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Kyrene Sikkeleri Üzerinde Betimlenen Silphion Bitkisi Işığında Antik Çağda Doğum Kontrolü:

Systematic Survey in Alicante, Spain. First Results

Alicante'de (İspanya) Sistematik Yüzey Araştırması. İlk Sonuçlar

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Avrupa'nın Akdeniz bölgesi arkeolojisi için yerleşme dışında gerçekleştirilen sistematik ve yoğun yüzey araştırması pek olağan değildir. Bu yazı bu tür uygulamayla ilgili bazı yöntemsel ve kronolojik sorunlarla birlikte ***Les Valls d'Alcoi*** *(Alicante, İspanya) yöresinde gerçekleştirilen yüzey araştırmasının ilk sonuçlarını tartışmaktadır.*

It is well known that information obtained from systematic and intensive survey, which uses an "off-site" strategy, is useful to any research studying human activity at a regional level (Dunnell, Dancey, 1983). However, data from this method face difficulties and shortcomings derived from two basic conditions:

- The amount and the extent of changes in the landscape due to both human (farming) and natural (erosion - redeposition) forces.
- The lack of stratified sites to help organize surface collections (especially the prehistoric ones) in to a chronological framework.

- While the first conditions tends to challenge conclusions that about the use of space, as the observed patterns might derive to a large extent from postdepositional processes, the second one raises the harsh problem of reliable assigning the observed patterns to particular chronological age. The difficulty inherent in this process gradually increases as we move back in the prehistoric calendar, and it seems that "invisibility" and chronological uncertainty are the unfortunate causes.

These difficulties may have had an influence on the planning and development of projects based on systematic and intensive survey (Cherry et al. 1991) that are nonexistent in Spain, where independently of the methodology being used, survey has been aimed at locating settlements (Ruiz Zapatero, 1988).

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A systematic survey project in the littoral valleys in the south central Valencian region of *L'Alcoià* and *El Comtat* (Alicante, Spain) began in 1987 and was coordinated by one of us (J. Bernabeu). The project was redesigned later, given the initial interest that was generated from findings and the need to study several methodological problems in greater depth, and M.C. Barton and J.E. Aura joined the coordinating team. In its final design, the survey encompassed five environments located in the region known as *Les Valls de l'Alcoi* or *Serpis*: the valley of *Polop* (headwaters of the *Alcoi*, ca. 750m above sea level), *Penàguila* (headwaters of the *Alcoi*, ca. 550m above sea level), middle *Serpis* (ca 450m above sea level), lower *Serpis* (*Lorcha*: ca 350m above sea level), and the *Vall d'Alcalà* (ca. 600m above sea level), which is nearer the coast (Figure 1). The central objective of the project was to find out the effects of the neolithization process on the territory, but, given the wide chronological range of the collections, the objective soon became limited.

In this paper, we present the first finds from the analyses of the collections of *Polop* and *Penàguila*, focusing on those prehistoric collections from the Middle Paleolithic to the Bronze Age.

1. Geographical Aspects

The valley of the upper *Polop* and the region of *Benifàllim-Penàguila* are located within the geographical unit known as *Les Valls de l'Alcoi*, on the inland of Alicante. It consists of a series of small valleys that converge in a depression, the basin of *Buñol* which originated from a fault, where the *Alcoi* or *Serpis* river flows. Both the valley of *Polop* and the valley of *Penàguila* belong to that series of valleys.

The valley of *Polop* belongs to the headwaters of the *Alcoi* or *Serpis* river, and is located about 6km SW of the city of Alcoi (Fig. 2A). The average altitude ranges from 700m to 900m above sea level. It runs from SW to NE, and in the SE is surrounded by the *Sierra del Carrascal* -about 1300m- and in the NW by the *Lloma de la Fontfreda*, which has a maximum altitude of 1100m.

The valley formed a closed drainage system in the late Tertiary or the early Quaternary, and the stagnant waters in it formed a thick sequence of marls. At some point, the drainage of the lakes and the fluvial erosion left one or several high banks in the marls along the river. The main drainage at that time was in the north side, and exited along the present course of the river *Barxell* (Ferrer, Fumanal , Guitart, 1993; La Roca, 1991).

Following this initial episode of incision, the valley seems to have undergone a significant degradation. However, out wash aprons which developed in several sites and marls were covered by thick land deposits. Possibly, the deposition was not episodic but cyclical, and diverse along the valley. Throughout the survey, some objects probably belonging to a Paleolithic chronology were found 2m beneath the present surface, as part of these sediments. The reddish and well developed $CaCo_3$ horizons of these land series may represent a long period of stability in the surface, with standing other processes of erosion. A more detailed research would possibly subdivide this Pleistocene filler of the valley floor.

This sequence which cuts and fills, is found in the central part of the valley as early as the late or post-Pleistocene period. Floors developed in this sediment are less reddish and contain a tiny proportion of CaCo3. On the basis of stratigraphy, the development of floor and the association of artifacts, it seems that these sediments date to the end of the Pleistocene, and the development of floor to the Early or Middle Holocene.

Sometime during the deposition of the Pleistocene series and their subsequent displacement, the drainage system of the valley changed significantly. Primary drainage moved from the North to the South of the valley, probably because of the capture of the river *Barxell* by the river *Polop* and its main tributary, the *Barranc del Troncal*. For the time being, an accurate chronology and reason for this change are not well understood. However, the contemporary or oldest incision of the upper course of the river *Serpis* -the streams of the upper *Polop* being its tributaries- was clearly located after the occupation of the settlement of *Niuet* in the late Neolithic (Bernabeu et al. 1994). Thus, it is still possible to understand how human activities associated with farming and stockbreeding contributed to the erosive episodes.

The surveyed zone in the valley of *Penáguila* is called *Les Puntes* (Fig. 2B). It stretches in the north of the *Serra de la Carrasqueta* and the southwest of the river *Penàguila*, about 650-550m above sea level (Roselló, Bernabé, 1978). It is sorrounded by mountains everywhere, except for the Northeast: by the mentioned *Carrasqueta*, 1330 m, and its offsets in the south and in the southwest; in the south-east les Puntes is surrounded by the offsets of the *Carrasqueta* and *Aitana*, which it joins in the East; and by the *Serreta*, 1051m, in the Northwest.

In geological terms, it is a structural valley between the calcareous anticlines of the *Serreta* and the *Carrasqueta*. Given the enveloping relief around *les Puntes*, the drainage network is clearly centripetal. Gullies converge into another, or into the main collector, the river *Penàguila*, (in a 1,25km stretch, to be accurate). Various remnants of flat surfaces are still found between gullies, *Les Puntes* being a generic toponym which conveys this meaning.

The surface is deeply dissected by the drainage network, with incisions ranging from 30m to more than 70m deep (Roselló , Bernabé, 1978: 91). Surprisingly, many of these gullies are very narrow, when compared to other transverse V-profile gullies in the region; they have no terrace, except some, which have a small recent terrace near the mouth.

All of this points to a very recent network embedding age in the *Polop* valley. The hypothesis is supported by the floor quality: the most evolved floor with a "Bw" alteration horizon and its corresponding "A" horizon, is usually buried under an "A/C" horizon, ("C" being aeolian silt and gully material). Gully waters and wind, instead of eroding this paleosoil, heaped sediments on it.

The Pleistocene drainage network was probably less deep, the deepest of which was found in the sharply sloping zones next to the mountain slopes. Paleocourses are assembled there today. Some of these slightly embedded courses probably disappeared when they reached the plain, while others went on to the main collector, acting not as a barrier to displacement as they do today.

In short, it seems that both valleys have had stable surfaces since at least the end of the Plesitocene. From then on and up until the Middle Holocene, a significant disruption took place, in the incision of water courses. Farming activities, especially ploughing, besides occasional erosion, might have a removed the old sediments which were redeposited into minor gullies, their place in the stratigraphic register was lost. Only ploughing is ubiquitous, however, and we can therefore conclude that the above mentioned conditions do not decrease the possibility of finding remnants of human habitation (which may be attributed to a long sequence in both cases).

2. Regional Sequence

Archeological research in the central and southern area of Valencia, from the inland region to the coast, has traditionally been intensive. Table 1 is based on the main stratrigraphies and their datings, and the regional sequence is adapted to the demands of the project's work. Nine periods have been retained:

Middle Paleolithic (MP). Apart from evidence concerning the Middle Pleistocene coming from the *Cova de Bolomor* (Tabernes de Valldigna, Valencia), near the area being studied (Fernández, 1993), the earliest evidence of human habitation in the region dates back to the Middle Paleolithic, ranging from the 80.000 bp- U/th- of *Cova del Salt* (Barton ,Clark, 1993; Galvan, 1992), to the 39.000 bp- C14- of *Cova Beneito* (Iturbe et al., 1993). The sequences in the *Cova del Salt* (Alcoi, Alicante), in the valley of *Polop*, and the nearby *Cova Beneito* (Muro, Alicante), are complete for the period.

Upper Paleolithic (UP). The sequence of *Cova Beneito* documents the evolution of the Upper Paleolithic, from the Aurignacian -ca. 34.000 BP- to the Solutrean-Gravettian -ca. 16.500 BP- (Iturbe et al., 1993). Occupations were always located in caves or shelters, open-air settlements have not yet been documented.

Late Upper Paleolithic (LUP). Broadly speaking, this period matches up with the Upper Magdalenian and the beginning of the Holocene industries (ca. 14.000-10.000 BP) in the regional sequence (Aura, 1995). The percentage of backed bladelets and burins in industries is higher than 60-70%, a defining feature of this moment. The sequences of *Cendres* and *Tossal de la Roca* (Villaverde, 1995; Cacho et al., 1995) are good examples of this.

The differentiation from the *Early Mesolithic* (EM) (ca. 10.000-8.000 BP), which matches the microlaminar Epipaleolithic, is based on the structure designed by Aura and Pérez Ripoll (1995). These authors point out an increase of end-scrapers, notches and denticulates, as well as a remarkable decrease of microlaminar tools and burins in the X millennium BP. Stratified collections belonging to this period scarcely exist (*Tossal de la Roca*)

The Recent Mesolithic (RM) or Geometric Epipaleolithic (8.000-6.800 BP) is characterized by the development of geometric microliths, mainly trapezoids and triangles. This period is well documented in the valleys of Alcoi in two sequences: *Tossal de la Roca* (Cacho et al., 1995) and *La Falguera* (Barton et al., 1990), the later in the valley of *Polop*. The late periods of these industries already had ceramics, and coincide with the early signs of farming and stockbreeding in the region.

Open-air sites are scarcely known. Only very recently some new information has indicated the existence of Late Mesolithic open air settlements. Such could be the case of *El Collado* (Oliva, Alicante), located on the present coastline (Aparicio, 1990).

The Early Neolithic (EN) falls within the wider impressed ceramics cultural horizon of Western Mediterranean (Bernabeu, 1989). Cardial decoration is representative of the early stages (NIA), while epicardial decoration (non cardial incised and impressed) is representative of more recent periods (NIB). The presence of animals (sheep and goats, cows, pigs and dogs) and plants (wheat, barley, peas and lentils) is documented in most of the settlements fitting the ceramic period, though not in all of them. This discrepancy is a central point in the debate about the neolithization process of in the Iberian Peninsula (Bernabeu, 1997; Fortea et al., 1987; Zilhao, 1993; Vicent, 1997).

According to the sequences of *Cova de l'Or* (Beniarrés) and *Cova de les Cendres* (Teulada-Moraira) , the Early Neolithic chronology is between 6.800 and 5.800 BP. The levels of La Falguera, in the valley of *Polop*, belongs to these period, following the preceramic levels of the Geometric Mesolithic.

The Middle Neolithic (5.800-4.800 BP) has been identified in the stratigraphies of *Cova de les Cendres, Cova de la Falguera* and *Cova de Santa Mayra* (Castells de Castells, Alicante). Even so, the available information about this period is limited.

There is more information about the *Late Neolithic*. Recent research, including excavations of settlements and caves, provide a wider view of deposition, living and social organization patterns of these groups (Bernabeu et al., 1993; Bernabeu et al., 1994).

The first aspect of these sites suggests an habitation in the valley watersheds. Habitat was organized in to large settlements (ca. 10-14 ha) but actually made up of widely spread domestic structures surrounded by ditches (Bernabeu et al., 1993 and 1994). The necropolis consist of collective burials in caves and shelters around the settlements.

Living is still based on farming and stockbreeding, but several changes in the exploitation of these resources can be observed. The analysis of the sacrifice patterns suggests a better use of secondary products.

Some changes pointing to a new model of settlement in the Bronze Age (3.800-3.200 BP) have been detected along the Bell Beaker (HCT: 4.200-3.800 BP). Metallurgy appears for the first time; previous settlements located in lower lands tend to disappear; individual burials in graves within the habitat appear. A restructuring of the territory into a set of hilltop or mountain-slope settlements can be made out. Inversions in the communal structure appear at this time; terraces or walls become common which imply a new type of social organization, the complexity of which is now being debated (Jover, López, 1995; Fernández, 1993).

3. Methodology

Our project was designed according to the fore mentioned objectives; we followed a strategy of survey and analysis that was not focused on settlements, but rather on stratified sampling units. Environments (*Areas*) with different characteristics were selected from all of the valleys along the river *Alcoi*. Each area was then subdivided into *Sectors* and *Subsectors*.

We used topographic maps (1:10.000 scale) to delimit sectors: gullies, tracks and roads served as the limits, but we always tried to represent the diversity of the geomorphological regions in our final results. Aerial photography (1:9.000) was used to delimit subsectors, the limits of which were forced to match up with farming terraces. Consequently, subsectors have different areas. In this way, each survey unit could be characterized by a three digit code: Area, Sector and Subsector.

3.1. Sampling system and strategy.

The existence of different environments was taken into account in designing the survey in both valleys. Thus, 4 regions were defined in *Polop*, on the basis of their situation relative to the main fluvial stream (North-South) and their altitude. These four regions were called Upper North (UN), Lower North (LN), Lower South (LS) and Upper South (US). Each of them was subdivided into sectors and subsectors, which are the smallest survey units.

Two regions were defined in the valley of *Penàguila*, on the basis of their altitude, and the following steps were the same as in the case of *Polop*. The identification of materials is simpler here: BP-2-4 means the valley of *Penàguila* (BP), *Sector* and *Subsector*. Table 2 shows the results of this design.

Several descriptive sections were included in the field card, the concerned location, geomorphological features, visibility, land-use and finds, with simply a presence/absence recording of basic categories e.g., lithics, polished stone, ceramics (handmade or wheeled) and structures.

3.2 Analysis techniques. Flint and pottery

Material remains collected during field work were carefully analysed in the laboratory, the data of which were saved in a database. The data were then statistically processed using SPSS 6.1 program. In both cases, the results were exported to MapInfo (a GIS program) for later processing.

Flint and pottery were assigned several common descriptive method: place where they were found-subsector-; material state of remains: *rodado* (smooth) for flint, and *erosionado* (eroded) for pottery; total amount of objects with identical characteristics; number of times the site has been visited.

Regarding flint, *rodado* (ROD) variable takes into account the presence of ridges -not edges- , blunt-like or not; on the other hand, the existence or absence of a edge damage have also been considered: irregular flakes in the edges and the amount of them (Mec1=no signs; Mec2; 25% edges; Mec3=>25%). In ceramics, only the first of these fields regarding the state of the surface has been taken into account (*erosionado*, EROS).

The next step in flint was the technological classification of the remains (flakes, blades, cores, etc). Morphological rather than metrical criteria have been considered in discriminating laminar products (blades and bladelets), i.e. more or less parallel edges that bear witness to their extraction from a laminar core.

Different fields (*size, cortex, heel*) give a detailed description of the categories above. *Section* (trapezoidal, triangular or irregular) and *dimensions* (if they are complete) fields are added when considering blades and bladelets.

Typological description comes after classification and technological description, once pieces with edge damage have been discriminated.

The ceramics description includes fields for the morphological classification (rim, neck, decoration) besides the already mentioned fields.

4. Taphonomy.

The variability observed in the densities of both lithics and ceramics (we are considering only prehistoric pottery here) is surprising.

One outstanding finding from *Polop* is the low frequency of ceramic objects (275 fragments) compared to lithic objects: 2676 cut lithic remains. In *Penáguila*, on the contrary, ceramic frequency (2066 evidences) are roughly equivalent to that of flint (2658 evidences). Nevertheless, standard deviations clearly show a significantly varied density in both collections. The resulting pattern is characterized by a huge dispersion of material throughout the surveyed zones (Fig. 3; Table 3).

The form and distribution of surface collections may be understood as a consequence of prehistoric activity, but the picture may also be result of other factors. This raises two questions in regards to an understanding of prehistoric behavior:

a) Is the variability of the sampling significantly influenced by the observation (collecting) condition?

