Chapter 2
Framework of Research

The discussion in the previous chapter of the evidence for the early use of fire has demonstrated the complexities involved in identifying the early stages of human control over fire and emphasized the need for a comprehensive approach to their study. The presence of burned flint items at the site of GBY provides a unique opportunity to investigate this pressing issue with a different methodological approach. This methodology draws on a variety of ethnographic, archaeological, and ethnoarchaeological studies, which generally suggest that small lithic products can be used as spatial indicators for a variety of activities, including the use of fire in the form of hearths. The theoretical foundations of this approach are presented in this chapter, which integrates the different components of the research program.

First, this chapter presents the *research objectives* of this study. Although these were initially designated for the analysis of burned flint items from GBY, they contribute directly to a much wider theme, the examination of hominin behavior and technological skills, which is also embedded within the objectives of this study.

Following the research objectives, the principles of the methodological approach are presented. The various research assumptions, as well as the construction of the applied methodologies, all draw on an extensive theoretical framework of *hearth-related spatial patterning*, which is discussed in the second part of this chapter. An understanding of these theoretical foundations is essential before approaching the *research hypotheses* and *methodology* of the study, presented at the end of this chapter.

2.1 Research Objectives

The initial objective is to report on the presence of burned flint items in the archaeological horizons of the Acheulian site of GBY. The burned flint items, which occur throughout the stratigraphic sequence in varying frequencies and in diverse spatial settings, are presented and analyzed in this work.

The burning of these flint items may have been the outcome of natural[1] or anthropogenic fire. Accordingly, the second objective of this study is to examine the possibility that these items are the result of anthropogenic fire (i.e., fire used by hominins). In doing so, we may establish evidence for the use of fire at GBY as early as 790,000 years ago. In order to achieve this goal, it is essential to obtain a reliable means of distinguishing an anthropogenic fire from a natural one. This is accomplished throughout the analysis of the spatial configuration of burned flint items, thoroughly discussed in the following parts of this chapter.

Considering the various advantages provided by fire, establishing evidence for the use of fire at GBY is of great importance for the evaluation of hominin behavior at the site. Thus, the third objective of this study is to inquire into different behavioral and technological aspects of the use of fire. These include the role of fire in the different occupation episodes of the site (i.e., the presence or absence of fire use in relation to different activities), and the apparent frequency of the use of fire throughout the various occupation episodes recorded at the site (i.e., is the use of fire a unique phenomenon or a routine practice).

2.2 Hearth-Related Spatial Patterning

The following discussion presents the theoretical foundations of this study, which generally suggest that the spatial patterning of a variety of activities, including the use of fire in the form of hearths, can be implied by lithic waste products of small size.

Human activities are spatially patterned and the fact that humans tend to carry out a vast range of activities in close vicinity to hearths is widely documented. The hearth assembles the social group and around it is the area in which social interactions, tool production, food processing,

[1] A thorough discussion of fire ecology, and specifically of the probability of natural fire at GBY, is included in Chapter 4.

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food consumption, and ritual ceremonies are carried out (e.g., Yellen 1977; Binford 1983, 1998; Spurling and Hayden 1984; Galanidou 2000, 1997). While numerous activities (e.g., social interactions) leave no tangible evidence for us to uncover, other activities (e.g., tool making and food processing) contribute directly to the formation of the archaeological record. Brooks and Yellen (1987) defined *procurement*, *processing*, *consumption*, and *manufacturing* as principal "*debris-generating*" behaviors. The latter involves the manufacturing of artifacts and is strongly associated with hearths (Brooks and Yellen 1987:82).

Hearths not only serve as spatial spots of accumulation but also influence the patterns of distribution of certain size groups of the assemblage. Binford (1978, 1983) suggested that the formation of certain spatial patterns during work around a hearth appears to be universal. More specifically, the distribution of debris often displays two concentric zones around the hearth: the *drop zone* in proximity to the hearth, where small fragments of bone/stone are left in situ (*residual primary refuse* in the terminology of Schiffer 1972, 1987), and the *toss zone*, an area further away from the hearth to which the larger debris is tossed (*secondary refuse* in the terminology of Schiffer 1972). Thus the area closest to the hearth is likely to display high quantities of small in situ refuse.

2.2.1 Small In Situ Refuse

The fact that small items are left in their original location while large items tend to be removed was reported as early as 1961 in Green's pioneering study of discard patterns (Green 1961:91). Notwithstanding, spatial analysis studies often concentrate on the larger refuse and features, despite the fact that "…the data most likely to be informative … are very small refuse items, such as chipping debris, small bone fragments, and plant macrofossils, which will often be found in primary context" (O'Connell 1987:104).

Smaller refuse is more likely to be found in situ for several reasons. Small items are less visible and are more likely to be missed during refuse clearance and preventive maintenance of the activity area (e.g., DeBoer 1983; Schiffer 1987), their small dimensions make them less hazardous (e.g., Hayden and Cannon 1983; Clark 1991), and they are more prone to trampling and thus penetrate deeper into the occupation surfaces (see DeBoer 1983 for a detailed discussion).

The fact that small refuse is more likely to be left in situ than large refuse is known as "McKellar's principle" (first published in Schiffer 1976:188). McKellar's work on the litter of the University of Arizona campus indicated that there is a critical size factor in refuse disposal patterns. She had found that items above 9 cm were consistently tossed into trash cans, while smaller items were left behind as primary refuse (Rathje 1979:10; Schiffer 1976:188, 1987:62). McKellar's principle has been confirmed in a variety of ethnoarchaeological studies (e.g., Schiffer 1987:62 and references therein, Stevenson 1991 and references therein). However, while the general principle has been widely adopted, no conventional limit has been defined as the critical size factor. In other words, what is considered small?

One extreme would be particles smaller than 1 mm (*microdebitage* in the terminology of Fladmark [1982], referring only to stone knapping products). Under a microscope, microdebitage can be further divided into *microflakes* and *microchunks* (Vance 1987). A maximum size of 2 mm, *microartifacts* in the terminology of Stein (Dunnell and Stein 1989; Stein and Teltser 1989, referring to all archaeological residues), has also been suggested. These microartifacts have been found to be significant in the study of both natural (see Dunnell and Stein 1989) and cultural (e.g., lithic manufacturing and discard: Hull 1987; duration of occupation: Simms 1988) formation processes. Other studies set the limit at 2.5 mm (Metcalfe and Heath 1990), 6 mm (Austin et al. 1999), 10 mm (Nadel 2001), 20 mm (Alperson-Afil and Hovers 2005), 25 mm (DeBoer 1983) or 50 mm (O'Connell 1987).

Despite the variability in scale, the various studies all share the view that small items are essential components in the reconstruction of site structure and are optimal indicators of activity areas (e.g., Hayden and Cannon 1983:134; Schiffer 1987:94; Simms 1988:208; Cessford 2003:3).

