QUANTITATIVE SPATIAL ANALYSIS: COMPUTER APPLICATIONS OF NEAREST NEIGHBOR AND RELATED APPROACHES TO THE ANALYSIS OF OBJECTS DISTRIBUTED ACROSS TWO-DIMENSIONAL SPACE

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Analytical techniques designed to deal with spatial distributions in archaeological contexts have recently been brought to the attention of the field (Whallon 1973, 1974). Developed originally by plant ecologists (Clark and Evans 1954), these approaches constitute a methodological advance over commonly used subjective criteria for the evaluation of the existence and/or significance of spatial patterns. This paper analyzes spatial associations of artefact types at Liencres, an open-air site on the north Spanish coast. A nearest neighbour analysis is a central feature of this study. Graphic output from the nearest neighbour program allows for objective measurement of spatially overlapping clusters of objects by com paring the distributions of those objects with random, maximally dispersed and maximally aggregated theoretical distributions adjusted for density. Jaccard's coefficient, chi-squared and Pearson's contingency coefficient are used 1) to compare tool frequencies occurring in 'shared space' (Hanson and Goodyear 1975), 2) to evaluate the (statistical) significance of point scatters and 3) to measure the strength of relationship between spatially co occurring pairs of tool types.

INTRODUCTION

This paper discusses several current approaches to intrasite spatial analysis and applies them to artifactual data from Liencres, an early Holocene open site in Cantabrian Spain. A nearest neighbor analysis is performed to assess the degree of aggregation or dispersion of common artifact types; Jaccard's coefficient provides a measure of similarity in spatial distribution for each pair of types; chi-squared evaluates the statistical significance of tool frequencies occurring in shared space and Pearson's contingency coefficient is used to measure the strength of relationship. The "shared tool" method advocated by Hanson (1975) is employed throughout.

The test site, Liencres, was discovered and excavated in 1969 (Clark 1974). Artifacts appearing on the deflated surface of a blowout were determined to be associated with the A-horizon of the *terra fusca* soil characteristic of Post-Pleistocene pedogenesis in the area (Butzer and Bowman 1971). Although a slight degree of vertical displacement may have occurred as a consequence of deflation, stratigraphic tests indicate a single, shallow (ca. 5 cm. thick) cultural stratum coextensive with that exposed in the deflated area. The degree of post-depositional disturbance is thus argued to have been minimal.

A systematic surface collection was undertaken first in order to determine the horizontal distribution of artifactual debris. Maximum surface scatter at the site covered an area some 9 m. wide by 20 m. long (ca. 180 $m.^2$). The area was small enough for a sample approaching 100% to be collected, thus the problem of sampling error did not enter into the project in its initial phase. A grid of 663 squares 50 cm. on a side was erected over the site. The positions of all artifacts were plotted on a master plan, and their co-ordinates entered on coding forms for subsequent analysis. More than 1,000 artifacts were collected; subsets taken from these point-provenienced data constitute the data used in this analysis.

It was concluded from the paucity of features and from the relatively thin scatter of lithic debris that occupation at the site was of short duration. That primary tool manufacturing activities were conducted was inferred from the scarceness of retouched pieces and the prevalence of debitage. No identifiable faunal remains were recovered, but the presence of a grinding slab, tiny shell and bone fragments, and phosphate concentrations suggest food processing and consumption, and some accumulation of garbage (Butzer and Bowman 1971; Clark 1974).

Although almost 40 morphologically defined types were recovered from the surface collection (de Sonneville Bordes and Perrot 1954, 1955, 1956; Clark 1971), data used in this study were restricted to the 15 tool and debitage categories which were numerically common on the site. In an effort to make inferences about past behavioral patterns, hypothetical and intentionally broad functions were assigned to each type at the outset, and some speculations were offered about materials worked, where appropriate to do so (Table 1). Finally, types were broken down into 1) those items which could be considered resultant from primary manufacturing activities, related to the acquisition of raw materials and core preparation, 2) secondary manufacture and its resultant byproducts, and 3) formalized tools, or systematically retouched pieces. The initial assumption was that activities identifiable from their archaeological residues might be spatially discrete or at least distinguishable from one another. A second assumption was that the artifacts constitute mainly "primary" and "de facto" refuse, in the jargon of Schiffer (1975); they are debris categories 1) discarded at the location of manufacture and/or use, and 2) items abandoned with the abandonment of the site (Schiffer 1975:104). Because of the transient nature of the occupation, it is argued that discrete dumps or "secondary" refuse discard areas would not have had time to develop.

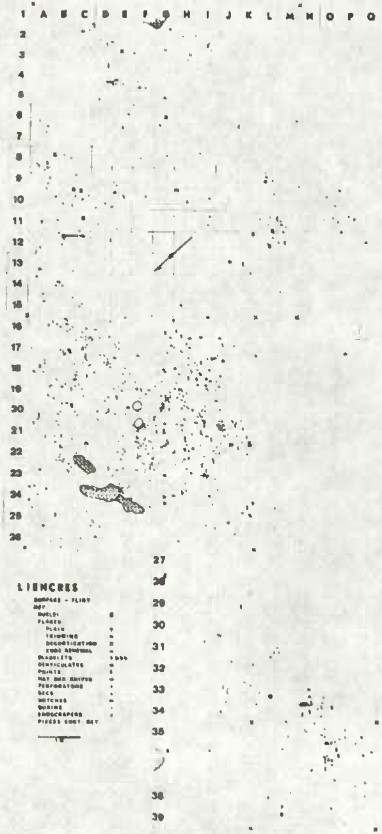


FIGURE 1. LIENCRES: SURFACE COLLECTION - DISTRIBUTION OF FLINT AND CHERT ARTEFACTS AND DEBITAGE. THE HATCHED AREAS ARE LIMESTONE OUTCROPS. THE CIRCLES IN (20,F) AND (21,F) REPRESENT A MASSIVE QUARTZITE GRINDING SLAB AND COBBLE, THE ONLY FEATURES PRESENT ON THE SITE SURFACE.

