REPORTS

LAND-USE DYNAMICS AND SOCIOECONOMIC CHANGE: AN EXAMPLE FROM THE POLOP ALTO VALLEY

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The Polop Alto valley, in eastern Spain, serves as the focus of a study of long-term temporal and spatial dynamics in human land use. The data discussed here derive from intensive, pedestrian, non-site survey. We employ the concept of artifact taphonomy to assess the various natural and cultural processes responsible for accumulation and distribution patterns of artifacts. Our results suggest that the most significant land-use changes in the Polop Alto took place at the end of the Pleistocene and accompanying the late Neolithic, while much less notable changes in land-use patterns are associated with the Middle-Upper Paleolithic transition and the initial use of domestic plants and animals in the valley.

El valle del Polop, en el este de España, se utiliza aqui como ejemplo para la discusión de la variabilidad temporal y espacial de larga duración asociada al uso del territorio durante la prehistoria. La información que se discute deriva de la prospección intensiva, e independiente de la localización de asentamientos. Se utiliza el análisis tafonómico de los artefactos para investigar los diversos procesos naturales y antrópicos responsables de las acumulaciones de artefactos y sus patrones de distribución. Nuestros resultados sugieren que los cambios más significativos en la estructuración del territorio en este valle tuvieron lugar hacia el final del Pleistoceno y en los momentos finales del Neolítico, mientras que los cambios asociados a la transición Paleolítico Medio-Superior, o al inicio del Neolítico en el valle fueron mucho menores.

Nearly two decades ago, Cherry (1983) outlined the need for more systematic archaeological survey in the Mediterranean and the value of data collected in this type of research. While site inventories have grown in the intervening years (e.g., see van Andel and Zanagger 1990), systematic survey projects remain rare in this part of the world—especially in the western Mediterranean where we work (e.g., Massagrande 1995). This stems in part from many of the same problems discussed by Cherry, including the degree of land modification by human and natural agents and its effects on the archaeological record, the difficulties inherent in organizing surface materials in chronological frameworks derived from excavations at stratified sites, and reconciling the advantages and disadvantages of extensive and intensive survey strategies.

Since 1987, we have been engaged in intensive systematic archaeological survey in the levantine mountain valleys of eastern Spain, and have been wrestling with the general concerns outlined by Cherry, as well as more regionally specific ones. In so doing, our methods have evolved (and are still evolving) as we have endeavored to bring survey data to bear on questions of changing human land-use. We strongly agree with Cherry as to the ability of survey to provide data, valuable in their own right, that are complementary to those collected in excavation. In this respect, survey data are especially useful for understanding human activities at a regional scale. While our ongoing work covers a much broader geographic area, we report here on one of the valleys, the Polop Alto, that has served as a proving ground for a variety of data collection and ana-

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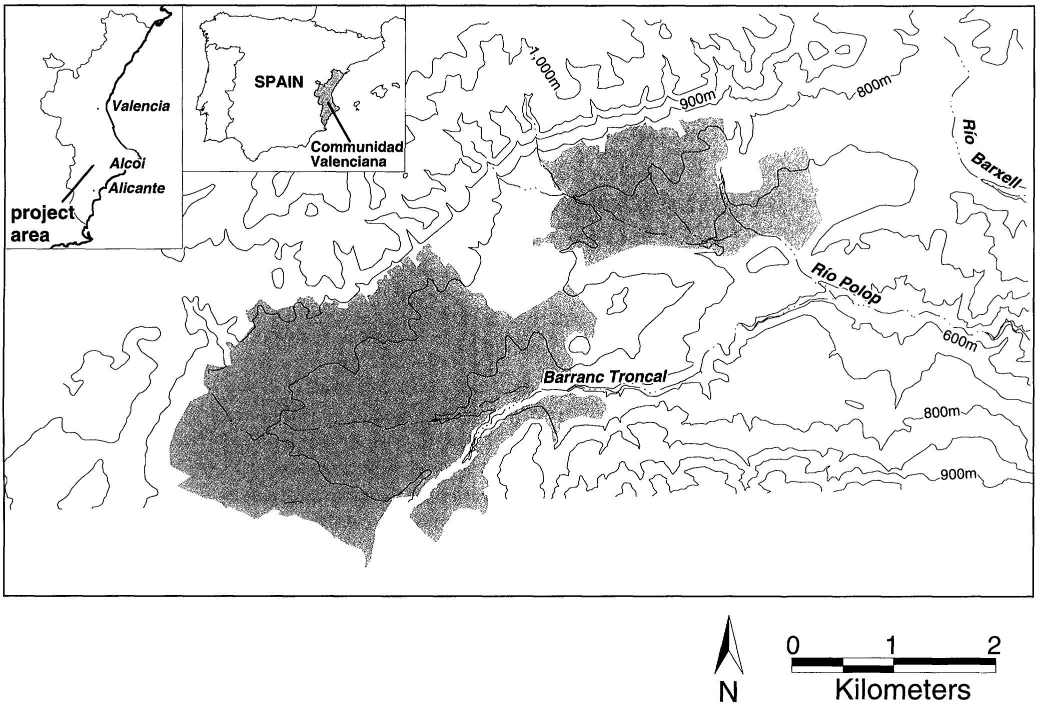


Figure 1. Location of the Polop Alto survey project.

lytical techniques since 1991. We hope that this work will be helpful to others dealing with the problems of implementing archaeological survey strategies in the Mediterranean Basin and also will shed light on human activities at a regional scale for the critical period covering the transition from foraging to food production.

Project Background

The Polop Alto Valley

The Polop Alto is located 6 km southwest of the town of Alcoi, in northern Alicante Province (Figures 1 and 2). Oriented southwest-northeast, the valley bottom varies in elevation from 700 m to 900 m. The Sierra Carrascal rises to over 1300 m to form the southeastern margin of the valley, and the Loma de la Fontfreda reaches elevations of 1100 m to form the northwestern margin. Excluding the steep slopes of the bordering highlands, the Polop Alto covers more than 9 km^2. The greater valley system, almost 30 km^2 in area, includes the headwaters for both the Río Polop and Río Barxell, two of the three sources of the Río Serpis, the major drainage of the region.

The Polop is one of several valleys chosen for study in a region encompassing the drainage of the middle and upper Río Serpis, in the coastal mountains of eastern Spain (Figure 1). Diverse topographic settings and vegetation communities offered a varied range of wild resources to the prehistoric inhabitants of these valleys, where human occupation dates to at least the early Upper Pleistocene. The valleys also contain arable land and sufficient precipitation for dry farming—600 to 900 mm annually, depending on altitude. Historically, crops have included cereals, legumes, tree crops (especially olives and almonds), and grapes; sheep and goats have been pastured in upland areas.

Our reconstruction of the Quaternary history of the Polop Alto is based on work by Pilar Fumanal, Michael Cuenca Walker, and project geomorphologist Neus LaRoca (Barton et al. 1992; Ferrer et al. 1993). The valley formed as part of the Cenozoic Baetic uplift, and filled with a thick sequence of marls by the late Tertiary or early Quaternary. By the Middle Pleistocene at the latest, fluvial erosion cut a series of high benches in the marl along the upper margins of the valley, especially noticeable today along its southern side.

Subsequently, alluvial fans developed in several locations and the marl was mantled with terrestrial deposits of variable thickness. During our survey, artifacts of probable late Paleolithic age, were found some 2 m below the present surface in such sediments. The deep reddening and well-developed $CaCO_3$ horizons in this older terrestrial series may represent a period of long-term stability in the surface, or, more likely, long-term aggradation with episodic surface stability, interspersed with erosion. At that time the primary drainage of the valley probably followed its northern side, exiting along the course of the present-day Río Barxell in the vicinity of the Middle Paleolithic site of Cova del Salt (see below).