Observed densities may no doubt depend on both observation condition and prehistoric activity (Nance, 1994). Some experiencies (Terranato, Ammerman, 1996) show that visibility (obscured by such things as vegetation) has a significant influence on the density of sites in a Km2. In our case, we had to redesign the analysis, as the analysis was based on a strategy of arbitrary survey units.

Some factors, (e.g. the vegetation layer, the time of the day when the survey was carried out, the seasonal effects of farming and rainfall, as well as erosion and redeposition of the geomorphological processes) played a more or less important role in the variability of the observed densities.

Some of these variables were registered during field work allowing different subsectors to be divided into three categories, according to surface visibility conditions (vegetation, farming and rainfall). Thus, a subsector with little or no surface vegetation which had been recently ploughed, and or surveyed a few days after rainfall, would have the highest visibility; on the contrary, the barren survey units, with plentiful and tall vegetation, would have a low degree of visibility.

On the basis of these groups, and considering separately lithics and ceramics density, Student T test was done to compare the average density of each group. Analysis were done in two levels: a) subsectors with remains; b) all subsectors (table 4).

The test shows some significant differences. For instance, differences in subsectors with some remains are significant ($p<0,05$) in ceramics and among those subsectors with middle or low visibility; if all subsectors are considered, differences between those with low visibility and the rest are significant. However, a different behavior between ceramics and flint was seen: average densities of ceramics were lower between V1-V2 than between V1-V3. Consequently, the following conclusions can be drawn:

- There is not a clear connection between an increase in visibility and higher average artifact density. For such a connection to exist, there should be an increase of average density between V2 and V3, but this is not the case.
- Yet, it is obvious that those subsectors with the lowest visibility have the lowest average densities, particularly in ceramics. This is because the subsectors with no remains are more significant in this group, as Table 5 shows.

It is not easy to understand this phenomenon since the absence of remains associated with subsectors with low visibility may be a consequence of both the field condition and the actual present or absence of remains. It seems, therefore, advisable to use the information provided by subsectors with remains in the evaluation of differences in densities.

- On the basis of previous observations, we can state that the level of remain densities are only partly influenced by visibility. Other variables must have influenced our observations. Present density may have a significant bearing on, which would explain why materials are found even under low visibility conditions. Consequently, we can conclude that collecting conditions do not alter significantly the representative character of collected collections, that character being stronger, the more the low visibility subsectors are and the lower the present density of remains is. Visibility effects, then, will not distort significantly our analysis.

b) To what extent have postdepositional factors shaped the variability of our samples?

Even if our picture were to match with reality, the question as to what extent this reality matches prehistoric activities remains open. To answer this we must study not only the global structure of the sample, but also its differential distribution among the various survey units.

In order to evaluate the effects of these postdepositional factors (or at least some of them), different variables aimed at measuring the effect of these processes were quantified. Thus, variables such as Mec2, Mec3, undetermined fragments, or fractures (including flakes and fragmented blades) can be considered signs of tillage; variables such as ROD and EROS, on the other hand, seem to indicate natural processes.

Ceramic surface erosion proved useless, as most of the collected fragments, with no exception, had eroded surfaces. For this reason, we will focus exclusively on the lithic analysis (Table 6).

Processes that may have influenced the distribution and composition of surface collections were common in both valleys. For instance traditional ploughing, limited by farming terraces was one such processes. Both valleys seem to have been cultivated for thousands of years, though over varying periods of time. This activity, while uncovering buried materials, reduces the resolution of spatial distribution patterns.

Regarding this subject, the practice of making terraces seems to have had similar displacement consequences that predate the introduction of the plough. In this case, however, materials are not likely to travel long distances, and their diffusion falls quickly with time (Odell, Cowen, 1987; Cowen, Odell, 1990). Actually, experience suggest that once a given distance has been traveled, the possibility of objects either moving back or away from their original position is balanced (Ammerman, 1985).

Terracing implies moving the land from a higher level and redepositing it on lower terrace. This suggest that materials on the higher terraces should belong to buried materials, those in middle terraces, to the original surface level, and those in the lower area should be mixed. Apart from this, movement of material will always take place within the limits of the terrace. Traces of ploughing, either traditional or mechanical, will also be detected, due in part to mechanical action: such as fractured material, edge damage, and a higher level of undetermined pieces.

Erosion, and the subsequent redeposition of materials, work on a higher scale, that may have altered the original distribution of the remains through a displacement of sediments in some zones with sharp slopes. Marly soils have facilitated the movement of materials that erode and redeposit with time, though they never go long distances from their original position. It may even happen in terraced areas, if farming fields were left for a long time. Together with this phenomenon, incision of fluvial streams -a seemingly recent occurance- might have destroyed the record completely in several areas of the valley (Berbaneu et al. 1994: 10-11).

Given the homogeneity of postdepositional factors, comparing the variables from both collections (especially samples that describe the state of the collection best) is surprising.

Pieces that show a slight mechanical alteration (Mec2: ca. 60%) predominate in both collections. The proportion of undetermined fragments and those that are identifiable (flakes and blades/bladelets) is high, but diverse. As a whole, the results show a collection consistent with a surface in use from constant farming. It would be interesting to compare these results with the corresponding results of collections from settlements in order to evaluate the influence of these processes. To this end, we have begun to analyse a collection from the Neolithic settlement of *Niuet*. From its results we will be able to establish if the values observed in the categories of undetermined fragments and the identifiable fragments can be understood a result of this process itself.

The most significant differences between both collections refer to proportions in the variables Mec1 (pieces with no mechanical alteration), Mec3 (very altered), and smooth (with clear evidence of erosion in their edges). Mec3 and Smooth clearly show higher values in *Polop* than in BP. The reason of this differential behavior becomes clearer through a more detailed analysis of the distribution of smooth pieces and those which have not been altered by technological or typological categories (Fig. 4).

The distribution of rolled pieces in *Polop* indicates that they concentrate in categories thought to represent an older chronology (Levallois /discoid cores, Scrapers, end-Scrapers). The proportion of the most recent pieces (blade cores, backed tools, geometric tools, retouched blades/bladelets) are very low or do not exist at all. The situation is the same in the BP collection, though the size of the sample (50 rolled pieces) does not allow a similar detailed analysis.

Categories with no samples of mechanical action tend to concentrate on the most recent pieces in both cases. Some interesting conclusions can be drawn from these observations:

-Firstly, smooth pieces seem to be associated with their own original chronology. Size is not likely to be a variable worth considering, as the cores show: levallois, flakes and blades are nearly the same size, but they have different proportions of eroded or mechanically retouched pieces (Fig. 4, b).

- Secondly, we may assume that these pieces were originally located in sharply sloped areas and, consequently, more likely to have undergone the earlier mentioned eroding processes.

-As a consequence, when we interpret the results of land-use patterns, we must take in consideration that these pieces was found in lower levels, as part of more recent collections.

The surface collection chronology can provide additional information with which to check these assumptions.

5. Chronology of Surface Collections

As we said earlier, the difficulty in organizing a surface collections made up of prehistoric material into some kind of chronological order is possibly one of the reasons why systematic survey projects based on an off-site strategy have made little impact.

We approached this problem by devising a rank system where every subsector was given a probability of belonging to each chronological period. The rank was based on the presence/absence of particular archaeological artifacts.

5.1. Chronology, ranks, and probabilities

From the most characteristic elements, on diachronic level, we developed a chronological evaluation criterion for surface remains. Table 7 states explicitly the criteria used to assign the ranks according to periods. Once these criteria were applied, each subsector received an assigned probability of belonging to every chronological period.

We should stress that, as we move forward along the chronological scale, the resolving capacity of materials is higher, thus the highest ranks (5 and 6) have not the same defining difficulty in all the cases. A comparison of preceramic and ceramic periods for a rank =6 shows that the distinctive factor in the former is defined by the combination of various objects, as well as by the lack of other objects. In the ceramic levels , the presence of a particular remain is sometimes enough to consider the highest probability in assigning a given chronology.

On the other side, some subsectors were visited twice or three times in the intervening years as the field work was carried out. A previous analysis of the chronological ranks has shown that there may be significant differences, if all the available information (all the collected materials) is used between the original survey and the subsequent surveys. In order to minimize errors that may derive from this circumstance, we have used all the available information to assign chronological rank to each subsector; in later calculations, however, only the materials collected in the first field work were taken into account, which guarantees a uniformity in the analyzed sample.

Figure 5 shows the Total Occupied Area for each period in both valleys. Its values are the summed area (Km2) by chronological periods, considering three different degrees of probability.

Figure 5A shows the added values of ranks 3 to 6. Rank 3 is less demanding concerning presence, but as restrictive as ranks 5 and 6 concerning absences.

Figure 5B includes rank 4, whose characteristics are similar to rank 5, although less restrictive, as it demands no absences.

Figure 5C adds up ranks 5 and 6, i.e. the ranks most likely to belong to their respective chronological periods.

In spite of several variations, the essentials in both collections are kept regardless the value of the rank used to assign each subsector to a particular chronological period. The most remarkable effect of using progressively higher ranks is the reduction of the occupied area for each period, with not a significant change in the observed tendency.

By using all the rank=3 or higher implies an availability of larger samples that, however, do not have a high chronological resolution. Rank 4, which allows for the possibility that collections belong to several different periods, demands the combined presence of various items. That is why we will base our observations on subsectors with a rank>3. It means admitting that the Late Upper Paleolithic periods in both valleys, the Middle Neolithic in *Polop*, and the Late Mesolithic in *Penáguila* (BP) are not represented.

Differences between *Polop* and *Penáguila* are evident: while preceramic periods, particularly the Middle Paleolithic, in *Polop* provide the great part of the materials, these same periods are practically nonexistent in *Penáguila*, whose materials seem to be related to ceramic periods. It corroborates the first impressions after the taphonomic analysis. These impressions, however, may be deceptive. We need some quantification that associates in an unequivocal way the probability that smooth material belongs to the most ancient periods.

The **Local Density Index** (LDI) measures the density of finds that are likely to belong to a given period, i.e. according to their rank. Their values, besides being an indispensable element (see later) for the understanding of the occupation/exploitation patterns, can be used to check the assumption that rolled materials must be related, in most cases, to the oldest collections. Fig. 6 shows the correlation coefficients (Pearson's R) between the percentage of smooth material and the LDI for subsectors rank >3 within each period. The results corroborate the initial assumptions:

- The values in *Polop* are 0,8 or higher for MP, UP and bell beaker periods, but are only statistically significant ($p<0,05$ of getting similar values in a random series) for the first two periods.

In BP, this relation only appears for the Upper Paleolithic period (the Middle Paleolithic being poorly defined in BP, as we noted earlier)

The consequence is evident: research on the settlement patterns that concern the differential location of settlements can only be carried out with reference to the oldest collections (Middle Paleolithic and, to a lesser extent, Upper Paleolithic).

If, alternatively, we merely describe and interpret globally those characteristics that define the patterns of occupation/exploitation, the picture of the long term tendency will not be significantly distorted as a result of postdeposition alterations.

6. Lond-Use Dynamics: Descriptive Values

We use two related variables to describe the pattern and distribution of the surface collections: Frequency/Recurrence and Specialization/Diversification.

6.1. Frequency and Recurrence. Seize and Intensity of Occupation

While the calculation of occupational use area allows one to evaluate the importance of each chronological period to the collection as a whole, it may misleade if these values are used as the occupations **Frequency Index** (FI). We should note, for instance, that the Middle Paleolithic covers a longer period than all other periods as a whole. Consequently, if we want to get more accurate information about occupation frequency, we need an index that relates the occupied area to the temporal probability of its occupation. In our case, we divided the total extension by the number of millenia in each period, according to the following values: MP=40; UP=20; LUP=4, EM=2, LM=1,2; EN and MN=1; LN=0,6 and Bell Beaker (HCT)=0,4.

Similarly, the calculation of the occupied extension tends to minimize the actual differences between various occupation types. It is difficult to establish these types on the basis of surface collections, but material density can be used as an index to provide information about intensity (absolute values) and recurrence of occupation (repeated frequency of occupation at the same place).

This information can be obtained through the **Local Density Index** (LDI). LDI is found by multiplying the rank of a collection (subsector) by the density of its materials, differentiating between preceramic and ceramic periods. Finally, original values are transformed into Z values, so that they can be compared between different periods and to make their graphic processing on plans easier. Thus, every subsector will have two values: one reflecting the probability of belonging to a particular period (rank); the other trying to reflect the kind of occupation (LDI), which ranges from high to low density.

The **Intensive Occupation Area** is calculated from LDI values, as the sum per periods of the areas (km2) with rank >3 and LDI>1s. If, as it happens with extension, their values are measured according to the millenia each period covers, the resulting value may be understood as the **Recurrence Index** (RI) of the occupation, the higher RI, the higher LDI. This index, if combined with frequency, yields an interesting information to describe the trends in the regional occupation/exploitation.

6.2 Specialization and Diversification

Densities and their variation can also provide us with relative information regarding the degree of specialization/diversification in the exploitation of regional resources. However, it would be pretentious of us to insist that all possible activities could be understood from surface collections. Our only interest lies in having information available with which subsectors can be ordered based on their density and variation. This assumes that a set of activities, limited or large are properly reflected in the object density of subsectors.

We understand that the tendency for artifact density and artifact type variation (calculated as the Coefficient of Variation) with time reflects an increase in the kinds of activities and, consequently, an increase in the exploitation of resources. The average density and the Coefficient of Variation have been calculated from of all subsectors with a rank>3.

Differences in the exploitative specialization of resources can be considered at a spatial level. If we divide the calculation of the proportion Intensive Occupation Area and the Total Occupied Area for every period, we get a picture of the evolutionary trend (ELI: **Specialized Locational Index**). Clearly, the highest specialization will coincide with a value of 1, where all the occupied lands will have a LDI higher than 1. This value, however, must be compared with the Total Occupied Area, so that specialization can be compared with periods in which it shows lower values.

7. Land-Use Dynamics: Some Understandings

Charts in Figure 7 summarize the information about frequency/recurrence and specialization/diversification in both valleys (A, B, and C for *Polop*; D, E, F for BP). In order to compare average densities and their corresponding variation coefficients at different scales, the absolute values of the former (objects/Km^2) were divided by 10.000. The following conclusions can be drawn after the comparison:

7.1. Preceramic periods in *Polop* can be divided into two groups. In the early stages (Middle Paleolithic) a remarkable feature of the occupation and exploitation of resources is the sporadic though recurrent pattern of land-use. This pattern persists for the entire 40 000 years of the *Middle Palaeolithic*. The low frequency of occupation, together with the lower average density per period, and an average variability (VC=1) in the kinds of occupation, suggest a barely diversified pattern in the exploitation of resources. Nevertheless, there is no spatial correlation: a low proportion of intensive occupation causes a diversified spatial distribution (Fig. 8).

The change in tendency seems to appear in the Upper Paleolithic. Its characteristics are: a gradual increase in frequency, that despite recurrence is kept within moderate limits; a slight increase in the average density of artifacts per period (0,21-0,25 compared to 0,18 in the Middle Paleolithic) and a lower coefficient of variation quotient; a reduction of the total occupied area and an increase in the *ELI*, which moves into its highest values in the Early and Late Mesolithic periods (values for the Late Mesolithic should be considered carefully, as only one subsector has a rank=4).

Overall, activity was concentrated in very limited zones that were repeatedly visited, and a wider range of activities were carried out in these zones, as the increase in the average density shows. Outside these sites, the impact of the occupation/exploitation is very limited, and so low in intensity that very few areas from focal points (Figs. 8 and 9). When comparing this picture with that corresponding to the Middle Paleolithic, there is a remarkable reduction in occupational intensity and a lack of a low intensity evidence.

This is probably the result of a situation in which foragers often repeatedly visited the same places as part of a year round cycle. We are facing, then, an increase in diversification, both in the exploitation of resources, and in the location of settlements. There is not much evidence from the Early Neolithic, but it seems to suggest that the tendency did not change significantly from the previous model.

7.2. The dramatic change in the exploitation of resources and in the occupation patterns likely took place in *Polop* during the Late Neolithic. Frequency and recurrence of occupations change dramatically, as Fig. 7A shows. The increase of average density (the highest one in the valley) and the Coefficient of Variation clearly suggest a higher intensification and diversification; the low *Specialized Locational Index*, moreover, points to the existence of remarkable occupational diversity, places with a high level of activity, and other more marginal places all, within a context where the proportion of intensive occupation decreases in relation to the total occupied area, which increases in relation to the Early Neolithic.

