M. OTTE et L.G. STRAUS (dir.), *Le Trou Magrite. Fouilles 1991-1992.* Liège, E.R.A.U.L. 69, 1995.

11

SPATIAL ANALYSIS OF LE TROU MAGRITE

Anthony E. MARTINEZ

ABSTRACT

The site of Trou Magrite was examined for the presence or absence of spatial structure. Data results indicate that a high degree of site integrity is present in some portions of the excavated area while evidence for potential stratigraphic disturbance is present along the edge of the cave talus.

INTRODUCTION

As described in Chapter 1, le Trou Magrite has historically served as a key site in developing the general chronology for much of the Paleolithic record of Europe. Since the first excavations at Trou Magrite in the mid-1800's, changes in theoretical orientation and numerous methodological developments lead us to ask new kinds of questions about this site. These range from broad issues of the site's place within long-term temporal and regional frameworks, to more specific issues of changes in the nature of the site occupation and activity organization in three-dimensional space.

The spatial analysis of archaeological remains recovered from excavations reported in this monograph will serve as a valuable complement to the data and site interpretations of past researchers. Analysis of the spatial properties of le Trou Magrite suggests a number of insights into the spatial dynamics at this site during < periods of human occupation. It also addresses the question of periods of human absence.

From the standpoint of the analysis of site structure, le Trou Magrite presents some interesting challenges. First, the total excavation area is relatively small (approximately 22 square meters). Second, excavation areas contained significant quantities of cave roof-all, especially in the lower strata, with bedrock outcrops at the base. These limestone boulders could have be expected to have impacted human usage of the site in a variety of ways. As elements which are, in some cases, over a cubic meter in size, they certainly constituted 'site-furniture', serving, for example, as surfaces for food preparation, seating, partitions, and *de facto* windbreaks.

To the analyst of archaeological site structure, the rockfall at le Trou Magrite is a distributional 'blanking' area. On the one hand it restricts the distribution of artifacts to areas that were associated with periods of human occupation. On the other hand, it also serves to 'funnel' artifacts into crevices among blocks, elongating the vertical distribution of artifacts affiliated with periods of human habitation. Finally, rockfall can be expected to have altered the archaeological landscape by crashing many meters down onto occupation surfaces littered with archaeological material. While rockfall can compact an archaeological layer and literally destroy artifacts and bones, it also serves to 'seal' layers into definable periods of geological activity within the cave.

Relative to these issues, this chapter asks the following questions.

1) Can the relative integrity of the different strata be evaluated objectively? If so, what is the evidence for intactness vs. disturbance?

2) Is there evidence for the survival of distinct 'living' surfaces in the excavated area of the site?

3) What role might carnivore activity have played in the accumulation of faunal remains among the strata?

In response to these questions, I present the results of spatial analysis using several methods which may assist in the interpretation of sites like le Trou Magrite. These include 1) maximum deviation functions for plotting data collected on a grid (meter square) basis, 2) lithic refit analysis, and 3) ISODATA2 clustering accompanied by vector quantization for classifying high dimensional relationships in archaeological data.

MATERIALS AND METHODS

Data Collection and Database Construction

Field provenience data used in this study are of two types. Artifacts and teeth ≥ ca. 1cm and bones ≥ 5cm in length were plotted in three dimensions relative to Cartesian space while smaller finds were collected in arbitrary 5-8cm levels (spits) and 50 x 50 cm subsquares. Stratum, excavation square, sub-square, and spit were recorded for all artifacts. For those items piece-plotted, orientation relative to magnetic north and inclination of primary and secondary axes relative to the horizontal level were also recorded.

Following construction of a database containing field provenience and laboratory analysis information, data were re-coded into new variables using several criteria. First, lithic raw material types were collapsed into a new dataset containing general probable source and material information in such a fashion that the full analytical list in Chapter 5 was condensed into :

flints/cherts
phtanite
limestone
sandstone/siltsone
other stones

Next, due to small sample sizes for some categories, a similar process was used to lump debris categories in Tables 4.1-4.2 into:

all micro debitage (< 1cm)
non-cortical angular debris
cortical angular debris
non-cortical flakes
cortical flakes
non-cortical blades
cortical blades
bladelets
cores & platform renewal flakes
Upper Paleolithic tools
Mousterian tools

For faunal data, identifications provided by A. Gautier (Chapter 7, this volume) were integrated with artifact provenience information and preliminary observations on modification. This resulted in the following database:

Artifact provenience
Faunal taxon
Element
Portion
Modifications

In order to utilize the full potential of the Trou Magrite dataset, non-piece plotted artifacts were tested against a maximum deviation function described by Martinez (n.d.). This function evaluates the relative departure of a given artifact's Cartesian coordinates relative to the scale of collection in horizontal and vertical dimensions against the size of the excavation or artifact scatter. A randomly assigned Cartesian coordinate within space constrained by the excavation limits of a 50 x 50cm subsquare, 5 centimeters thick is within approximately 25 cm horizontal space and 2.5 cm of vertical space of where it could be expected to have been found had it been individually plotted. This is a conservative estimate based upon the square of the hypotenuse of the excavation plane in XYZ dimensions. It has been suggested by Kroll & Isaac (1984) that a more realistic estimate of variation from actual location is . the square of the hypotenuse. In the case of artifacts at Trou Magrite, this suggests that had non-piece plotted artifacts been piece-plotted, they would have a statistical likelihood of being within 12.5 centimeters in horizontal space and 1.25 cm vertical space from a space-constrained randomly assigned Cartesian coordinate. Relative to; 1) the number of artifacts collected, 2) the size of the excavation area, and 3) the type of spatial analysis performed in this study, even a conservative estimate of maximum spatial deviation of a re-plotted artifact becomes statistically insignificant. Non-piece plotted artifacts were, therefore, assigned space-constrained random Cartesian coordinates resulting in a single dataset containing values for: X,Y,Z, and Artifact Type.

Data Visualization

As a first step to data analysis, artifact distributions were mapped as two dimensional plan maps and three dimensional point clouds. In addition, three-dimensional 'fence' plots were constructed from stratigraphic data collected in the field (see Figs. 11.1-11.2-11.3-11.4-11.5). These plots were then inspected for general trends in the distribution of data relative to 1) other artifacts, 2) limestone rock-fall and bedrock, and 3) stratigraphic membership.

