AN EXAMPLE OF SUPERVISED CLASSIFICATION IN PALEOLITHIC ARCHAEOLOGY *

As it is well known, classification problems in Pattern Recognition obey to two different kinds of decision logic: *unsupervised* and *supervised*.

In the problems of unsupervised classification one deals with *tentative* classifications (usually the classes are expressed according tree structures). The consistency of these "a priori" classifications should then be controlled by means of standard univariate and multivariate statistical tests.

The unsupervised decision logic is the type of logic that is commonly used in archaeological problems, where one seeks tentatively patterns and structures in a data set.

As an example, we can briefly summarize the results of an unsupervised classification of the end-scrapers (a very common Upper Paleolithic tool) of the layer A1 of Grotta Polesini, near Rome (Bietti *et al.* 1983, 1985; Bietti 1985).

In Fig. 1 one can see an "a priori" tree structure. The five classes: ESBN: end-scrapers on blade without complementary retouch; ESBR: end-scrapers on blade with complementary retouch; ESFN and ESFR: the same on flake (defined from a lithotechnical and not a lithometric point of view); TRNG: triangular end-scrapers, with a pointed end, are essentially drawn from the traditional stylistic and morphological classifications. As a matter of fact, in Fig. 2 one can see one of these classifications: the G. Laplace's (1968) one, where the types G1, G2, G3, G4 are essentially our classes ESBN, ESBR, ESFN, ESFR (the triangular end-scraper is not considered in the Laplace's list).

Every class is described by six features or parameters: lenght, width, thickness, curvature, asymmetry of the front contour and triangularity: these parameters have been defined elsewhere (Bietti, Zanello 1980).

The first statistical test, in order to establish the consistency of the "a priori" classes is the T-Test: in Table I one can see the result of this test at a 99% confidence level. It is worth noting that only the triangular end-scrapers seem to be well characterized as a *type*, and furthermore, the asymmetry feature is essentially a pleonastic parameter.

These results are confirmed by multidimensional mapping algorithms, such as the scatterplot of the distances between the two means (see, for instance,

* This paper is based on a communication presented at the XI U.I.S.P.P. international congress (Mainz, 1987).

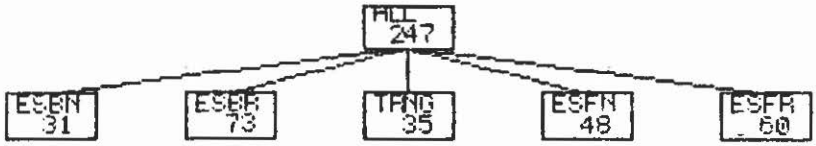

Fig. 1 — Simple "a priori" tree-structure for the end-scrapers of layer A1 of Grotta Polesini (from BIETTI *et al.* 1983).

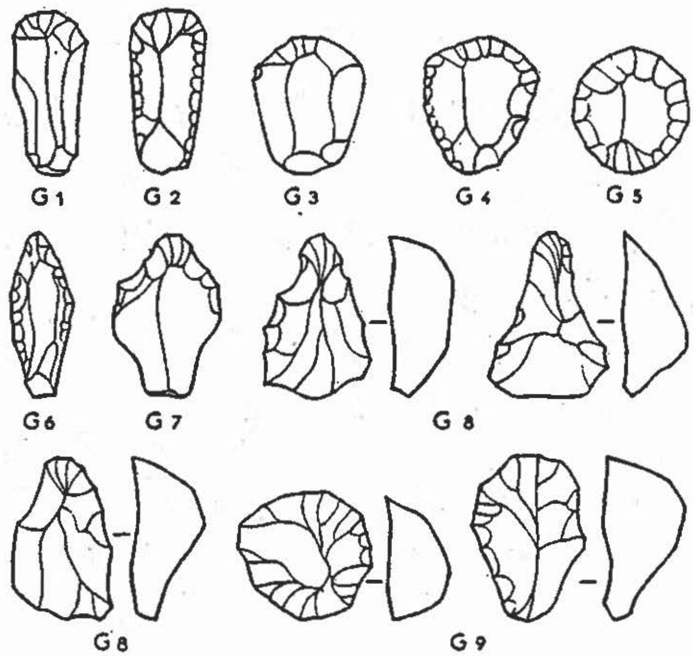

Fig. 2 — A traditional classification of Upper Paleolithic end-scrapers (from LAPLACE 1968).