FIGURE 2. LIENCRES: SURFACE COLLECTION - DISTRIBUTION OF QUARTZITE ARTEFACTS AND DEBITAGE.

TABLE 1

DEBITAGE CATEGORIES AND RETOUCHED PIECES COMMONLY FOUND AT LIENCRES - MORPHOLOGICAL TYPES, HYPOTHETICAL FUNCTIONS AND MATERIALS WORKED.

PROCESS	MORPHOLOGICAL TYPES	SPECULATIVE FUNCTIONS	MATERIALS WORKED
PRIMARY MANUFACTURE + BYPRODUCTS	unmodified cobbles (Q)	raw material; hammering, crushing	stone, vegetal matter (nuts, seeds)
	split cobble segments (Q)	core preparation; hammering, crushing	stone, vegetal matter (nuts, seeds)
	nuclei	raw material	none
	primary decortication flakes	core preparation; cutting, slicing	wood, antler/bone, hides, vegetal matter
	core removal flakes (F)	core rejuvenation	none
SECONDARY MANUFACTURE + BYPRODUCTS	secondary decortication flakes	secondary manufacture; light cutting, slicing	wood, antler/bone, hides, vegetal matter, flesh
	plain flakes	secondary manufacture; light cutting, slicing	wood, antler/bone, hides, vegetal matter, flesh
	trimming flakes (Q)	edge retouch on Asturian picks	none
	trimming flakes (F)	secondary retouch, shatter	none
	bladelets	light slicing, cutting, shaving	wood, antler/bone, hides, vegetal matter, flesh
FORMALIZED TOOLS	notches	light shaving, scraping cylindrical objects	wood, antler/bone
	denticulates	sawing, shredding fibrous material	wood, antler/bone, fibrous vegetal matter
	perforators	drilling, piercing	wood, antler/bone, hides
	becs	piercing, possibly graving	wood, antler/bone
	burins	scraping, graving	wood, antler/bone
	nucleiform endscrapers	planing, scraping	wood
	picks	hammering, mashing, digging	wood, bone/antler, earth
	choppers	chopping, shredding, heavy-duty cutting	wood, bone/antler, flesh
	chopping tools	chopping, shredding, heavy-duty cutting	wood, bone/antler, flesh
	grinding slabs	grinding, crushing	seeds, nuts, vegetal matter, pigments

THE NEAREST NEIGHBOR ANALYSIS

With the aid of a computer program written originally by T.P.Muller at the University of Chicago, and subsequently much revised, a nearest neighbor analysis was performed on the surface array, using the Clark and Evans (1954) formula for first-order nearest neighbor, testing for significance using the standard normal variable (Fig.3). The nearest neighbor statistic is an objective measure of the degree of departure from randomness toward maximal dispersion or aggregation of points distributed across a 2-dimensional surface. For obvious reasons, the statistic is extremely sensitive to area; area was defined at Liencres as equivalent to the area of the grid shown in Figs. 1 and 2. The boundary problem (cf. Whallon 1974:22, 23) was not particularly important in this case because areas on the peripheries of the grid were also inspected. Only on the northeast side of the scatter did any artifacts occur in proximity to and outside of the grid boundary. The positions of these pieces were plotted and suitable adjustments in the sample size were made for each type.

The results of this analysis are presented in Table 2. It was noted, first, that quartzite nuclei, split cobble segments and plain flakes tended to be more or less randomly distributed, along with flint core renewal flakes, perforators, becs and nucleiform endscrapers. This implies that activity sets in which these items functioned were generally distributed in space across the site, or, alternatively, that these items were discarded at random after use. The influence of large N on the nearest neighbor statistic would seem to be pronounced. Those types which depart most markedly from ran domness are flint trimming, plain and decortication flakes, all of which are more aggregated than would be expected. The distributions of quartzite decortication and trimming flakes also departs significantly from randomness. These are precisely those types which are numerically most common on the site surface.

NEAREST NEIGHBOR STATISTIC

$$R_n = \frac{\sum_{i=1}^{r} r_i / N}{\frac{1}{2\sqrt{\rho}}} \qquad \text{where:}$$

r = distance to first nearest neighbor, summed over N
N = number of measurements taken in the observed population
ρ = density of the observed population, given by N/A
A = area in units comparable to those used to compute r

Range R_n = 0 to 2.15, where R_n = 0, N points are clustered in one spot in A, or, alternatively, occur as pairs, triplets etc.; R_n = 1 indicates a random distribution in A and R_n = 2.15 indicates maximal dispersion.

TEST OF SIGNIFICANCE

$$c = \frac{\bar{r}_a - \bar{r}_e}{\sigma_{\bar{r}_e}} \qquad \text{where:}$$

$\bar{r}_a = \sum r/N$, the mean distance to nearest neighbor
$\bar{r}_e = 1/2\sqrt{\rho}$, the mean distance to nearest neighbor expected in an infinitely large random distribution of density
$\sigma_{\bar{r}_e} = 0.26136/\sqrt{\rho}$, the standard error of the mean distance to nearest neighbor in a randomly distributed population of density ρ

(after Clark and Evans 1954:445-453)

FIGURE 3. THE NEAREST NEIGHBOR STATISTIC (R_n) AND ITS TEST OF SIGNIFICANCE (c) (CLARK AND EVANS 1954:445-453).

TABLE 2

LIENCRES: SURFACE COLLECTION - THE NEAREST NEIGHBOR STATISTIC (R_n) FOR COMMON ARTIFACT TYPES. OBSERVED ($\bar{r}_a$) AND EXPECTED ($\bar{r}_e$) MEAN DISTANCES ARE GIVEN, WITH STANDARD DEVIATION BY DENSITY ρ ($\sigma_{\bar{r}_e}$), STANDARD NORMAL VARIABLE (c) AND ITS ASSOCIATED PROBABILITY (p(c)).

