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THE AGRO PONTINO SURVEY PROJECT

Methods and preliminary results

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FIGURES FROM FLINT: FIRST ANALYSES OF LITHIC ARTIFACTS COLLECTED BY THE AGRO PONTINO SURVEY

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SUMMARY

Lithic artifacts collected by the Agro Pontino survey have been coded for a number of variables. These data are being used to search for chronological variability that may help date the sites that have been defined and to establish samples needed for research using the survey data.

1. INTRODUCTION

This article describes the approach to the analysis of lithics used during the Agro Pontino survey project. Lithics refers to four major categories—flint and related types of stone, obsidian, other types of stone, and whole pebbles (whole pebbles were considered artifacts when found outside their natural geological matrix). The discussion concentrates on the flint artifacts, which constitute the bulk of the collection and have been the focus of attention so far.

In 1980, we constructed a preliminary codebook with conventional descriptors—size, type, breakage, condition, etc.—for variables and began to code the lithic artifacts. In 1983, one of us (HK), while in Rome, added standard tool typologies (Bordes 1961; De Sonneville-Bordes and Perrot 1954-56, etc.) to the codebook and completed the coding of everything collected to that time. Although the variables themselves have remained the same over the years, the variable categories were gradually expanded and modified. These changes and the need to retrieve information about the artifacts for various purposes—dating, development of research design, analysis of post-depositional processes, etc.—prompted us to recode all previously collected artifacts in 1986-87.

These data have been incorporated in the Agro Pontino database. The periods thought to be represented at sites have also been entered into the database and are regularly updated.

In this paper we first review the variables, then we discuss our approach to dating the artifacts and two of the analyses undertaken for this purpose, then we briefly discuss the distribution of the materials, and finally we give some preliminary results of analyses that have been done in conjunction with selecting adequate samples for one of our research projects.

2. SELECTION AND MEASUREMENT OF VARIABLES

The variables selected, their level of measurement, and, where applicable, their categories are listed in Table 1 along with the frequency of occurrence among the flint artifacts. In this section we discuss what analyses the variables can be used for, some of the distinctions in coding the artifacts, and how we have used the data so far.

Weight. Weight is used to approximate artifact size. Size can be used to rapidly partition artifacts—large and small unbroken blades, for example. Size, along with other properties, also affects how an artifact behaves in post-depositional contexts and is essential to help to determine if artifacts have been locally transported by slopewash. So far, we have used size as a test implication for the finding that recent rain or irrigation of an agricultural field facilitated survey visibility as measured by relative densities of artifacts. It was

TABLE 1. DESCRIPTIVE VARIABLES FOR FLINT AND ASSOCIATED MATERIALS ($N = 8017$).

Variable	Level of measurement	Categories	Unit of measurement	<i>N</i>	%
Weight	interval		tenths of grams		
Cortex	ordinal	10% or less		2266	28.26
		11-20%		955	11.91
		21-30%		903	11.26
		31-40%		937	11.69
		41-50%		958	11.95
		51-60%		948	11.82
		61-70%		443	5.52
		71-80%		274	3.42
		81-90%		219	2.73
		91-99%		114	1.42
Patina	nominal/ ordinal	no patina		1481	18.46
		slight patina		3192	39.82
		medium patina		2560	31.93
		heavy patina		784	9.77
Waste type	nominal	flake core		2396	29.89
		prismatic blade core		132	1.65
		flake		3969	48.26
		blade		742	9.26
		block		244	3.04
		bipolar segment		208	2.59
		flake-core problem		122	1.52
		indeterminate		247	3.08
		resharpening piece		57	.71
Breakage	nominal	whole item		4856	60.59
		proximal end present		741	9.25
		distal end present		619	7.72
		medial segment		308	8.84
		whole item with broken side		379	4.73
		combination of breakage		646	8.06
		other breakage		217	2.71
		indeterminate		249	3.11
		Condition	nominal	no special condition	
burned				809	10.09
burned and rounded				9	.11
rounded				245	3.06
rounded and re-retouched				32	.40
re-retouched				30	.37
other				3	.04
indeterminate				3	.04
Hammerstone	nominal	no hammerstone/anvil marks		7749	96.66
		hammerstone/anvil marks		268	3.34

TABLE 1. (CONTINUED).

Variable	Level of measurement	Categories	Unit of measurement	N	%
Tool type	nominal	end scraper		164	2.04
		side scraper		421	5.25
		burin		69	.86
		point		68	.85
		other blade tool		500	6.23
		other flake tool		1642	20.48
		other core tool		401	5.00
		not a tool		4676	58.32
		tool on flake-core		41	.51
		indeterminate		35	.43
Retouch	nominal	no retouch/utilization		4649	57.99
		utilized		1581	19.72
		denticulate retouch		85	1.06
		scalar/scaliform		534	6.66
		parallel/sub parallel		111	1.38
		invasive		17	.21
		bifacial		29	.36
		other		999	12.46
		indeterminate		12	.15

predicted that if this finding were true, the less dusty the field, the greater the proportion of small lithic finds (Loving *et al.* 1985). The test with Kendall's τ showed a slight, but significant correlation ($N = 257$, $\tau = -.2137$, $p < .001$). In section D.3 below, size is taken into account in the investigation of the relationship between amount of cortex on artifacts and the distance to the raw material source at the place where they were discarded.

Patina. Patina is the result of weathering of flaked surfaces on flint and similar types of stone. Initial analyses of the survey artifacts showed that there very well may be a relation between patina and age (Kamermans 1984). Although a few of the artifacts collected by the survey have a milky white or milky blue patina, most have what is called a "glossy" patina (Rottländer 1975). Simple and accurate measurements of patina seem not to have been developed, and a very general method was used for our analysis. A few artifacts were selected as standards for each category of the patina variable. Individual items were compared against these standards for coding the variable. Visually, the standards are four degrees of surface sheen, which can probably be ascribed to differing degrees of patina. The relationship between patina and relative age of surface artifacts found in the Agro Pontino is being investigated (see section 3.3).

Waste type. Rather than separating tools from debitage at the outset, each item was coded as a waste type and a tool type. For example, a bipolar segment made into a side scraper was coded as a bipolar segment for waste type and as a side scraper for tool type, and a bifacial point was coded indeterminate for waste type and as a point for tool type. In standard typologies, these distinctions are usually quasi-explicit, e.g. *grattoir simple* (always on a blade) and *grattoir sur éclat* in De Sonneville-Bordes's and Perrot's

typological system, and no hierarchical structure is imposed. Technological and functional differences can perhaps be identified by making this distinction.

The final detachment, excluding minor shaping or retouch, was used to determine the waste type. If the final detachment had the features of a positive flake scar it was coded as a flake or blade; if it had those of a negative scar it was coded as a core (see, e.g. Crabtree 1972). This was sometimes difficult to operationalize, because many of the items were made on pebbles and had non-overlapping positive and negative flake scars. If no decision could be made, these were coded 'flake-core problem'. Flakes were coded as blades if their length was at least twice as long as their width or they were broken and had features of prismatic blades. Similarly, cores were coded as prismatic blade cores if they had (a) prepared platform(s) and uni- or bi-directional parallel removals of blades. Bipolar segments had either the characteristic orange-segment shape or were split cobbles with sheared bulbs and embedded compression rings. Items without fracture features and small shattered fragments were coded 'block'. Core rejuvenation pieces and small to very small, but formed flakes were classed as resharpening pieces.