In conclusion, ethnographic observations have laid the foundations for site structure reconstruction, which is based on the recognition that the association between features (e.g., hearths) and the spatial distribution of artifacts can provide the contextual framework of artifact concentrations (Simek 1984). Consequently, in attempting to reconstruct the formation process of hearth-related spatial patterns, we can draw on the following inferences:

1. A wide range of activities is carried out in close proximity to hearths.
2. Hearths are spatial spots of refuse accumulation.
3. Small refuse is more likely than large refuse to be left in situ.
4. Hearths are thus likely to display dense concentrations of small refuse.

Archaeological evidence of similar hearth-related discard patterns has been reported as early as the Middle Paleolithic (e.g., Vaquero and Pastó 2001) and from a variety of archaeological settings. These include open-air sites (e.g., Gilead 1980; Hietala 1983; Gilead and Grigson 1984; Goring-Morris 1988, in prep.; Leesch et al. 2005; Sergant et al. 2006), rockshelters, and cave sites (e.g., Galanidou 1997; Vaquero and Pastó 2001), in all of which the hearths are readily identifiable features.

2.2.2 Phantom Hearths

We are often required to characterize artifacts or features recovered from archaeological contexts. Hearths, however, are features of all contemporary hunter-gatherer societies, and when found in such contexts they exhibit high variability of construction methods, size, and functions. The lack of a clear archaeological definition of a hearth appears to result from their universal contemporary occurrence, as well as from their apparent variability. The recent ethno-geoarchaeological project carried out by Mallol et al. (2007) characterized different sedimentary aspects of Hadza hearths through soil micromorphology. Their study provides examples of a variety of Hadza hearths and illustrates the variability in construction, morphology, intensity, and function of the hearths. Galanidou (1997) provides a summary of ethnographic examples of hearths used by hunter-gatherers and horticulturists in caves and rock shelters; again, a high degree of variability is recorded for the types, number, and functions of the hearths. These case studies also emphasize the notion that a hearth is not necessarily a built (e.g., stone-lined) feature; out of nine case studies, five groups use open hearths, three use stone-lined or log-lined hearths, and yet another uses open hearths that are occasionally lined with stones (Galanidou 1997:141–144). Ethnographic data thus suggest that open hearths involving no construction are more common than hearths requiring the excavation of shallow or deep pits, lining with stone or wood, or structuring of any sort: "Hearths made directly on the underlying substrate without any particular previous preparation appear to be a well established transcultural phenomenon … the demarcation of combustion zones with stones is limited in the world of modern foragers" (Meignen et al. 2007:103).

Thus, if we were to define a hearth we would not include the building or structuring of the combustion area as a basic element. It seems that the only common feature of all hearths is the simple fact that people intentionally burn fuel in order to produce a fire. Accordingly, an archaeological definition of a hearth will specify that a hearth is a combustion area, variable in structure, size, and depth, which preserves the remains of burned materials. In his "Dictionnaire de la Préhistoire" Leroi-Gourhan suggested the following definition of a hearth: "Dans la terminologie ancienne, est souvent synonyme de *couche archéologique*, celle-ci se révélant par un sédiment sombre comportant des charbons de bois et des foyers au sens strict" (Leroi-Gourhan 1988:405). According to this definition, the hearth will exhibit discoloration (dark sediments) and charcoal will be preserved. Schiegl et al. (1996) suggest another definition that similarly depends on the state of preservation: "Good field evidence for the use of fire is the presence of well preserved hearths. Such hearths are usually round or oval-shaped and often have an upper layer composed of light coloured minerals, a lower layer rich in charcoal, and a substrate of reddened sediment" (Schiegl et al. 1996:763–764).

These descriptions, however, appear to suit the definition of a "well-preserved hearth" better than that of a "hearth". The ethno-geoarchaeological study of Mallol et al. (2007) mentioned above demonstrated that the preservation of combustion features is not a straightforward issue, particularly in open-air sites: "Micromorphological results suggest that the anthropogenic signature of open air combustion structures can be detected depending on the rates of sedimentation and the impact of postdepositional disturbance factors … If the rates of sedimentation are low, leading to erosion, the remains of an ephemeral open air fire are likely to disappear" (Mallol et al. 2007:2050). Similarly, discoloration of sediments around and beneath the hearth depends on a variety of factors (e.g., fuel used, soil moisture, chemical variations in sediments) and requires favorable depositional and post-depositional conditions in order to be preserved in the archaeological record (Bellomo and Harris 1990; Canti and Linford 2000; Linford and Canti 2001; see also the discussion in Section 1.2.1).

In summary, it is evident that the definition of a hearth varies in terms of sedimentological setting, intensity, size, fuel used, structure, and function. These variables will eventually dictate the archaeological appearance of these features, i.e., whether hearths will exhibit a stone lining, whether ash and/or charcoal will be preserved, or whether discoloration of the sediments will occur. Consequently, as in the ethnographic record, the archaeological occurrences of hearths are extremely variable and uneven, and hearths are independently defined for each site.

Examples from the Middle Paleolithic include Abric Romani, where hearths were identified "by the presence of homogenous lenses of ash and charcoal, and thermal alterations of the underlying surface" (Vaquero and Pastó 2001:1212). At Kebara Cave, hearths appear "… in different forms, most often as lenses consisting of black and white layers of varying dimensions but also as ashy white accumulations; grey sediments composed of consolidated aggregates of ashes and black charcoal; zones of consolidated grey ash; and alternating thin, grey-white and black layers over large areas" (Meignen et al. 2007:93). At Grotte XVI (Dordogne, France), analyses of the thick ash deposit clearly defined the presence of hearths: "However, none of the more complex preparations – rock lining or excavated pits – associated with later Upper Paleolithic features have been discerned …" (Rigaud et al. 1995:911). At Site C in Belvédère, where both charcoal and burned flint artifacts were recorded (Stapert 1990), the location of the hearth was nonetheless recognized in the center of concentrations of burned flint, as the charcoal was probably "… carried away by flowing water after abandonment of the site. It seems that the flowing water did not have a strong erosive effect, because it left the flint concentration, including many tiny chips, in place" (Stapert 1990:5).

As the archaeological appearance of hearths is variable in color, size, contour, depth, and the use of stones for construction, it is difficult to generate an archaeological definition that suits these features. However, since hearths serve as focal points for activities, they display areas of refuse accumulation, specifically small refuse. These patterns can easily be identified when we examine sites in which the hearths are well preserved.

In this study, however, we are concerned with *phantom hearths* that display no directly observable features. Leroi-Gourhan's definition of *structures latentes* established the approach to such archaeological features, namely that these can be discernible through observable patterns of artifacts' spatial distributions (Leroi-Gourhan and Brézillon 1972).

