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Transformation Analysis and the Reconstruction of On-Site and Off-Site Activities: Methodological Remarks

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One, if not the main, focus in Middle Paleolithic research is still the question of whether the observed concepts of blank production, as well as the different forms and frequencies of stone tools, derive from functional processes, or if they are better explained as resulting from cultural development. To analyze aspects of this discussion, which has been called the Binford-Bordes-discussion in the German literature (Richter 1997:134), it is necessary to control two other important factors that are, without doubt, responsible for some of the diversity among Middle Paleolithic assemblages: the influence of space and time. Both can be excluded as explanatory variables if contemporaneous assemblages from one region with similar environmental settings are used. It follows that the investigation of functional and/or cultural variability in the Middle Paleolithic should start on a regional scale in a limited chronological time range.

Chronology, however, is a major problem even if regional assemblages should be ordered according to their relative ages only. It seems as if typological comparisons alone, based on the hypothesis of an evolutionary development of stone tools, are not an adequate solution. In addition, analyses based on those type forms that are supposed to have a chronological relevance use only a part of the archeological data related to the production and use of stone tools (Rolland 1988; Sackett 1988). It is for this reason that two of the major complexes of Central European Middle Paleolithic, the Mousterian and the Micoquian, were believed to be units distinct in space and time (Bosinski 1967:84 *Einheiten in Zeit und Raum*) and thus the result of cultural changes over a long period of time. As soon as all artifacts, including debitage, from well-stratified sequences were used, and not just tool types (with a focus on type forms), different hypotheses emerged (Geneste 1985, 1988, 1990; Richter 1997; Soressi 1999; Uthmeier 2000).

The presence of the Levallois concept in both industries, as well as similarities in many other technological and typological variables, led to the hypothesis that the Central European Mousterian and Micoquian assemblages were produced by the same groups of Neandertals. The differences between both industries, which can be reduced, in a much simplified view, to the presence or absence of bifacial tools, seem to originate in different activities, rather than relating to different chronological positions and/or cultural traditions. The same analytic approach that tries to explain all artifacts in an assemblage in terms of typology, technology, raw material procurement, and settlement pattern, led to the hypothesis that assemblages of the so-called Szeletian (Allsworth-Jones 1986) may also represent the remains of special activities of the Mousterian and Micoquian-producing Central and Eastern European Neandertals (Uthmeier 2000).

Apart from the question of whether modified pieces alone bear sufficient data to answer chronological questions, it is common sense that multi-layered sites provide the most adequate data to establish a regional chronology. In this regard, the data from the Late Middle Paleolithic of Crimea is of exceptional quality. After more than twenty years of intensive research, many multi-layered open air sites, rockshelters, and caves from a small region situated along the ridges of the Crimean Mountains are known (Chabai 1998a). Among these, Kabazi II with more than 25 archeological horizons embedded in more than 15 geological layers is one of the major sequences for the Upper Pleistocene in Europe (Chabai 1998b; Chabai et al. in press). Sites like Kabazi V, Starosele, Buran-Kaya III, Karabi Tamchin, and Chokurcha I also have several archeological layers containing different industries and faunal material (Burke 1999a, 1999b, Chapter 16; Patou-Mathis 1999, Chapters 8 and 22). In combination with the analysis of malacofauna (Mikhailesku 1999, Chapter 19), small mammals (Markova 1999, Chapters 3, 17, 23), and pollen-sequences (Gerasimenko 1999, Chapter 2), it is possible to reconstruct different activities within local and regional paleoenvironments (Burke et al. 1999). For chronological comparisons, absolute dates were made with different dating methods to control and correlate the stratigraphical sequences (Rink et al. 1998).

According to Schiffer (1987), however, the distribution of finds within a given excavated unit may not only be the result of human activities, but may also be due to geological processes and other non-human agents. Geological processes that move artifacts after human occupation are supposed to be especially active in multi-layered caves and rockshelters (Richter 1987). Only after isolating processes that might lead to an admixture of artifacts from different archeological levels is it possible to meaningfully analyze and interpret human activity. Apart from other aspects, the following questions are considered to be important: Do all artifacts from an archeological horizon belong to a single episode of human settlement, or were they left in the course of several repeated visits to the same long-exposed living floor? What were the shapes of the artifacts that first entered the site, and from where did they come? Which part of the *chaîne opératoire* took place on-site, and which part happened off-site? What concepts were used for the production of blanks, and for what purpose were the tools made? Finally, what was the function of the site, and how does the site fit into a regional settlement pattern?

To answer these questions, it is necessary to isolate distinct short-term episodes. Afterwards, these distinct episodes can be analyzed in regard to their technology, typology, and the activities they represent, embedded in the use of the regional landscape. We believe that the sorting of stone artifacts into their original nodular context, the subsequent treatment of these nodules as minimal prehistoric units, and the interpretation of these units in terms of on-site and off-site activities are new methods that help to get closer to the recognition of functional processes in Paleolithic assemblages (Figure 11-1).

The Approach: Sorting Artifacts into Nodules

Today, the grouping of artifacts into different classes of raw material is a standard method in analyzing stone tool assemblages. In most studies, these classes represent geological formations and/or distinct raw material sources. It is only since the work of K.-H. Rieder (1981/82, 1990), J. Hahn (1988), and W. Weissmüller (1995) that the attempt to sort artifacts by using macroscopic attributes (Figure 11-2) into even smaller units has become more widely known. Inspired by the diversity of Jurassic and Cretaceous raw materials found in southern German Middle and Upper Paleolithic assemblages, they used carefully recorded attributes like the texture and color of the fracture, the structure and color of the cortex, and the presence or absence of microfossils to define individual nodules even when refits were missing. While the diversity of attributes within a unit thought to be the equivalent of a single nodule should tend towards zero, the differences between these units should be as numerous as possible. Unlike Weissmüller (1995:61), we decided not to sort artifacts under 3 cm if they were classified as simple chips. Chips from bifacial flaking and from retouch or the resharpening of working edges, however, were included in the samples. The attempt to sort artifacts into raw material units results in four different categories:

(1) Single piece: one artifact that shares no raw material attributes with any other artifact from the analyzed assemblage.

(2) Workpiece: two or more artifacts, with refits or without, that belong to a single nodule.

(3) Raw material source (or variant): two or more artifacts that belong to different nodules. The variety of raw material attributes is within the known variability of the raw material source.

(4) Formation: two or more artifacts, the origins of which can only be traced back to their geological genesis.

While in most cases a distinction between different geological formations, as well as between different raw material sources is possible, the identification of individual nodules requires knowledge of the variability of attributes such as color, cortex, and fossils within a given raw material source. The significance

