



Universiteit
Leiden

The Netherlands

Analecta Praehistorica Leidensia 28 / Interfacing the past : computer applications and quantitative methods in archaeology CAA95 Vol. I

Kamermans, Hans; Fennema, Kelly; et al., ; Kamermans, Hans; Fennema, Kelly

Citation

Kamermans, H., Fennema, K., & Et al.,. (1996). Analecta Praehistorica Leidensia 28 / Interfacing the past : computer applications and quantitative methods in archaeology CAA95 Vol. I, 272. Retrieved from <https://hdl.handle.net/1887/32752>

Version: Not Applicable (or Unknown)
License: [Leiden University Non-exclusive license](#)
Downloaded from: <https://hdl.handle.net/1887/32752>

Note: To cite this publication please use the final published version (if applicable).

ANALECTA
PRAEHISTORICA
LEIDENSIA

28

PUBLICATIONS OF THE INSTITUTE OF PREHISTORY
UNIVERSITY OF LEIDEN

INTERFACING THE PAST

COMPUTER APPLICATIONS AND QUANTITATIVE
METHODS IN ARCHAEOLOGY CAA95 VOL. I

EDITED BY
HANS KAMERMANS AND KELLY FENNEMA



UNIVERSITY OF LEIDEN 1996

contents

VOLUME I

Hans Kamermans Kelly Fennema	Preface
Data Management	
Jens Andresen Torsten Madsen	IDEA – the Integrated Database for Excavation Analysis 3
Peter Hinge	The Other Computer Interface 15
Thanasis Hadzilacos Polyxeni Myladié Stoumbou	Conceptual Data Modelling for Prehistoric Excavation Documentation 21
E. Agresti A. Maggiolo-Schettini R. Saccoccio M. Pierobon R. Pierobon-Benoit	Handling Excavation Maps in SYSAND 31
Alaine Lamprell Anthea Salisbury Alan Chalmers Simon Stoddart	An Integrated Information System for Archaeological Evidence 37
Jon Holmen Espen Uleberg	The National Documentation Project of Norway – the Archaeological sub-project 43
Irina Oberländer-Târnoveanu	Statistical view of the Archaeological Sites Database 47
Nigel D. Clubb Neil A.R. Lang	A Strategic Appraisal of Information Systems for Archaeology and Architecture in England – Past, Present and Future 51
Nigel D. Clubb Neil A.R. Lang	Learning from the achievements of Information Systems – the role of the Post-Implementation Review in medium to large scale systems 73
Neil Beagrie	Excavations and Archives: Alternative Aspects of Cultural Resource Management 81
Mark Bell Nicola King	The MARS Project – an interface with England's past 87

Archaeometry

- M.J. Baxter
H.E.M. Cool
M.P. Heyworth
Detecting Unusual Multivariate Data: An Archaeometric Example 95
- Jon Bradley
Mike Fletcher
Extraction and visualisation of information from ground penetrating radar surveys 103
- Gayle T. Allum
Robert G. Aykroyd
John G.B. Haigh
Restoration of magnetometry data using inverse-data methods 111
- W. Neubauer
P. Melichar
A. Eder-Hinterleitner
Collection, visualization and simulation of magnetic prospection data 121
- A. Eder-Hinterleitner
W. Neubauer
P. Melichar
Reconstruction of archaeological structures using magnetic prospection 131
- Phil Perkins
An image processing technique for the suppression of traces of modern agricultural activity in aerial photographs 139
- Statistics and Classification**
- Clive Orton
Markov models for museums 149
- Juan A. Barceló
Heuristic classification and fuzzy sets. New tools for archaeological typologies 155
- Kris Lockyear
Dmax based cluster analysis and the supply of coinage to Iron Age Dacia 165
- Christian C. Beardah
Mike J. Baxter
MATLAB Routines for Kernel Density Estimation and the Graphical Representation of Archaeological Data 179
- John W.M. Peterson
A computer model of Roman landscape in South Limburg 185
- Sabine Reinhold
Time versus Ritual – Typological Structures and Mortuary Practices in Late Bronze/Early Iron Age Cemeteries of North-East Caucasia ('Koban Culture') 195
- Leonardo García Sanjuán
Jesús Rodríguez López
Predicting the ritual? A suggested solution in archaeological forecasting through qualitative response models 203
- Johannes Müller
The use of correspondence analysis for different kinds of data categories: Domestic and ritual Globular Amphorae sites in Central Germany 217
- J. Steele
T.J. Sluckin
D.R. Denholm
C.S. Gamble
Simulating hunter-gatherer colonization of the Americas 223

- Paul M. Gibson An Archaeofaunal Ageing Comparative Study into the Performance of Human Analysis Versus Hybrid Neural Network Analysis 229
- Peter Durham Image Processing Strategies for Artefact Classification 235
Paul Lewis
Stephen J. Shennan
- Gijsbert R. Boekschoten A new tool for spatial analysis: "Rings & Sectors plus Density Analysis and Trace lines" 241
Dick Stapert
- Susan Holstrom Loving Estimating the age of stone artifacts using probabilities 251
- Oleg Missikoff Application of an object-oriented approach to the formalization of qualitative (and quantitative) data 263