This suggests a village farming organization, with a stable central occupation, where energy consuming activities were carried out, and the widest range of activities took place. Apart from it, other locations can be found, which are characterized by lower recurrence and diversity, or greater specialization. The map at the top of Fig. 10 shows this situation, with a set of subsectors that are located in the center of the valley, where most of the materials from the period are concentrated. With regards to this period, the HCT suggests a reduction of the occupied area and a clear tendency towards specialization (Figs. 7B and C).

7.3. Preceramic periods s in *Penàguila* (BP) are not that important (as, for instance, the small absolute extension ascribed to the Middle Paleolithic shows). The pattern of the periods (UP and EM) does not differ from that described in *Polop*.

The Early Neolithic, however, displays a similar pattern to that described for the Late Neolithic in *Polop* (Figs. 7D, E and F).

We are inclined to interpret this model as the consequence of a new village system inaugurated by Neolithic groups: radial exploitation focused on areas of highest resource density and diversity. This would produce a location pattern characterized by densely occupied central areas, surrounded by other less densely occupied areas. Other locations that reflect more sporadic or specialized occupations may exist in further out or alternatively, there may be new occupations derived from the segmentation of the original group.

Fig. 11 shows the distribution of the subsectors belonging to the Early Neolithic according to LDI values. The spatial organization described above can be clearly seen: a central core, (Sector BP-2; subsectors 4 and 6) where areas with the highest density concentrate, surrounded by others with a decreasing LDI. Another small core, made up of two subsectors further up the river courses (Sector BP-3), points the presence of one of these more specialized occupation points.

7.4. The expanding occupation of the valley, based on the same organizational pattern, reached its most important development in the Late Neolithic (Fig. 12). The densest occupation and greatest intensity of exploitation belong to this period, which shows an expansion of the settlement. Ironically, the next period, basically defined from denticulated sickle tools, has the opposite effect: the occupied area become smaller, and the average density and the variation coefficient dropped (Fig. 7 D and F). This tendency, in more pronounced way, can also be seen in *Polop*.

This process announces the characteristics of the Bronze Age, when occupations tend to be located on the highest levels in the valleys. A clear change in the farming system takes place at this time (ca. 3.800-3.200 BP): from a farming point of view, increasingly marginal areas were occupied and exploited after the introduction of the plough. From this perspective, we might understand a lack or a small presence of occupation from Bell Baker period and from the Bronze Age, the results of a farming exploitation directed from other sites was considered beyond the surveyed sectors: on the hilltops of the surrounding valleys (Bernabeu et al. 1989).

8. Discussion

The results of comparing two collections belonging to *Polop* and *Penàguila* river valleys have been presented in the sections above. Both collections were collected as part of a systematic survey project based on an off-site sampling and analysis strategy.

This kind of survey strategy is unusual in Spain, where locating settlements is the systematic survey project's starting point. In the course of our investigation we have learned that this methodological perspective did not fit the nature of the surface register, often characterized by a continuum of materials with varying densities. Using the settlement as a central focus has raised two serious problems:

- what densities should or should not be considered settlements,
- what densities should be disregarded in the analysis beyond the arbitrary limits imposed by the first problem.

The off-site survey strategy frees us from these problems and allows to examine all available information which we can use to enrich our understanding of region-wide occupation and resource exploitation strategies.

It is not our intention to outline alternative conclusions. Rather we have intended our conclusions to complement others reached by alternative survey techniques and excavation. Ultimately our conclusions will have to be compared against those from excavation. Some of the conclusions are worth discussing:

1. Toponomic analysis has shown that collections in a secondary position are more likely to be associated with older periods in both valleys. However, this does not apply to all subsectors, but it clearly limits

an approach where location is an important variable. Therefore, more detailed analysis of subsectors should be carried out, including variables, such as slope or present-potential erosion of floors.

All variables concerning the impact of constant farming on surface collections must be compared to collections from stratified contexts. Nevertheless, in order to explain the observed variability between *Polop* and *Penàguila* (i.e., the proportion of indeterminet fragments (much higher in *Polop*) and identifiable fragments higher in *Penàguila*) other variables will have to be studied. For instance, in *Polop*, the highest proportion of indeterminent fragments may be due to constant farming in places where raw material is located. In *Polop*, resources are plentiful and accessible through ploughing, which is not tha case in *Penàguila*. If this were true of *Penàguila*, this category might have been included in all the calculations that indicate use density.

2. Broadly speaking, understandings of regional occupation/exploitation patterns are mutually consistent. However, the different behavioral pattern revealed in Polop and Penàguila concerning the appearance of village organization (Recent Neolithic in *Polop*, and Early Neolithic in *Penàguila*) must be explained. The central feature of the debate about the transition to agriculture has been polarized between the so-called indigenous position (diffusion of information) and migration position (diffusion of population).

The dual model (Bernabeu, 1997) suggests that the neolithization process did not end with the assimilation of local Mesolithic groups, even in places where Mesolithic groups came in contact with expanding Neolithic groups. After the initial stages, the stabilization of an agricultural border (caused by ecological and social factors), gave rise to interaction where by Mesolithic groups experienced a neolithization process. A segregation between both communities, which keep different territories throughout the whole process, was the consequence of that situation. Different economic and cultural variables enable us to read this territorial segregation in the peninsular Mediterranean area.

This situation is likely to give a more accurate understanding of the observed pattern in *Polop* and *Penàguila*. Thus, settling of Neolithic groups in regions with favorable ecological conditions for the development of early farming systems (*Penàguila*) favors interaction processes with Mesolithic groups located in the border (*Polop*), that eventually will end up transforming. Along all this period, not only the use of economic resources, but also the territory occupation and exploitation patterns keep different between both groups, in spite of not being far away one from the other, as it happened in the case we discuss in this paper. The shelter of *La Falaguera*, with superimposed aceramic and ceramic levels, in the *Polop* valley is being excavated now, and the information to check this assumption will be provided by this excavation.

NOTLAR

1. Bell Beaker: pottery decoration.
2. Pflecha. Flint arrowheads
3. Hinv. Blades/bladelets with invasive retouch.
4. Labs. Enlarged rims associated with open shapes (plates).
5. Dhoz. Denticulated shickle blades.
6. G2. Geometric tools. Lunates or rectangles.
7. G1. Geometric tools. Trapezes or triangles.
8. Esgr. Curved pottery decoration.
9. Epi. Epicardial style. Pottery decoration: impressed and incised.
10. Card. Cardial. Shell impressed decoration on pottery.
11. Tldro. Bifacial drills.
12. Ehoz. Sickle blades.
13. Hret. Blades and bladelets with marginal retouch.
14. Blade tech: Blade technology (blades, cores)
15. M1. Microburins.
16. Dorso: backed blades or bladelets.
17. Trc.: Truncations
18. Rsp. End-scrapers
19. Blr. Burins.
20. Must.: Side-scrapers; levallois and musterian points.
21. MyD. Notches and denticulations (on flakes)
22. Flake tech. Flake technology: flakes, levallois-discoid cores.

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PERIOD	^{14}C BP	SITE
Middle Palolithic (MP)	80.000-39.000	Beneito Cave
		El Salt, Cave
Upper Paleolithic (UP)	35.000-14.000	Beneito
Late Upper Paleolithic (LUP)	14.000-10.000	Tossal de la Roca, Shelter
		Cendres, Cave
Early Mesolithic (EM)	10.000-8.000	
Late Mesolithic (LM)	8.000-6.800	La Falguera, Shelter
		Tossal de la Roca
Early Neolithic (EN)	6.800-5.800	Or, Cave
		La Falguera
		Cendres
Middle Neolithic (MN)	5.800-4.800	La Falguera
		Cendres
Late Neolithic (LR)	4.800-4.200	Les Jovades, Open air site
		Niuet, open air site
Bell Beaker (HCT)	4.200-3.800	Cendres
		Arenal, open air site

Table 1. Regional framework based upon stratified sites.

	POLOP	PENAGUILA (BP)
Total Area	6,37	8,09
Random	2,53 (39%)	1,56 (20%)
No Random	1,19 (18%)	0,56 (7%)
TOTAL	3,72 (57%)	2,12 (27%)

Table 2.The sq. Km and proportions of surveyed areas in Polop and Penàguila valleys.

	Lithics	Ceramics
POLOP	Average: 1132,5	Average: 198,5
	S. Deviation: 2974,8	S. Deviation: 1861
	Rank: 0-23968,6	Rank: 0-22969,9
PENÀGUILA (BP)	Average: 1342,6	Average: 1348,1
	S. Deviation: 4448,4	S. Deviation: 5009,1
	Rank: 0-49428,5	Rank: 0-57500

Table 3. Observed distribution on lithics and ceramics.

Visibility Groups	Sample 1	Average	Standar Deviation	T Test prob.	Sample 2	Average	Standar Deviation	T p
Ceramics								
V1	14	15,9	59,4	-3,11	47	4,7	32,4	-3,08
V2	27	3263,2	5416,8	<0,01	43	2049,1	4550,9	<0,01
V1	14	15,9237	59,4	-1,22	47	4,7	32,4	-2,79
V3	74	7,1	7197,8	0,22	106	1659,5	6100,9	<0,01
V2	27	3263,22	5282,5	0,58	43	2049,116	4550,9	0,43
V3	74	377,1	7197,8	0,56	106	59,5	6100,9	0,67
Lithics								
V1	14	923,3	1242,9	-1,2	47	275,1	786,6	-1,89
V2	27	4106,8	9806,6	0,23	43	2578,7	7972,9	0,07
V1	14	923,3	1242,9	-0,97	47	275,1	786,6	-3,18
V3	74	1883,2	3629,9	0,33	106	1314,6	3148,9	<0,01
V2	27	4106,81	9806,6	1,15	43	2578,7	7972,9	1,01
V3	74	883,2	3629,9	0,26	106	1314,6	3148,9	0,32

Table 4. The effect of visibility on the observed densities of lithics and ceramics in Penàguila valley. For comparative effects a T Test was calculated separatedly between Subsectors with finds (sample 1) and all Subsectors (Sample 2).

	V1	V2	V3	TOTAL
0	33 (70%)	16 (37%)	32 (30%)	81 (41%)
1	14 (59%)	27 (63%)	74 (70%)	115 (59%
TOTAL	47 (24%)	43 (22%)	106 (54%)	195

Table 5. Subsectors without (0) and with artifacts (1) by visibility groups: V1= poor; V2= middle V3= good

	Total	Smooth	Mec1	Mec2	Mec3	F.indet.	Fracturas
POLOP	2672	355 (0,12)	397 (0,15)	1590 (0,60)	685 (0,25)	1464 (0,55)	755 (0,28)
BP	2658	50 (0,02)	623 (0,23)	1696 (0,64)	339 (0,13)	967 (0,36)	1186 (0,44)

Table 6. Absolute values and proportions of the taphonomic variables in Polop and Penaguila (BP) collections.

	6	5	4	3	2	1	0
BELL BEAKER (HCT)	P: Bell Beaker.	P: Dhoz.	P: Pflecha	P: Hinv + Labs.	P: hinv or labs.	P:Lithics,pottery	
							A: Artifacts
LATE NEOLITHIC	P: Pflecha + Labs. + Hinv.	P: Pflecha + (Hinv or Labs)	P: Pflecha or hinv or Labs	P: Blade Tech. + (hret, tldro, ehoz, Cerámica or G1)	P:Blade tech+ (Hret, Tldro,ehoz,Pottery, or G1)	P:Lithics,pottery	
	A: Bell Beaker, Dhoz	A: Bell Beaker, Dhoz		A: Bell Beaker, Dhoz,Esgr,Card			A: Artifacts
MIDDLE NEOLITHIC	P: Esgr.	P: (Hinv or G2) + (Epi or Peina)	P: (Hinv or G2)+ (Epi or Peina)	P: Blade tech..+ (hret, ehoz,Pottery, o G1)	P: Blade tech. + (Hret, Tldro, ehoz, Pottery o G1)	P:Lithics,pottery	
		A: Bell Beaker, dhoz, pflecha		A: Bell Beaker, Dhoz,Pflecha, Card.			A: Artifacts
EARLY NEOLITHIC	P: Card.	P: Epi+ (G1 or Trc); (Hret, Tldro or ehoz) + (G1 or Trc) + pottery	P: Epi+ (G1 or Trc); (Hret, Tldro or ehoz) + (G1 or Trc)+ Pottery	P: Blade tech + (Tldro,Hret, ehoz, Pottery, or G1)	P: Blade tech. + (Tldro, Hret, ehoz, Pottery or G1)	P:Lithics,pottery	
		A: Campaniforme, Pflecha, Esgr, Dhoz.		A: Campaniforme, Pflecha,Esgr,Dhoz.			A: Artifacts
LATE MESOLITHIC	P: (G1 o M1) + dorso + (Rsp or Trc)	P: (G1 o M1) + Rsp + (Dorso or Trc)	P: (G1 o M1) + rsp + (Dorso or Trc)	P: Blade Tech.+ (G1, Trc or Rsp)	P: Blade tech.+ (G1,Trc or Rsp)	P:Lithics	
	A: Pottery, G2, hoz, Pflecha	A: Pottery, G2, hoz, Pflecha		A: Pottery, G2, hoz, Pflecha			A: Lithics
EARLY MESOLITHIC	P: Dorso + Rsp + myd.	P: (Dorso o Rsp) + MyD.	P: (Dorso or Rsp) + MyD.	P: Blade tech or . Rsp o Dorso	P: Blade tech. or Rsp or Dorso.	P:Lithics	
	A:G1,G2, Hoz, Tldro, Pottery, Pflecha	A:G1,G2,hoz, Tldro, Pottery, Pflecha		A:G1,G2,hoz, Tldro, Pottery, Pflecha			A: Lithics
LATE UPPER PALEOLITHIC	P: Rsp + Brl + Dorso	P: Dorso+ (Brl. or Rsp)	P: Dorso + (Brl. or Rsp.)	P: Blade tech. Or Rsp, Brl o Dorso	P: Blade tech. or Rsp, Brl or dorso	P:Lithics	
	A:G1,G2,hoz,Tldro, Pottery, Pflecha	A:G1,G2,hoz, Tldro, Pottery, Pflecha		A:G1,G2,hoz, Tldro, Pottery, Pflecha			A: Lithics
UPPER PALEOLITHIC	P: Blade tech. + Rsp+ Brl	P: Blade tech + (Rsp or Brl)	P: Blade tech. + (Rsp or Brl)	P: Blade tech or Rsp or Brl	P: Blade tech or Rsp or Brl	P:Lithics	
	A:G1,G2, hoz,Tldro, Pottery	A:G1,G2, hoz,Tldro, pottery		A:G1,G2, hoz,Tldro, Pottery			A: Lithics
MIDDLE PALEOLITHIC	P: Flake tech + MyD + Must.	P:Flake tech. + (Must. or myd)		P:Tec Lascas + (Must or myd)	P: Flake tech. or Must.	P: Flake tech. or Must.	P:Lithics
	A:Pottery, Blade tech., . Pflecha	A:Pottery, Blade tech, Pflecha.		A:Pottery, Blade tech, Pflecha.			A: Lithics

Table 7. Chronological periods and associated ranks. P= Presence; A= Absence.