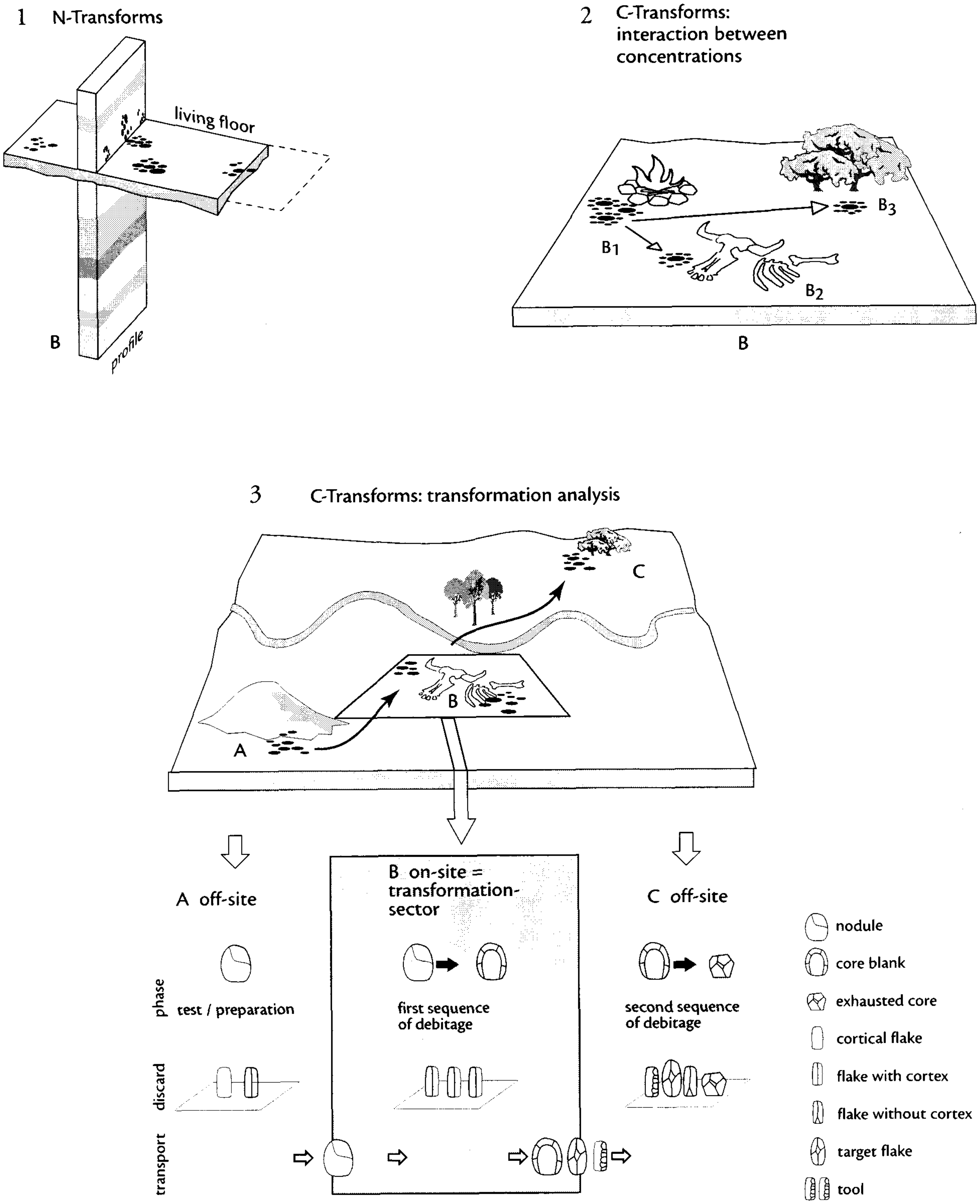

Figure 11-1—Analyzing stone tool assemblages on the basis of workpieces. Because they are considered to be equivalents of refits, workpieces can be used for the analysis of N-transforms and C-transforms: 1–the vertical and horizontal distribution of workpieces helps to identify and solve stratigraphical problems after N-transforms were active; 2–the mapping of artifacts accumulated in workpieces helps to reconstruct the spatial distribution of activity zones on a living floor; 3–single pieces and workpieces help to reconstruct on-site and off-site phases of the *chaîne opératoire* (A–outcrop; B–excavated site; C–ephemeral site).

of the raw material units for functional interpretations varies with the level of resolution reached in the sorting. Because they consist either of single artifacts or contemporaneous pieces, the categories "single pieces" and "workpieces" are regarded as the shortest temporal activities in the Paleolithic that we are able to recognize and explain in a broader context, e.g., *chaîne opératoire*, local activities, and regional settlement patterns (Figures 11-1, 11-2, 11-3). In general, Paleolithic assemblages are seen as an accumulation of such short-term events. Single pieces, for example, were manufactured elsewhere, imported, and—either after being used or not being used at all—discarded. Workpieces, on the other hand, went through either some or all phases of the *chaîne opératoire* at the site. In reality, the other two categories, the raw material sources and the geological formations, are also comprised of a number of single pieces and/or workpieces, but, due to related raw material attributes, it is impossible to separate every single event, e.g., each nodule. Within the framework of the search for nodules, they are defined as the sorting remnant (Weissmüller 1995: 58). If compared with the entire assemblage, it can only be assumed that the procurement of raw material for the production of two or more cores coming from the same raw material outcrop or geological formation took relatively little time.

The attempt to identify nodules must not be looked at as a failure if such a high resolution can only be achieved for part of an assemblage. Theoretically, even the recognition of some single pieces or workpieces allows better hypotheses to be formulated about the intentions of Paleolithic people than if such information is lacking. Yet, how is it possible to check if the macroscopic attributes used to separate nodules were sufficient, especially when refits are missing? The following list gives some features that permit a plausible sorting into workpieces:

(1) The number of artifacts of a workpiece and the estimated sum of their volumes. If present-day raw material sources were sampled, it is possible to estimate the size range of the nodules. Therefore, it is possible to check if the total amount and the maximal length of the artifacts in a workpiece fall into the range of volume and metric attributes known for the sampled nodules.

(2) The shape of a nodule and its geological provenance. If pieces with cortex allow conclusions about the shape of a nodule (plaquette, etc.) and its geological provenance (river terrace, residual, or primary

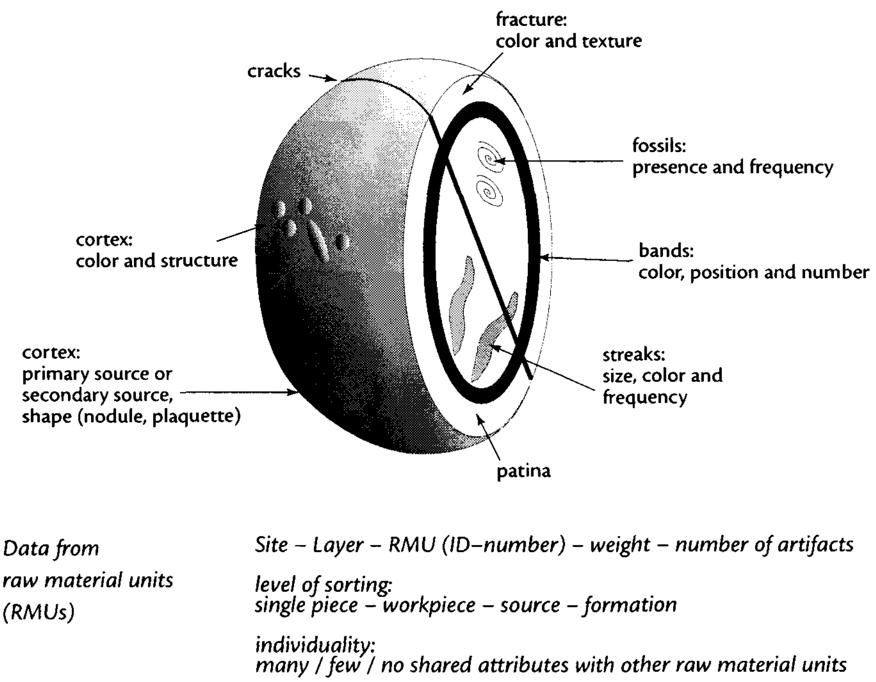

Figure 11-2—Attributes used as defining criteria for the sorting of artifacts into raw material units. Single pieces that share no attributes with any other artifact of the sample are treated as an unquestionable import; small units with an individual combination of attributes (workpieces) are supposed to be an equivalent of refitted debitage on the site.

source), all artifacts with cortex should be classified the same (e.g., plaquette from primary source).

(3) Refits. Refits should exclusively occur within workpieces.

(4) Technology. If the attempt to identify a concept of blank production was successful, all artifacts of a workpiece should fit into the expected variability of blanks for this concept (e.g., if a core is recognized as Levallois, no blank normally expected for the discoidal concept (Böeda 1995) should be present).

(5) Spatial distribution. If the finds are considered to be in situ, the mapping of artifacts from a numerically larger workpiece should show a concentration.

Raw Material Requirements for Successful Sorting into Workpieces

Only unpatinated artifacts allow identification of raw material sources, since the formation of patina destroys the original surface of the fracture (Rottländer 1983:554–558). At the same time, the identification of workpieces and single pieces presupposes different macroscopic attributes between nodules coming from the same raw material source. The origin of Jurassic hornstone and Cretaceous flint as cyclical secretions in parallel layers (Floss 1994:81) formed during the submersion of microorganisms below the seabed favored the genesis of individual nodules that differ in volume, color, and in the presence or absence of streaks and fossil inclusions. In addition, the vulnerability to chemical solution and mechanical abrasion of the outer nodule covering leads to different molding of the cortex. Other raw materials of biogenetic origin, such as radiolarite, however, appear to be more homogeneous. Raw materials developed during processes of metamorphosis, like quartzite and chalcedony, as well as magmatic raw materials developed during volcanic activities, often do not have such a broad spectrum of individual attributes. In general, raw material procurement that uses several outcrops of different geological origins makes the sorting of artifacts into workpieces easier. The Middle Paleolithic assemblages of southern Germany, where the sorting into nodules was first done, are good examples of such procurement strategies. In most cases, the diverse spectra of raw materials are the result of repeated cycles of purposeful surveys for mainly local sources from the mountain ranges of the Swabian and Franconian Alps, where formations of different geological eras found their way onto the Pleistocene surface (Weissmüller 1995:108–111).