VOLUME II

Geographic Information Systems I

- David Wheatley Between the lines: the role of GIS-based predictive modelling in the interpretation of extensive survey data 275
- Roger Martlew The contribution of GIS to the study of landscape evolution in the Yorkshire Dales, UK 293
- Vincent Gaffney Extending GIS Methods for Regional Archaeology: the Wroxeter Hinterland Project 297
Martijn van Leusen
- Trevor M. Harris Multi-dimensional GIS: exploratory approaches to spatial and temporal relationships within archaeological stratigraphy 307
Gary R. Lock
- Philip Verhagen The use of GIS as a tool for modelling ecological change and human occupation in the Middle Aguas Valley (S.E. Spain) 317
- Federica Massagrande The Romans in southwestern Spain: total conquest or partial assimilation? Can GIS answer? 325
- Shen Eric Lim Recent examples of geographical analysis of archaeological evidence from central Italy 331
Simon Stoddart
Andrew Harrison
Alan Chalmers
- Vincent Gaffney Satellite Imagery and GIS applications in Mediterranean Landscapes 337
Krištof Oštir
Tomaž Podobnikar
Zoran Staničič
- Yvette Bommeljé The long and winding road: land routes in Aetolia (Greece) since Byzantine times 343
Peter Doorn

- Javier Baena Preysler
Concepción Blasco
- Application of GIS to images and their processing: the Chiribiquete Mountains Project 353

Geographic Information Systems II: The York Applications

- Julian D. Richards
- From Site to Landscape: multi-level GIS applications in archaeology 361
- Harold Mytum
- Intrasite Patterning and the Temporal Dimension using GIS: the example of Kellington Churchyard 363
- A. Paul Miller
- Digging deep: GIS in the city 369
- Julian D. Richards
- Putting the site in its setting: GIS and the search for Anglo-Saxon settlements in Northumbria 379
- Jeffrey A. Chartrand
- Archaeological Resource Visibility and GIS: A case study in Yorkshire 389

Visualisation

- John Wilcock
- A description of the display software for Stafford Castle Visitor Centre, UK 405
- Christian Menard
Robert Sablatnig
- Pictorial, Three-dimensional Acquisition of Archaeological Finds as Basis for an Automatic Classification 419
- Katalin T. Biró
- Simple fun – Interactive computer demonstration program on the exhibition of the Szentgál-Tűzköveshegy prehistoric industrial area 433
- György Csáki
Ferenc Redő
- Documentation and modelling of a Roman imperial villa in Central Italy 437
- Maurizio Forte
Antonella Guidazzoli
- Archaeology, GIS and desktop virtual reality: the ARCTOS project 443
- Germà Wünsch
Elisabet Arasa
Marta Pérez
- Dissecting the palimpsest: an easy computer-graphic approach to the stratigraphic sequence of Túnel VII site (Tierra del Fuego, Argentina) 457
- David Gilman Romano
Osama Tolba
- Remote Sensing and GIS in the Study of Roman Centuriation in the Corinthia, Greece 461
- F.J. Baena
F. Quesada
M.C. Blasco
- An application of GIS intra-site analysis to Museum Display 469

Education and Publication

- Robin B. Boast
Sam J. Lucy
- Teaching with objects 479

- Martin Belcher
Alan Chalmers
Andrew Harrison
Simon Stoddart
Teaching the Visualisation of Landscapes – Approaches in Computer based learning for Archaeologists 487
- Anja C. Wolle
Stephen J. Shennan
A Tool for Multimedia Excavation Reports – a prototype 493
- G. Gyftodimos
D. Rigopoulos
M. Spiliopoulou
Exploring Archaeological Information through an Open Hypermedia System 501
- Martijn van Leusen
Sara Champion
Jonathan Lizee
Thomas Plunkett
Toward a European Archaeological Heritage Web 511
- Mike Heyworth
Seamus Ross
Julian Richards
Internet archaeology: an international electronic journal for archaeology 521
- Virgil Mihailescu-Bîrliba
Vasile Chirica
A Survey of the Development of Computer Applications in Romanian Archaeology 529
- Kris Lockyear
Computer-aided publication in practice 535

Estimating the age of stone artifacts using probabilities

1 Introduction

This article describes an application of the Bayesian approach to estimate the age of lithic artifacts collected by surface surveys in West Central Italy (fig. 1). Although the application refers to very specific circumstances and cannot be directly transferred to a different situation or region, the general procedure may be useful as a way to systematically pull together disparate information to assign materials to classes.

2 The archaeological problem

The problem was to estimate the age of lithic artifacts collected on the surface of older land formations during archaeological surveys of the Agro Pontino (Voorrips *et al.* 1991), the Fondi Basin (Bietti *et al.* 1988), and the area around Cisterna (Attema 1993) in West Central Italy (fig. 2). Physical geographers from the University of Amsterdam, who mapped the soils in the area, established the relative ages and surface stability of various formations (Sevink *et al.* 1982: 1984). Subsequent research provided absolute dates for some of the older formations with stable surfaces (Hearty/Dai Pra 1986; De Wit *et al.* 1987), which is where Palaeolithic materials could be found coming up in the plough zone. On these stable surfaces one would not expect to find sites for excavation, but instead recover a portion of a fossil archaeological landscape in the form of a palimpsest of artifacts discarded over thousands and thousands of years.

Some of the stone artifacts collected could be assigned to tool types that are considered chronologically diagnostic in the region. These artifacts were used to date sets of aggregated fields, termed sites, in a very general way, i.e., Middle Palaeolithic, Early Upper Palaeolithic etc. This is a standard procedure for dealing with lithic scatters, at least in America (e.g. Bamforth 1986) and Northern Europe (e.g. Arts 1989). Information published about the coastal area north of the Agro Pontino, where surfaces are also rather stable, led us to believe that we, too, could identify changes in site distribution over time in this way. In working with the materials, however, it became apparent that this would not be possible.