Breakage. Breakage patterns may indicate variability in the use of particular tool types. Most categories of the breakage variable could be coded only for items which have distal and proximal ends—flakes, blades, and bipolar segments. Broken cores were generally coded 'other breakage'. Because most items had some patina, it was generally possible to distinguish recent breaks from non-recent ones. Recent breaks were not coded, but sometimes recent breakage made coding of some other variables difficult or impossible.

Condition. Three kinds of condition were coded—burnt, rounded, and re-retouched.

Burning can indicate an attempt to improve flaking characteristics (Crabtree 1972), location of a former controlled fire, or post-depositional burning, among other things. About 10% of the flint artifacts are burned. Of these, 25% were classified as blocks or could not be classified because of burning. Most of the other burnt items were flake cores and flakes. A larger number of burnt items are associated with aeolian deposits than would be expected by chance ($\chi^2 = 49$, $df = 1$, $p < .0005$), but the association is very weak ($\phi = .07$). It is interesting, nevertheless, that over 70% of the burnt artifacts are associated with sandy soils—aeolian and littoral deposits. That 76% of these exhibit some patina argues against the practice of burning off stubble in fields, which is rather common today, being a major factor.

Rounding generally indicates transport by water. About 3.5% of the artifacts are rounded; most are flakes and flake cores. Three-fourths of the rounded items were found in association with the pebble beds, mainly those of the Borgo Ermada level. The significance of these rounded artifacts is that they must have been discarded before or during the formation of the Borgo Ermada beach ridge about 90,000 years ago.

Re-retouching indicates that formerly discarded tools and debitage were used as a source of raw materials for making tools. The formerly discarded tool is generally more rounded and/or more patinated than the portion bearing the scars of reuse. Among the rounded tools found, 13%, mostly flake cores, had been subsequently retouched.

Hammerstone and anvil marks. The recording of this variable makes it possible to determine the kinds of stones used as hammerstones and anvils. The presence of hammerstone and/or anvil marks was determined by feeling for rough spots on the cortex, a procedure established after examining experimental pieces. In many cases these marks could also be seen.

Tool type. Very broad categories were used for the tool type variable. Although we wanted some indication of the number and general types of tools, it did not seem reasonable to construct a tool typology without specific research goals. It was not expected that all tools could be classed in standard tool typologies, and this proved to be the case (see below). Items with signs of utilization or edge damage were coded as tools.

Retouch. Type of retouch is related to the style and function of stone tools. The retouch variable also coded utilization or edge-damage, which was coded as present if a localized polish could be seen along an edge with 10x magnification. Parallel/sub-parallel and scalar/scaliform definitions followed those given by Bordes (1961:9). Denticulated retouch was coded as present if there was a series of at least three small notches along an edge.

Of the 3,265 items classified as tools, 1,787 exhibited some form of retouch. The five classes of retouch used in the analysis were woefully inadequate to encompass the diversity of types of retouch in the collections, and 999 items were scored as having 'other' retouch, resulting in this variable being incompletely coded. When the variable is needed for a particular analysis, complete recoding of retouched items will have to be done. To date, scalar/scaliform retouch is by far the most common type of retouch. There are few incidences of denticulated retouch and very few of bifacial and invasive retouch.

Tool typologies. An attempt was made to classify tools with the most commonly used typologies for Palaeolithic assemblages in Italy. Bordes's (1961) typology is generally used for Middle Palaeolithic assemblages; for Upper Palaeolithic assemblages, the systems of De Sonneville-Bordes and Perrot (1954-56), Laplace (1964), and Bietti (1976-77), which customizes the De Sonneville-Bordes and Perrot French Upper Palaeolithic typology for the Upper Palaeolithic in Central Italy, are used. The original purpose of using several Upper Palaeolithic systems was to see which could classify more of the tools found by the survey; Bietti's system performed better in this respect (Kamermans 1984). Classified tools were used to provide initial dating of sites (see section 3.1). A little more than 25% of the tools could not be typed. In some cases, it was simply that the typology specified that the type must be made on a blade and the example we had was identical to the type in every respect except it was not made on a blade. About 40% of the end scrapers could not be typed either because of this reason or because they were not "stylistically" distinctive for a time period (see section 3.1 below). But, also shaped pieces in our collection, mainly dart points, which probably are Neolithic or later if the collections in the *Museo Nazionale Preistorico Etnografico 'Luigi Pigorini'* are any indication, had no counterparts in any of the typologies.

3. APPROACH TO DATING PROBLEMS

Dating problems are always an obstacle for research dealing mainly with surface materials. Very early in the survey project we decided not to expect that lithics could be assigned to anything but very broad chronological categories—Middle Palaeolithic, Upper Palaeolithic, Epigravettian, Mesolithic, Neolithic, and Bronze Age. We also developed the notion that items should be dated in quasi-probabilistic terms that expressed our certainty about to which period(s) an artifact could be assigned. For example, a levallois flake might be assigned with 100% certainty to the Middle Palaeolithic, a trapeze with 20% certainty to the Mesolithic and 80% to the Neolithic, and a primary decortication flake with 16.6% to all chronological categories. In the long run, sites are to be "dated" on the basis of overall age "probabilities" of the artifacts. In the short run, the process of dating is iterative, and the dates for sites are in flux.

The distribution of sites by time period, as currently assessed, is shown on Figures 3-6 in the appendix.

3.1 Dating of sites with diagnostics

In order to assign age probabilities to artifacts so that sites could be dated, we began with temporally "diagnostic" artifacts and attributes (see Table 2). To be considered a diagnostic the item had not only to fit into the typological category, but also to visually

TABLE 2. TEMPORALLY "DIAGNOSTIC" ARTIFACTS.

Period	Types	Attributes
Middle Palaeolithic	Bordes's types 1-24	
Early Upper Palaeolithic	Bietti's types 1-21, 51, 63-64 De Sonneville-Bordes's types 15, 17, 49, 55 Laplace's type 12	
Late Upper Palaeolithic	Bietti's types 52, 82-95	Microlithic technique
Palaeolithic/Mesolithic *		
Neolithic	Eneolithic dart points flat, pointed blades Long prismatic blades with serrated retouch and square ends Geometrics	Obsidian Ground stone

* It is difficult to make any distinction between the Epigravettian and Mesolithic in this area, not only because so few Mesolithic sites are known, but also because the Mesolithic adaptation seems to have been more a different mode of exploiting resources than a distinctive industry. See Bietti (1984) for a description about the Mesolithic in Lazio.

TABLE 3. DISTRIBUTION OF SITES BY CHRONOLOGICAL PERIOD.

Period	Single-component sites	Multi-component sites
Middle Palaeolithic	49	71
Early Upper Palaeolithic	16	62
Late Upper Palaeolithic	17	152
Neolithic	16	46

resemble those types from closed contexts in the area. For example, a side scraper was not given a type number in Bordes's system unless it looked like a Pontinian (the local Mousterian industry) artifact. The diagnostic artifacts were assumed to have a 100% probability of having a date of a certain time period. In a separate procedure collections from fields were aggregated into sites on the basis of spatial proximity of the artifacts and physiographic associations. The sites were assigned to periods on the basis of the diagnostic artifacts in the collections. Table 3 shows how sites were distributed by time period.

In analyses discussed below in which we compare time periods the sample consists either of the diagnostic artifacts drawn from all sites or all the artifacts in single-component sites.

3.2 Analysis of artifacts

Collections from sites assigned to only one lithic period were grouped according to period for analysis to identify possible technological differences between chronological periods. Table 4 shows the variables defined for this analysis. Also, it was noted, if cortex was present, whether items had been made from pebble flint or nodular flint.

