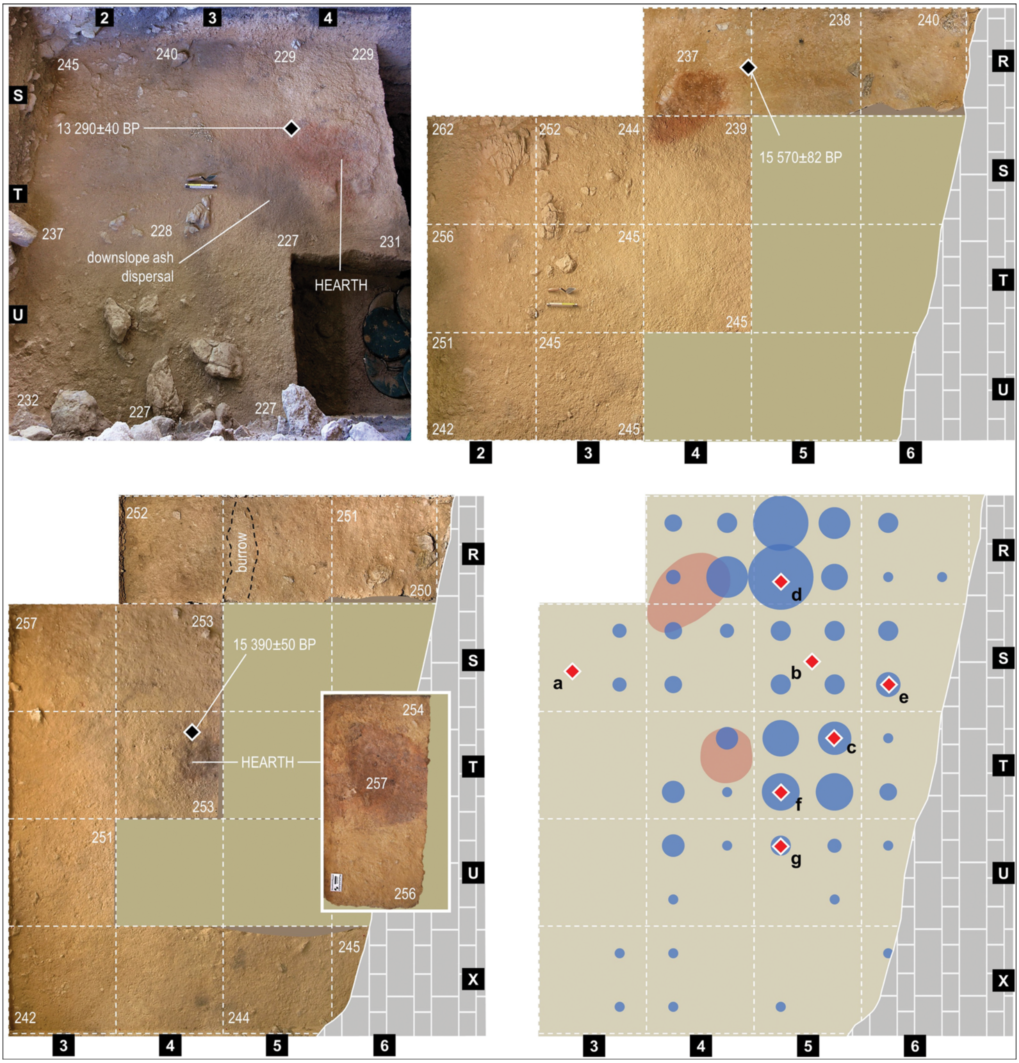

Figure 4. La Boja: the OH4 floors. In the top-right and bottom-left panels, the solid colour represents 1m² grid units excavated in the initial testing phase whose décapage records had, at this elevation, been drawn rather than photographed. Top left: décapage of OH3 (Upper Magdalenian), separated from OH4 by approximately 50mm-thick, sterile unit IL1b. Top right: base of the first décapage within OH4. Bottom left: base of the second décapage within OH4; the inset documents the subsurface red patch apparent after the excavation of the T4 hearth's ash and charcoal fill. Bottom right: the obsidian finds (a–g) and the two hearth features projected on a bubble plot of the distribution of all bladelets, retouched and unretouched, with quadrant provenience (n = 248; the largest bubble, in R5-SE, corresponds to 16.9 per cent of the total). Elevations are in centimetres below datum. Original photographs, orthorectification and figure preparation by João Zilhão.