Lithic Refit Analysis

During the course of general lithic analysis several observations were made which assisted the refit analysis of Trou Magrite. These observations included the systematic inspection of chipped stone raw material, size, shape, debitage type, color, patination, cortical surface, grain size, and inclusions. Pieces were then conjoined on the basis of any attributes of Hertzian morphology that might indicate a direct correspondence.

Vector Quantization

Vector Quantization (VQUANT), is a classification algorithm that examines and classifies high-dimensional similarity. Its use and application are, at present, restricted to engineering and industrial applications such a ion beam configuration (Wilson 1990) and digital signal compression (O'Rourke & Sloan 1984; Heckbert 1982). As a mathematical algorithm, however, I believe that it holds significant potential for application within archaeological analysis of site structure and offers certain advantages over many commonly used techniques. Unlike clustering methods such as K-means or simple ISODATA, VQUANT is extremely robust in dealing with high-dimensional space. Eight dimensional limitations as described by Fukunaga (1972), frequently reached in archaeological applications, are generally avoided, while meaningful classification results have been reported in as many as 32 dimensions (Heckbert 1982).

Describing its usage might be made more clearly by example. If one visualizes a three-dimensional point cloud representing artifacts in different stratigraphic layers, a number of data relations may be present. Some artifacts could be clustered in groups about particular site features, while others may be dispersed about the periphery of the site. The orientation of the point cloud may be along a particular plane, indicating either post-depositional differences in site usage, natural dispersion process, or an effect of data recovery methods. The inclination of the point cloud may suggest that artifacts are arranged along potential living surfaces, or that they are distributed along a prehistoric slope.

VQUANT analysis begins with the question, along what axis does one wish to begin examining the data? Possible options are: 1) along the axis which follows the maximum data span (in the archaeological example, along the plane

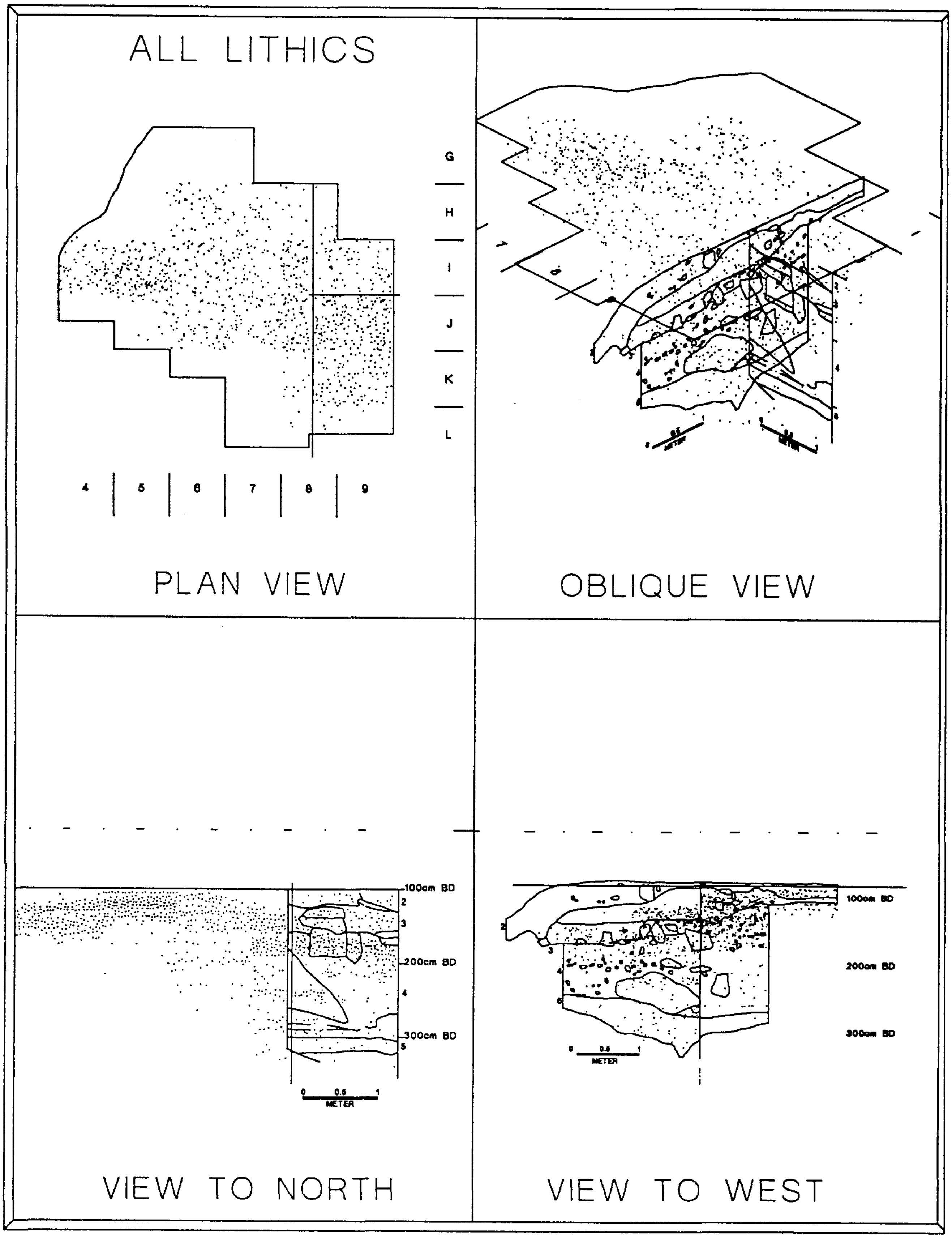
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Figure 11.1