As part of the survey project and fulfilment of requirements for his doctorate, Kamermans (1993)



Figure 1. Location of study area.

conducted a land evaluation study of the region using artifacts collected by the Agro Pontino survey. Basing himself on presence/absence of periods represented at sites, determined by the presence of chronologically diagnostic tools and cores in the region, as stated above, he found that all the apparent differences in land use throughout the Palaeolithic could be explained by intervening geological processes. Thus, he concluded that the region was regarded as a single unit, at least for resource exploitation, throughout the Palaeolithic.

In the course of my investigation of the Agro Pontino materials, I found that there seemed to be so many sites with more than one chronological component that it would be unlikely that we should discover any spatio-temporal differences using presence/absence of components at sites.

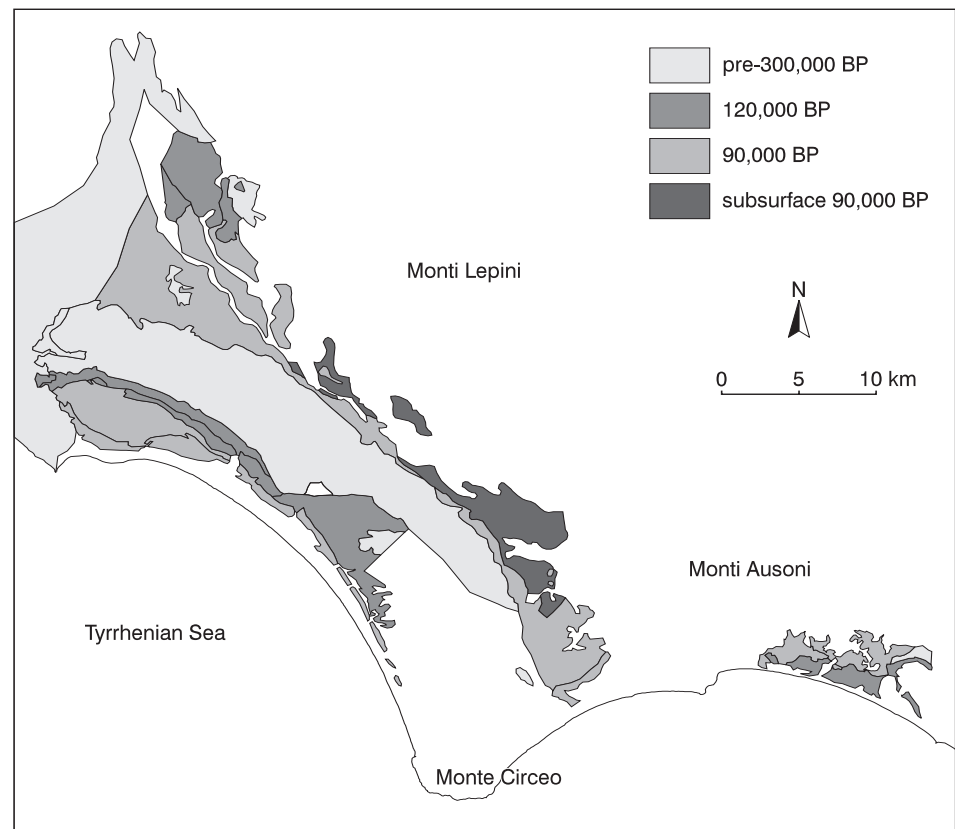


Figure 2. Distribution of older formations in the study area.

This aspect of the archaeological record of the Agro Pontino is brought into relief by comparing it with a more extensive sample along the Tyrrhenian coast. Mussi and Zampetti (1984-1987), two Italian researchers, had compiled the association of three Palaeolithic cultures — Mousterian, Aurignacian, and Epigravettian — represented in 49 sites along the coast from the Tevere to the Monte Circeo, including several on the Agro Pontino.

A set of chi-square tests on the co-occurrence or lack of it between these cultures shows that associations are due to chance (fig. 3), whereas the associations between the three cultures in sites on the Agro Pontino are all more than expected and the probability that this is due to chance is less than .05 in each case. Thus, the archaeology of the Agro Pontino appears to be quite different from the coastal area in general.

This situation meant that the evidence for differential use of the landscape within a cultural period and any changes through time would require an estimate of age at the level of the individual artifact rather than at the level of the site or location. To my knowledge, this had never been done with surface artifacts.

3 Expertise for estimating the age of artifacts

A recent article by Buck and Litton (1991) not only encouraged archaeologists to use Bayesian approaches, but provided a clear description about how to do so. Their idea that prior probabilities and additional data collected were forms of expertise was absolutely crucial. Bayes's theorem provides a way to pull together various kinds of expertise.

We did have or could collect various types of information, or forms of expertise, that might contribute to estimating artifact age.

3.1 AGE OF LAND SURFACES AND ARCHAEOLOGICAL CULTURES IN THE REGION

The first type of information was the age of land surfaces in the area (fig. 2). Absolute dates for the latest tuff deposits are .338 Myr BP, stage 9-10 (?) (Fornaseri 1985) and for the Latina level are .54 Myr BP, stage 15 (De Wit *et al.* 1987). Minturno level deposits, including the beach ridge and associated aeolian sands, the coastal and inland lagoons, and the travertines, were dated to the last interglacial, *c.* .12 Myr BP, stage 5e, and Borgo Ermada level deposits, the beach ridge and coastal and inland lagoons,

Table 1. Approximate ages of geological formations on the Agro Pontino and archaeological cultures in West Central Italy.

Years BP	Formation	Archaeological culture
9,000		<i>Mesolithic</i>
12,000	Late Glacial aeolian sands	----- <i>Epigravettiano</i>
20,000		----- <i>Gravettiano</i> <i>Aurignaziano</i> <i>Uluzziano</i>
35,000		-----
90,000	Borgo Ermada level	<i>Pontiniano</i>
120,000	Minturno level	----- <i>Musteriano</i> <i>Acheuleano</i>
350,000	Colli Albani tuff	
550,000	Latina level	

were dated to about .09 Myr BP, stage 5b (Hearty/Dai Pra 1986).