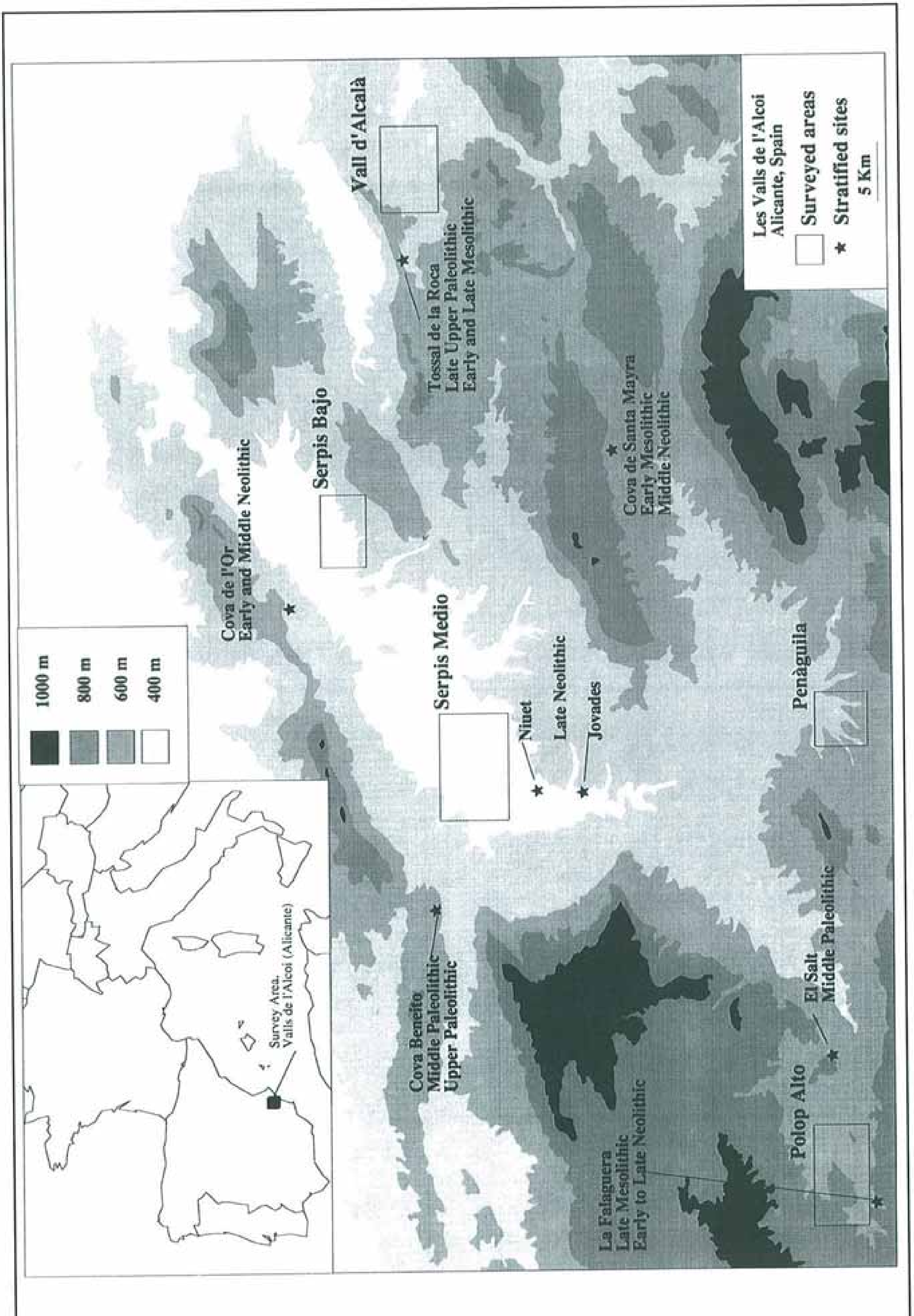


Figure 1: Survey area project.

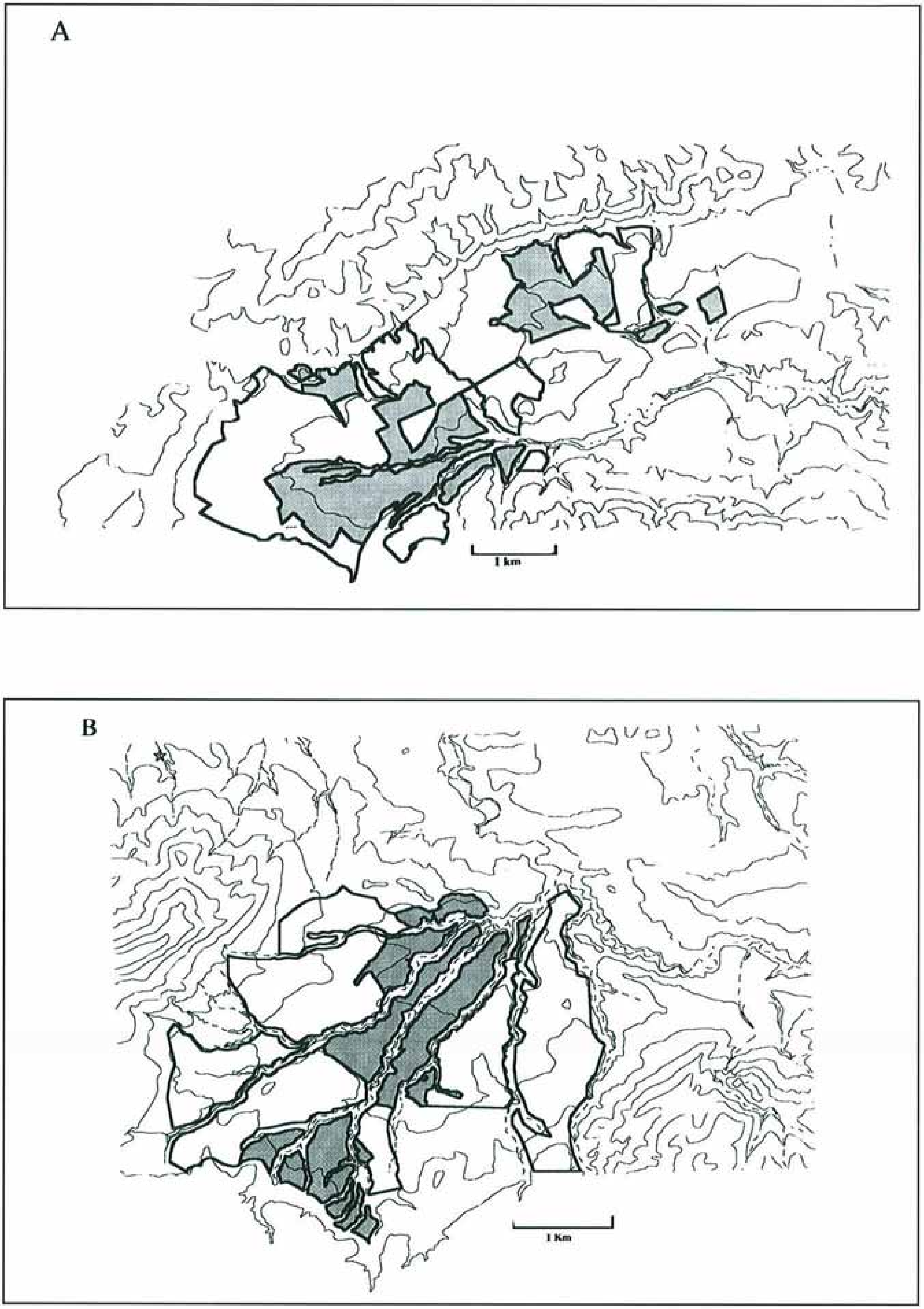


Figure 2: Polop (A) and Penáguila (B) valleys. Surveyed sectorsin grey.

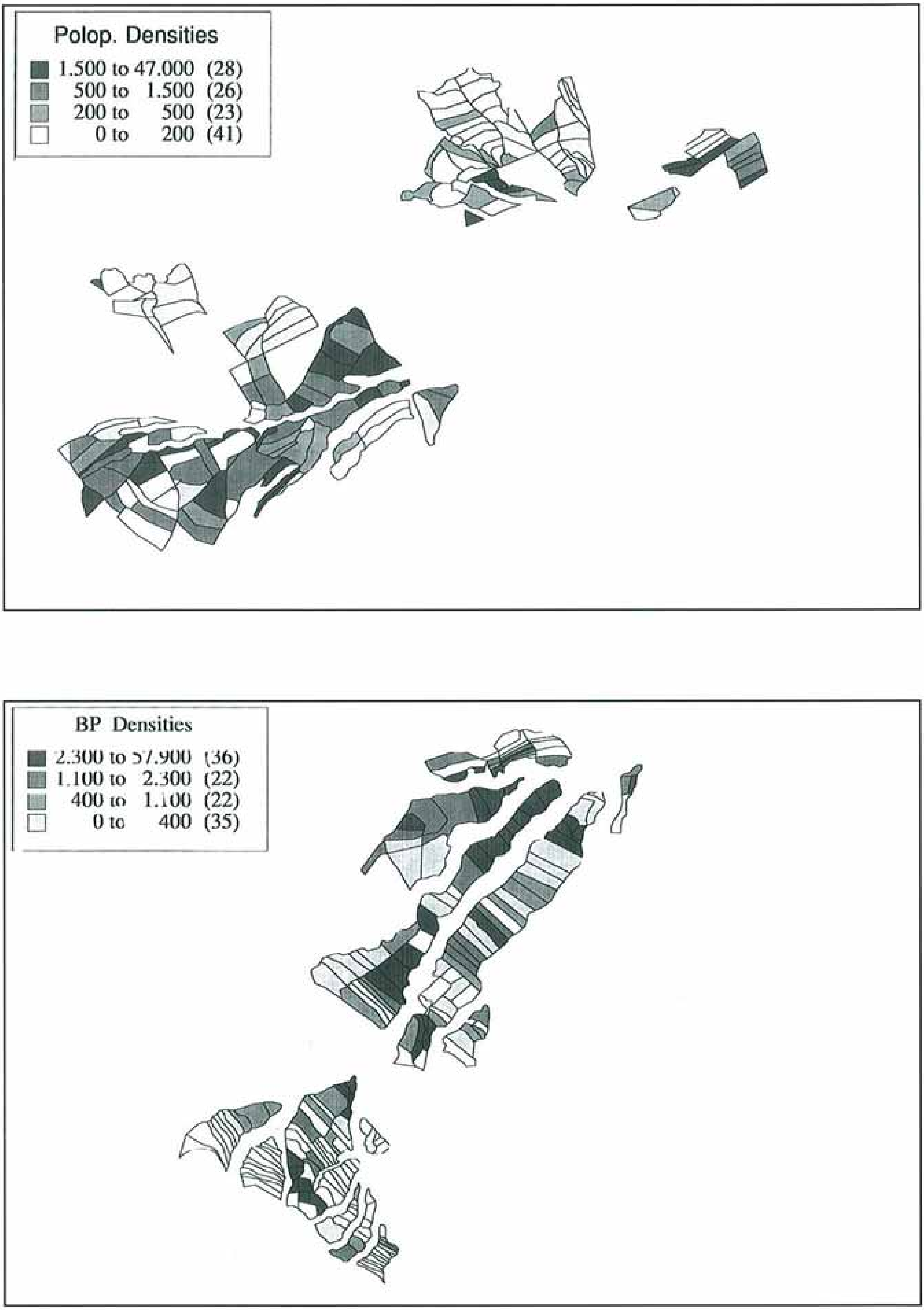
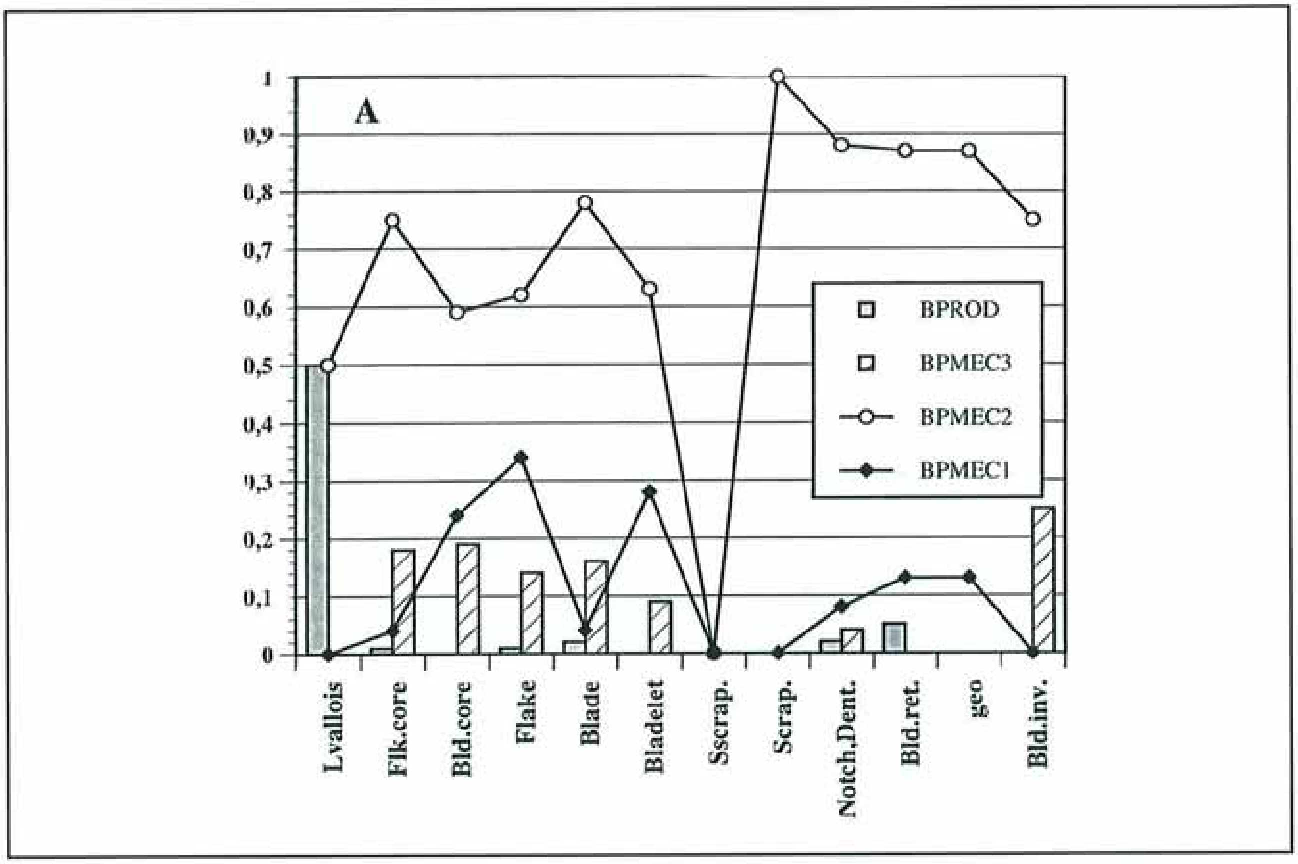


Figure 3: Subsectors by densities in Polop and Penáguila (BP) valleys.



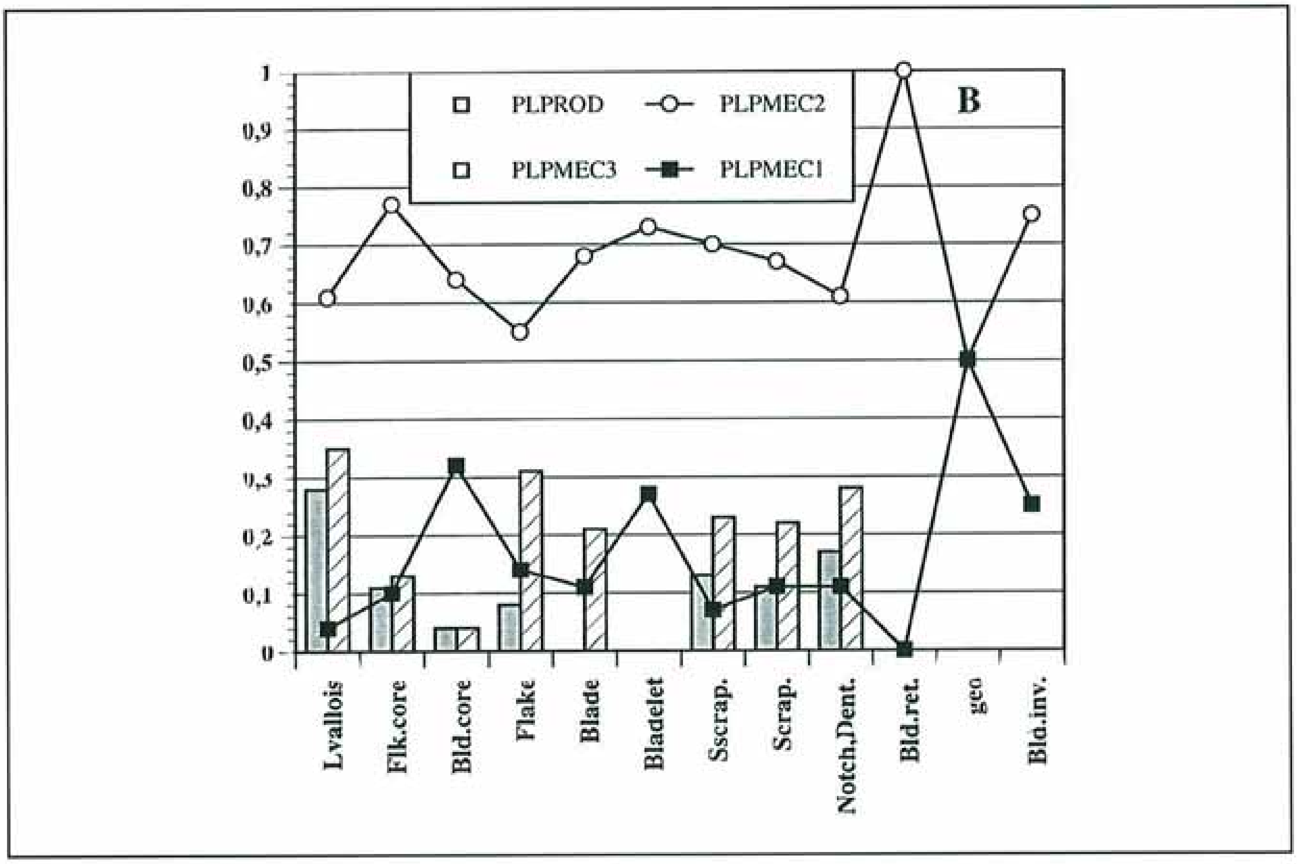


Figure 4: Smouth ridges (ROD) and edge damage (MEC) by technological and typological categories in BP (A) and Polop (B).

