

have the lowest $^{208}\text{Pb}/^{232}\text{Th}$. A plausible hypothesis is that all the old zircons first formed at $\sim 4,300$ Myr, then lost Pb during one or more early events such as the known felsic magmatism at $\sim 3,500$ Myr and the uplift and weathering of the zircon provenance at $\sim 3,100$ Myr. Their present compositions would lie on the hypothetical chord shown in Fig. 1 if no Pb had been lost subsequently. Instead, because Pb loss also occurred recently, they are variably scattered below it.

In the absence of other evidence, we have attempted to use the internal structure, morphology and Th, U contents of the detrital zircons to suggest the nature of their original source rocks. The nearly universal rounding of the zircons is ambiguous, as we cannot ascertain how much of the rounding is due to mechanical abrasion and how much to metamorphic corrosion. The most important genetic features of the 140 analysed zircons are the lack of internal structure and the lack of inclusions in most grains, the blunted euhedral forms of some zircons, and the faint euhedral zoning in the rest. Their mean U, Th, at about 100 and 50 p.p.m. respectively, is distinctly low relative to the average crustal zircon, and zircons with similar morphological features and with low U and Th contents are known in only a few rock types. Zircon populations made up almost entirely of coarse, rounded, uranium-poor, transparent, inclusion-free, unzoned zircon occur in pyroxene granulites¹². Consequently, we favour mafic rocks that experienced granulite facies metamorphism as the probable sources for most of the detrital zircons from the Jack Hills conglomerate. In contrast to the old zircons from Jack Hills, all but one of those from Narryer have distinc-

tive subhedral forms and pronounced euhedral internal zoning. The Narryer zircons also have significantly higher uranium, but not thorium, contents. These differences suggest that the zircons in the Narryer quartzite came from felsic igneous rocks not recrystallized by granulite grade metamorphism, and provide evidence for considerable geological complexity in the ancient terrain contributing zircons to the two metasedimentary belts.

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Carbon-14 dates point to man in the Americas 32,000 years ago

N. Guidon* & G. Delibrias†

* Laboratoire d'Anthropologie Préhistorique d'Amérique, Ecole des Hautes Etudes en Sciences Sociales, 44 rue de la Tour, 75016 Paris, France

† Centre des Faibles Radioactivités, Laboratoire Mixte CNRS-CEA, Boîte Postale 1, 91190 Gif-sur-Yvette, France

The view that man did not arrive on the American continent before the last glaciation has been supported by the fact that until now the known and dated archaeological sites have not been of very great antiquity. But now we report radiocarbon dates from a Brazilian site which establish that early man was living in South America at least 32,000 years ago. These new findings come from the large painted rockshelter of Boqueirão do Sitio da Pedra Furada, the walls and the ceiling of which are decorated with a rich set of prehistoric paintings. We have excavated a sequence containing abundant lithic industry and well-structured hearths at all levels. Carbon-14 dates from charcoal establish a continuous chronology indicating human occupation from $6,160 \pm 130$ to $32,160 \pm 100$ years BP. A date of $17,000 \pm 400$ BP, obtained from charcoal found in a level with fragments of a pictograph fallen from the walls, testifies to the antiquity of rupestral art in this region of Brazil.

The site of Boqueirão of Pedra Furada is one of the 200 known painted rock-shelters located in a remote region of the Brazilian plateau famous for its richness in prehistoric rupestral art (Fig. 1). This site, discovered in 1973 by the French-Brazilian archaeological mission in Piauí, is a rock-shelter situated on the steep bank of a 100-m non-calcareous sand-stone cliff, standing 20 m above the bottom of the valley of Pedra Furada.

The first excavation campaign at the site of Boqueirão of Pedra Furada was undertaken to date the rupestral art which is abundant in the region, and the first two dates obtained were from $7,640 \pm 140$ yr (Gif-4928) and $8,050 \pm 170$ yr BP (Gif-4625)¹.

The excavations were extended in area and depth during the following years. In 1985, the bedrock was finally reached after more than 3 m of sediment had been excavated.

Traces of human occupations succeed one another throughout the stratigraphic sequence. Based upon the distribution and number of artefacts which were in any case associated with the hearths, it appears that the site was occupied only by a small human group on temporary basis. The first traces of human presence in the shelter are a few scattered pieces of charcoal and two lithic pieces, found in the lowest layer A. These were a large pebble bearing the scars of several flakings, and a flake. This lowest level could not be dated.

All of the sedimentary layers contained remains which can be classified, according to the lithic industry and the type of structures of the hearths, in two main stages called Pedra Furada and Serra Talhada². The artefacts unearthed in the surface layer E are different from those found in the lower layers, but not characteristic enough to permit definition of a cultural phase.

