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Assessing the Integrity of Older Archeological Collections: an Example from La Ferrassie

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Abstract
Initially excavated in the early twentieth century, La Ferrassie is one of the most important sites for the Middle Paleolithic of Western Europe. Aside from the numerous Neanderthal remains found there, the stone artifacts recovered from the site are featured prominently in discussion and debates of Mousterian variability. Recent renewed excavation of the site, however, suggests a considerable preference in the kinds of stone artifacts saved during the initial excavation. Here, we assess the nature and extent of this selection and its effects on the final collection. Results indicate that large, complete, retouched pieces were preferentially retained by the original excavators, and that the artifact collection available for study represents only 2–3% of the original lithic assemblage present in the deposits. This has significant implications for early interpretations of Mousterian industries that were based on such collections and their potential analytical value.

Keywords Middle Paleolithic · Stone artifacts · Recovery bias · Archeological collections

Introduction

It is an axiom that archeologists destroy evidence in the very act of excavation. Over the history of our relatively young discipline, excavation techniques have dramatically improved, allowing us to recover, and therefore save, more information. Nonetheless, every excavation has to make decisions as to what data to collect—meaning the recovery of both objects and contextual information—and these decisions are, and

Dedication We would like to dedicate this paper to our very good friend and colleague, Harold Dibble, who unexpectedly passed away in June 2018.

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should be, based on the project's research design. No matter what research questions are being investigated at the time, we also make every effort to collect as much information as possible within the constraints afforded by available resources simply because those data may be relevant at some later time to other researchers asking different questions or applying different analytical techniques. Regardless of the amount of care exercised during excavation or the range of recovered information, the data that are saved have inevitably gone through a sort of filter that reflects both excavation methodologies and what was deemed important at the time. Such filters, often referred to as excavator or recovery bias (Dibble and Lenoir 1995; Dibble et al. 2005), can have a significant effect on the nature of the saved collection. When studying or using data from a collection, it is, therefore, important to gauge those effects and assess both the nature and degree to which recovery bias may have distorted what was originally present.

This study assesses such effects in a collection of Middle Paleolithic artifacts coming from the site of La Ferrassie, one of the more important Paleolithic sites in southwest France. Its archeological deposits span both the Middle and Upper Paleolithic, and the large number of Neanderthal skeletal remains recovered from the site made it unique in Europe for most of the last century. The site is also eponymous for a Middle Paleolithic assemblage variant, or facies, known as the Ferrassie Mousterian, which was featured in the Mousterian variability debate (Bordes 1961a, b; Bordes and de Sonneville-Bordes 1970; Binford and Binford 1966; Mellars 1970; Rolland and Dibble 1990). Although the site was originally excavated by one of the true pioneers of French Paleolithic archeology, Denis Peyrony, his extensive excavations took place over a hundred years ago, well before the advent of modern excavation techniques—it was, in fact, the first Paleolithic site that he excavated. Later, more limited excavations were carried out by Delporte from 1968 to 1973 (Delporte and Delibrias 1984) and, from 2009 to 2014, by Turq and colleagues in the extreme western portion of the site (Turq et al. 2012).

Before presenting our analyses, it is important to put Peyrony's work in the intellectual context of his day. In the late nineteenth century, when Paleolithic archeology as a discipline was only beginning (Coye 1997; Hurel and Coye 2011; Daniel 1975), there were two principal goals. The first was to demonstrate that stone objects found in association with extinct animals, which demonstrated an antiquity much greater than was generally believed possible, were indeed of human origin. In part, this was accomplished through experiments (Coutier 1929; Evens 1872; Holmes 1894) that ultimately became a mainstream research approach for understanding prehistoric stone tool production (Bordes 1947; Crabtree 1966; Tixier 1979; see Johnson 1978). The second goal was to develop a classificatory system, based on associated fauna (e.g., Lartet and Christy 1869) and the objects themselves (e.g., de Mortillet 1869, 1872, Comment 1913, Breuil 1913), that would enable researchers to broadly outline the evolutionary stages through which the human lineage developed.

Peyrony's work in the earlier part of the twentieth century, at La Ferrassie and other sites, produced a number of important lithic collections that served to develop an initial chronological organization of Paleolithic industries. Peyrony's contributions to Paleolithic prehistory were, however, much larger than this. Building on the work of Lartet and Christy in the Perigord region of France, he focused on refining stratigraphic methods and collected representative samples of tools from different stratigraphic layers. At times, especially for some of the larger sites, this involved the removal, by hand, of hundreds or even thousands of cubic meters of sediment. In competition with some of his contemporaries, especially Otto Hauser, Peyrony carried out several operations simultaneously—for example, in 1913, he worked not only at La Ferrassie but also at La Roque Saint Christophe, Le Moustier, and La Madeleine (Peyrony 1912–1948). And at the same time, he was responsible for developing administrative oversight of these resources—purchasing sites and properties and arranging for their protection. One of the sites he purchased was the sixteenth century château in Les Eyzies to serve as a museum of prehistory, which ultimately became the French Musée National de Préhistoire (MNP), with Peyrony himself as its first director. In this way, he was instrumental in engaging the public with prehistory.

Like his contemporaries, he employed local workers, especially farmers during their off season, to serve as excavators at his sites, and delegated much of the responsibility for oversight to others. Nonetheless, he would regularly visit the sites and at times, especially when an exceptional discovery was made, would personally take charge of performing more meticulous excavation and recording. Peyrony himself did much of the processing and cleaning of the recovered objects, and organized them into collections that were often exchanged or sold to other museums.

The site of La Ferrassie is important for many reasons, and not just in terms of its place in the history of Paleolithic archeology, but also because its rich and deeply stratified deposits were instrumental in establishing the nature of industrial variability through time in this region. This fact makes it all the more important to try to understand the degree to which the material recovered and saved by Peyrony reflects what was actually in the ground. One way to do this is to compare the composition of the Peyrony collection (Peyrony 1907, 1934) with the assemblages recovered in the course of our own recent excavations. Following a brief background of the two collections, we will present the results of such comparisons focusing on the Middle Paleolithic assemblages. We will then discuss some of the implications that this study has for future analyses of older collections that are currently held in museums, and offer some guidelines for future research of them.