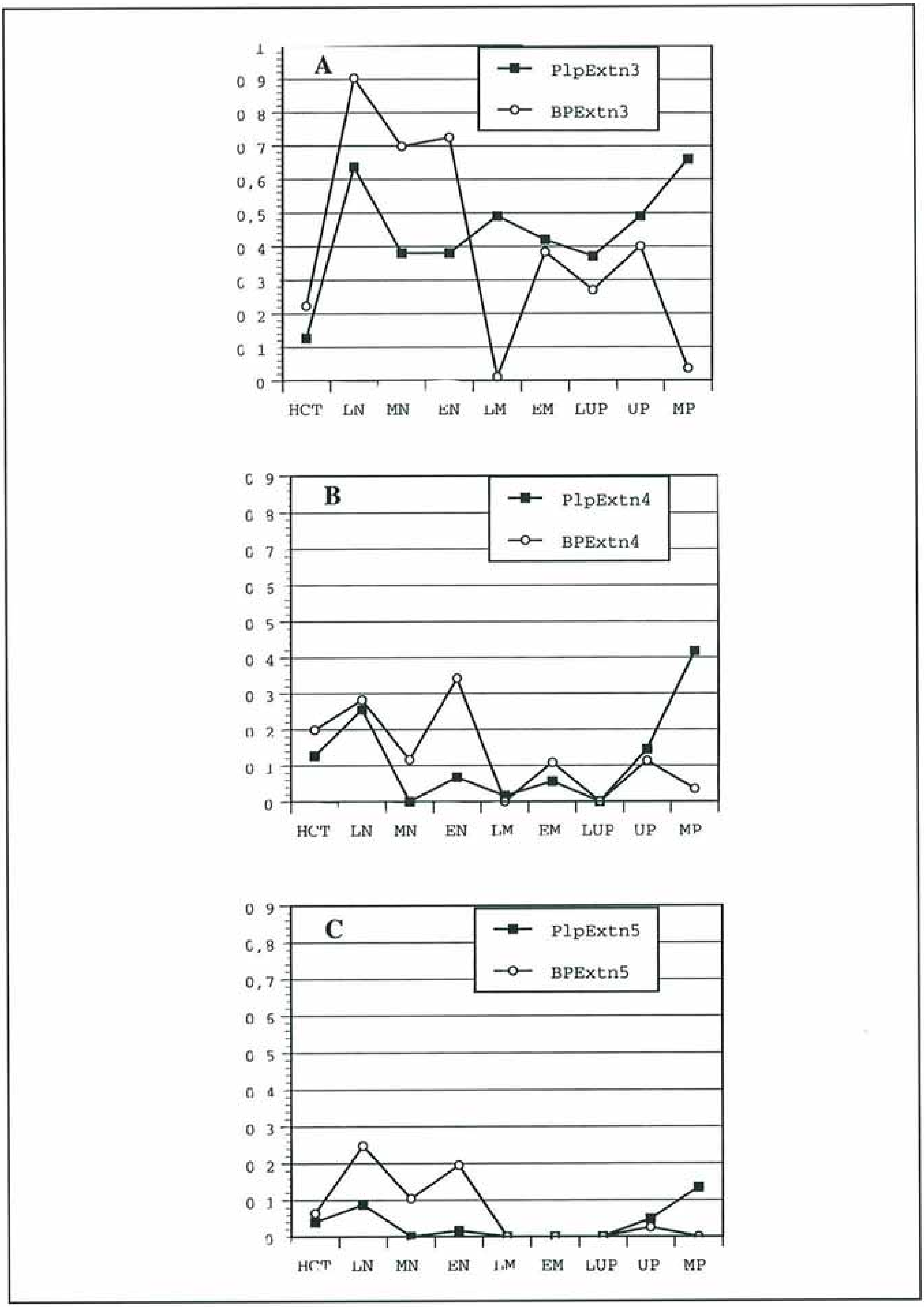


Figure 5: Summed areas by period of Polop (Plp) and Penáguila (BP) using subsectors with rank>3 (A), rank>4 (B) or rank>5 (C).

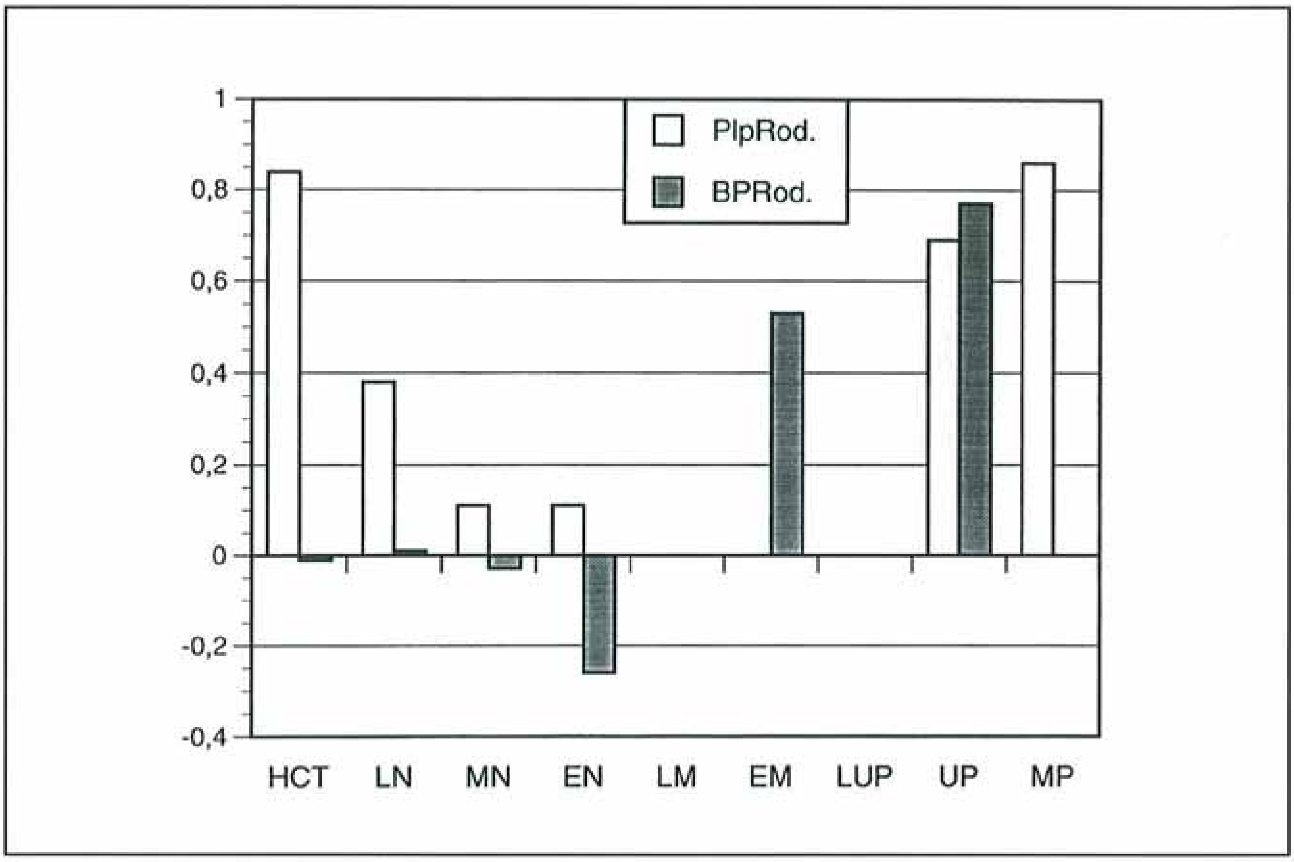


Figure 6: Correlation coefficients between smooth ridges and chronological periods in Polop (PlpRod) and Penáguila (BPRod)

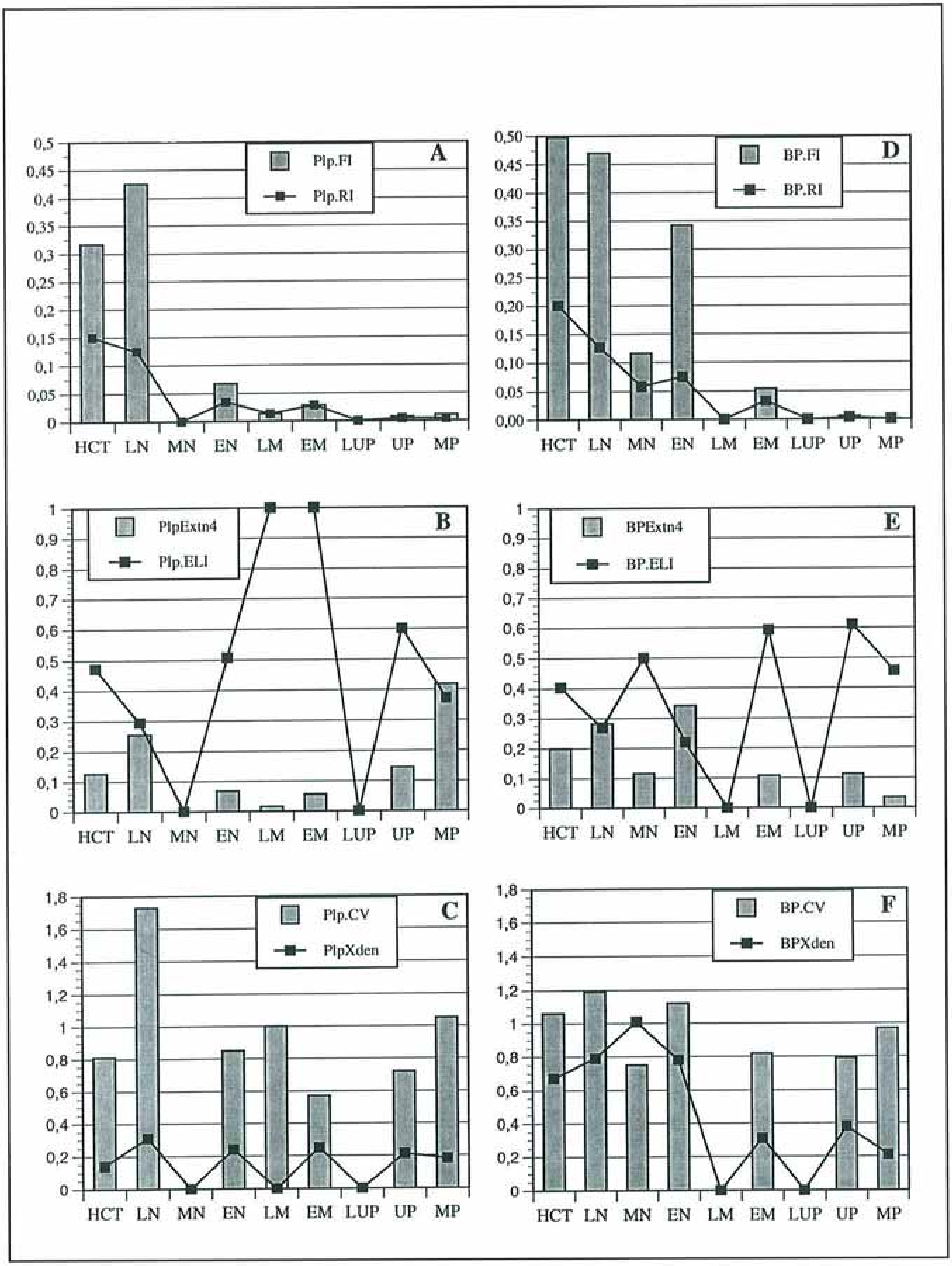
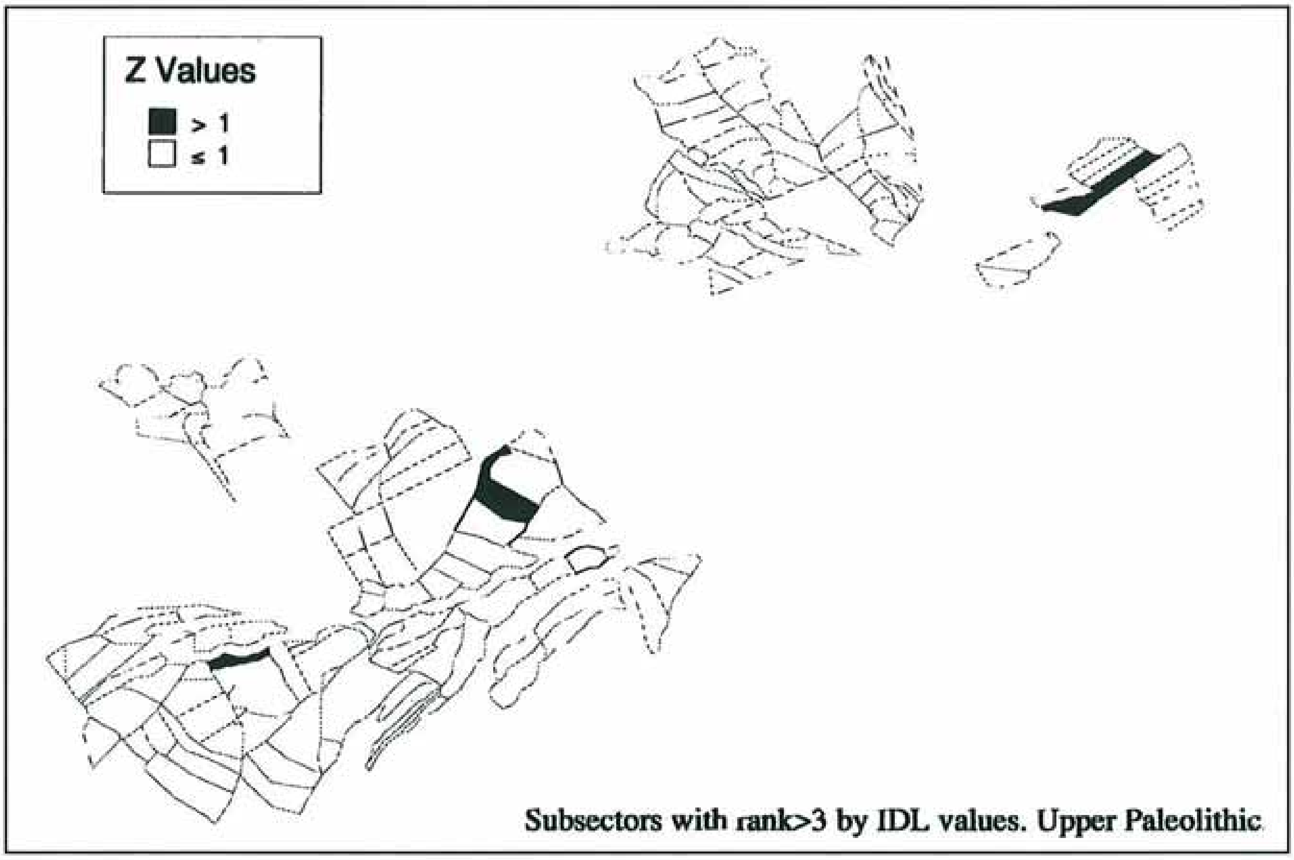


Figure 7: Comparative values of different indexes from collections of Polop (Plp) and Penáguila (BP). See text (points 5 and 6) for explanation. FI= Frecuence Index; RI= Recurrence Index; Extnt= Total Occupied Area; ELI= Especialized Locational Index; CV= Coefficient of Variability; Xden= mean of artifact density.