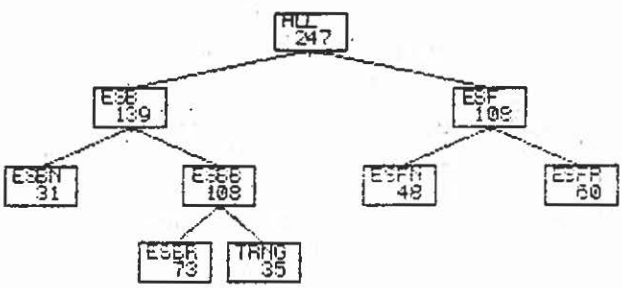

Fig. 3 — Modified tree-structure for the data shown in Fig. 1.

Feat. / Class	Length	Width	Thick.	Curv.	Asymm.	Triang.
ESBN-ESBR	No	Yes	No	No	No	No
ESBN-TRNG	Yes	No	Yes	No	No	Yes
ESBN-ESFN	Yes	No	Yes	No	No	No
ESBN-ESFR	No	Yes	No	No	No	No
ESBR-TRNG	Yes	No	Yes	No	No	Yes
ESBR-ESFN	Yes	No	Yes	No	No	No
ESBR-ESFR	Yes	No	No	No	No	No
TRNG-ESFN	Yes	No	No	No	No	No
TRNG-ESFR	Yes	No	No	No	No	Yes
ESFN-ESFR	No	No	No	Yes	No	No

Table I — Results of the T-Test at 99% confidence level for the classes of layer A1, according to the tree-structure shown in Fig. 1.

GELSEMA, EDEN 1980). To this end, we have used a modified "a priori" tree-structure, shown in Fig. 3. The mapping algorithm has been applied to the intermediate nodes ESBB and ESF and the results are shown respectively in Fig. 4a and 4b: one can immediately see that the TRNG class is rather well separated from the ESBR class while no clear separation can be observed between the ESFN and ESFR classes.

This unsupervised classification experiment therefore seems to indicate that at Grotta Polesini, layer A1, the end-scrapers can be classified as triangulars + "others", in spite of the circumstance that in the traditional classifications, such the Laplace's one, the triangular end-scraper is a "subtype" of the G2, the end-scraper on retouched blade.

We now turn to the supervised decision logic. In contrast with the unsupervised logic, we have here an "a posteriori" decision pattern: we start with a "learning set" (in most archaeological cases it is the result of a "tentative" unsupervised classification) and then we try to classify a new "unknown" set, according standard statistical decision techniques, such as, for instance, linear maximum likelihood, Fisher linear discriminant analysis, Bayes decision logic, etc.

We have tried to use supervised classification (a real *exercise* in this type of classification) again for the end-scrapers of Grotta Polesini, but now for the ones coming from the layer C12. According to A.M. Radmilli (1974) this layer

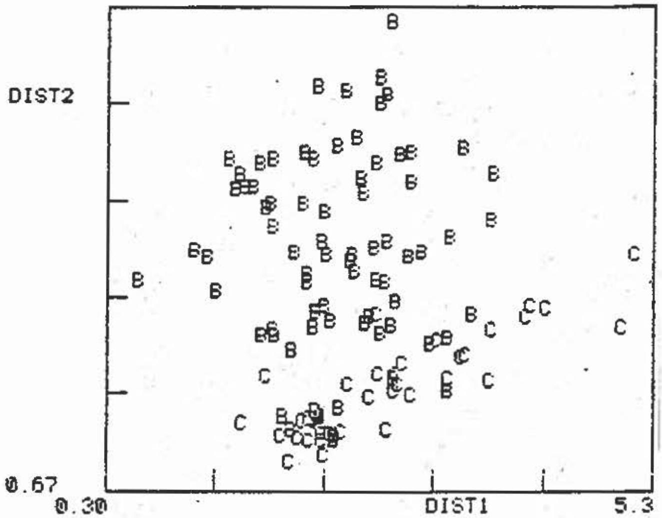

Fig. 4a — Scatterplot obtained by the mapping algorithm of the distance of the two means for the classes ESBR (label B) and TRNG (label C) for the layer A1 of Grotta Polesini (from Bietti 1985).