The Middle Paleolithic Deposits of the "Grand Abri" of La Ferrassie

The Peyrony/Capitan Excavation

The "Grand Abri" of La Ferrassie, located in southwest France (Fig. 1), is actually the remnant of a large cave that collapsed over the course of the Paleolithic occupations (Goldberg et al. 2015, 2016). It was excavated intermittently by Denis Peyrony (and Louis Capitan, who was primarily responsible for financing the excavation) from 1907 until 1922. Today, only the northern portion of the cave wall remains (making it appear as a rock-shelter, or *abri*), with a large section of remaining deposits exposed in the eastern part of the site (Delporte and Delibrias 1984) and a smaller bench of sediments remaining along the northern wall. During the course of his work, Peyrony removed between 500 and 700 m^3 of sediment from the site. Underneath the Upper Paleolithic deposits, four strata yielded Middle Paleolithic/Mousterian assemblages (Table 1): Layer A (at the base) produced an assemblage with handaxes, Layer B was described

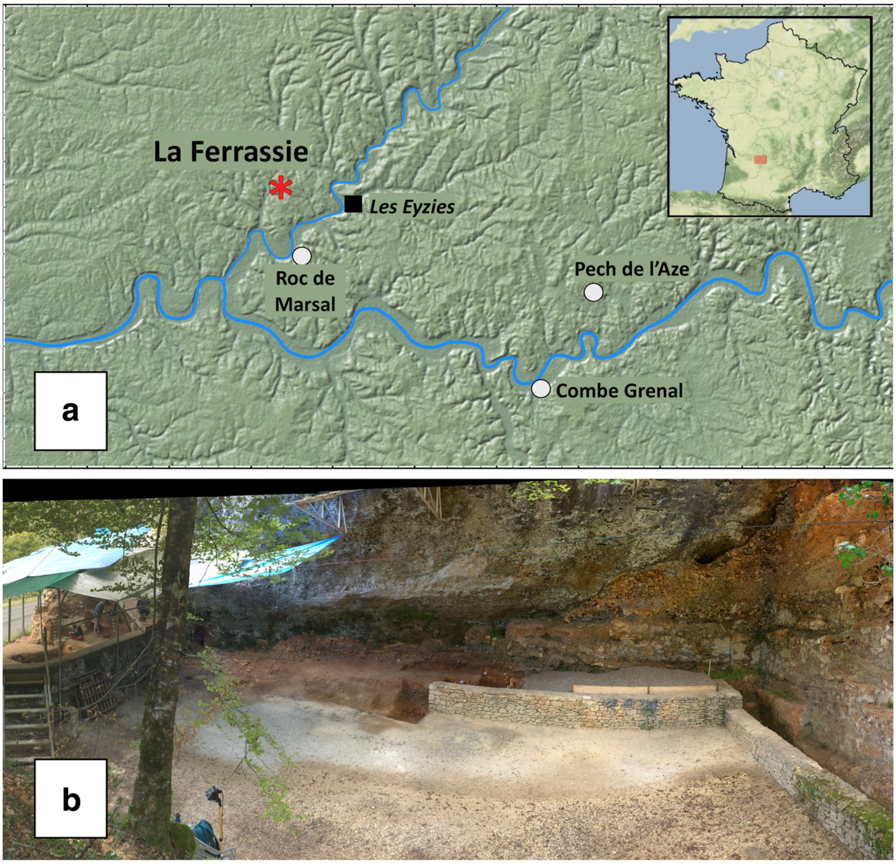

Fig. 1 **a** Map showing the location of La Ferrassie. **b** Photo of La Ferrassie at the end of the 2014 field season looking north into the area excavated by Peyrony. At the left is the area (under tarps) excavated from 2009 through 2014 (photo credit: S. J. P. McPherron)

as an "inter-occupation" (presumably seen as mainly sterile); and Layers C and D were designated as Mousterian (Capitan and Peyrony 1922; Peyrony 1934).

The analysis presented here is based on the collection that Peyrony saved, currently housed at the MNP. It should be emphasized that there are certain problems associated with the collection. First, an unknown number of objects were given to other institutions, a practice that was very common at that time. Second, there are some objects currently on display in the museum that were not studied by us. Finally, there are problems with interpreting the provenience of some of the objects in the collection. Most, but not all, of the objects or containers are designated with layer, although the layer designations are not consistent: some are interpretable (e.g., *Couche A* = Layer A; *Mo I*, *Moust I*, and *Moust Inf* = *Moustérien Inferior*, or Lower Mousterian; and *Moust S* and *Moust Sup* = *Moustérien Supérieur*, or Upper Mousterian), but others were less obvious and were, therefore, excluded from this study. This left 2437 objects that were clearly labeled as being either from a specific Mousterian layer or from the Mousterian deposits in general. There were others (a few hundred objects) that were not labeled or had labels that we were not able to interpret confidently. A further source of

Table 1 Comparison of Peyrony's initial and later stratigraphic sequences with the new sequence

<table>
<tr><th colspan="2">Peyrony/Capitan 1909-1921</th><th colspan="2">Peyrony 1934</th><th colspan="2">New Levels</th></tr>
<tr><td>8</td><td>Upper Aurignacian</td><td rowspan="3">F - M</td><td rowspan="3">Aurignacian</td><td>9</td><td rowspan="3">Aurignacian</td></tr>
<tr><td>7</td><td>Middle Aurignacian</td><td>8</td></tr>
<tr><td>6</td><td rowspan="2">Lower Aurignacian</td><td>7a–7b</td></tr>
<tr><td>5</td><td>E</td><td>Chatelperronian</td><td>6</td><td>Chatelperronian</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Upper Mousterian</td><td>D</td><td rowspan="2">Mousterian</td><td>5a–5b</td><td rowspan="5">Mousterian</td></tr>
<tr><td>C</td><td>4</td></tr>
<tr><td>3</td><td>layer of rock fall</td><td rowspan="2">B</td><td rowspan="2">Inter-occupation</td><td>3</td></tr>
<tr><td>2</td><td>Lower Mousterian</td><td>2</td></tr>
<tr><td>1</td><td>Acheulian</td><td>A</td><td>Bifaces + large flakes</td><td>1</td></tr>
<tr><td colspan="6">bedrock</td></tr>
</table>

information on the collection is a series of paper forms completed by François Bordes reflecting his analysis of the collection at some point in the mid-1900s (copies of these forms were given by him to HLD in the late 1970s). These type sheets comprise 3419 objects identified as coming from Layer A, C, D1, or D2.

The Recent Excavation (2009–2014)

The area excavated during the most recent project is located at the extreme western edge of the deposits of the Grand Abri and included limited excavation of the Upper Paleolithic deposits on the terrace and interior of a small cave located above (Turq et al. 2012). A total of approximately 20 m^2 was excavated. Nine major layers were identified that span the Middle and early Upper Paleolithic; in general, the new stratigraphy follows Peyrony's sequence, although five Mousterian layers were recognized (to his four) and only four Upper Paleolithic layers (including one containing a Chatelperronian industry) (see Table 1). Preliminary field observations and lithic orientation analysis suggest that the layers were formed via a variety of depositional and post-depositional processes (endokarst fill, fluvial and scree deposits, cryoturbation, runoff, erosion) (Goldberg et al. 2015, 2016; McPherron 2018). Sedimentological and micromorphological analyses are currently underway. The excavation methodology was based on that developed in the course of work on several other Paleolithic sites and is described in more detail elsewhere (Dibble and Lenoir 1995; Dibble et al. 2018; Goldberg et al. 2012; Turq et al. 2011). During excavation, all lithic artifacts and faunal remains ≥ 2.5 cm in maximum dimension were point provenienced (yielding a total of 6365 lithics). Objects smaller than this were bulk provenienced with the sediments and recovered after wet-screening through 6-mm and 2-mm meshes.