Considering the hearth-related spatial patterning discussed above, we assume that clusters of debris, specifically small burned debris, are indicators of the locations of hearths and are defined as *phantom hearths* – features that lack other observable traits (e.g., structuring, discoloration of sediments, ash, charcoal). If we were to pursue the locations of the hearths, we should be able to trace them in the center of these concentrations. At the Middle Paleolithic occupation at Belvédère, clusters of burned artifacts suggested the presence of hearths in the centers of these concentrations (Stapert 1990). At the Magdalenian sites of Champréveyres and Monruz in Switzerland, hearths are characterized by various amounts of cobbles, stone slabs, and extremely abundant and well-preserved wood charcoal (Leesch et al. 2005). Regardless of the remarkable preservation of these sites, the spatial distribution of burned flint microartifacts has proved to be an optimal indicator for the precise location of the hearths, illustrating "…the legitimacy of mapping the burned flint chips to locate the combustion areas" (Leesch et al. 2005:7). Similarly, at the Mesolithic site of Verrebroek in Belgium, the patterns illustrated in the archaeological data were supported by various experimental studies that suggested that "simple surface hearths can be localized quite accurately on the basis of the distribution of severely burnt or overheated chips (2 mm–1 cm)" (Sergant et al. 2006:1006). In addition, it has been suggested that small items exhibit higher frequencies of burning than large items. Similarly to the observed effects of fire on bones (e.g., Stiner et al. 1995; Villa et al. 2002, 2004), this pattern may result from the fact that fire fractures and cracks material into smaller pieces, resulting in higher frequencies of burning amongst small items. A recent experimental study (Sergant et al. 2006) has demonstrated strong fragmentation of flint artifacts caused by burning. In this experiment "the initial 143 artifacts (larger than 1 cm) and 530 chips were shattered to 240 artifacts (larger than 1 cm) and 3419 chips, i.e., a multiplication with factor 1.7 and 6.45" (Sergant et al. 2006:1002). Since large quantities of small-sized burned flint items are expected to be found, large enough samples can be available for spatial analysis.

Thus, based on the above observations, spatial clustering of burned material, specifically small burned flint items, is considered in this study to be the main criterion in the identification of anthropogenic fire. The various possible spatial configurations of the small burned flint items at GBY are embedded within the different research models, specified below.

2.3 Research Hypotheses

The general hypothesis of this study is that the presence and spatial configuration of burned flint items can be used to identify anthropogenic fire in the attempt to establish evidence for hominins' early use of fire. Accordingly, the research hypotheses integrate both of these aspects – the identification of burning damage on flint and the characterization of their spatial clustering. However, as in any spatial analysis study, we are compelled to assume adequate preservation of the original spatial configuration of the archaeological occurrences. Thus, before addressing the hypotheses concerning the effects of fire on flint and the spatial patterning of anthropogenic fire, the following short discussion concerns the various sedimentological and taphonomic considerations suggestive of the preservation of the original spatial configuration of the archaeological remains at GBY.

2.3.1 Taphonomic Considerations

In the framework of this study, two different factors support the assumption that the observed distribution patterns represent the original configuration of the archaeological material. First, the archaeological occurrences of GBY are recorded in a lake shore environment, in which the oscillating water level of the lake allowed the rapid sealing of the archaeological material (Feibel 2001). Accordingly, various taphonomic observations suggest that post-depositional processes had a limited effect on the original location of the archaeological material (e.g., Goren-Inbar et al. 1994, 2002b, 2004; Ashkenazi et al. 2005; Goren-Inbar and Sharon 2006; Rabinovich et al. 2008, in press).

Secondly, the major components of this study are small flint items. As previously discussed, such small items tend to remain in their original location for a variety of reasons and are thus particularly reliable components in any spatial analysis. Despite this, in a lake shore environment such as that of GBY microartifacts may be subjected to particular taphonomic phenomena associated with lake margin processes.

Experimental studies of such processes carried out by Morton (1995) provide valuable data on the association between artifact weight and transport mode. It has been suggested that during lake transgression or regression events, heavier artifacts tend to subside with the sediment, while the "… lighter artifacts would either be transported downshore or downslope" (Morton 1995:77). In such a case, we would expect to find that smaller items do not cluster together but are rather arranged in a linear distribution along the presumed shore line. Lake margin environments can also spatially rearrange material in a non-linear manner and form clusters of denser concentrations. Natural features (e.g., fallen trees, bushes, or beach cusps) can provide obstructions and act as accumulators in a lacustrine environment. The comprehensive experiments carried out by Morton (1995) have demonstrated that in such cases, during transgression and regression of the lake, the heavier artifacts remain buried with minimal disturbance while the smaller ones became trapped and then buried at the obstruction. However, the "… complete absence at the obstruction of any artifacts over 10 grams …" (Morton 1995:120) led Morton to the following conclusion: "The recognition of a 'hydraulic jumble' (Isaac 1984) has been an important pursuit as an alternative hypothesis for the formation of archaeological sites. The experiments outlined have showed that these accumulations can indeed occur, but not without an obvious 'fingerprint'. Far from being a 'jumble', these sorts of archaeological concentrations would consist of well-sorted artifacts, all within a specific weight category" (Morton 1995:122).

Morton's experiments emphasize the strong relationship between artifact weight and wave energy. Accordingly, in low-energy environments, like that of GBY (Feibel 2001), the varied taphonomic phenomena that are often illustrated in lake margins will not necessarily occur: "Since a combination of random hydrodynamics and proximity to other particles causes artifacts to be braced into the sediment, they are quickly covered over or the edges become blanketed in sediment. This causes the artifacts to assume a lower, less resistant profile and hastens sedimentation. It is this sort of hydrodynamics that ensures that in a lake margin … it is possible that all smaller flakes and debitage are not removed" (Morton 1995:177).

In the framework of this study, we can benefit from these observations while analyzing the distribution patterns of flint microartifacts. We can thus assume that if the archaeological occurrences of GBY were significantly subjected to lake margin processes that rearranged the spatial configuration of the archaeological material, then flint microartifacts:

1. Will not exhibit clustering but rather a linear distribution along a presumed shoreline.
2. Will exhibit clustering; however, since size sorting is involved, they will not be associated with larger artifacts.

2.3.2 The Effects of Fire on Flint

A basic assumption in this study is that the identification of particular burning damage on flint items from an archaeological occupation provides sufficient evidence for the presence of fire. This assumption is based on a variety of experimental studies that have demonstrated the different effects of fire on flint.

Exposure to fire changes the mechanical properties of lithic material. Experimental studies, carried out mostly on flint or chert, demonstrated that exposure to high temperatures (~350–500°C) causes macroscopically identifiable (i.e., visually observable) alterations such as discoloration, potlid fractures, crazing, and fragmentation (Purdy and Brooks 1971; Purdy 1975, 1982; Julig et al. 1999; Sergant et al. 2006).

Early experiments in heating of silica minerals recognized that processes of expansion and contraction, which occur when materials are heated or cooled rapidly, result in explosions of the heated material (Crabtree and Butler 1964). However, the identification of specific features of burning damage and the particular means by which they are formed was first presented by Purdy (1975; Purdy and Brooks 1971). Her experiments have shown, for example, that "potlids always occurred during the heating process, never during the cooling process; thus they must be a result of expansion" (Purdy 1975:136).

Potlids are small, typically "bowl-shaped" pieces of lithic material that are exfoliated from the surface. Their exfoliation creates a depression (i.e., a potlid fracture) in the artifact from the size of a pinhead to larger (DeBano et al. 1998:271).