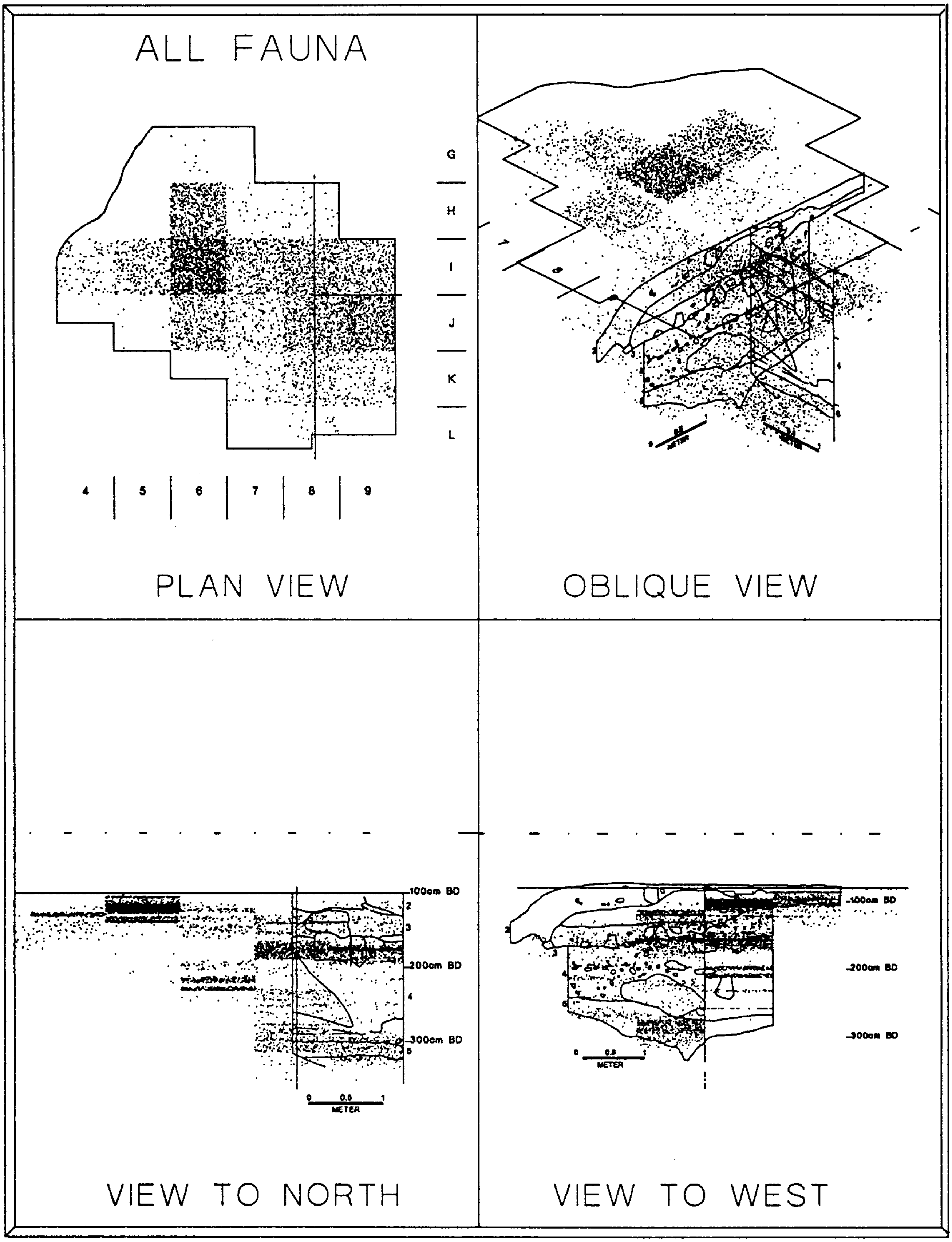
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Figure 11.2

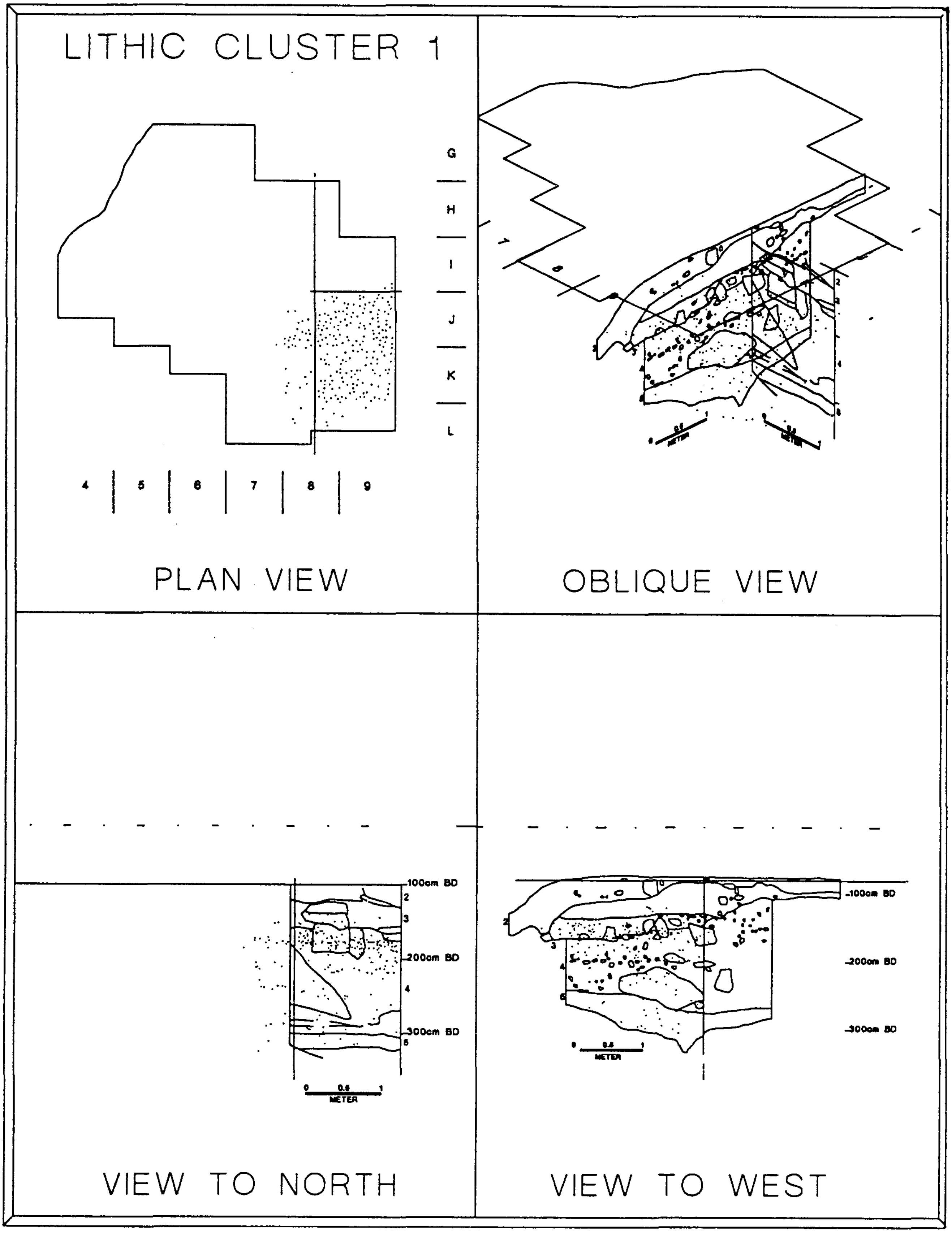
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Figure 11.3