activities took place and along the outer edge of which the hearths were positioned. Within this sheltered space, the bladelet blanks were concentrated in two clusters, each associated with one of the hearths (Figure 4). The piece-plotted bladelets in the south-east quadrant of grid square R5 were all found between 2.42 and 2.45m below datum, that is, at elevations

Table 1. La Boja. Composition of the OH4 stone-tool assemblage.

	Chert		Quartzite		Obsidian		Hyaline quartz		TOTAL	
Category	**N**	**g**	**N**	**g**	**N**	**g**	**N**	**g**	**N**	**g**
Prismatic cores	4	31.65	–	–	1	2.16	1	2.49	6	36.30
Type-list cores (a)	6	37.02	–	–	–	–	–	–	6	37.02
Core trimming elements	5	11.62	–	–	–	–	–	–	5	11.62
Flakes	36	165.82	1	1.99	–	–	–	–	37	167.81
Small flakes (<25mm)	47	59.03	–	–	–	–	–	–	47	59.03
Blades	8	18.45	–	–	–	–	–	–	8	18.45
Bladelets (b)	205	69.47	–	–	3	0.29	–	–	208	69.76
Chips	1203	185.77	–	–	–	–	–	–	1203	185.77
Chunks	34	118.32	–	–	–	–	–	–	34	118.32
Flake tools	7	42.50	–	–	–	–	–	–	7	42.50
Blade tools	5	10.71	–	–	–	–	–	–	5	10.71
Bladelet tools	40	6.23	–	–	3	0.57	1	0.05	44	6.85
TOTAL	**1600**	**756.59**	**1**	**1.99**	**7**	**3.02**	**2**	**2.54**	**1610**	**764.14**

a) Burins and splintered pieces.
b) Including burin spalls and splintered piece spalls.

Table 2. La Boja. Stone-tool typology of OH4.

Type	N	%
On flake blanks		
Dihedral burin, straight	1	1.6
Burin on concave truncation	1	1.6
Notched piece	2	3.2
Denticulated piece	2	3.2
Splintered piece	3	4.1
Retouched flake	1	1.6
Atypically retouched piece	1	1.6
Retouched piece (burin) fragment	1	1.6
On blade blanks		
Simple endscraper on blade	1	1.6
Ogival endscraper	1	1.6
Thumbnail endscraper	1	1.6
Continuously retouched blade, unilateral	1	1.6
Notched piece	1	1.6
On bladelet blanks (including burin spalls and splintered piece spalls)		
Hypermicrolithic retouched bladelet (one, hyaline quartz)	6	9.7
Marginally backed bladelet	33	53.2
Atypically retouched bladelet (two, obsidian)	5	8.1
Pointed bladelet	1	1.6
TOTAL	62	100.0

corresponding to the reddened patch denoting the R-S/4 feature, which lies at 2.44m below datum. Square T5 was excavated during the initial test phase and almost all the bladelets in this cluster are sieve finds; the piece-plotted finds were retrieved between 2.47 and 2.54m below datum, which is consistent with the elevation (2.53m below datum) of the adjacent T4 hearth.

The good preservation of the T4 feature implies that a significant amount of time elapsed before the site was frequented again; sufficient time passed to allow for the remains of the first event to be buried by sediment, protecting the associated hearth from the trampling and disturbance caused by the second event. The stratigraphic ordering and uncertainty intervals of the radiocarbon dates suggest that the 0.2m-thick OH4 deposit formed within, at most, the 120 years (about six human generations) between 18 714 and 18 831 cal BP. This evidence implies an accumulation rate of ≥1.7mm/year and that OH4's two occupation events—separated by approximately 0.1m—can be no more than around 60 years (or three human generations) apart, and possibly rather less.