Recent experiments have demonstrated that only those artifacts that are in direct contact with the fire and heated to a temperature above 300°C will eventually show heat damage (Sergant et al. 2006). These experiments subdivide fire-damaged flint artifacts into three classes: (1) weakly burned: few traces of heat damage, except for a weak reddish shine and a few isolated cracks; (2) moderately burned: more visible heat damage, such as potlid fractures, cracks, and color changes; and (3) heavily burned (overheated): display total dehydration resulting in a white to gray discoloration (Sergant et al. 2006:1000).

In sum, only direct exposure of flint to fire results in visible heat damage, and heat damage is diversified and includes a variety of features. In the attempt to identify the presence of fire at a site as ancient as GBY, we chose to be extremely cautious and consider only items that are unquestionably burned. Therefore, the identification of burned flints had to rely on features that are clear and unique to exposure to fire. Of the various heat-damage patterns, potlidding is the most distinctive feature.[2] Thus, we assume that the occurrence of

[2]The use of discoloration of flint as a distinctive feature for the identification of burning is not a reliable measure for the flints of GBY; embedded within the waterlogged sediments, the majority of flint items are darkly patinated.

potlid fractures on flint items from the site of GBY is sufficient evidence for the presence of fire.

2.3.3 Patterns of Anthropogenic Fire

The identification of burned material at an archaeological occupation attests to the presence of fire; however, it is necessary to ascertain that this fire is anthropogenic rather than natural.[3] In this study, following the theoretical foundations discussed above, it is assumed that anthropogenic fire, in the form of hearths, will not damage flint items throughout the entire occupation surface but rather result in relatively small but non-random frequencies of burned items that are spatially clustered. Consequently, the spatial patterning of burned flints can confirm the presence of anthropogenic fire at an archaeological occupation.

The attempt to identify clusters of burned flint items is, however, accompanied by true complexities. When defining spatially discerned activities, we usually assume an association between particular tasks and specific archaeological material (e.g., an animal processing spot should exhibit spatial aggregation of worked bones, stone knapping areas should similarly display denser areas of lithic debris, etc.). However, when attempting to identify clusters of burned flints, we are actually examining items that spatially derive from a larger bulk of the flint component of the analyzed surface. This is of great importance, since the flint component may *a priori* be spatially clustered; thus, in a case where flint knapping was confined to a specific location, the original spatial patterning of the flints will exhibit clustering. A random, or uniform, burning pattern upon this will also appear clustered, so that any fire, whether anthropogenic or natural, can result in clustering of burned flints. Thus, where the unburned and the burned flints entirely overlap (spatially) each other, we cannot rule out the possibility of a natural fire. Based on these notions, several models are examined regarding the presence and distribution of burned flint items in each of the archaeological horizons analyzed in this study. These models particularly emphasize the spatial configuration of the burned flint microartifacts with respect to the unburned ones:

Model 1: Burned flint items are not present in the examined horizon; thus there is no evidence of fire, whether natural or anthropogenic; *Model 2*: Burned flint items are present in the examined horizon. However, the burned and unburned flint items are distributed identically; thus there is evidence for the presence of fire at the site but we cannot rule out the possibility of a natural fire, deforming flint wherever it occurs; *Model 3*: Burned flint items are present in the examined horizon. In addition, these burned flints occur in distinct clusters, whereas the burned and unburned items are not distributed identically. Thus there is evidence for the presence of fire at the site, and this fire has deformed flint in specific localities that do not entirely coincide with the original distribution of the unburned flint. This resulted in spatially discerned clusters of burned material that can be confidently interpreted as the remnants of anthropogenic fires.

[3]As previously noted, a thorough discussion of fire ecology, and specifically of the probability of natural fire at GBY, is included in Chapter 4.

These models will be examined for each of the analyzed archaeological horizons.

The means by which these models are evaluated are presented in the following section, which incorporates the various methodological procedures applied in this study.

2.4 Methodology

The previous sections of this chapter have laid the foundations of the methodological approach applied in this study: to examine the presence and spatial distribution of small burned flint items in order to identify possible clusters of burned material. The following section presents a detailed methodological account of the various procedures involved in the identification, analyses, spatial plotting, and spatial analyses of the burned flint items from GBY and their associated lithic assemblages.

The different methods comprise two stages, the second dependent on the first. The first involves the compilation, analysis, and preparation of the data, which eventually enabled its transformation into a geographical information database. The second includes the various tools used for the spatial display of the data and analysis of the observed spatial patterns.

2.4.1 Excavation Methods and Provenance Recording

Excavations at the site of GBY were carried out in three main areas, all located on the eastern bank of the Jordan River (Fig. 1.3). A horizontal 1 × 1 m grid was constructed above the excavated surfaces, corresponding to the coordinates of the Israel grid.

Excavation was conducted along the strike and dip of the layers with the aim of exposing the tilted archaeological horizons laterally (Goren-Inbar et al. 2002b: Figures 4 and 5); this procedure enabled the detailed representation of the spatial organization of each occupation surface. The standard unit of excavation was thus the tilted projection of a horizontal 1 m^2 grid square. Each horizontal grid square was further subdivided into four 0.5 × 0.5 m sub-squares and excavated in spits that covered the area of one sub-square to an average depth of 5 cm.

Once exposed, the surface (i.e., the living floor) was drawn and items were retrieved with a full spatial reference (X, Y, and Z); these "coordinated pieces" consist mostly of items larger than 2 cm (i.e., macroartifacts). Other items retrieved during excavation, the "uncoordinated pieces", were labeled according to the spatial reference of the spit (i.e., excavated unit/sub-square, and an elevation range). Such items can thus be located with an exactitude of 0.5 × 0.5 × 0.05 m.

In addition to material retrieved during excavation, the entire excavated volume of sediments embodying the archaeological horizons was wet-sieved during field work[4] using a 2 mm sieve. The wet-sieved sediments were then bagged with their recorded spit location and transported to the Institute of Archaeology for further analysis. Sorting of the sieved sediments yielded rich and varied assemblages, such as fruits, seeds, grains, bones and teeth of micromammals, fish, and crabs, and specks of charcoal. Most of the small lithic items, which are the main evidence on which this study is based, were retrieved through this procedure. These include all stone items (basalt, flint, and limestone) that range in size from 2 to 20 mm (henceforth microartifacts). As the wet-sieved sediments were retrieved from the field with their recorded spit location, these microartifacts can be located with an exactitude of 0.5 × 0.5 × 0.05 m.

2.4.2 Analyzed Samples

As this study examines the spatial distribution of burned flint items, the spatial recording of the archaeological material is fundamental. Thus, items for which the spatial data are incomplete (i.e., retrieved items for which the spatial record is lacking) are not included in the analyses. Accordingly, the various illustrations as well as the corresponding summary tables of the lithic inventory occasionally exclude an insignificant number of items.

This report includes the available data as of May 2007; several levels, either where the spatial exposure is minimal (i.e., Layer VI-14), or where no archaeological material was observed during fieldwork (i.e., Layers II-2, II-3), are not presented in this work.

