# Efficiency of Chipped-Stone Techniques: An Analytical Model Based on GIS Data

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Abstract

The paper proposes an analytical model based on GIS-built terrain models for assessment of efficiency of chipped-stone techniques. The model includes four successive steps. The first one gives an approximate estimate of initial sizes of the nodules, out of which successive stages of core reduction occur. The second one includes GIS data that permit assessment of traits based mostly on digital terrain models. The third step assesses the type of relationship: linear or not between the amount of waste and the GIS defined features. The fourth one allows to build up various strategies based on the dependence between the platform position (optimal value), the amount of waste, the number of secondary platforms, the number of the long blanks detached, and the relative amount of core exploitation failures.
GIS analysis mainly starts from characteristics of the present-day landscape but the aim is to put greater emphasis on the palaeo-geographic context of the sites.
The combined analytical model with GIS data makes it flexible to assess independently different strategies of past human behaviour.

§1 The present approach creates new analytical methods and GIS applications for addressing the question of measuring the efficiency of chipped-stone technological cycles and aims at developing wider theoretical approaches in defining the factors for raw material procurement and technical choices for tool manufacturing of prehistoric communities. So far we came to the conclusion that the degree of technological complexity largely depends on natural and human factors. The first ones concern the geological situation of flint and other raw material outcrops within the terrain where prehistoric people moved and settled. Human factors also contribute to the degree of technological complexity and raw material procurement. So far we developed two models: upper Palaeolithic risk-avoidance strategies and the choices of Mesolithic/early Neolithic people made for raw material procurement and chipped -stone techniques relative to other constant resources. We confine, however, our presentation only to natural factors that contribute to the complexity of chipped-stone techniques. As a starting point we propose a reconstruction of theoretical ellipse that encircles symmetrically a Levallois core. The present approach can be equally well applied to other major core types. Brantingham and Kuhn (2001) suggested ellipse as a method for mathematical modeling of core reduction. We apply their idea of working within an ellipse for reconstruction of the maximal dimension of a nodule from which a given core (leftover) was derived through successive stages of core reduction.

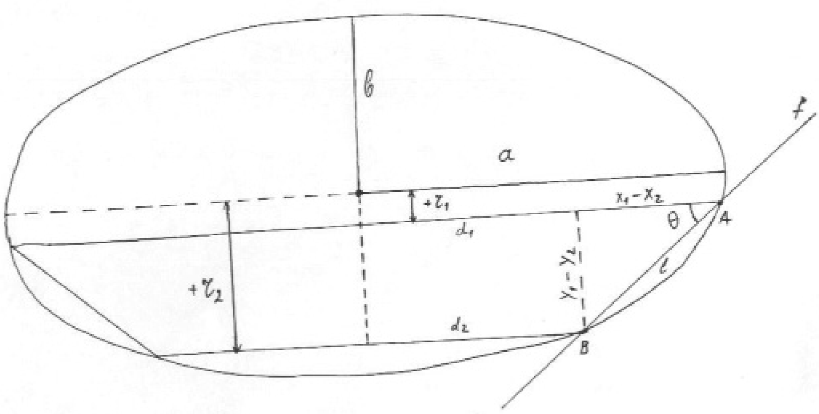

Figure 1 Calculation of the theoretical ellipse that encircles a Levallois core leftover. The same geometry can easily be applied for calculation of the theoretical ellipses of the other major chipped-stone core types.

The calculation has three stages. The first one defines the coordinates of points A and B in terms of x1 =d1/2, x2 = d2/2 and y1 and y2. These are also points of intersection of the straight line f defined as y = mx + n, where m = tgq. It establishes a relation between d1/2 and m, n, a, b within an ellipse equation. The second group of equations is based on the fact that the straight lines g1 and g2 cross the ellipse at points A and B. The third stage defines a system of two equations for both axes of the theoretical ellipse a and b which are derived from the first two stages of calculation. It is proven that the system has only one solution (Fig.1).

By calculating the theoretical ellipse on different in size and in type cores at a given archaeological site we are able to reconstruct more precisely the original dimensions of the nodules selected by prehistoric people. These data can easily be compared with the size, shape, quality, etc. of the natural nodules (concretions) from the outcrops used by prehistoric communities. This allows us to reconstruct and describe the reduction stages relative to different technical cycles. We can expect a strong correlation between technical cycles and reduction stages that define in two independent ways the amount of waste at each archaeological site. While the assessment of waste of the first one can be controlled through the characteristics of the debitage, the assessment of waste of the second one can be defined directly by the difference between the number of reduction stages and cores (leftovers) and the natural sizes of the nodules (concretions) that occur at raw material outcrops. Each of these technical lines of reconstruction of waste can be defined by polynomial expressions whose coefficients would strongly depend on features such as availability of raw materials, distance, quality, etc.