This is also true for the southern part of the Crimean Peninsula, where the genesis of the Crimean Mountain ranges (Figure 11-3) led to the exposure of different raw material sources (Ferring 1998). The first range, rising at the southern bank of the Crimean Peninsula, is composed of Jurassic limestone, sandstone, and conglomerate. The second range is built up by Cretaceous sedimentary rock that is, in part, overlain by laccoliths. The third and lowermost range in the north consists of clay, sand, and limestone from the Tertiary period. Many primary raw material sources known today (Figure 11-3) are situated in the eastern part of the second range of the Crimean Mountains, along the valley of the Burulcha River and near the small town of Russakovka (see also Figure 12-1). Because dark colors, ranging from black to dark grey and greyish-brown, dominate most of the samples we took in that area (Table 11-1), it is possible that the outcrops belong to the same layer of Cretaceous flint. At the same time, we observed a great variability in shape, color, and streaks between the nodules. Secondary raw material sources such as outcrops of residual flint and river terraces are even more numerous and mainly located along the Bodrak, Kacha, and Alma river valleys. In some cases, as in the Bodrak Valley, the river has cut into primary raw material sources. As a consequence, nodules with rolled cortex and those with chalky cortex lie near the riverbeds. As far as the sorting into workpieces is concerned, conditions on the Crimean Peninsula are good because the raw material there is characterized by different geological formations within a small area and, at the same time, nodules from the same raw material source show variability in color, structure, and cortex.

When compared with the situation today, it is not easy to calculate the distribution of and the access to raw material outcrops during the Upper Pleistocene. According to Chabai et al. (1999:228), some of the outcrops were exposed only in a late phase of the Upper Pleistocene when the rivers cut their beds deeper into the landscape. Nodules from secondary sources, especially when taken out of river terraces, have been rolled and crushed during their natural transportation and therefore are often of poor quality. Others, which were collected at the bottom of slopes with primary sources, are in comparably bad condition because of weathering. Today, many artificial terraces make it easy to locate and sample the above-mentioned raw material sources. For Neandertals, the acquisition of good quality raw materials must have been much more difficult.

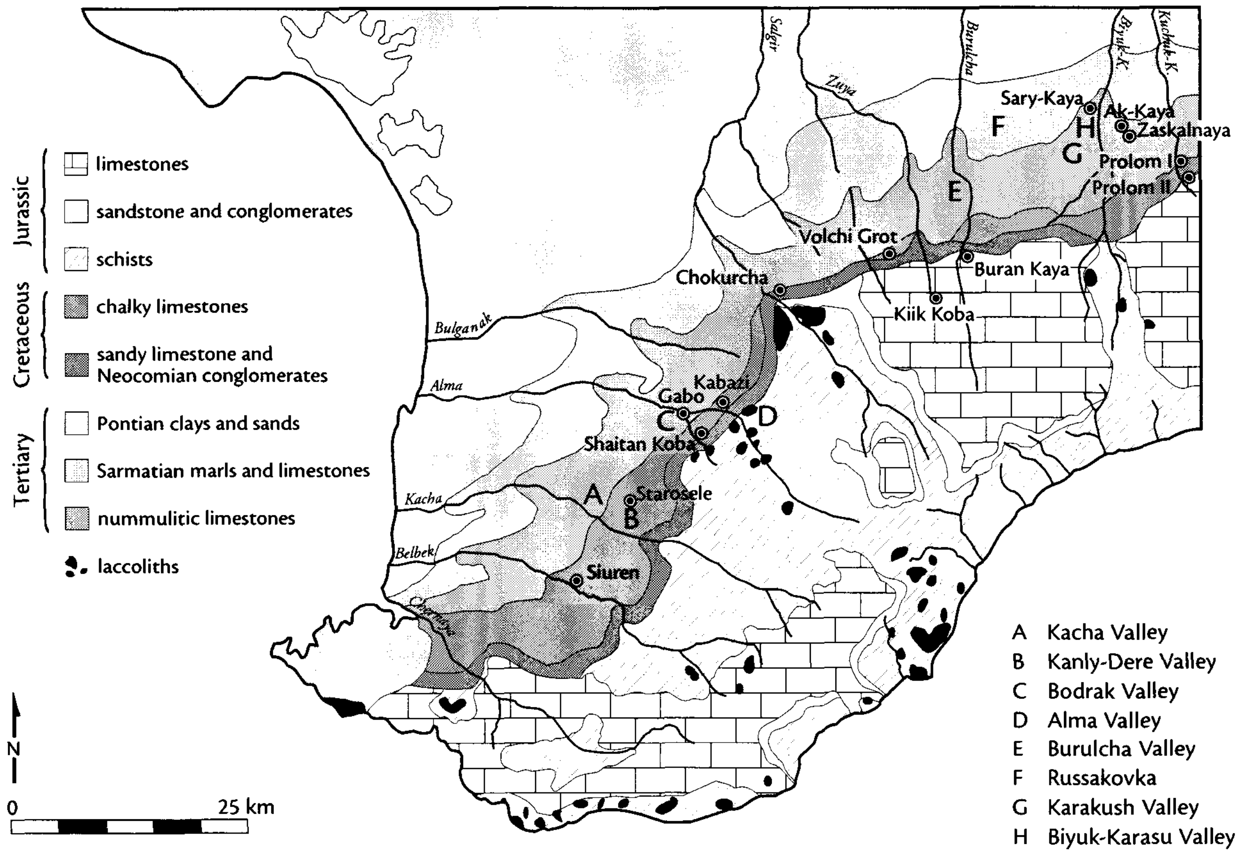

Figure 11-3—Map of raw material sources and important Middle Paleolithic sites in the southwestern part of the Crimean Peninsula. The sources are the result of sporadic, non-systematic excursions and therefore not representative. See Table 11-1 for descriptions of sources (A–H). (Adapted from Daniloff 1905:carte IV by K. Monigal.)

Analysis of Natural Site Formation Processes on the Basis of Workpieces

After analyzing the formation processes of archeological sites, Schiffer (1987) distinguished the cultural transformation processes (C-transforms) that include all human activities connected with the production, use, and discard of artifacts from geological and non-human activities. The latter, termed environmental or natural site formation processes (or N-transforms), are active during and after the discard of artifacts and include, among others, erosion, solifluction, cryoturbation, and bioturbation (Figure 11-1: *1*). If natural site formation processes were active, they may have disturbed the original context of artifacts discarded on an archeological living floor, or, even worse, may have led to a mixing of artifacts that were originally embedded in distinct archeological layers. Thus, they hamper the analysis of the cultural processes that are the main focus of archeological interest. Consequently, it is necessary to recognize the presence of natural site formation processes, and to estimate to what degree they distort the archeological data. In the past, the projection of excavated finds onto profiles and the refitting of artifacts were used to solve the problem of post-depositional processes. During their attempt to clarify the stratigraphic situation and to identify contemporaneous artifacts in disturbed multi-layered Middle and Early Upper Paleolithic cave sites in southern Germany, Rieder (1981/82; 1990) and Hahn (1988:108–117), for the first time, sorted artifacts into distinct nodules and treated them as equivalent of refits. Because artifacts from several geological layers accumulated in refits and workpieces, Hahn (1988:79–84) came to the conclusion that the actual number of human visits in the Aurignacian layers of Geißenklösterle Cave had to be reduced drastically. Only two assemblages, AH II and AH III, remained, although several archeological horizons had been defined during excavations.

The late Middle Paleolithic G-layers of the Sesselfelsgrotte (Richter 1997), dated to OIS 3, are another prominent example of the influence of natural formation processes on Paleolithic sites. A low rate of sedimentation was combined with an intensive, often

TABLE 11-1
Description of raw material samples mapped in Figure 11-3

Source	*Location*	*Sample no.*	*Fracture color*	*Fossil inclusions*	*Bands and streaks*	*Cortex*	*Nodule shape*	*Type of raw material deposit*
A	Kacha Valley	†	honey-colored	none	none	rolled	round	river terrace
B	Kanly-Dere Valley	†	dark grey to brown, white speckled	none	none	white up to more than 1 cm thick	round	primary (rock underneath Starosele)
C	Bodrak Valley	1 8	dark yellow-brown to yellow-brown	yellow-brown, ≤0.3 cm or light brown and needle shaped	medium brown with dark brown edge, not clearly limited streaks	white and beige, >0.4 cm thick, smooth	round	primary/ secondary source (cliff cut by river; material was sampled either out of river terrace or from debris near the primary source)
		2 10 11	dark grey	light grey, ≤2 cm, clearly limited	medium grey streaks	beige, irregular, partly weathered	round and flat	
		3	medium grey-brown	light grey, ≤1 cm, clearly limited	unclear, lighter streaks	beige, smooth, partly rolled	round	
		4	black	light grey, ≤0.7 cm, not clearly limited	none	white, smooth	round	
		5	medium grey-brown	light brown, ≤2 cm, clearly limited	light grey and dark grey streaks	beige and white, smooth	round	
		6 9	dark grey-brown	light grey-brown, ≤2 cm, in part clearly limited	light grey-brown streaks	white and beige, irregular	round	
		7	light grey-violet	light grey, inside yellow-brown, ≤0.5 cm, clearly limited	weak, light grey streaks	white and beige, smooth	round	
D	Alma Valley	1 2	dark brown	light grey, ≤0.5 cm, some ≤2 cm	black band underneath cortex	beige, weathered	round	residual (sampled from slope and river terrace)
		3	dark grey		brown band underneath cortex	white, >1 cm thick		
E	Burulcha Valley	1	dark brown	light brown or white, ≤1 cm	none	white to light grey	plaquettes and round nodules	primary, in layers directly from the rock
F	Russakovka	1 2 3	dark brown	light brown, only few, ≤0.4 cm, not clearly limited	none	beige, irregular	round	primary, at the base of the slope residual
G	Karakush Valley	1 2	dark brown to medium brown	light brown, ≤0.3 cm, not clearly limited	none	white to brown, pockmarked, rolled	round and flat	residual
H	Biyuk-Karasu Valley	1 2	dark brown to medium grey	Sporadically, light brown up to 0.4 cm	none	white	round and flat	residual