Table 1 shows the temporal juxtaposition between the archaeological cultures and the age of land surfaces. Given the approximate ages of archaeological cultures, the Lower Palaeolithic *Acheuleano* and Middle Pleistocene Middle Palaeolithic *Musteriano* and *Pontiniano*, would be restricted to the tuff and Latina levels.

3.2 TYPOLOGY AND TECHNOLOGY OF LITHIC ARTIFACTS RECOVERED FROM EXCAVATIONS

The second source of information was the artifacts recovered from major excavations in the area reported in the literature (table 2). Altogether, the information conveyed by the excavators constitutes a kind of collective expertise for the area. The completeness and detail of the reports, however, vary considerably, and, of course, the typologies used to describe the materials also vary according to whether the assemblages are Lower or Middle Palaeolithic or Upper Palaeolithic. In the more complete reports diverse kinds of information are offered. In addition to counts of typed tools are counts of different types of cores, counts of different types of debitage (flakes, blades, bladelets, burin spalls, etc.), counts or indices of Levallois flakes, and in some cases, counts of Pontinian scrapers (Middle Palaeolithic side scrapers with Quina retouch), which is a kind of ‘stylistic’ category.

As an archaeologist wanting to tap this expertise for my particular problem, I asked, ‘given the contents of excavated sites, what is the probability that a particular

Open air and cave sites along the Tyrrhenian coast, West Central Italy (N = 49)

	<i>Aurignaziano</i>	
	present	absent
<i>Musteriano</i> present	17 (17.6)	4 (3.4)
<i>Musteriano</i> absent	24 (23.4)	4 (4.6)

Chi-square = 0.19, df = 1
Approximate $p = .65$

Surface scatters on older formations in the Agro Pontino and Fondi Basin (N = 208)

	<i>Aurignaziano</i>	
	present	absent
<i>Musteriano</i> present	68 (52.6)	82 (97.4)
<i>Musteriano</i> absent	5 (20.4)	53 (37.6)

Chi-square = 24.7, df = 1
 $p < .05$

	<i>Aurignaziano</i>	
	present	absent
<i>Epigravettiano</i> present	13 (10.7)	12 (14.3)
<i>Epigravettiano</i> absent	8 (10.3)	16 (13.7)

Chi-square = 1.76, df = 1
 $p = .18$

	<i>Aurignaziano</i>	
	present	absent
<i>Epigravettiano</i> present	59 (41.8)	60 (77.2)
<i>Epigravettiano</i> absent	14 (31.2)	75 (57.8)

Chi-square = 25.61, df = 1
 $p < .05$

Figure 3. Comparison between sample on the coast of West Central Italy as compiled by Mussi and Zampetti (1984-1987) and sample from surfaces of older formations on the Agro Pontino and Fondi Basin.

artifact collected on the surface of the Agro Pontino comes from each of the 7 archaeological cultures?’.

The first step in the application was to construct probabilities for tool and core types etc., from the excavation reports available. This was done in three steps:

1. The Middle and Upper Palaeolithic type lists (Bietti 1976-1977; Bordes 1961) were combined to create a single type list that could incorporate the more common types. The artifact illustrated in figure 4 will be used as an example. It is typologically and technologically an end scraper on a flake. All Middle Palaeolithic end scrapers, Bordes types 30 and 31, most of which are made on flakes, were put into the same category as Upper Palaeolithic end scrapers on flakes, Bietti type 3.
2. Then, for each archaeological culture, counts of tool types were summed across the sample for that culture and percentages calculated.
3. Then, two probability tables were constructed, which were made conditional on the age of the land surface (table 3). The first table, to be used for artifacts found on tuff soils and the Latina level, was made by summing the percentages for each type across all seven

Table 2. Archaeological cultures represented in excavated sites in West Central Italy (compiled from: Bietti 1976-1977, 1984a, 1984b; Kuhn 1990; Piperno/Biddittu 1978; Segre-Naldini 1984; Taschini 1967, 1979; Tozzi 1970; Vitagliano/Piperno 1990-1991; Zampetti/Mussi 1988).

Archaeological culture	Site	Absolute dating, BP
<i>Mesolithic</i>	Riparo Blanc	8,565 ± 80
<i>Epigravettiano</i>	Peschio Ranano	9,730 ± 150
<i>Epigravettiano</i>	Riparo Salvini	12,400 ± 170
	Palidoro	15,900 ± 150
<i>Aurignaziano</i>	Grotta Barbara Fossilone, level 21	
<i>Pontiniano</i>	Grotta Breuil	36.6 ± 2.7 (Kyr)
<i>Must. denticulato</i>	Fossilone, level 27	
<i>Pontiniano</i>	Grotta di San Agostino (levels 1 to 3)	54 ± 11 to 43 ± 9 (Kyr)
<i>Pontiniano</i>	Grotta Guattari (levels 1-5)	77.5 ± 9.5 to 54.2 ± 4.1 (Kyr)
<i>Pontiniano</i>	Grotta della Cava	
<i>Pontiniano</i>	Grotta dei Moscerini (levels 39-25)	96 ± 1 to 79 (Kyr)
<i>Pontiniano</i>	Monte delle Gioie	
<i>Pontiniano</i>	Sedia del Diavola	
<i>Musteriano</i>	Torre-in-Pietra, level d	
<i>Acheuleano</i>	Torre-in-Pietra, level m	

Table 3. Prior probabilities that an end scraper on flake is associated with different archaeological cultures (based on 103 end scrapers on flakes reported in the literature).