ARTIFACT TYPE	N	R_n	$\sum r/N (=\bar{r}_a)$	$\rho = N/A$	$1/2\sqrt{\rho}\ (=\bar{r}_e)$	$0.26136/\sqrt{N\rho}\ (=\sigma_{\bar{r}_e})$	c	p(c)
pebbles, cobbles: unmod.,								
quartzite	11	.551	52.871	.000029	91.592	14.436	-2.67	.0076
nuclei, flint	18	.648	47.727	.000048	71.597	8.821	-2.70	.0058
nuclei, quartzite	6	.919	124.849	.000016	124.038	26.460	+0.03	.9760
split cobble segments,								
quartzite	14	.681	57.346	.000037	81.186	11.342	-2.10	.0358
flakes, decortication:								
flint	267	.598	11.146	.000723	18.589	.585	-12.81	.0002
flakes, decortication:								
quartzite	54	.432	18.009	.000146	41.336	2.940	-8.13	.0002
flakes, plain: flint	194	.595	13.001	.000525	21.809	.818	-10.76	.0002
flakes, plain: quartzite	14	.777	65.429	.000037	81.221	11.342	-1.39	.1646
flakes, trimming: flint	91	.691	22.117	.000246	31.841	1.745	-5.57	.0002
flakes, trimming: qtzte.	19	.508	36.390	.000051	68.687	8.357	-3.86	.0002
flakes, core renewal:								
flint	5	.533	80.942	.000013	135.888	31.764	-1.73	.0836
bladelets, flint	43	.757	35.488	.000116	46.322	3.692	-2.93	.0034
perforators, becs:								
flint	11	1.125	106.023	.000029	91.600	14.436	+1.14	.2542
notches, denticulates:								
flint	11	1.288	121.880	.000029	91.600	14.436	+2.10	.0358
retouched bladelets:								
flint	6	.452	61.457	.000016	124.039	26.469	-2.36	.0182
burins: flint	8	.381	43.750	.000021	107.411	19.851	-3.21	.0014
endscrapers, nucleiform:								
flint	8	1.135	130.328	.000021	107.411	19.851	+1.15	.2502

BASIC STATISTICS AND THE COEFFICIENT OF JACCARD

It should be kept in mind that the nearest neighbor statistic measures the degree of dispersion or aggregation of points; by itself, it does not provide any information about the association of the types represented by those points. The mean distance to nearest neighbor, however, and its standard deviation are basic statistics which are useful in regard to this problem. Theoretically, the interval defined by the mean distance to nearest neighbor plus its standard deviation, or $\bar{x} + s$, should include 84% of the distances between items of like type in the distribution. Inspection of Table 3 indicates that the proportion of n included in $\bar{x} + s$ is actually about 85%. This fact is useful, as Whallon (1974) has pointed out, for the definition and comparison of spatial clusters of artifact types. Circles the radii of which correspond to the interval $\bar{x} + s$ are constructed for each type; the sum of the circle areas constitutes what might be called the type specific interaction space. CALCOMP plotter generated interaction spaces for major debitage categories are given in Figs. 4-8. By using the overlay procedure advocated by Whallon (1974), 120 non-reflexive pairwise comparisons were made of the 15 most commonly represented artifact types. All types with frequencies fewer than 8 were eliminated. The comparisons were evaluated using the similarity coefficient of Jaccard(Sokal and Sneath 1963:126-129). If, for each comparison, A is the first type and B the second, it is possible to construct a 2 x 2 contingency table of the form given in Fig. 9. The proportion of N items in the AB intersect is contrasted with the proportion of items in A but NOT IN B, and in B but NOT IN A. The fourth cell in the table, items not in A and not in B is, in this case, an empty set (Hanson 1975; Hanson and Goodyear 1975). The proportions are essentially a ratio between shared and unshared items which excludes the empty set (Hanson 1975). The results are given in Table 4 and may be interpreted directly as an item-based index of spatial association ranging from 1.00, which would imply distributions in which all items in A are contained in B, and vice versa, to zero, in which case no items in A are contained in B. As is clear from inspection of Table 4, the major debitage categories overlap extensively in terms of their interaction space, which implies that the various activities related to core preparation and primary production of flakes and blades were conducted in areas which were not spatially discrete.

THE CHI-SQUARED TEST

Although the coefficient of Jaccard can be interpreted directly in terms of a correlation coefficient matrix, or used as a basis for a cluster analysis (Whallon 1974), it should be noted that the statistical significance of the values obtained is not known. In other words, no parametric value can be attached to the proportion of positive matches, a weakness of clustering techniques in general. In order to assess the statistical significance of the associations, standard chi-squared tests were performed on the same pairwise comparisons evaluated with the coefficient of Jaccard. In this test, the null hypothesis (H_O) is that the observed cell frequencies do not differ by an order of magnitude greater than that which would be expected due to chance

TABLE 3

LIMEURES: SURFACE COLLECTION - BASIC STATISTICS FOR ASSOCIATION COMPARISONS OF COMMON ARTIFACT TYPES. TOTAL NUMBER COLLECTED BY TYPE (N), NUMBER USED IN CALCULATIONS (n) ARE GIVEN, WITH SUM OF DISTANCES TO NEAREST NEIGHBOR ($\sum x_i$) FOR AREA REDUCED 50%, MEAN DISTANCE TO NEAREST NEIGHBOR ($\bar{x}$), SUM OF SQUARED DEVIATIONS ($\sum(x_i-\bar{x})^2$), SAMPLE STANDARD DEVIATIONS (s), MEAN PLUS STANDARD DEVIATION ($\bar{x}+s$), ADJUSTED RADIUS ($\frac{1}{2}\bar{x}+s$) FOR MEASUREMENTS TAKEN ON ORIGINAL MAPS, AND PROPORTION OF n INCLUDED IN $\bar{x}+s$.