Included in this report are 15 archaeological layers (Table 2.1); the analysis of each of these layers incorporates the following components:

Table 2.1 The archaeological layers included in the study, from the topmost layer of the stratigraphic sequence (younger) to the lowermost (older); area in m^2, volume in m^3

						Lithics counts	
		Layer	Level	Area[a]	Volume[b]	>2 cm*[c]	≤2 cm*[d]
GBY excavation areas	C	V-5		6.39	1.59	408	36,770
		V-6		7.04	1.97	356	6,585
	A	I-4		5.25	1.57	32	6,696
		I-5		5	0.55	63	15,350
	B	II-2/3		4.67	0.47	139	7,502
		II-5		25	13	180	3,903
		II-5/6		19.14	0.38	142	10,531
		II-6	L-1	23.79	4.28	2,295	58,086
		II-6	L-2	25.62	3.07	1,412	79,670
		II-6	L-3	17.92	2.50	1,199	96,094
		II-6	L-4	16.64	2.16	1,729	118,434
		II-6	L-4b	13.69	0.82	768	8,778
		II-6	L-5	13.39	1.20	450	37,609
		II-6	L-6	12.62	1.38	732	13,357
		II-6	L-7 upper occupational horizon	12.60	1.38	1,098	25,915
		II-6	L-7 northern test pit	2.75	1.51	332	12,555
		II-6	L-7 southern test pit	4.25	2.89	104	6,874
		Total		215.76	40.72	11,439	544,709

[a]Area represents the spatial extent of the excavated material (see Section 2.4.5)

[b]Volume is the excavated area multiplied by the estimated mean of excavated thickness based on cross-sections

*Lithic counts represents the total number of lithic artifacts of all raw materials including: [c] items larger than 2 cm (i.e., macroartifacts: flakes and flake-tools, cores and core-tools, and bifacial tools and [d] smaller items (i.e., microartifacts)

[4]Layers I-4 and II-5, revealed during the first season of excavations at the site, were partially wet-sieved; sampling included a single full bucket from each sub-square of a given depth unit of excavation.

1. All the lithic material retrieved in the course of excavation (flint, basalt, and limestone); including microartifacts, macroartifacts, and pebbles (described below under "lithic analyses").
2. Lithic material retrieved through sorting of the wet-sieved sediments:
   - Microartifacts, including flint, basalt, and limestone
   - Cores and core-tools (items lacking a ventral face)
   - Pebbles

Excluded from this analysis are the flakes and flake-tools retrieved from the sorting of the wet-sieved sediments and natural small stone items that do not bear signs of knapping and hence are not identified as microartifacts (these are discussed in detail below, under "Lithic Analyses").

2.4.3 Lithic Analyses

The lithic assemblages referred to in this study comprise various raw materials, including flint, basalt, and limestone. In addition, they consist of both natural items (i.e., pebbles) and modified items – macroartifacts (>2 cm) and microartifacts (≤2 cm). The analyses of the lithic assemblages are specified below, according to the different lithic categories.

2.4.3.1 Microartifacts

The main component of this study is the numerous microartifacts (≤2 cm), retrieved from the various archaeological layers, during excavation or from the sorting of the wet-sieved sediments. Unlike macroartifacts, flint microartifacts occur in extremely large quantities in each of the archaeological layers, thereby providing large enough samples of burned items for spatial analysis.

A large number of stone microartifacts was retrieved from the different archaeological occurrences; analyses of these items were carried out in the following steps:

1. *Differentiating between natural and modified items*: in order to ensure that the examined spatial patterns represent evidence of hominin activity, only items that are unquestionably the result of stone knapping are included in this study. Thus, natural items (e.g., small pebbles) are excluded. Only items that exhibit characteristic knapping features of flaked material (e.g., ventral face, striking platform) are included in this category and are defined as microartifacts.
2. *Defining raw material*: microartifacts are sorted into different classes of raw material, including basalt, limestone, and flint. The general inventory of these is presented for each of the archaeological layers.
3. *Identifying burning damage on flints*: the final and most vital stage of analysis is the identification of burning damage on the flint microartifacts (equivalent principles are used for the identification of burning on flint macroartifacts and flint pebbles). Identification is based on the presence of typical macrofractures (i.e., potlid fractures), known to result from the exposure of flint to high temperatures (see the detailed description above under "Research Hypotheses"). The identification of burning is thus based entirely on visual observation (Appendix 1).

During this research, samples of burned flint microartifacts were submitted to thermoluminescence (TL) analyses.[5] The results of the TL study have demonstrated that the analyzed samples must have been exposed to high temperatures in a heating event in the remote past (Alperson-Afil et al. 2007); these results provide independent verification that the observed potlid fractures are indeed the result of burning.

2.4.3.2 Macroartifacts

This category comprises artifacts larger than 2 cm of three different types: cores and core-tools (i.e., CCT), flakes and flake-tools (i.e., FFT), and bifacial tools (i.e., handaxes and cleavers). The general inventory of these is presented for each of the studied archaeological layers by raw material; spatial distribution is examined only for the burned flint macroartifacts.

2.4.3.3 Pebbles

Of the various analyzed lithic components of this study, unmodified items are included only within this category. The category classified here as "pebbles" refers to natural items larger than 2 cm (i.e., pebbles and cobbles) and consists of flint, basalt, and limestone. The general inventory of the pebble assemblage is reported for each of the analyzed archaeological layers; spatial distribution is examined only for burned flint pebbles.

2.4.4 Database Construction

The analyzed lithic assemblages are organized in two different types of *Access* database. This distinction originates in the use of two different databases of lithic analyses in the excavation project of GBY. In the first, each database

[5] The principles of the TL method are discussed in Section 1.2.

row incorporates the attributes of a single item, whether a macroartifact or a microartifact. The second type of database consists only of microartifacts retrieved through sorting of the sieved sediments; here, each row incorporates the total content of a sediment unit (i.e., of an excavated spit). The difference between these two databases required separate procedures in order to convert the data into spatially manageable geographical information; more specifically, the database in which the entire content of an excavated spit was depicted in a single row had to be converted into a "single-record row" database. This conversion enabled spatial plotting of all items, discussed below.

For each of the lithic items, the recorded data includes: stratigraphic assignment, provenance recording (either a full X, Y, Z reference or a 0.5 × 0.5 m quadrant and a range of elevations), raw material definition, and in the cases of flint items the presence or absence of burning damage.

2.4.4.1 Assigning Artificial Coordinates

A large number of macroartifacts and the majority of microartifacts were retrieved with a general spatial reference, either during excavation or throughout the sorting of the wet-sieved sediments. The spatial reference of these includes the X and Y quadrant (0.5 × 0.5 m) and depth of spit (Z is a range of depths). Such spatial recording allows only the representation of relative frequencies of lithic items per excavated unit. Other spatial analyses, such as creating a density map, would necessitate measuring the distances between different features and thus require that the data be depicted as distinct points.

