Moinhos and Mina do Paço: Middle Paleolithic lithic chipping stations in the Sado Basin, Alentejo, Portugal

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ABSTRACT

This paper describes the assemblages from three Middle Paleolithic lithic extraction and preliminary reduction sites in the Sado River Basin, Alentejo, Portugal. The sites were discovered as part of the Sado River Drainage Survey (SRDS), the goal of which was to document the Palaeolithic occupation in the region and assess prehistoric land-use patterns over time. The three sites in question (Moinhos 1, Moinhos 2, and Mina do Paço) are located on gentle slopes near jasper outcrops, in relatively elevated positions and exhibit low to moderate artifact densities, despite which assemblage sizes are relatively large. The distribution of lithics appears restricted to the plow zone. The three assemblages are very similar in terms of typological and technological attributes, with a dominance of discoid and centripetally prepared Levallois cores, and only moderate amounts of platform faceting on both cores and flakes. The few typological differences between the sites are primarily attributable to the varying quality of the locally available lithic raw material (jasper). Cores and waste products are common, but end-products are rare, with most probably being exported to task or habitation sites by the knappers. Although retouched tools are scarce at both locations, Levallois flakes are more common at Mina do Paço. The regional context revealed by the SRDS suggests low population density and possibly even intermittent use of the Sado river Basin by Middle Paleolithic hominins.

Key words: Middle Paleolithic – lithic technology – Neanderthal – land-use patterns

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RESUMO

O presente artigo descreve os conjuntos de três estações de extracção lítica e exploração de núcleos do Paleolítico Médio, na bacia do rio Sado, Alentejo, Portugal. Os sítios foram descobertos na sequência da Prospecção da Bacia do Riio Sado (SRDS), cujo objectivo foi documentar a ocupação da região no Paleolítico e determinar padrões de ocupação do território ao longo da Pré-história. Os três sítios em questão (Moinhos 1, Moinhos 2 e Mina do Paço) situam-se em declives suaves perto de afloramentos de jaspe, em locais mais ou menos elevados e apresentam fraca a moderada densidade de artefactos, apesar das dimensões relativamente grandes dos conjuntos. A distribuição dos líticos restringe-se à zona arada. Os três conjuntos são muito semelhantes no que diz respeito a características tecnológicas e tipológicas. Predominam os núcleos Levallois discóides e centrípetos, sendo apenas moderada a quantidade de talões facetados tanto em núcleos como em lascas. As poucas diferenças tipológicas entre os sítios devem-se principalmente à qualidade variável da matéria-prima (jaspe) disponível no local. Aparecem com frequência núcleos e restos de debitagem, mas os produtos acabados são raros, tendo sido provavelmente levados pelos talhadores para povoados ou locais de trabalho. Embora os instrumentos retocados sejam escassos em ambos os locais, as lascas Levallois aparecem mais na Mina do Paço. O contexto regional revelado pelo SRDS sugere baixa densidade populacional e ocupação intermitente da bacia do rio Sado pelos hominídeos do Paleolítico Médio.

Palavras-chave: Paleolítico Médio – tecnologia lítica – Neandertal – padrões de ocupação do território

INTRODUCTION

One important feature of the archaeology of Southern Iberia is that it has produced some of the most recent Middle Paleolithic sites and Neanderthal fossils on record (Barton *et al.*, 1999; Hublin *et al.*, 1995; Zilhão, 2006). A number of these are located in Portugal (Angelucci and Zilhão, 2009; Antunes, 2000; Antunes and Cunha, 1992; Antunes *et al.*, 1989; Ferring *et al.*, 2000). Although recent research has questioned some of these dates (Zilhão *et al.*, 2010), the Portuguese sites continue to shed important light on Neanderthal subsistence and settlement patterns, and the possible interaction between Neanderthals and anatomically modern *Homo sapiens* (AMHs) towards the end of the Pleistocene (Raposo 1995; Vaquero, *et al* 2006; Zilhão 1993, 2000, 2001; Zilhão and Villaverde, 2008). Most of the known MP sites in Portugal are located in the central part of the country, notably, the Estremadura, the Tagus River valley and the environs of Lisbon, but this distribution is probably partly a result of archaeological coverage. The limestone regions in the northern half of the country include caves and rock-shelters that preserve archaeological deposits and have attracted more attention, although recent work in southern Portugal has also yielded significant MP sites particularly near the coast (Bicho, 2004). Until this century, the Sado River Basin in southern Portugal remained essentially unexplored *vis à vis* the Palaeolithic.

The Sado River Drainage Survey (SRDS) was carried out from 2005 until 2008 under the auspices of the Instituto Português de Arqueologia (now IGESPAR) and was funded by the Social Sciences and Humanities Research Council of Canada. The proximate goal of this survey was to investigate a part of southern Portugal which had previously attracted only limited attention from Paleolithic specialists (Burke *et al.* 2009, nd). The ultimate goal of the SRDS was to generate sufficient spatial data to model Paleolithic land use patterns over time in lower

Alentejo and to see if these correlated with changes in climate and/or population turnover, specifically the replacement of Neanderthals by anatomically modern *Homo sapiens*. Of the 83 survey locations that yielded lithic artifacts, most were individual find-spots and diffuse lithic scatters; nine localities achieved sufficient artifact densities to qualify as sites or localities of interest (Burke *et al* 2009, nd). This paper describes the lithic assemblages obtained through systematic surface collection from three of the most productive areas surveyed: Moinhos 1, located adjacent to a jasper outcrop associated with volcanogenic massive sulphide deposits (VMS); Moinhos 2, c. 700 m west of Moinhos 1 where weathered blocks of jasper from a sub-surface vein were present; and Mina do Paço, also adjacent to a VMS jasper outcrop.

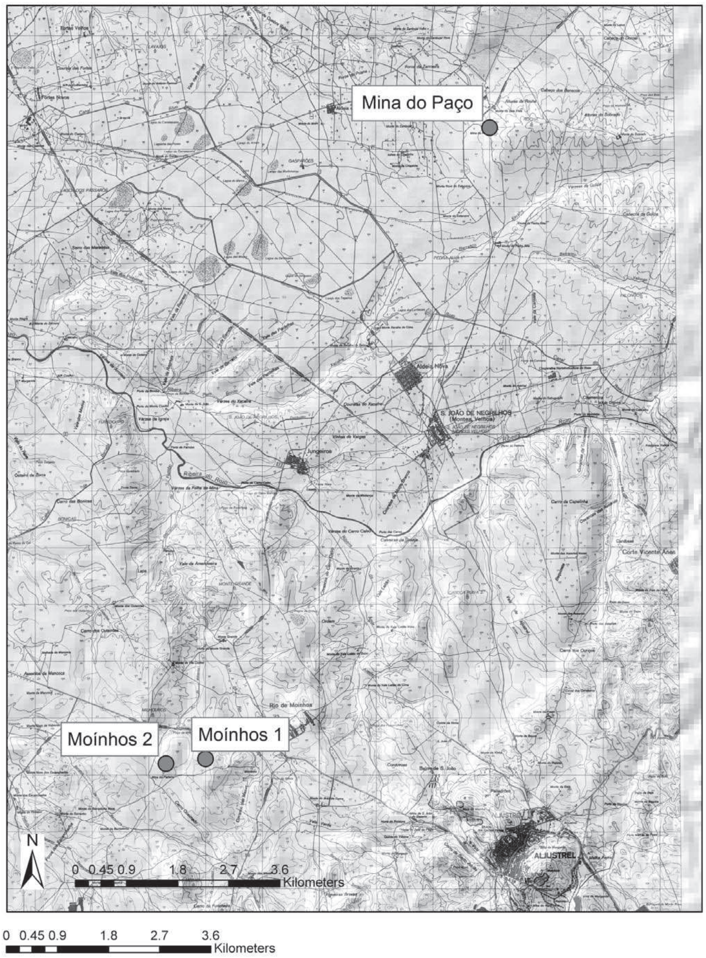

Fig. 1 – Location of Sado River Drainage Survey and the Moínhos 1 and 2 and Mina do Paço sites.

Both Moinhos sites derive their names from the village of Rio de Moinhos, located 1.2 km northeast of Moinhos 1. Mina do Paço lies 1.8 km southeast of the town of Gasparões, and is named for the recently abandoned polymetallic mine (Cu-Pb-Zn associated with the Fe-Mn oxides) adjacent to the artifact distribution. Excluding modern materials and the remains of recent mining activity present at Moinhos 1 and Mina do Paço, the archaeological materials from the three sites are diagnostic of the Middle Paleolithic.

SURVEY METHODOLOGY

Survey methodology is described in full elsewhere (Burke et al. 2009, nd.). Suffice to say that the survey was designed to systematically sample three distinct geographical contexts: Pleistocene terraces, lithic raw material sources, and small bodies of water (seasonal lakes) distributed on the Alentejano plain, as well as randomly sampling other contexts (e.g., river terraces of unknown age and topographically distinct features). Jasper is encountered in primary outcroppings and maps of the outcrops were obtained from Dr. Matos, Instituto Nacional de Engenharia, Tecnologia e Inovação, Beja.

The field methodology involved survey teams of 3-5 individuals, equipped with WAAS enabled GPS units (Garmin® eTrek Legend), walking parallel transects roughly 5 meters apart in a designated survey location. Although GPS accuracy varied with time of day and location, accuracies of 3m or better were common. Each transect was automatically recorded, and any artifacts encountered were collected and recorded as waypoints. GPS data were uploaded onto a laptop on a daily basis and processed using MapSource®. Data were then converted, uploaded into ArcGIS 9.2 (ESRI®), and projected onto digitally stored topographic maps. This permitted daily assessment of survey coverage and facilitated visualizations of artifact locations and the calculation of artifact densities on the landscape. Finds were bagged individually along with provenience information and, at the end of each day, washed and evaluated for clear signs of human-induced scars. This could be a difficult decision in the case of crypto-crystalline quartz, as the interior faces of flakes were often distorted and proximal ends were often crushed. Since quartz «rubble» was a ubiquitous component of sediment deposits in many of the survey locations, particularly the terraces, flakes that were not demonstrably of human manufacture were rejected from the assemblages. Special care was necessary near historic mining of the VMS deposits because that also produced substantial amounts of fractured quartz and jasper «rubble». With jasper, evaluation was easier because the more homogeneous nature and finer grain of the rock preserved flake attributes more clearly. Any pieces ultimately determined to be non-artifactual were discarded, and their data removed from the list of waypoints. To avoid confusion, their catalog numbers were not reassigned to other specimens. The resulting assemblages are curated at the Museo Municipal, in Aljustrel.

GEOPHYSICAL CONTEXT

The Sado River basin encompasses an area of 7,692 km^2 (excluding the estuary), with a mean altitude of 127 meters asl. The Basin lies within the Iberian Pyrite Belt (IPB) which is composed of Paleozoic volcanic rocks overlain by metamorphic rocks, in turn mantled by sedimentary deposits. Basement rocks in the IPB are a filito-quartzite group including ubiquitous veins of crypto-crystalline quartz, a volcanic sedimentary group including schists, silicious tuffs, rhyolites, dacites, diabases, jasper and chert, and a Flysh group consisting of grauvaques, schists and conglomerates (Martins *et al.* 2002-3). Mining of metallic ores, principally copper, lead and zinc, associated with the VMS deposits, began during

Roman times. More recently, it has been active in the region from the 19th Century onward, and remains centered in Aljustrel (Barriga 1983, 1990; Barriga and Carvalho 1997; Martins, Alves and Costa 2002-2003).