During the most ancient cultural phase, Pedra Furada, large circular hearths are found. They are well built with fallen blocks and contain large quantities of charcoal and ash. Lithic industry is abundant and localized around the hearths. The raw materials used for the fabrication of tools were quartz and quartzite, from the pebbles present at the site. Based upon typological and archaeological criteria, this cultural phase has been divided into four stages. In the earlier stage, Pedra Furada I, a lithic collection composed of 560 pieces was found, principally pieces with blunt points obtained by two, three or four convergent flakings, made of pebbles or flakes. Besides these typical tools, pebble-tools (chopping tools and choppers) appear as well as denticulates, burins, notched pieces, retouched flakes and double-edged flakes (Fig. 2).

In addition to the retouched pieces, the collection includes pebble-hammers, flaked pebbles, flakes and fragments produced by flaking. In this level, fragments of painted rock, fallen from the walls, are perhaps evidence of the ancient practice of rupestral art. Two dates, $31,700 \pm 830$ yr (Gif-6652) and $32,160 \pm 1,000$ yr (Gif-6653) have been obtained from charcoal coming from the first hearth found at the site.

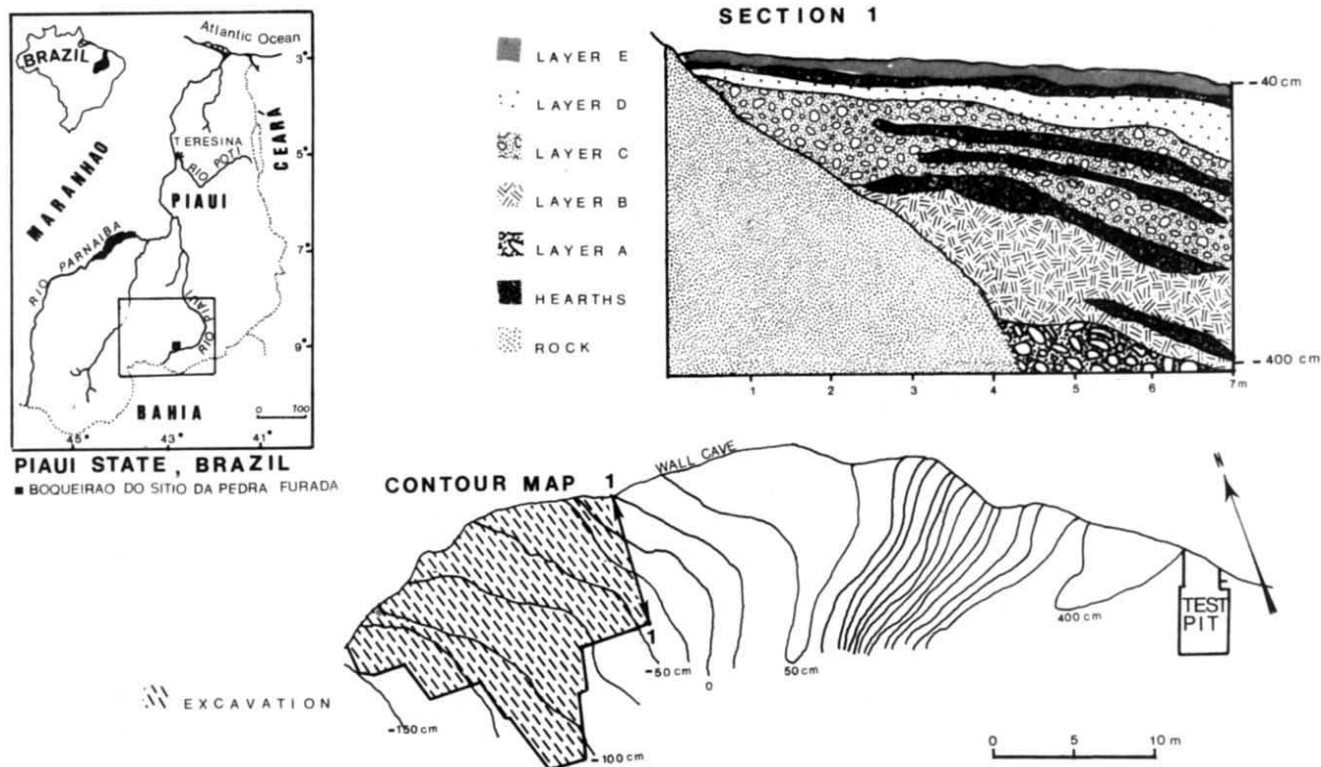


Fig. 1 The shelter 'Toca do Boqueirao do Sitio da Pedra Furada' is situated in the state of Piauí, in northeastern Brazil. This area, known by archaeologists as Sao Raimundo Nonato, is one of the most important in America, with 244 sites discovered there: 186 painted shelters, 13 painted and engraved shelters, 10 sites with only engravings, and 1 site with fossil megafauna. Five distinct sedimentological layers were distinguished, from the bottom to the top: **A**, beige-coloured sand containing coarse grains (≥ 1 mm): 5% pebbles and silt: 8.5 to 10.5%. The sediment is compact. **B**, compact beige-pink sand with silt: 6 to 8% and lower percentage of coarse grains. Pebbles are more abundant in some places. **C**, pinkish sand with silt, 4 to 6% and with