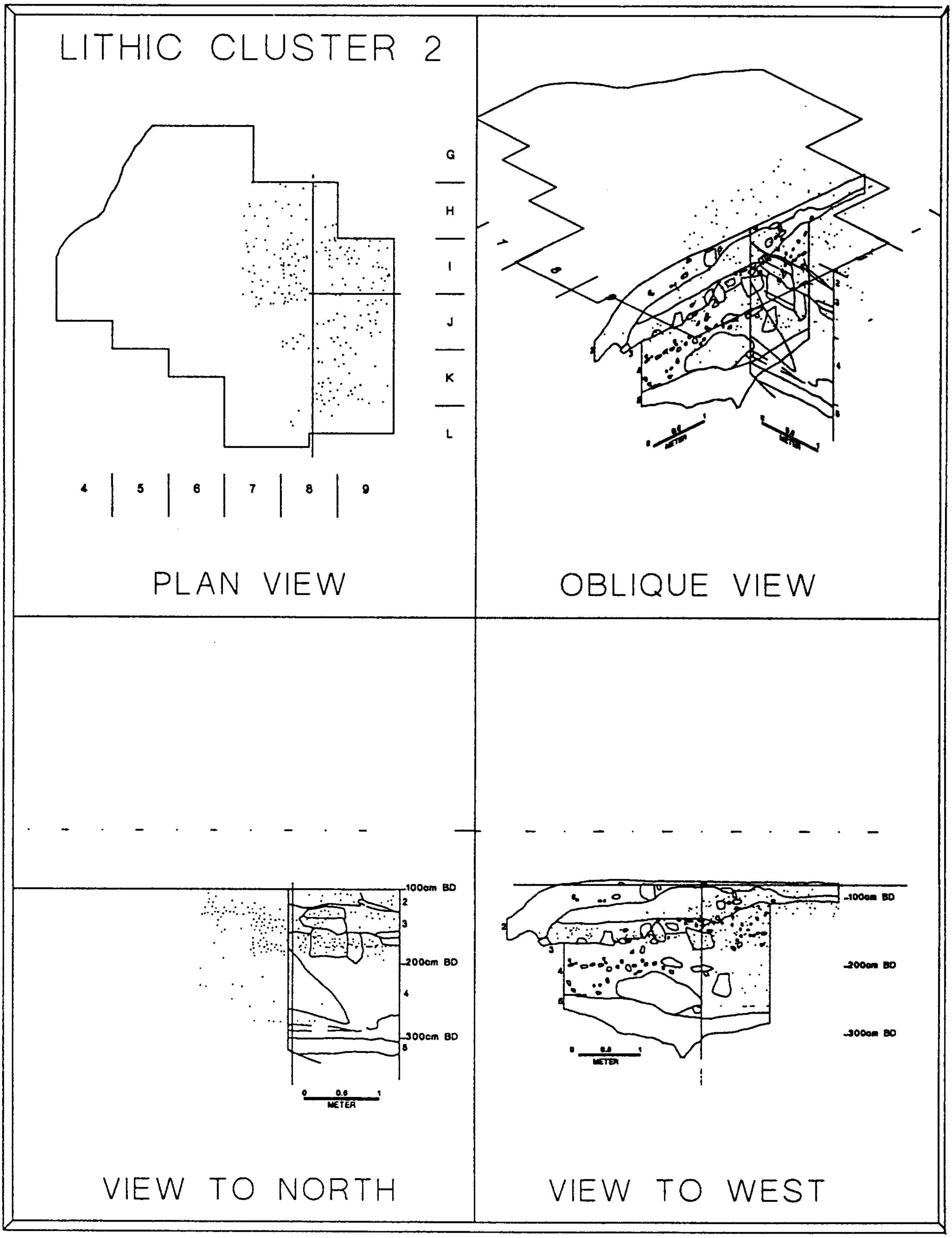
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Figure 11.4

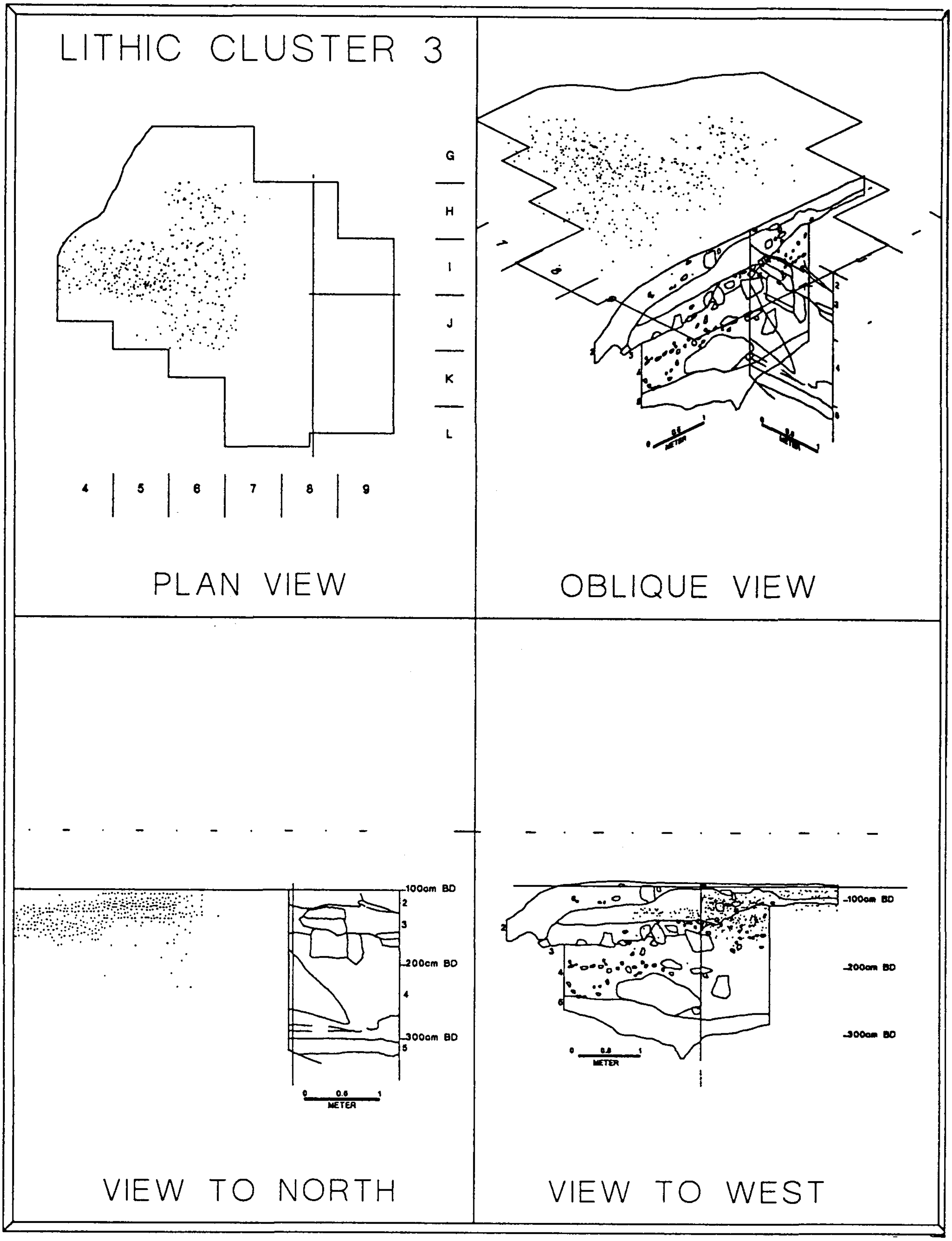
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Figure 11.5