At the elevation of OH4 the excavation trench had a surface area of around 15m^2, and so the volume of excavated sediment was approximately 3m^3. The density of find distributions is consequently very low (537/m^3; by weight, 254.7g/m^3) and, per unit of excavated area and individual occupation (assuming both were of similar importance), the number of discarded lithic raw material items is correspondingly small (54/m^2; by weight, 25.5g/m^2). These values suggest limited use, in terms of both recurrence and visitor numbers, of the restricted space available within the shelter. This conclusion stands even if we bear in mind that the occupation surface extended westward, and so perhaps as much as half remains unexcavated; an assemblage twice the size would still be small and, if scattered around an area also twice the size, would be no denser.

The stone-tool assemblage

Seventy-seven per cent of the lithics (40 per cent by weight) are debris (chips and chunks), with the remainder of the material comprising largely unretouched (13 per cent) and retouched (3 per cent) bladelets (Figure 5). Cores are represented by prismatic volumes (six), burins (three) and splintered pieces (three) (Tables 1–2). More than 99 per cent of the pieces are of chert; a quartzite flake, a core and bladelet tool of hyaline quartz, and the seven obsidian objects (Table 3) are therefore exceptional.

That burins and splintered pieces were used as cores is corroborated by the characteristic by-products found among the retouched pieces (Aubry *et al.* 1997; Zilhão 1997). The splintered-piece blanks are recognisable by their thinness, shattering of the proximal end and marked undulation of the ventral side; two of the blanks (one of which is hypermicrolithic) were transformed into marginally backed bladelets. In the burin-reduction of flake or blade blanks, the spall's dorsal side tends to feature a cut of the blank's ventral side and spalls are otherwise recognisable by their flat or twisted profiles and low width/thickness ratios. At La Boja the ratio for burin spalls (n = 40) is 2.16±0.74 and for the regular, unretouched bladelets (n = 169) is 3.84±1.12. One hypermicrolithic burin spall was transformed into a marginally backed bladelet and another bore a continuous, short, low-angled, unilateral retouch.

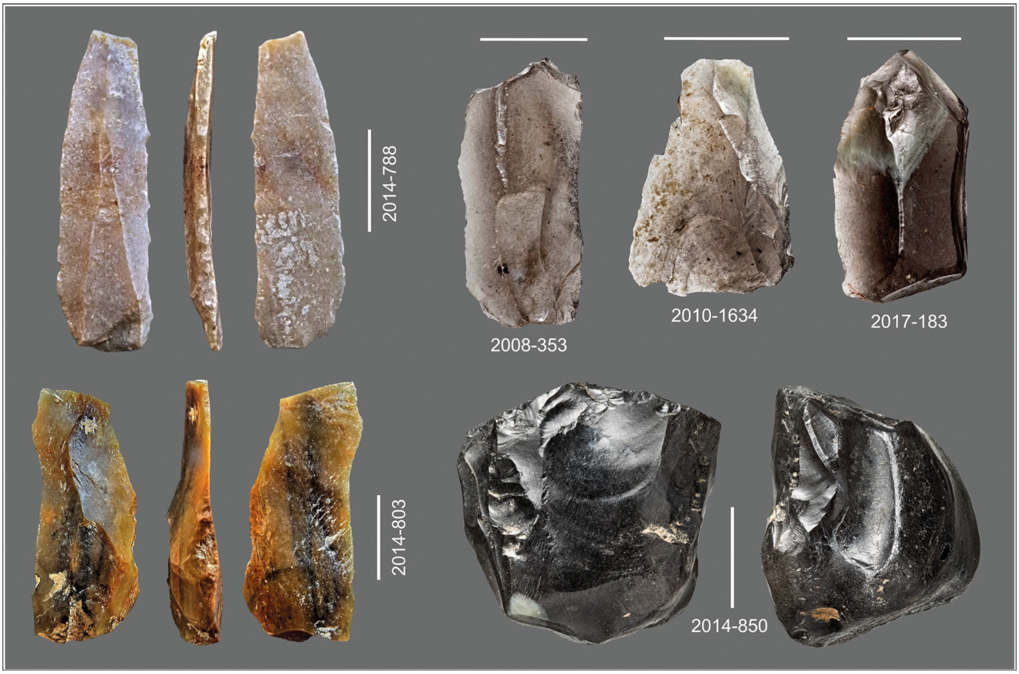

Figure 5. La Boja: the OH4 microlith production. Chert: marginally backed bladelets (2014-788, 2014-803). Obsidian: bladelets with irregular edge retouch (2008-353, 2017-183), unretouched blank (2010-1634) and core (2014-850). Scale bars are 5mm. Photographs by João Zilhão and José Paulo Ruas.