gravels and pebbles in some places. **D**, brown to beige coloured sand with coarse grains (≥ 1 mm): 8% and gravels and pebble-beds in some places. This layer is rich in organic matter, mostly ash and charcoal. **E**, at the surface, brown-grey coloured layer with composition identical to that of the lower layers. It is very loose and contains numerous organic remains. The layers B, C, D and E contain saucers or lenses-shaped hearths characterized by a heavy concentration of ashes and charcoal.

Table 1 Carbon-14 dates in years BP and correlation between divisions and sedimentological layers for the site of Pedra Furada

Layers	Occupations	Chronology	Rock art
Layer E	Last occupations	Relative: 5,000 BP	Agreste tradition
Layer D	Phase Serra Talhada	IV Final Stage 6,160 \pm 130 BP (GIF 5863) III Late Stage 7,750 \pm 80 BP (GIF 6161) 7,640 \pm 140 BP (GIF 4928)	Nordeste tradition
Layer C	Phase Pedra Furada	II Middle Stage 8,050 \pm 170 BP (GIF 4625) 8,450 \pm 80 BP (GIF 6162) I Early Stage Relative: 10,000–12,000 BP IV Final Stage 17,000 \pm 400 BP (GIF 5397) III Late Stage 21,400 \pm 400 BP (GIF 6160)	Fragments of pictographs spalled from the walls
Layer B		II Middle Stage 23,500 \pm 390 BP (GIF 6158) \geq 25,000 BP (GIF 5648) \geq 25,000 BP (GIF 5398) 25,200 \pm 320 BP (GIF 6147) 26,300 \pm 800 BP (GIF 6309) 26,400 \pm 500 BP (GIF 5962) 27,000 \pm 800 BP (GIF 6308) 29,860 \pm 650 BP (GIF 6651) I Early Stage 31,700 \pm 830 BP (GIF 6652) 32,160 \pm 1,000 BP (GIF 6653)	Painted fragments spalled from the walls Painted fragments spalled from the walls
Layer A	First occupations	???	

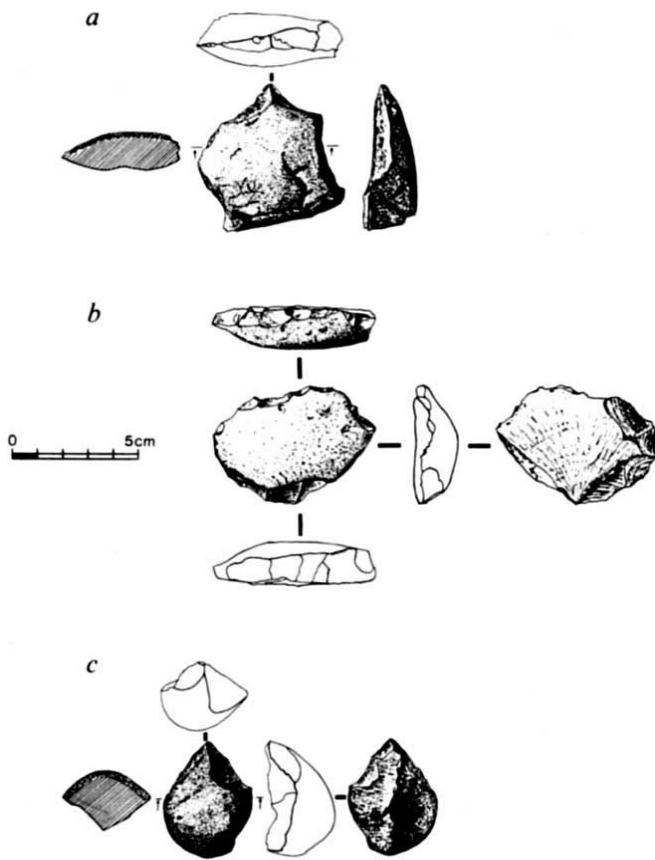


Fig. 2 Large quantities of lithic artefacts were recovered at Pedra Furada I. The lithic pieces are performed by unifacial retouching with a hard hammer although some bifacial pieces are present. *a*, A notched point made from quartz flake; the retouch on edges is flat and regular. *b*, *c*, Blunt points obtained by 2, 3 or 4 convergent flakings. Blunt points are made from flakes or pebbles, they show some traces of utilization.