†Marks & Monigal 1998:125

repeated, human use of the comparatively small cave over a brief period. The G-layers, with a depth of only 50 cm, contained no fewer than six archeological horizons that were, in part, preserved as living floors. With the help of a cluster analysis, Richter (1997:50–62) determined that each human visit was correlated with a characteristic combination of workpieces discarded in different excavation units (e.g., squares in layers). The mapping of the clusters showed that the artifact concentrations were scattered vertically, and that the centers of the three-dimensional distributions were the places where the activities originally took place (*Doppelkegelmodell*: Richter 1997:54). In most cases, this was around fireplaces. Altogether, twelve visits were identified, with changes in the use of the occupational surfaces through time. After using workpieces (e.g., nodules) as the smallest units, the chronological resolution was higher than it was according to the stratigraphic data from the excavations: except for the uppermost layers, each archeological horizon represented a number of short visits, each of them using only a part of the cave. In the framework of the analysis of N-transforms in the G-layers of the Sesselfelsgrotte, combinations of workpieces were defined as the shortest recognizable human activities in space and time. In this case, the time axis was provided by the sedimentation rate of the cave in-filling, whereas the space was the excavated area.

The late Middle Paleolithic sites in the mountainous region of Crimea, however, seem to be less strongly affected by problems resulting from low, and at the same time, often changing, sedimentation rates. Still today, large quantities of colluvial sediments mixed with pebbles and boulders accumulate at the bottom of slopes exposed to the south. The combination of arid conditions that hamper vegetation, large seasonal ranges of temperature, and high rainfall within short periods of the year (Ferring 1998:fig. 2-5) have led to high rates of sedimentation, either as colluvium or as exfoliation. If sediment traps such as caves, rockshelters, or fallen boulders stop the process of erosion, long stratigraphies consisting of thin archeological horizons separated by archeologically sterile 5 cm to 30 cm levels are preserved. Distinct concentrations of artifacts and faunal remains, as well as fireplaces associated with unpatinated artifacts, indicate the in situ preservation of many archeological horizons in Kabazi II, Kabazi II, Starosele, Buran-Kaya III, and Chokurcha I that were studied by us. Because N-transforms seem to have less importance, this article is focused on the analysis of cultural site formation processes.

Analysis of Cultural Site Formation Processes on the Basis of Workpieces

Human activities before, during, and after the discard of artifacts were summed up by Schiffer (1987) under the term C-transforms. It has already been said that Crimean Middle Paleolithic sites are characterized by a high rate of sedimentation. This speaks for the presence of well-preserved, in situ living floors. At the same time, the thickness of the archeological horizons at many sites measures only several centimeters. This is seen as a strong argument for the hypothesis that surfaces were only briefly accessible. It follows that the rapid sedimentation often led to a preservation of real living floors where it is possible to correlate artifact concentrations with distinct Neandertal activities. There is still the chance, however, that more than one visit, each dedicated to different activities and separated by years, might have accumulated on a well-preserved living floor. In contrast to permanent settlements of agricultural communities, where artifacts from structures like houses, pits, or graves can be traced back to distinct activities over a short period, most Paleolithic communities are thought to have lived as highly mobile hunter-gatherers, leaving behind settlements with less pronounced structures. Ethnographic data from the Nunamiut (Binford 1978: 488–497) show the repeated use of campsites, especially of caves and rockshelters, within several years. As a result, artifacts and structures of different visits, dedicated to different activities, might be found on the same archeological surface.

In the past, the mapping of in situ artifacts, and especially the mapping of refits, was used to clarify the question of whether the distribution of artifacts was the result of a single episode or the result of more than one visit. If the overall distribution of artifacts shows a single concentration, with structures in the center or nearby, it is generally concluded that the discarded artifacts can be traced back to a single visit. If the overall distribution of artifacts shows more than one concentration, in theory two classes of refits can be distinguished: (1) a considerably high number of refits between concentrations is interpreted as an interaction of humans and is therefore taken as a strong argument for the simultaneity of the concentrations, or (2) the fact that refits are mainly distributed within the concentrations is seen as an indicator for isolated and therefore separated human activities. Because they are considered to be an equivalent of refits, the mapping of workpieces allows analogous considerations (Figure 11-1: *2*): the spatial distribution of artifacts from a nodule also provides information about the presence and the extent of interactions among artifact concentrations. At the same time, the analysis of workpieces leads to a larger and therefore more reliable data set.

As far as the question of the distribution of contemporaneous artifacts is concerned, only distinct nodules give suitable data. If the analysis is dedicated to *chaînes opératoires* of blank and tool production, it is possible to include all classes of raw material units; e.g., the geological formations, raw material sources, workpieces, and single pieces. The reconstruction of concepts and methods of blank and tool production with the help of workpieces has the advantage that the artifacts are sorted back into the units from which they came (e.g., the raw nodules), instead of classifying them into techno-typological classes that artificially interrupt the history of the core reduction. The completeness of all artifacts coming from one nodule may tell at least a part of this history.

The importance of an analysis of the *chaîne opératoire* that focuses on single nodules lies in the observation that different shapes of nodules might lead to different technological treatments, especially in initial core preparation. Among others, the refits of the Magdalenian open-air site of Étiolles are a good example of the correlation between different methods of preparation of bi-convex blade cores and the shape of the nodule (Pigeot 1987:fig. 12). For the Middle Paleolithic, a high correlation between the shape of nodules and the concept of blank production (Uthmeier 1998:488), as well as the lack of association between these two factors (Peresani 1998) have been reported. Only when artifacts are looked at in their original context—either after refits or after a sorting into workpieces—is it possible to securely detect the presence of such correlations.

All methodological aspects connected with the sorting of artifacts into workpieces mentioned so far were not new attempts, but variants of methods originally used for the analysis and interpretation of refits. With the transformation analysis, Weissmüller (1995:58–71) has developed a new method that is not only dedicated to on-site activities connected with the production and use of stone tools, but also looks for activities that took place off-site. Comparable to the work of Richter (1997), the assemblages in the Mousterian layers of Sesselfelsgrotte, dated to OIS 5 and analyzed by Weissmüller (1995:66), are defined as a combination of workpieces that share the same horizontal and vertical distribution. At the same time, it is assumed that the excavated area of the small rock-shelter covers, at least, most of the originally inhabited space. In cases where N-transforms are considered to be inactive, it follows that workpieces with incomplete *chaînes opératoires* should have resulted either from the import or the export of artifacts (Figure 11-1: *3*). Thus, transformation analysis is a method that elucidates the mobility of hunter-gatherers, who, while on the move, transported tools, blanks, cores, and/or nodules (Weissmüller 1995:71). Since the beginning of human stone tool production, raw material had to be transported from outcrops to the sites where sharp edges were needed (Isaac 1989:304). While the transport of local nodules from the Lower Paleolithic onwards has been a generally accepted interpretation, there have been different opinions about artifacts prepared for future use. For the Upper Paleolithic, the mobility of even larger numbers of artifacts between campsites is widely accepted (Geneste 1990:fig. 3), sometimes reaching more than 30% of all blanks from a core (Hahn 1988:14, 247). For the Middle Paleolithic, there has been a long debate about whether Neandertals were producing mainly expedient tools or, to the contrary, also had long lasting and highly mobile curated tools (Binford 1979). Since the work by J.-M. Geneste (1988, 1990), we have good reasons to support the curated tools hypothesis and to assume that the biography of Neandertal stone tools was characterized by on-site production, as well as by transportation.