ARTIFACT TYPE	N	n	$\sum x_i$	$\bar{x}$	$\sum(x_i-\bar{x})^2$	s	$\bar{x}+s$	$\frac{1}{2}\bar{x}+s$	% n included in $\bar{x}+s$
QUARTZITE:									
flakes, trimming	19	15	359	23.93	4442.9	17.81	41.74	20.87	.866
flakes, decortication	53	50	811	16.22	21060.66	20.73	36.95	18.47	.880
flakes, plain	14	12	584	48.66	12615.06	33.86	82.52	41.26	.833
split cobble segments	14	11	488	44.36	1016.55	10.08	54.44	---	.816
pebbles, cobbles:									
unmodified	11	9	243	27.00	4682.00	24.21	51.21	---	.666
nuclei*	7	3	145	48.33	3266.67	40.41	88.74	---	.857
FLINT:									
flakes, trimming	91	83	842	10.14	5052.84	7.85	17.99	---	.903
flakes, decortication									
	267	256	1697	6.62	6604.75	5.08	11.70	---	.875
flakes, plain	194	185	1405	7.59	10755.15	7.64	15.23	---	.902
flakes, core removal*	5	4	94	23.50	801.00	17.23	40.73	---	.750
bladelets, unretouched									
	43	40	547	13.67	6008.79	12.41	26.08	---	.900
nuclei	18	16	412	25.75	4022.96	18.11	43.86	---	.875
bladelets, retouched*	6	5	182	36.40	3457.20	29.39	65.79	---	.800
perforators, becs	11	8	247	30.87	4456.90	25.23	56.10	---	.750
notches, denticulates	11	9	503	55.88	1110.85	11.78	67.66	---	.888
burins	8	8	361	29.00	3068.00	16.15	45.15	---	.888
endscrapers, nucleiform									
	8	8	486	60.75	2130.48	17.46	78.23	---	.875
continuously retouched									
pieces*	5	5	472	94.40	11857.20	54.44	148.84	---	1.000

* indicates n too small for inclusion in calculations

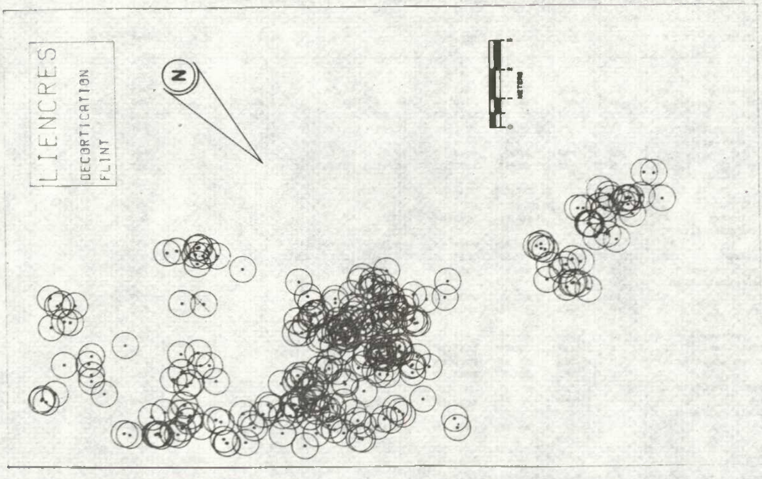


FIGURE 4. LIENCRES: SURFACE COLLECTION - DISTRIBUTION OF FLINT PRIMARY AND SECONDARY DECORTICATION FLAKES.

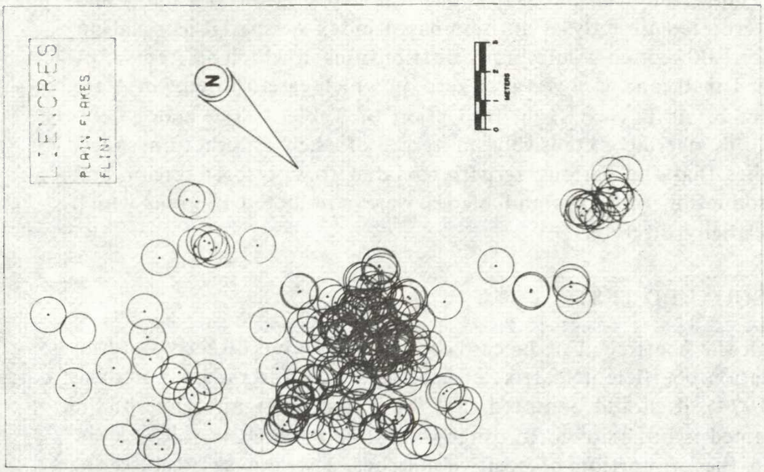


FIGURE 5. LIENCRES: SURFACE COLLECTION - DISTRIBUTION OF FLINT PLAIN FLAKES.

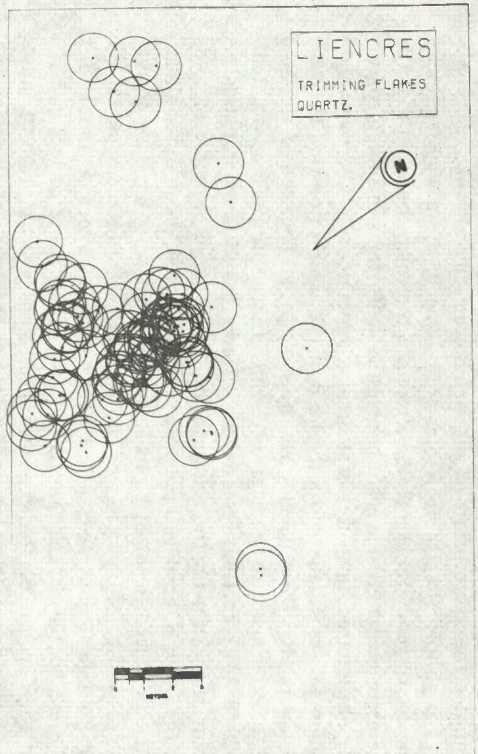


FIGURE 6. LIENCRES: SURFACE COLLECTION - DISTRIBUTION OF FLINT TRIMMING FLAKES.