The next stage, Pedra Furada II, produced 711 lithic pieces. Eight different hearths which correspond to eight distinct periods of occupation have been dated, giving ages from $23,000 \pm 390$ yr (Gif-6158) to $29,860 \pm 650$ yr (Gif-6651) (Table 1). Hence the site Pedra Furada was occupied at different times and probably on a temporary basis from 32,000 to 23,000 yr BP. This occupation is supported by the presence of numerous hearths and the abundant evidence of lithic industry.

The characteristic tools of Pedra Furada III are the blunt points made out of pebbles or flakes, along with chopping-tools, denticulates, knives, retouched and unretouched flakes, and pebbles bearing flaking scars. This stage was dated at $21,400 \pm 400$ yr (Gif-6160). A new series of occupations which represents the final stage of Pedra Furada is characterized by side-scrapers and blunt points. The other retouched pieces are small bifaces, denticulates and double-edged tools.

A carbon-14 date was obtained for one of the hearths and gave the age of $17,000 \pm 400$ yr (Gif-5397). A piece of rock with two red painted lines was found in the same hearth. This pictograph indicates the practice of rupestral art at that time and makes the site of Pedra Furada the most ancient rupestral art site known in America, and one of the most ancient in the world.

The upper layers of the site have produced artefacts which belong to another cultural unit, Serra Telhada: flint and siltite appear little by little and replace quartz, as the raw material for tools, the retouching of the tools is of better quality, and the

hearths are of different types. The absence of hearths and charcoal have precluded the dating of the beginning of this phase. An age of between 10,000 and 12,000 years BP can be suggested based on analogy with lithic material found in a test pit in section E of the site which gave an age of $10,400 \pm 180$ yr (Gif-5862).

Higher in the stratigraphic column, a level of dense occupation is found. The hearths are surrounded by pebbles and blocks and the base covered by a slab, showing traces of successive utilizations. The lithic industry is quite varied and the flaking of blades is an innovation. The proportion of pieces of flint is important even though quartz and quartzite continue to be employed. Retouched pieces include end-scrapers, side-scrapers, knives, blunt points, planoconvex retouched blades and flakes, chopping-tools, bifaces, notched-pieces and pebble-hammers.

Ochre, which is present in large quantities in this level, as well as fragments of painted rock, suggest that rupestral art has been an important activity during this period, which has been placed between $8,050 \pm 170$ (Gif-4652) and $8,450 \pm 80$ yr (Gif-6162). Subsequently, the hearths become larger and more diversified in their structure. Towards the end of the phase Serra Telhada, they become elliptical in outline. Rich in ashes and charcoal, they also contain fragments of bone, wood, leaves, and fruit pits. Nearby are found a large quantity of lithic objects such as flint end-scrapers of three types: discoidal, steep, and nosed. The end of this phase has been dated at $6,160 \pm 130$ yr (Gif-5863). The uppermost sediments are very disturbed by recent human activity and cannot be used for study.

Thanks to the abundance of charcoal present in almost all of the levels, the occupation of this site has been dated in a systematic manner. The seventeen carbon-14 dates obtained from charcoal samples collected during the excavation of the site, are summarized in Table 1. From bottom to top, their succession is not only internally consistent but also consistent with the stratigraphy. These dates, along with the archaeological remains discovered, make it possible to establish the sequence of the different cultural phases of the site. They also establish the antiquity of the human presence in the region. Most archaeological sites known at present in America are not very old. The most ancient ones, the stratigraphy and the dating of which have not given rise to controversy, are comparatively young: 13,000-yr-old for the site of Monte Verde in Chile³, 14,200-yr-old for the site of Alice Boer in Brazil⁴ and 19,450 yr for Meadowcraft Rockshelter in Pennsylvania⁵. Others, recently claimed as being older, are doubtful since the presence of man has not been proved, or since the methods used for dating are questionable. An example of questionable dates is provided by the very old dates of bones, obtained by aspartic acid racemization⁶. Holocene ages were produced for these same samples when measured by accelerator mass spectrometry⁷. The present findings for the site of Pedra Furada testify to the presence of man in the north of South America 32,000 years ago, and strongly suggest that the migration from Asia to North America occurred earlier.

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