The basement complex is overlain by Miocene marine and continental sediments, principally sands, clays, conglomerates and tabular carbonates. Little limestone occurs in the study region and flint is therefore absent. Available raw materials include poor quality cherts, jasper, crypto-crystalline quartz and some fine-grained quartzites suitable for knapping, although these are of highly variable quality. Gravels derived from basement rocks contain quartz, quartzite and jasper cobbles, exploited by prehistoric knappers.

Tectonic processes have strongly influenced the current topography of the Sado basin and the formation of the Grândola horst at the beginning of the Pleistocene subdivided the Sado drainage system into two different sedimentary regimes. In the north, extending from Grândola to the Sado estuary, is a littoral platform characterized by fine sands often re-worked by aeolian processes. In the southern half of the study region, from Grândola to the Sado River headwaters in the Serra da Vigia, is a surface characterised by sandy, detritic, and highly variable fluvial sediments (Pimentel 1989; Pimentel and Azevedo 1991) and relatively thin soils, particularly on hillsides. Fluvial terraces are difficult to detect in the northern sector, and the few identified remain undated (Pimentel 1989). In the south, there is a single Quaternary (?) terrace north of Panoias, and two terraces to the south (Pimentel 1989; Pimentel and Azevedo 1991). The sites examined here lie in the southern sector of the Sado River Basin.

LITHIC RAW MATERIAL SOURCES IN THE SRDS REGION.

There are no flint deposits in the study region and cherts are rare. Jasper and quartz are the dominant lithic raw material resources. Jasper, quartz and occasionally quartzite are present in the form of cobbles in Plio-Pleistocene contexts throughout the region. Twenty-six potential jasper sources (primary locations) in the SRDS survey region were identified with the help of maps of local mining activities supplied by Dr. J. Matos, INETI (Beja). All of these sources were surveyed during the course of the project. Lithic artifacts were discovered at several of these locations (Fig 2). More than 50% of the total number of sites, localities and lithic scatters recovered during the SRDS survey lie within 5 km of a jasper source – including the two most important sites (Mina do Paço, Moinhos 1), two localities (Moinhos 2, Brejo) and several lithic scatters (Alamo, Pedras Serranas, Penique) – indicating that the location of available primary raw material sources was known to Paleolithic people, who systematically exploited them. The largest concentration of archaeological remains occurs between Moinhos and Mina do

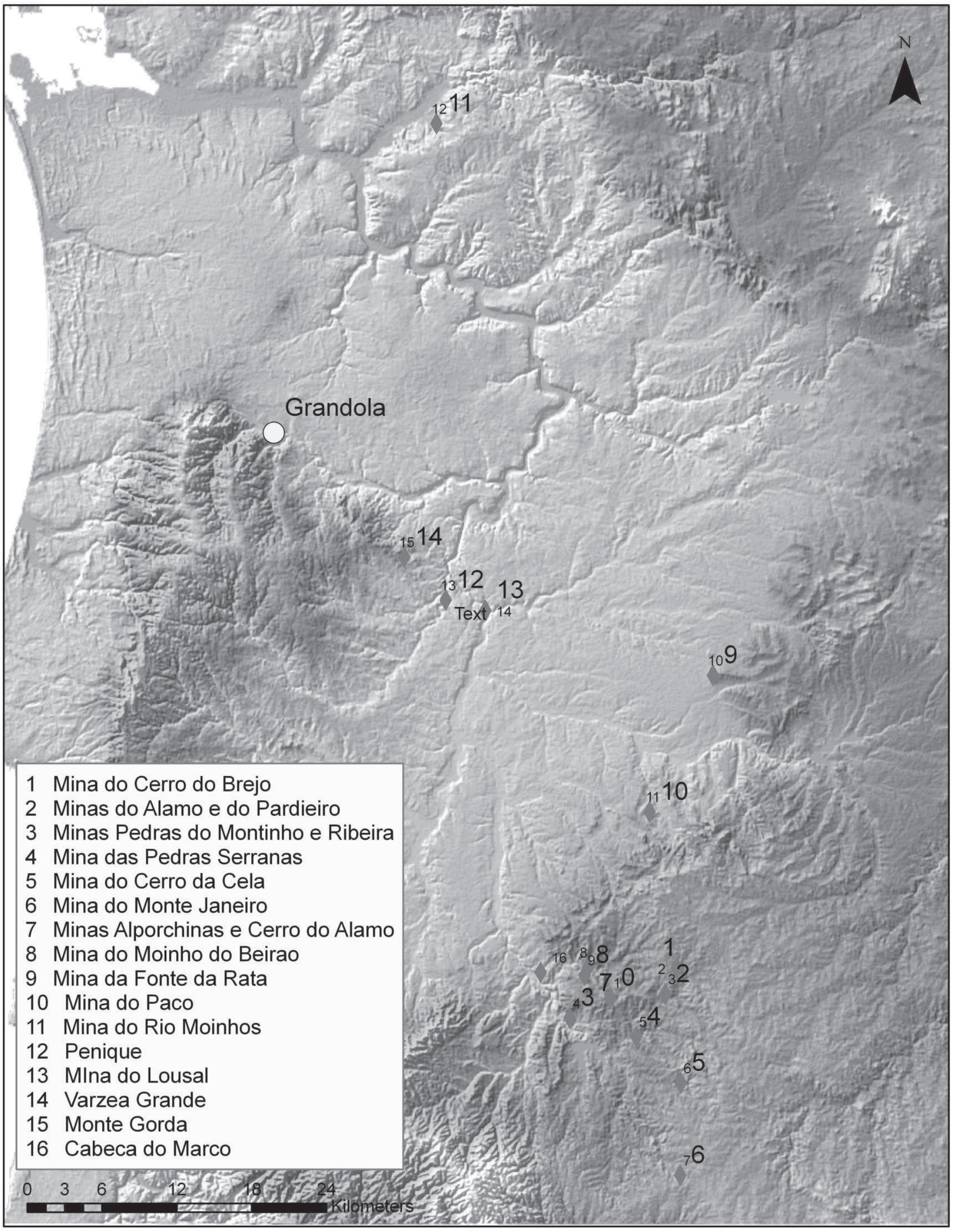

Fig. 2 – Jasper sources in the Sado River drainage.

Paço. A least-cost analysis indicates that this region (see Fig. 2) offers the easiest approach routes to either source.

Geochemical analyses using X-ray fluorescence of geological jasper samples from Moinhos and Mina do Paço show that they are mainly composed of SiO_2, Al_2O_3 and Fe_2O_3T (>99% by weight based on 28 samples, Figure 3) and that Mina do Paço jasper has a slightly higher silica content (95.4% vs. 93.1%). Repeated

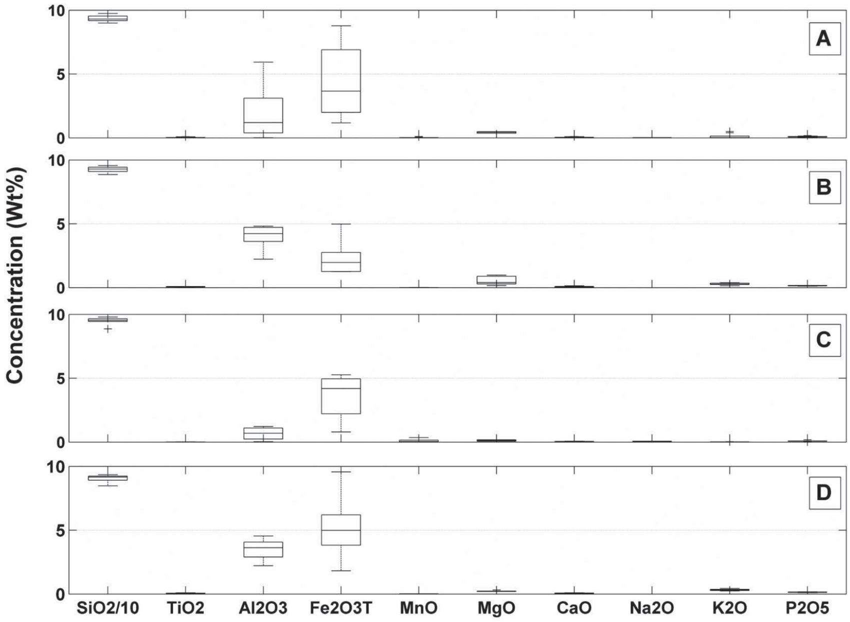

Fig. 3 – Major element (EDXRF) boxplot diagrams for A- Moínhos geological samples (N=10), B- Moínhos archaeological flakes (N=5), C- Mina do Paço geological samples (N=8) and D- Mina do Paço archaeological flakes (N=5) showing that only three major elements (SiO2, Al2O3 and Fe2O3T) compose > 99 weight % of the jasper samples. Please note that SiO2 values are divided by 10 for clarity.

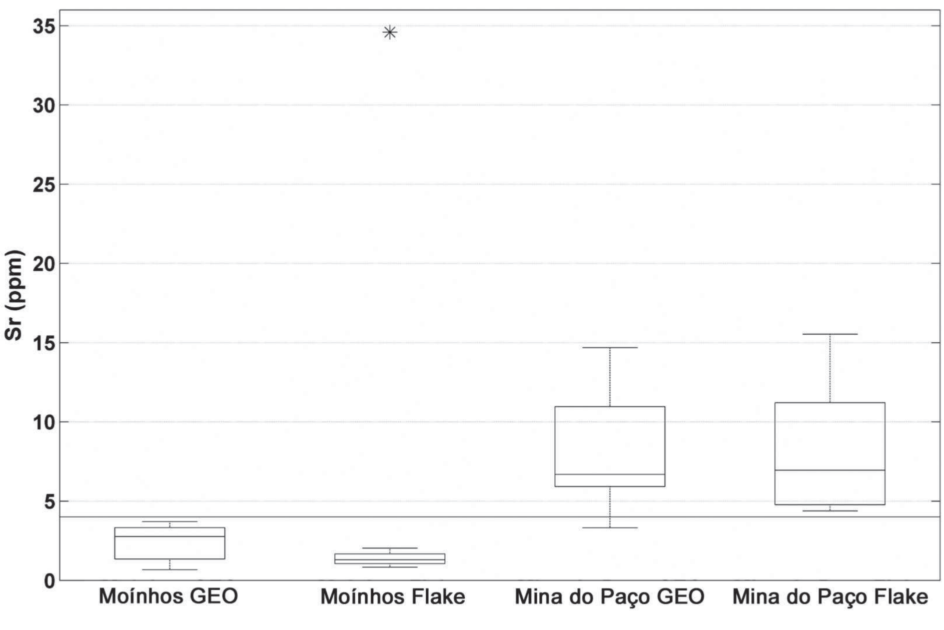

Fig. 4 – Strontium boxplot diagram for geological samples and archaeological flakes. Strontium is the only element that can be used to discriminate between Moínhos and Mina do Paço jasper. A reference line is drawn at 4 ppm for clarity. Sample MOI-13 (1433) acts as an outlier and is plotted here with an * symbol, it was not used to produce the Moínhos flake box.