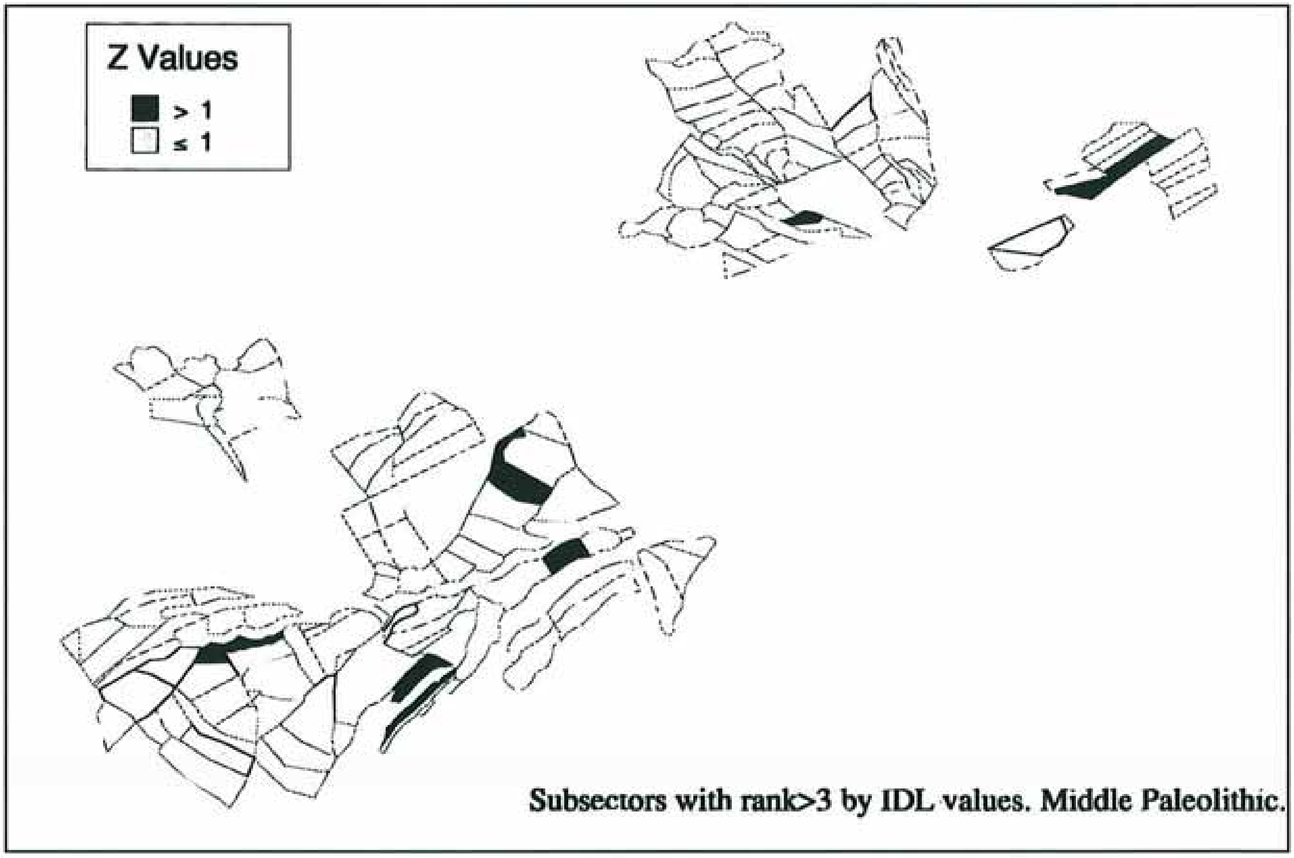
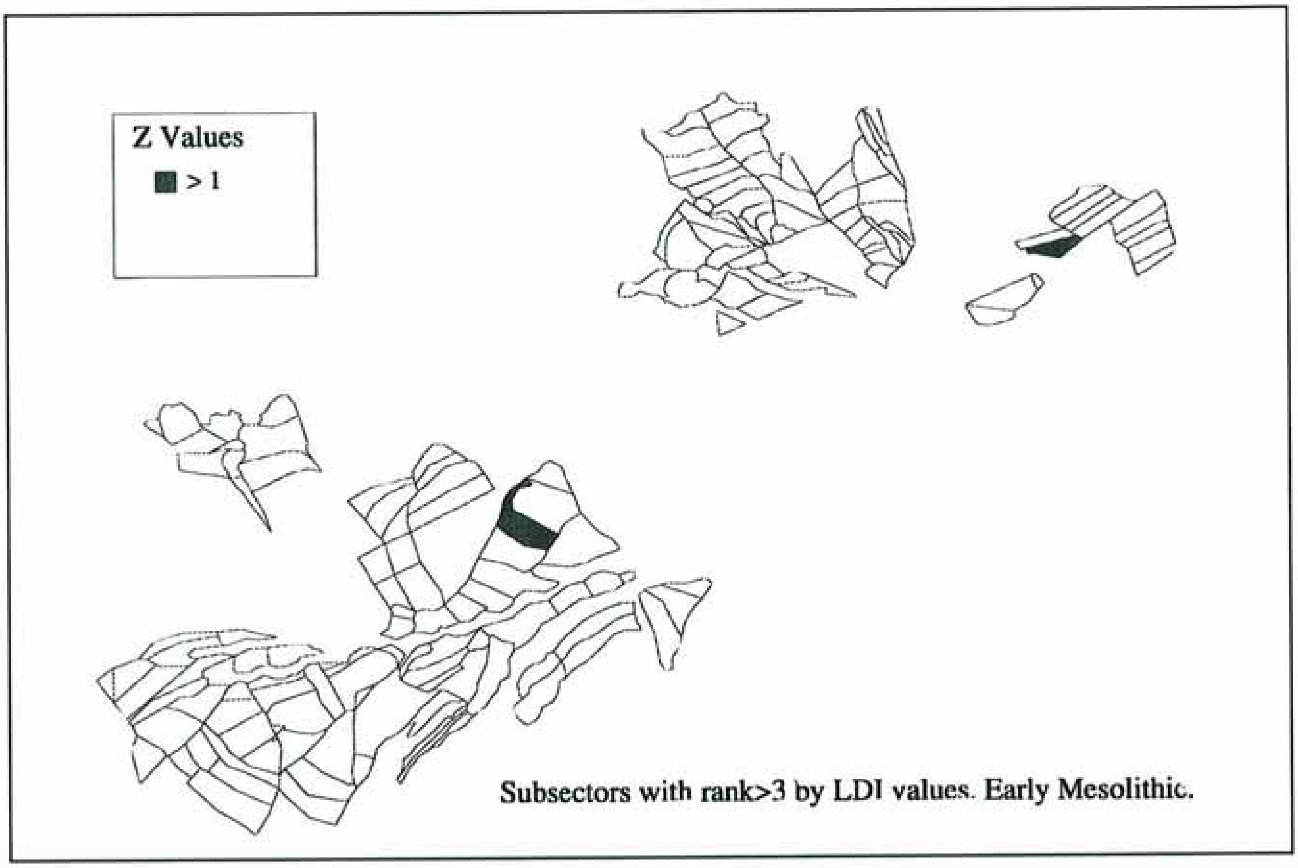


Figure 8: Polop valley.



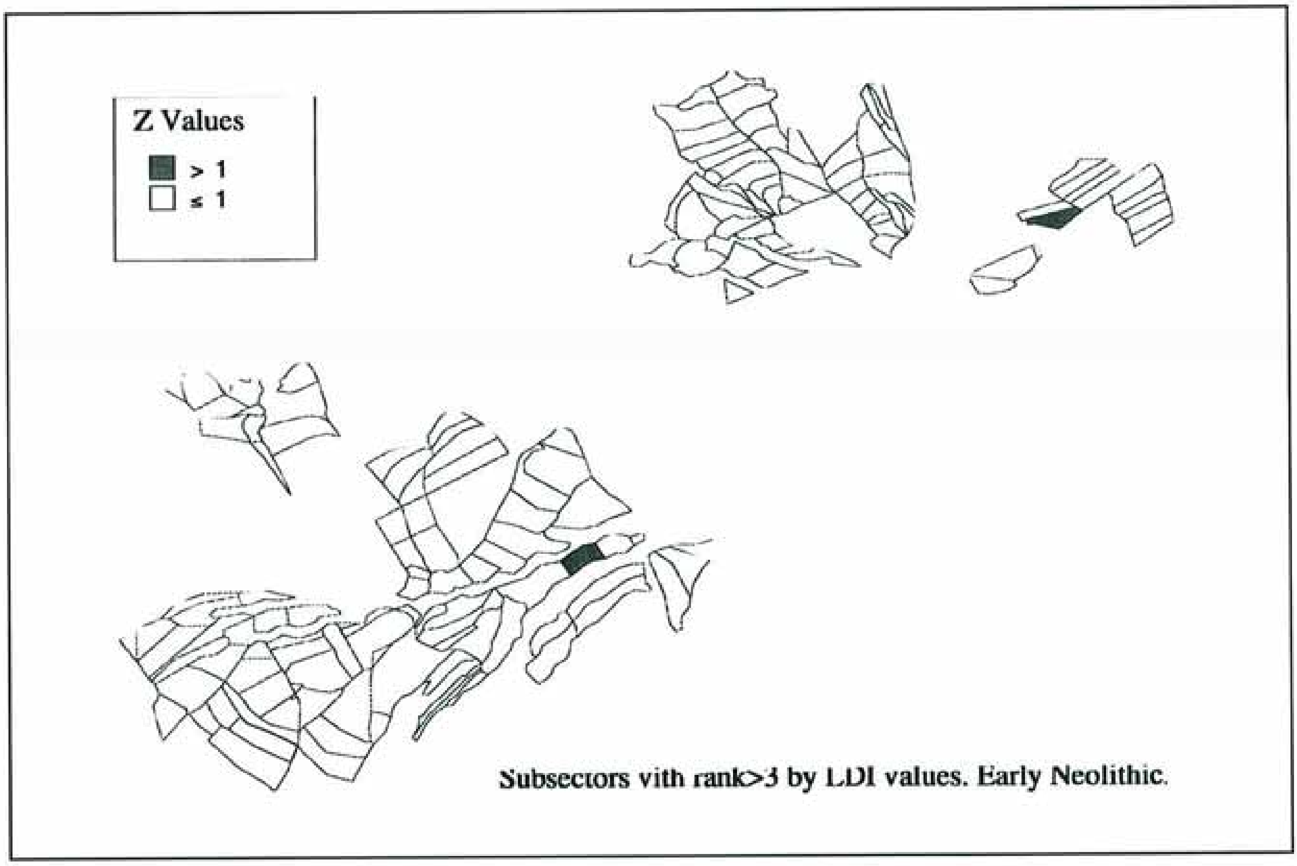


Figure 9: Polop valley.

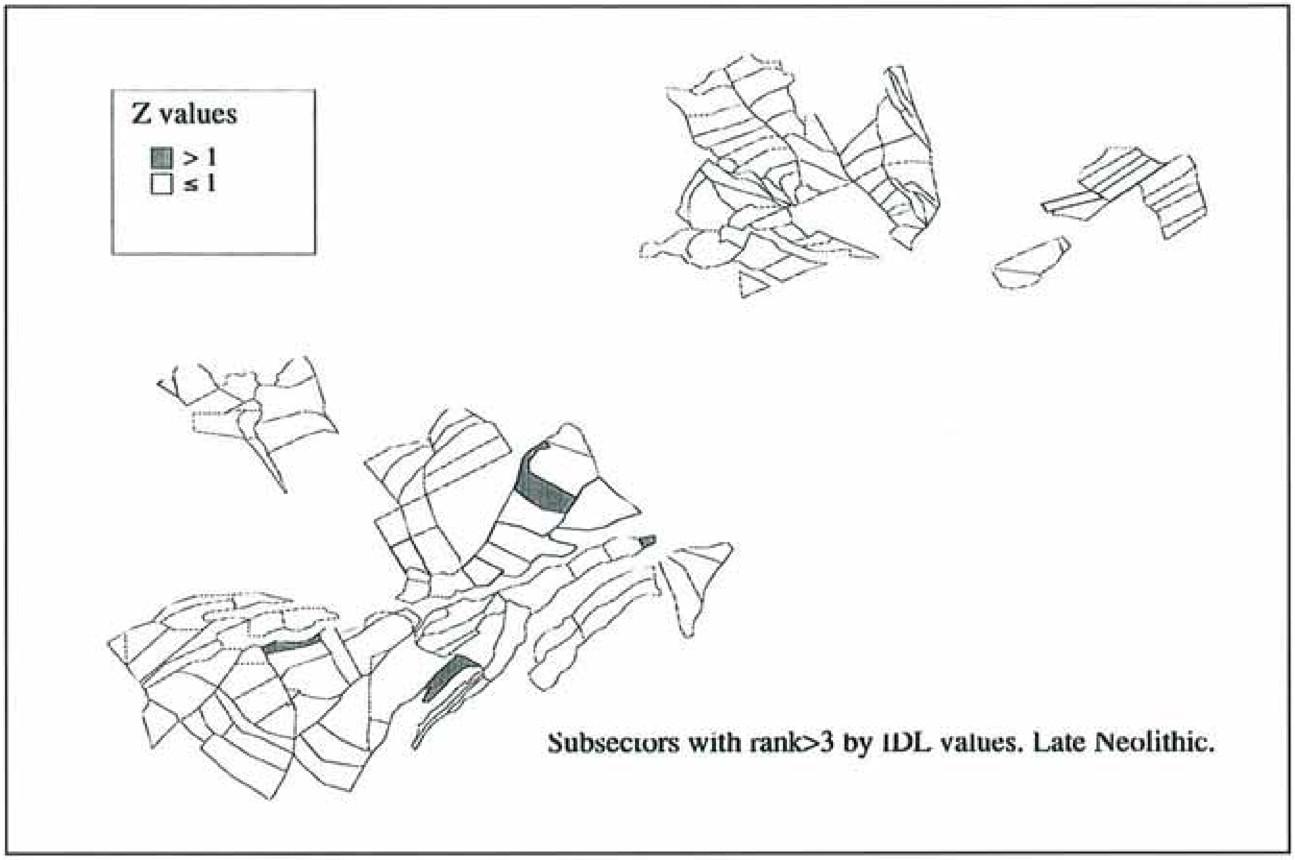
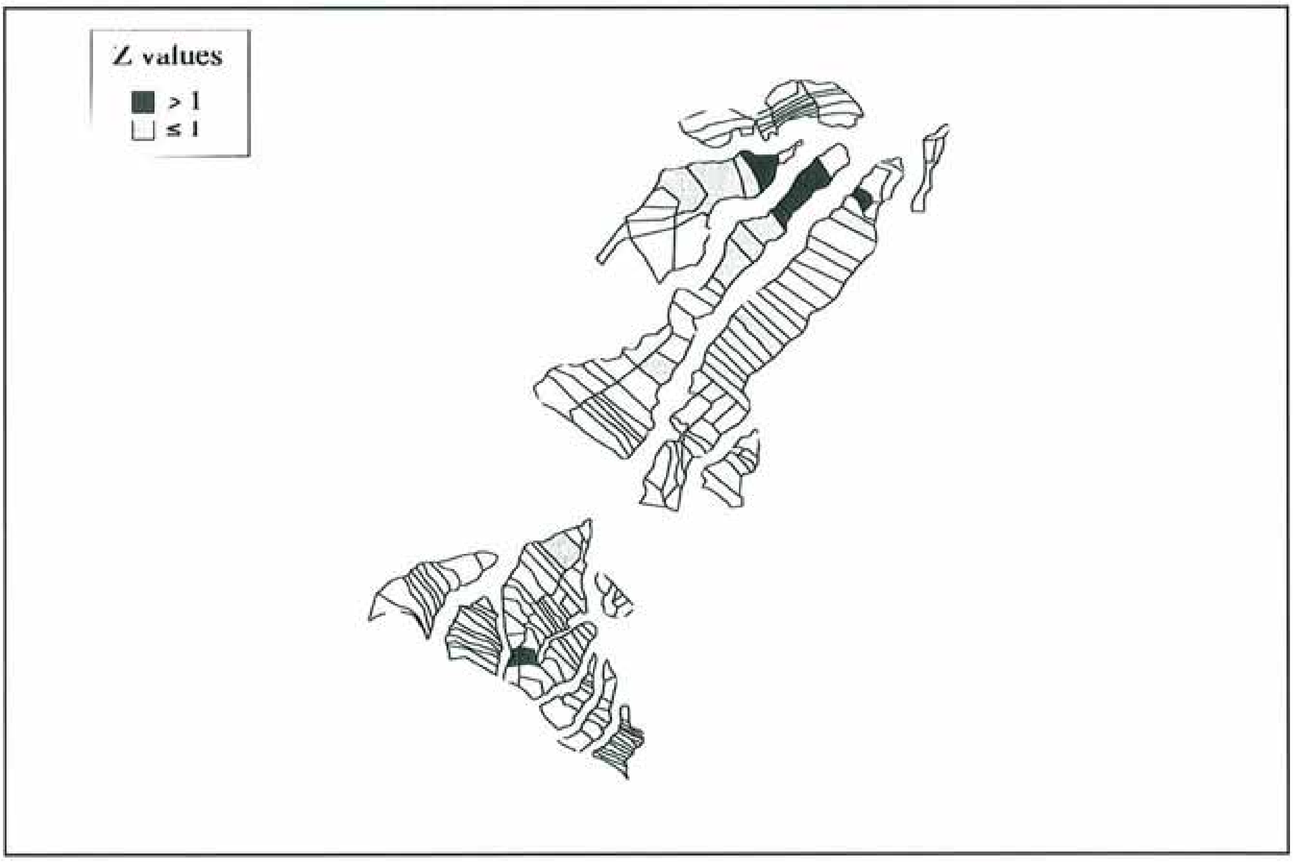
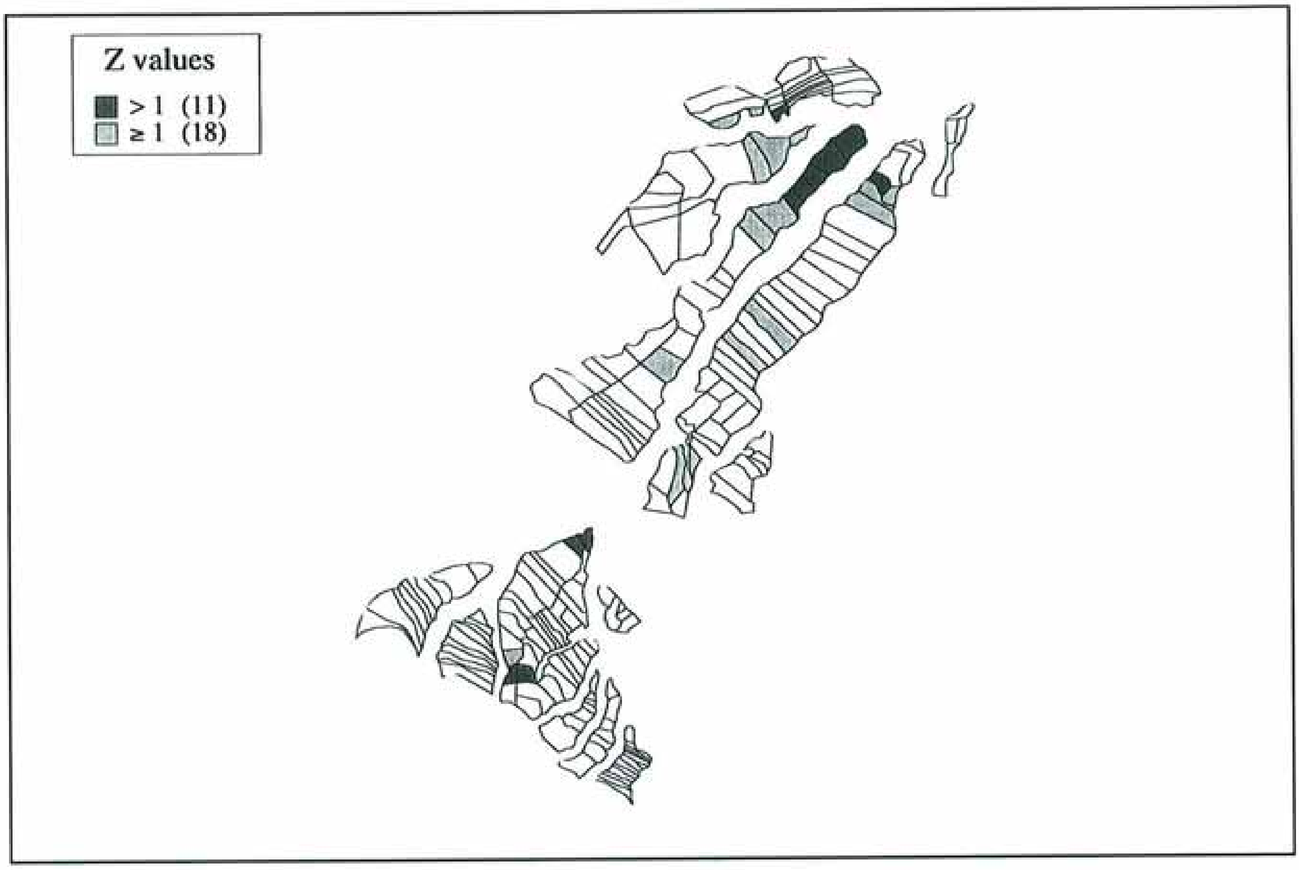