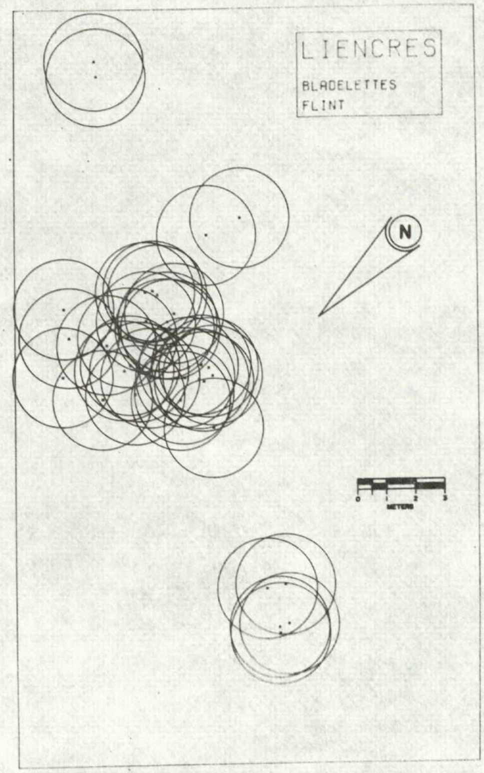


FIGURE 7. LIENCRES: SURFACE COLLECTION - DISTRIBUTION OF FLINT BLADES AND BLADELETS (UNRETOUCHED).

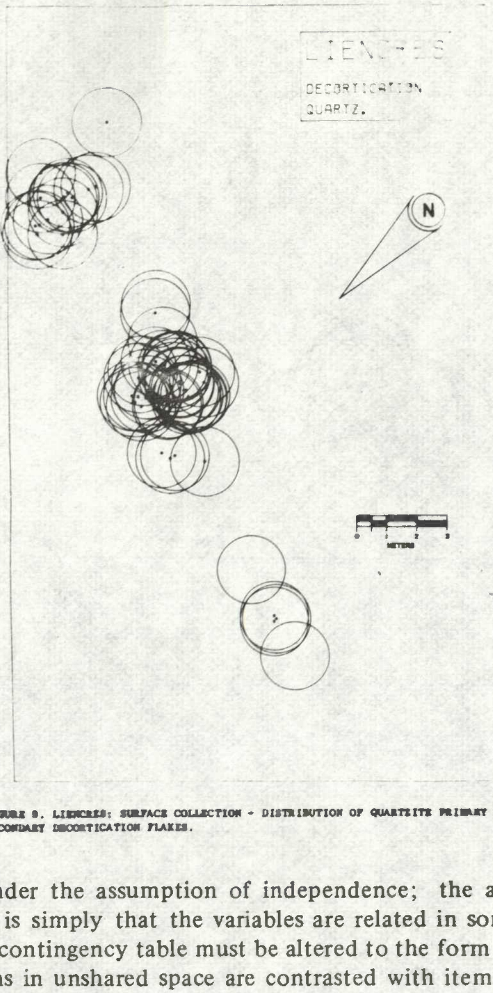
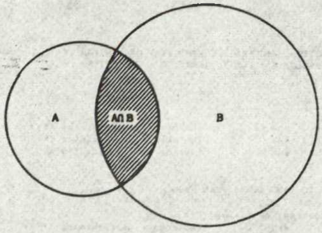


FIGURE 9. LIENCRES: SURFACE COLLECTION - DISTRIBUTION OF QUARTZITE PRIMARY AND SECONDARY DECORTICATION FLAKES.

variation under the assumption of independence; the alternative hypothesis (H_1) is simply that the variables are related in some way (Blalock 1972). The contingency table must be altered to the form shown in Fig. 10 so that items in unshared space are contrasted with items in shared space. As noted, chi-squared measures statistical independence. 'The expected (cell) frequencies are calculated on the basis of the assumption that the variables are not related (that is, they are the same for all four cells); the observed frequencies measure the degree to which that assumption is violated' (Blalock 1972:279). In the present case, if items A and B are statistically independent, then knowing the values for one will not aid in predicting the values for the other. Out of 120 pairwise comparisons, 47 were determined to be statistically significant at alpha less than or equal to .01. This means that, if a probability of Type I error equal to .01 is considered acceptable, a statistically significant relationship exists between types A and B. In terms of these spatial data, A and B could either be more or less closely associated than would be the expectation under the assumption of independence. No information is provided about the strength of the relation-



JACCARD'S COEFFICIENT OF SIMILARITY

	A	NOT A	
B	n_{AB}	n_{aB}	n_B
NOT B	n_{Ab}	n_{ab}	n_b
	n_A	n_a	n

$$S_A = n_{AB} / (n_{AB} + u) \quad \text{where:}$$

n_{AB} = items in A and B
n_A = items in A
n_B = items in B
n_a = items not in A
n_b = items not in B
n_{ab} = items not in A and not in B (here an empty set)

u = items in A and NOT B plus items in B and NOT A (n_{Ab} + n_{aB})

(after Sokal and Sneath 1963:126-129)

FIGURE 9. THE SIMILARITY COEFFICIENT OF JACCARD (S_A), CONTINGENCY TABLE AND MARGINALS USED FOR PAIRWISE COMPARISON (SOKAL AND SNEATH 1963:126-129).

ship between A and B; all that has been demonstrated is that a relationship of some sort exists. It should be borne in mind that if sample sizes are large, as they are in some cases here, statistical significance is easily attained, given even a very slight relationship. It is thus beneficial to make use of some objective measure of the *strength* of relationship.