A more recent cut-and-fill sequence is present in the central part of the valley. Soil developed on these sediments is less reddened and contains minimal $CaCO_3$. On the basis of stratigraphy, soil development, and associated artifacts, these sediments probably date to late Pleistocene, and soil development to the early- to mid-Holocene.

Following deposition of the Pleistocene series and probably after emplacement of some or all of the late/post-Pleistocene series, the primary drainage shifted from the north to south side of the valley—probably by the capture of most of the Río Barxell drainage system by the Río Polop and its primary tributary, the Barranc del Troncal. This event is associated with deep incision (30 m or more) of the Polop and its major tributaries. Although the exact date and cause for this change in the valley hydraulics are not yet known, similarly deep incision of the upper Río Serpis—the local base level for the Polop Alto streams—postdates late Neolithic occupation at the site of Niuet (Bernabeu et al. 1994). Given this probable post-Neolithic timing, human activities such as agriculture or forest clearance may have contributed to this erosional event. Overall, however, much of the Polop Alto seems characterized by surfaces that have been stable or aggrading since at least the late Pleistocene, potentially recording the long span of human occupation.

Archaeological Background

Evidence of human occupation dates from the Middle Paleolithic onward (Barton 1988; Barton and Clark 1993; Iturbe et al. 1993; Villaverde 1984; Villaverde and Martí 1984), and extends regionally well into the Middle Pleistocene (Fernandez 1993). Prior archaeological research in the Polop Alto includes excavations at the Middle Paleolithic site of Cova del Salt (Barton 1988; Galvan 1992) and a few small salvage projects such as at the Mesolithic-Neolithic site of Abric de la Falguera (Aura 1984; Barton et al. 1990; Domenech 1990). Although this paper focuses on Paleolithic through Neolithic land use, there also is evidence for Bronze Age, Iberic Iron Age, Roman, Moorish, and later Medieval settlement in the valley.

The earliest well documented sites within the area are Cova del Salt, at the eastern exit of the Polop Alto, and Cova Beneito, about 15 km to the northeast (Barton 1988; Iturbe et al. 1993; Villaverde 1984). Travertines that immediately underlie occupation horizons at Salt have produced Uranium series dates of 80,157 and 81,583 bp (Barton and Clark 1993; Galvan 1992). Middle Paleolithic industries appear to persist relatively late in the Pleistocene in eastern and southern Spain (Villaverde et al. 1998). Radiocarbon dates from Beneito put the final Mousterian at ca. 39,000 bp (Barton 1988; Iturbe and Cortell 1987; Iturbe et al. 1993).

While Beneito is the only well-documented Upper Paleolithic site in our broader survey area, numerous locales of this age are known throughout the broader region (see Aura et al. 1993; Davidson 1989; Villaverde et al. 1998). Beneito typifies the Upper Paleolithic sequence of the region, with occupations from the Aurignacian, beginning ca. 34,000 bp, through the late Solutreo-Gravettiense (i.e., the regional late Solutrean), ending after 16,500 bp (Iturbe et al. 1993). To date, only cave and shelter sites have been excavated and systematically studied regionally, although a few open-air Paleolithic sites are known. This situation is more likely a function of preservation and the focus of archaeological endeavors than a reflection of Paleolithic settlement (see Villaverde et al. 1998).

Dated at ca. 14,000 bp to 8,000 bp, the late Pleistocene and early Holocene occupation of the region is represented by lithic industries in which microblade technology (including backed bladelets) comprises a significant component of lithic assemblages (Aura and Pérez 1992; Fortea 1973; Villaverde et al. 1998). Classed generally as Upper Magdalenian or Epipaleolithic, depending primarily on age, relevant lithic assemblages display a considerable degree of uniformity in composition, although geographic and temporal variation does exist (Aura and Pérez 1992; Fortea 1973; Villaverde et al. 1998).

There is a little more information on prehistoric settlement for this period. Nevertheless, most known sites are still cave/shelter localities. A bimodal pattern is evident at a regional scale, characterized by small sites with low artifact densities and often a single occupational horizon, and by much larger sites with larger, more diverse assemblages and evidence of multiple occupations (Aura and Pérez 1992).

In the Geometric Mesolithic industries that follow the Epipaleolithic, backed bladelets are replaced by geometric microliths among retouched microblade artifacts. In the Polop Alto, the Mesolithic horizon at Abric de la Falguera (Aura 1984; Domenech 1990) has been radiocarbon dated to 7,410±70 bp (6,357–6,171 B.C.)[1] (Barton et al. 1990). The dating of the end of the Mesolithic is somewhat equivocal due to questions about its relationship with the Neolithic I (Barton et al. 1990; Bernabeu et al. 1993: 189–260; Fortea et al. 1987; Juan-Cabanilles 1990).

The Neolithic I in eastern Spain begins at least by 5,600 B.C. and extends up to ca. 4,500 B.C. (Acosta 1987; Ammerman and Cavalli-Sforza 1984:44, Appendix; Badal et al. 1989; Bernabeu 1989:Appendix 1; Bernabeu et al. 1989; Bernabeu and Juan-Cabanilles 1994; Fortea et al. 1987; Martí et al. 1987; Muñoz 1987; Olaria and Gusi 1987; Pellicer 1987). Thus, the eastern Spanish Neolithic begins about 2,000 to 2,500 years after the earliest documented agriculture and less than 1,500 years after the beginning of the ceramic Neolithic in the Near East.

Domesticate sheep and goats, and wheat, barley, and pulses are present at many, but not all, Neolithic I sites. However, wild plants and animals comprise a significant, but variable fraction of food remains. Ceramics, initially decorated with impressions from the serrated edges of Cardium shells (Cardial ware) and later incised or painted as well, also are found on Neolithic I sites. While geometric microliths, like those in Mesolithic assemblages, occur at these sites, they comprise a significantly smaller fraction of assemblages. On the other hand, small blades with continuous, fine edge wear are regularly found in the Neolithic I sites, but are lacking in Mesolithic sites (Fortea et al. 1987; Martí et al. 1987; Martí and Juan-Cabanilles 1987:25–37).

For both the Geometric Mesolithic and the Neolithic I, known sites are few and are primarily cave and rockshelter locales—although a few open sites have been identified in recent fieldwork (Martí and Juan-Cabanilles 1987:33–37; Martí et al. 1987; Bernabeu et al. 1989). Again, this seems to have more to do with factors of preservation and visibility, and the focus of archaeological research than with prehistoric activity. Hence little is known of land-use patterns.

Spanning more two millennia, the Neolithic II is considerably better known, both regionally and locally, than the Neolithic I. It has been divided in three major stages regionally: the Neolithic IIA is dated at ca 4,500–2,900 B.C.; the Neolithic IIB (ca. 2,900–2,400 B.C.) and Bell Beaker stage (ca. 2,400–2,200 B.C.) are roughly contemporaneous with the better known "Los Millares" culture of southeastern Spain (Gilman and Thornes 1985).