Table 3. Description, weight (g) and element composition in μg/g (ppm) of the La Boja and Carboneras obsidians determined by EDXRF (a).

Sample	Description	Weight	n	MnO	Fe_2O_3	Zn	Ga	Rb	Sr	Y	Zr
La Boja (artefacts)											
2008-353	Bladelet tool	0.18	2	721	9605	20	16	366	189	18	81
2010-459 (b)	Lamellar flake	0.07	–	–	–	–	–	–	–	–	–
2010-797 (b)	Bladelet tool	0.15	–	–	–	–	–	–	–	–	–
2010-1634	Bladelet	0.09	1	694	9378	21	15	360	188	19	90
2010-1889 (b)	Lamellar flake	0.13	–	–	–	–	–	–	–	–	–
2014-850	Prismatic core	2.16	1	711	9544	19	16	366	188	19	81
2017-183	Bladelet tool	0.24	2	675	9021	19	15	345	178	19	79
Carboneras (geological samples)											
GS1	Pebble	4.10	3	658	8889	17	14	343	179	18	77
GS2	Pebble	6.19	3	686	9158	19	15	357	185	18	80
GS3	Pebble	4.02	3	718	9505	18	15	365	189	18	82
GS4	Pebble	3.49	2	704	9308	19	15	354	182	18	79
GS5	Pebble	3.20	3	713	9465	20	15	359	184	18	80
GS6	Pebble	9.38	3	702	9316	17	14	353	182	19	78

a) n = Number of 'point measures' per sample (collimator: 3 × 3mm); when n>2, the elementary values given are the average of all the measurements.
b) These specimens were identified among the sieve finds thoroughly revised specifically for this study, after the element analysis of the others had already been carried out.

The characteristics of this small assemblage indicate that knapping activities consisted primarily of the exploitation of small, carry-on volumes of raw material with the intention of producing microliths to be mounted as cutting elements of composite tools. Reduction sequences were short: most cores are recycled debitage or exhausted tools, and most retouched blanks are marginally backed bladelets, such as those in Figure 5.

The obsidian finds

In Figure 4 the bladelets marked b–g are sieve finds assigned to the centre of the square or quadrant from which they were recovered. Only the core, a (2014–850), could be piece-plotted (Figure 3). Pieces a, b (2008–353) and c (2010–1889) come from the very base of OH4, and all three therefore belong to the first occupation event. The findspots of d (2017–183), e (2010–1634), f (2010–459) and g (2010–797) constrain them to the elevation of the red patch denoting the R-S/4 hearth; these objects must have been discarded during the second occupation event. No refits can be made, supporting the interpretation of on-site discard related to two distinct occupations.

The core retains most of the cortex. A single platform was used to exploit an extraction plane set up along a 13.3mm-long axis. A limited number of blanks was produced; the largest measurable scar is 12.6mm long. This size is consistent with the length of the bladelets (9.6–12.7mm), of which three (2008–353, 2010–797 and 2017–183; Figure 5) bear irregular edge retouch that may have been caused by wear. At discard, the three unbroken prismatic flint cores in the assemblage were 22.6–23.7mm long and bore scars no longer than 16.6–23mm. Among the chert bladelets selected for retouch that, presumably, represent the intended size range, the length of the complete specimens lies between 9.9 and 25.1mm (Figure 6).

Based on this evidence, obsidian entered the site both as complete pebbles for on-site knapping and as finished items discarded or lost upon having become worn or blunt. The metrics concur in revealing that, in terms of length, the obsidian products fall at the lower end of—but within—the size range of retouched chert bladelets, while varying around the means for width and thickness (Figure 6). As with the single hyaline quartz bladelet tool, the fact that the obsidian products are shorter must result from the constraints imposed by the size of available raw material.