But to what extent were artifacts moved by Neandertals, in general? What percentage may we expect for example, compared to the Upper Paleolithic? Most attempts so far compare the number of artifacts from different raw material sources, often by grouping the distances between the outcrops and the sites (Floss 1994; Geneste 1990; Roebroeks et al. 1988). The interpretation is mainly focused on the number of artifacts that come from distant raw material sources. Probably due to vegetation and topography, distances for imported raw material in Central and Eastern Europe tend to be longer than in Western Europe (Floss 1994:355). Beside the general trends achieved by the analysis of regional and/or long distance raw material transport, it seems sure that a quantity of Middle Paleolithic artifacts moved within local logistical territories (Floss 1994:355). These movements within the range of local raw material procurement, from a campsite to more or less contemporaneous hunting stands, butchering sites, raw material outcrops, or to areas where organic resources were collected, are neither well known nor understood. In part, the lack of information is caused by the simple counting of artifacts by different raw material sources. The data raised tend to be incomplete, because artifacts might have been imported not only as single pieces, but also as nodules, and because artifacts might have been carried out of a site. The transformation analysis tries to estimate the overall number of artifacts transported into and out of the site, even if no or only a few refits were found. How does this work?

In the overwhelming number of cases, the reduction of lithics follows a general pattern that can be described, following Geneste (1986, 1988), as a sequence that starts with the acquisition (phase 0), is followed by the decortication (phase 1), the preparation and the flaking of blanks (phase 2), modification/

retouch (phase 3), the use of tools (phase 4), and, finally, the discard of artifacts (phase 5). By asking of every workpiece whether the artifacts cover all these phases, or represent only a part of them, transformation analysis helps to figure out in what condition a nodule or core was imported, what steps of the schematic *chaîne opératoire* took place on-site, and what artifacts were probably taken off-site. Because artifacts can be attributed to initial or final phases, it is possible to formulate hypotheses about the point in time when artifacts were used or discarded off-site (Figure 11-1: *3*). For example, if flakes with cortex are missing, it is assumed that decortication as an initial phase of the *chaîne opératoire* not only happened elsewhere, but also in the past. If all blanks of the core reduction except for the core itself were found within a workpiece, it is assumed that the core was taken to another campsite for future activities.

At the present state of knowledge, the acquisition of lithic raw materials during the Paleolithic seems to be, with only few exceptions, the result of an embedded strategy. If it is true that the search for nodules and visits to outcrops are more or less always combined with other activities, then the steps of the *chaîne opératoire* recognized as off-site activities give information about past and future campsites. The more steps of the core reduction that lack artifacts, the shorter is the section of the transformation that took place on-site and the longer is the time the workpiece spent at other sites. The condition of import can be defined as an indicator for the amount of time that has passed since a nodule was taken out of the outcrop: single pieces without cortex or workpieces that consist of few tools should already have had a longer biography when entering a site than workpieces that were imported as a raw nodule. In theory, it might also be considered that an increasing number of missing artifacts from initial phases of the *chaîne opératoire* correlates with the distance the workpiece has been moved and/or the number of stops between the outcrop and the discard. In reality, it is only possible to describe the variability of possible activities unaware of the fact that they might have been contemporaneous (in the sense of ephemeral camps), part of a past base camp, or the result of several short stops in the past. The same must be said about artifacts of workpieces that were exported. If only a few tools were exported, we may conclude that short activities at ephemeral campsites were planned, whereas the export of many decorticated nodules and cores may be seen as an indicator for the planning of longer stays. Again, these are theoretical expectations that cannot be proved.

Transformation analysis classifies the section of the *chaîne opératoire* produced on-site by using the number of cortical flakes, the presence or absence of blanks, and the dorsal scar patterns that indicate core and tool reduction steps. With this classification at hand, it is possible to formulate hypotheses about major aspects of regional settlement patterns: Do short sections of the *chaîne opératoire* dominate the workpieces of an assemblage and did the visit therefore have the character of a short stop? Or, to the contrary, are there more workpieces that represent the complete *chaîne opératoire* and indicate a longer episode? How many workpieces were brought into the site as raw nodules, and how many came in as prepared core blanks? Using the same criteria, and by applying a hierarchical system of classes, it is possible to compare the so-called transformation sections of workpieces that make up an assemblage (intra-site analysis). In a second step, it is possible to compare the overall transformation of different assemblages embedded in a stratigraphical sequence (Weissmüller 1995; Richter 1997) or from different sites (Chabai et al. in press).

The Conditions for Success: Site Preservation and Trench Size

Both transformation analysis and the methods to identify N-transforms are based on sorting stone tool assemblages into workpieces. At the same time, there are essential differences. Even if workpieces are known to be incomplete because the excavation covers only a part of the original settlement, a meaningful analysis of N-transforms is still possible. Like refits, artifacts from different layers that accumulate in a workpiece indicate that N-transforms were active. Because incomplete workpieces are thought to indicate off-site activities, the transformation analysis asks for assemblages that are not affected by N-transforms or insufficient trench sizes. Are these demands realistic, at all? As far as archeological horizons in Eurasia are concerned, the key for an in situ preservation of living floors suitable for the transformation analysis lies in a rapid sedimentation after humans left the site. Although the conditions are not as excellent as they are at the famous late Magdalenian hunting camps of the Paris Basin (Pigeot 1987), it has already been said that at most Crimean Middle Paleolithic sites studied by us, Pleistocene surfaces were buried quickly after they were abandoned by Neandertals.

In addition, not all artifacts are affected by N-transforms in the same way. Whereas small chips are easily removed by erosion, larger artifacts like flakes and cores are more resistant and may remain in their original positions. It is mainly this class of artifacts, greater than 3 cm, that is used for the reconstruction of the *chaîne opératoire*. Even when merely larger artifacts are analyzed, however, the transformation analysis still considers not only workpieces with a complete *chaîne opératoire* as important units of analysis, but also incomplete ones. During the first attempts in Geißenklösterle (Hahn 1988) and Sesselfelsgrotte (Weissmüller 1995; Richter 1997), the transformation analysis showed that many workpieces were not complete. Weissmüller (1995:67) was not sure to what extent artifacts were missing due to N-transforms or C-transforms (therefore he spoke of evacuation). Do we have more detailed criteria to establish if workpieces are incomplete because of natural site formation processes and/or insufficient areas of excavation, or because artifacts were taken away during cultural site formation processes? In our opinion, the mapping of the overall distribution of artifacts, as well as the mapping of the distribution of workpieces, can be used as criteria to establish whether the workpieces are representative for all on-site activities or not. As a first step, the overall distribution of finds (artifacts, bones, fireplaces, pits, etc.) is looked at for the following criteria:

(1) Within the excavated area, is there one concentration of finds, or are there several?
(2) Do the concentrations lie in the center of the excavated area and thin out towards the borders of the trench, or were only parts of the concentrations unearthed?

If it is obvious that only a part of the settlement was excavated, the analysis of the local topography may give information about the original size of the site:

(1) Is the settlement situated on a plain, or does the topography show steep slopes, etc.? Is it possible to estimate the size of the area with appropriate settlement conditions and therefore the potential overall size of the site?
(2) Within this area, is there any information about the presence or structure of other concentrations yet unexcavated, like artifacts coming from the surface? Or, to the contrary, do any older excavations yield information about this? In Starosele, for example, the distribution of the artifacts from Levels 1 and 3 excavated recently (Marks and Monigal 1998:120) enabled the reconstruction of numerous concentrations that were originally lined up in front of the long rockshelter, but were obviously not recognized as such during the first excavations.

Even in the worst case, when only a part of an originally much larger site was excavated, it is possible to determine areas of isolated and therefore complete activities by mapping the artifacts that belong to workpieces:

(1) Does the mapping of workpieces show clusters, and if so, are there any clusters surrounded by archeologically sterile areas?
(2) If not, is it possible to isolate single workpieces that fulfill these criteria?

The following list gives some theoretical examples for the distribution of artifacts assumed to be coming from the same living floor, and describes the consequences that different answers to the criteria stated above may have for transformation analysis.

Figure 11-4A shows the overall distribution of one or more concentrations situated well in the center of an excavated area. In this case, it is assumed that only a few artifacts were discarded on-site, but outside the excavated area. The artifacts missing in the *chaînes opératoires* of the workpieces were produced and/or used elsewhere. It is possible to reconstruct what artifacts were moved to and from the site, and what was left at other sites. Therefore, the transformation analysis gives meaningful information about the function of the site within a region.

Figure 11-4B shows the overall distribution of artifacts from several concentrations that are, in part, not completely excavated. In this case, the transformation analysis gives only meaningful information about those workpieces that are found within concentrations that are clearly delimited and were found at a considerable distance from the borders of the excavated area.