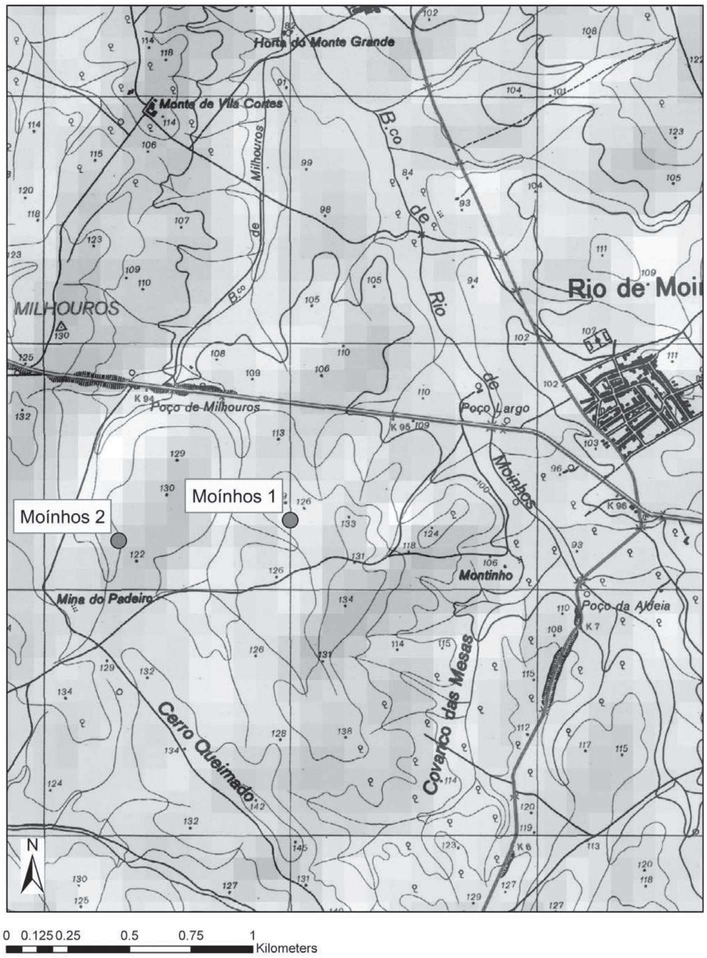

Fig. 5 – Locations of Moínhos 1 and 2.

analyses of major, trace and rare earth elements indicate that these and other jaspers in the region are difficult to distinguish due to their «purity». We were able to differentiate between the Moinhos and Mina do Paço sources on the basis of one element: strontium (Figure 4) but we caution the reader that it is not advisable to depend on one element alone in distinguishing sources of raw materials.

MOINHOS

The raw material source of Moinhos is located near the village of Rio de Moinhos, roughly 10 km northwest of Aljustrel (Fig.1). Surveys undertaken at Moinhos resulted in the identification of two localities (Moinhos 1 and Moinhos 2) (Fig. 5). The center of the artifact distribution of Moinhos 1 is at 37º 53′ 29.45» -8º 13′ 42.69» (UTM[1] 568000 4194284) and is focused on a bedrock outcrop which includes massive jasper lenses occurring on the hilltop, roughly 126 m above sea level. This feature was mined historically and two large pits are cut into the bedrock, but it is now abandoned and is overgrown with thick brush and oak trees and the surrounding hillside is covered with mine tailings (rock chips). The soil near the mine is thin and contains much gray decomposed schist suggesting that bedrock is close to the surface. To the west, the hill slopes down to the eastern branch of the seasonally dry Barranco de Milhouros, a small tributary of the Rio de Moinhos.

Moinhos 1 was surveyed in 2006 and 2007. In 2006 much of the site was covered in crops, as a result the survey concentrated on the narrow gully formed by the Barranco de Milhouros (Fig. 5). A total of 36 lithic artifacts were collected in the bed of the Barranco in 2006. Faunal remains are not preserved at any of

[1] European Datum 1950

the Moinhos localities. Four parallel transects, 150 m in length from the hilltop towards the Barranco were also surveyed, but no artifacts were encountered as ground cover was dense. In 2007 the fields were covered in crop stubble and the slopes below the mine, extending towards the Barranco could be surveyed. While visibility was far from ideal, artifacts were found on the hill slope on all sides of the outcrop. Lithics are concentrated on the southwest slope of the hill and in the Barranco, however. The relatively thin distribution of artifacts on the western slope may reflect, at least partially, collection strategy which was very conservative in the vicinity of the mine, where recent mine tailings covered the surface. Only pieces with clear diagnostic features were collected and it is conceivable that the lithic counts are artificially low near the mine pits (and down slope) as a result. The apparent concentration in the Barranco may also be a result of gradual sheet-erosion. Twenty transects surveyed west of the Barranco, opposite the jasper outcrop, produced only 4 artifacts demonstrating that the outcrop itself was the focus of prehistoric activity. A 5 m wide, freshly plowed fire-break forming a southwest – northeast line and passing 35 m north of the outcrop was surveyed in 2007. This feature afforded excellent visibility and resulted in the recovery of 23 artifacts, clearly concentrated near the outcrop and decreasing in frequency away from it, and more dense west of the outcrop (Fig. 5). The site, therefore, is deemed to have existed on the west slope of the hill.

Moinhos 2 is located 750m west of Moinhos 1 at 37º 53′ 26.86», -8º 14′ 8.18» (UTM[2] X=567304, Y=4194201) on the far side of a small hill when viewed from Moinhos 1 (Fig. 5). The crest of the hill (altitude 130m asl) has a very thin soil cover, containing a lot of decomposed schist, supporting a small cluster of oak trees; down-slope the soil layer thickens to a richer, light brown sandy clay and the slopes of the hill are cultivated. A survey of Moinhos 2 was conducted in 2007, when the entire west slope of the hill was freshly plowed to a depth of at least 40 cm, affording perfect survey conditions.

A few large angular blocks of jasper were found in a loose pile (likely a result of field clearing activities) on the slope at Moinhos 2, indicating the presence of a jasper outcrop in the vicinity. Some of these blocks are nearly 1 meter across and could have been sources of lithic raw material in the past. Smaller, weathered chunks of jasper are scattered down-slope of the blocks. Artifacts are clustered on the west slope of Moinhos 2 in a roughly 80 by 60 m area at 120 m asl. All of the finds appear to be restricted to the plow zone, a situation occurring in all of the other Paleolithic sites found during the SRDS survey. This was confirmed in 2008, when two 1 x 1 meter test pits excavated in the center of the artifact distribution yielded only a single artifact in the plow zone and none in the sub-soil.

[2] European Datum 1950

MINA DO PAÇO

Mina do Paço is located in the vicinity of a large jasper lens associated with the gray-green schist country-rock, UTM[3] X=572999 Y=4205387. The site, named after the mine that used to exist there, is a significant lithic scatter situated on the southwest end of a low ridge overlooking the village of Gasparões, c. 1.5 km to the northwest (Fig.6). Mina do Paço overlooks a broad plain (formed predominantly of Plio-Pleistocene sediments) to the north and west where several small seasonal lakes (*lagoas*), now mostly dry or landfilled but active within recent memory, occur. The closest of these little lakes is located on the eastern edge of Gasparões village and a Middle Paleolithic locality centered on this lake was identified during the SRDS survey (Burke *et al* 2009, nd.), attesting to hominin exploitation of other resources (animal and/or plant) in addition to lithic raw material in the vicinity of Mina do Paço. The history of occupation of Mina do Paço may be more complex than occupations at Moinhos 1 and 2, therefore.

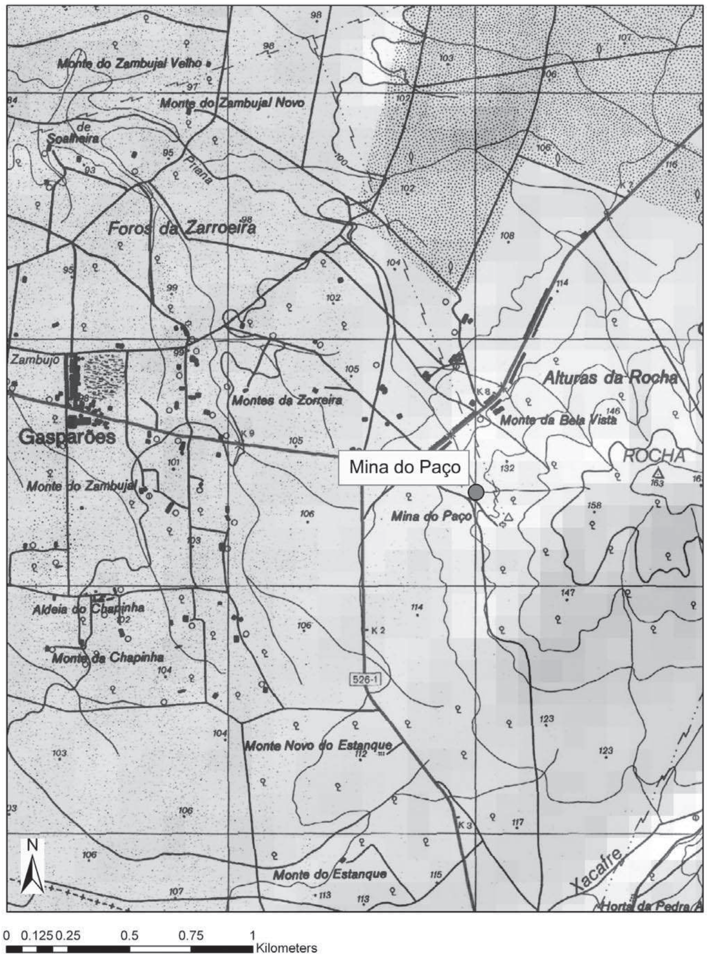

Fig. 6 – Location of Mina do Paço.

The open-air site of Mina do Paço lies within the boundaries of a 20th Century mining concession, recently transformed into a large olive plantation. The filling of old mine shafts, ground leveling activities, installation of a drip irrigation system and planting of the olive trees, combined with annual plowing to inhibit weed growth between the trees, means the site has suffered considerable disturbance in recent times. However, surface visibility is excellent and successive surveys have shown that artefact distributions are fairly circumscribed (Fig.7). Although individual artifacts may not be in their original depositional context, therefore, the site can be considered essentially *in situ*, at least on a regional

[3] European Datum 1950

scale. Systematic surface collections were conducted in 2006, 2007 and 2008, and sondages were excavated in 2006, yielding a total lithic assemblage numbering N = 707 artefacts, of which N=657 were collected and catalogued; no faunal remains were recovered. The four 1x1 m sondages excavated in 2006 revealed a dramatic decrease in the number of artifacts below the current land surface. Below a depth of 30 cm, i.e. below the plow zone, the sediment is archaeologically sterile and bedrock was encountered at depths of between -40 to -60 cm. We conclude, therefore, that this open-air site lies essentially in the modern plow zone where it has been disturbed but retains some spatial integrity. The existence of a mining shaft immediately in front of the jasper outcrop would indicate that any part of the site that may have existed there is now obliterated, however a clear concentration of artifacts was found south of the visible jasper outcrop, with the distribution tailing off at the base of the slope.