The lithic artifacts from both the new and old collections were analyzed identically. Flakes with retouch are considered "tools," and both flakes and tools were coded for completeness: complete, proximal, medial, or distal. The typological aspects of the assemblage are based on Bordes' classification system (Bordes 1961b; see Debénath and Dibble 1994). The only size variable included here is weight, which was recorded individually for each object to the nearest gram.

The following analyses demonstrate that there is a significant bias represented in Peyrony's collection, primarily in object size and completeness, and an emphasis on retouched pieces—especially the more heavily retouched ones—at the expense of unretouched flakes and other lithic products. The analyses are conducted using the R statistical software (R Core team 2017) with packages of *grid* (R Core team 2017), *ggplot2* (Wickham 2009), *scales* (Wickham 2017), *ggpubr* (Kassambara 2017), *dplyr* (Wickham et al. 2017), and *tidyr* (Wickham and Henry 2018). We employ two approaches in our analysis to evaluate possible biases in artifact recovery. First, statistical tests (binomial test for equal proportion and chi-square test) are used to compare the relative proportions of various artifact classes and types between the two collections. An alpha level of 0.05 is employed to assess statistical significance. However, to minimize the issue of inflated type I error due to multiple testing, we correct the alpha level to 0.006 by applying the Bonferroni correction (over eight tests). Second, we examine the cumulative proportions of retouched types in the two collections. For this second analysis, because the two collections have very different sample sizes and the frequencies of some retouched types are quite limited, any difference between the two collections may be due to sampling error. To account for this issue, we bootstrap the newly excavated collection over 1000 iterations to derive 95% confidence intervals (2.5th and 97.5th percentiles) for the retouched types to facilitate our comparison. Following Marwick (2017), the code and data for reproducing the figures (except for site maps) and table values are achieved and available for reuse under the CC-BY license (see Supplemental Information).

Evaluating the Nature and Degree of Selection in the Peyrony Collection

Object Size

At the outset of our study, it was clear that the Peyrony collection reflects a rather high degree of preference for larger objects. As can be seen in Fig. 2, the median weights of lithic objects in his collection are much higher than for those recovered in the new excavations, which in itself suggests primarily larger objects were saved.

Another way to look at this is to examine the frequency distribution in 5-g intervals of weight. It has been known for some time that during nodule reduction products are produced in a variety of sizes, but they follow a power law distribution (Brown 2001; Lin et al. 2016; Stahle and Dunn 1982), with smaller objects produced in higher frequencies than larger ones. This pattern has been noted in many archeological assemblages (e.g., Ahler 1989; Neumann and Johnson 1979) and has been explored in more detail in experiments (Amick et al. 1988; Bertran et al. 2012; Lin et al. 2016; Magne and Pokotylo 1981; Newcomer 1971; Stahle and Dunn 1982). In the absence of natural processes that may alter this distribution, the frequency distributions of object sizes are relatively consistent across lithic assemblages produced by different core reduction technologies or that utilized different sizes or shapes of raw materials (Bertran et al. 2012; Lin et al. 2016).

The top two plots in Fig. 3 show the frequency distribution of all lithic objects by weight in the two collections. The newly excavated assemblage follows the expected pattern, containing large amounts of small-sized objects and fewer larger ones. In contrast, the Peyrony collection is mostly dominated by larger-sized artifacts, and pieces that fall below 25 g are fewer in number in comparison. To address the possibility that only smaller, unretouched flakes were discarded, the size distribution

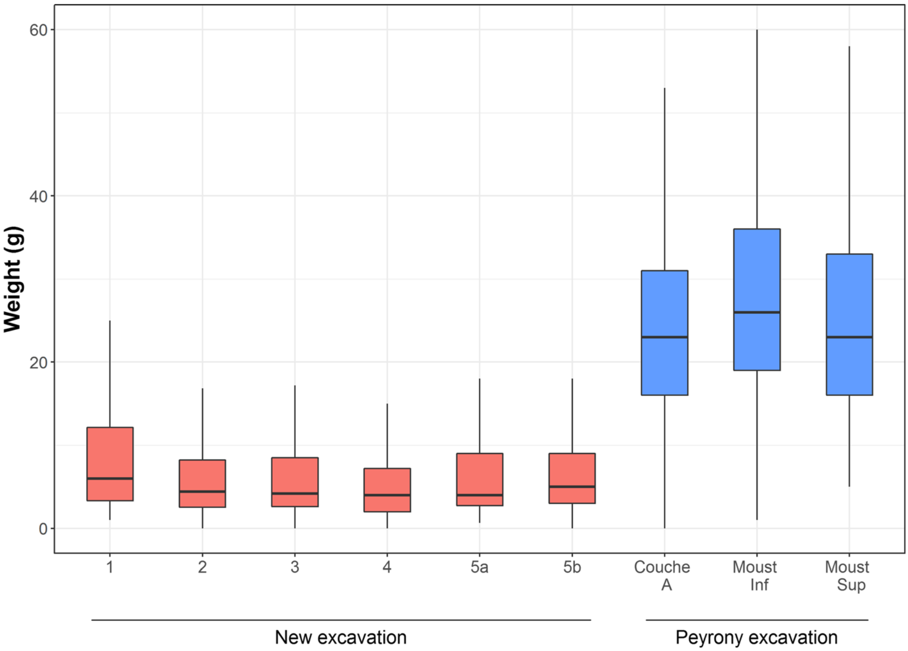

Fig. 2 Distributions of overall artifact weight by stratigraphic layer in the two collections. Red boxplots represent samples from the recent excavation collection; blue boxplots represent those from Peyrony's excavation. Outliers are omitted for clarity

of scrapers alone is also compared between the two collections. Note that here we include retouched Levallois point (Type 4), (elongated) Mousterian point (Types 6–7), and limace (Type 8) in the scraper category due to the presence of scraper retouch on these artifact forms. If the artifact size distribution of Peyrony's collection was primarily a result of retaining retouched artifacts at the expense of small, unretouched flakes, then we would expect the distribution of scraper size in the Peyrony collection to be somewhat comparable to that of the newly excavated assemblage. The bottom two plots in Fig. 3 show this is not to be the case. This discrepancy suggests that the deficit of smaller-sized objects was systematic in nature and independent of other criteria, such as the presence of retouch. It is possible to be even more precise: given that the frequency of scrapers above the 25-g threshold in the Peyrony collection resumes the size drop-off curve seen in the more recent collection, the size threshold for this recovery bias probably occurs at or around this point. We are not claiming that this was an explicit protocol during his excavation, but only that scrapers heavier than 25 g were likely more systematically retained by Peyrony than those falling below this size threshold. We will return to these frequency distributions later when estimating the total number of objects that was discarded at the time of the earlier excavation.