of the most artifacts), 2) along the axis of greatest data variance (along the axis of greatest differences in numbers or types of artifacts, or 3) along the principal eigenvector of the data (along the axis which intersects the greatest number of significantly meaningful clusters of artifacts).

Next, the number of clusters present in the dataset are needed. While this may seem like a ridiculous requirement (if we knew how many clusters were present in the data why would we bother clustering them?), VQUANT establishes where data clusters are and what high-dimensional relations are present within cluster zones. One of the most robust and intuitive approaches to determining number of clusters is provided by a refined ISODATA algorithm, also known as ISODATA2. This technique 'reads' a data set and determines the minimum and maximum number of clusters possible given the contents and interrelationships of a dataset. In practice, ISODATA2 matches the sum of squared Euclidian distance against the smallest possible variance in the location of cluster centroids. This is a technique quite similar to that used by a MAXCLUST function in K-means analysis, however, the ISODATA2 function is a heuristically based, automatic classification algorithm. This translates to an ISODATA2 algorithm is 'smart' enough to determine how many cluster are present in the data without the user having to 'guess' a reasonable starting number for the maximum number of clusters.

As a next step, VQUANT can take the data provided by ISODATA2 regarding minimum number of significant clusters and begin high-dimensional analysis of data relations. In the archaeological example, following ISODATA2 analysis, we now know the general number of clusters that can reasonably be expected to be present given the number, type and position of our artifacts. Using VQUANT, we can now begin to ask the question, "Where are the artifacts and what associations of artifacts are there relative to the rest of the site?" This in turn helps answer along which type of axis to split the data. Our options, again, are 1) maximum span, 2) maximum variance, or 3) principal eigenvector. Given that we are interested in examining intra as well as inter-relationships between strata 2-5 at Trou Magrite, VQUANT splitting along the principal eigenvector was chosen so that cluster region identification would be primarily a function of similarity of relative position, number and type of artifacts distributed about the excavation area. Applied to the Trou Magrite dataset, VQUANT and ISODATA2 analysis was carried out using the KHOROS program developed at the University of New Mexico. In order to determine the geographic location and orientation of clusters, a KHOROS post-processor developed by Scott Wilson was used to evaluate the position, inclination and contents of each cluster region.

RESULTS

Data Visualization

Data visualization at Trou Magrite suggests a number of patterns. The western portion of the excavation area (G-K/4-6) is characterized by a tight vertical distribution of both lithic and faunal data. The faunal distribution in the northeastern portion of the excavation (J-H/7-9) seems to be substantially less dense in this portion of the site than in the area to the immediate south. As this area is 1) directly beneath the present-day drip line, and 2) was found in excavation to be largely indurated with flowstone, I suspect that this is a function of bone preservation rather than an actual characteristic of the data. Lithic artifacts in the southern portion of the excavation area (J-L/7-9) appear to be dispersed in vertical space, while faunal data are generally clustered in this part of the site into stratigraphically superimposed layers of artifacts that overlap the lithic distribution (see Figs 11.1 & 11.2). This 'layering' of faunal remains in the southern portion of the excavation area may well be a product of accretional deposition of bones on the talus slope of the cave, interspersed by periodic deposition and erosion of lithics on and from the exposed talus.

Lithic Refit Analysis

Analysis of the Trou Magrite data for lithic refits was largely unsuccessful. Of the 4000+ chipped stone items in the assemblage measuring greater than 1cm, 15 items were found to directly refit (see Table 11.1). Two major obstructions to refit analysis were encountered. First, the high incidence of limestone artifacts prevented large-scale study of the assemblage, as the surface of these artifacts was consistently eroded. Second, the strategy for lithic reduction at Trou Magrite appears to have been highly intensive, with a premium placed on the conservation of lithic raw materials (especially cryptocrystalline ones). As a result, few artifacts remained which had enough definable features to 'put back together'. All artifact refits are restricted in vertical space, and are located in portions of the site that on the basis of visual inspection (above) and vector quantization (below) appear to be stratigraphically intact.

Vector Quantization

VQUANT analysis of Trou Magrite revealed a number of statistical problems with the data, but also suggests a number of patterns. Initial inclusion of combinations of lithic and bone data in combined analysis runs suggests that the shear frequency of unidentifiable bone fragments (nearly 8000) filters out the determination of patterns among other types of artifacts. Removal of this item as a category helps, however. The remaining small number of faunal remains that are definable with respect to element and location are spatially dispersed, and seem to exhibit no significant clustering with respect to horizontal space. Relative to vertical space, identifiable faunal remains are virtually restricted to strata 2 and 3. This is likely a function of preservation factors as strata 2 and 3 contained a higher frequency of artifacts and bones than strata 4 or 5 with general preservation of bones being generally better in upper strata.