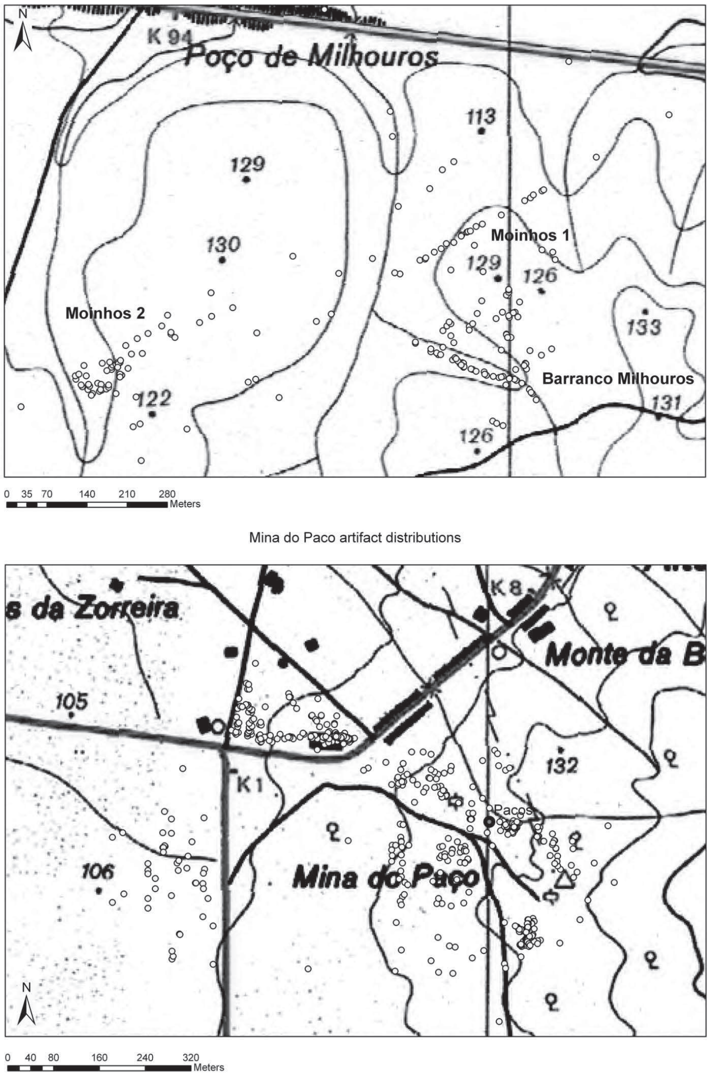

Fig. 7 – Artifact distributions at Moínhos and Mina do Paço.

The surviving jasper vein exposed by the modern mine is vertical in orientation and ranges from 30 to 100 cm thick. The rock itself is dark red (Munsell 10R 3/6) speckled with black, has a metallic sheen, and is brighter in color than the jasper outcropping at Moinhos. Pieces retrieved from this outcrop were massive and homogenous, in contrast to the more diaclastic jasper encountered at Moinhos. However, since mining activities have probably obliterated the original surface outcropping it is impossible to determine if hominins were directly exploiting this lens. Weathered chunks of jasper occur on the surrounding surface and the presence of weathered cortex on many of the artifacts suggests that, as at Moinhos (see below), weathered jasper rubble obtained at or near the outcrop was the main source of lithic material during the Pleistocene.

LITHIC ANALYSIS

Artifacts were analyzed during each field season by MB and LM and transferred to the Museu Municipal de Aljustrel for permanent storage, with the exception of N = 50 pieces that were spatially referenced but not collected during the final survey season. The assemblages from the two Moinhos sites consist almost exclusively of cores designed for the production of large flakes along with some possible core tools (crude core-bifaces) and only three retouched flake tools as well as debris from core production. Cores for flake production and debris also dominate the Mina do Paço assemblage. No prismatic blades, blade cores, ground stone or ceramic artifacts were present at the sites with the exception of a single blade and a metate fragment discovered at Mina do Paço on the periphery of the main lithic scatter.

Specimens were sorted into the following artifact categories: flaked pieces (cores and bifaces) and detached pieces (flakes, flake fragments angular fragments and retouched flake tools) (Schick and Toth 1993; Toth 1985). Attributes for each specimen were recorded for the following variables, following Bordes (1961) as modified by Debenath and Dibble (1994): artifact category; type; striking platform; flake scar orientation; cortex; raw material; surface condition; and presence of laterite encrustation (this was noted at Moinhos 1 and 2 only), the last two variables being a consequence of taphonomic processes. Metrical attributes recorded include: maximum length along the axis of flaking in the case of flakes, along the face bearing the largest flake removal in the case of cores, maximum width perpendicular to the length axis, and maximum thickness. The surface of each artifact was characterized as either «fresh», with no observable surface damage; «abraded», exhibiting slight but continuous rounding of the ridges between scars and a smoothing of the naturally granular feel of flaked surfaces on the local jasper; and «rolled», in which edges were both crushed and rounded, all ridges were visibly blunted and all surfaces heavily abraded. All data were processed using SPSS 16.0.[4]

The classification of stone tools has long been a topic of controversy and inter-individual variation is a persistent problem (Bisson, 2000; Dibble, 1995, *inter alia*) because the relatively simple stone artifacts of the Lower and Middle Paleolithic often exhibit continuous rather than discrete morphological variability (Roe, 1968; Dibble, 1984, 1985). Retouched tools are rare in Moinhos 1 and 2 (N = 3 out of 200 artifacts analyzed) and Mina do Paço (N = 9 out of 576 artifacts analyzed) and cores constitute the most significant artifact – and the most difficult to characterize. The approach adopted here was to employ the volumetric

[4] Data on the Moinhos 1 and 2 assemblages were recorded by Michael Bisson and Liliane Meignen. Data on Mina do Paço were recorded by Gaëtan Lebret in consultation with Bisson and Meignen.

approach of Boëda (1988; Boëda *et al.,* 1990) in the classification of the cores, while recognizing the dynamic nature of the core reduction process (Baumler, 1995) which may be particularly evident at primary raw material sources such as these.

MOINHOS

Initially, the material from Moinhos was treated as three separate samples. The Moinhos 1 sample collected from the bed of the Barranco de Milhouros was analyzed separately from the artifacts recovered from the hillside; the third sample includes all of the materials from Moinhos 2. These distinctions allowed us to control for the possibility that these different locations represent different depositional contexts with distinct chronologies. Although the precise relationships of the surface samples from Moinhos are impossible to directly assess, the statistical analyses summarized below establish the fundamental technological similarity of all three collections, without ruling out the possibility that Moinhos 1 includes material from two temporally separated episodes of hominin exploitation of the outcrop.

Of a total of 200 specimens collected at Moinhos, 93.5% are made of jasper; 3.5% are brown quartzite; and 2 % are crypto-crystalline quartz (2%). Also present at Moinhos 2 was a single Levallois core made of a fine-grained, olive yellow (Munsell value 5Y 6/8) quartzite and a small flint flake fragment. Quartz and quartzite could have been obtained as large pebbles or cobbles derived from Plio-Pleistocene deposits exposed in local stream beds and should also be considered a local material. The olive yellow quartzite and flint specimens are apparently non-local material (although it is possible that Plio-Pleistocene gravels contain small amounts of both rock) and may provide evidence of the curation and transport of at least some high quality lithic raw material across the landscape. The jasper at both Moinhos outcrops is variable in color, but is mostly dusky red with a Munsell value of 10R 3/4 (Munsell, 2000). During the Pleistocene, jasper was probably locally available as exposed and naturally fractured outcrops and as weathered and rolled chunks downhill from the outcrops. The presence of weathered cortex on many of the cores and detached pieces shows that hominins primarily used weathered chunks and cobbles rather than actually mining the veins. Because the Moinhos sites are on active erosion surfaces (Pimentel, 1989; Pimentel and Azevedo, 1991), it is unclear how visible the outcrops were in the past – they may have been mantled by soil, with only the weathered jasper rubble being available for exploitation. Although the Moinhos jasper is the best lithic material available within a radius of at least 5 km, it is far from ideal. Informal experiments at flaking weathered cobbles (MB) reveal that it has a somewhat coarser texture than the jasper from Mina do Paço, and that the pieces have a higher frequency of internal cracks and flaws, making more elaborate core-reduction strategies (such as Levallois) difficult to execute. Because geochemical analyses (see above) show no significant differences in the silica content, it is the crystalline structure and presence of flaws that make the Moinhos jasper more difficult to flake.

All three Moinhos samples are dominated by cores (Table 1); the sample from the Barranco has the highest percentage (72.2%), followed by Moinhos 1 hillside (41.9%) and Moinhos 2 (28.2%). Taken together, cores comprise 42.5% of the combined Moinhos collections, a strikingly high percentage. Detached pieces, i.e. flakes and flake fragments constitute most of the rest of the collections. Retouched flake tools (1.5%), Levallois flakes (1%) and normal blades are rare (0.5%), although one of the retouched tools is on a blade blank. The most typologically ambiguous artifact category is a group of 10 crude, partial or whole bifaces including pointed, amygdaloid and roughly circular forms (5%) mostly derived from the Barranco de Milhouros sample (FIG 6). In cross-section, these bifacial pieces tend to be plano-convex with the flatter of the two faces having larger flake removals, and the more convex face having smaller and much more poorly executed flake removals. Although this is not a pattern we would expect in a Middle Paleolithic assemblage, these artifacts border on being centripetal or discoid cores since none of them exhibit unambiguous attempts to regularize or straighten their edges, and we treat them here as «biface-cores» of uncertain chronological attribution. A similar biface-core was found at Mudança, a river terrace that lies in the region between Moinhos and Mina do Paço. Including the ambiguous «biface-core» specimens, in the three Moinhos samples partial[5] and full discoids are the most common core type (32.1%), followed by casual cores (informal cores with a few unidirectional removals, 31%) Levallois (17.9%) forms and biface-cores (11.9%); there are also a few bi-directional (two platform) cores, and cores on flakes (3.4% each). Among the Levallois cores, recurrent reduction strategies outnumber preferential ones 2 to 1.

Initial analysis of artifact frequencies at Moinhos suggests some differences between the three localities present (Table 1). Levallois and discoid cores are proportionally more common in the Moinhos 1 sample than in Moinhos 2, biface-cores are restricted to Moinhos 1, primarily the Barranco Milhouros collection, and flakes and flake fragments are more common in Moinhos 2. A cross-tabulation[6] of artifact type by site samples yielded a Pearson chi-square value of 47.866 (df=24), which is statistically significant (p=.003). The differences between the

[5] Strict application of Bordes' typology would classify some of the partial discoids as «chopping tools» (Type # 61) however in this context they are cores.

[6] These data were processed using SPSS 16.0. In all the significance testing reported here, the null hypothesis is rejected only if probability values are # .05.