Thus far, Neolithic and early Upper Palaeolithic collections have been analyzed and compared. The Neolithic collections comprised 23 cores and 60 blades and flakes from 3 sites, the early Upper Palaeolithic ones 4 cores and 25 flakes and blades from 8 sites. The proportion of blades relative to flakes in the early Upper Palaeolithic collection was greater than in the Neolithic collection (chi-square = 5.85, $df = 1$, $p < .02$). Flake and blade lengths, widths, and thicknesses and their ratios, however, completely overlapped. In contrast, both the width (Kolmogorov-Smirnov: $n_1 = 14$, $n_2 = 8$, chi-square = 3.72, $df = 2$, $p < .2$) and the depth (Kolmogorov-Smirnov: $n_1 = 14$, $n_2 = 10$, chi-square = 5.83, $df = 2$, $p < .1$) of blade and flake butts were larger in the Upper Palaeolithic collection than in the Neolithic collection.¹ This may be related to differences in flaking techniques; possibly related differences observed were larger and more pronounced bulbs in the Upper Palaeolithic collection. Other differences were that bulb height and extent were positively correlated in the Neolithic collection, but varied independently in the Upper Palaeolithic collection. Also, the Upper Palaeolithic collection had one core and nine flakes made from nodular flint and the Neolithic collection none.

The next step in this analysis is to determine which variables are interdependent and, drawing from the lithic technology literature, to establish the technologies and conditions that might have produced them, collecting more data from the artifacts, if necessary.

TABLE 4. VARIABLES CODED FOR TECHNOLOGICAL FEATURES OF LITHICS.

Cores and split cobbles	Flakes and blades	
	ventral side	dorsal side
1. technique of flaking	1. extent of bulb, its height and abruptness of termination	1. number, orientation, size of previous removals
2. number of faces flaked	2. length, width, thickness of item	2. depth of retouch
3. orientation of flake removals	3. type of termination	3. edge angles
4. type of platform, number of removals, and angle of removals	4. presence/absence of ripples, <i>érrailleux</i> scar, force marks, striae	4. parallelism of sides on blades
5. dimensions of remnant platforms	5. type of butt, dimensions, and angle of inclination	

TABLE 5. OBSERVED AND EXPECTED VALUES FOR CHRONOLOGICALLY DIAGNOSTIC ARTIFACTS VERSUS AMOUNT OF PATINATION.

Period	Amount of Patination				Total
	None	Slight	Medium	Heavy	
Middle Palaeolithic	42 (44.6)	153 (161.0)	194 (196.1)	102 (89.3)	491 79.7%
Upper Palaeolithic	4 (7.2)	26 (25.9)	41 (31.5)	8 (14.4)	79 12.8%
Later	10 (4.2)	23 (15.1)	11 (18.4)	2 (8.4)	46 7.5%
Total	56 9.1%	202 32.8%	246 39.9%	112 18.2%	616 100%

3.3 Patina and relative age of artifacts

In inspecting the relation between the age of the diagnostic artifacts divided into three groups—Middle Palaeolithic, Upper Palaeolithic, and later—and the degree of patina (Table 5), it was immediately apparent that progressively greater age was probably associated with progressively heavier patina, but that a third variable, or more, was involved. Two major potential sources of variation were entertained—depositional contexts of the artifacts and artifact lithology. Since our lithological subdivision of the artifacts was rather gross, but depositional contexts had already been fairly well studied, we decided to investigate the relation among the sediments where artifacts had been found, the amount of patina, and chronotypological classification. Preliminary analysis showed that aeolian and littoral sands and lagoonal clays seemed to have a very different relationship to patina than tuff, travertine and colluvium, and so the analysis was done using two groups.

The three variables—sediment, patina, and typological age—within the group of artifacts recovered from the tuff, travertine, and colluvium ($N = 83$) were independent when tested with chi-square (chi-square = 4.8, $df = 6$, $p = .56$); but, in fact, the sample for the Upper Palaeolithic and later is so small ($N = 4$) that very little can be said.

The result from the group recovered from aeolian and littoral sands and lagoonal clays ($N = 528$) showed that the probability that age, patina, and sediment were independent in this group was very low (Table 6). Using hierarchical loglinear modelling (Shenman 1988; SPSS, Inc. 1988) the simplest model found to fit the data is that patina is a function of both the age and the depositional context of the artifact (chi-square = 16.47, $df = 16$, $p = .420$), as shown in Table 6. The more complex, triple-pair model produced a close fit with the data (chi-square = 6.6, $df = 12$, $p = .879$) and is a significant improvement in a statistical sense over the simpler model (chi-square = 9.87, $df = 4$, $p < .02$).

To interpret these results, we shall first examine the relations covered by the simple, double pairs model (age by patina and patina by sediment) and then look at the relationship between age and sediment that was included in the more complex, triple pairs model. The relationship that patina has to age and sediment is shown in Table 7a. It seems that greater age is closely associated with a greater amount of patina in these sediments. The relative proportions of both Middle Palaeolithic and Upper Palaeolithic artifacts increase from the categories of no patina through medium patina, but then almost all heavily patinated artifacts are Middle Palaeolithic ones. Half of the later artifacts are coded for slight patina and their relative proportions decrease steadily from the no patina category

TABLE 6. RESULTS FROM MODELS USED IN LOGLINEAR ANALYSIS ($N = 528$).

Model	Chi-square	<i>df</i>	<i>p</i>
Independence	95	28	< .0005
Pairs:			
age by patina	55.7	22	< .0005
patina by sediment	56.6	22	< .0005
age by sediment	83.1	24	< .0005
Double pairs:			
age by patina & patina by sediment	16.5	16	.420
age by sediment & patina by sediment	43.9	18	< .001
age by patina & age by sediment	43.0	18	< .001
Triple pair:			
age by patina & patina by sediment & age by sediment	6.6	12	.879

TABLE 7. COUNTS AND PERCENTAGES OF ARTIFACTS ASSOCIATED WITH PATINA CATEGORIES, TYPOLOGICAL AGE, AND TYPE OF SEDIMENT.

Observed values (O), row percentages (R), and column percentages (C) are ordered O C
R

a. Relationships among variables in the simple, double pair model:

Age				Sediment							
Middle Palaeolithic (N=408) 77.2%	Upper Palaeolithic (N=75) 14.2%	Later (N=45) 8.5%	(N=528) 100%	aeolian sand (N=122) 23.1%	littoral sand (N=133) 25.1%	lagoonal clay (N=273) 51.7%					
Patina											
None (N=39) 100%											
25	6.1 64.1	4	5.3 10.2	10	22.2 25.6	10	7.5 25.6	19	6.9 48.7		
Slight (N=169) 100%											
121	29.6 71.6	25	33.3 14.8	23	51.1 13.6	42	34.4 24.8	43	32.3 25.4	84	30.7 49.7
Medium (N=215) 100%											
165	40.4 76.7	40	53.3 18.6	10	22.2 4.6	52	42.6 24.1	72	54.1 33.4	91	33.3 42.3
Heavy (N=105) 100%											
97	23.7 92.3	6	8.0 5.7	2	4.4 1.9	18	14.7 17.1	8	6.0 7.6	79	28.9 75.2
100%		100%		100%		100%		100%		100%	

b. Additional relationship—age by sediment—included in the complex, triple pair model:

Age (N=528) 100%	Sediment						
	aeolian sand (N=122) 23.2%		littoral sand (N=133) 25.1%		lagoonal clay (N=273) 51.7%		
Middle Palaeolithic (N=408) 100%	83	68.0 20.3	102	76.7 25.1	223	81.7 54.6	
Upper Palaeolithic (N=75) 100%	20	16.4 26.6	23	17.3 30.6	32	11.7 42.6	
Later (N=45) 100%	19	15.6 42.2	8	6.0 17.7	18	6.6 40.1	
		100%		100%		100%	

through the heavy patina category. The effect of sediment on patina appears more complicated. All sediments have relatively few artifacts with no patina and exhibit virtually no differences in proportions of no patina and slight patina categories (given overall proportions of artifacts from each type of sediment). The medium patina category of artifacts shows a relative increase in those from littoral sands at the expense of those from lagoonal clays. This situation is totally reversed in the heavy patina category where the relative proportion of artifacts from lagoonal clays is greatly increased at the expense of those from littoral sands and to a lesser extent those from aeolian sands.