Recent archaeological work is providing a more comprehensive picture of Neolithic II subsistence, land use, and social organization (Bernabeu 1993; Bernabeu et al. 1994; Bernabeu and Juan-Cabanilles 1994). As with the Neolithic I, sheep and goats dominate Neolithic II domestic faunas. However, mortality patterns suggest that they were raised for wool as well as meat. Cattle also are found in Neolithic II faunal assemblages, with mortality patterns that suggest their use as draft animals and may mark the introduction of the plow. Macrobotanical remains from regional Neolithic II sites such as Les Jovades (near Alcoi) and Arenal de la Costa (in the neighboring Albaida valley) indicate a continued dependence on the same domestic plant taxa—wheat, barley and pulses—as found at Neolithic I sites (Bernabeu 1993; Bernabeu and Martí 1992).

Although the Neolithic IIA is known only from two cave sites, Neolithic IIB sites are more numerous, including both cave/shelter and open sites. Extensive settlements (10–14 ha. is common), comprised of scattered houses within ditch enclosures, are commonly found in valley bottoms, close to better agricultural land. Burials include multiple graves in natural caves or rockshelters, usually in the vicinity of the habitation sites. During the final Bell Beaker period, valley bottom settlements disappear in favor of surrounding slope and the hilltop locations, and communal tombs are replaced by individual graves within habitation areas.

Methodology

Methodological Considerations

The methods employed in the survey were influenced by a number of considerations. First, the overall goals of the survey project were to study the spatial and temporal dynamics of prehistoric land use, economy, and social organization, and locate Paleolithic

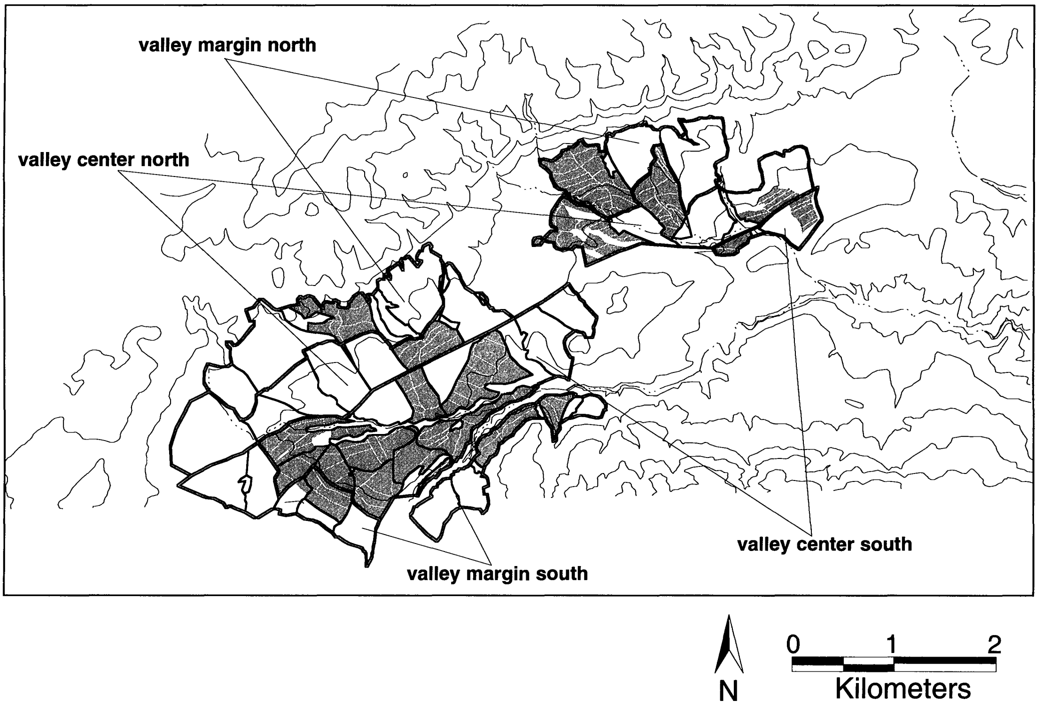


Figure 2. Sampling strategy used in the Polop Alto survey. Double lines outline sampling strata; heavy lines outline survey units; shaded survey units indicate areas sampled; white lines outline collection/provenience units. A housing development that could not be surveyed, Montesol, occupies 1.3 km^2 of the north valley margin stratum.

through Neolithic settlements for future excavation. A multistage sampling design was used to accomplish these objectives.

Second, previous work in the Serpis valley suggested both temporal and density differences between cultural material found along major drainages and their lower terraces and that found on the upper terraces and alluvial fans of valley margins. A further consideration was the shift in the drainage pattern from the north to the south side of the valley. These factors led us to independently sample valley center and valley margin areas, and the northern and southern portions of the valley center.

Finally, agriculture has been practiced in the Polop Alto for over 5,000 years, and terracing from the Bronze Age onward (Trelís 1988, 1992). Currently, the entire valley is terraced and plowed, with several consequences for archaeological survey. The long history of cultivation, compounded by terracing, has greatly blurred any patterning in the surface distribution of artifacts (Cowen and Odell 1990; Odell and Cowen 1987; Steinberg 1996), making infield identification of discrete settlements difficult. This situation led us to employ a non-site survey and collection strategy. The small, clearly demarcated, terraced fields found throughout the valley made convenient collection and provenience units. On the other hand, the presence of closely spaced terrace walls, usually 1 to 2 m in height, paralleling the long axis of the Polop Alto made it difficult to employ the more arbitrary survey units, such as transects and quadrats, commonly used in North America.

Sampling Strategy and Analytical Methods

Given the considerations discussed above, we divided the Polop Alto into a valley margin stratum, a north valley center stratum (including the paleodrainage system), and a south valley center stratum (representing the current drainage system). Because of topographic differences between the north and south sides of the valley, the valley margin stratum was subdivided to ensure that samples were taken from both sides of the valley. The end result was four sampling strata: north valley margin, south valley margin, north valley center, and south valley center (Figure 2, Table 1).

Each stratum was divided into a series of survey units—roughly equal-area groups of fields divided

Table 1. Survey Coverage Statistics for Each of the Four Sampling Strata.

		North Valley Margin	South Valley Margin	North Valley Center	South Valley Center	Survey Total[a]
Total Area (sq. km)		1.31	.79	1.97	2.62	6.69
Total Survey Units		7	10	13	13	43
Random	units surveyed	2	2	2	5	11
Sample	area surveyed (sq. km)	.60	.21	.42	1.30	2.53
	% of total	45.8%	26.6%	21.3%	49.6%	37.8%
Nonrandom	units surveyed	0	2	4	2	8
Sample	area surveyed (sq. km)	.00	.15	.49	.55	1.19
	% of total	.0%	19.0%	24.9%	21.0%	17.8%
Survey	units surveyed	2	4	6	7	19
Total	area surveyed (sq. km)	.60	.36	.91	1.85	3.72
	% of total	45.8%	45.6%	46.2%	70.6%	55.6%

[a] excludes areas where survey was not possible, such as housing development of Montesol.

by prominent barrancos (or roads in the cases where appropriate barrancos could not be followed). The survey units in each stratum were numbered and a random sample was drawn for initial survey (Figure 2, Table 1). Because of the expected higher density of cultural materials in the south valley center (the probable locus of Neolithic II settlement on the basis of work in the Serpis) a larger initial sample was drawn from this stratum than the others. Based on the results of the initial survey, additional survey units were selected non-randomly for inspection.