The obsidian sources

Small outcrops of Neogene volcanic rocks exist in the Murcia region (e.g. the islets of the Mar Menor coastal lagoon, 75km south-east of La Boja). None, however, feature obsidian. We therefore focused on the second closest potential source, the Cabo de Gata Volcanic Zone, Almería (Figure 7), which formed during the Miocene, between 14 and 7 million years ago (IGME 1981; Mattei *et al.* 2014; Soriano *et al.* 2014). Here, a short article in a regional journal describes four occurrences of obsidian in and around the town of Carboneras (Leal-Echevarría & García-Guinea 2005). Two ('near Los Ranchos') only yielded granules (2–3mm), too small for the production of stone tools. Another of the four identified occurrences ('Canteras') yielded pebbles of up to 35mm. The location, however, is within the

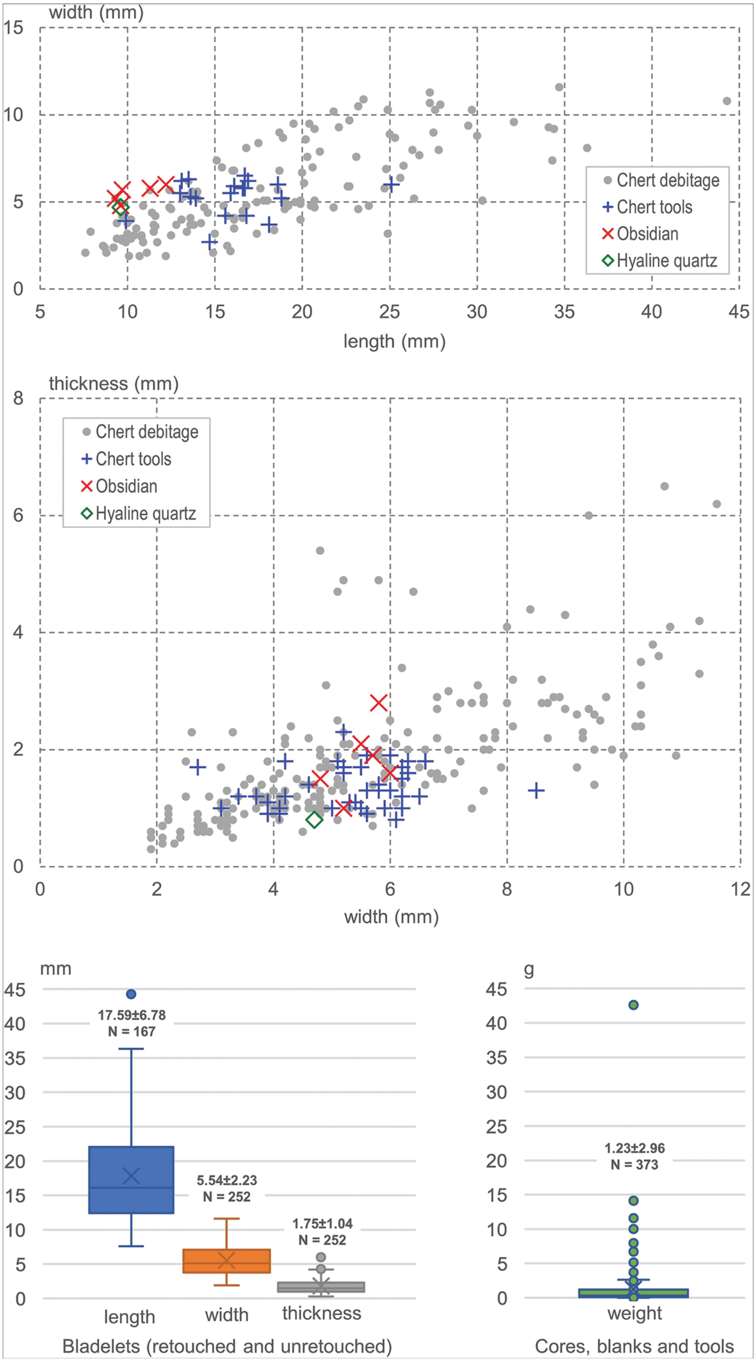

Figure 6. La Boja: the OH4 stone tools. Bladelet size and weight of discarded items (chippage and chunks excluded). Illustration by João Zilhão.