Archaeological culture	If found on Latina level or tuff:	If found on Minturno or Borgo Ermada level:
<i>Acheuleano</i>	.11	-
Middle Pleistocene	.04	-
<i>Musteriano,</i> <i>Pontiniano</i>		
early Upper Pleistocene	.03	.04
<i>Pontiniano</i>		
middle Upper Pleistocene	.08	.09
<i>Pontiniano</i>		
<i>Aurignaziano</i>	.30	.35
<i>Epigravettiano</i>	.03	.04
<i>Mesolithic</i>	.41	.48

archaeological cultures and dividing each percentage by the sum to give the probabilities. The second table, to be used for artifacts found on the surfaces of other formations was constructed the same way, but only five of the archaeological cultures were used.

With this information, prior probabilities were assigned to all survey artifacts that could be put in one of the listed classes conditional upon the age of the land surface where they were found. The end scraper in figure 4 was found on soils in travertines, which developed during the Last

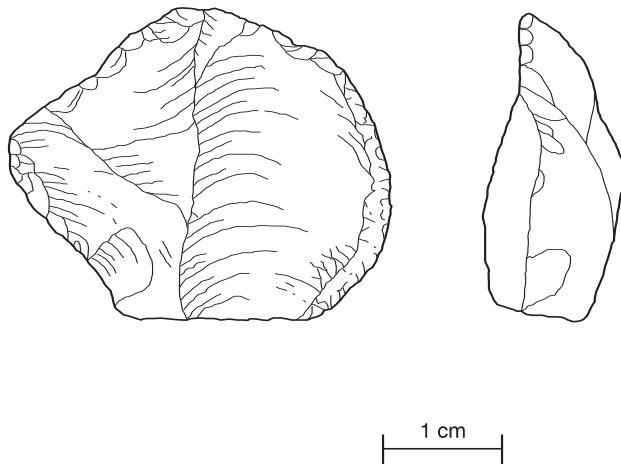


Figure 4. An end scraper on flake collected on travertine soils in the Agro Pontino.

Interglacial, in the same period as the Minturno level, *c.* 120,000 BP. Thus, the prior probabilities for it are found in the second probability table in table 3.

3.3 TECHNOLOGICAL ATTRIBUTES OF LITHIC ARTIFACTS
The third source of potential information was technological change in lithic manufacture. Lithic specialists (e.g. Cotterell/Kamminga 1987; Crabtree 1972b; Faulkner 1973; Parry 1987) have shown that changes in such things as core platform preparation, flake profiles, flaking angles, types of fracture etc., can reflect changing techniques and tools used for lithic manufacture, which would certainly have occurred over the long period of time represented in this region. There was also reason to suspect that approaches to flaking the local raw materials changed during the Middle Palaeolithic in this region (Kuhn 1990, 1990-1991).

After selecting variables potentially relevant in a technological sense from publications by lithics specialists, I collected the data from about 900 flakes and 400 cores from four excavated collections housed in Rome. These collections were Grotta Guattari, dated from about .78 through .50 Kyr BP, level 3 of Grotta Breuil, dated to about .36 Kyr BP (both in Schwarcz *et al.* 1990-1991), part of the Aurignacian in Riparo Salvini and part of level 21 Grotta dei Fossellone (Blanc/Segre 1953; not dated radiometrically) and the *in situ* portions of Riparo Salvini (collected by A. Bietti; not dated radiometrically), dated to about 12,400 BP (Avellino *et al.* 1989). Probability tables were constructed using the chronologically significant technological variables or combinations of them that emerged from the analysis of the collections. The probabilities were derived directly from the data itself or from models that fit the data.

Unfortunately, it was not possible to study samples from all seven archaeological cultures, and it was necessary to collapse categories to middle Middle Palaeolithic and earlier, late Middle Palaeolithic, Early Upper Palaeolithic, and Late Upper Palaeolithic and later (table 4). The probabilities for tool and core types were recalculated to fit these four temporal categories. If samples from the other cultures — i.e. Lower Palaeolithic, Middle Pleistocene Middle Palaeolithic, and Mesolithic — are analysed technologically, then this will no longer be necessary.

The next step in the application was to calculate posterior probabilities for all items that had acquired a prior probability in the first step and that could be coded for the relevant technological variables listed in the technological probability tables. In doing so, it was assumed that these two sets of probabilities were independent of each other. This was necessary because I had no information about the relationship between tool types and the technological variables.

The end scraper on a flake found on soils developed in Last Interglacial travertines (fig. 4) has adjusted prior probabilities for four archaeological temporal categories as shown in table 5. Technologically, this artifact is a conchoidal tertiary flake with a smooth prepared platform, with dorsal flaking oblique to the direction from which the flake was struck, and with no ventral features, i.e. an erillure scar or fissures, and no signs of abrasion adjacent to the butt on the dorsal side. The probabilities for a flake with these characteristics occurring per temporal category provide additional information. The posterior probabilities are calculated using Bayes's Theorem. So, the end scraper, which has prior probabilities in favour of Late Upper Palaeolithic or later changes to probabilities in favor of Early Upper Palaeolithic.

All other artifacts with technological attributes that were chronologically significant according to the analysis of excavated materials and had no prior probabilities were assigned prior probabilities on the basis of these attributes or combinations of them.