Using only a minimal set of formal procedures that can easily be adapted to GIS applications, the present approach provides a number of analytical tools for assessment of optimal exploitation of raw material sources. It provides a set of automatic applications that can define the overall technical efficiency in minimizing preparation waste and maximizing tool manufacturing. However, technological complexity and optimal exploitation of resources cannot be confined only to mini/max solutions of core reduction geometry (Tsonev 1999, Tsonev in press). There are other human factors that also contribute to the overall complexity of chipped-stone techniques. I shall present a simple case study that can show the difficulty in defining the right approach for assessment of these technical cycles.

In Temnata Cave Gravettian sequence, Bulgaria, there is a marked difference in the contribution of meso-local flint varieties and the extra-local flint varieties to the efficiency of lithic techniques (Tsonev, in press). Starting from bottom level X the significant increase of the imported high-quality flint varieties (both meso-local and extra-local) is positively correlated with a significant increase of the slenderness of the blades. From this point of view, the increased supply with high-quality flint varieties contributes to the efficiency of chipped-stone techniques.

There is another view, if we consider the distribution only of the extra-local flints from the Gravettian levels. Their percentages fluctuate considerably: from 1.4% at level X to 18.7% at level Vb. In most cases these percentages do not contribute to the overall efficiency of chipped-stone techniques and have no economic value. They just mark the directions of "communication corridors" the Palaeolithic people used.

Thus within the frame of GIS database, it is possible to adapt different approaches for verifying various working hypotheses about the efficiency of chipped-stone techniques.

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§2 The study of the cultural choices reflected by the lithic techniques adopted by individuals and groups in prehistory should be based on the knowledge of the geo-environmental conditions in which they lived and operated. Geo-referenced maps of both chert outcrops and archaeological sites with lithic assemblages, related by means of GIS software to databases of the chert regionally available and the flint actually used at each site, can be valid tools, and can allow further cultural inferences through the application of specific statistical analyses.

This approach has been recently tested in the easternmost region of northern Italy - Friuli Venezia Giulia - where a flint dedicated database has been created starting from the case study of non-systematic surface collections of lithic artifacts belonging to different prehistoric periods (Montagnari Kokelj et al. 2001, Montagnari Kokelj et al. in press 1). Particularly in such cases - but the observation can have a more general value - a traditional chrono-typological approach must be combined with the study of technology and lithology in order to go beyond the pure determination of when the site was used, and try to make hypotheses on the role that it might have played within one, or more, subsistence-settlement systems (Binford 1983; Binford 1989).

What was evident from the very beginning of our study is the absolute necessity to have specific geological maps assessing the presence and location of regional chert outcrops. Due to the fact that in our case these did not exist, vector thematic maps in .dwg and .dxf format have been elaborated by using AutoCAD Map: the topographical basis is given by the Regional Numerical Technical Map at 1:25.000 and the graphical elements are related to categories of spatial data (points, lines and areas).

The result is shown in Figure 2 This image combines separate representations: the map of the primary formations, i.e. of those lithologies where chert is syngenetic to the enclosing sediment; that of the secondary deposits, including both chrono-stratigraphical units of coherent lithologies and loose deposits, where chert is present as re-deposited material; the map of the main tectonic structures (see Fig.2).

These maps are related to specific database tables of deposits containing their geological description, with parameters such as lithology, color, lithofacies, sedimentary structures, main fossils and age.

Each table is completed by a photo of the sample taken from the deposit under study during preliminary field surveys aimed at checking the geo-morphological and geological features of the area. Accurate macro-analyses of the deposits and thin sections of each sample have been carried out contextually.

The more geological part of our study would not be complete without database tables for the chert contained in all these deposits, where a general description is followed by a more detailed one of cortex, mineralogical, morphometric and morphological characteristics of the chert and of its distribution.