In all, 40 percent of the Polop Alto was intensively surveyed (3.7 km^2 out of 9.3 km^2). As is the case in all field projects, the choice of methodologies employed involves a set of trade-offs in terms of the types of information recoverable and recovered. As discussed in the rest of this paper, our methods—intensive, pedestrian, nonsite survey, and systematic artifact collection—have allowed us to do detailed modeling of ways in which prehistoric humans used the landscapes of the Polop Alto. On the other hand, foregoing extensive survey methods focused on site recording and inventory has restricted our study to five comparatively compact upland valleys, of which the Polop Alto is one.

All areas surveyed were walked by crews of four to eight people, spaced about 15 m apart. All observed prehistoric artifacts were collected. Later materials, such as Ibero-Roman and Medieval ceramics, also were noted and diagnostic examples collected. Notes were kept for each area surveyed and standardized site forms were completed for artifact clusters noted during the fieldwork. Detailed topographic maps (1:10,000 scale) and high-resolution aerial photographs (~1:8,700 scale) were used to define survey units and collection units and locate them on the ground for survey. Contour lines from the topographic maps were digitized in a computer-aided drafting program (DesignCAD) and a geographic information system package (MapInfo), and overlaid with survey unit and collection unit outlines digitized from the aerial photos. MapInfo was used for spatial analysis and display of the survey data.

Preliminary analysis of collections was conducted in the field laboratory with more detailed analysis conducted later at the University of Valencia and Museo d'Arqueologia in Alcoi. Lithics were size-graded and sorted primarily into technological categories; modified forms also were noted (e.g., scrapers, sickle blades, and geometric microliths) and taphonomic information (see below) was collected. Prehistoric ceramics were classed by vessel form and surface treatment.

Artifact Accumulations and Taphonomic Processes

While artifacts were collected from virtually all collection units surveyed, artifact density varied considerably across the survey area, ranging from 0 to 56,050 per km^2, with a mean of 1,953 per km^2. These values are intermediate between surface artifact density in arid, deflated regions such as western Jordan (Geoffrey A. Clark, personal communication 1996) and the heavily vegetated and cultivated terrain of temperate Europe (Michael Jochim, personal communication 1996) (see also Bintliff and Snodgrass 1988, especially Figure 2). A total of 4,721 artifacts were collected during the survey (see Figure 3). These were primarily lithics (4,336); only 383 prehistoric sherds were found. The low density of prehistoric

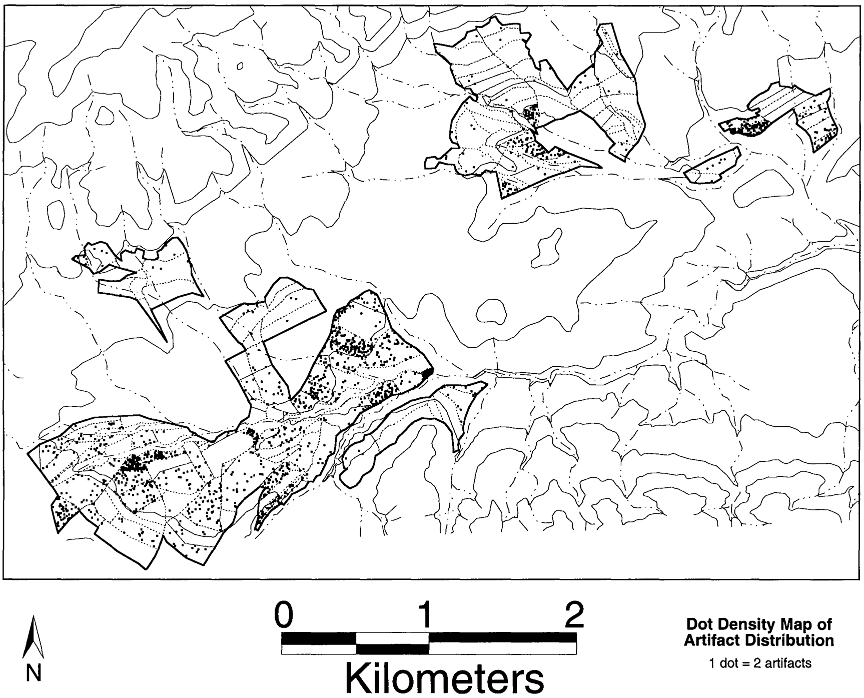


Figure 3. Map of artifact density in the Polop Alto project area. Heavy line marks areas surveyed; dashed lines outline collection/provenience units.

ceramics (mean = 226/sq. km; range = 0–23,512/sq. km) is somewhat surprising considering the long occupational history of the Polop and the presence of Neolithic and Bronze Age settlement.

The highest artifact densities were found in central valley locations, with the primary concentrations along the current south-side drainage of the valley and secondary concentrations along north-side paleodrainage. Ceramics were predominantly confined to valley center strata, with most in the south valley center stratum; the highest concentrations of surface artifacts and the highest concentration of ceramics was found along a low interfluve between the modern Barranc del Troncal and paleodrainage system in the north valley center.

The residues of past human behavior potentially can comprise a rather wide diversity of phenomena, including ruins of stone structures, earthworks, sedimentary fills, burned or chemically altered sediments, and anthropogenic soils. However, artifact accumulations make up the most common class of behavioral residues encountered by archaeologists, especially in the context of surface survey and non-urban societies. Artifact accumulations (including their density, diversity, location, and morphology) are likely to be the result of a complex suite of cultural and natural processes that differentially affect the landscape (Dunnell 1992; Stafford and Hajic 1992; Stafford 1995; Zvelebil et al. 1992). Integrating information about the effects of these processes on artifact assemblages is equivalent to incorporating taphonomic information—such as evidence for accumulating agents, differential element loss, and morphological alteration—into interpretations of faunal assemblages. Hence, we think it useful to employ the concept of artifact taphonomy in making inferences about past human activities from modern artifact distributions at landscape scales, especially when dealing with behavioral residues from residentially mobile foragers and simple agriculturalists. Employing the perspective of artifact taphonomy, we seek not simply to identify gaps or distortions in the archaeological record, but to match inferences to the appropriate resolution for the available data and use an understanding of formation processes to gain additional information about past human behavior (Dibble et al. 1997; Paddayya and Petraglia 1993; Stafford 1995; Zvelebil et al. 1992). In this respect, several processes have had important effects on the distribution and composition of artifact assemblages.

Artifact visibility, and hence observed artifact density, is as much a function of modern surface conditions as it is of prehistoric activity (see Nance 1994). These conditions can include vegetation cover, the extent and nature of agricultural activities, geomorphic processes of erosion and deposition, and even the amount of cloud cover and time of day when an area is walked. Many of these conditions were recorded in field notes for the Polop, and we attempt to account for them in the discussion below. Nevertheless, analysis of the Polop Alto dataset has led to our increased appreciation for the importance of surface conditions for interpreting information derived from survey, and we have initiated detailed, systematic recording and analysis of such information in subsequent work.

Preliminary results (Barton et al. 2000; Bernabeu et al. 1998) suggest that vegetation overgrowth of fields (from fallowing and overgrowth between trees in orchards) has the most marked effect on artifact recognition, but that this effect seems limited to areas with low artifact densities. Overgrown collection units are more likely to have no artifacts reported than are non-overgrown units. Surprisingly, however, there is no significant difference in artifact density between overgrown and non-overgrown units from which artifacts were recovered. Possibly the reason for this non-intuitive pattern is that survey crews were more likely to miss all artifacts in overgrown fields with few artifacts than cleared fields with few artifacts. However, if artifacts were seen in overgrown fields (more likely with higher artifact densities), survey crews inspected these fields more closely than they did with cleared fields and, hence, recovered artifacts at about the same rate in both settings. This suggests that interpretations of spatial patterning based on areas of low artifact density could be misleading, but those based on moderate- to high-density artifact accumulations should be more reliable to the extent that they reflect actual modern artifact distributions.