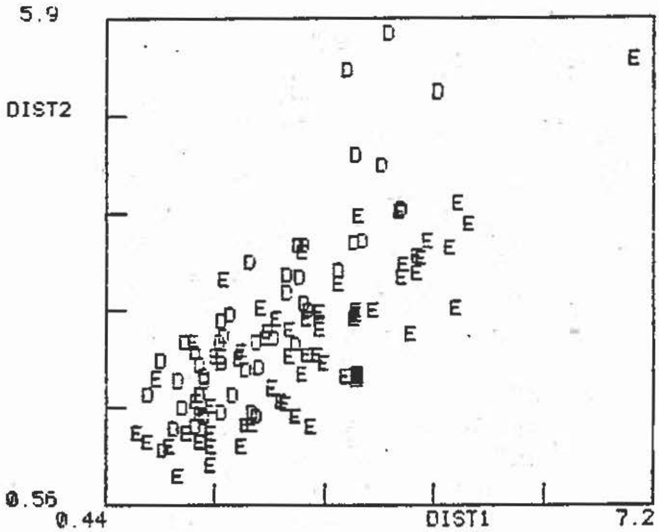

Fig. 4b — Same as in Fig. 4a for the classes ESFN (label E) and ESFR (label F).

should be the oldest of the stratigraphical sequence, while layer A1 should be the youngest. We have an absolute date of about 10.300 B.P. for a layer 7 which should be, therefore, intermediate between the layers A1 and C12. According to A.M. Radmilli (1974) the chronological difference between the upper and the lower layers should also be confirmed by the typological differencies in the tool-kit.

It is reasonable to think that the results of a supervised classification should not be in contrast with an "a priori" tentative unsupervised classification: therefore we started with tentative tree-structures for the end-scrapers of the layer C12 of the same type of these used for the layer A1, and they are shown in Fig. 5a and 5b. The T-Test for the classes shown in Fig. 5a, always at 99% of confidence level, is given in Table II. As for the layer A1, the asymmetry parameter is irrelevant. There are some differencies in the diagnostic features, in comparison with table I, but the triangular end-scrapers still are rather well separated from the other classes, as it can be seen from Fig. 6, which shows the scatterplot of the classes ESBR and TRNG according to the distances of the two means (the analogous of Fig. 4a).

The supervised classification of the set of layer C12 then proceeds in the following way: a learning set is derived simply dividing by two the A1 sample, and it is shown in Fig. 7a and 7b for the two tree-structures respectively.

One then proceeds to attach the decision process to the various nodes (non terminal-nodes) in order to test the validity of the classification structure to be tested (in our case these are the tree-structures of the layer C12 shown in Fig. 5a and 5b). Taking into account the simple tree-structure (respectively Fig. 5a for the test set and Fig. 7a for the learning set) the results by means of the linear maximum likelihood are given in Table III, where the confusion matrix is given for all the five classes: as it can be clearly seen the best classification is given for the triangular end-scrapers, which are well classified up to the 85%. In contrast, the misclassification for classes such as ESFR and ESBR reaches about 50%, and it is even worse for the classes ESBN and ESFN. These results are in agreement with the ones of the unsupervised "a priori" classification, as in principle should be.

We have also tried to use the Fisher discriminant classifier, and the misclassification raises in this case: one has however to observe that very seldom the Fisher method can be fruitfully applied to archaeological samples, because of the peculiar statistical constraints of this type of classification.

We have then used the linear maximum likelihood method for the more complex tree-structures (respectively Fig. 5b for the test set and Fig. 7b for the learning set). The results at the two lowest non terminal nodes, ESBB and ESF, are shown in Table IV: again the best classified class is TRNG and the class ESFR is better classified than the class ESFN. The same situation can be observed for the classification at the node ESB, which takes into account only the end-scrapers on blade (Table V), and at the node ALL (Table VI), where we have a general outlook of all the testing processes at the initial and the intermediate nodes.

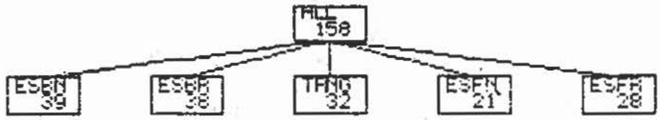

Fig. 5a — Same as in Fig. 1 for the layer C12 of Grotta Polesini.

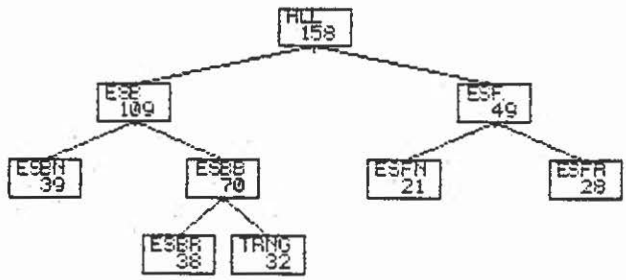

Fig. 5b — Same as Fig. 3 for the layer C12 of Grotta Polesini.