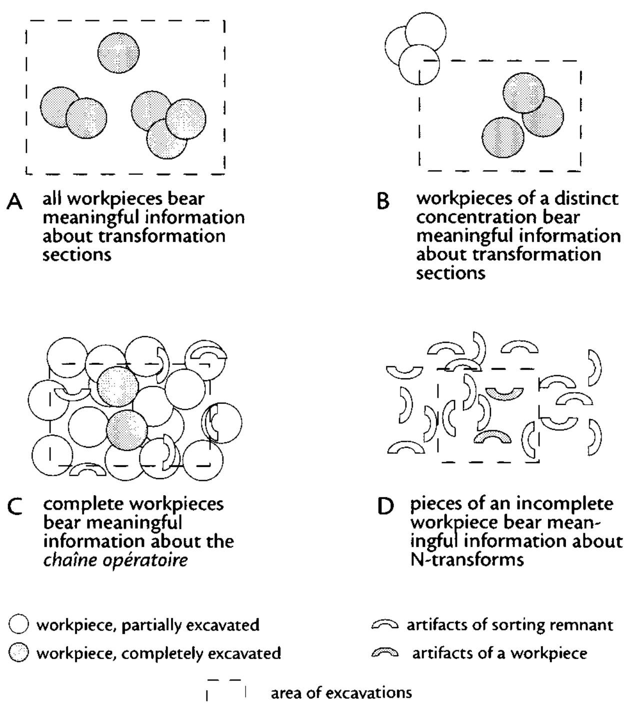

Figure 11-4—Hypothetical distributions of workpieces inside and outside the excavated area. For the transformation analysis, it is important that N-transforms and trench size can be more or less excluded as an explanation when phases of the *chaîne opératoire* are reconstructed as off-site activities. A workpiece is an accumulation of artifacts with identical macroscopic raw material attributes.

When the mapping of workpieces or refits does not show interactions with other, only partially excavated concentrations, then the cluster of workpieces may represent a distinct visit, or activity, at the site.

In Figure 11-4C, the overall distribution of artifacts shows no clustering, at all. Obviously, a large concentration (or several concentrations mixed after many people moved on the surface) was only partly excavated. Within the even scatter, single workpieces show a limited distribution. Because no zone of activity can be isolated, the transformation analysis does not allow a representative reconstruction of off-site activities of past, contemporaneous, or future campsites. Although only a defined, yet unrepresentative, part of all activities, each workpiece alone still represents human actions limited in space and time. Thus, the spatial distribution on-site, the off-site moves, and the *chaîne opératoire* of artifacts belonging to each complete workpiece can be analyzed as a non-representative snapshot of activities.

In Figure 11-4D, the distribution of artifacts shows concentrations neither in respect to zones of activity nor in respect to limited concentrations of workpieces. In this case, an interpretation of transformation analysis as on-site and off-site activities does not make sense. Incomplete workpieces may only help to identify problems of N-transforms.

Summary: a New Method for Old Problems

Because processes of N-transforms and C-transforms are both traced back to their smallest temporal cohesion in single nodules, the sorting of stone tool assemblages into workpieces offers advantages over conventional methods that operate on the level of geological formations or raw material sources. At the same time, the high resolution of the raw material sorting can be changed at any time by combining single pieces and workpieces with raw material sources and the latter with geological formations. In doing so, the assemblages initially organized for a transformation analysis can easily be compared with assemblages where the sorting into workpieces still has not been carried out or was not successful due to patination, for example.

The transformation analysis itself seems to be more problematic. Even if there are no patinated artifacts, one may argue that the demand for well preserved and, at the same time, completely excavated sites or concentrations is a principal obstacle that makes this method a promising but unrealistic approach. On the other hand, the requirements for complete and contemporaneous finds are a banal, yet general, problem for working in prehistory. Except for refits, any other conventional approach like the Bordian type list (Bordes 1950) or a classification based upon the presence or absence of type forms (Bosinski 1967) is confronted with the problem that artifacts that might essentially change the classification could have been deposited outside the excavation areas or are missing due to erosion (see also Rigaud and Simek 1987). The sorting and mapping of workpieces, however, does not only show that artifacts are missing. In contrast to conventional approaches, it is also possible to separate that part of the scatter that is more or less complete. Compared with refits, the part identified as being complete is supposed to be larger.

The transformation analysis itself tries to explain a defined part of an assemblage by means of production, use, and discard of artifacts. Following Geneste (1988, 1990), a given assemblage is understood as a local (on-site) part of activities dynamically embedded in a regional settlement pattern, with campsites visited in the past and planned for the future. To us, including the aspect of settlement dynamics into the analysis of stone tools by looking at nodules as the smallest units in time and space seems to be more promising than an analysis dedicated to the *chaînes opératoires* of geological formations. By reconstructing on-site and off-site activities site by site, and by establishing a regional pattern of raw material procurement and use, we are searching for correlations between concepts for blank production, tool production, and tool use, on the one hand, and segments of the regional settlement system, on the other. Finally, we can separate modes of artifact production related to functional aspects, such as season and duration of occupation or a specific game hunted, from cultural factors.

Theoretically, transformation analysis shares many features of the processual archeology approach (Bernbeck 1997:35–48) and the theory of cultural materialism (Harris 1979). It is assumed that Paleolithic artifacts and settlements have stored information that can be measured objectively and that are sufficient to reconstruct important aspects of material culture. Material culture itself, however, is not seen as resulting from economic adaptation alone. In general, it is assumed that the variability in Middle Paleolithic hunter-gatherer industries can only be explained multi-dimensionally. Among others, technical norms for tool production, closely tied to the social environment of their enculturation, should also play an important role, especially in the life of traditional societies (Apel 2000). But although the perception of an environment might differ due to cultural values, it is believed that natural conditions do limit the range of possible strategies for survival and therefore have a strong influence on the development of important social features such as the demography of a population or of single groups, the willingness of individuals or groups to cooperate and form alliances, the system of social norms and values, and the acceptance of technological innovations.

Within Workpieces: Conventional Data

Raw material units are treated as sub-assemblages. This means that attributes (Table 11-2) are counted or measured within each raw material unit in respect to the level of sorting, which are single pieces, workpieces, raw material sources, or geological formations. Except for maximum length measured for each artifact (Weissmüller 1995:62-63), the data are grouped (e.g., frequencies of different blank types). In many cases, attribute variability is divided into nominal classes. Others, like cortex on the dorsal surface, are measured on an ordinal scale, while only some, such as the weight of each unit, are based on metrics. To provide a shared basis for comparisons, we decided to describe the raw material itself by a combination of a given list of attributes (aspects of the structure of the cortex, the presence or absence of streaks, etc.). Some general observations, like the color of the fracture, have to be recorded individually because the variability seemed to be too extensive for a code.

The conventional data (Table 11-2) includes the total weight and the total number of artifacts, as well as the frequency of cortex classes and the maximal length of each artifact sorted into a raw material unit. The classes of blank types (compare Kurbjuhn, Chapter 14) were selected for their use for a quantitative analysis of the concepts and methods recognized during the reconstruction of *chaînes opératoires*. The reconstruction of a *chaîne opératoire* itself is based on an analysis of characteristic artifacts such as cores, crested flakes, blades, or Levallois flakes in a raw material unit. Several raw material units with identical technological features might be combined for the reconstruction of a *chaîne opératoire*. Modified pieces are divided into artifacts with simple modifications of lateral edges and artifacts that show surface shaping. To avoid misunderstandings, it must be stressed that this view of surface retouch does not follow the conventional distinction between unifacial and bifacial tools (for more details, see Richter, Chapter 13). As É. Boëda (1995b) has pointed out, two essentially different modes of blank production can be observed: blanks that result from the debitage of cores, on the one hand, and blanks that result from surface shaping, on the other. Therefore, the surface shaping is not modification in the conventional sense, but is part of the production of blanks (*biface support*) that is followed by the modification and/or use of working edges (*biface outil*). This approach is comparable to the type list that is generally used for the Crimean Middle Paleolithic (Chabai and Demidenko 1998). In addition, tools shaped by surface retouch may be made from nodules, as well as from flakes or blades produced in the course of different concepts and methods, and they may show surface retouch only on one side, like *limaces* or *pointes à face plan* (Demars and Laurent 1992:131, fig. 51:1-2, 4-6), or on both sides, like handaxes. Thus, it is useful to define criteria for surface-shaped tools. Surface-shaped tools are understood as artifacts that show a regulation of thickness, outline, and/or cross section by surface retouch that is produced by soft hammer technique. However, not every tool that shows surface retouch is necessarily a surface-shaped tool. Some *pointes à face plan* illustrated by Demars and Laurent (1992:129, fig. 50: 3, 5) show a lateral surface retouch that is restricted to the active part of the working edges only. It is therefore a modification for use, for hafting, etc. Only if the surface retouch produces one or more sequences of convex or flat scars that completely alter at least one side of the piece and are later used as a surface for further modifications of the working edges, are pieces classified as surface-shaped tools. Like cores, surface-shaped tools are analyzed by the method described by Richter (Chapter 13), the working step analysis.