Superficially, these results might appear to be the result of taphonomic processes, especially the action of water flow that can remove smaller objects (e.g., Dibble 1995a; Dibble et al. 1997, 2006; Nash and Petraglia 1987; Schick 1986). However, geoarcheological and lithic orientation studies during the course of the recent excavation have revealed no evidence of such processes in that area (McPherron 2018; Goldberg and Aldeias, personal communication), and the objects themselves show no signs of water

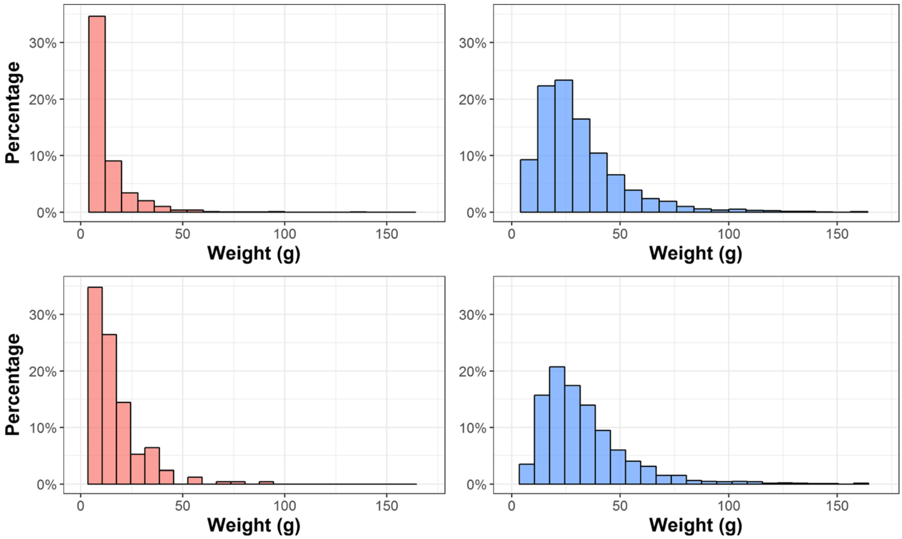

Fig. 3 Relative frequency distribution by weight of all artifacts (top row) and scrapers (bottom row) in the two collections. Red columns represent the new collection from the recent excavation; blue columns represent Peyrony's collection

transport (rolling or ridge abrasion). Assuming that the assemblages represented by the two collections are broadly comparable, this observation leaves us with the more likely explanation that smaller pieces were simply not saved during Peyrony's excavation.

Artifact Completeness and Presence/Absence of Retouch

Because a single object can potentially be broken into several medial and distal fragments, this analysis is limited to complete objects and those retaining only their proximal ends—the total of both complete and proximal ends represents a kind of "minimum number" of flake products present, with proximal ends representing broken ones (Hiscock 2002). Table 2 summarizes the quantity of complete and broken objects in the two lithic collections. Separate binomial tests of the differences in proportions of these elements (i.e., complete versus broken) between the two collections result in significant differences for both retouched pieces ($Z = 13.03$, $p < .0001$) and unretouched flakes ($Z = 5.14$, $p < .0001$). This shows that the Peyrony collection reflects a strong selection bias for complete artifacts.

Also shown in Table 2, the overall proportion of retouched elements in the Peyrony collection is substantially higher than those of the new collection, whether we look at just complete and proximal pieces ($Z = 57.47$, $p < .0001$) or for the entire collection, including medial and distal fragments ($Z = 60.28$, $p < .0001$). This discrepancy indicates that there was an especially strong preference in Peyrony's excavation to save retouched lithics over unretouched ones.

Types of Retouched Artifacts and Levallois Products

Table 3 compares the quantities of the various retouched types represented in the two collections. An obvious discrepancy is that there are substantially more notches and

Table 2 Frequencies of complete/broken retouched and unretouched artifacts in the two collections

Artifact class	Peyrony collection	New collection
Retouched pieces		
Complete	1426	221
Proximal	94	98
% complete in platform-bearing pieces	93.82%	69.28%
All (inc. medial and distal fragments)	1776	531
Unretouched flakes		
Complete	284	2542
Proximal	43	894
% complete in platform-baring flakes	86.85%	73.98%
All (inc. medial and distal fragments)	401	4664
All artifacts		
% retouch (complete + proximal)	69.69%	5.70%
% retouch (all)	81.43%	9.49%

denticulates in the newly excavated assemblage than are present in the Peyrony collection. In fact, despite the fact that the sediment volume recovered in the new excavation is only a small fraction of the amount removed by Peyrony's excavation, the new excavation actually recovered more notches/denticulates, and more of the so-called Upper Paleolithic types (Debénath and Dibble 1994) in absolute numbers. Unsurprisingly, a chi-square test shows that the proportion of the various retouched types differs significantly between the two collections ($X^2 = 461.42$, df $= 4$, $p < .001$). This difference remains evident in the bootstrapped data shown in Fig. 4a, where the bootstrapped confidence interval drawn from the newly excavated lithic assemblage failed to capture cumulative profiles exhibiting the extremely low proportion of notches and denticulates as seen in the Peyrony collection.

There are also discrepancies among the scraper types, with relatively more single scrapers recovered from the new excavation. A chi-square test again indicates that the

Table 3 Frequencies of various general retouch types in the two collections. The Bordian tool types (see Debénath and Dibble 1994) of 9–11 are grouped as single scrapers; 12–17 as double scrapers; 4, 6–8, and 18–24 as convergent/transverse scrapers; 30–35 and 40 as Upper Paleolithic types; and 42–43, 51–52, and 54 as notches/denticulates

Artifact type	Peyrony collection		New collection	
	N	Percent	*N*	Percent
Single scraper	734	47.8	172	38.2
Double scraper	265	17.2	32	7.1
Convergent/transverse scraper	435	28.3	29	6.4
Upper Paleolithic types	16	1.0	20	4.4
Notches/denticulates	87	5.7	197	43.8

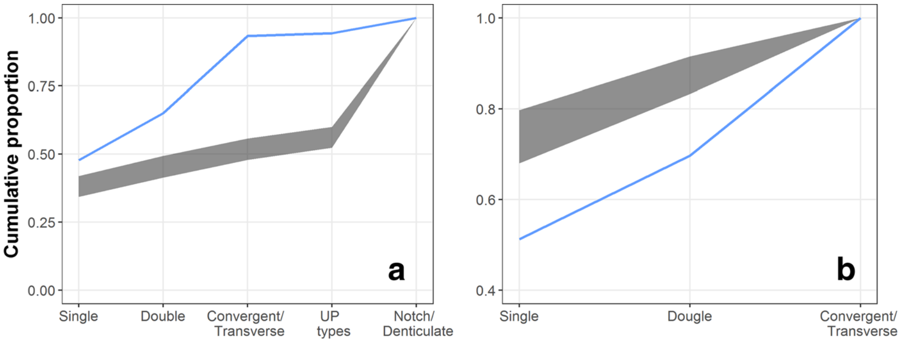

Fig. 4 Comparison between the cumulative proportions of various retouched artifact types in Peyrony's collection (blue lines) and the bootstrapped 95% confidence interval of cumulative proportions of the same artifact types in the new collection (gray area). **a** Includes scrapers, Upper Paleolithic types, and notches and denticulates. **b** Includes scrapers only

numbers of various scraper types differ between the two collections ($X^2 = 44.47$, df = 2, $p < .001$). Figure 4b shows that the proportions of the different scraper types from Peyrony's collection do not overlap at all with the bootstrapped confidence interval of the newly excavated assemblage. So, although the earlier excavation emphasized the collection of retouched pieces in general, there is also a bias evident in the variety of types that were saved: basically, the types that exhibited the more obvious modifications—those scrapers, such as convergent and transverse types, that were more heavily retouched (Dibble 1987, 1995b)—were the ones most likely to be saved.