The reason for the different effects of the sediments on patina may be related to soil properties. Rottländer (1975:109) cites a number of environmental factors that have been found to effect glossy patina in laboratory experiments: "the pH value of the soil; the sodium/potassium (Na/K) ratio provided the soil is alkaline; the former presence of plants if the soil is acid, and [...] the amount of water that passed over the artifact since its deposition." The pH of the littoral and aeolian sands and lagoonal clays on the marine terraces of the Agro Pontino and the Fondi Basin to the south ranges from 5.0 to 8.6 (by H₂O; 4.0-8.2 by CaCl₂). On the whole, littoral and associated sands tend to be more acid than the lagoonal clays (Sevink *et al.* 1984, section 9.2). Rottländer (1975:109) also found that the initial coating of patina may act as a seal against further reaction with the soil until the item becomes slightly cracked or pitted, from, for example, repeated freezing and thawing. This may explain why 30-35% of the artifacts from each of the sediments have slight patina.

The triple pair model shows that the association between age of artifacts and sediment is an additional factor (Table 7b). Somewhat more of the Middle Palaeolithic artifacts are associated with lagoonal clays and somewhat more of the Upper Palaeolithic and later artifacts are associated with aeolian and littoral sands. Moreover, the Upper Palaeolithic artifacts are about equally divided between the aeolian and littoral sandy sediments, whereas the proportion of later artifacts associated with aeolian sands is greatly increased at the expense of the proportion associated with littoral sands.

At present, the results from this analysis suggest that artifacts found in lagoonal clays with heavy patina most probably date to the Middle Palaeolithic and those with medium patina to the Upper Palaeolithic. Artifacts found in sands with heavy or medium patina probably date to the Middle Palaeolithic, those with slight patina to the Upper Palaeolithic or later, and those with no patina to later than the Upper Palaeolithic. Although the model fits very well with the empirical evidence, the analysis will have to be redone if and when our "diagnostic" sets of artifacts change or are expanded.

4 GENERAL DISTRIBUTION OF LITHIC MATERIALS

During the survey 8,449 lithic artifacts were collected. These consisted of 8,065 flint items, 112 items of obsidian, 66 items made of other types of stone, and 206 whole pebbles.² The probabilistic sample recovered about 24% of the flint artifacts from the beach ridge-lagoon vegetational unit along the coast (see Loving *et al.* Figure 3, this volume). The aeolian area produced 30%, the Latina lagoon 38%, the colluvium 7%, and the peaty graben 1%.

About 60% of the flint artifacts were found in association with a notable landscape feature—an elevated area, a drainage channel, or, most commonly, both.

4.1. Artifact characteristics in relation to the pebble beds

A major feature of the beach ridge-lagoonal area, at least along the southwest coast, is the pebble beds, where flint pebbles of a size appropriate for making tools are found. Certain characteristics of the artifacts may be a function of these beds being the raw

material source. In comparison with areas where no pebbles occur, a larger proportion of cores and bipolar segments are associated with the pebble beds than would be expected by chance. The opposite is true for flakes and blades; indeed, over half of the flakes were found in the aeolian areas and on the Latina lagoon, and almost half of the blades were found in the aeolian areas. The number of items with 40-50% or more cortex and the number of unbroken items is also higher than expected where pebble beds occur.

4.2 Size of artifact and percentage of cortex compared with distance to raw material sources

The raw material source for the flint tools, the pebble beds, is more or less localized and certain artifact features most probably are related to the distance the artifact was deposited away from the source. The research on the Middle-Upper Palaeolithic transition (see Loving *et al.*, this volume) attempts to measure differences in mobility between the Middle and Upper Palaeolithic by comparing stages of discard of the artifacts in a flow model vis-à-vis distance to raw material source. In order to evaluate whether or not the sample had sufficient spatial extent to carry out this analysis, a preliminary investigation of the relations among the size of the artifact, its percentage of cortex, and distance to the nearest pebble bed was undertaken, under the assumption that amount of cortex could serve as a surrogate for stage of discard.

A first analysis used Middle Palaeolithic diagnostic artifacts and ordinal level measurements. It was expected that, controlling for artifact size, the amount of cortex on artifacts would decrease with distance, although not necessarily linearly. The artifacts generally exhibited the expected pattern, and it was decided that the Middle Palaeolithic sample was probably sufficient in extent.

Unfortunately, too few of the Upper Palaeolithic diagnostic tools had any cortex at all to analyze them in the same manner. Partly for this reason and partly because the analysis did not offer any insight into the relationship among the variables, we had a closer look at the variables with partial correlation. This time all artifacts from the Middle Palaeolithic, early Upper Palaeolithic, and late Upper Palaeolithic single-component collections were used, and the variables were not aggregated into ordinal classes. Distance and weight, which were positively skewed, were transformed into logarithms, and cortex was considered the dependent variable. Table 8 shows the zero order and first order correlation

TABLE 8. ZERO-ORDER AND FIRST-ORDER PARTIAL CORRELATION COEFFICIENTS BETWEEN AMOUNT OF CORTEX AND DISTANCE TO SOURCE AND BETWEEN AMOUNT OF CORTEX AND WEIGHT OF ARTIFACT, SHOWN BY TIME PERIOD, WITH AMOUNT OF CORTEX AS THE DEPENDENT VARIABLE.

Period	Zero-order			First-order	
	Cortex-distance	Cortex-weight	Distance-weight	Cortex-distance controlling for weight	Cortex-weight controlling for distance
Middle Palaeolithic (N = 398)	-.2395 (p < .0005)	.5369 (p < .0005)	-.0309 (p = .270)	-.2643 (p < .0005)	.5456 (p < .0005)
Early Upper Palaeolithic (N = 74)	-.0861 (p = .233)	.3978 (p < .0005)	-.0921 (p = .218)	-.0542 (p = .324)	.3930 (p < .0005)
Late Upper Palaeolithic (N = 174)	-.1404 (p = .032)	.4399 (p < .0005)	.0006 (p = .497)	-.1566 (p = .020)	.4444 (p < .0005)

coefficients and their probabilities under the null hypothesis of no correlation for the three periods. Distance and weight seem to have independent effects on cortex. In every case, weight exhibits a stronger correlation with cortex than does distance. The negative correlation between distance and cortex is stronger in the Middle Palaeolithic collection than in the late Upper Palaeolithic collection. What is interesting is that distance to the pebble beds and amount of cortex seem to have no relationship in the early Upper Palaeolithic collection. In section 3.2 above, it was noted that the early Upper Palaeolithic collection contains some items made from nodular flint, which is not found in the Agro Pontino. Thus, the results of the partial correlation may indicate that some of the early Upper Palaeolithic items have a different raw material source. Given this possibility and the dependency of the analysis on an early Upper Palaeolithic sample composed of artifacts made on pebbles, it was decided to incorporate the early Upper Palaeolithic samples found in the Fondi Basin to the south. The artifacts deposited there are further away from the pebble beds, but not closer to other flint sources as far as we know.