3.4 PATINA OF FLINT ARTIFACTS DEPENDENT ON AGE, FLINT TEXTURE, AND SOIL PARENT MATERIALS

The fourth and last source of information about age of surface artifacts in the Agro Pontino region was degree of patination. That the glossy patina on many of the artifacts collected by the Agro Pontino survey might be related to age of artifacts was suggested by Dick Stapert of the University of Groningen when he first saw them. So that this might be investigated, all artifacts were coded by comparing them with four items showing different categories of glossy patina — none, slight, medium, and heavy. Theoretically, glossy patination develops as

Table 4. Probabilities that an end scraper on flake comes from four temporal categories.

Archaeological culture	Original probability	Temporal category	Adjusted probability
if found on Latina level or tuff:			
<i>Acheuleano</i>	.11	middle Middle Palaeolithic or earlier	
Middle Pleistocene	.04		
<i>Must. & Pont.</i>			.18
early Upper Pleistocene	.03		
<i>Pontiniano</i>			
middle Upper Pleistocene	.08	late Middle Palaeolithic	.08
<i>Pontiniano</i>			
<i>Aurignaziano</i>	.30	Early Upper Palaeolithic	.30
<i>Epigravettiano</i>	.03	Late Upper Paleolithic or later	
<i>Mesolithic</i>	.41		
			.44
if found on Minturno or Borgo Ermada levels:			
early Upper Pleistocene	.04	middle Middle Palaeolithic or earlier	.04
<i>Pontiniano</i>			
middle Upper Pleistocene	.09	late Middle Palaeolithic	.09
<i>Pontiniano</i>			
<i>Aurignaziano</i>	.35	Early Upper Palaeolithic	.35
<i>Epigravettiano</i>	.04	Late Upper Palaeolithic or later	
<i>Mesolithic</i>	.48		
			.52

Table 5. Effect of additional information about technological features for estimating the age of the end scraper on a tertiary flake (based on 348 tertiary flakes examined from excavated collections).

	prior probabilities	probabilities based on technical features	posterior probabilities
middle Middle Palaeolithic or earlier	.04	.11	.01
late Middle Palaeolithic	.09	.36	.13
Early Upper Palaeolithic	.35	.39	.55
late Upper Palaeolithic or later	.52	.15	.31

superficial projections of silica are dissolved by soil water and deposited in superficial depressions on the surface of a fracture of flint, creating a glassy appearance. Important properties of the soil that promote or hinder solution of silica are pH and temperature in conjunction with the amount of organic compounds and aluminum ions (Luedtke 1992; Rottländer 1975). A few years ago, a loglinear model was found incorporating degree of patination, three archaeological periods, and three different kinds of sediment showing that these variables were probably interrelated in our samples (Loving/Kamermans 1991).

In examining the materials, we had also noted that more coarsely grained flints seemed to have less patina. According to geologists, it is probable that differences in the texture of the fracture surface seen macroscopically is due to porosity and clustering of quartz crystals in the stone as well as texture and that these properties affect both rates of weathering and appearance (Luedtke 1992).

Artifacts that had acquired a .6 probability or more for one of the four temporal categories in the previous steps of the application were used to build new loglinear models predicting for degree of patination based on age, sediment,

Table 6. Probabilities derived from loglinear models predicting degree of patination from age, type of sediment and stone texture (based on 1417 artifacts collected by surface survey).

Materials found in soils developed in travertines, aeolian and littoral sands:						
	light patina			heavy patina		
	fine-grain	medium-grain	coarse-grain	fine-grain	medium-grain	coarse-grain
middle Middle Palaeolithic or earlier	.18	.23	.24	.29	.30	.31
late Middle Palaeolithic	.23	.24	.24	.27	.29	.29
Early Upper Palaeolithic	.17	.22	.24	.30	.32	.33
late Upper Palaeolithic or later	.42	.31	.27	.14	.08	.07

Table 7. Effect of additional information about patina and texture for estimating the age of the end scraper on flake example.

	prior probabilities based on tool or core type and technological features	probabilities based on patina and texture	posterior probabilities
middle Middle Palaeolithic or earlier	0.01	.30	.03
late Middle Palaeolithic	.13	.29	.19
Early Upper Palaeolithic	.55	.32	.75
late Upper Palaeolithic or later	.31	.08	.02

and texture. Incorporating texture in the models showed that it had more effect than the type of sediment and as much effect as age of the artifact on the degree of patination; furthermore, texture of raw material is associated with the age of the artifact, so we even learned something we had not known before. After selecting the models that best fit the data, probability tables for age of artifacts given, degree of patination, texture, and type of sediment on which they were found were constructed from the models. There are two models. One for soils developed in tuff and lagoonal clays and a second one for all other soils (table 6).

The end scraper on a flake (fig. 4) was found on soils developed in travertine. It has a medium texture out of three categories — fine, medium, coarse — and a heavy degree of patination out of two categories — light and heavy. Based on these properties alone, it would have about equal probabilities of coming from one of the first three categories, but a very low probability of coming from the fourth category — Late Upper Palaeolithic or later.

The next step in the application, then, was to calculate posterior probabilities for all artifacts with prior probabilities that had not been used for analysis to construct the last set of probability tables. Again, it was assumed that information for prior probabilities was independent of the

added information. The additional information for the end scraper on flake gives it a much higher probability of dating to the Early Upper Palaeolithic (table 7).

All other flint artifacts collected by the survey from older surfaces that had not acquired probabilistic estimates of age in the previous steps were assigned probabilities deriving from each of the temporal categories using this last set of probabilities tables.

4 Computerized aspects of the application

Calculating posterior probabilities as other sources of information become available is an extremely tedious procedure. Thus, a small computer program was written by Albertus Voorrips (University of Amsterdam) that allowed probabilities to be typed in and then performed the necessary calculations. This made it easier to ‘walk’ a sample of artifacts through the estimation procedure to see how the application performed.