Finally, it appears that Peyrony also preferentially saved Levallois flakes, whether or not they were retouched. As summarized in Table 4, the frequencies of Levallois and non-Levallois elements share significant differences between the two collections in the forms of both flakes ($Z = 8.409$, $p < .0001$) and retouched tools ($Z = 6.934$, $p < .001$).

Estimating the Number of Lithic Objects Discarded by Peyrony

Considering the evidence presented above that there were significant biases affecting Peyrony's excavation, it raises the question of just how many artifacts were, therefore, discarded during the course of his excavation. Here we present two ways to look into this question.

The first way is to compute the density of artifacts from the new excavation and extrapolate this to the estimated volume of sediment removed during Peyrony's

Table 4 Number and percentages of Levallois vs. non-Levallois flakes and retouched pieces, from the two collections

	Unretouched flakes			Retouched pieces		
	N Levallois	*N* non-Levallois	% Levallois	*N* Levallois	*N* non-Levallois	% Levallois
Peyrony collection	131	270	32.7	525	1251	29.6
New collection	750	3914	16.1	77	454	14.5

excavation. As shown in Fig. 5, the new excavation removed approximately 8.7 m^3 and recovered 6365 lithic objects greater than 2.5 cm in maximum dimension from the Mousterian layers, roughly 734 objects per m^3. Based on the general layout of the site and the location of remaining deposits, Peyrony removed a total of approximately 150 m^3 of Mousterian deposits. Assuming that artifact density/spatial distribution and the thickness of the Mousterian deposits were constant throughout the site (and we have no indication otherwise), his excavation would have recovered ≈ 110,000 lithics ≥ 2.5 cm in maximum dimension.

Another way to estimate the number of objects discarded by Peyrony is based on what has already been shown about the nature of his recovery criteria—a preference for saving larger, complete, and more heavily retouched objects—coupled with the known patterns regarding the frequency distribution of lithic weight classes and what is known about the lithic assemblage based on the new excavation.

It was previously shown that of the retouched types, Peyrony was more likely to save scrapers, especially ones larger than around 25 g, and above this size, the size distribution appears to match that of the newly excavated assemblage (Fig. 3b). We will assume that the frequencies of these types in his collection accurately reflect what was originally in the deposits and will, therefore, build our estimates around them. The second assumption is that the original composition of the assemblage coming from his excavated area, especially in terms of the ratio of scrapers to other lithic classes (other retouched types, complete and broken objects, cores, and shatter), was similar to what was recovered in the new excavation. This allows us to calculate the ratio of scrapers to the total of all other artifact classes in our assemblage, and from there, using his scraper counts, to estimate the total number of objects originally contained in the deposits he excavated. However, the ratio of scrapers to all other lithic products is not constant, but

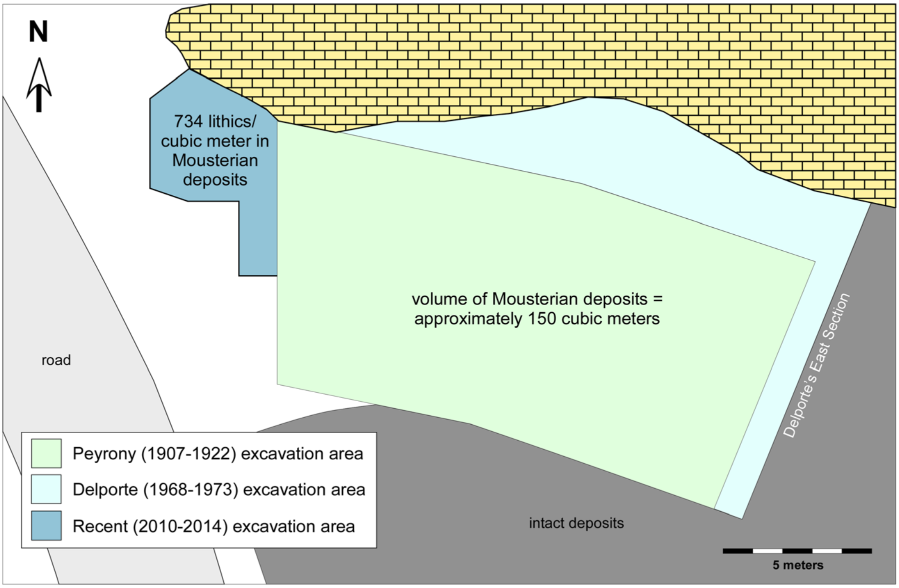

Fig. 5 Map of La Ferrassie showing the area excavated by Peyrony from 1907 to 1922 and the area excavated from 2010 to 2014. The Mousterian layers excavated by Peyrony comprised approximately 150 m^3 in total. In the areas excavated from 2010 to 2014, the average density per cubic meter of artifacts ≥ 2.5 cm is 734

varies according to size: while the totality of flake products follows a power law distribution, that is, the number produced increases inversely to size, retouched pieces in general, and scrapers in particular, are often made on larger flakes (Dibble and Lenoir 1995; Dibble 1995b; McPherron and Dibble 2000). Thus, the ratio of other products to scrapers also increases inversely with size: smaller flakes are proportionally more numerous, but relatively fewer of them are transformed into scrapers. This means that the ratio of all lithic products to scrapers should be calculated for each size class.

A final complication is that in the new excavation, the number of artifacts weighing more than 45-g interval is minimal, and with such low *N*s, sampling error for each size class becomes an issue. To overcome this problem, ratios between scrapers and the number of the other artifacts are computed for the combined number of scrapers falling in four weight intervals: 25–30 g, 30–35 g, 35–40 g, and 40–50 g (Table 5). The limits of the 95% confidence interval for these ratios were calculated by bootstrapping with 1000 iterations, and these are then multiplied by the number of scrapers to approximate the confidence interval range of the total artifact frequency in each weight interval.

The next step, again based on the newly excavated assemblage, is to compute similar ratios—this time relative to the total number of artifacts in the 25–45-g anchor interval ($N = 227$)—for the remaining size classes (Table 6). Again, the limits of the 95% confidence interval of the ratio for each of these weight classes were obtained by bootstrapping with 1000 iterations.