Type		Site			Total
		Moínhos 1 Streambed	Moínhos 1 Hillside	Moínhos 2	
Casual/informal Core	Count (%)	8 (22.2)	12 (12.9)	6 (8.5)	26 (13.0)
Partial Discoid Core	Count (%)	5 (13.9)	5 (5.4)	2 (2.8)	12 (6.0)
Discoid Core	Count (%)	3 (8.3)	5 (5.4)	7 (9.9)	15 (7.5)
Preferential Levallois Core	Count (%)	1 (2.8)	4 (4.3)	0 (.0)	5 (2.5)
Recurrent Levallois Core	Count (%)	1 (2.8)	6 (6.5)	3 (4.2)	10 (5.0)
Bidirectional Core	Count (%)	1 (2.8)	0 (.0)	2 (2.8)	3 (1.5)
Core on Flake	Count (%)	2 (5.6)	1 (1.1)	0 (.0)	3 (1.5)
Biface-Core	Count (%)	6 (16.7)	4 (4.3)	0 (.0)	10 (5.0)
Cortical Flake	Count (%)	2 (5.6)	11 (11.8)	7 (9.9)	20 (10.0)
Partially Cortical Flake	Count (%)	1 (2.8)	10 (10.8)	11 (15.5)	22 (11.0)
Overstruck Partially Cortical Flake	Count (%)	0 (.0)	2 (2.2)	0 (.0)	2 (1.0)
Normal Flake	Count (%)	5 (13.9)	22 (23.7)	21 (29.6)	48 (24.0)
Naturally-backed Flake	Count (%)	0 (.0)	0 (.0)	1 (1.4)	1 (.5)
Overstruck Normal Flake	Count (%)	0 (.0)	1 (1.1)	0 (.0)	1 (.5)
Levallois Flake	Count (%)	0 (.0)	2 (2.2)	0 (.0)	2 (1.0)
Scraper on the Interior Face	Count (%)	0 (.0)	2 (2.2)	0 (.0)	2 (1.0)
Scraper with Proximal Thinning	Count (%)	1 (2.8)	0 (.0)	1 (1.4)	2 (1.0)
Blade	Count (%)	0 (.0)	1 (1.1)	0 (.0)	1 (.5)
Proximal Flake Fragment	Count (%)	0 (.0)	5 (5.4)	7 (9.9)	12 (6.0)
Other Flake Fragment	Count (%)	0 (.0)	0 (.0)	3 (4.2)	3 (1.5)
Total	Count (%)	36 (100.0)	93 (100.0)	71 (100.0)	200 (100.0)

Table 1 – Artifact inventory of the three Moínhos components.

samples may result from taphonomic factors and collection bias rather than by differences in prehistoric behavior, however. The most important taphonomic factor at Moinhos is flowing water. The Barranco de Milhouros collection is dominated by cores, as noted above, with only 27.8% detached pieces. The average maximum dimension of lithics in the Barranco sample is 65.28 mm, significantly (One Way ANOVA p. = .000) larger than the Moinhos 1 hillside sample (average = 51.77 mm) and the Moinhos 2 sample (average = 46.56 mm). It is likely that smaller artifacts such as flakes were removed from the barranco by running water, leaving the cores in place. The surface condition (see below) of artifacts from Barranco de Milhouros supports this view.

A degree of unintentional collector bias is also a likely contributor to differences between the samples. As noted above, crop cover at Moinhos 1 during 2006 and 2007 may have decreased the chances of seeing smaller artifacts. In addition, since the hillside near the outcrop was covered by historical mine tailings, our collection strategy was very conservative at Moinhos 1 and some flakes and many flake fragments may have been rejected because they were not considered sufficiently diagnostic. On the other hand, survey conditions at Moinhos 2 were ideal in 2007, possibly resulting in higher frequencies of smaller specimens, including flakes and fragments, being recovered.

Excluding flakes and fragments, there is no statistically significant difference between the Barranco de Milhouros and Moinhos 1 samples (chi-square = 14.517; df = 9; p = .105). For this reason these samples are treated together in the technological comparisons (below) and referred to collectively as «Moinhos 1» throughout. The typological composition of the combined Moinhos 1 sample is not significantly different from Moinhos 2 (chi-square = 15.955; df = 11; p = .143).

Metrical attributes follow a similar pattern: lithics from the Barranco de Milhouros sample are roughly 25% to 35% larger than the Moinhos 1 and Moinhos 2 samples, respectively. Flowing water has almost certainly removed smaller specimens from the Barranco sample; this is confirmed by the ratio of detached pieces (flakes and flake fragments) to cores (0.33/1) in this sample compared to Moinhos 1 (1.58/1) and Moinhos 2 (1.73/1). At Moinhos 1, grass cover and mine tailings inhibited the recognition of artifacts and probably selected against smaller or incomplete specimens being recovered. The ideal collecting circumstances at Moinhos 2 resulted in a relatively larger number of small pieces including flake fragments being recovered there.

Site	Minimum	Maximum	Mean	Std. Dev.	N
Moínhos 1	34.6	108.7	68.83	15.09	49
Moínhos 2	13.4	98.3	63.21	19.27	19
Mina do Paco	32.0	97.0	59.49	13.13	64

Table 2 – Maximum dimensions of cores.

Technological attributes also show a broad pattern of similarity between the combined Moinhos 1 assemblage and Moinhos 2. The two technological variables reported here are striking platform morphology and flake scar orientation. These were selected because they are a direct reflection of the strategies employed in the preparation of cores and in the removal of the large flakes that were the desired product of core reduction. In this respect cores are the most informative artifact category, as they exhibit more evidence of manufacture strategies than do individual flakes (Baumler, 1995; Boëda, 1988).

A comparison of the cores from the Moinhos sites shows considerable similarity with respect to both scar orientation (Table 3) and platform attributes (Table 4). With the exception of the casual/informal cores, in which unidirectional irregular scar patterns are the rule, the core assemblage of the Moinhos sites, globally speaking, is dominated by centripetal face preparation. By definition, discoid cores have centripetal scar patterns – the 15 Levallois cores and 2 of 3 cores on flakes are also centripetally prepared, however. Since face preparation of Levallois cores may be unidirectional, unidirectional convergent (point), opposed platform («bipolar») or bidirectional (Boëda, 1995; Meignen, 1995; Van Peer, 1992) this represents preferential selection on the part of the knappers. There is nothing inherent in the jasper available at Moinhos that would preclude these other flaking strategies, and thus centripetal preparation must be seen as the behavioral preference of the knappers.

Scar Orientation		Site		Total
		Moínhos 1	Moínhos 2	
Unidirectional Irregular	Count (%)	22 (36.7)	4 (21.1)	26 (32.9)
Centripetal	Count (%)	31 (51.7)	12 (63.2)	43 (54.4)
Bidirectional	Count (%)	7 (11.7)	3 (15.8)	10 (12.7)
Total	Count (%)	60 (100.0)	19 (100.0)	79 (100.0)

Table 3 – Orientation of flake scars on the largest flake removal face of cores at Moínhos 1 and 2.

Striking platform types on cores are similarly distributed at Moinhos 1 and 2 (Chi Square = .414, df = 3, p = .937). Single facet (plain) platforms are the most common platform type, followed by cortical platforms and almost identical percentages of dihedral and multiple facet forms. Again, there is a significant association between the complexity of the core itself and the degree of platform preparation (Chi Square = 37.186, df = 12, p = .000), with cortical platforms dominating casual/informal cores, plain and dihedral platforms more common on discoid cores, and multiple facet and dihedral platforms on Levallois cores. The faceted platform surfaces from the last major flake removal on the Levallois and discoid cores are primarily flat, thus *chapeau de gendarme* platform morphology, although present, is not common.

Striking Platform		Site		Total
		Moínhos 1	Moínhos 2	
Plain	Count (%)	27 (60.0)	10 (62.5)	37 (60.7)
Dihedral	Count (%)	9 (20.0)	3 (18.8)	12 (19.7)
Multi-facet	Count (%)	9 (20.0)	3 (18.8)	12 (19.7)
Total	Count (%)	45 (100.0)	16 (100.0)	61 (100.0)

Table 4 – Striking platforms on cores at Moínhos 1 and 2.

The frequencies of different types of detached pieces recovered from the Moinhos sites are summarized in Table 5. Cortical and partially cortical flakes are well represented (39.7%), as would be expected at a lithic source where the initial stages of reduction are taking place. Unretouched normal flakes are slightly more common (42.2%). Only two Levallois flakes and three scrapers were recovered, one of which was made on one of only two blades (non-prismatic) in the collection. There were no recognizable *éclats débordant* (Boëda, 1988, 1995), products of the creation of the lateral and distal convexities on the face of a Levallois core in the collection, but in a centripetal core preparation strategy these may be impossible to distinguish from normal, cortical or partially cortical flakes.

Type	Frequency	Percent
Cortical Flake	20	17.2
Partially Cortical Flake	22	19.0
Overstruck Partially Cortical Flake	2	1.7
Normal Flake	49	42.2
Naturally-backed Flake	1	.9
Overstruck Normal Flake	1	.9
Levallois Flake	2	1.7
Scraper on the Interior Face	2	1.7
Scraper with Proximal Thinning	1	.9
Blade	1	.9
Proximal Flake Fragment	12	10.3
Other Flake Fragment	3	2.6
Total	116	100.0%

Table 5 – Combined totals of detached pieces from Moínhos 1 and 2.

Among the flake attributes (Table 6), cortical platforms are most common, followed in rank order by plain, dihedral, multiple facet and *chapeau de gendarme*. Curiously, the two recognizable Levallois flakes do not have *chapeau de gendarme* platforms, which are present instead on normal flakes. Excluding the cortical flakes, exterior flake scar patterns are primarily unidirectional irregular (69.7%) and centripetal (27.3%), with a few bidirectional (3%). These frequencies are what would be expected from the early stages of centripetal preparation and reduction of cores.

The three formal tools in the assemblage all feature irregular unifacial retouch – all three are classified as scrapers, but they could be considered denticulated scrapers. Two of the scrapers have retouch on the interior face: a slightly concave lateral scraper on a rolled normal blade support (Figure 7g), and a short segment of continuous retouch forming a roughly straight edge near the tip of an elongated flake (Figure 7f). The third tool is a well executed concave-convex scraper edge on a small flake with a thinned back (Figure 7h). This group of formal tools

Platform Type	Frequency	Percent
Cortical	40	42.1
Plain	36	37.9
Dihedral	9	9.5
Multi-facet	7	7.4
Chapeau de Gendarme	3	3.2
Total	95	100.0%
Platform Missing	3	
Indeterminate (damaged)	18	
Total	21	
Total	116	

Table 6 – Combined totals of striking platform types from Moínhos.

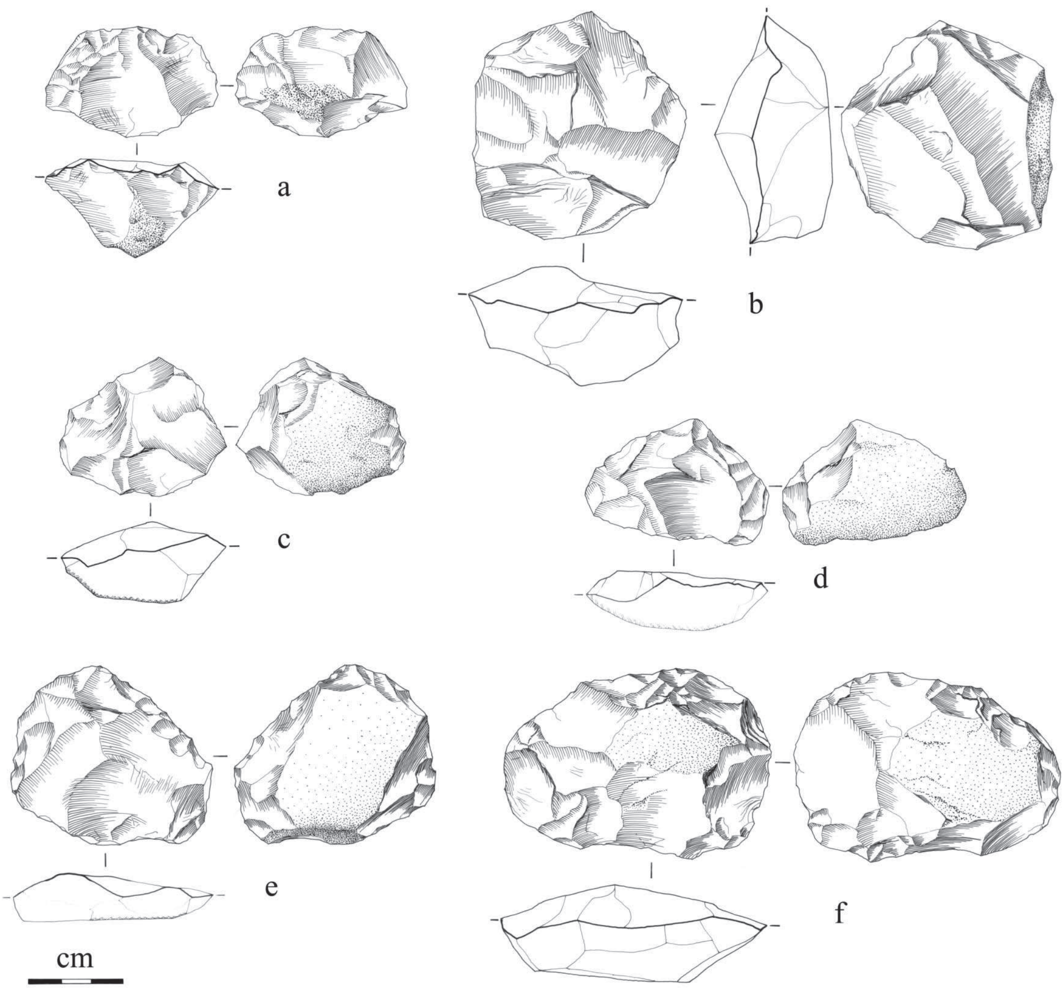

Fig. 8 – Moínhos 1 cores. a: preferential Levallois flake core; b through e: recurrent Levallois flake cores (with E, abraded surface); f: biface core. All jasper.