A schema was drawn up to order the decisions used in the application. The order was generally the same as presented in the preceding section, but was adjusted to accommodate certain logical and archaeological precedents. For example, artifacts used for developing the models for degree of patina retained the probabilities used before the analysis. Likewise,

certain technical attributes, most of them metrical, restricted an artifact to fewer chronological categories.

The schema was the basis for Voorrips to write a computer program to route the approximately 9000 artifacts collected by the surveys through the decision pathways, identify the appropriate probability tables, do the necessary calculations, and write out the final probabilities.

5 Assignment of artifacts to temporal categories

The final step in the application was to assign individual artifacts to one of the four temporal categories on the basis of their final probabilities. Since I do not know a way to determine a significant departure from a uniform distribution, a value of .6 or more for any one category seemed reasonable to accept as a best estimate.¹ In this way, about 4000 artifacts, a little over 40%, were assigned to one of the four temporal categories. By collapsing temporally adjacent categories into General Middle Palaeolithic and General Upper Palaeolithic, an estimate of age could be made for an additional 10% of the artifacts.

6 Discussion

These results made it possible to use counts and densities, to correct for time by calculating discard rates, and thereby to begin to see some patterning in possible use of the area. Although the data are now more tractable than before, there are certain drawbacks to the application. For one, there is no independent means of checking the validity of the results. For another, many decisions were made to construct the probability tables, and other archaeologists might do it slightly differently, which would most probably alter the outcome. Just how 'stable' the results that I obtained are is a matter for future investigation incorporating information from other or new analyses in the probability tables.

The procedure is most suitable for situations where the certainty about assignment to a class is low. If prior probabilities for an artifact belonging to a class are low, they will remain low unless additional information assigns low probabilities for the other classes. If, on the other hand,

probabilities for belonging to two or more classes are about equal, additional information incorporated into the procedure will either increase the certainty of assignment of an artifact to one of the classes or it will maintain the initial uncertainty, showing that for that case the additional information is irrelevant for assignment to a class.

Acknowledgements

I would like to thank Amilcare Bietti of the University of Rome and the members of the Istituto Italiano Paleontologia Umana for access to the excavated collections and the Fondi Basin survey materials housed in Rome. I am, as usual, indebted to my partner in life and work, Albertus Voorrips; without his contribution, I would be doing the calculations into the next century. Katarina Biró, Hungarian National Museum, critically reviewed the analysis on which the technological probabilities are based.

Most of the financial support for the Agro Pontino survey was provided by the Instituut voor Pre- en Protohistorische Archeologie, Universiteit van Amsterdam. Additional funding was provided by NWO (Nederlandse Organisatie voor Wetenschappelijk Onderzoek) grant nos. 280-152-024 and 280-152-033. The project would not have been possible without the cooperation of the Soprintendenza di Lazio and the Nederlands Instituut te Rome and the participation of many students from the Instituut voor Pre- en Protohistorische Archeologie, the Instituut voor Prehistorie Leiden, and the Università di Roma, who did most of the field walking for the survey.

Finally, in preparation for this article, I would like to thank Hans Kamermans and an anonymous reviewer for their comments, which helped to improve the article and correct some of my oversights.

note

1 Bob Laxton suggested that Monte Carlo techniques might be used to establish probabilities for various probabilities under different numbers of classes.

references

- Arts, N. 1989 Archaeology, environment and the social evolution of later band societies in a lowland area. In: C. Bonsall (ed.), *The Mesolithic in Europe*, 291-312, Edinburgh: J. Donald.
- Attema, P. 1993 *An Archaeological Survey in the Pontine Region*. Ph.D. dissertation. Archeologisch Centrum Groningen, Rijkuniversiteit Groningen.
- Avellino, E. 1989 Riparo Salvini: A new Dryas II site in Southern Lazio. Thoughts on the Late Epi-Gravettian of Middle and Southern Tyrrhenian Italy. In: C. Bonsall (ed.), *The Mesolithic in Europe*, 516-532, Edinburgh: J. Donald.
- A. Bietti
L. Giacomini
A. Lo Pinto
M. Vicari
- Bamforth, D.B. 1986 Technological efficiency and tool curation, *American Antiquity* 51(1), 38-50.
- Bietti, A. 1976-1977 Analysis and illustration of the Epigravettian industry collected during the 1955 excavations at Palidoro, *Quaternaria* 19.
- 1984a Primi risultati dello scavo nel giacimento epigravettiano finale di Riparo Salvini (Terracina, Latina), *Atti XXIV Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria nel Lazio, 8-11 Ottobre 1982*, 195-205.
- 1984b Il Mesolitico nel Lazio, *Atti XXIV Riunione Scientifica dell'Istituto Italiano di Preistoria e Protostoria nel Lazio, 8-11 Ottobre 1982*, 79-102.
- Bietti, A. 1988 Ricognizione sistematica di superficie nella Piana di Fondi (Latina), Primi risultati, *Archeologia Laziale* IX, 389-396.
- M. Brucchiatti
D. Mantero
- Blanc, A.C. 1953 *Excursion au Mont Circé*, Guides, Rome, INQUA, IVe Congress.
- A.G. Segre
- Bordes, F. 1961 *Typologie du Paléolithique Ancien et Moyen*. Bordeaux: Delmas.
- Buck, C.E. 1991 Applications of the Bayesian paradigm to archaeological data analysis. In: K. Lockyear/R. Sebastian (eds), *Computer Applications and Quantitative Methods in Archaeology 1990*, 93-97, BAR International Series 565, Oxford: Tempus Reparatum.
- C.D. Litton
- Cotterell, B J. 1987 The formation of flakes, *American Antiquity* 52(4), 675-708.
- J. Kamminga
- Crabtree, D. 1972 *An Introduction to Flintworking*, Occasional Papers of the Idaho State University Museum, no. 28.
- Faulkner, A. 1973 Mechanics of erailure formation, *Newsletter of Lithic Technology* II(3), 4-12.
- Fornaseri, M. 1985 Geochronology of volcanic rocks from Latium (Italy), *Rendiconti della Società Italiana di Mineralogia e Petrologia* 40, 73-106.
- Hearty, P.J. 1986 Aminostratigraphy of Quaternary marine deposits in the Lazio region of Central Italy, *Zeitschrift für Geomorphologie N.F.* 62, 131-140.
- G. Dai Pra
- Kamermans, H. 1993 *Archeologie en Landevaluatie in de Agro Pontino (Lazio, Italië)*. Ph.D. dissertation. Faculteit der Ruimtelijke Wetenschappen, Universiteit van Amsterdam.