It is now possible to estimate the number of artifacts that was originally in the deposits excavated by Peyrony. Using the counts in his collection, the numbers of scrapers across the four anchor weight intervals are multiplied by the artifact to scraper ratios shown in Table 5, along with the 95% confidence interval limits. For the other size classes, the ratios shown in Table 6 are used to calculate the total estimated *N*s, along with their 95% confidence interval limits. Summing the estimates across all weight classes (Table 7) yields the estimated total quantity of artifacts excavated by Peyrony at 104,979, with a confidence interval of 59,571–280,970. The middle value is, in fact, very close to the estimate presented earlier (≈ 110,000) that was based on the total volume of sediments excavated by him and assuming a constant artifact density per cubic meter.

Of course, there is no way to verify these results. However, the fact that these two estimates are based on methods that have different assumptions gives at least some confidence in concluding that the existing Peyrony collection contains somewhere on

Table 5 Counts of scrapers and the ratios between the number of scrapers and the number of remaining artifacts for the four anchoring size intervals from the new collection

Weight (g)	No. of scrapers	No. of remaining artifacts	Artifact to scraper ratio	Bootstrapped ratios		No. of total artifacts	95% CI	
				2.5th	97.5th	Actual	2.5th	97.5th
25–30	8	80	10	5.36	25.34	88	51	211
30–35	13	49	3.77	2.23	7.38	62	42	109
35–40	10	37	3.7	2.00	8.33	47	30	93
40–45	4	26	6.5	2.88	32.00	30	16	132
Total						227	139	545

Table 6 Counts of total artifacts for the remaining size classes and their ratios with respect to the total number of artifacts within the anchor intervals (25–45 g)

Weight (g)	No. of total artifacts	Ratio with respect to the combined artifact total in 25–45 g ($n = 227$)	Bootstrapped 95% CI	
			2.5th	97.5th
0–5	2932	12.92	12.62	13.24
5–10	1441	6.35	6.07	6.63
10–15	502	2.21	2.02	2.38
15–20	297	1.31	1.16	1.45
20–25	143	0.63	0.53	0.73
25–45	Anchor			
45–50	18	0.08	0.04	0.12
50–55	9	0.04	0.02	0.07
55–60	12	0.05	0.03	0.08
60–65	4	0.02	0	0.04
65–70	1	0.004	0	0.01
70–75	2	0.009	0	0.02
75–80	2	0.009	0	0.02
80–85	1	0.004	0	0.01
85–90	1	0.004	0	0.01
90–95	2	0.009	0	0.02
95–100	3	0.01	0	0.03

the order of 2–3% (or 1–6% if we consider the confidence interval) of the material originally present.

Summary and Discussion

There is little doubt that Peyrony's collection represents not only a very small fraction of the lithic objects originally contained within the deposits he excavated, but also that certain kinds of objects were preferentially saved—basically the larger, more complete, and more heavily retouched objects (especially scrapers), and Levallois flakes (and tools made on Levallois flakes). This had the effect of significantly altering the character and composition of his collection. Figure 6 shows traditional Bordian cumulative graphs that display the typological characteristics of the "essential types" (primarily retouched pieces; see Debénath and Dibble 1994) of the two collections, correlating Peyrony's layers with those defined in the new excavation. The material from Peyrony's Level A is not dissimilar from the new collection from Layer 1, with fairly low percentages of scrapers and higher percentages of notched tools. Comparing Peyrony's Lower Mousterian assemblage to new collection materials from Layers 2 and 3, the former clearly displays an elevated proportion of scrapers of various types and a minimal number of notches and denticulates. The new collections from Layers 4 and 5a/5b do contain more scraper types and are closer in line with the materials from

Table 7 Estimates of total artifact quantity by size class for Peyrony's excavation

Weight (g)	No. of scrapers	Estimated		
		No. of scrapers + remaining artifacts	2.5th	97.5th
0–5		54,996	32,004	143,853
5–10		27,030	15,394	72,035
10–15		9414	5123	25,859
15–20		5569	2942	15,754
20–25		2683	1344	7931
25–30	194	2134	1234	5110
30–35	169	806	546	1416
35–40	129	606	387	1204
40–45	95	712	369	3135
45–50		336	101	1304
50–55		170	51	761
55–60		226	76	869
60–65		77	0	435
65–70		17	0	109
70–75		38	0	217
75–80		38	0	217
80–85		17	0	109
85–90		17	0	109
90–95		38	0	217
95–100		55	0	326
Total		104,979	59,571	280,970

Peyrony's Upper Mousterian, although notches and denticulates remain considerably underrepresented in Peyrony's assemblage.

As mentioned above, there are several possible explanations for these differences. One is that the Mousterian industries coming from the area of La Ferrassie excavated by Peyrony differed significantly from what existed in the part of the site excavated by us. However, type counts published by Tuffreau (1968) for Delporte's later excavation at the site, which took place along the northern wall of the cave and along the eastern section (and, therefore, spatially encompassed Peyrony's excavation area), are not very dissimilar from those coming from the new excavation, or are somewhat intermediate between the new excavation and Peyrony's (Fig. 7). It should be noted, however, that it has not been possible to correlate Delporte's stratigraphy directly with that of the new excavation. In fact, our assessment of the Mousterian layers along the north wall excavated by Delporte suggests that they were affected considerably by post-depositional processes. Nonetheless, his newer data, overlapping at least in part with that obtained from the area excavated by Peyrony, does not support the notion that there was significant lateral variability in the types of industries represented.

Another possibility, given that the total type counts of Peyrony's collection as analyzed by us and by Bordes are different (compare Figs. 6 and 7), is that the existing