Lithic artifacts, however, do exhibit significant spatial structure and clustering. VQUANT analysis indicates the existence of 5 distinct clusters definable on the basis of 1) artifact type, 2) raw material type, and 3) spatial location. In evaluating these clusters, it became clear that several phenomena describe the nature of the lithic clusters distribution. First, these clusters were characterized by properties of being constrained or dispersed in Cartesian space. Second, these clusters are formed of assemblages composed of the following artifact and raw material categories:

TABLE 11.1: Artifact Refit Sets

ARTIFACT#	ARTIFACT TYPE	STRATUM
I4-85	non-cortical flake	3
I4-86	non-cortical debris	3
I4-87	non-cortical debris	3
I4-88	non-cortical flake	3
I5-62	non-cortical flake	2
I5-64	non-cortical flake	2
I6-93	non-cortical debris	2
I6-97	cortical blade	2
I6-98	cortical blade	2
I6-192	non-cortical blade	2
I6-194	non-cortical blade	2
J8-231	core	4
J8-231.1	non-cortical flake	4
J8-305	cortical flake	5
J8-306	cortical flake	5

1) cryptocrystalline materials with a predominance of Upper Paleolithic tools

2) limestone, sandstone (including quartzites) and other raw material categories with a general predominance of Mousterian tool types.

These properties with respect to lithic raw material and artifact type suggest that the lithic data might also be thought of in terms of being dispersed or constrained within a domain defined by material type, frequency of blades, and Upper vs. Middle Paleolithic tool types.

Lithic Cluster 1

The first VQUANT lithic cluster is characterized by several properties. Geographically, it is restricted in horizontal space to squares J-L/7-9 (Fig 11.3). In vertical space, however, it cross-cuts strata 3 through 5, but with the greater part of its constituent artifacts being from strata 3 and 4. Cluster 1 contains 3 phtanite flakes, including one Upper Paleolithic tool, but no other cryptocrystalline materials. This assemblage is essentially made up of limestone, sandstone, and other less lustrous raw material types. Tools within this group include 15 limestone Upper Paleolithic tools, 1 sandstone Upper Paleolithic tool, and 4 limestone Mousterian tools. Technologically, this assemblage represents the gamut of lithic reduction sequence, and contains cores, cortical and non-cortical debris and debitage, blades, and tools. Based upon 1) this cluster's cross-cutting of stratigraphic boundaries and 2) presence of both Mousterian and Upper Paleolithic tool types, lithic cluster 1 is clearly mixed.

Lithic Cluster 2

In contrast to lithic cluster 1, lithic cluster 2 is characterized by an abundance of cryptocrystalline materials, including 30 Upper Paleolithic tools, no Mousterian tools, 4 flint cores, and most stages of the lithic reduction process. Located in squares J-H/7-9 (Fig 11.4), lithic cluster 2 is reasonably well-constrained within strata 2 and 3 in a dispersed distribution. Approximately two dozen isolated artifacts seem to have moved down through crevices in rock-all into stratum 4, but relative to the total size of the distribution in cluster 2, this appears to not be significant.

Lithic Cluster 3

This cluster contains products of the full range of technological reduction strategies and lithic raw material types. Occupying squares G-K/4-6 (Fig 11.5), cluster 3 is highly restricted in vertical space within strata 2 and 3. Some evidence for artifacts 'dribbling' down crevices between rock boulders along the 6-7 square line is present in the form of less than a dozen outlier flakes in stratum 4. Relative to the nearly 3000 items in this roughly 3 x 4 meter area, however, these artifacts represent only a fractional percentage of the cluster population. This cluster contains 42 flint Upper Paleolithic tools, 16 limestone Upper Paleolithic tools, 1 siltstone Upper Paleolithic tool, and no Mousterian tool types. Of particular note is that this cluster contains nearly three times as many blades and bladelets than any other identified group.

Lithic Cluster 4

Lithic cluster 4 partially overlaps with lithic cluster 2 (Fig 11.6), and is characterized by an absence of flint or chert artifacts, abundant limestone flakes, cores, and blades, 21 limestone Upper Paleolithic tools, and significant quantities of sandstones & siltstones (including 4 quartzite Upper Paleolithic tools and 1 quartzite Mousterian tool). Lithic cluster 4 is fairly well constrained in stratum 2, 3 and the upper part of stratum 4. It also has, however, a vertical 'tail' that extends into the upper portion of stratum 5 in the form of numerous artifacts that had slipped downwards. Its horizontal distribution is also somewhat dispersed, as it occupies squares H-K/6-9.

Lithic Cluster 5

Lithic cluster 5 closely overlaps lithic cluster 1 (squares J-L/7-9) (Fig 11.7), and, like lithic cluster 2, is dispersed in vertical space over stratum 3 through stratum 5. Its artifact assemblage is composed of abundant flints and cherts, no limestone or sandstones, 45 Upper Paleolithic tools, and 1 Mousterian tool.

Summary of Patterns

In general, visual inspection, lithic refit analysis, and VQUANT analysis all suggest that the western portion of the excavation area (G-K/4-6) is substantially intact and the northeastern region (J-H/7-9) is largely intact. Analysis also suggests that the southern portion (J-L/7-9) may be the product of episodic deposition of lithics and fauna down a talus slope. With respect to all artifacts and the total excavation area, lithic and faunal data generally overlap in areas of the site that appear to be stratigraphically intact. In areas where VQUANT analysis suggests lithic artifacts are of mixed provenience, faunal data are observed to be clustered into overlapping layers.

DISCUSSION

The general spatial pattern displayed by the Trou Magrite data is complex. Squares G-K/4-6 are definable as a space-constrained area in which the artifact categories are characterized by an abundance of raw material types, but a general tendency to be include artifacts that are Aurignacian / Upper Paleolithic types. This is consistent with an interpretation of this portion of the site as being stratigraphically intact. Examination of the artifact distribution in the this portion of the site with respect to Cartesian space also indicates lenses of artifacts suggesting multiple occupations and/or 'living surfaces'.