It has been suggested that assigning a random spatial reference within the excavated area provides a reliable, and almost identical, spatial representation (Gilead 2002). Taking this into consideration, using the *Visual Basic* language within the *Access* program (Microsoft®Accesss 2002) items with a general spatial reference were given a new reference point within their recorded sub-square. This procedure enabled the plotting of each of the excavated lithic finds and included the following stages:

Each of the archaeological layers was treated independently within a separate database. The database was then sorted according to the recorded excavated units of the particular layer. Each of these excavated units had a defined excavated area (0.5 × 0.5 m sub-squares or 1 × 1 m squares), from which a certain number of lithic items was retrieved. This area (a) was then divided by the maximum value of items retrieved from that area (n) so that each item could be plotted separately within an a/n area (δ). Let us hypothesize a case in which a given 1 m^2 excavated area ($a = 1$) has 100 flint items ($n = 100$). If these 100 items were distributed *evenly* within the 1 m^2 area each item would occupy an area of 1/100 m^2 ($\delta = 0.01$). The new reference point for each of these items is defined as the southwestern corner of each δ cell, so that:

$$a = \sum \delta_{1-n} \left(\delta_1 + \delta_2 + \delta_3 + \delta_4 \cdots \delta_n\right)$$

This procedure enables the items to be plotted *uniformly* within their recorded spit, ensuring that the new plotted data are as consistent as possible with the recorded data of sub-square precision. Other plotting methods (e.g., random plotting) may have resulted in the formation of artificial clusters within the area of the sub-square.

In addition, it is important to note that the analysis of spatial patterns in this study is carried out on the data according to their original sub-square recording (see Sections 2.4.6.1 and 2.4.6.3) and that the point-plotted data are used mainly for illustrating the observed patterns of distribution (i.e., in the density maps of kernel type – see Section 2.4.5).

Several procedures required a three-dimensional representation of the data (e.g., assigning a stratigraphic classification, specified below). In these cases the vertical position (i.e., Z coordinate) of the items was essential. As previously discussed, many "uncoordinated" pieces were retrieved from the field with a recorded *range* of elevations. Due to the tilted position of the archaeological exposures, elevations were recorded in two corners of the excavated unit, northeastern (NE) and southwestern (SW), at the beginning (TOP) and end (BOTTOM) of each excavation phase (defined as a 5 cm spit of excavated material). In order to convert these elevations into a single Z point, the average of the recorded elevations was calculated so that the new Z point represents the elevation at the center (both vertical and horizontal) of the excavated unit:

$$NEW\ Z = \frac{\{[(NETOP + NEBOTTOM)/2] + [(SWTOP + SWBOTTOM)/2]\}}{2}$$

This procedure enabled analysis of a small number of layers that required additional treatment in order to allow spatial plotting of the excavated material:

Layers I-4 and I-5: these two layers were exposed during 1989, the first season of renewed excavations, when fieldwork focused on two areas; the southeastern part of the study area (Area A) and some 45 m to the northwest (Area B) (Fig. 1.3).

In Area A, the tilted nature of the archeological occurrences was revealed during excavation. Upon the quarrying of Trench I, each of the observed archaeological layers was assigned an individual reference name (i.e., I-4 and I-5). These two layers, observed in various sections within the excavated area, exhibited a sedimentological divergence between gray clay (I-4) and a coquina mixed with sandy and clayey lenses (I-5). As excavations proceeded, the distinction between these two horizons became evident and material was given a definite stratigraphical assignment. However, for some of the excavated material a stratigraphic assignment was not specified. These circumstances resulted in an excavated assemblage in which some of the material is recorded with a full spatial reference (i.e., excavated grid unit, range of elevations, and specific layer), while other material lacks registration of the stratigraphic assignment.

In order to allow spatial plotting of the excavated material from Area A, it was necessary to determine the stratigraphic position of some of the excavated assemblages. Using *ArcScene* (ESRI®ArcScene™9.3), the three-dimensional data analysis software available in the ArcGIS package,[6] the entire assemblage of Area A was plotted three-dimensionally and then divided into two separate stratigraphical units. The division was enabled through the use of a "virtual" 3D surface, designed to depict the tilted contact between I-4 and I-5. The outlines of this "contact surface" follow the contact lines of I-4/5 as drawn in the various field cross-sections; thus items above the surface were assigned to I-4 and items below it to I-5.

In addition, in order to enlarge stratigraphic clarity during fieldwork in Area A, the area was excavated on either side of a baulk (Fig. 1.3); thus the spatial exposure of these layers is not continuous. Furthermore, during that season, the excavation of the relatively sparse exposure and density of Area A came to an end before more extensive exposure of the layers, and fieldwork then focused on the denser occurrences of Area B.

Accordingly, in this study the data presented for Area A include the general lithic inventory of the entire exposed surfaces, while the spatial presentation involves only one area, to the north of the baulk, where the excavation reached Layer I-5; the spatial account is thus minimal and no further spatial analyses are carried out for these layers.

Layer II-6 L-7: this stratigraphic unit is the lowermost occupational level of Area B, excavated during the 1995–1997 seasons. The upper part of Layer II-6 L-7 revealed an occupational surface embedded within a sandy matrix made up primarily of crushed mollusks.

At the end of the 1996 season, excavations in two areas (one in the southern part and another at the northernmost edge of the exposed surface) completed the exposure of the upper occupational horizon of Layer II-6 L-7 and items were drawn and removed from the excavated surface. Thus, during the 1997 season excavation in Layer II-6 L-7 penetrated deeply into two test pits at the edges of the excavated surface, while excavation of the central part of the surface uncovered the upper occupational horizon. Excavation of these two test pits reached the bottom of Layer II-6 L-7 – the contact between Layer II-6 and the underlying Layer II-7. These two test pits revealed a sorted sedimentological sequence, with a very coarse conglomerate at the base that fines upwards, exhibiting a thin clayey layer above the conglomerate and a thick series of sands above it.

The entire layer, from the conglomeratic base (with its two test pits) to the sandy top, was designated II-6 L-7. Due to these sedimentological differences, items retrieved from the two test pits had to be separated from the general assemblage of the upper occupational horizon of Layer II-6 L-7. This was accomplished by isolating the material retrieved from the specific excavated units of the test pits during the 1997 season (as excavation season is specified in the databases). The upper occupational horizon of Layer II-6 L-7 thus includes material from these two areas excavated during the 1995–1996 seasons as well as the entire exposed surface of Layer II-6 L-7 from the central area between the test pits.

As in Area A, the discontinuous nature of these test pits does not allow spatial analysis; thus the data displayed for the Layer II-6 L-7 test pits consist of the general lithic inventory, and only a schematic spatial illustration of the flint microartifacts is presented. A similarly brief description is given for Layer II-2/3, which was exposed over a relatively small area (4.67 m^2) that does not permit in-depth spatial analysis.

2.4.5 Generating Distribution Maps and Density Maps

The assignment of artificial coordinates to the lithic microartifacts and macroartifacts enabled the various databases of lithic material to be used as geographical information that can be integrated into ArcGIS software. This package is a collection of software and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. Of the software available, *ArcMap* (ESRI®ArcMap™9.3) was used for the spatial display and analyses of the archaeological data in this study.