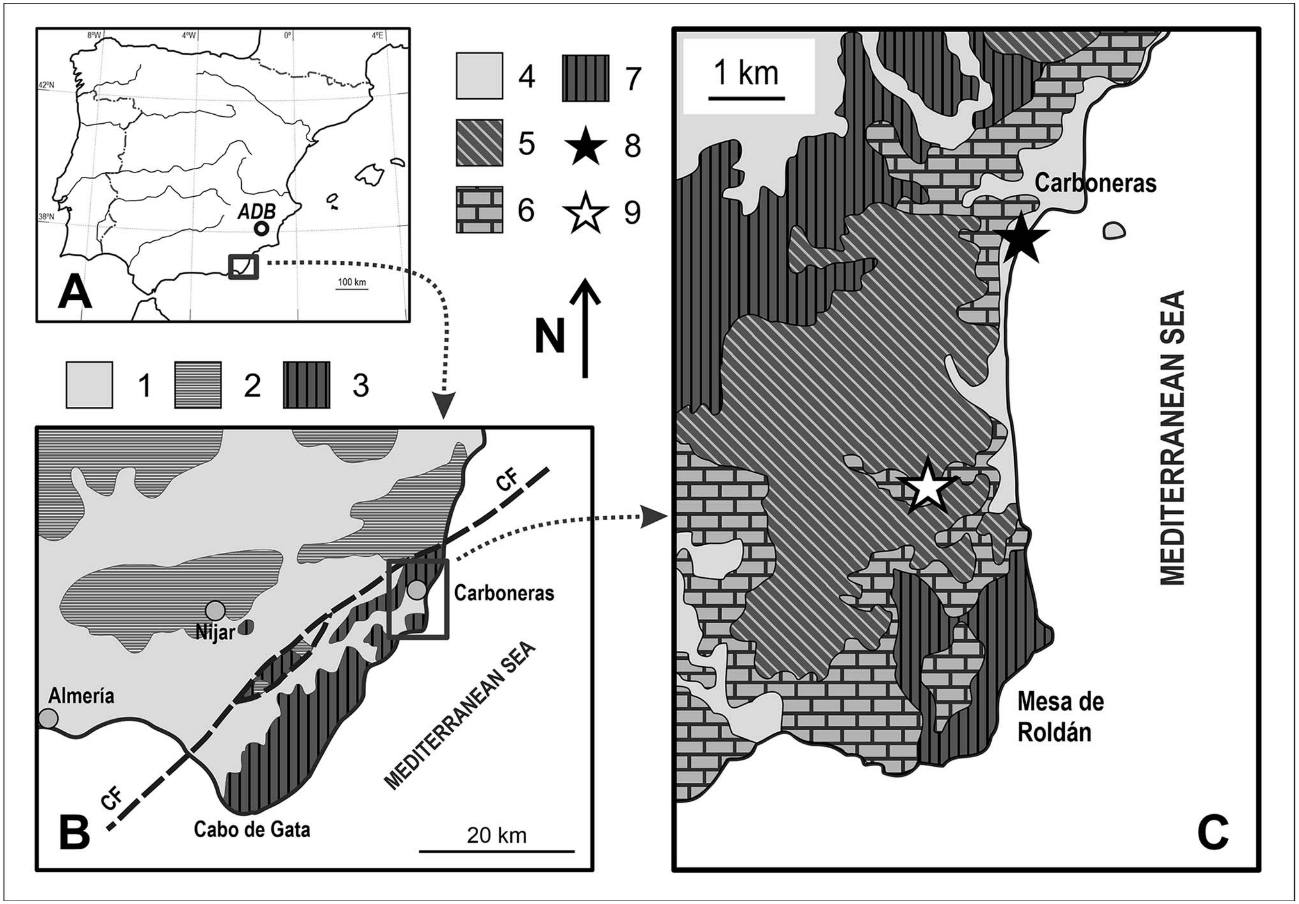

Figure 7. Carboneras: location and geological context. A) Situation in Iberia; B) sketch map of the Cabo de Gata Volcanic Zone; C) simplified geological map of the Carboneras surroundings. Key (panel B): 1) Neogene and Quaternary sedimentary rocks and sediments; 2) Palaeozoic and Mesozoic rocks; 3) Neogene volcanic rocks. Key (panel C): 4) Quaternary sediments; 5) Pliocene sedimentary rocks; 6) Miocene sedimentary rocks; 7) Neogene volcanic rocks; 8) 'casco urbano' obsidian source; 9) 'Concesión La Mezquita' quarry. CF) Carboneras Fault. Modified after IGME (1981), Aguirre et al. *(2008) and Soriano* et al. *(2014). Illustration by Diego E. Angelucci.*

perimeter of the large 'Concesión La Mezquita' quarry, associated with a cement and concrete factory, and inaccessible for the present study. The fourth occurrence ('casco urbano') is within the town's urban perimeter (Figure 8). Between 2016 and 2018, we were able to inspect the location on three occasions; samples were collected on all three visits (Figure 9).

Originally, the 'casco urbano' source consisted of a volcanic breccia and hyaloclastite featuring perlite and obsidian fragments, as well as pitchstone, outcropping at the base of the local coastal/marine sedimentary sequence and exposed by the incision of a short *rambla* (ravine). As early as 1807, this outcrop was identified as the origin of the so-called *piedras gatas* (the vernacular term used locally to designate the obsidian pebbles). By the time Leal-Echevarría and García-Guinea visited the site 15 years ago, however, the outcrop had been buried or destroyed by construction work, and the obsidian pebbles they collected were recovered from rubble heaps at the bottom of the landfilled rambla. This is the location of our own collection points 1a and 1b. Our other collection points are isolated finds (2a) or soil heaps (2b) that contain numerous obsidian pebbles and result from the disposal of rubble derived from the 'casco urbano' source.