Squares J-H/7-9 appear to be largely stratigraphically intact, though the vertical distribution of artifacts within this area were somewhat elongated and 'dribbles' from strata 2 & 3 into portions of stratum 4. Faunal data are less

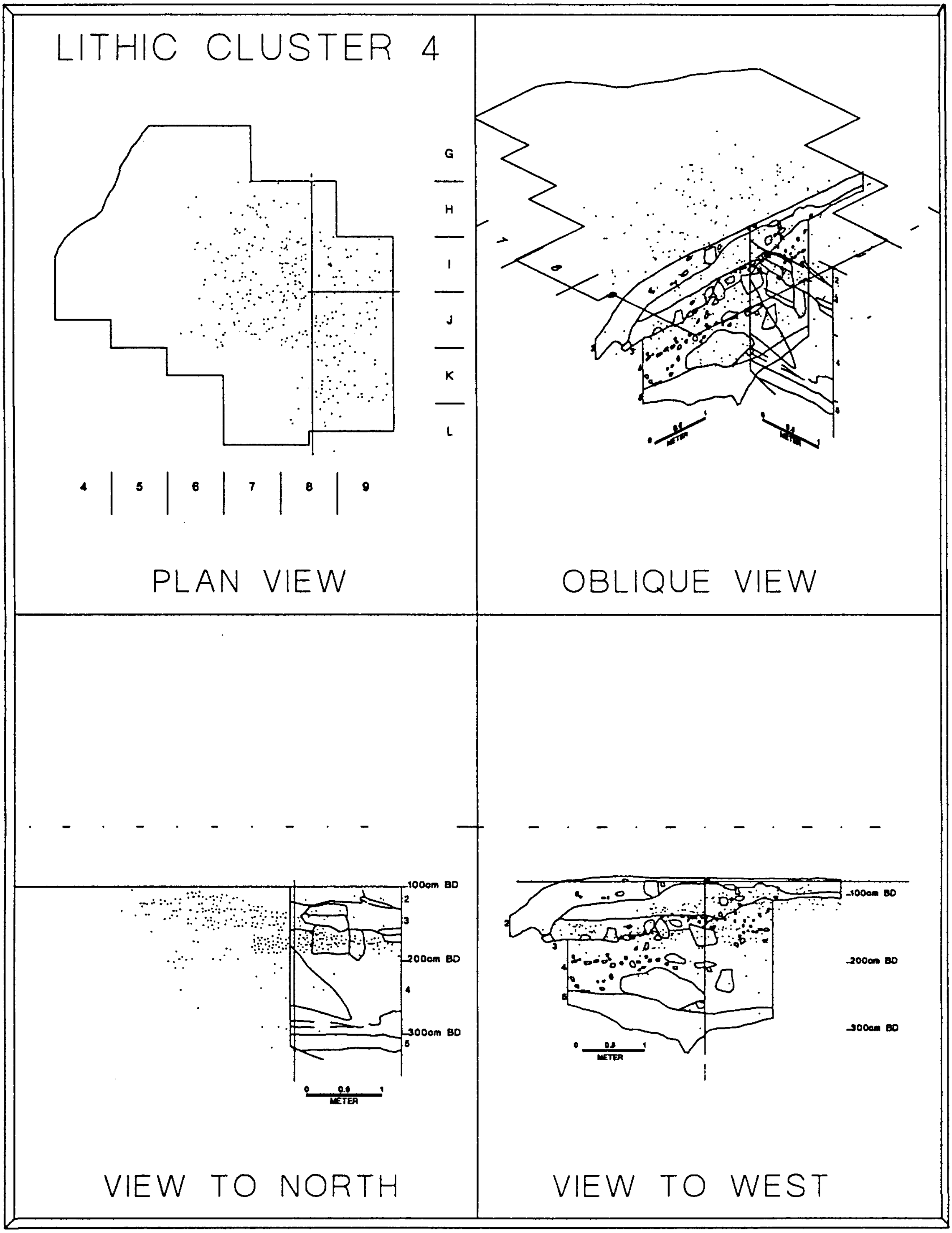
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Figure 11.6

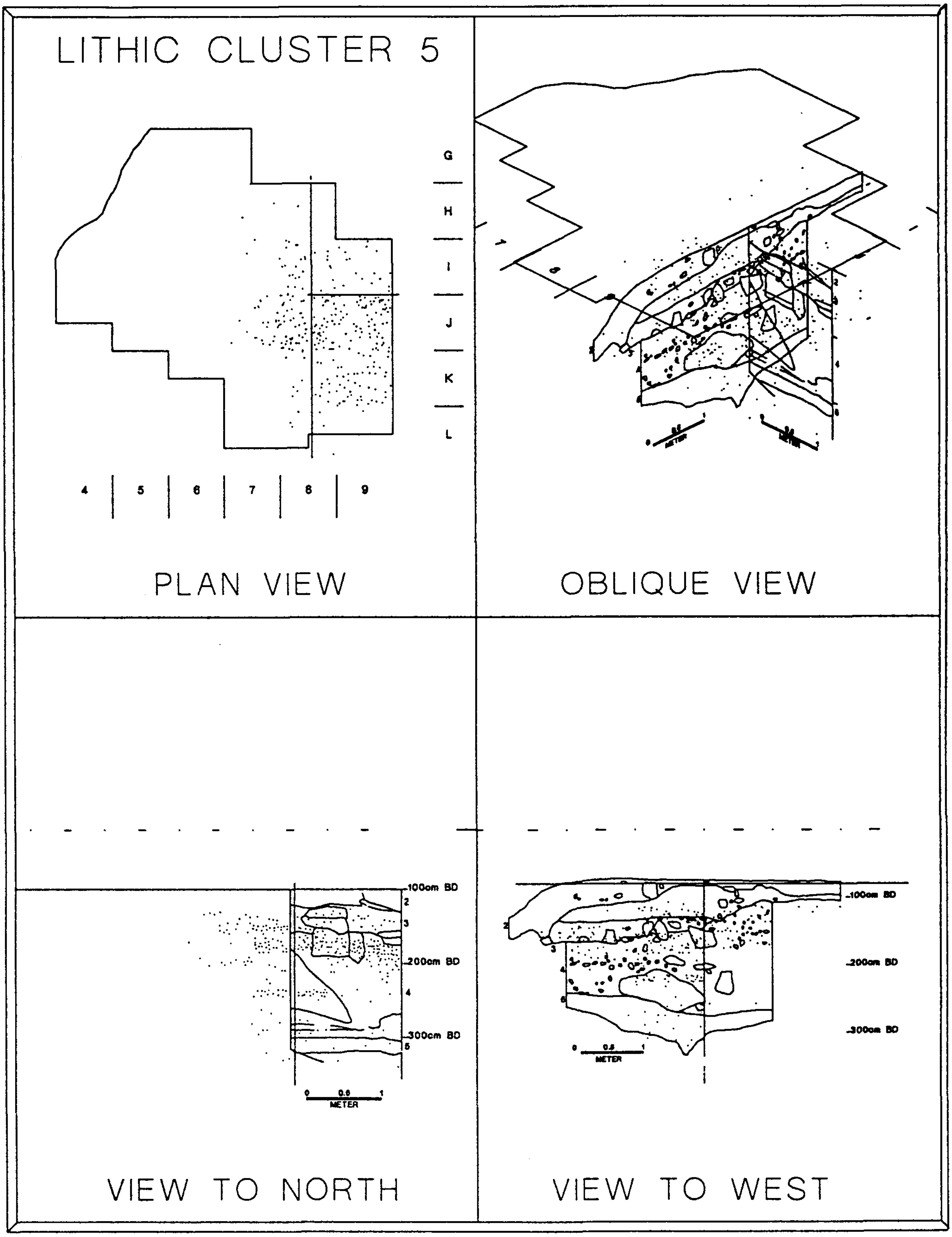
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Figure 11.7