Multiple regression of the three variables showed that together distance and weight explained 27.6% of the variance in cortex in the Middle Palaeolithic collection ($R = .5255$) and 21.3% ($R = .4619$) in the late Upper Palaeolithic collection. Although this shows that more variables are involved in the relation between cortex and distance, it is already apparent that with respect to the amount of cortex the Middle Palaeolithic and late Upper Palaeolithic are more similar to each other than either is to the early Upper Palaeolithic. The difference between the Middle Palaeolithic and the late Upper Palaeolithic may mean that distance was less a constraint during the latter period, and/or it may be due to technological differences, since the late Upper Palaeolithic is a leptolithic industry. This remains to be investigated.

5 DIVERSITY AND ASSEMBLAGE STRUCTURE

The final application to be discussed is the grouping of tool types and waste types that were used to evaluate adequacy of the size of samples for measuring mobility structure in the research on the Middle-Upper Palaeolithic transition (see Loving *et al.*, this volume). The evaluation used a diversity index.

Diversity indices are affected by the number of classes as well as how equally these classes are filled, and so it was thought important that classes be broad and chronologically insensitive. Thus, classes were constructed that, theoretically, should be so. No distinctions were made between flakes and blades or between burins and borers, for example. The classes were: scrapers, burins and borers, points, other retouched pieces regardless of waste type, utilized pieces regardless of waste type, cores, flakes and blades, blocks, and resharpening pieces.

When the overall frequency distribution of these classes was compared with the single-component collections, however, it was apparent that there were differences among the collections currently representing the different chronological periods. Each collection was evaluated with a chi-square test using the overall distribution as the expected distribution. Also diversity indices were calculated for all collections, including the overall collection.

The chi-square test showed differences between the overall collection and the Middle Palaeolithic one ($N = 248$, chi-square = 24.86, $df = 8$, $p < .01$) and also the Neolithic one ($N = 53$, chi-square = 13.43, $df = 8$, $p < 0.1$). In the Middle Palaeolithic collection, this was primarily due to almost twice as many scrapers and resharpening pieces and many more blocks than expected from the overall distribution. The Neolithic score was due to fewer scrapers and more cores than the overall distribution.

The diversity indices also showed differences (see Table 9). The Middle Palaeolithic index is higher than the overall one because the classes are more evenly filled. The other three periods lacked at least one class; even so, the late Upper Palaeolithic diversity index

TABLE 9. DIVERSITY INDICES OF ALL FLINT ARTIFACTS AND SINGLE-COMPONENT COLLECTIONS OF FOUR CHRONOLOGICAL PERIODS, SHOWN BY NINE ARTIFACT CLASSES.

Artifact class	All artifacts	Middle Palaeolithic	Upper Palaeolithic early	Upper Palaeolithic late	Neolithic
scrapers	-.1942	-.2763	-.2686	-.2416	-.0749
burins	-.0833	-.1108	-.0846	-.0728	-
points	-.0867	-.0665	-.0846	-.0728	-.0749
other retouched tools	-.2555	-.2414	-.2441	-.2416	-.1950
utilized items	-.3038	-.2763	-.3444	-.3482	-.3146
cores	-.3552	-.3466	-.2894	-.3099	-.3622
flakes/blades	-.3465	-.3340	-.3218	-.3321	-.3146
blocks	-.1592	-.2030	-	-.2179	-
resharpening pieces	-.0165	-.0389	-	-	-
$H = - \sum_{i=1}^s p_i \log p_i$	1.8009	1.8938	1.6375	1.8369	1.3358

where:

s = artifact class

p = number of artifacts in a class

is higher than the overall one. Thus, we may want to conclude that, contrary to our intentions, the classes selected are not chronologically insensitive, at least in this area.

Might these results, however, reveal structural differences in collections between time periods? Before suggesting this, we needed to answer at least two questions. The first was, are the sample sizes representing the time periods large enough to have any confidence in these results? And the second was, how different does the diversity index have to be before a difference is significant?

To answer the first question we subjected all collections, except the Middle Palaeolithic one which clearly had a large enough sample size, to the same analysis used to evaluate the adequacy of sample size of the artifacts collected from individual sites (see Loving *et al.*, this volume). Figure 1 shows that the late Upper Palaeolithic collection is adequate, i.e., that the running mean of the standard deviation of the diversity index stabilizes, that the Neolithic collection is probably adequate, but that the early Upper Palaeolithic collection should be larger.

To answer the second question, we used a method devised by K. Kintigh (1984, 1989) for comparing samples with generated expected diversities for given sample sizes; the generation is made from the sample itself and is based on richness—the number of classes filled—and uses overall frequencies as the “standard” for evenness. Figure 2 shows the results obtained using Kintigh’s (1988) computer program DIVERS. The curves of expected values were generated using all the flint artifacts collected by the survey. Both the Middle Palaeolithic and the Neolithic samples are more than 1.65 standard deviations away from the mean of the simulated curve in richness ($p < .1$), the Middle Palaeolithic being higher than the mean and the Neolithic lower. In evenness, the Middle Palaeolithic sample is also more than 1.65 standard deviations higher than the mean of the simulated curve, but the Neolithic sample is so low that it is completely out of the range of the simulated curve.

If we assume that greater richness and more evenly filled classes represents a larger span of activities in the past, we can suggest why there are differences in diversity between the Middle Palaeolithic and Neolithic collections. The Middle Palaeolithic