The valley has been cultivated for millennia. On the one hand, this makes buried cultural materials visible at the surface. On the other, it reduces the resolution of spatial patterning. This has affected the methods we used to reconstruct and evaluate prehistoric land use. Still, artifacts do not seem to move a great distance from their positions prior to plowing, and the rate at which they disperse from their original locations rapidly decreases with time (Odell and Cowen 1987; Cowen and Odell 1990; Steinberg 1996).

A more significant land-altering process in the Polop (as well as throughout the Mediterranean) is erosion in two forms, partly a result of agriculture. Sheet erosion has resulted in the removal of surface sediments over some areas of the Polop Alto, while downcutting has caused the deep incision of many of the major drainages of the valley and gullying in their consequent streams. Of these two processes, sheet erosion probably has had the most significant effect on the spatial distribution of artifacts. While light to moderate erosion of this nature can redistribute artifacts or differentially winnow artifacts of different sizes (Baumler 1985; Wainwright 1994), this does not seem to be the case in the Polop (although it may be more relevant for the other valleys we have surveyed). In some places, especially around the upper valley margins, all Quaternary soils have been intensively stripped to the underlying marls, and all late Quaternary artifacts have been transported with the eroded sediments. Further, the consistent lack of any but subrecent artifacts in these stripped areas (even where adjacent collection units contained abundant prehistoric artifacts) suggests that this erosion is a comparatively recent phenomenon.

Most artifacts transported during sheet erosion in the Polop seem to have been buried in reworked sediments that have choked minor drainages or carried to the deeply incised major drainages and incorporated into the bed loads of these streams. The latter fate also is the most likely one for artifacts directly disturbed by stream incision (see also Barton et al.2000). The overall result of these cultural and natural taphonomic processes seems to be primarily localized movement of most cultural materials due to agriculture, the complete loss of the archeological record in some parts of the valley, and minimal redeposition of eroded materials among assemblages remaining in more or less original context.

We identified areas of significant sheet erosion from the high-resolution aerial photographs—bright white areas where the underlaying calcareous marls were exposed. The area of collection units was then decreased by the amount affected by sheet erosion prior to calculating artifact density. In this way, artifact densities, and land-use patterns modeled from it, are based on only minimally eroded areas[2]. We also recorded information on postdepositional alteration of artifacts in the form of edge damage and surface abrasion to assess the degree to which artifacts may have been moved from original depositional contexts. These data are discussed below in the context of prehistoric settlement patterns.

Chronology and Land-Use Measures

Organizing surface artifacts in a chronological framework often is considerably more problematic than is the case with buried, stratified archaeological materials (Jones and Beck 1992; Zvelebil et al. 1992). Nevertheless, combining archaeological and geomorphological information has allowed us to develop a chronological framework that is appropriate to the quality of the data available and still permits us to identify significant patterns of change in land use. Our approach to chronology takes a number of factors into account. First, an artifact class may be temporally meaningful in its initial appearance, but may persist for a long time. Second, the absence of an artifact class, as well as its presence, may be of chronological importance. Third, in an area like the Polop that has seen human occupation since the Middle Paleolithic, there is a strong likelihood that many assemblages represent a palimpsest of human activities. Fourth, and perhaps most important, dating artifact assemblages is a statistical estimate regardless of the method used. Different methods (e.g., soil development, ^{14}C, and inscribed coins) provide different degrees of reliability in dating, but all are probablistic.

With these considerations in mind, we developed a means of ranking artifact assemblages according to the probability that they derive from a particular chronological interval. These are shown in Table 2. Each collection unit was assigned an ordinal value—"Temporal Index"—for each interval on the basis of the artifacts recovered. Presence/absence measures and simple ranks are more appropriate here than actual probabilities. Few well-dated open-air sites were known prior to our work and almost none have been excavated. Although collections from excavated cave and shelter sites were used as a qualitative guide to temporal variation in assemblage composition, differences between assemblages from cave/shelter and open air sites (Barton and Clark 1993) severely limit potential quantitative use of these datasets.

The intervals used (Middle Paleolithic, Upper Paleolithic, late Upper Paleolithic/Mesolithic, Neolithic I, and Neolithic II) reflect both the overall coarse temporal resolution of surface collections and the increasingly finer resolution possible with later materials. In other areas we have surveyed, where the availability of more detailed data permit, we have employed a more detailed chronological framework (Bernabeu et al. 1998) Nevertheless, the temporal intervals used here still provide useful chronological divisions for examining the dynamics of human activities in the Polop Alto. This method of estimating the age of surface artifact accumulations is not fundamentally different from widely used archaeological approaches to dating for surface survey. However, we have tried to systematize (and make more replicable) what is usually a more subjective assessment. Also, our age estimates explicitly include a level of uncertainty, which we feel is more realistic. Furthermore, our approach to chronology also has allowed us to incorporate taphonomic information into our modeling of prehistoric land use.

In addition to serving as the basis for a chronological framework in the Polop Alto, the distribution of Temporal Index (TI) values provides information about spatial patterning of land use through time, including variability in the locations of artifact-producing activities and the areal extent of the landscape utilized by prehistoric occupants. Patterning in TI values is shown in Figures 4–6 and discussed further below.

We also have developed another index, Settlement Intensity Index (SII), to measure variation in the nature of prehistoric land use, in addition to its distributional patterning. In the context of surface survey, evidence for human activities is generally limited to artifact frequency and form—especially in cases (such as in the Polop) where built features are not preserved on the surface. Here we focus primarily on artifact frequency as a surrogate measure of occupational intensity—referring to the combination of group size, residence time, and reoccupation frequency for a locale (Barton 1988:108). Given a dataset almost entirely limited to artifact accumulations, the components of occupational intensity can be very difficult to distinguish—although Wandsnider (1992) has proposed a helpful modeling technique. Nevertheless, assessing occupational intensity at a regional scale provides valuable information about prehistoric land-use patterns.

In creating SII, we make a reasonable and often justifiable assumption (commonly although usually implicitly made in most survey projects) that the occu-

Table 2. Temporal Index.

Period	Temporal Index .9	.7	.5	.3	.1	0
Neolithic II	**present**: Late Neol. tools[a] or Late Neol. ceramics	**present**: ceramics or ground stone	**present**: Neol. tools[b], ceramics or ground stone	**present**: blade tech.[c]	**present**: artifacts	**present**: N/A
	absent: N/A	**absent**: backed tools and Early Neol. tools[d]	**absent**: N/A	**absent**: N/A	**absent**: N/A	**absent**: artifacts
Neolithic I	**present**: (backed tools and [ceramics or Early Neol. tools]) or Early Neol. ceramics	**present**: Neol. tools, ceramics or ground stone	**present**: backed tools or ceramics	**present**: blade tech.	**present**: artifacts	**present**: N/A
	absent: Late Neol. tools and Late Neol. ceramics	**absent**: Late Neol. tools and Late Neol. ceramics	**absent**: N/A	**absent**: N/A	**absent**: N/A	**absent**: artifacts
Late Upper Paleolithic and Epipaleolithic	**present**: backed tools	**present**: backed tools	**present**: backed tools or blade tech.	**present**: backed tools or blade tech.	**present**: lithics	**present**: N/A
	absent: Neol. tools and ceramics	**absent**: ceramic density <75/sq. km[e]	**absent**: ceramic density <75/sq. km	**absent**: N/A	**absent**: N/A	**absent**: lithics
Upper Paleolithic	**present**: U. Paleo. tools[f], and blade tech.	**present**: U. Paleo. tools or blade tech.	**present**: U. Paleo. tools or blade tech.	**present**: U. Paleo. tools or blade tech.	**present**: lithics	**present**: N/A
	absent: backed tools, Neol. tools, and ceramics	**absent**: backed tools, Neol. tools, and ceramics	**absent**: ceramic density <75/sq. km	**absent**: N/A	**absent**: N/A	**absent**: lithics
Middle Paleolithic	**present**: M. Paleo. tools[g]	**present**: M. Paleo. tools	**present**: M. Paleo. tools	**present**: M. Paleo. tools or flake tech.[h]	**present**: lithics	**present**: N/A
	absent: U. Paleo. tools, backed tools, Neol. tools, blade tech., and ceramics	**absent**: backed tools, Neol. tools, and ceramics	**absent**: ceramic density <75/sq. km	**absent**: N/A	**absent**: N/A	**absent**: lithics