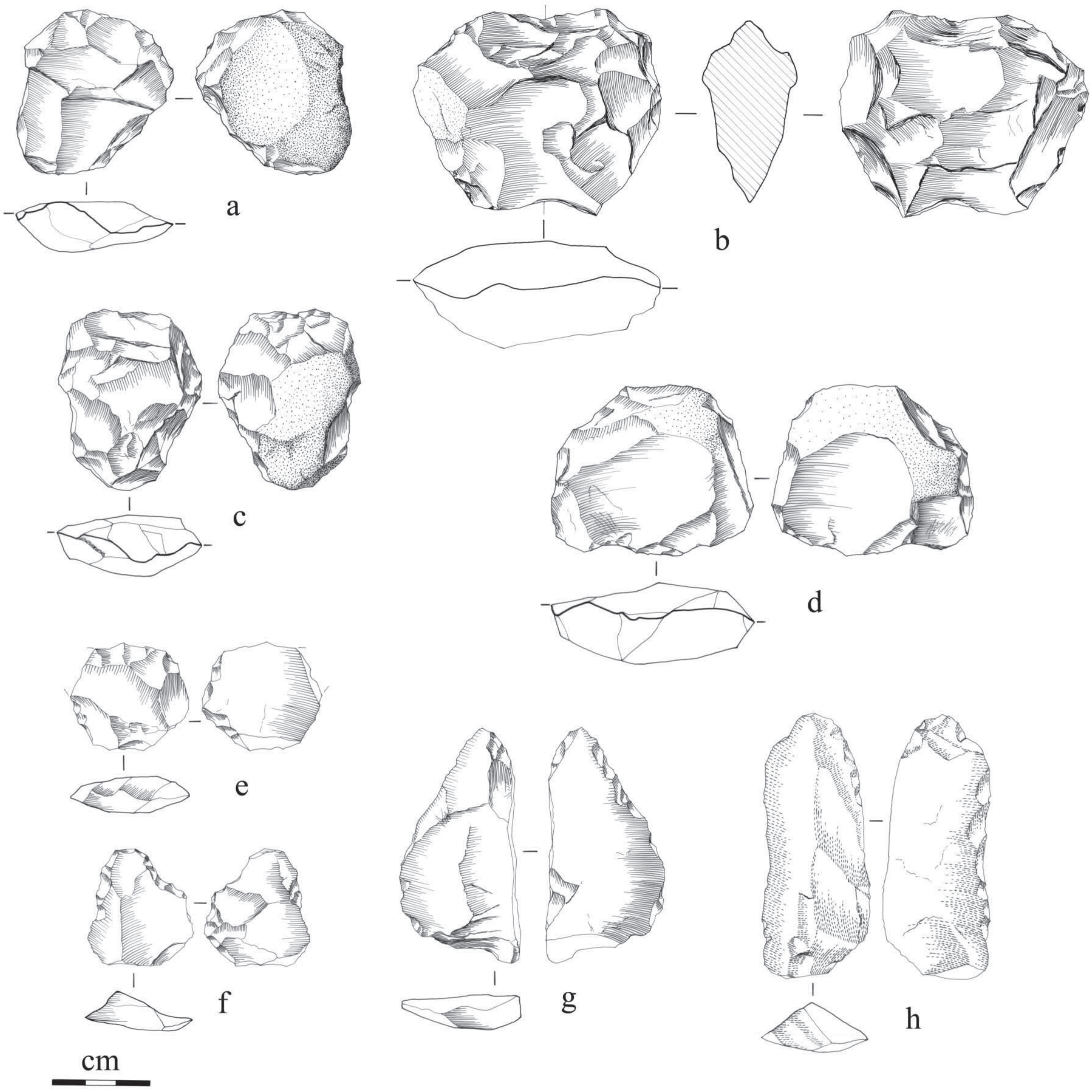

Fig. 9 – Moínhos cores and retouched tools. a: atypical recurrent Levallois flake core; b & c are discoid cores or bifacial pieces; d: partial discoid core; e: core on a flake; f: convex-concave scraper on a flake fragment with bulbar thinning; g and h: scrapers on the interior surface, with g made on a blade blank. All jasper. A through c and e through h: Moínhos 1; d: Moínhos 2.

is far too small to arrive at generalizations about the kinds of formal tools ultimately created from the blanks made at the Moinhos sites.

Although the artifacts at Moinhos appear concentrated at the surface or in the plow zone rather than being *in situ* in undisturbed deposits, the presence of small laterite nodules (concretions) adhering to the surfaces of 20.5% of all specimens demonstrates that the artifacts at both Moinhos sites were buried for a significant amount of time at some point after their initial discard. Laterite forms in a number of ways, and one of these is as a precipitate of dissolved iron and/or aluminum compounds that migrate up from decomposing bedrock during warm, wet climate periods (Nahon, 1986). The small nodules observed in our collection would only have formed when the lithics were encased in soil. We are unable to determine whether laterite formation occurred post-Pleistocene or earlier. There is no difference in the representation of laterite encrustation in the three samples from Moinhos suggesting that all three localities were subject to similar depositional histories, at least initially.

The surface condition of the artifacts supports our interpretation of the taphonomic processes acting on the Moinhos samples (above). Only 1% of the lithics collected at Moinhos 1 or 2 were judged to be fresh, whereas 53% were rolled and the rest abraded. As expected, Moinhos 1 streambed (also known as Barranco de Milhouros) had the highest proportion of rolled artifacts (86.1%), followed by Moinhos 1 hillside (52.7%) and Moinhos 2 (36.6%).

We conclude, therefore, that Moinhos 1 (including Barranco de Milhouros) and Moinhos 2 are lithic extraction and reduction sites that were active during the Middle Palaeolithic, although Moinhos 1 likely represents a palimpsest and could include other occupations of unknown age.

MINA DO PAÇO LITHICS

Including both the systematic surface collection and the test pits, a total of 707 artifacts were found at Mina do Paço, of which 449 were large enough (≥1.5 cm maximum dimension) for analysis. The remaining 258 specimens were small chips and chunks obtained in the excavations that are omitted from this analysis. The collection included 63 (14.1%) cores, 375 detached pieces out of which 190 (42.5%) were non-cortical, 137 (30.6%) were cortical, 39 (8.7%) were Levallois blanks, and 9 (2%) were retouched flake tools. Two hammer-stones were also found (Table 7). The artifacts were almost all made of jasper (99.3%); two of the three non-jasper specimens are hammer-stones – the only piece of flaked raw material is a single quartzite flake. Crypto-crystalline quartz that is homogeneous enough to be worked does not appear to naturally occur in the vicinity of the site, and any quartz flakes would have been easy to recognize. The dominance of jasper, therefore, reflects hominin use of the best quality locally available lithic raw material for tool manufacture. There is very little evidence for the presence of non-local raw materials, although some «exotic» raw material (above) is indicated.

Among the cores at Mina do Paço (N = 63), the most common types are preferential (23.8%) and recurrent (22.2%) Levallois. In addition, there are 7 cores (11.1%) that are executed with a preferential face, but have a cortical striking platform and thus are not true Levallois (Boëda, 1988) although their fundamental design follows Levallois volumetric principles, bringing the total of Levallois or Levallois-like cores to 57.1%. The next most common cores are casual/informal

Type		Site	
		Moínhos	Mina do Paço
Casual/informal Core	Count (%)	26 (13.0)	12 (2.7)
Partial Discoid Core	Count (%)	12 (6.0)	0 (.0)
Discoid Core	Count (%)	15 (7.5)	5 (1.1)
Preferential Levallois Core	Count (%)	5 (2.5)	15 (3.3)
Core with Preferential Face	Count (%)	0 (.0)	7 (1.6)
Recurrent Levallois Core	Count (%)	10 (5.0)	14 (3.1)
Bidirectional Core	Count (%)	3 (1.5)	0 (.0)
Bipolar Core	Count (%)	0 (.0)	1 (.2)
Pyramidal Core	Count (%)	0 (.0)	2 (.4)
Core on Flake	Count (%)	3 (1.5)	7 (1.6)
Biface-Core	Count (%)	10 (5.0)	0 (.0)
Cortical Flake	Count (%)	20 (10.0)	25 (5.6)
Partially Cortical Flake	Count (%)	22 (11.0)	57 (12.7)
Overstruck Partially Cortical Flake	Count (%)	2 (1.0)	0 (.0)
Normal Flake	Count (%)	48 (24.0)	71 (15.8)
Naturally-backed Flake	Count (%)	1 (.5)	0 (.0)
Overstruck Normal Flake	Count (%)	1 (.5)	0 (.0)
Levallois Flake	Count (%)	2 (1.0)	29 (6.5)
Proximal Levallois Flake Fragment	Count (%)	0 (.0)	7 (1.6)
Distal Levallois Flake Fragment	Count (%)	0 (.0)	1 (.2)
Levallois Flake Siret Fragment	Count (%)	0 (.0)	2 (.4)
Retouched Flake (informal)	Count (%)	0 (.0)	1 (.2)
Scraper on the Interior Face	Count (%)	2 (1.0)	0 (.0)
Scraper with Proximal Thinning	Count (%)	2 (1.0)	0 (.0)
Typical Endscraper	Count (%)	0 (.0)	1 (.2)
Burin	Count (%)	0 (.0)	1 (.2)
Convex/concave Lateral Scraper	Count (%)	0 (.0)	1 (.2)
Notch Tool	Count (%)	0 (.0)	2 (.4)
Double Notch Tool	Count (%)	0 (.0)	2 (.4)
Denticulate	Count (%)	0 (.0)	1 (.2)
Blade	Count (%)	1 (.5)	6 (1.3)
Proximal Flake Fragment	Count (%)	12 (6.0)	71 (15.8)
Proximal Flake Fragment, Cortical	Count (%)	0 (.0)	18 (4.0)
Proximal Flake Fragment, Partially Cortical	Count (%)	0 (.0)	37 (8.2)
Siret, Cortical	Count (%)	0 (.0)	3 (.7)
Siret, Partially Cortical	Count (%)	0 (.0)	1 (.2)
Siret	Count (%)	0 (.0)	15 (3.3)
Other Flake Fragment	Count (%)	3 (1.5)	23 (5.1)
Other Flake Fragment, Cortical	Count (%)	0 (.0)	4 (.9)
Other Flake Fragment, Partially Cortical	Count (%)	0 (.0)	5 (1.1)
Hammerstone	Count (%)	0 (.0)	2 (.4)
Total	Count (%)	200 (100.0)	449 (100.0)

Table 7 – Artifact inventories from Moínhos (combined sample) and Mina do PaHo.