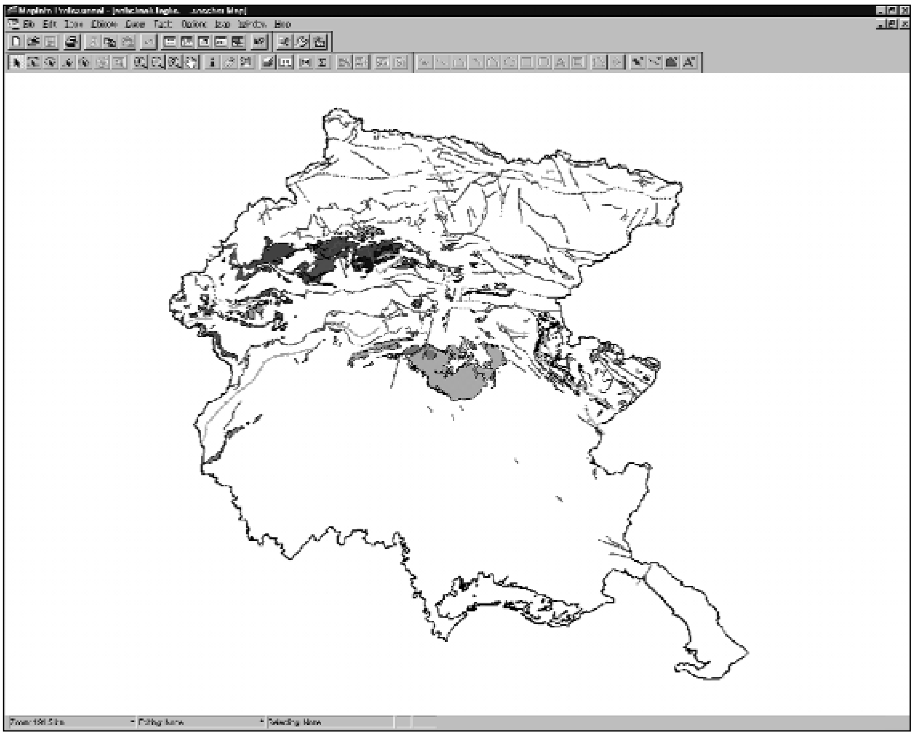

Figure 2 Friuli Venezia Giulia - northeastern Italy: overlay of primary formations, secondary deposits and main tectonic structures maps

- the code tables of the thematic maps: a pre-defined code allows in fact to link them to textual and image data stored into a relational database Access, importable into GIS MapInfo;
- 4 technical tables about deposits and chert description;
- the artefacts table, that contains some of the geological parameters already included in the other tables, plus others that belong to a more traditional archaeological approach.

The last table has been prepared for the first case study concerning lithic surface scatters, but it can clearly be used in any other case, and certainly more profitably for tools coming from stratigraphical contexts.

Moreover, when looking at the structure of our GIS, one can see that it has been created as a flexible system, linkable to other databases: in particular, we refer to one already implemented - ArcheoGIS, the archaeological map of the Isonzo Valley (Montagnari Kokelj 2001) - and to another - CRIGA, the GIS supported database of the archaeological caves of the Karst region (Montagnari Kokelj et al. in press 2) - in course of implementation by the same interdisciplinary team of the University of Trieste.

Within the CRIGA project, for instance, we have already planned to test the artefacts table on lithic assemblages from stratigraphical levels.

We believe that the integration of the different research lines indicated so far can be useful to analyse the relationship between chert, as natural rock potentially usable for making tools, and flint, as raw material actually used by man in specific sites in the past, in order to make hypotheses on the dynamics of procurement strategies and territorial exploitation. These strategies are likely to change through time, but the knowledge of the geo-lithological characteristics of a specific area is one of the elements indispensable to evaluate the cultural choices involved in long/short distance transport of raw materials, as the first test studies show already very clearly.

More information on the Italian interdisciplinary project can be found in the web: http://www.units.it/lithics.

Certain parameters included in the tables have a more archaeological character, as they focus specifically on the knapping qualities of a particular rock, which depend not only on the factors indicated so far, but also on another important one, i.e. the tectonic situation of the area. The map of the main tectonic structures allows in fact to identify, already on the surface, those areas where the chert is of bad quality due to fracture.

At this point it is important to underline that the geo-lithological part of our research, briefly dealt with so far, actually stems from continuous feedbacks from the archaeological area, and at the same time is very tightly connected with it at informatic level.

The geo-lithological maps and tables are in fact only some of the components of the whole system, the management of which has been facilitated by the use of a GIS software. The structure of the GIS contains:

- 5 thematic maps, 4 of which - geological sample points, primary formations, secondary deposits, structural map and archaeological sites - have been elaborated at regional level and one - single surface collection area - at local level;

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