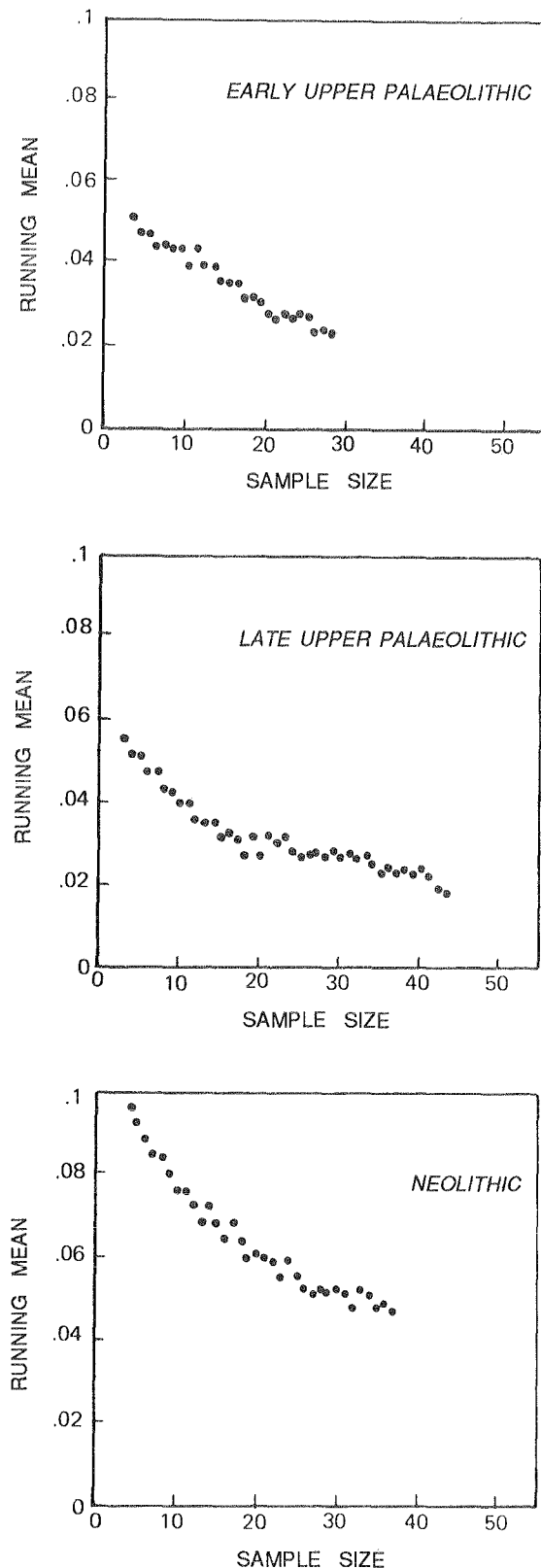


Figure 1. Running mean of standard deviations of diversity indices versus sample size, shown by period.

diversity is possibly a result of a full range of activities for at least a limited span of time and not merely a palimpsest of limited activities over a long period of time, which may or may not be indicated for the Upper Palaeolithic. The Neolithic diversity, on the other hand, possibly indicates a very limited range of activities, perhaps seasonal transhumance and/or very localized occupation, perhaps along the coast engaged in exchanging obsidian, which is found on the Pontinian islands about 30 km offshore and was distributed in Central Italy (Hallem *et al.* 1976). Considerable quantities of this obsidian have been found between Sabaudia and Monte Circeo on the southwest coast of the Agro Pontino (Ceruleo and Zei 1986).

6. SUMMARY AND CONCLUSIONS

Surface materials collected from a region present different kinds of problems for analysis than do materials collected from an excavation, but they also offer different kinds of opportunities. The biggest problem is dating the finds. Thus far we have found two variables, butt dimensions and patina, that may help to date the sites and to partition some of the artifacts in multicomponent sites. The search for technological differences among single-component sites continues and results will be evaluated using dated collections from sealed contexts.

Nevertheless, it is a gross simplification, if not pure fiction in most cases, to assume that artifacts found together were deposited together prehistorically. It is also less than optimal to use "diagnostic" types to make preliminary assessments of the age of collections, not so much because the typological approach is increasingly discredited, but more because one has an unknown probability of being wrong in each case.

But, we have made such assumptions in order to try to exploit the opportunities a regional survey offers. It would be difficult, for example, to investigate the relation between patina, sediment, and age of artifacts in any other context. It would also be difficult to see features of the early Upper

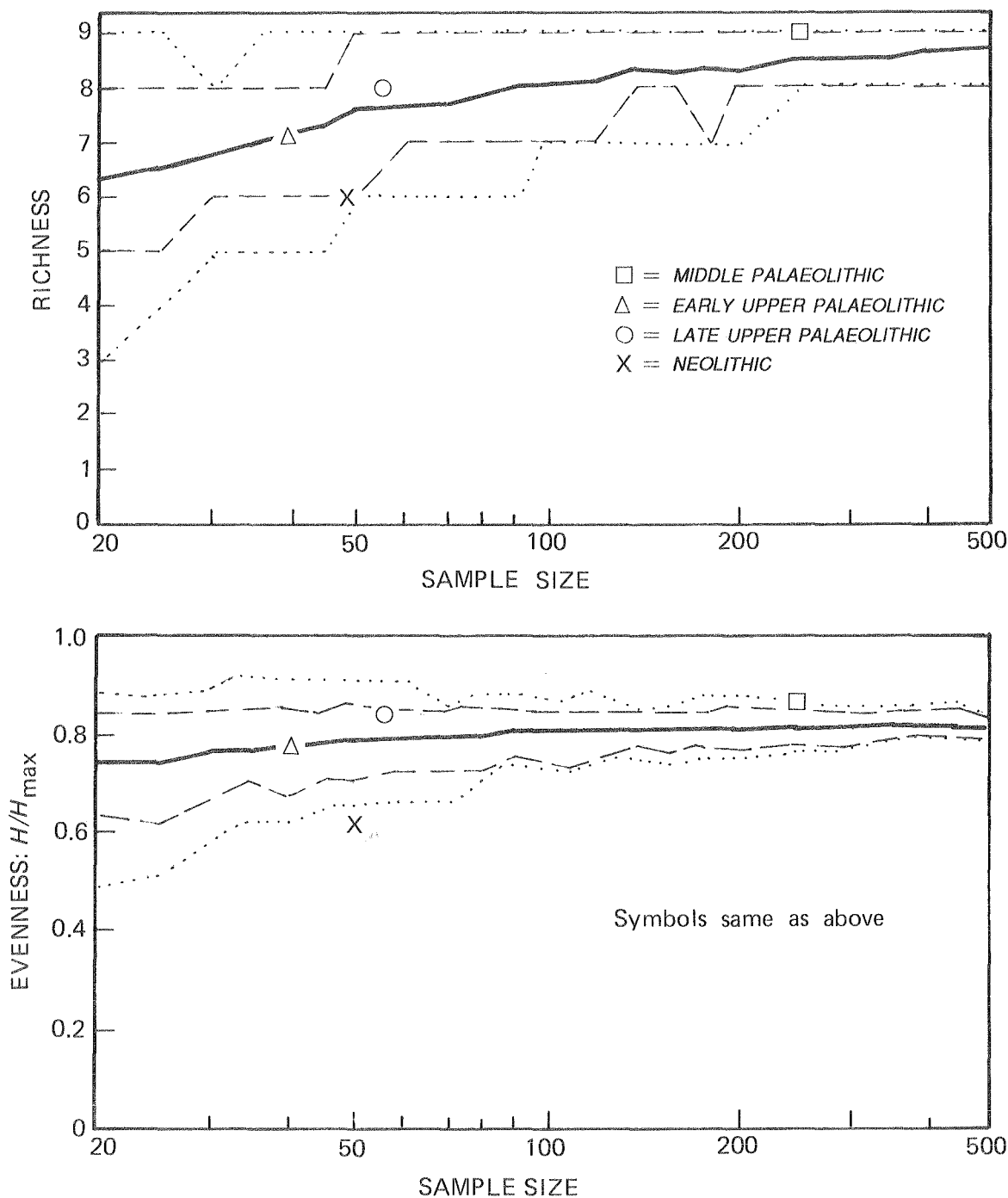


Figure 2. Diversity of collections and expected diversity versus sample size. upper: richness, lower: evenness.

Palaeolithic collections that, when compared with collections of other periods, point to more than one source of raw materials. Of course, if many of the assessments of the ages of collections turn out to be wrong, then the results of these first analyses will be invalid and the analyses will have to be redone. That seems a small price to pay if in the process we identify hitherto unrecognized chronological variation in the artifacts and can contribute to a regional perspective on the prehistory of the Agro Pontino and surroundings.

NOTES

1. Butt depth measurement followed Dibble and Whittaker's (1981:285) "platform depth" measurement.
2. The number of flint artifacts cited here (8,065) and that in Table 1 (8,017) differ because some items were lost before they could be analyzed.