PEARSON'S CONTINGENCY COEFFICIENT

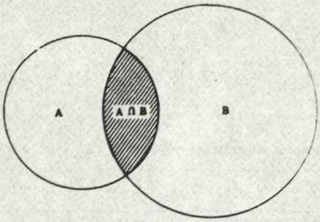
A chi-square based statistic called Pearson's contingency coefficient was used to assess the strength of relationship between all types which had chi-squares significant at the .01 level (Conover 1971:170-172; Blalock 1972: 297,298). Pearson's coefficient (Fig. 11) ranges from zero to .707, in the case of a 2 x 2 table. Zero indicates that the variables are completely independent; .707 indicates perfect association. The maximum value which the C statistic can take on increases according to the number of rows and columns in the table. For large tables, it approaches but never attains unity. The maximum value is sometimes used as a scalar to render C more

LIENCRES SURFACE COLLECTION: JACCARD'S COEFFICIENT OF SIMILARITY (S_A) - ASSOCIATIONS AT .900, .850 AND .800 LEVELS. F = FLINT, CHERT; Q = QUARTZITE.

S_A GREATER THAN OR EQUAL TO .900:			
nuclei (F)	and	(notches + denticulates (F))	.896
unretouched bladelets (F)	and	(notches + denticulates (F))	.944
nuclei (F)	and	(perforators + becs (F))	.965
S_A GREATER THAN OR EQUAL TO .850, LESS THAN .900:			
(primary + secondary decortication flakes (F))	and	(notches + denticulates (F))	.848
plain flakes (F)	and	endscrapers (F)	.856
split cobble segments (Q)	and	nuclei (Q)	.857
plain flakes (F)	and	(primary + secondary decortication flakes (F))	.859
split cobble segments (Q)	and	burins (F)	.869
trimming flakes (Q)	and	nuclei (Q)	.869
(primary + secondary decortication flakes (Q))	and	(notches + denticulates (F))	.875
plain flakes (F)	and	(notches + denticulates (F))	.882
trimming flakes (F)	and	(notches + denticulates (F))	.886
S_A GREATER THAN OR EQUAL TO .800, LESS THAN .850:			
trimming flakes (F)	and	unretouched bladelets (F)	.798
split cobble segments (Q)	and	(notches + denticulates (F))	.800
split cobble segments (Q)	and	(perforators + becs (F))	.800
plain flakes (F)	and	nuclei (F)	.806
(primary + secondary decortication flakes (F)	and	endscrapers (F)	.807
plain flakes (F)	and	unretouched bladelets (F)	.814
plain flakes (F)	and	trimming flakes (F)	.814
endscrapers (F)	and	trimming flakes (F)	.818
endscrapers (F)	and	unretouched bladelets (F)	.823
trimming flakes (Q)	and	(notches + denticulates (F))	.826
(primary + secondary decortication flakes (F))	and	(perforators + becs (F))	.827
trimming flakes (Q)	and	burins (F)	.833
nuclei (Q)	and	nuclei (F)	.840
split cobble segments (Q)	and	core renewal flakes (F)	.842
(primary + secondary decortication flakes (Q))	and	(perforators + becs (F))	.843

readily interpretable by setting the upper limit of the coefficient equal to 1.00, as in Fig. 11 (Blalock 1972:298). The 47 pairwise comparisons which had significant chi-squares were evaluated using Pearson's C to assess the strength of relationship. Because only those comparisons with significant chi-squares were used, and because Pearson's statistic is itself based upon a chi-squared distribution, it follows that all of the comparisons so evaluated would be statistically significant at alpha less than or equal to .01.

Results obtained by applying Pearson's coefficient to the Liencres data are presented in Table 5. Only adjusted coefficients greater than .700 are listed. Inspection of the table shows, first of all, that the 47 comparisons which the chi-squared test determined to be significant at the .01 level are reduced to just 12. Second, if the hypothetical functions assigned at the beginning of the analysis are applied to these strongly related pairs, it becomes possible to distinguish tool kits related to 1) primary and secondary tool manufacture, and edge renewal; 2) to light cutting/slicing/shaving of animal and vegetal matter; and 3) to core preparation and primary manufacturing activities. The first would seem to include quartzite nuclei and trimming flakes; the second comprises flint plain and decortication flakes, unretouched bladelets, notches and denticulates; and the third consists of flint and quartzite nuclei. Other kits seem to combine these functions, or are more difficult of interpretation. The distributions of the three principle tool kits at Liencres are presented in Figs. 12-14. Tool manufacturing and edge renewal seem to be activities confined mainly to the southeastern



CHI SQUARE (2 X 2)

	A	B	
A	(a) n_{AA}	(b) n_{AB}	$(a + b)$ $n_{AA} + n_{AB} = n_A$
B	(c) n_{BA}	(d) n_{BB}	$(c + d)$ $n_{BA} + n_{BB} = n_B$
	$n_{AA} + n_{BA}$ $(a + c)$	$n_{AB} + n_{BB}$ $(b + d)$	N

$$\chi^2 = \frac{N(ad - bc)^2}{(a + b)(c + d)(a + c)(b + d)}$$ where:

$a = n_{AA}$ = items in A NOT IN B
$b = n_{AB}$ = items of A IN B
$c = n_{BA}$ = items of B IN A
$d = n_{BB}$ = items in B NOT IN A

FIGURE 10. CHI-SQUARED TEST FOR A 2 X 2 CONTINGENCY TABLE, WITH MARGINALS USED FOR PAIRWISE COMPARISON (BLALOCK 1972:279-281).