An individual *ArcMap* project was designed for each of the analyzed archaeological layers. The databases of lithic items were then inserted into the *ArcMap* file, each depicted as a separate layer of geographical information.

Following insertion of the data, a systematic methodology of spatial display and analysis was maintained (see Appendix 2).

The initial phase of analyses consisted of evaluating the spatial distribution of the point-plotted items, which can be illustrated in regular point-distribution maps (Fig. 2.1a). These illustrations are used in this study to display the distribution of macroartifacts. However, when the lithic

[6]See: http://www.esri.com/software/arcgis/about/desktop_gis.html

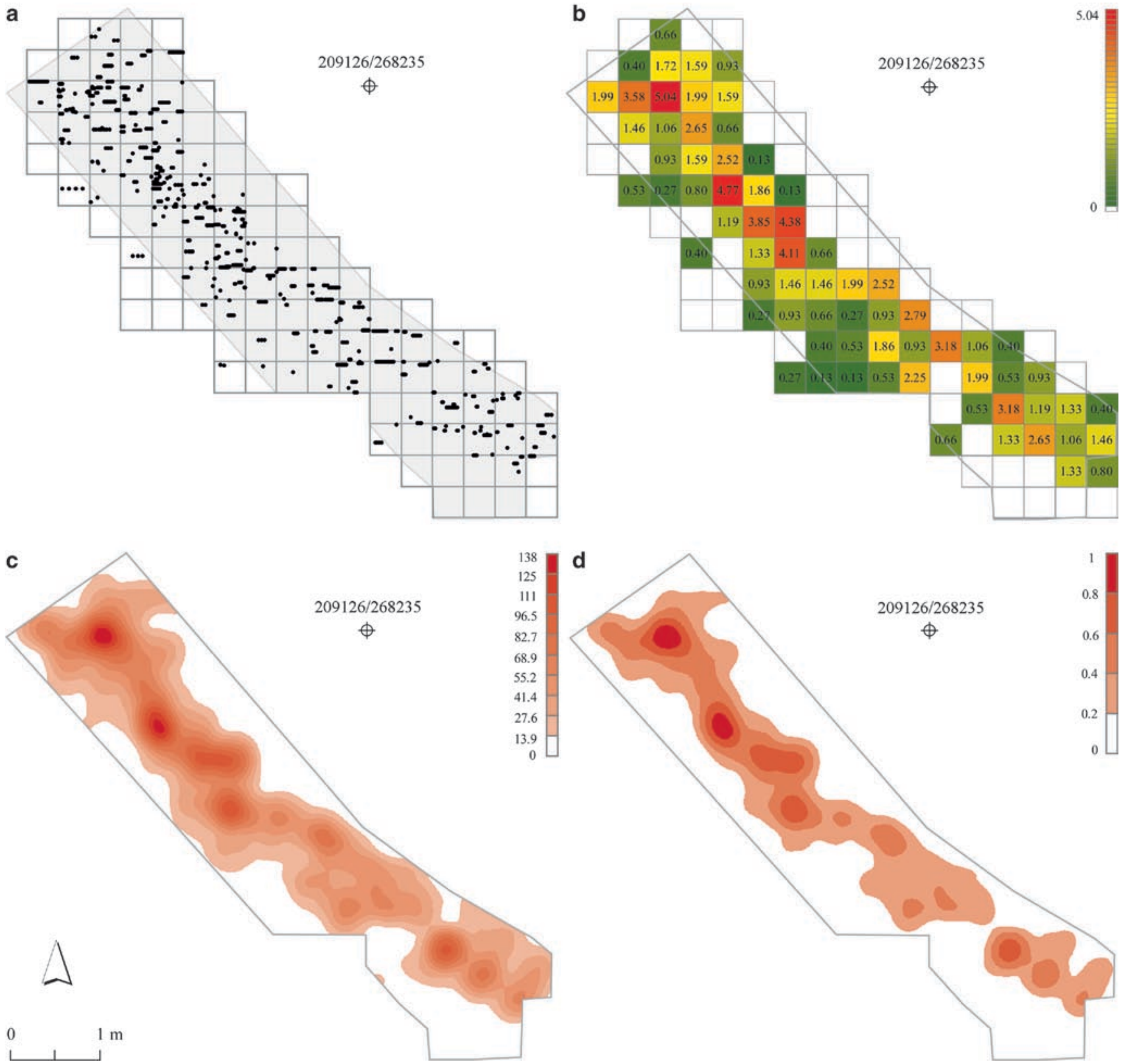

Fig. 2.1 The stages of building distribution and density maps, demonstrated on the assemblage of burned flint microartifacts from Layer II-6 L-1 (N = 754): (**a**) point-plotted distribution map; (**b**) percentages of microartifacts per excavated unit; (**c**) kernel density map; and (**d**) standardized kernel density map

category contains extremely large quantities, as is the case for microartifacts, it is impossible to distinguish areas of high density within the general distribution pattern. This necessitated a schematic illustration of the relative percentages of microartifacts per excavated unit. In order to emphasize areas of high density, these illustrations use a green-to-red color scheme, which depicts different degrees of frequency by gradually altering colors (green for low frequencies, red for high frequencies) (Fig. 2.1b).

In order to achieve a reliable representation of the extent of the excavated area of each layer, we have depicted the margins of the excavated area according to the distribution of the archeological finds that is available from the field maps of the living floors (available for Layers V-5, V-6, and II-6 L-1 to L-7) and from the distribution of coordinated pieces (i.e., items that were given full XY coordinates in the field; these include FFT, CCT, bifacial tools, and pebbles). The spatial extent of these items is the optimal representation of the boundaries of the excavated area of each archaeological layer. The outline of this area is illustrated in all distribution and density maps. As some of the excavated material, particularly the microartifacts, was given artificial coordinates within the excavated spit (i.e., square or sub-square), the graphic representations of percentages of microartifacts per excavated unit, which refer mechanically to grid sub-squares, include areas that are not fully excavated (e.g., a full sub-square will be illustrated in the graphic presentation of percentages per excavated unit even where only the corner of the sub-square was excavated).

In order to illustrate areas of high density graphically, the point-plotted data of microartifacts distribution were converted into kernel density maps (Fig. 2.1c). Kernel density calculates the density of point features around each output cell (determined in this study as 0.01 m). Conceptually, a smoothly curved surface is fitted over each point. The surface value is highest at the location of the point, and diminishes with increasing distance from the point, reaching 0 at the search radius distance from the point, determined here as 0.5 m; thus, only a circular neighborhood is possible. The density value at each output cell is calculated by adding the values of all the kernel surfaces where they overlie the cell center.[7]

Determination of different search radii thus changes the scale of the analysis results. With a smaller radius, fewer points will fall within the search radius, resulting in numerous small, "dense" features. Increasing the radius will result in more points falling within the search radius; this number (of points) will be divided by a larger area when calculating density, resulting in larger, generalized concentrations. The values of cell size (0.01 m) and search radius (0.5 m) were chosen for this study as they closely represent the genuine patterns observed within the schematic illustrations of the data (see Appendix 3, where a comparison of different cell sizes and search radii is illustrated in comparison with the density patterns as depicted through data interpolation of sub-square precision [methodological procedures are specified in Appendix 2]). Finally, in order to create a uniform scale (from 0 to 1) that will enable comparison between kernel density maps of different data sets (e.g., in-between layers; burned vs. unburned flint), the densities have been standardized by the maximum values of each data set (Fig. 2.1d).