Feat. Class	Length	Width	Thick.	Curv.	Asymm.	Triang.
ESBN-ESBR	No	No	No	Yes	No	No
ESBN-TRNG	Yes	No	No	No	No	Yes
ESBN-ESFN	No	No	Yes	No	No	No
ESBN-ESFR	No	Yes	Yes	Yes	No	No
ESBR-TRNG	No	No	No	No	No	Yes
ESBR-ESFN	No	No	Yes	No	No	No
ESBR-ESFR	No	Yes	Yes	No	No	No
TRNG-ESFN	No	No	Yes	No	No	Yes
TRNG-ESFR	No	Yes	Yes	No	No	Yes
ESFN-ESFR	No	Yes	No	No	No	No

Table II — Same as in Table I but for the classes of layer C12, according to the tree-structure shown in Fig. 5a.

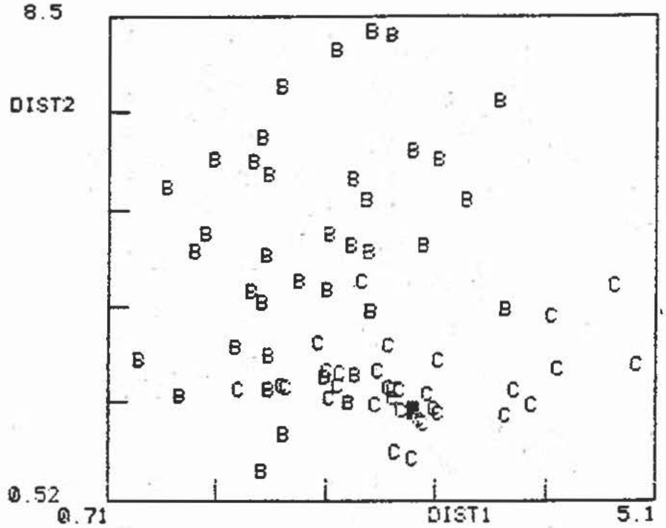

Fig. 6 — Same as a Fig. 4a for the layer C12 of Grotta Polesini.

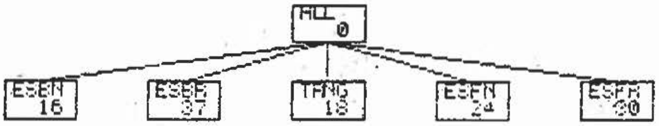

Fig. 7a — The learning set for the supervised analysis derived from the sample of the layer A1 shown in Fig. 1.

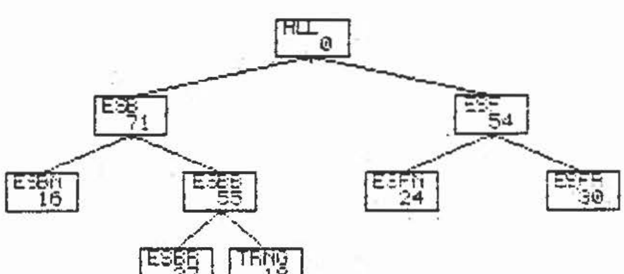

Fig. 7b — Same as in Fig. 7a but derived from the tree-structure in Fig. 3.

	ESBN	ESBR	TRNG	ESFN	ESFR
ESBN	11	19	3	3	3
ESBR	3	19	8	2	6
TRNG	2	1	27	2	0
ESFN	5	2	3	8	3
ESFR	0	5	1	6	16

Table III — Confusion matrix obtained by the linear maximum likelihood at the node ALL of the tree-structure shown in Fig. 5a. Vertical: prior; horizontal: posterior.

	ESBR	TRNG
ESBR	29	9
TRNG	2	30

	ESFN	ESFR
ESFN	10	11
ESFR	7	21

Table IV — Same as Table III for the nodes ESBB and ESF of Fig. 5b.

	ESBN	ESBB	ESBR	TRNG
ESBN	27	12	9	3
ESBR	10	28	20	8
TRNG	6	26	2	24

Table V — Same as Table III for the node ESB of Fig. 5b.

	ESB	ESF	ESBN	ESBB	ESFN	ESFR	ESBR	TRNG
ESBN	31	8	21	10	3	5	7	3
ESBR	28	10	8	20	2	8	15	5
TRNG	29	3	5	24	3	0	2	22
ESFN	11	10	8	3	8	2	0	3
ESFR	5	23	0	5	7	16	5	0

Table VI — Same as Table III for the node ALL of Fig. 5b.