Finally: the Classification of Transformation Sections

The essential data for transformation analysis include a classification of the transformation section and the spatial distribution of each raw material unit. More detailed information is found in Weissmüller (1995: 58–71) and Richter (1997:50–62). Here, only the essential features of transformation analysis are described. Transformation analysis is based on single pieces and all artifacts of a workpiece left at a site. As long as they do not belong to the modification and resharpening of tools, chips less than 3 cm are not taken into account. On the one hand, ordinary chips are not supposed to be moved between sites and, on the other hand, it is often not possible to securely assign them to a phase of the *chaîne opératoire*.

Table 11-2
Conventional data from raw material units

Identification of Raw Material Unit
- site
- year(s) of excavation
- layer
- individual number

1. DATA TAKEN FROM ALL ARTIFACTS > 3 CM

01 weight

02 number of all artifacts

03 blank type and frequency of cortex: number of artifacts in ordinal categories
- 1 nodule, completely covered by cortex
- 2 core, partly covered by cortex or without cortex
- 3 cortical flake or blade
- 4 flake or blade, partly covered by cortex
- 5 flake or blade, without cortex
- 6 blank type not identified (unclassified fragment, chunk)

04 longest possible measurement in mm: metrical category (measurement of individual artifacts, differentiated into the classes listed under 03)

2. DATA TAKEN FROM ALL ARTIFACTS BELONGING TO BLANK TYPE 3–5

05 blank types for technological analysis: number of artifacts in nominal categories
- 1 flake, simple
- 2 *couteau à dos naturel*
- 3 flake, crested
- 4 flake, lateral remant of crest
- 5 flake, pseudo-Levallois point
- 6 flake, Levallois
- 7 flake, Levallois point
- 8 blade, Levallois
- 9 blade, simple
- 10 blade, crested
- 11 flake, width > length (*Breitabschlag*)
- 12 flake, Kombewa
- 13 chunk
- 14 chip
- 15 flake, surface retouch
- 16 flake, resharpening

3. DATA TAKEN FROM MODIFIED PIECES

06 preservation of modified pieces: number of artifacts in nominal categories
- 1 modified piece, surface shaping, proximal fragment
- 2 modified piece, surface shaping, distal fragment
- 3 modified piece, surface shaping, complete
- 4 modified piece, retouch of simple blank, proximal fragment
- 5 modified piece, retouch of simple blank, distal fragment
- 6 modified piece, retouch of simple blank, complete

07 modified pieces, typology: number of artifacts in nominal categories
- 1 point
- 2 sidescraper, simple
- 3 sidescraper, double
- 4 sidescraper, convergent
- 5 sidescraper, *déjeté*
- 6 sidescraper, transverse
- 7 sidescraper, more that 2 working edges
- 8 endscraper
- 9 burin
- 10 backed piece
- 11 end retouch
- 12 notch
- 13 denticulate
- 14 bec
- 15 pebble tool
- 16 piece > 3 cm with use retouch
- 17 piece < 3 cm with use retouch
- 18 modified piece, surface shaping, 1 working edge
- 20 modified piece, surface shaping, 2 working edges
- 21 other modifications

(18, 20) → *Analysis of operational steps*

The transformation section itself is defined as the total number of phases of a *chaîne opératoire* that are recognized as being conducted on-site. Single pieces with no equivalents in respect to their raw material attributes were imported. Workpieces, with two or more artifacts with identical raw material attributes, are examined for the presence and frequency of artifacts that indicate different phases of the *chaîne opératoire*, e.g., pieces with cortex, core trimming elements, and wastes from modification or rejuvenation. The classification of the transformation section is based on the presence or absence of these artifact classes (Figure 11-5). The borders of the transformation section are defined as the initial and final phase of the sequence of the *chaîne opératoire* that happened on-site. Apart from workpieces that have passed through the entire *chaîne opératoire*, from the preparation of a nodule to the use and discard of formal tools, workpieces that represent only a part of the *chaîne opératoire* are of special interest. They yield information about

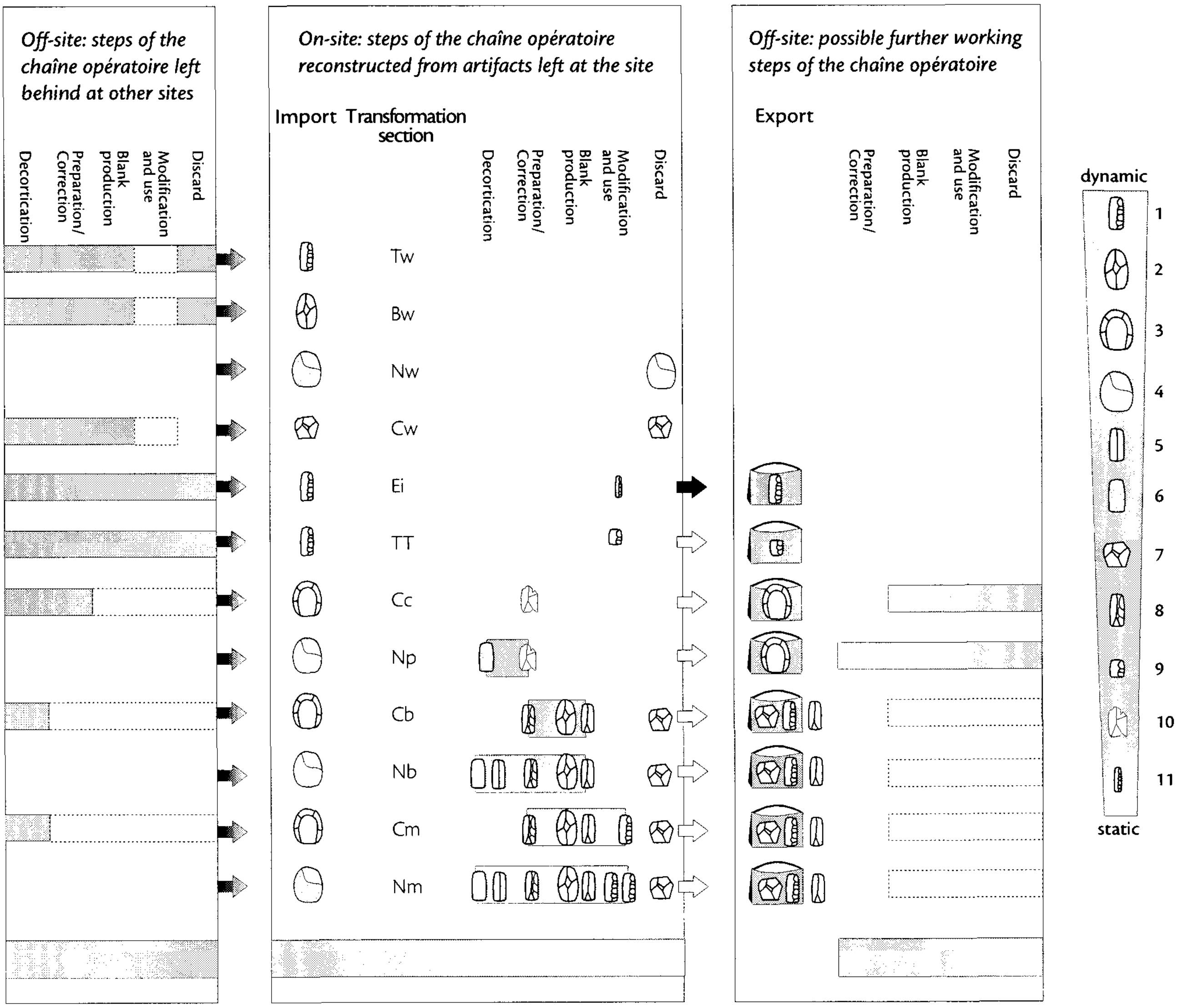

Figure 11-5—Overview of the main categories for the classification of the transformation section of a single piece or workpiece. Left: securely reconstructed (grey) and possible (white) phases of the *chaîne opératoire* conducted before the workpiece entered the site. Center: reconstructed transformation section based on artifacts discarded on-site (in grey: limits of the transformation section; blanks and modified pieces produced in between might be exported). Right: unquestionably (black arrows) and possibly (white arrows) exported artifacts (inside the "bag"; the export of cores and modified pieces can be securely reconstructed, because static objects are left on-site). Far right: schematic representation of static and dynamic objects: *1*–modified piece; *2*–target flake; *3*–core blank; *4*–raw nodule, possibly tested; *5*–flake; *6*–cortical flake; *7*–reduced core; *8*–core preparation flake; *9*–tool fragment; *10*–chunk; *11*–chip from modification.

the regional movements of people. The temporal relationship among phases of the *chaîne opératoire* present and missing is constructed by the hypothesis that the more the reduction of lithics moves from the cortex towards the interior of a nodule, the younger are the artifacts. Modification or use of working edges is only possible after the preparation of a core and the detachment of blanks. If artifacts are missing from initial or final phases, it is concluded that their detachment and possible use happened off-site. If, for example, a workpiece consists of blanks without cortex, some tools, and a core, within the methodological framework it is a logical consequence that the decortication of the nodule happened previously. At the level of workpieces, it is probable that initial phases of the *chaîne opératoire*, when missing, belong to past human activities. Missing artifacts of late phases of the *chaîne opératoire*, to the contrary, were taken away for future activities. If, for example, a workpiece consists of cortical flakes only, it is assumed that a nodule was prepared for future core reduction at another place.