In this study, kernel density maps are produced only for microartifacts, since these occur in large numbers that do not allow evaluation of spatial patterns in their "point-plotted" form. A uniform scale (from 0 to 1) with five levels of density is applied to all the density maps (the lowest density level is 0–0.2 and the highest is 0.8–1.0). In addition, a uniform color scheme is applied to the kernel density maps, in which each lithic category is depicted in a different color; blue for unburned flint, red for burned flint.

[7]The kernel function is based on the quadratic kernel function described in Silverman 1986: 76, Equation 4.5.

2.4.6 Analysis of Spatial Patterns

The initial stage of analysis, in which distribution and density maps of the flint microartifacts were produced, drew attention to areas of high density and provided basic evidence for the presence or absence of clusters of burned flint microartifacts. However, in order to verify that these clusters are not the random outcome of the original distribution of the entire flint component, it was essential to determine the degree of overlap between the distribution of the burned and unburned flint microartifacts.

As thoroughly discussed above (see Section 2.3), when the burned and unburned flint microartifacts overlap absolutely we cannot rule out the possibility of a natural fire. Conversely, when the clusters of burned flint microartifacts do not coincide with those of the unburned flint we can plausibly suggest that an anthropogenic fire is the agent responsible.

Several methods were applied to examine the degree of overlap between the burned and unburned flint microartifacts.

2.4.6.1 Homogeneity Analysis: Observed and Expected Burning

This method examines the distribution of the burned flint microartifacts in comparison with that of the unburned ones. In the case of an absolute overlap between the distributions of the burned and unburned flint microartifacts, we expect the relative percentage of burned items to be homogeneous across the exposed surface, displaying similar values in each of the excavated grid units. Thus, if the general percentage of burned flint microartifacts in a particular layer is 2.00%, we expect that within each of the excavated units (i.e., 0.5×0.5 m sub-squares) the percentage of burned items within the total flint microartifacts of the sub-square will similarly be 2.00%.

In order to compare between the observed and expected percentages of burned items in each excavated unit, the expected percentage of burned flint microartifacts was subtracted from the observed percentage. The value obtained through this calculation is the deviation between the observed and expected percentage of burning in each excavated unit; units of positive values are excavated sub-squares in which the observed percentage of burning exceeds the one expected in the case of uniform distribution of the burned flint microartifacts (see detailed procedures in Appendix 2).

2.4.6.2 Generating Random Patterns

This method of generating random patterns attempts to illustrate patterns of density in a case of random distribution of burning across the exposed surface. Three independent random scenarios were sequentially produced for each of the analyzed archaeological layers (see detailed procedures in Appendix 2). A "random selection" tool was used in order to produce a random selection of a particular number of items out of the entire assemblage of flint microartifacts. The number of randomly selected items is equivalent to the number of burned flint microartifacts recorded in the analyzed layer. This procedure was sequentially repeated three times. Next, for each data set of randomly selected flint microartifacts a kernel density map was produced, following the same criteria (i.e., cell size, search radius, and scale normalization) as in the other kernel density maps of this study (detailed above). A green color scheme is consistently used for the random density maps.

These procedures yielded three possible scenarios of random densities. Discrepancies between these and the observed density patterns of the burned flint microartifacts can be used as an additional indicator of the significance of the observed patterning of burned flint microartifacts.

2.4.6.3 Statistical Tests

The ArcGIS package supports various types of spatial statistic tools (e.g., cluster analyses, nearest-neighbor analysis, etc.) However, as discussed previously (see Section 2.3.3), differentiating the patterning of the burned flints from the unburned ones is not a straightforward issue. The burned flint microartifacts spatially originate from the larger flint component (in each analyzed layer), which may *a priori* be spatially clustered; thus we cannot consider the burned flint microartifacts a spatially distinct sample on which spatial statistic analyses can be performed. If we did this, we would have failed to notice the possible overlapping of the burned and unburned flints, which is a fundamental factor in a reliable identification of anthropogenic fire.

A chi square test, however, can examine the spatial differences between the burned and unburned flint microartifacts, providing a statistical parameter of probability for that differentiation. The chi square (χ^2) value was thus calculated for the burned flint microartifacts over all the excavated units (i) through the following equation:

$$\chi^2 = \sum_i \frac{(OBS_i - EXP_i)^2}{EXP_i}$$

so that the absolute chi square test value of a particular archaeological layer is the summary of χ^2 values of all excavated units (i = number of excavated units).

The probability level (p) of the chi square test is then extracted by comparing the calculated chi square value to a critical value from a chi square table, with degrees of freedom corresponding to that of the data ($df = i - 1$).

The chi square goodness of fit supplies a parameter of differentiation between the observed distribution and an expected, uniform, distribution. It does not indicate, however, what specifically is significant. This can be portrayed in the standardized residuals (SR), which are the signed square root of each category's contribution to the χ^2:

$$SR = \frac{OBS_i - EXP_i}{\sqrt{EXP_i}} \sim N(0,1)$$

What the above formula actually states is that the standardized deviations are approximately (asymptotically) normally distributed. i.e., given a large enough sample and a sufficient number of units, one would expect (under the assumptions of the null hypothesis) that about two thirds of the units will have SR values in the −1 to +1 range, about 95% will be between −2 and +2, etc. Thus, any unit for which the SR value is greater than 2.00 (and the expected value is larger than 5) is considered a substantial contributor to the significance observed in the chi square test (e.g., Haberman 1973).

Standardized residuals were thus calculated for the burned flint microartifacts of each excavated unit. Where burned flint microartifacts are distributed significantly different from the unburned ones, we can evaluate the contribution of different excavated areas to the observed difference.

2.4.6.4 Analysis of High-Density Clusters

The previous sections have outlined the methodologies for the identification of significant clusters of burned flint microartifacts. These clusters are the ones that display high levels of density (i.e., reaching the fifth and highest recorded density level), and are distributed significantly different from the unburned flint microartifacts. Such clusters are interpreted here as possible remnants of anthropogenic fires (i.e., hearths). Following their identification, these clusters are examined with reference to the distribution of other burned flint items (i.e., FFT, CCT, and pebbles).

The attempt to characterize the clusters of burning is further accompanied by various measurements of the kernel of the clusters, where the highest level of density is recorded. The measurements refer to the general geometry (area and diameter) and lithic composition (relative percentages of burned and unburned flint microartifacts).

Chapter 3 presents the results obtained through the use of the various methodologies on some 15 archaeological occurrences within the GBY depositional sequence.

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