To confirm that Carboneras was the provenance of the La Boja obsidian we undertook non-destructive EDXRF (energy dispersive X-ray fluorescence) analysis of four of the archaeological finds (Figure 5) and of six geological samples from collection points 1a and 2a (Table 3 & Figure 9). The results show that the Carboneras obsidian is very homogeneous and of the same composition as the La Boja finds, with which it forms a discrete cluster, clearly distinct from the Italian sources (Lugliè *et al.* 2014; Orange *et al.* 2017; Nicod *et al.* 2019) (Figure 10).

Collection point 2b yielded a few volumes of glass-rich ignimbrite with embedded obsidian pebbles, illustrating how the latter would have been encountered in their primary position. At points 1a, 1b and 2a, however, the obsidian pebbles are devoid of such gangue. The minimal, if any, rounding of pebbles from these three locations contrasts markedly with the appearance of the pebbles and cobbles found in the Pleistocene coastal deposits seen above the volcanic series along the Carboneras beach and the ramblas that drain into it. This observation would seem to preclude the long-distance displacement of these obsidian pebbles, whether from upriver or from landforms now submerged by sea-level rise; they must therefore correspond to locally derived material, originally available in the alluvial gravel at the base of the rambla. It is probable that this was also the case with the core that travelled from Carboneras to La Boja almost 19 000 years ago.

Discussion

At La Boja obsidian was recovered from only a single horizon, with none found in either under- or overlying layers. One possible explanation is that knowledge of the Carboneras source was not acquired until the Early Magdalenian and thereafter was somehow lost. Yet the well-known taste for exotic raw materials in the Upper Palaeolithic of South-western Europe, especially during the preceding Upper Solutrean, may not support this interpretation.

Alternatively, one might correlate this unique and short-lived usage with the onset, around 18 kya, of the Dryas I climate phase, which, in the Mediterranean, was a period of significant aridity. Indeed, it is likely that OH4 (approximately 19 kya) and OH3 (approximately 16