Note: Criteria for assigning Temporal Index (TI) values to assemblages from each collection unit. TI is treated as a pseudo-probability such that assemblages with the highest probablility of dating to a given temporal interval (Upper Paleolithic, for example) are assigned a TI of .9 for that interval. Those with the lowest probability are given a value of .1. TI=0 for assemblages with no artifacts. Criteria for assigning Temporal Index values are cumulatively exclusive from highest to lowest values. For example, an assemblage is given a TI value of .5 for Neolithic II only if it meets the minimum criteria for rank 2 and fails to meet the minimum criteria for .7 and .9.

[a] Late Neolithic lithic tools include bifacial projectile points and denticulated sickle blades. The latter also occur in Bronze Age contexts, but are only found in association with other Neolithic artifacts in our collections from the Polop Alto; hence they are used here as a marker for the Late Neolithic.

[b] Neolithic tools (Early and Late) include plain (i.e., undenticulated) sickle blades and bifacial drills (taladros).

[c] Besides prismatic blades, evidence for blade technology includes crest blades, blade cores, and blade core face and platform rejuvenation flakes.

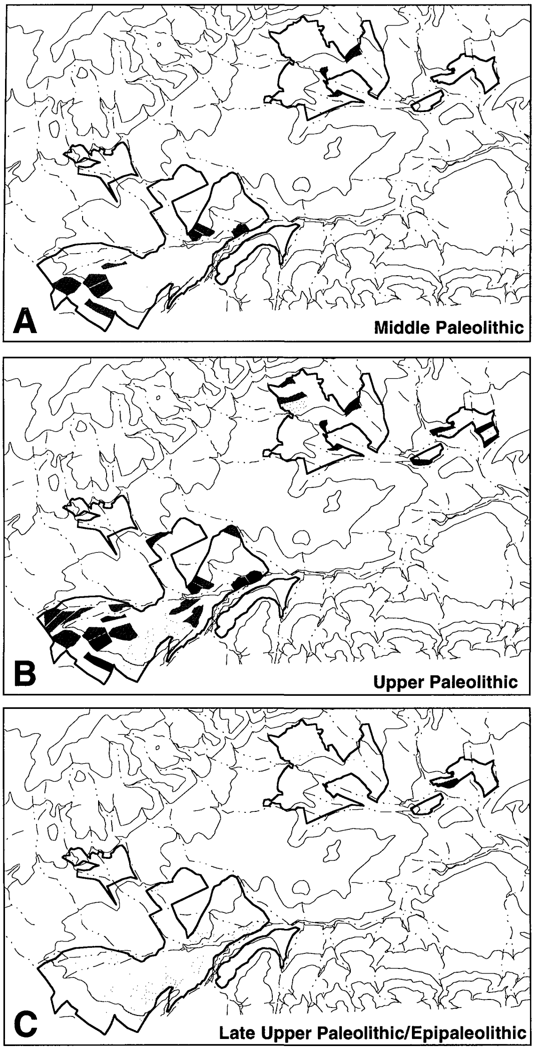
[d] Early Neolithic tools are finely retouched (utilized) bladelets. Backed tools include backed bladelets, backed points, and geometric microliths.

[e] This is an empirical figure for "background" ceramics derived from examining density histograms of ceramics for the entire Polop Alto survey area.

[f] Upper Paleolithic tools include endscrapers, burins, truncations, and perforators.

[g] Middle Paleolithic tools include sidescrapers (including transverse and déjéte scrapers), notch/denticulates, and Mousterian points.

[h] Flake technology includes flakes and flake cores—both prepared (e.g., discoid and levallois) and amorphous.



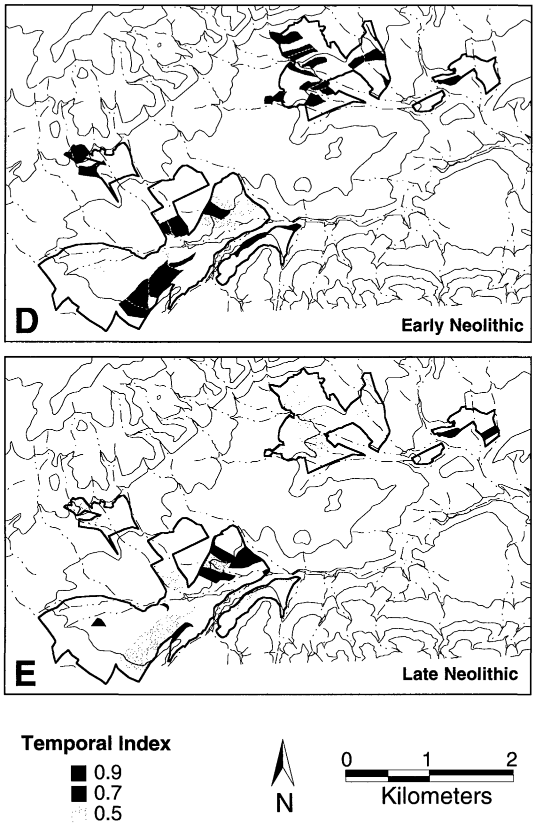


Figure 4. Maps of changing settlement as indicated by Temporal Index for each chronological period (see text for explanation of temporal index). Heavy line outlines areas surveyed.

pation(s) responsible for depositing most of an artifact assemblage also is most likely to leave the clearest temporal signal in the assemblage. The clarity of temporal signals is measured by TI. Hence, SII represents Temporal Index weighted by artifact density (in pieces per square kilometer to compensate for variation in collection unit size) for each collection unit.[3]

Because the original collection units—individual fields—are irregular in size and shape, we overlaid the valley with a regular grid of one hectare squares, transferring SII values from original collection units to overlaying grid squares. This effectively acts as an image filtering process to smooth land-use patterns and make them more visually apparent. This regular grid of SII values also facilitates additional quantitative spatial analysis.[4] The result of this modeling is shown in Figure 7.

Modeling Prehistoric Land Use

Temporal Index and Land Use

Figure 4 shows maps of the Polop Alto survey area that are shaded according to Temporal Index (TI) values for time intervals from the Paleolithic through Neolithic. That is, they show the likelihood of occupation for collections units across the valley for different time intervals. These data are summarized in Figure 5. While Figure 4 displays information for all areas surveyed, Figure 5 summarizes only the randomly selected survey units to minimize potential selection bias in estimating land-use extent for the valley.