(19.0%) and cores on flakes (11.1%). Discoid cores, which were common at Moinhos, are significantly less so at Mina do Paço (7.9%). Pyramidal (3.2%) and bipolar (1.6%) cores are present but very rare.

Unretouched detached pieces include 188 whole flakes and 187 flake fragments. Non-cortical normal flakes and flake fragments are the most common (48%), followed by partially cortical flakes and fragments (26.7%). Cortical flakes and fragments are also common (12.7%) as would be expected on a site where primary knapping is taking place. Levallois flakes and fragments are present in reasonable numbers (10.4%). Blades are present (1.6%), but although they meet Bordes (1961) metrical criterion, none are prismatic, and are better characterized as blade-like flakes The number of flakes with a *siret* (longitudinal break along the axis of flaking) fracture among the flake fragments is notable (11.2% of all fragments). While conducting flaking experiments in both Levallois and discoid technique using jasper from the Mina do Paço outcrop, MB found that the material, although easier to flake than the Moinhos jasper, seemed to be more brittle and therefore more prone to *siret* fractures.

The 9 formal tools from Mina do Paço are simple and minimally retouched. Notched forms predominate, with two single notches, two double notches and one denticulate. The two single notches are not particularly deep and one is on the interior face near the platform. These may have been produced by utilization rather than deliberate retouch. Both double notch tools were large (45mm and 48mm maximum dimensions) and may be cores on flakes. The denticulate has 4 adjacent notches and is the most diagnostic of these tools. There are also two examples of Bordes' (1961) tools of «Upper Paleolithic» type, all made on typical Middle Paleolithic flake blanks. These include an endscraper on a Levallois flake support and a burin with three spall removals on the interior face. The final tool is a convex/concave lateral scraper on a Levallois flake. It may be noteworthy that there is only one lateral scraper in this collection. The tool sample is too small to enable us to confidently determine its relationship to other Portuguese, Spanish or other European assemblage types, and nearly half of the pieces may not actually bear deliberate retouch. Trampling by humans and animals can produce notch-like forms (Tringham *et al.*, 1974), and the artifacts have been exposed on the surface for a significant amount of time. Recent edge damage caused by trampling or plowing can usually be identified on flint due to differential patina, however the jasper encountered in the Sado Basin is resistant to chemical weathering, making both ancient and recent post depositional damage more difficult to identify. Notches and denticulates are often found in greater numbers in open-air circumstances and near lithic sources, however, (Mellars, 1996) and are very common in the MP of Portugal and the rest of Iberia (see below). These tools may represent the occasional renewal of tools made of organic materials at a site

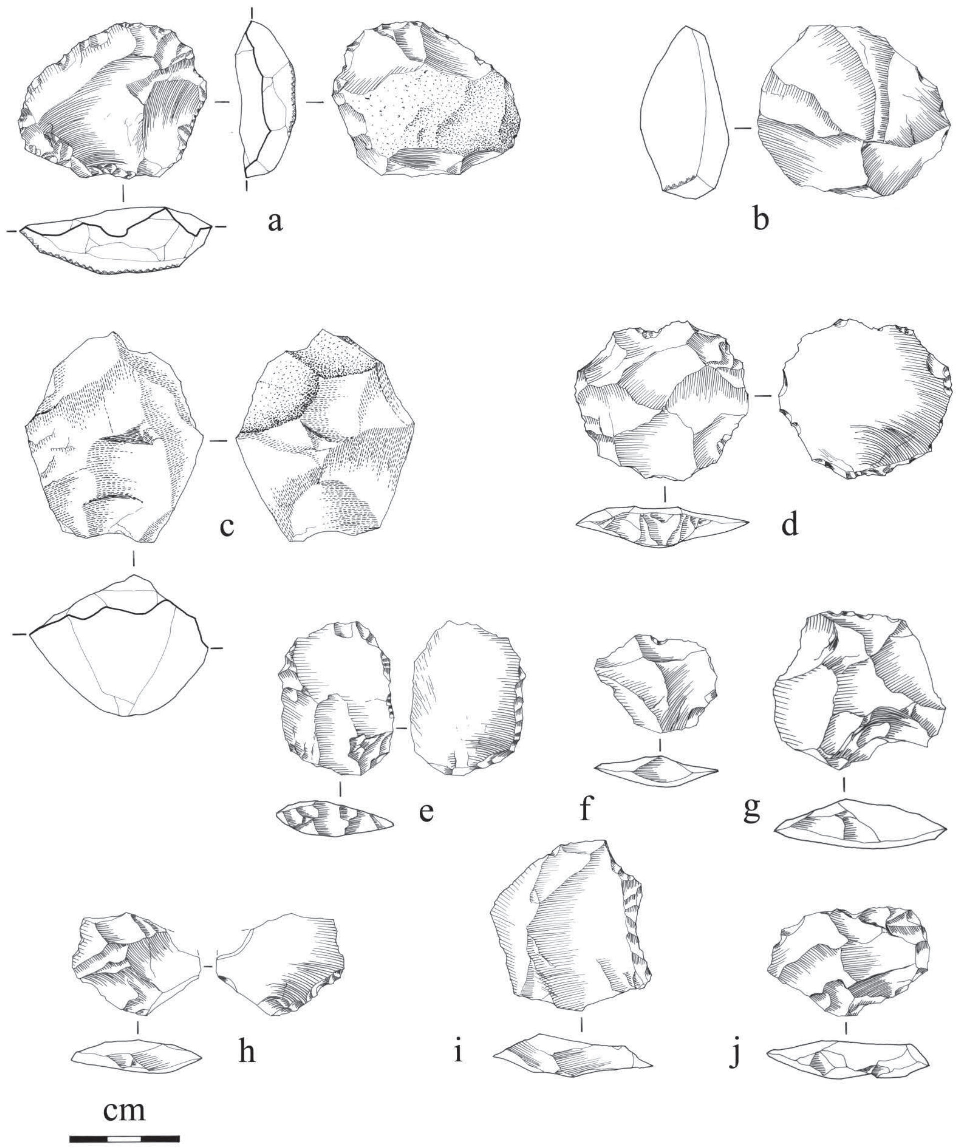

Fig. 10 – Mina do Paço lithics. a: preferential Levallois flake core; b and c: recurrent Levallois flake cores; d through f: Levallois flakes with e being atypical in that it removed part of the edge of the core and could be a éclat debordant; g: large notch; h: scraper on the interior surface; i: convex-concave scraper; j: small notch. All retouched tools on Levallois blanks. All jasper.

where the primary activity was the collection of lithic raw material and knapping. There are fewer Levallois flakes in this assemblage than would be expected from the number of cores. If we take into account the ratio of Levallois blanks (8.7%) as compared to experimental results (Geneste, 1985) it is clear that part of the Levallois production was carried away from the site by the Mousterian knappers, a characteristic consistent with a reduction site. We conclude, on the basis of the technological and typological analysis, that Mina do Paço is an open-air lithic extraction and reduction site active during the Middle Palaeolithic, with some evidence for other activities (maintenance) occurring indicating that a campsite may have been present.

COMPARISON OF MOINHOS AND MINA DO PAÇO

Because we lack a means of dating the three sites, it is important to determine if they reflect a common technological tradition. From a techno-typological perspective, there are statistically significant (Chi-Square 203.81; df 40; p. 0.000) differences between the two localities (Table 7), with proportionally more casual and discoid cores and cortical flakes at Moinhos, and more cores with a preferential face for exploitation (Levallois cores), Levallois flakes and flake fragments at Mina do Paço; the biface-cores are only found at Moinhos 1. There are also fundamental similarities in the technologies used, however. For example, centripetal strategies for the preparation of core faces dominate at both localities (Moinhos 54.4%, Mina do Paço 56.6%). Likewise, scar patterns on whole flakes are similarly distributed between the localities. Both sites also include significant numbers of informal and minimally reduced cores, which would be expected at a raw material source as cobbles were tested and discarded. Nevertheless, the differences, which occur in the more extensively worked cores, appear to outweigh the similarities.

At Moinhos, core reduction strategies are predominantly discoid; at Mina do Paço, Levallois. Discoid cores produce thicker flakes (Dibble, 1989) which are not symmetrical across the axis of flaking; Levallois technique generally produces thinner and more symmetrical flakes with an effective cutting edge around the entire periphery except for the platform. Levallois flakes may have thinner platform ends if platform preparation was of the *chapeau de gendarme* type, and this makes them more suitable for hafting (Debénath and Dibble, 1994). Likewise, there is statistically significant variation between localities in striking platforms on flakes, with proportionally more cortical platforms at Moinhos, and faceted platforms at Mina do Paço (Table 8), a pattern consistent with overall differences in technologies being employed. Since both core types are found at each locality, both strategies were part of the technological repertoire drawn on by the knappers, and the choice of one over the other warrants discussion.

Site		Striking Platform					Total
		Cortical	Plain	Dihedral	Multi-facet	Point	
Moínhos	Count (%)	56 (32.6)	73 (42.4)	21 (12.2)	22 (12.8)	0 (.0)	172 (100.0)
Mina do Paço	Count (%)	61 (18.5)	163 (49.5)	20 (6.1)	73 (22.2)	12 (3.6)	329 (100.0)

Table 8 – Striking platforms on whole flakes from Moínhos (combined sample) and Mina do Paço.

The overall picture is of centripetally oriented discoid and Levallois core reduction strategies being employed at all three of the sites examined here. Some differences between the assemblages are attributable to our recovery techniques. For example, the greater number of flake fragments at Mina do Paço is partly a consequence of the higher recovery rate of small pieces during excavation of the test pits, which contributed most of the smaller pieces, and to the presence of recent mine tailings at Moinhos 1, which caused us to deliberately omit any ambiguous flake fragments from our sample (see above). However, the basic techno-typological differences remain. The differential emphasis on discoid and Levallois techniques could be a consequence of temporal differences between the localities, and/or reflect deliberate choices of strategies to produce a particular form of end-product. One possible explanation is the nature of the Jasper at both localities. The greater frequency of cortical flakes at Moinhos may be a result of the relatively poor quality of the local jasper, which would have necessitated testing a greater number of weathered blocks to find one which could be used to produce desired blanks. This may also account for the relatively greater variability in core types and higher frequency of cortical platforms observed at Moinhos, where informal cores and discoids predominate. A similar linkage between core technologies and lithic raw material quality has been noted elsewhere in Portugal (Leotard *et al.*, 1996; Raposo and Cardoso, 1998b) and Spain (Ferrerons, 2008). Nevertheless, complex reduction strategies like Levallois can be executed on poor materials such as quartz (Jaubert and Mourre, 1996; Meignen *et al.*, 2009), so raw material constraints alone do not necessarily explain the differences observed here.

DISCUSSION

In the absence of *in situ* undisturbed deposits, absolute dating of these sites is not possible. The same basic technological strategy of discoid and Levallois debitage is employed at all three sites and there is no evidence of the production of either normal or Levallois blades at any of them. In Portugal, generally speaking, these techniques dominate MP assemblages (Raposo, 1995; Zilhão, 2006). Discoid cores can and do occur throughout the Upper Paleolithic in Portugal, including in what may be Late Aurignacian assemblages, where they are associated with carinated and prismatic blade cores (Aubry *et al.*, 2004) which are absent in the Sado River Basin (Burke *et al.*, 2009, nd). The attribution of Moinhos and Mina do Paço to the MP is therefore likely. Typological comparisons with dated MP assemblages in Iberia are possible, but caution should be exercised because of the recurring problem of inter-classifier variability (summarized in Bisson, 2000) and by the observation that discoid and Levallois cores can grade into each other

(Raposo, 2000), particularly when poorer quality raw material like quartz, quartzite and jasper are exploited.