- Kuhn, S.L. 1990 *Diversity within Uniformity: Tool Manufacture and Use in the 'Pontinian' Mousterian of Latium (Italy)*. Ph.D dissertation, University of New Mexico, Albuquerque.
- 1990-1991 Preliminary observations on tool manufacture and use histories at Grotta Breuil, *Quaternaria Nova* I, 367-378.
- Loving, S.H.
H. Kamermans 1991 Figures from flint: first analysis of lithic artifacts collected by the Agro Pontino survey. In: A. Voorrips/S.H. Loving/H. Kamermans (eds), *The Agro Pontino Survey Project*, Studies in Prae- en Protohistorie no. 6, 99-116, Amsterdam: Instituut voor Pre- en Protohistorische Archeologie Albert Egges van Giffen, Universiteit van Amsterdam.
- Luedtke, B.E. 1992 *An Archaeologist's Guide to Chert and Flint, Archaeology Research Tools*, no. 7. Los Angeles: University of California, Institute of Archaeology.
- Mussie, M.
D. Zampetti 1984-1987 La presenza umana nella pianura Pontina durante il Paleolitico medio e superiore, *Origini* XIII, 7-26.
- Parry, W.J. 1987 Technological change: Temporal and functional variability in chipped stone debitage. In: W.J. Parry/A.L. Christenson (eds), *Prehistoric Stone Technology of Northern Black Mesa, Arizona*, Occasional Paper no.12, 199-256, Southern Illinois University at Carbondale: Center for Archaeological Investigations .
- Piperno, M.
I. Biddittu 1978 Studio tipologico ed interpretazione dell'industria acheuleana e pre-musteriana dei livelli *m* e *d* di Torre in Pietra (Roma). *Quaternaria* XX, 441-428.
- Rottländer, R. 1975 The formation of patina on flint, *Archaeometry* 17(1), 106-110.
- Schwarz, H.P.
W. Buhay
R. Grün
M. Stiner
S. Kuhn
G.H. Miller 1990-1991 Absolute dating of Sites in Coastal Lazio, *Quaternaria Nova* I, 51-67.
- Segre-Naldini, E. 1984 Il musteriano di Grotta della Cava, Sezze Romano (Latina), *Atti della XXIV Riunione Scientifica dell'Istituto Preistoria e Protohistoria nel Lazio, 8-11 Ottobre 1982*, 142-147.
- Sevink, J.
P. Vos
W.E. Westerhoff
A. Stierman
H. Kamermans 1982 A sequence of marine terraces near Latina (Agro Pontino, Central Italy), *Catena* 9, 361-378.
- Sevink, J.
A. Remmelzwaal
O.C. Spaargaren 1984 *The Soils of Southern Lazio and Adjacent Campania*. Amsterdam: Universiteit van Amsterdam Fysisch Geologisch en Bodemkundig Laboratorium Publicatie 138.
- Taschini, M. 1967 Il 'Protopontiniano' rissiano di Sedia del Diavolo e di Monte delle Gioie (Roma), *Quaternaria* IX, 301-319.
- 1979 L'industrie lithique de Grotta Guattari au Mont Circé (Latium): Définition culturelle, typologique et chronologique du Pontinien, *Quaternaria* XXI, 179-247.
- Tozzi, C. 1970 La Grotta di S. Agostino (Gaeta), *Rivista di Scienze Preistoriche* 25, 30-87.
- Vitagliano, S.
M. Piperno 1990-1991 Lithic industry of level 27 *beta* of the Fossellone Cave (S. Felice Circeo, Latina), *Quaternaria Nova* I, 289-304.

- Voorrips, A.
S.H. Loving
H. Kamermans (eds) 1991 *The Agro Pontino Survey Project*. Studies in Prae- en Protohistorie no. 6. Amsterdam: Instituut voor Pre- en Protohistorische Archeologie Albert Egges van Giffen, Universiteit van Amsterdam.
- Wit, H.E. De
J. Sevink
P.A.M. Andriessen
E.H. Hebeda 1987 Stratigraphy and radiometric datings of a mid-Pleistocene transgressive complex in the Agro Pontino (Central Italy), *Geologica Romana* 26, 449-460.
- Zampetti, D.
M. Mussi 1988 Du paléolithique moyen au paléolithique supérieur dans le Latium. In: M. Otte (ed.), *L'Homme de Néandertal*. Actes de colloque international de Liège (4-7 décembre 1986), La Mutation, vol. 8, 273-288. Études et Recherches Archéologiques de l'Université de Liège, No. 35.

Susan Holstrom Loving
Willem Beukelstraat 30
1097 CT Amsterdam
The Netherlands
e-mail: SHL@IVIP.FRW.UVA.NL