Because TI is used as a rough estimate of the likelihood of occupation within each of the chronolog-

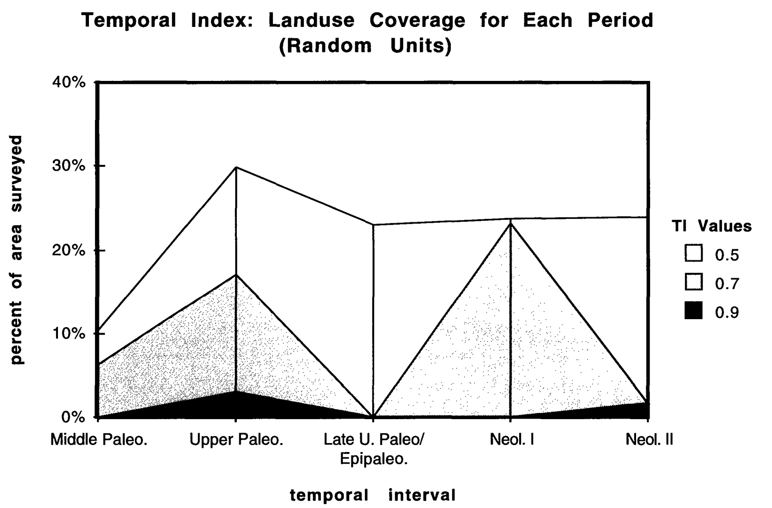


Figure 5a. Changing extent of land use as indicated by Temporal Index. Graph shows sumed areas of all randomly selected collection units with the three highest TI values for each chronological period.

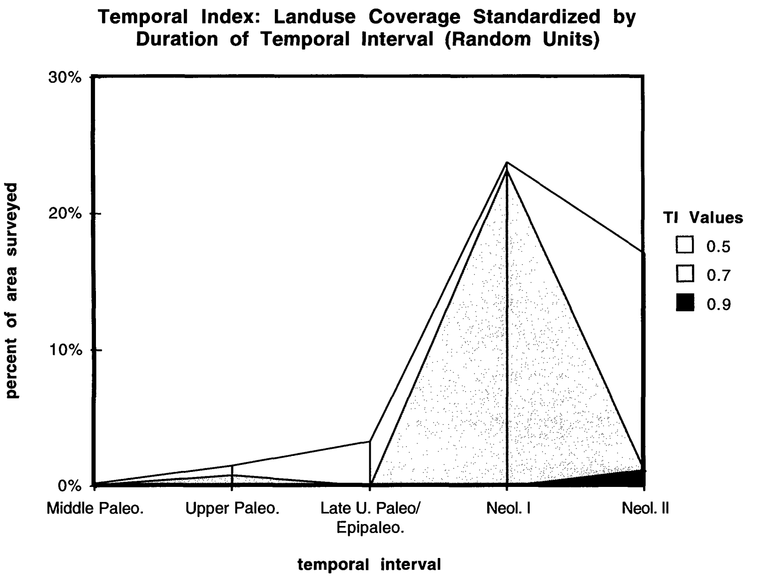


Figure 5b. Extent of land use standardized by duration of each temporal interval. Total area for each interval divided by the duration in millennia. See text for duration.

ical intervals used here, TI values are not comparable among different time intervals. That is, a collection unit with a TI of .7 for the Upper Paleolithic represents a greater likelihood of occupation during that interval than does a unit with a TI of .5 for the Upper Paleolithic, but does not necessarily indicate a greater likelihood of occupation than a unit with a TI of .5 for the Neolithic I. For this reason, we compare the distribution patterns for occupation indicated by TI among different chronological intervals rather than the particular TI values. For example, Figure 5 compares the total area of collection units with TI=.7 for each chronological interval.

There are clear differences through time in the distribution artifact accumulations. Collection units with TI values of .7 and above are very common for the Upper Paleolithic and the Neolithic II (Figures 4 and 5a), initially suggesting more extensive human use of the Polop Alto during the late Upper Pleistocene and mid-Holocene that at any other time examined

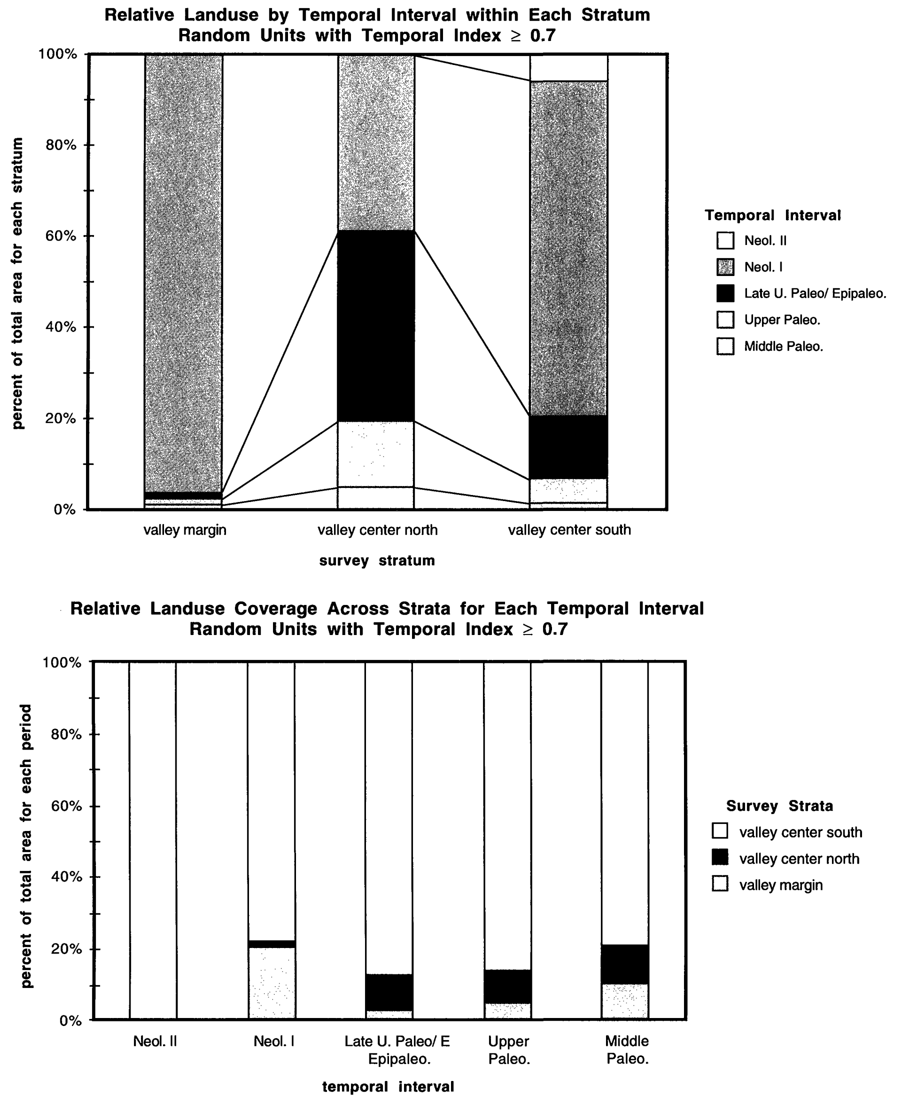


Figure 6. Land-use distribution as indicated by Temporal Index (standardized by temporal interval). Graph in Figure 6a (upper) shows the percentage of area in each stratum occupied by collection units with the two highest TI values for each temporal interval. Figure 6b (lower) shows percentage of total area for collection units with two highest TI values that fall into each survey stratum by temporal interval.

here. However, the extent of land use that registers on the modern landscape also has an important temporal component. That is, land use over a long period of time can result in a greater accumulation of artifacts than the same form of land use over a short period of time. Because the temporal intervals used here are of different duration, it is more realistic to examine the extent of land use in terms of area per unit time rather than just area.