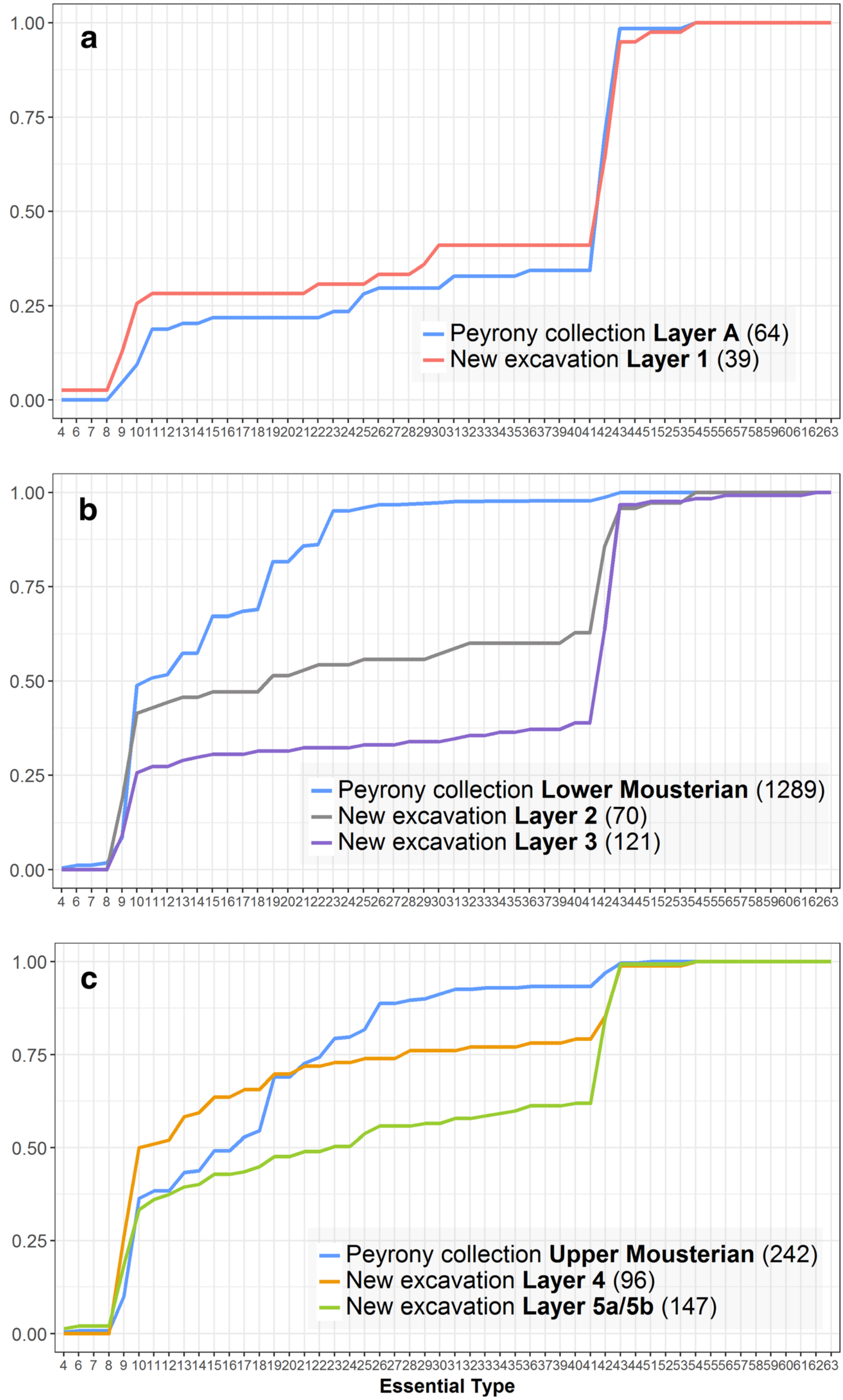

Fig. 6 **a–c** Cumulative proportions of Bordian essential types from the two collections by stratigraphic divisions. Numbers in bracket indicate sample size

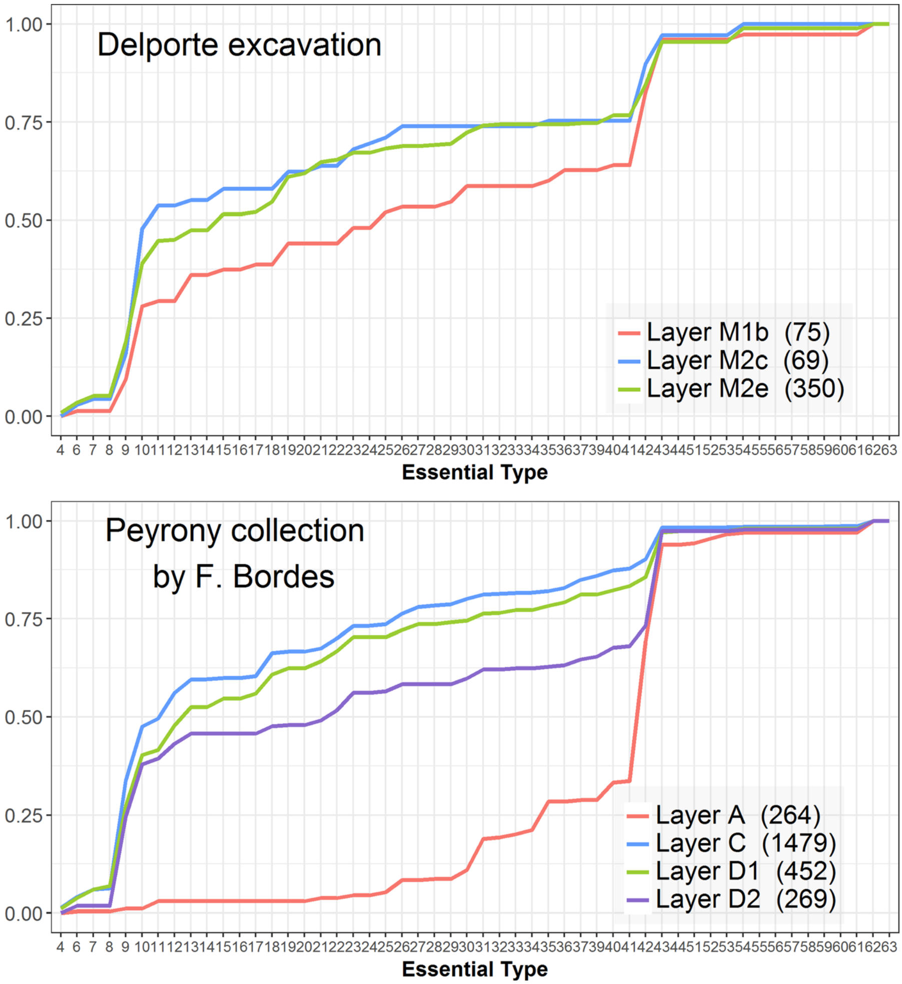

Fig. 7 Cumulative proportions of Bordian essential types from Delporte's excavation and Peyrony's collection analyzed by Bordes. Numbers in bracket indicate sample size

collection housed at the MNP, or at least the part examined by us, does not represent the totality of the material recovered by Peyrony. First of all, almost a quarter of the collection is not adequately labeled to be included in our study, though Bordes may have included some of these. Second, it was a common practice in the early twentieth century that excavated materials were shared with other museums or private collectors, and so some of his original collection may exist elsewhere. And finally, there are some objects on display at the MNP that were not included in the present study. It is unlikely, though, that these "missing" objects would significantly change the character from what we see here, especially in terms of the low percentages of smaller and unretouched objects.

So, we are left with the conclusion that Peyrony's criteria for deciding what to save and what to discard at the time of his excavation led to his collection being somewhat misrepresentative of what was originally contained within the site. The significance of applying such criteria for retaining particular kinds of objects during excavation cannot be overstated given that the relative frequencies of different retouched types and percentages of Levallois have traditionally been the main criteria for classifying Mousterian assemblages into different varieties, or facies (Bordes and Bourgon 1951; Bordes 1961a; Debénath and Dibble 1994). In traditional Bordian systematics, the Ferrassie Mousterian facies is defined as having a relatively high proportion of scrapers, which makes it, along with the Quina Mousterian, part of the Charentian group. The characteristic that distinguished the Ferrassie Mousterian from the Quina is the significant presence of Levallois technology in the former (Bordes 1950, 1961a; Bordes and de Sonneville-Bordes 1970). However, as we have demonstrated above, both of these characteristics in the original La Ferrassie collection reflect the preferential recovery of scrapers and Levallois elements over other lithic forms in the original excavation, and therefore misrepresent what was originally present in the assemblage. It is unfortunate that this collection served as the basis for defining this particular Mousterian assemblage variant.