PEARSON'S CONTINGENCY COEFFICIENT

$$C = \frac{\sqrt{\dfrac{\chi^2}{\chi^2 + N}}}{.707}$$ where:

$\chi^2 = \chi^2$ statistic for a 2 X 2 table with 1 degree of freedom
N = table total $(n_a + n_b)$

Range C = 0 - .707 (for a 2 X 2 table): 0 indicates that the variables are completely independent; .707 indicates maximal association, and is sometimes used as a correction term to render the interpretation of C more readily understandable by setting the upper limit of C equal to 1.00.

FIGURE 11. PEARSON'S CONTINGENCY COEFFICIENT (C)(BLALOCK 1972:297-298).

TABLE 5

ADJUSTED PEARSON'S COEFFICIENTS GREATER THAN .700 FOR SIGNIFICANT CHI SQUARES ($\alpha < .01$). Q = QUARTZITE, F = FLINT.

PAIRWISE COMPARISONS	$\chi^2(\alpha < .01)$	$p(\chi^2)$	C/.707	SPECULATIVE FUNCTION
nuclei (Q) + trimming flakes (Q)	14.66	.000	.893	primary and secondary tool manufacture; edge removal
nuclei (F) + (notches + denticulates(F))	17.58	.000	.868	primary manufacture; shaving, scraping, shredding of wood, antler/bone, vegetal matter
plain flakes (F) + trimming flakes (F)	112.61	.000	.751	tool manufacture
plain flakes (F) + unretouched bladelets (F)	80.86	.000	.711	light slicing, cutting, shaving of wood, antler/bone, vegetal matter, flesh, hides
plain flakes (F) + decortication flakes (F)	240.54	.000	.826	ditto
unretouched bladelets (F) + (notches + denticulates (F))	36.68	.000	.898	ditto
nuclei (Q) + nuclei (F)	9.00	.001	.736	primary manufacture
split cobble segments (Q) + (notches + denticulates (F))	9.03	.001	.738	core preparation; hammering, crushing; light shaving, scraping, sawing of wood, bone/antler, flesh; shredding of fibrous material
split cobble segments (Q) + (perforators + becs (F))	9.03	.001	.738	core preparation; hammering, crushing; drilling or piercing of hides; graving bone/antler, wood
split cobble segments (Q) + burins (F)	11.29	.000	.823	core preparation; hammering, crushing; scraping and/or graving of wood, antler/bone
trimming flakes (Q) + burins (F)	10.53	.000	.779	tool manufacture and edge removal; scraping and/or graving of wood, antler/bone
large/small cobbles (Q) + (perforators + becs (F))	10.83	.000	.824	?

(upper left) portion of the site, as indicated by the heavy concentration of quartzite nuclei and trimming flakes in that quadrant (Fig. 12). Residues from cutting/slicing/shaving activities have a more general distribution, but show a marked concentration toward the center of the site (Fig. 13). Core preparation and/or disposal is again confined to the southeastern quadrant, as indicated by the concentration of flint and quartzite nuclei there (Fig. 14).

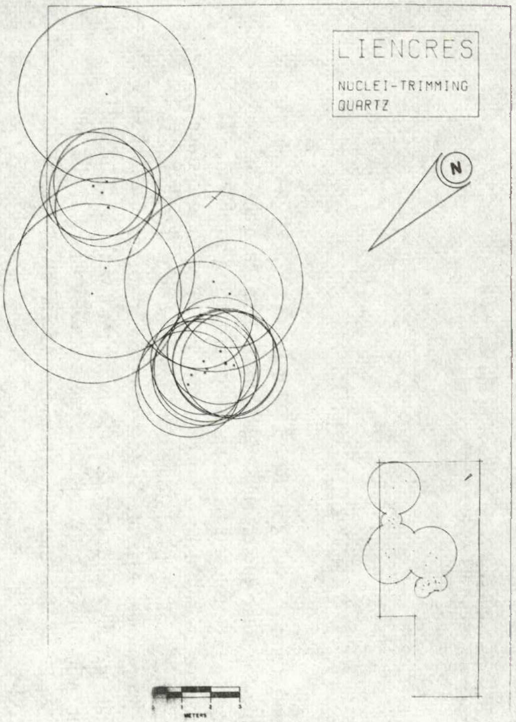


FIGURE 12. LOCUS OF QUARTZITE TOOL MANUFACTURING AND EDGE RENEWAL, AS DEFINED BY THE COMBINED TYPE-SPECIFIC INTERACTION SPACES OF QUARTZITE NUCLEI AND TRIMMING FLAKES. INSET AT LOWER RIGHT IN THIS AND SUBSEQUENT FIGURES GIVES SITE BOUNDARIES USED IN THE NEAREST NEIGHBOR ANALYSIS.

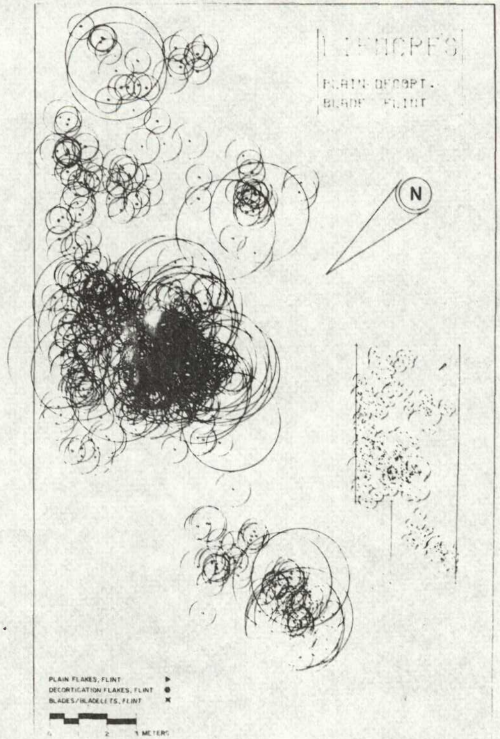


FIGURE 13. LOCUS OF CUTTING/SLICING/SHAVING ACTIVITIES, AS DEFINED BY THE COMBINED TYPE-SPECIFIC INTERACTION SPACES OF FLINT PLAIN AND DECORTICATION FLAKES, UNRETOUCHED BLADELETS, NOTCHES AND DENTICULATES.