frequent here than in the rest of the excavation area, but I suspect that this is a function of preservation factors rather than real activity distributions. Like the western portion of the site, artifact clusters are characterized by a diversity of raw material types, blades, and Upper Paleolithic tools. This evidence suggests that this portion of the site is of Aurignacian affiliation, though it is somewhat less intact than the western portion of the site with respect to its vertical and perhaps horizontal axes.

Squares J-L/7-9, near the talus edge, seem to be characterized by a dispersed lithic assemblage overlapping clustered zones of bones in vertical space. Some elements of the clusters defined by VQUANT analysis in the southern excavation area suggest that artifacts of Aurignacian affiliation are present (i.e., large number of cryptocrystalline materials, blades and Upper Paleolithic tools). The association of these items, however, with; 1) a lithic raw material diversity that is a mix of types found in upper <u>and</u> lower strata, 2) a vertical distribution of lithic clusters that cuts across strata 2 through 5, and 3) the co-occurrence of both Upper and Middle Paleolithic tool and debitage types is consistent with an hypothesis of stratigraphic disturbance of this portion of the site.

The faunal distribution in the southern portion of the site can be broken into 4 distinct clusters in vertical space which overlap one another in horizontal space. Of these layers, only a single lithic cluster is definable in vertical space that overlaps this bone distribution. It is characterized by being in stratum 4, and contains a high incidence of limestone debitage and a relatively low frequency of blades.

The co-association of clustered zones of bones in vertical space with a dispersed lithic distribution in the southern excavation area invites speculation. As this portion of the site is located along the talus of the prehistoric cave mouth, it is not unreasonable to suppose periods of episodic deposition and erosion resulting in a dispersed distribution of lithic artifacts. This may, in turn, also account for the clustered bone layers in this area of the excavation. A distributed lithic distribution containing successive layers of bone accumulation is consistent with a hypothesis of periodic alternation of human and animal occupation of the site.

CONCLUSION

Data visualization, lithic refit analysis and vector quantization analysis were employed in the spatial analysis of strata 2-5 at Le Trou Magrite (Table 11.2. Spatial structure is present in the form of discrete clusters of artifacts of Aurignacian affiliation in the western and northeastern portion of the excavated area in strata 2 and 3. These clusters are definable into lenses of artifacts that may be associated with occupation surfaces and considerable site integrity in this portion of the excavation area. The southern portion of the excavation area, along the prehistoric talus, seems to exhibit less evidence for spatial integrity, and is instead characterized by overlapping faunal distributions that may be

TROU MAGRITE
Summary of Lithic Cluster Memebership

	CLUSTER					Total
	1.00	2.00	3.00	4.00	5.00	
ARTIFACT TYPE						
flint/chert debitage < 1cm		261	938		300	1499
flint/chert non-cortical debris		25	74		25	124
flint/chert cortical debris		7	11		6	24
flint/chert non-cortical flakes		244	614		255	1113
flint/chert cortical flakes		31	50		32	113
flint/chert non-cortical blades		33	71		24	128
flint/chert cortical blades		12	8		4	24
flint/chert bladelets		53	52		19	124
flint/chert cores & platform renewal flakes		4	10		10	24
flint/chert Upper Paleolithic tools		30	42		45	117
flint/chert Mousterian tools					1	1
phtanite debitage < 1cm		1	1		3	5
phtanite non-cortical debris		2			1	3
phtanite non-cortical flakes	1	1	10		2	14
phtanite non-cortical blades		1	2		2	5
phtanite cores & platform renewal flakes	1					1
phtanite Upper Paleolithic tools	1					1
limestone debitage < 1cm	43		66	139		248

(continued)

TABLE 11.2 .

TROU MAGRITE
Summary of Lithic Cluster Memebership

	CLUSTER					Total
	1.00	2.00	3.00	4.00	5.00	
limestone non-cortical debris	32		50	44		126
limestone cortical debris	5		4			9
limestone non-cortical flakes	293		704	630		1627
limestone cortical flakes	9		7	14		30
limestone non-cortical blades	22		127	80		229
limestone cortical blades			1	3		4
limestone bladelets	2		15	16		33
limestone cores & platform renewal flakes	9		12	7		28
limestone Upper Paleolithic tools	15		16	21		52
limestone Mousterian tools	4					4
sandstone/siltstone debitage < 1cm			3	1		4
sandstone/siltstone non-cortical debris	1		1	1		3
sandstone/siltstone non-cortical flakes	11		33	38		82
sandstone/siltstone cortical flakes	3		5	21		29
sandstone/siltstone non-cortical blades	2		8	9		19
sandstone/siltstone cortical blades				2		2
sandstone/siltstone cores & platform renewal flakes	1			2		3

(continued)

TABLE 11.2 .

TROU MAGRITE
Summary of Lithic Cluster Memebership

	CLUSTER					Total
	1.00	2.00	3.00	4.00	5.00	
sandstone/siltstone Upper Paleolithic tools	1		1	4		6
sandstone/siltstone Mousterian tools	1			1		2
other stone debitage < 1cm	2		3	1		6
other stone non-cortical debris	5			5		10
other stone cortical debris	1		1			2
other stone non-cortical flakes	11		10	3		24
other stone cortical flakes	2		1	1		4
other stone non-cortical blades			2			2
other stone bladelets				2		2
other stone cores & platform renewal flakes	1					1
Total	479	705	2953	1045	729	5911

TABLE 11.2 .

consistent with a hypothesis of alternating periods of human and carnivore use of the cave.

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