Figure 10: Polop valley.



Figür 11: Penáguila valley. Subsectors with rank>3 by LDI values. Early Neolithic.



Figür 12: Penáguila valley. Subsectors with rank>3 by LDI values. Late Neolithic.

A Large-Scale Geophysical Prospection in Acemhöyük, the site of the Assyrian Trade Colony Period

Asur Ticaret Kolonileri Yerleşmesi Acemhöyük'te Uygulanan Geniş Ölçekli Jeofizik Aramalar

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Keywords: Acemhöyük, archaeogeophysics, magnetic, resistivity, self potential
Anahtar Sözcükler: Acemhöyük, arkeojeofizik, manyetik, özdirenç, doğal gerilim,

Bu yazı Orta Anadolu'da bulunan ve Asur Ticaret Kolonileri dönemine tarihlenen Acemhöyük'te uygulanan geniş ölçekli jeofizik çalışmaları ve sonuçlarını içermektedir. Asur Ticaret Koloni Çağı sürecinde Orta Anadolu ticaret, sanat ve kültür bakımından üstün düzeydeydi. Böylece ticaretin atılımıyla bölgedeki kentsel gelişim de hızlanmıştır. 1960'lı yıllardan beri süren kazılar Acemhöyüğün Asur Ticaret Kolonileri Çağında (M.Ö. 1900 - 1800) çok önemli bir merkez olduğunu göstermektedir. Bununla birlikte kent M.Ö. 1789± 50'de bilinmeyen bir nedenle tümüyle yanıp tahrip olmuştur. Böylece 3. kat olarak tanımlanan bu kültür evresi diğer katmanlarla karşılaştırıldığında farklı bir fiziksel özelliğe sahiptir ve jeofizik anomali oluşumu açısından da önemli bir katman durumundadır. 3. kat yapı birimleri ve onların diğer mimari yapı katlarıyla olan ilişkisini saptamak amacıyla, geniş ölçekli jeofizik çalışmalar gerçekleştirilmiştir. Bu araştırmalar sırasında özdirenç, manyetik ve doğal gerilim yöntemleri uygulanmıştır. Çalışmaların başlangıcında ölçümler, arkeolojik özellikleri iyi bilinen Asur Ticaret Kolonileri Çağıyla ilişkili Hatipler Sarayının kuzeyinde bazı jeofiziksel test profilleri alarak yapılmıştır. Ölçümler, yanık arkeolojik yapılar ve nesnelerin seçilen jeofizik yöntemlerle saptanabileceğini göstermiştir. Acemhöyük kazı alanında yürütülen jeofizik çalışmalar höyüğün arkeolojik yerleşimleri üzerinde önemli jeofizik anomaliler oluşturan bir katmanın varlığını göstermiş ve yerleşmenin özelliğine uygun olarak seçilecek jeofizik yöntemlerle arkeolojik kalıntı ve yapıların belirlenebileceğini göstermiştir. Jeofizik araştırmalar sonucunda yerleşmenin iki değişik bölgesinde kazılar yapılmış ve jeofizik veriyle uygun bazı sonuçlar alınmıştır. Kazı sonuçları, alanda yanık durumda bulunan 3. yapı katının jeofizik yöntemlerle belirlenerek bulunduğunu ortaya koymuştur.

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Introduction

Archaeological sites have long been investigated by geophysical methods. However, large-scale implementation of geophysical methods has only been practised in the last decade. Since then, recent technological improvements in the fields of geophysical instrumentation and computer technology have enabled archaeologist to quickly collect and exploit data from archaeological sites. It has become possible to explore on map archaeological locations in more detailed ways with new geophysical methods, thanks to the rapid development of signal and image processing techniques in the past decade. Even non specialists can interpret the data collected from the archaeological sites once the data have been processed. Thus, within the context of archaeometrical studies interest in geophysical prospection has increased rapidly. Furthermore, when such positive results can be correlated with geophysical evidence it will be possible to increase the reliance of the method. Mound sites hills, which could be widely seen on the Anatolian and Mesopotamian landscape, were of great importance to understand trade, culture, and art, as well as in ancient urban development. Mud brick, an important building material, quickly erodes by natural agencies and over time, it finally turn into small hills which in geophysics we observe in the form of covered anomalies. Mound sites includes stone building foundations, walls of various materials, ovens, furnaces, mine processing workshops, rubbish wells, and intensified ceramic materials. Considering that almost all of them were exposed to fire, they are important locations in terms of potential geophysical studies. Yet, since there have been few geophysical studies made on mound sites, there is little information that such areas can be determined by geophysical methods.

The objective of this study is to reveal methods that would be more suitable to specific research programs, especially programs where research is conducted on artificial hills. During the large-scale geophysical studies from 1992 to 1994 on Acemhöyük, we tried to describe the hill in geophysical terms, and we searched for the potential success of geophysical methods on the hill. The significance of large-scale geophysical prospection is best evidenced in areas exposed to fire especially by the excavation of the 3rd building level in NE-SW and NW-SE directions in the site.

The Geological-Geographic Setting and a Brief History of Acemhöyük

The archaeological site of Acemhöyük situated at the south end of Tuz Gölü lies on the west side of a normal fault, east of the lake. The mountainous part, east of the fault, is covered by a thick layer of andesitic and ignimbrite basalt which are of Neogene age, originate from the volcanic system of Hasan Dağ and Erciyes dağı. The region, on which Acemhöyük is located, is part of the larger Konya plain, and is covered by Pliosen and Quaternary sediments of younger age. The main materials of these young sediments, which are composed primarily of clay, occasionally sand and rarely of unhydrite salt sequences, are volcanites which were eroded from the east (Drahor et al., 1999).

Acemhöyük is located in the town of Yeşilova which is 18km northwest of Aksaray near Hasan dağı. The artificial hill lies near the Melendiz river in the middle of a large and fertile plain. The hill, which has an oval shape, is one of the largest artificial hills of Anatolia, measuring 700m long on the east-west axis and 600m wide on the north-south axis. The maximum height of the hill is about 20m. In addition, it is thought that there was a large Karum located at the site, now probably buried under the present town.

Excavations at the site began in 1962; even though the initial settlement at the site is at least as early as the Early Bronze Age (3000BC); however, the most prosperous period of the höyük was from the Assyrian Trade Colonies era, between 2000 and 1700 BC. Following that period, both the mound and the Karum site were deserted and they were not inhabited again until the Early Hellenistic period. The resettlement of some parts of the hill and Karum during Hellenistic and Roman periods ended in 3rd. Century AD. The topography of the site is raised to form four large bulges on the landscape. Excavations on three of those bulges revealed in the 3rd stratigraphic level the presence of great buildings, burned down during the age of the Assyrian Trade Colonies. The building in the south, is called Sarıkaya Palace, the one in the north is called Hatipler Palace and the one in the west is named burnt building (Yanık Bina). On the lower bulge in the northwest, lies the palace's kitchens. The foundations of the palace and other buildings are composed of a stone base, where thick wooden beams were placed on it. The ruins of the two-storey palace were built of wood and mud bricks. The walls are usually 1-1.5m in width. The palaces were abandoned after the great fire dating to 1789±50 BC. (Özgüç, 1968; Öztan, 1990).

Geophysical Research Plan

Geophysical prospection in Acemhöyük is oriented to two major objectives:

Detecting archaeological layers in höyük type archaeological settlements by using geophysical methods; particularly in the highly burned archaeological structures.

Mapping the mound by implementing geophysical methods in large areas, and thus the buried architectural plan could be imaged by using geophysical data.

The first instalment of these surveys was carried out in the north of the Hatipler Palace, an area that was highly burned and was partially excavated in 1960's. The geophysical surveys were conducted by a test profile in this area. After obtaining positive geophysical results in the test profile, geophysical surveys were initiated on a larger-scale in different areas of the mound. These areas and the applied geophysical techniques are as follows;

Resistivity, magnetic, and self-potential surveys in the north of Hatipler Palace (Fig.1).

Magnetic surveys between Hatipler and Sarıkaya Palaces (Fig.1).

Magnetic surveys in the burned structure (Yanık Bina) which was found to the south of the höyük (Fig.1).

Resistivity, magnetic, and self-potential surveys in the north Karum which was located around the höyük (Fig.1).

The survey procedures of these geophysical methods are:

Resistivity: In the survey, the twin probe array was used. In measuring procedures, the grid interval was 1.5m and the investigation depths were 1,2,3 and 4m. The other important advantage of this array is the gradient measurement, which can be easily compared to self-potential data.

Magnetic: The data by gradient measurement were collected at a grid intervals of 2m.

Self-potential: SP data were collected in 1 and 2m grids and in 1,2 and 6m electrode intervals using gradient measuring techniques.

Geophysical Surveys on the Test Profile

First geophysical measurements were carried out as a test profile in a selected area to the north of the Hatipler Palace. The purpose of the profile was to determine the different geophysical responses on the höyük, and to determine survey procedures that could be effectively used in this area. The measuring profile was 54m, and geophysical data were collected by 1m intervals from east to west direction.

Resistivity: This is the oldest geophysical method used in archaeological prospection. Its application showed that the method was very effective in archaeological settlements (Atkinson, 1952; Hesse, 1966a,b; Clark, 1975; Hesse et al., 1986). However, the disadvantage in using resistivity is the low contrast between soil and archaeological settlement resulting from the intensive use of mud brick materials. This phenomenon is especially more intense if there is a thick mud brick layer in the area. Moreover, if the amount of stone in the walls and foundations is too few or absent, the low resistivity contrast is a considerable problem. The Acemhöyük archaeological remains, however, were burned in very intense fire; the mud brick material changed in both its physical and chemical composition. We therefore believed that this conflagration would increase the success of resistivity method on the mound. For this reason, resistivity measurements were carried out by Wenner, dipole-dipole and twin probe array, and the depth investigations were chosen at 1,2,3 and 4m intervals in the test profile. At this stage, we searched for the appropriate array. The results showed that the twin probe array revealed more acceptable anomalies than the other arrays. Furthermore, we believed that one other advantage of this array produced a gaussian anomaly which could be an advantage in signal processing. Thus, we decided that the large-scale resistivity studies would be carried out by twin probe. The data obtained in the test profile were plotted against the different investigation depths. Moreover, the easily observed physical changes seen in the profile from former archaeological excavations were also included in the plots. Thus, these results were compared to each other and the effective interpretations were made. When we look at the resistivity graphics in fig.2a, we observe that the resistivity anomalies in burnt walls are very visible, particularly in graphics of 1m investigation depth. Thus, we believed that the burnt walls could be determined by the resistivity method in this area.

Self-potential (SP): Use of the self-potential (SP) method on archaeological sites has been very limited; only Wynn and Sherwood (1984) in the USA have obtained positive results. For this reason a new method could be tried, the response of which could be observed due to the very different chemical and physical make-up in höyük type archaeological settlements. Furthermore, a big fire such as the type Acemhöyük experienced, may have altered the properties in these areas. The self-potential data were collected by a gradient array in1m measuring interval. In this process, the electrode interval was choosen as 2m. Total SP data were also obtained by arithmetical addition of the corrected gradient data at the measuring points. Afterwards, gradient and total SP data were display graphically. As can be seen in this graphic, the SP anomalies were observed in areas of physical and chemical changes and in burned zones. This is an important result about self-potential anomalies in archaeological settlements, and it shows that detailed surveys must be applied in this area. The anomalies were processed by forward and inversion techniques, and thus the parameters (i.e., the polarisation angle, and the depth and origin of co-ordinates selected directly above the centre of the source) were determined. The most important result in this area is the similarity between the observed changes in the soil and the parameters revealed with SP geophysical exploration. Thus, areas containing different changes may be modelled with geophysical methods (Fig.2b).

Magnetic: The heavily burned materials were the principal reason for using magnetic prospection in this area. Burned areas are important because they produce magnetic anomalies; the data can be collected by gridding and mapping to determine archaeological structures. (Weymouth, 1986; Becker, 1993; Tsokas et al., 1994). In this study, the total magnetic field measurements were carried out in the first 38m of the extremely burned test profile. The anomaly amplitudes, caused by burned material, increase or decrease according to its depth. Extremely magnitized burial structures that are close to the surface, produce very strong anomaly amplitudes. If the structures is at a depth of 3-5 rate, the anomaly amplitude will decrease. Thus, magnetic anomalies can be found in all sensor heights for structures, that are extremely magnetized and very close to the surface. In contrast, the selection of sensor height will be important. When structures are buried at different depths they are magnetized at different values in the höyük type of deposits. The height of the sensor is important in detecting buried structures. In this study, we collected data with the Geometrics G-856 total field proton magnetometer. The sensor heights was placed at 60, 120, 180 and 240cm. Then the data were organized in graphical form and compared with each other. After this, we found that sensor heights, of 60 and 180cm were the next effective in detecting archaeological structures. Thus, gradient data were easily obtained with these two sensor heights. The results (collected by both top and bottom sensors and the gradient process) are shown in fig.2c,d. As can be seen from the total magnetic field and gradient curves, very strong anomalies are found over the extremely burned zones, walls and other archaeological objects (Fig.2c,d). Thus, we believed that magnetic anomalies can easily be detected by using these sensor heights.

