993).
49. D. Meltzer, *Evol. Anthropol.* **2**, 157; D. G. Steele and J. F. Powell, *ibid.*, p. 138.
50. A. C. Roosevelt, Ed., *Amazonian Indians from Prehistory to the Present: Anthropological Approaches* (Univ. of Arizona Press, Tucson, AZ, 1994).
51. K. Hill and A. M. Hurtado, *Am. Sci.* 77, 437 (1989).
52. A. Roosevelt and S. Beckerman, organizers, *Hunter-Gatherers of Lowland South America* (taped symposium, AAAS, Washington, DC, 1991), pp. 176–177.
53. T. D. Price and J. A. Brown, Eds., *Prehistoric Hunter-Gatherers: The Emergence of Cultural Complexity* (Academic Press, Orlando, FL, 1985).
54. T. C. Van Der Hammen, in *Bol. IG-USP, Publ. Esp.* **8**, 1 (1991).
55. M. Bush and P. Colinvaux, *Vegetatio* **76**, 141 (1988); N. Smith, in *Ann. Am. Assoc. Geog.* **70**, 553.
56. D. Campbell, in *Large-Scale Ecology and Conservation Biology*, P. J. Edwards. R. M. May, N. R. Webb, Eds. (Blackwell, Oxford, UK, 1994), pp. 179–197; W. Balee, in *Resource Management in Amazonia: Indigenous and Folk Strategies* D. A. Posey and W. Balee, Eds. (NYBG, New York, 1989), pp. 1–21; A. Anderson, Ed., *Alternatives to Deforestation* (Columbia Univ. Press, New York, 1990).
57. B. Chayla, H. Jaffrezic, J.-L. Joron, *C. R. Acad. Sci. Paris* **227**, 273 (1973).
58. Y. Liritzis and M. Kokkoris, *Nucl. Geophys.* **6**, 423 (1992).
59. J. Huxtable and R. M. Jacobi, *Archaeometry* **24**, 164 (1982).
60. J. R. Prescott and J. T. Hutton, *Radiat. Meas.* **23**, 497.
61. The Lower Amazon Project research was funded by NEH (Santarém, grants RO21464 and RO22319), NSF (Marajó, grants INT8306494, BNS8509846, and BNS8712180), and a MacArthur fellowship prize (1988 through 1993). We thank our counterpart A. Duran Coirolo (Arqueologia, MPEG); N. N. Sadeck (Monte Alegre), H. Amaral (Santarém), M. Eck, B. Sommer, J. Dunlap, J. McCarron, D. Schaepe, N. Taintor, M. L. and O. Ribeiro, H. and F. H. Brito de Assuncão, J. and O. da Silva Ribeiro, M. J. and S. Neves Ribeiro, D. Valente da Silva, A. O'Brien, L. Brown, J. Douglas, and D. Goldberg for field assistance; L. C. Batista Lobato and C. Rosário (MPEG) for identifications; G. De La Penha (Ministerio de Espacio), R. Coeli and M. Tadeu (Instituto Brasileiro do Patrimônio Cultural), A. Rodrigues de Oliveira (Director, MPEG), and P. Friaes (GEDEBAM) for logistical support; J. Jones and H. O'Brien for cartography; J. VanStone, E. Steinberg, K. Weiner, P. Tiscione, S. Barut, R. White, W. Hurt, K. Tankersley, J. Morrow, R. Rick, and M. Consens for consultation; J. Foerster, P. Kremer, and E. O'Donnell for administrative services; L. Dorman for printing,; D. A. White and H. Lundberg for photos; E. Quinn, M. Cosentino, R. Mazurek, M. Charleton, and J. Jimenez for research assistance; and J. Sliva, G. Powell, and Z. Jastrzebski for art.