To be clear, the findings here do not question the presence of Levallois assemblages that are rich in scrapers. For instance, the Layer 4 assemblage from the renewed excavation at La Ferrassie does contain notable quantities of scrapers, and its essential cumulative profile does approach that of the Charentian (Fig. 6). However, our results do cast doubt on Ferrassie Mousterian as a distinct facies because the assemblage elements used to define the industry in the first place was more likely an "artifact" of preferential recovery of these particular lithic elements. In reality, the actual proportions of Levallois elements and scrapers in Peyrony's excavated assemblages are expected to be lower than the values reported originally. Indeed, based on our reanalysis of Peyrony's collection, the percentages of Levallois products for the two Mousterian layers (Lower and Upper Mousterian) are 45% and 39% respectively. In contrast, our renewed excavation produced much lower Levallois proportions in the corresponding layers, with 17.4% and 16.5% for Layers 2 and 3, and 16.2%, 11.6%, and 17.5% for Layers 4, 5a, and 5b. The point here is that the original data used to define the Ferrassie Mousterian is likely biased and the characteristics used to distinguish the Ferrassie Mousterian from other facies probably exist as continuums rather than boundaries among Middle Paleolithic assemblages. Indeed, based on his review of several Mousterian collections, Geneste (1985) noted that assemblages oriented toward Levallois technology had varying percentages of scrapers, with no clear separation to warrant the definition of distinct facies.

It should be emphasized that our intention in investigating the nature and degree of recovery bias by Peyrony is not meant to impugn his work, since to a very large extent it was a product of the intellectual goals he was trying to achieve coupled with limitations of contemporary archeological methods. Indeed, for the history of Paleolithic excavations in southwest France, it is possible to outline in broad strokes how recovery techniques have impacted the resulting collections.

First, there are collections that resulted from excavations that took place during the nineteenth century. Often these were recovered from dubious or even unknown stratigraphic contexts and almost exclusively reflect the kinds of objects that were deemed important, i.e., diagnostic or representative, at the time. Such collections may be of interest to current researchers primarily for their historical value, but they may contain objects that have exceptional technological, typological, or lithological characteristics and perhaps diagnostic elements that can be used to map their distribution. However, they may also be missing categories of objects now considered to be important and have virtually no potential for any sort of quantitative analysis.

By the time of the early twentieth century, many excavations paid more attention to natural stratigraphy, or at least the broad outlines of stratigraphic successions, but with, at best, only limited spatial provenience, and often, as was the case at La Ferrassie, objects with particular characteristics were preferentially retained. Another example comes from Ami's excavation at Combe-Capelle Bas, which took place not long afterwards, from 1926 to 1931 (Ami 1931). He too preferentially retained scrapers at the expense of notches and denticulates, thereby significantly altering the typological character of the industry (Dibble and Lenoir 1995). Depending on the quantity of objects recovered, it may be possible, at least tentatively, to characterize the assemblage in terms of current assemblage systematics, i.e., the kind of typological variant represented, although as we have shown here, the prevalence of certain types may be under- or overrepresented. The general lack of unretouched pieces in particular renders technological studies questionable and precludes any quantitative or statistical assessment.

During the second half of the twentieth century, techniques for recording the three-dimensional coordinates of objects had been developed (Laplace-Jauretche and Méroc 1954) and adopted by prehistorians such as Bordes in his work at Combe Grenal and Pech de l'Azé I (McPherron et al. 2012). However, not all objects were provenienced in this way—often unretouched objects were simply collected and bagged by stratigraphic unit and possibly arbitrary depths (Dibble et al. 2009b), and smaller objects were not recovered with screens. It has also been shown that Bordes himself, considered by some to be the "father" of modern methods of Paleolithic archeology (Sackett 2014), had applied specific criteria for the recovery of faunal materials. Discamps and Faivre (2017), for example, found that his excavation at Combe Grenal preferentially saved teeth and "diagnostic" elements—typically articular ends of bones—relative to shaft fragments (see also Binford 1981; Chase 1986), in large part due to his emphasis on paleontology (his work predating modern zooarcheological methods). At the last French site he excavated (Pech de l'Azé IV, from 1970 to 1977), he still did not use screens and left individual excavators to decide for themselves what to point provenience or retain in bulk (Dibble et al. 2005, 2018). Many excavations utilizing such methods were carried out and the resulting collections served as the basis for developing current assemblage systematics (Bordes 1961a, b). In spite of better attention to their stratigraphic context, which can sometimes be assessed based on projections of the coordinate data (e.g., McPherron 2005; McPherron et al. 2005), methods for evaluating post-depositional or taphonomic processes that may have affected the assemblages had still not yet been developed or widely used. All of these factors contributed to lessening of their utility for quantitative or statistical assessment.

More recent Paleolithic excavations have developed and applied many methods designed to assess site formation (Texier 2009; Goldberg 1979; Goldberg et al. 2001, 2009; McPherron 2005, 2018; Shahack-Gross 2017) and improve the accuracy and precision of object proveniences (McPherron and Dibble 2002; Dibble et al. 1995; Rigaud 1982), and the use of screening (both wet and dry) has become common. Thus, our understanding of the archeological record and how it formed has increased significantly. However, the trade-off is that the pace of excavation has slowed considerably, which means that more limited areas can be excavated with the same investment

(McPherron et al. 2012). This is a kind of sampling error that can, in turn, limit our ability to interpret spatial variability within and between sites. Nonetheless, it has to be admitted that our own excavations will be criticized in the future for our own recovery biases that reflect not only the methods of excavation employed but also our own research objectives.

The important point to bear in mind is that archeological collections are always the result of some sort of filtering: what was considered unimportant or non-diagnostic at the time of any excavation may assume more importance with the development of new techniques or new research questions. Moreover, we also know that aside from problems resulting from the original excavation methodology, other issues may affect a collection even after it is curated (Dibble et al. 2009a, b). What we have demonstrated here is that it is possible to evaluate and characterize the nature and extent of these potential biases, even with very limited excavation. By understanding these processes, researchers can develop appropriate analytical protocols, such as raw material sourcing studies (Turq 2000; Turq et al. 2017) and analysis of burnt lithic proportions as a proxy of fire episodes (Sandgathe et al. 2011), to maximize the archeological information that can be extracted from these datasets. In turn, this means that many, if not most, older collections can continue to be of value, depending on the kinds of questions being addressed. Fortunately, even limited excavations can recover sufficient quantities of material that can be used to assess both the degree and nature of previous selection criteria. Nonetheless, we cannot escape the conclusion that all collections suffer from some kinds of deficits in their recovery and, therefore, they should be studied with these caveats in mind.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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