Large-Scale Geophysical Explorations

Rather recently, geophysical instruments are well developed by electronic and computer technologies, and can collect a lot of information in one day at any archaeological site. Thus, a research area can be mapped entirely in a very short time. This is called large-scale geophysical exploration and is extensively used. In studies of this kind, many geophysical methods are used in combination and the physical properties of buried archaeological objects can be investigated in a very short time, and can help quite effectively archaeological excavation compared to traditional excavation techniques. Acemhöyük was selected as a prototype because the area had been excavated for very long time, and the architectural plan of the Assyrian Trade Colony period was partly known. Controls by excavation gave the possibility to make comparison with our large-scale geophysical prospections. After receiving positive geophysical results from the test profile, the large-scale geophysical explorations were carried out by implementing 3 different geophysical methods. The first geophysical study (i.e., magnetic, resistivity and self-potential) was conducted in the north part of Hatipler palace. The second survey (using the magnetic method) concentrated on the area between Hatipler and Sarıkaya palace, covering a large area. Small-scale magnetic prospection studies were carried out in the burned structure area (Yanık Bina). In the final stage of these surveys, a small-scale area was selected to the north of the Karum. Magnetic, resistivity and self-potential methods were used.

Resistivity surveys

The resistivity surveys were carried out north of Hatipler palace and in the northern part of the Karum area (Fig.1). The first study area was north of Hatipler palace, 17m from the test profile. The investigated area was determined according to the grid-system of the archaeological excavation. The surveyed area was 50x76m in dimension, and the measuring points and profile intervals were selected at 1.5m and 2m, (1.5x2m) respectively. The resistivity data were collected by resistivity profiling using twin probe array. In this array, a current and one potential electrode were placed in a fixed position. The other current and potential electrodes are transported between each measuring point . Furthermore, the mobile electrodes are transported along the rope, which are marked according to the operational grid system. So, this process is quickly completed on the measuring profile. In this setting, the configuration factor of the array was approximately $\pi.a$ where a is the spacing of the mobile electrodes (Aspinall and Lynam, 1970; Drahor, 1993a; Tsokas et al., 1994). In this study, the resistivity data were collected for 1 and 3m depths. The measurements were made by the METZ SAS-203 resistivity instrument, which is a signal average system. There was not a climatic change and the moisture content of soil did not change during our measurements. Thus, the background values were not affected by the different environmental conditions. Only a few differences, which occurred when we moved fixed points, were corrected by a simple correction technique.

The data collected from the north of Hatipler palace was imaged by gray scale at two different depths (Fig.3a and b). As can be seen in the maps, the anomalies have different characteristics. Due to the high clay content of the soil, the resistivity contrasts did not appear on these maps. However, at the 1m depth the map shows a higher resistivity contrast compared to the map at the 3m depth level. We thought that this could be from the Islamic graves, which are very close to the surface. These graves have a simple form and contain a gravestone over the head of the body. The gravestones were buried inside at a depth of 30-40cm sometime in the last century. Thus, the high resistivity anomalies in the 1m depth map may be due to these burial gravestones. In order to eliminate measuring errors, we applied a low-pass filter to the raw data. We can show that the 1m depth map was cleaned of surface disturbances, and that the burial gravestones clearly appear (Fig.4a). To determine the shallowness of archaeological remains, however, we applied a high pass filter to these data (Fig.4b). Furthermore, to increase the signal-noise ratio, we added a signal detection filter. The signal detection filter maps show that the shallower gravestones (Fig.4c) produced the anomalies in the southwest part of the map. Similar processes were applied to the 3m depth map, and the high resistivity anomalies found in south and southwest part of the investigation area were more effectively imaged (Fig.5a,b,c).

Another resistivity study with a dimension of the 34x41m, was carried out in the northern Karum area. The data was collected by the dipole-dipole array due to modern settlement. As the modern houses were very close to the investigation area, the fixed probes of the twin array were not inserted. The resistivity survey was carried out at 1 and 3m depths. As can be seen from the maps, a strong resistivity contrast, as observed on the höyük in resistivity maps, could not be obtained. We estimate that the high resistivity anomalies in the northern and southern parts of the dipole-dipole 1m map are generated by the effects of structural foundations near the surface (Fig.6a). For the 3m spacing in the same area, the anomalies generally ran in aa NE-SW direction, although the resistivity contrast decreased (Fig.6b) (Drahor et al., 1996). After the signal detection filter had been applied to the same data, these anomalies more clearly be observed. Therefore, an architectural structuring similar to a höyük can be considered.

Self-potential (SP) surveys

The use of self-potential (SP) method at archaeological sites has been very limited; thus anomalies resulting from SP method are not well understood. It is for this reason that the method is not frequently used in archaeological prospection. We believe that vertical capillary water flow around stone walls the porosity of soil surrounding archaeological structures, the moisture and clay ratio of soil, and changes in soil pH values of the soil, may contribute to SP anomalies. However, an SP anomaly may also occur if moist conditions are cutting through the sulphiric and oxidized deposits below the surface (Drahor et. al., 1996). We believed that the SP method might give a positive result in a höyük type setting, and therefore we used this method in several areas. In the surveying process, the physical changes, which can easily be seen from the surface area, were observed by empirical methods, and these observations were added to the graphics and to the maps. Moreover, measurements were plotted on a detailed plan, which would be used as theoretical and detailed background for future surveys. As mentioned above, the SP surveys were successfully carried out in the test profile. The detailed SP surveys were continued in the A, E and Karum areas. SP electrode intervals were chosen at 1 and 2m intervals for area A and 2 and 6m for area E and the Karum. In addition, the SP data were collected in two directions perpendicular to each other in area E, and changes from the measuring directions were also investigated. The gradient SP data obtained by 2m electrode intervals from area A and E were mapped by gray-scale imaging (Fig.7a). As can be seen from the SP gradient map, the positive and negative voltages were similar to the directions of archaeological structure. In the western part of the map, the anomalies, which follow each other in regular form, were in same positions as the anomalies on the 3m depth resistivity map. The main goal of an SP survey is to explain the possible mechanism by which structures were buried. For this reason, SP data were processed by forward and inversion techniques, and three important parameters were determined. Thus, the area was modelled by means of SP parameters, which might signed the burial of archaeological remains. In the first stage, the data was processed by the nomogram technique (Bhattacharyya and Roy, 1981), and the results formed the initial values in inversion process (Ram Babu and Atchuta Rao, 1988; Jagannadha Rao et al., 1993). In the inversion process, sphere, vertical cylinder, inclined sheet and 2-D sheet models were used. After this process, the appropriate parameters were established according to the measuring position in cartesian co-ordinates, thus the horizontal projection of the polarization centre was found (Fig.7b). This drawing technique demonstrated that polarization angles and variations of depth could easily be seen; thus the investigation area was modelled in simple form. The results of inversion processes pointed out that our models, produced from the same polarization angle, were in a NE-SW and NW-SE orientation, the same as the archaeological structures. This is an important result in terms of SP analysis for archaeological investigations. This situation showed that the archaeological structures could be easily recognised by the self-potential method in höyük type of sites (Drahor, 1993 a,b; Drahor, 1994; Drahor et al., 1996). Furthermore, the anomalies which were observed in a N-S directions in the middle of the map, corresponded to deposits from earlier excavations (Fig.8, shown with arrow. We can therefore say that the SP method is rather sensitive to soil changes. To control our results, an excavation was made in a 5x5m area (shown as a square on fig.7b). The results obtained from this excavation will be discussed below.

Another survey area where the self-potential method was applied is a 26x26m section in the Karum area. The data was collected in 6m electrode intervals by gradient measurements. The gradient data shows that anomalies are generally oriented in NE-SW and NW-SE directions. Thus, the anomalies are similar to the höyük (Fig.6c). We suppose that similar architectural plans might be found in this area.

Magnetic surveys

Magnetic survey is one of the oldest methods used in archaeological prospection. The method has been applied in large number of archaeological sites to solve problems and it has been refined through time (Aitken, 1959; Aitken and Tite, 1962; Scollar and Krueckeberg, 1966; Clark, 1975; Weymouth, 1986; Tsokas et al., 1994). The method is fast and effective especially in areas where the features are burned. The initial work was the test profile, and rather it was extended to cover a large area where positive results had already been obtained. The data was collected in 2x2m grid intervals by gradient measurements. The sensor height was placed at 60 and 180cm along the test profile. The data was corrected by the base correction method and then mapped. As the area between the Hatipler and Sarıkaya palaces was designed as the area for archaeological excavations our magnetic prospection was more intensively implemented in this part. Furthermore, magnetic surveys were also set up to define the limits of the Karum and of the Burned Structure (Yanık Bina) (Fig.1). The magnetic measuring began between Hatipler and Sarıkaya palaces in area E, just north of the Hatipler palace. Magnetic measurements continued to the south in AHS1 (contains AHD1, AHD2, AS2 and AS3 areas) and AHS2 (contains AH1, AH2, AH3, AS1, and AS). In addition, geomagnetic gradient, resistivity and SP maps were drawn to show the directions of anomalies on topographic maps (Fig.8). Interesting anomaly groups were observed in area AHS1, among them a circular anomaly found in the south-west part of the map was very specific. The results showed that this anomaly may be related to an archaeological structural layer in the eastern part of the Hatipler palace (the burned fortification wall?). The anomaly groups are generally concentrated in the north, and run in a NE-SW and NW-SE direction. They may indicate the burned archaeological remains. Moreover, the anomaly with low amplitudes and in the northwestern part of the map also has some very interesting characteristics. Lower magnetic anomalies were also observed in the western part of the map in area AHS2. However, the magnetic values were strengthened in the eastern part of the map (particularly in area AS). The magnetic gradient values fluctuated between -40 and 40 nT/m in this area, and the magnetic contrast was very good. Furthermore, the difference between the maximum and minimum levels obtained by the bottom sensor was 180 nT in this area. We can say therefore that this area may be highly burned. The magnetic anomalies were generally concentrated in northern and southern part of the area. The anomaly directions also run in a NW-SE and NE-SW direction, which may point to another burned architectural deposit. The anomalies in the southern part of the map are very interesting and may be related to a third archaeological layer (Fig.9a).

The main target of geophysical survey in this sector was to determine the geophysical properties of buried archaeological remains, such as their location and depth. Furthermore, different signal analyses and image processing techniques were also applied to the geophysical data, so the interpretation could be strengthened. We obtained very interesting results by using two new techniques. The first technique is an inverse filtering of magnetic data. Karousova and Karous (1989), Tsokas and Papazachos (1992) and Papazachos and Tsokas (1993) explain the theoretical properties of the method in detail. The main purpose of this method is to determine the total magnetic field by the superposition method at every measuring point over bodies which were found at different depths. Then the data thus obtained were screened with a filtering coefficient. We used several filtering coefficients, to determine the different properties of structures in the surveyed area. In this process, filtering coefficients were convoluted with its shape function, and therefore best filter coefficients were obtained to determine the burial structures in investigation area. After this process, the parameters are as follows:

Burial depth of the body: 2m, Inclined angle of body: 90°, Inclined length of body: 2m, Length of body: 3m, Width of body: 2m

This filter gave good results in area AHS2 where the highest magnetic contrast in the Acemhöyük area was located. The gray-scale image (shown in fig.9b) was created by these coefficients that were convoluted with bottom sensor magnetic data in area AS. As shown in this figure, the anomalies in the southern part of the map are clearly enhanced. The anomaly groups with NE-SW and NW-SE direction are associated with the structural bases part of the third layer excavated since 1960's. Resistivity and self-potential surveys in northern of the Hatipler palace also revealed similar results. Furthermore, archaeological excavations from 1966 pointed out a similar association with the third architectural layer (Özgüç, 1968).

Another processing technique applied in this area is pseudo-gravity. Baranov (1957) and Baranov and Naudi (1964) defined the theoretical properties of this technique. Here the pseudo-gravity equations obtained by Hilbert transforms were used (Ram Babu et al., 1989). In this process, the vertical and horizontal magnetic field, reduced to magnetic north, vertical and horizontal gradient, and pseudo-gravity values were independently obtained by the total magnetic field data ; these results were then compared with one another. The pseudo-gravity anomaly map of area AS is presented in fig.9c. The magnetic anomalies found in the southern part of the map were clearer than the anomaly group in the northern part. The results of this technique were not as useful as the other methods applied during this study. The foundations of the Burnt Building has also revealed high magnetic values. The area of this building, designed as AO and AO1 cover an area of 40x40m (Fig.1). The data was processed and interpreted by similar techniques. An anomaly with high magnetic values was found in the southern part of the area; this anomaly may be due to a highly burned structure. Furthermore, after processing, an anomaly in the shape of a square was determined very clearly. We thought that this structure might be burned and therefore similar to structures found in area AS (Fig.10a,b,c,d).

The final geophysical work was the magnetic survey in the northern part of the Karum. The area selected for geophysical testing is 30x40m. As it is evident on the map, the high magnetic anomalies are generally located in the southern part of the investigation area; this situation is similar to the results of the resistivity and to SP prospections (particularly 1m dipole- dipole map). An interesting anomaly is located in the middle of the investigated area, and it is indicated with an arrow in the maps, points out that this location might also have been burned. It was possible to observe this anomaly with clearity in the results from self-potential and magnetic methods (Fig. 6c and d).

Result

The results of our geophysical prospection at Acemhöyük can be summarized as;

The central part of the höyük was partly mapped by implying geophysical methods on a large-scale (approximately 2 hectars) (magnetic, resistivity and self-potential). Especially, the intensively surveyed part around the Hatipler and Sarıkaya palaces, has yielded significant results.

Test and field studies showed that the highly burned mud brick wall remains could clearly be determined through resistivity methods. Unburned mud brick walls however, were not clearly detactable due to their weak resistive contrast. Thus we can say that if there is no visible burnt material in the deposit, it will be difficult to find anomalies by impulses resistivity studies.

The implementation of the SP method at Acemhöyük is important, as it is the first experimentation of this method in a mound site. This survey pointed out that the self-potential method is improved the interpretation in highly burned areas. Furthermore, the method was experimentally developed by field observation and experiment, and we can conclude that highly burned archaeological materials produce SP anomalies. The amplitudes of these anomalies are about 10-20mV/m, but these amplitudes reach to 40mV/m in some areas. This amplitude is very important in determining the cause of SP anomalies. An SP anomaly appears at our site corresponded to physical changes in the surface of the höyük.

In the process of measuring, we collected three different mud brick materials for magnetic susceptibility measuring. They were burned at different temperatures and they were analysed by N. Orbay (1994). According to Orbay (1994, pers. comm.), the burned materials (for example slag) have high magnetic susceptibility values. This result showed that these kinds of materials might be important for magnetic surveying. After the magnetic researches, these kinds of materials were clearly determined by magnetic prospection method. The magnetic data were processed by different signal processing techniques, which greatly facilitated the interpretation of the map.

Our work at Acemhöyük by implementing different types of geophysical prospection on large scale, has clearly demonstrated the advantages of this strategy at höyük type of archaeological sites.

The results of our geophysical prospection was controlled by two archaeological soundings. The first excavation was carried out in 5x5m grid in area A- just north of Hatipler palace. The excavation continued down to 2.5m in depth, and 1st, 2nd, and 3rd layers related to Assyrian Trade Colony period were exposed. In the 2nd layer, a kiln, an oar processing workshop and other structural foundations were found which can be related to processing workshop. Furthermore, ceramic vessels used for copper processing were found (Öztan, 1993, 1994) (Photograph.1). These fragments were highly eroded due to oxidation and the moisture in the soil. We believe that the self-potential anomalies obtained in this trench may comes from the kiln and buried copper fragments. Thus the experimental results show that burned mud brick materials produce SP anomalies. Another important result in this area was the unburned third level. A sounding to test the results of geophysical prospection was carried out in AS. The test excavation was 10x10m and located between the following co-ordinates: (10,32), (10,42), (20,32) and (20,42). After the excavation, a highly burned building complex, related to the 3rd layer, (contemporary with the palace) was found. The excavation shows that an intense fire burned the building. Like the palace, the mud brick walls of the building were 90cm thick. The whole extent of the palace's big room was found. What was recovered by archaeological excavation concords well with the results of our geophysical prospection, both in its orientation and in its size (Öztan, 1995). By inverse filtering, the anomaly indicated a building with the dimensions of 7 x 7 m, and this was justified with the results of the excavation (photograph 2). This result showed that data processing and enhancement techniques were very successful and that they were effective in recording buried archaeological structures. Accordingly, we can suggest that the inverse filtering technique might determine the other buried structures, and their dimensions.

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