REFERENCES

- Bietti, A., 1976/1977.
Analysis and illustration of the Epigravettian industry collected during the 1955 excavations at Palidoro (Rome, Italy). *Quaternaria* 19:197-387.
- Bietti, A., 1984.
Il Mesolitico nel Lazio. *Atti della XXIV Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria nel Lazio, October 8-11, 1982.*
- Bordes, F., 1961.
Typologie du Paléolithique Ancien et Moyen. Publications de l'Institut de Préhistoire de l'Université de Bordeaux. Memoire No. 1. 2nd edition. Bordeaux: Imprimeries Delmas.
- Ceruleo, P., and M. Zei, 1986.
Il giacimento preistorico della penisola dei Casarini sul Lago di Paola (Saubaudia) in provincia di Latina. *Studi per l'Ecologia del Quaternario.*
- Crabtree, D.E., 1972.
An Introduction to Flintworking. Occasional Papers of the Idaho State University Museum, No. 28. Pocatello.
- Dibble, H.L., and J.C. Whittaker, 1981.
New experimental evidence on the relation between percussion flaking and flake variation. *Journal of Archaeological Science* 8:283-296.
- Hallam, B.R., S.E. Warren, and C. Renfrew, 1976.
Obsidian in the Western Mediterranean. *Proceedings of the Prehistoric Society* 42:85-110.
- Kamermans, H., 1984.
Artefacten onderzoek Agro Pontino Project. Internal report. Istituto Olandese Roma.
- Kintigh, K.W., 1984.
Measuring archaeological diversity by comparison with simulated assemblages. *American Antiquity* 49:44-54.
- Kintigh, K.W., 1988.
The Archaeologist's Analytical Toolkit. Computer programs. Tempe, Arizona.
- Kintigh, K.W., 1989.
Sample size, significance, and measures of diversity. In: R.D. Leonard and G.T. Jones (eds.), *Quantifying Diversity in Archaeology.* Cambridge: Cambridge University Press. p. 25-36.
- Laplace, G., 1964.
Essai de typologie systématique. *Ann. Università di Ferrara*, sez. XV, supplement 1.
- Loving, S.H., A. Voorrips, and H. Kamermans, 1985.
New finds in old fields. Internal report. Instituut voor Prae- en Protohistorie, University of Amsterdam.
- Rottländer, R., 1975.
The formation of patina on flint. *Archaeometry* 17:106-110.
- Sevink, J., A. Remmelzwaal, and O.C. Spaargaren, 1984.
The Soils of Southern Lazio and Adjacent Campania. Fysisch Geografisch en Bodemkundig Laboratorium, University of Amsterdam. Publication no. 38.
- Shennan, S., 1988.
Quantifying Archaeology. Edinburgh: Edinburgh University Press.
- Sonneville-Bordes, D. de, and J. Perrot, 1954-56.
Lexique typologique du Paléolithique supérieur. *Bulletin Société Préhistorique Française* 51:237-355; 52:76-79; 53:408-412; 53:547-559.
- SPSS, Inc., 1988.
Statistical Package for the Social Sciences. Version X. Computer programs. Gorinchem, The Netherlands.

APPENDIX: MAPS OF THE AGRO PONTINO SHOWING SITES IDENTIFIED BY THE SURVEY FOR THE DIFFERENT PERIODS.

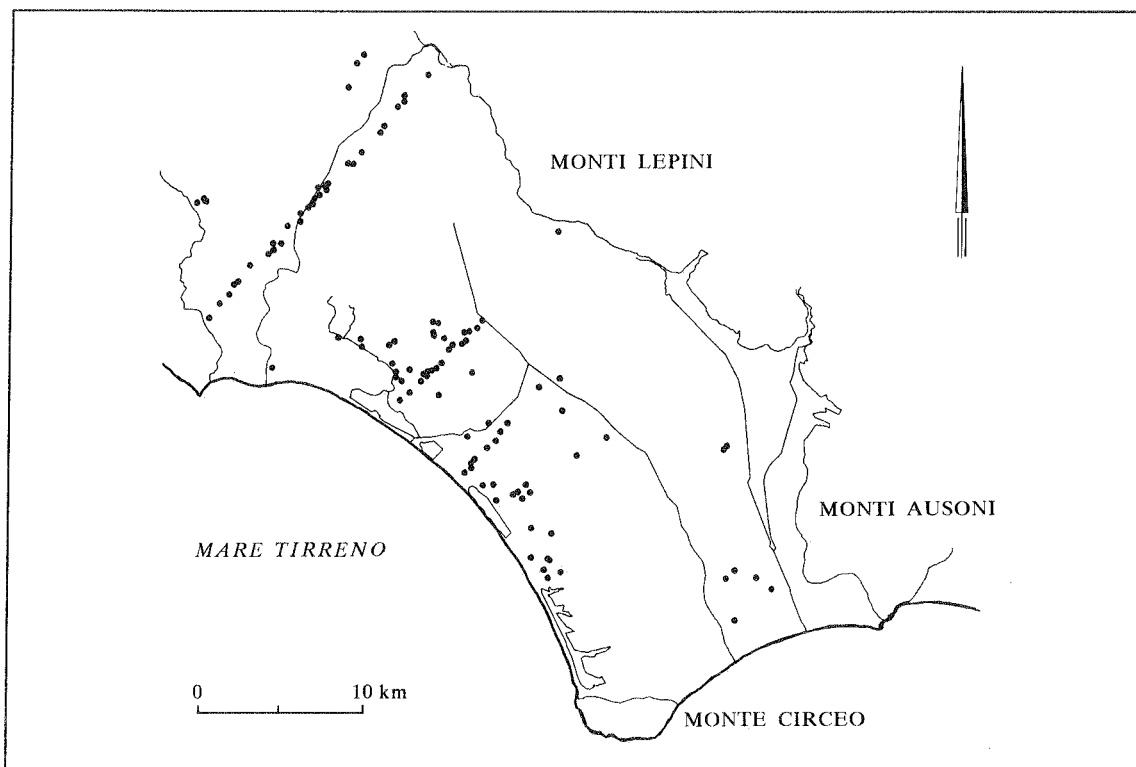


Figure 3. Middle Palaeolithic sites identified by the survey.