	ESBN	ESBR	TRNG	ESFN	ESFR
ESBN	4	8	1	0	2
ESBR	8	15	3	3	7
TRNG	3	1	12	1	0
ESFN	7	2	1	6	8
ESFR	2	6	5	4	13

Table VII — Same as Table III for the other half of the sample of layer A1 at the node ALL of Fig. 1.

Even if all these results agree substantially with the unsupervised classification, one could argue that the generally poor supervised classification result derives from the circumstance that we have used as learning set the end-scrapers of layer A1, and their distribution may well be different from those of layer C12, simply for a chronological effect, as it is suggested by the aforementioned traditional analysis.

Actually, the same supervised analysis can be performed for the other half of the original A1 sample, that now becomes the test set, and the learning set is obviously again the first half of the sample.

The results, for the simple tree structure (i.e. Fig. 7a) are given in Table VII, and as it can be seen, the situation is very similar to the one of layer C12: the class TRNG is always the best classified. On the other hand the misclassification of the class ESFR is worse for layer A1: this circumstance is in agreement with the poor resolution between the classes ESFN and ESFR shown in the scatterplot of Fig. 4b; as a matter of fact, the same scatterplot for layer C12 shows a better separation between the two classes (Fig. 8).

What can we learn from this exercise on supervised classification? A first result is the congruence with the results of the unsupervised classification: a rather poor classification could not be transformed in a good classification only by means of "a posteriori" checks.

From the point of view of the lithic typology both layers A1 and C12 of Grotta Polesini seem to show only a structure of triangular end-scrapers +

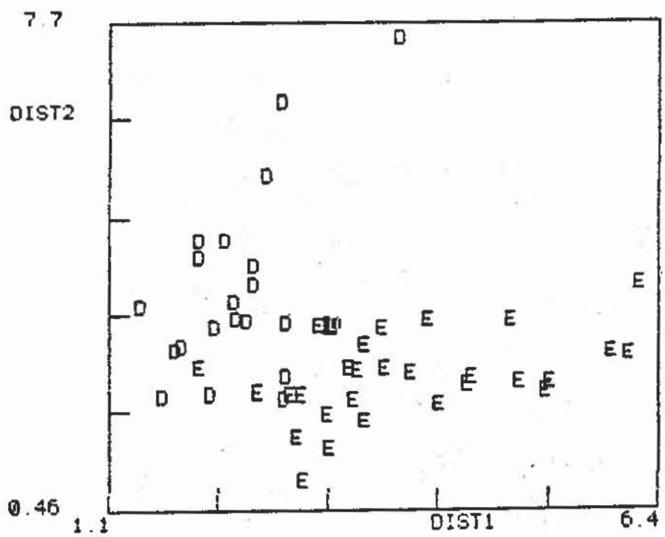

Fig. 8 — Same as in Fig. 4b for the layer C12 of Grotta Polesini.

"others": the comparison with the traditional classification of Fig. 2 is rather embarassing. In fact, the only recognizable type from our analysis, the triangular end-scraper, is *not* present in Fig. 2: it seems that some of the "primary" types of G. Laplace are distinguished only by single formal elements, such as the presence or absence of complementary retouch, and metric features are not playing any role at all.

In our opinion, more attention should be given to functional considerations in building a typology: it may well be that all these "other" end-scrapers at Grotta Polesini, which show such a poor level of distinction, are just simple variants of a single functionally (and therefore culturally, from a behavioural point of view) well defined type.

In any case, as a conclusion, it should be stressed that the results obtained here have to be interpretated strictly following a *contextual* perspective: it may well be that other Upper Paleolithic sites, even in the same region, could show completely different typological patterns. This amounts to say that, in our opinion, the traditional typological lists are often too general, too much oriented towards large scale comparisons in space and time, and very little concerned to a more deep understanding of behavioural patterns on a more local scale.

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ABSTRACT

As an example of Pattern Recognition problems in prehistory, the Authors present two different kinds of classification (unsupervised and supervised) applied to a sample of common Upper Paleolithic tools: the end-scrapers of Grotta Polesini, coming from layer 1 and layer C12. The results, obtained with the use of statistical techniques, lead to a general conclusion: in building a typology more attention should be given to functional considerations and to a deep understanding of behavioural patterns on a more local scale. The traditional prehistoric typological lists are thus criticized, because often too general and too much oriented towards large scale comparisons in space and time.