If artifacts are missing in between the earliest and latest phase present, while at the same time the distribution of artifacts indicates complete preservation and excavation of the workpiece, it is concluded that the missing artifacts were transported to other sites after their detachment.

Apart from the crucial question of whether the assemblage or concentration analyzed is indeed complete, another more theoretical problem might also hamper the classification of the transformation section. This is closely tied to the aim of the method itself: the mobility of artifacts between sites. The following hypothetical example should illustrate the problem: a nodule is imported into a site, the cortex is removed, and a core is prepared. Is it a probable scenario that all blanks except the core are taken to another site? Because only a core was actually discarded on the site, the attempt to classify the transformation section would end up with an import of a single piece, although all previous phases of the *chaîne opératoire* also happened on-site. To us, however, this scenario seems not very probable. It is more plausible to assume that not all artifact classes have the same chance to be moved between sites. The results of the work of Geneste (1990) pointed in the same direction when he described that Neandertals during the Middle Paleolithic in Aquitaine more often took scrapers from one site to another than other artifact classes. Concerning their potential to be transported, Weissmüller (1995:67–68) divided artifacts into static and dynamic objects (Figure 11-5). Dynamic objects, such as flakes and blades, are thought to have a high mobility potential, whereas static objects such as chips, waste from rejuvenation, tool tips, and chunks, tend to fall down after detachment without being moved any farther. Objects with a tendency to be static are produced during all phases of the core preparation, debitage, and modification. Therefore, it is highly unlikely that all artifacts of a phase of a *chaîne opératoire* are moved. Or, if traces of a phase of the *chaîne opératoire* are missing completely, then they must have been produced and discarded off-site. Dynamic objects with a high potential of being moved are expected to be produced neither at the start nor at the end of a *chaîne opératoire*, but most probably during blank production and blank modification.

Weissmüller (1995:69) suggested that there must have been on-site flaking if two artifacts belonging to the same nodule are present, no matter if a core has been found or not. In fact, the term workpiece originally refers to this assumption. For Weissmüller, the transport of considerable quantities of blanks and/or modified pieces played only a minor role in Neandertal strategies of stone tool production and use. With only a few exceptions, he expected that only single pieces were taken from one campsite to another. For us, this view seems to be too dogmatic. As an alternative, we consider that the probability that several artifacts of the same workpiece were actually produced on-site increases with the presence of static objects, a growing number of unmodified blanks, the presence of core trimming elements, and the fact that the artifacts belong to different phases of a *chaîne opératoire*. To the contrary, the presence of several formal tools made of dynamic objects from the same workpiece might be the result of importation, especially when the raw material source is far away. The following list, translated from Weissmüller (1995: 68–69), gives an overview of the classes used by us to distinguish different transformation sections within raw material units (compare also Figure 11-5 and Kurbjuhn, Chapter 14).

(1) Single pieces imported as dynamic objects onto the site, but without on-site debitage or modification:

Bw (Weissmüller 1995:68: Go) = a single blank without debitage, brought onto the site and discarded without formal modification.

Tw (Weissmüller 1995:68: Wo) = a single modified blank (e.g., a formal tool) without debitage, brought onto the site and discarded after use.

Cw (Weissmüller 1995:68: Ko) = a single core, brought onto the site, at least after decortication, probably after preparation and some reduction, but discarded without further reduction on the site.

Nw (Weissmüller 1995:68: Ro) = a single unprepared nodule without reduction.

(2) Single pieces detached as static objects:

Ei (Weissmüller 1995:68: Ei) = an isolated tip, detached or broken off from a formal tool in the course of its use. The formal tool entered the site as a modified piece, and was exported after the tip was lost.

(3) Two or more artifacts from the same workpiece as dynamic and/or static objects:

TT (Weissmüller 1995:68: WE) = two or more fragments of a formal tool that was imported as a dynamic object and broke into static pieces during its use; a part of the formal tool might have been exported afterwards.

Mi (Weissmüller 1995:68: Mi) = two or more isolated pieces (static objects) resulting from the modification of a blank that was brought onto the site as a dynamic object, modified and probably used, and exported afterwards.

TM (Weissmüller 1995:68: WM) = a formal tool with one or more detached flakes from modification and/or rejuvenation.

Cc (Weissmüller 1995:69: Kk) = correction of a core. Two or more chunks or core trimming elements, without or very little cortex, that were detached as static objects during the re-preparation of a core. As an object with the potential of mobility, the core might be discarded, but might also be missing.

Np (Weissmüller 1995:69: Rp) = preparation of a raw nodule. Two or more chunks or core trimming elements with a high frequency of cortex, or two or more cortical flakes that were detached as static objects during decortication of a nodule. As an object with a potential of mobility, the core might be discarded as well, but might also be missing.

Cb (Weissmüller 1995:69: Kg) = blank production from a core. Two or more flakes or blades, with part of a crest or not, without or with very little cortex. The pieces result from the debitage of a core that was (at least in part) decorticated off-site. If the core is present, one more flake is sufficient for a classification. If several blanks are present, they might also include core-trimming elements. Because flakes and blades without crests and cores are supposed to be dynamic objects, several pieces including the core might have left the site.

Nb (Weissmüller 1995:69: Rg) = blank production from a raw nodule. Two or more cortical flakes or blades, flakes with cortex, flakes with part of a crest or not, in combination with artifacts with none to little cortex. The artifacts result from decortication, preparation, and flaking of a nodule that was brought directly from the source onto the site. If the core is present, one more cortical flake is sufficient for this classification. If several blanks are present, they might also include core-trimming elements. Because flakes and blades without crests and cortex, as well as cores, are supposed to be dynamic objects, several pieces might have left the site.

Cm (Weissmüller 1995:69: Km) = blank production from a core with modification of blanks. The artifacts needed for the classification are the same as for a Cb (blank production from a core), with additional proof for the modification of blanks into formal tools. Because tools are dynamic objects, it might happen that only a tool tip proves the modification of a blank. Because this class represents the entire *chaîne opératoire*, many dynamic objects occur, and the workpieces might be to a large extent incomplete between initial and final phases. Therefore, a great diversity of possible combinations of artifacts leads to the same classification of the transformation section. The following two examples should illustrate this. A classification as Cm is based on the presence of several flakes without cortex, a crested flake, several formal tools, and a core. Also classified as Cm are a crested flake and a resharpening flake. For the latter example, the biography of the workpiece is much longer than it seems at first sight. From a prepared core brought onto the site, at least one flake and one core trimming element were removed, and at least one blank was modified, resharpened, and then exported together with the core (and several other blanks/tools?).

Nm (Weissmüller 1995:69: Rm) = blank production from a raw nodule with modification of blanks. This transformation section is similar to Cm, with additional cortical flakes, and a high frequency of cortex.

Originally, the hierarchy of classes listed above was designed for Mousterian assemblages with no or only random bifacial (surface-shaped) tools. The Crimean Middle Paleolithic assemblages studied by us, however, are in part characterized by considerable frequencies of surface-shaped tools (Chabai 1998a). If surface shaping is recognized, either by the presence of a surface-shaped tool or by the presence of typical flakes and chips of its production, then the classes of Weissmüller are given the notation */facial. While some workpieces only include one surface-shaped tool and the rest of the *façonnage*, others might consist of conventional debitage and (unifacial) surface shaping. When surface-shaped tools are not only made from nodules, but also from ordinary flakes, this happens quite often. Because the number of classes should be restricted, it is not useful to extend the existing list with additional numbers of classes for these hybrid workpieces. Thus, only the general presence or absence of surface shaping is recorded.