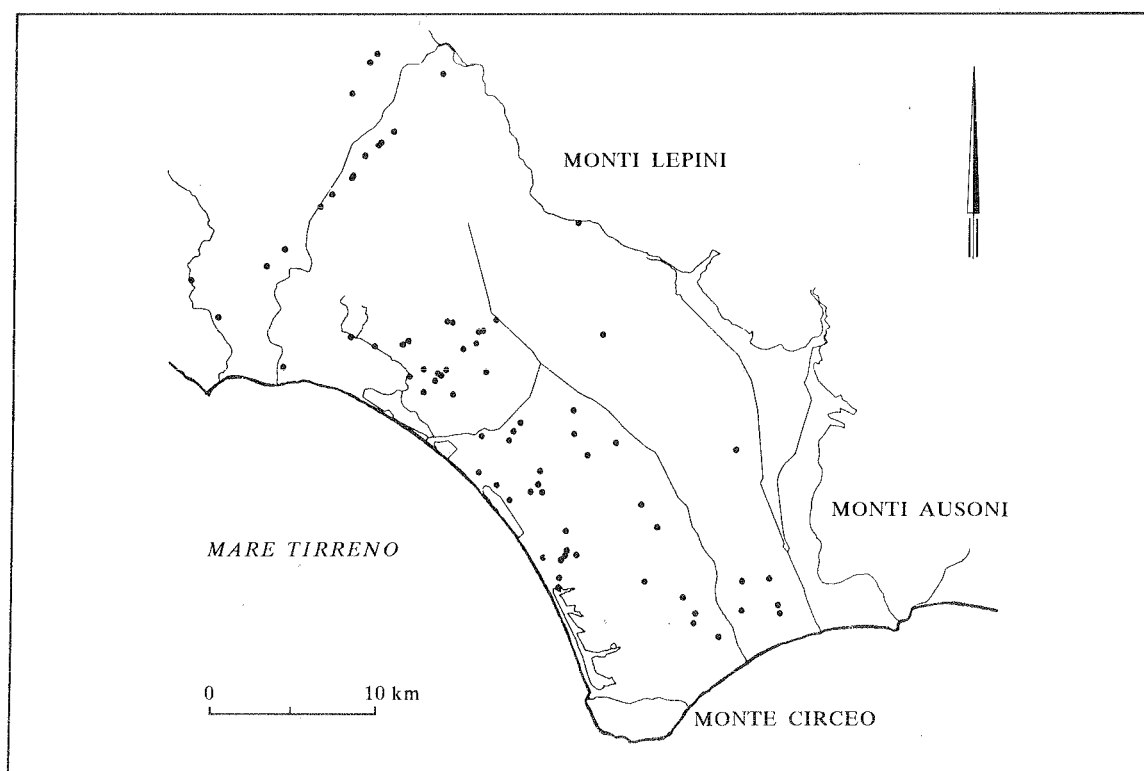


Figure 4. Early Upper Palaeolithic sites identified by the survey.

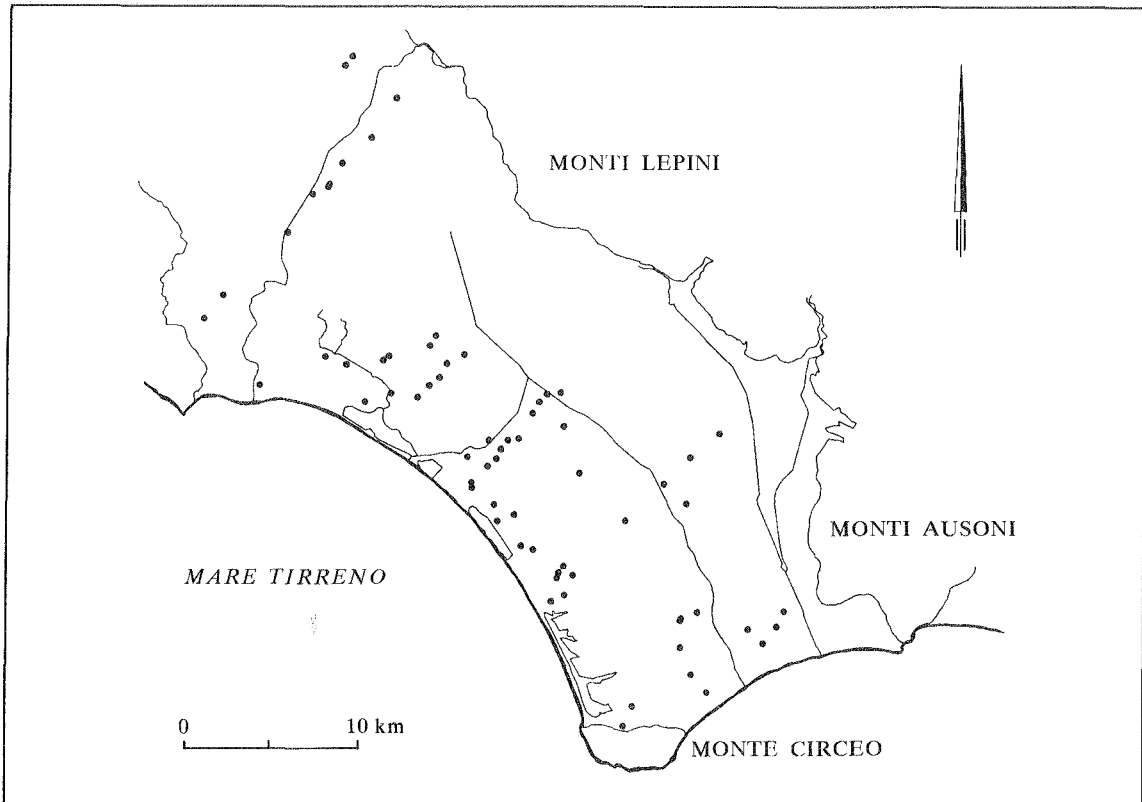


Figure 5. Late Upper Palaeolithic and Mesolithic sites identified by the survey.

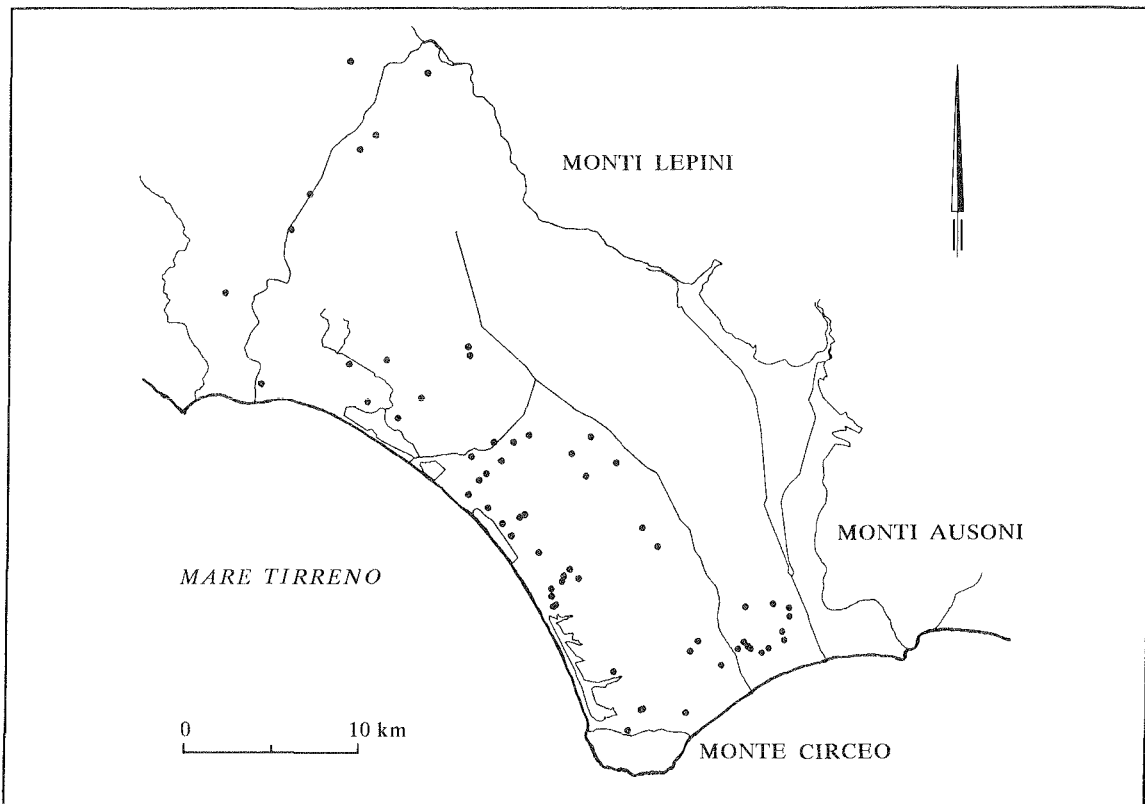


Figure 6. Neolithic sites identified by the survey.