Nevertheless, we offer the following comparison with 9 MP sites described elsewhere in Portugal (Table 9). Because of the different classificatory systems employed by various authors, in this table broad categories of cores (Levallois, discoid) are listed (as present or absent), but raw materials and tool categories are listed according to their relative frequency. All nine open-air sites used in the comparison contain discoid cores, five sites include both preferential and recurrent Levallois cores, and the remaining four sites have only recurrent Levallois cores. The Kombewa core-on-flake technique is recorded at one site, Barrosos (Aubry *et al.*, 2004). In all cases, local lithic raw materials were employed almost

Site	Raw Material	Levallois Cores	Discoid Cores	Kombewa Cores	Primary Flaking Strategy	Primary Tool Types
Open air						
Vale Santo 3 [1]	Fl	P	P	A	C	None
Curva do Belixe [1]	Fl	P	P	A	C	None
Santo Antão do Tojal [2]	Q, Qz, F	P	P	A	C	S, N
Estrada do Prado [3]	F, Qz, Q	P	P	A	C	S, N, D
Conceição [4]	Q, Qz	P	P	A	C	D
Barrosos [5]	Qz, F, Q	P	P	P	C	S, D
Vilas Ruivas [2]	Qz, F	P	P	A	C	D, S
Foz do Enaxarrique [6]	Qz	P	P	A	C	D, S
Tajo Estuary [2]	Qz	P	P	A	C	None
Caves & Rock-shelters						
Buraca Escura [5]	F	P	P	A	C	L
Columbeira [7]	Q, Qz, F	P	P	A	C	D, N, S
Figueira Brava [8]	Q, Qz, F J	P	P	A	C	S, D, N
Caldeirão [9]	Q, Qz	P	P	A	C	S, N, D
Oliveira layers 8&9 [10]	F, Qz, Q	P	P	A	C	N, D, S
Oliveira layers 10-14 [10]	F, Qz, Q	P	P	P	C	N, D, S
Salimas Level IV [2]	F, Q	P	A	A	C	P, S
Correio Mór [11]	F	P	P	A	C	D
Escoural [12]	Q	P	P	A	I	D, N, S

Table 9 – Technological and typological attributes of selected Portuguese MP sites. In sites having more than one attribute for a variable, the attributes are listed in descending order of abundance. Key: Raw Materials (Q = quartz, Qz = quartzite, F = flint, J = jasper); Levallois cores (P = present, A = absent); Discoid cores (P = present, A = absent); Kombewa cores (P = present, A = absent); Primary flaking strategy (C = centripetal, I = irregular); Primary tool types (S = scrapers, D = denticulates, N = notch tools, P = points, L = Levallois flakes). Sources: 1. Ferring *et al* 2000, Bicho 2001; 2. Raposo 1995; 3. Mateus 1984, Raposo 1995; 4. Raposo and Cardoso 1997, Raposo 2000; 5. Almeida et al 2003, Aubry et al 2004; 6. Raposo *et al* 1985, Raposo 1995; 7. Raposo and Cardoso 1998a; 8. Cardoso and Raposo 1993; 9. Zilhão 1992, 1997; 10. Andelucci and Zilhão 2009, Zilhão *et al* 1991; 11. Zbyszewski *et al* 1987; 12. Leotard et al 1996, Otte 1996.

exclusively and evidence for transport of lithic raw materials in the form of tools, blanks or cores is very rare. Four of the open-air sites are lithic acquisition locations (Conceição, the Tajo Estuary, Curva do Belixe and Vale Santo 3) in which retouched tools are either rare or absent; the other sites are either designated as residential sites or camps. Of the six sites where formal tools are described, scrapers dominate half, and denticulates and notches outnumber scrapers in the other half. In all cases, denticulates and notches are an important part of the retouched tool assemblages. Two sites, Barrosos (Aubry *et al.*, 2004) and Foz do Enxarrique (Raposo *et al.*, 1985) include tools where the retouch was on the interior surface of the blank (also observed in the SRDS sites).

Preferential and recurrent Levallois technique is present in 9 out of 10 of the cave and rock-shelter assemblages, and discoid technique in 8 of 10. The relative importance of Levallois and discoid techniques could not be determined at one site (Buraca Escura) because the collection was too small (Almeida *et al.*, 2003). The Kombewa technique occurs in two sites. In some sites, the relative representation of Levallois and discoid techniques was probably influenced by the nature of the available lithic raw material. This was the case in Columbeira (Raposo and Cardoso, 1998) and Figueira Brava (Cardoso and Raposo, 1993), where the most common lithic raw materials were quartz and quartzite promoting the use of discoid technique, and Gruta do Escoural, where blocks of quartz were primarily worked into globular (polyhedral) cores (Leotard *et al.*, 1996; Otte, 1996). Levallois technique was more common in the four assemblages (Gruta da Oliveira layers 8 & 9 and layers 10-14; Salemas Level IV; Correio Mor) where flint was available in appreciable quantities. As with the open-air sites, centripetal flaking was the dominant strategy in the execution of cores in all of these assemblages, with the exception of the globular cores from Escoural. At Gruta da Oliveira, layers 8 & 9 also included a number of unidirectionally worked cores (Angelucci and Zilhão, 2009).

Most of the cave or rock-shelter sites in this comparison are residences or campsites. These sites could be expected to have a wider variety of functional categories of tools reflecting a greater range of activities than open-air sites such as Moinhos 1, Moinhos 2 and Mina do Paço, therefore (Binford, 1973). Scrapers are most common in Figueira Brava (Cardoso and Raposo, 1993), described as a Typical Mousterian assemblage, and at Caldeirão (Zilhão, 1992, 1997), but in other cases denticulates and notches dominate. This includes Columbeira (Raposo and Cardoso, 1998), Oliveira layers 8 & 9 and layers 10-14 (Zilhão *et al.*, 1991; Zilhão, 2009), Correio-Mór (Zbyszewski *et al.*, 1987) and Escoural (Leotard *et al.*, 1996)). Retouch on the interior surface was present in both assemblages from Oliveira and at Columbeira.

In summary, the three assemblages under study appear to resemble late MP assemblages described for southern Iberia (e.g., Zilhão, 2006) where centripetal strategies producing discoid and Levallois cores are common. The very limited number of retouched tools in the Sado Basin sites may also be consistent with a late MP date. Denticulates and notches are common in virtually all of the well documented Portuguese MP assemblages, most of which date to the later half of the overall European Paleolithic sequence. These include Caldeirão (ca. 35,000 BP, Zilhão, 2006), Columbeira (ca. 34-31,000 cal BP, Delibrias *et al.*, 1986[7]), Conceição (between 74,500 +11,600 -10,400 and 27,200 ±2,500, Raposo and Cardoso, 1998b), Escoural (48,900 +5,800-5,500 BP, Raposo, 1995), Figueira Brava (between ca, 45,000 and 30,000 BP, Raposo, 1995), Foz de Enxarrique (33,600 ± 500 cal BP, Brugal and Raposo, 1999) and Gruta da Oliveira Layers 8 (ca. 35-38,000 BP, Zilhão *et al.*, 2010) & 9 (ca. 44-43,000 BP, Zilhão, 2006) (Table 9). However, the earlier MP of Portugal is less well represented in published collections (Santo Antão do Tojal, 81,900 +4,000 -3,800 BP, Raposo, 1995), and therefore the core reduction strategies represented at Moinhos and Mina do Paço cannot in themselves link these sites solely to the late MP. The same can be said for the predominance of notches and denticulates in the small sample of formal tools. As noted above, these types often occur at open air and lithic reduction sites, and some may be the products of post-discard damage rather than deliberate hominin action. Therefore, a firm chronology of the Sado River Basin MP sites must await the discovery of datable *in situ* material.

The one significant difference between any of the SRDS assemblages and the Portuguese late MP is the presence of the biface-cores at Moinhos 1. These artifacts do not resemble bifacial preforms such as are known to have been produced during the Portuguese Chalcolithic (Forenbaher, 1998), and are more severely weathered than most of the characteristically MP artifacts at the site, which indicates that they are probably not post-Pleistocene in origin. They are unlikely to be poorly executed Acheulian handaxes as none of them resemble the pointed forms and cleavers that characterize the Portuguese Lower Paleolithic (Mozzi *et al.*, 2000; Raposo *et al.*, 1993; Viana, 1945), and the undoubtedly Acheulian handaxes found by the SRDS at Vermelha and Cabeça de Marco (Burke *et al.*, 2009, nd). It is possible that they represent an earlier exploitation of the outcrop (though probably also Middle Palaeolithic in age) but it is also possible that they represent failed centripetal cores as a consequence of the flawed jasper occurring in the Moinhos outcrop. Until comparable material is found in datable contexts elsewhere in Portugal the Moinhos biface-cores remain a mystery.

[7] These dates have been criticized by Zilhão (2006), but are defended by Raposo and Cardoso (Cardoso *et al* 2002).

CONCLUSION

Technologically, the three open-air lithic acquisition sites examined in this paper are consistent with several other MP sites in Portugal (above) in that their predominant blank production strategies are centripetal Levallois and discoid. As would be expected at lithic acquisition sites, informal cores and blocks tested once or twice are relatively common. Levallois was the preferred technique at Mina do Paço, discoid at the Moinhos sites. These reflect a deliberate choices on the part of the Middle Paleolithic knappers, as the hominins at both localities were aware of and did employ both techniques, a situation observed at other European Middle Paleolithic sites (Meignen *et al.*, 2009). Whether these choices were influenced by the quality and flaking characteristics of the jasper at each outcrop or by other factors, including technological tradition, the desire to produce end-products with particular morphological characteristics and/or chronology, is unknown. Other typological differences between the sites (above) may be related to the range of activities taking place at each of them. Retouched tools are not common at any of these sites, comprising less than 2% of each collection, however. This suggests that retouched tools and/or suitable blanks and cores were exported to residential and/or other special activity sites for use. At Mina do Paço, although the percentage of retouched tools is similar to the proportion encountered in the assemblages from Moinhos, the number of Levallois flakes is significantly higher. Since Levallois flakes may be used as expedient cutting tools (Debenath and Dibble, 1994) for processing meat from animals this may indicate that Mina do Paço served not only as a lithic acquisition station, but also as a temporary camp from which hunters could watch for game approaching the nearby lake at Gasparões.

The Sado River Basin lithic procurement sites articulate with the preliminary results of the SRDS survey (Burke *et al.*, 2009, nd) pointing to the occupation of the Sado River Basin by a relatively small, thinly dispersed Neanderthal population during the MP. This adds to a growing etbody of data from Portugal (Bicho, 2004; Raposo, 1995; Zilhão, 2001) and southern Iberia in general (Finlayson and Pacheco, 2000), that supports a model of small, thinly dispersed Neanderthal bands moving across the landscape seasonally hunting both large mammals and smaller game as well as collecting plants and aquatic and marine resources. As part of this mobile adaptation, lithic sources were exploited for both tool blanks and cores, which were transported across the landscape and used as needed. The size of Neanderthal territories has generally been considered to be small (Mellars, 1995), but there is some evidence for the transport of lithic materials over distances of at least 30 km in southern Portugal (Bicho, 2004). Further research in Baixo-Alentejo and the Algarve will help us refine our understanding of Neanderthal land-use patterns in their final refuge.

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