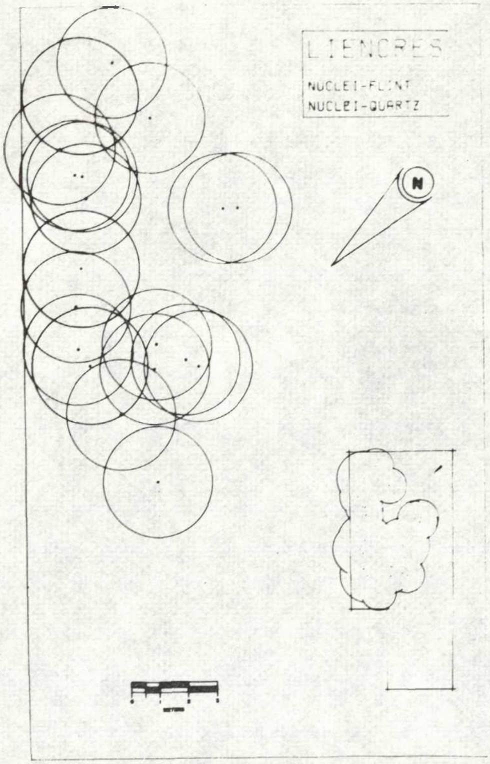


FIGURE 14. LOCUS OF CORE PREPARATION, AS DEFINED BY THE COMBINED TYPE-SPECIFIC INTERACTION SPACES OF FLINT AND QUARTZITE NUCLEI.

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REFERENCES CITED

Blalock, H.M.
1972 – SOCIAL STATISTICS. McGraw Hill Book Company. New York.

Butzer, K. and D. Bowman
1971 – Some Sediments from Asturian archaeological levels from sites in Cantabrian Spain. in THE ASTURIAN OF CANTABRIA: A RE-EVALUATION, Unpublished Ph.D. Dissertation, Department of Anthropology, University of Chicago.

Clark, G.A.
1971 – THE ASTURIAN OF CANTABRIA: A RE-EVALUATION, Unpublished Ph.D. dissertation, Department of Anthropology, University of Chicago.

1975 – Liencres: una estacion al aire libre de estilo Asturiense cerca de Santander. CUADERNOS DE ARQUEOLOGIA, Vol. 3, 84 pages. Bilbao.

Clark, P.J. and F.C. Evans
1954 – Distance to nearest neighbor as a measure of spatial relationships in populations. ECOLOGY, Vol. 35, pp. 445-453.

Conover, W.J.
1971 – PRACTICAL NONPRAMETRIC STATISTICS. Wiley and Sons, Inc. New York.

Dacey, M.F.
1963 – Order neighbor statistics for a class of random patterns in multidimensional space. ANNALS OF THE ASSOCIATION OF AMERICAN GEOGRAPHERS, No. 53, pp. 505-515.

Hanson, G.T.
1975 – The analysis of spatial distributions in archaeological contexts: the Brand site. Paper read at the 40th Annual Meetings of the Society for American Archeology (Dallas, Texas; May, 1975).

Hanson, G.T. and A. Goodyear
1975 – The shared -tool method of spatial analysis: Applications at the Brand Site. MS on file with the Department of Anthropology, Arizona State University.

Monmonier, M.S.
1968 – Computer mapping with the digital increment plotter. PROFESSIONAL GEOGRAPHER, Vol. 20, pp. 408-409.

Pielou, E.C.
1959 – The use of point-to-plant distances in the study of the pattern of plant populations. JOURNAL OF ECOLOGY, Vol. 47, pp. 607-613.

1969 – AN INTRODUCTION TO MATHEMATICAL ECOLOGY. Wiley Interscience Series, Wiley and Sons, Inc. New York.

Pinder, D.A. and M.E. Witherick
1972 – The principles, practice and pitfalls of nearest neighbor analysis. GEOGRAPHY, No. 257, Vol. 57, Part 4 pp. 277-288.

Schiffer, M.B.
1975 – Behaviour chain analysis: activities, organization and the use of space. FIELDIANA ANTHROPOLOGY, Vol. 65, pp. 103-119. Chicago.

Sokal, R.R. and P.H. Sneath
1963 – PRINCIPLES OF NUMERICAL TAXONOMY. W. Freeman and Co. San Francisco.

Sonneville-Bordes, D. de and J. Perrot
1954 – Lexique typologique du paleolithique superieur. BULLETIN DE LA SOCIETE PREHISTORIQUE FRANCAISE, Tome LI, pp. 327-334. Paris.

1955 – Lexique typologique du paleolithique superieur. BULLETIN DE LA SOCIETE PREHISTORIQUE FRANCAISE, Tome LII, pp. 76-78. Paris.

1956 – Lexique typologique du paleolithique superieur. BULLETIN DE LA SOCIETE PREHISTORIQUE FRANCAISE, Tome LIII, pp. 547-559. Paris.

Thompson, H.R.
1956 – Distribution of distance to nth neighbour in a population of randomly distributed individuals. ECOLOGY, Vol. 37, pp. 391-394.

Whallon, R.
1973 – Spatial analysis of occupation floors I: The application of dimensional analysis of variance. AMERICAN ANTIQUITY, Vol. 38, pp. 266-278.

1974 – Spatial analysis of occupation floors II: The application of nearest neighbor analysis. AMERICAN ANTIQUITY, Vol. 39, pp. 16-34.