The result of such "standardization" by temporal interval duration is shown in Figure 5b. When viewed in this way, there is a clear increase in land-use extent over time through the Neolithic I, followed by a decrease in the Neolithic II. The Late Upper Paleolithic/Epipaleolithic displays comparatively minimal evidence for human presence in the Polop. The Neolithic I displays the most extensive land-use pattern, although this may in part be a function of uncertainty in differentiating some Neolithic I and II assemblages (i.e., the peak of land-use coverage is for TI=.7). However, other measures discussed below also suggest that Neolithic II land use was more

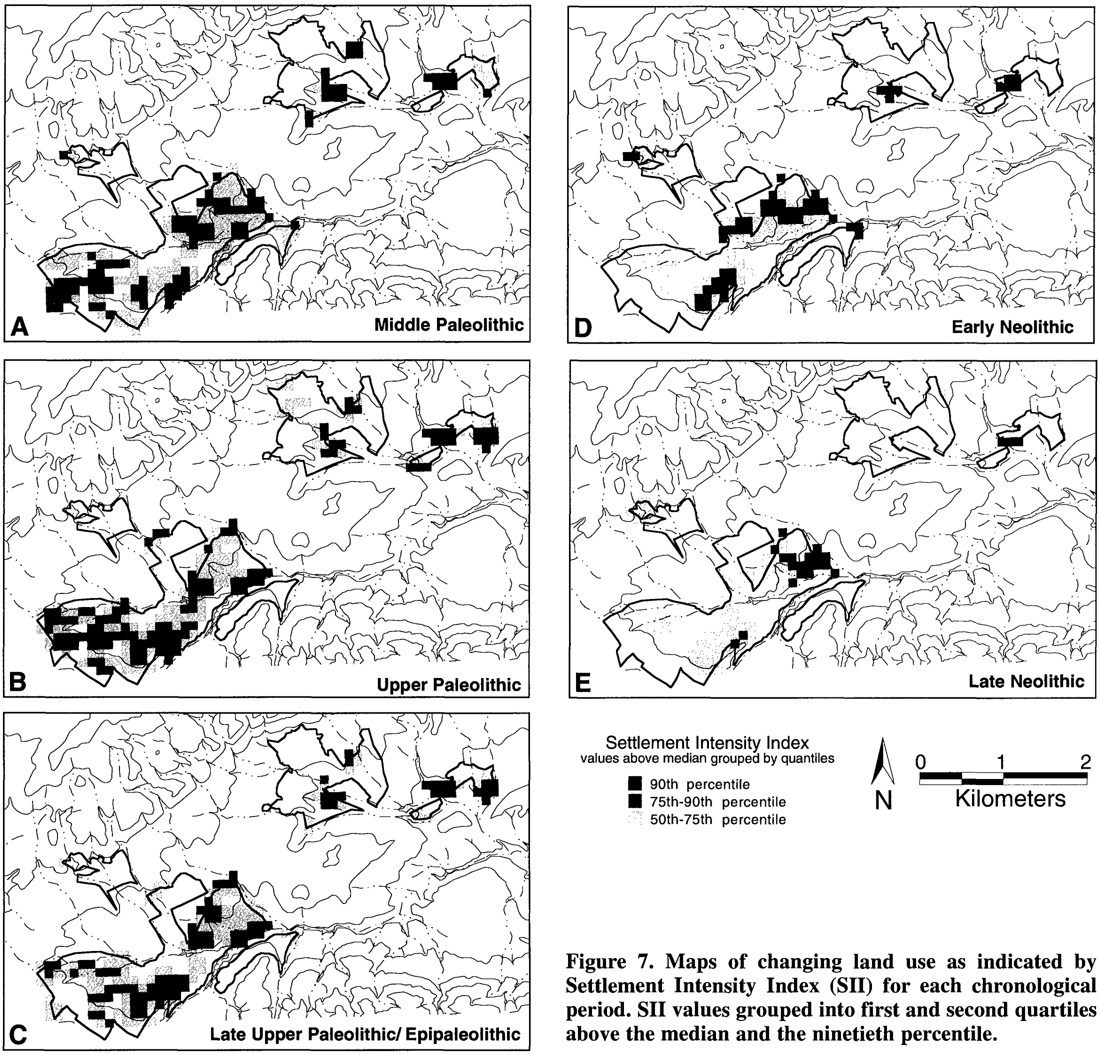


Figure 7. Maps of changing land use as indicated by Settlement Intensity Index (SII) for each chronological period. SII values grouped into first and second quartiles above the median and the ninetieth percentile.

intensive but covered less area than prior periods.

The part of the Polop Alto used by humans, as indicated by Temporal Index, also varies by time period (Figures 4 and 6). Neolithic II land use is almost entirely concentrated along the Barranc Troncal, in the south valley center stratum, while Upper Paleolithic land use is along the Troncal headwaters and in more upland areas, distributed in all three survey strata (although the majority of units with $TI^3.7$ for the Upper Paleolithic are found in the south valley center stratum, most of these are in the upper part of this stratum). Evidence for human use of the Polop Alto also is distributed across all three survey strata for other time periods, with Neolithic I land use evenly distributed between the valley margin and south valley center strata.

Settlement Intensity Index and Land Use

Figure 7 shows Settlement Intensity Index values for each time period. As with Temporal Index, raw SII values are not directly comparable from one time period to another. This is because SII is a function of Temporal Index weighted by artifact density. In addition to noncomparability of TI values discussed above, artifact densities vary greatly with chronological interval. While this is informative, it obscures spatial variation in land-use patterns addressed here. For this reason, we examine spatial variation in SII in terms of quantiles above the median value for each time interval rather than using raw values, treating it more like an ordinal than a ratio variable. We focus here on the spatial distributions of the most inten-

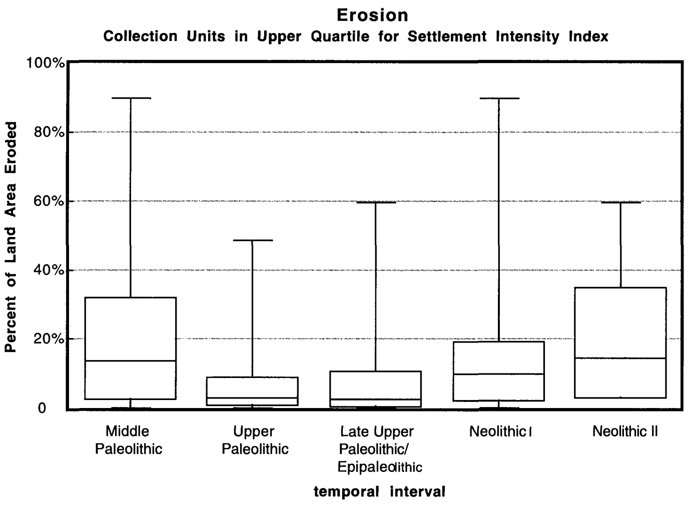


Figure 8. Box and whisker plots of percent of collection unit with evidence of severe sheet erosion, for units with Settlement Intensity Index values in the upper quartile for each chronological period. ANOVA results: df=4, F=1.762657, p=.1427084.

sively occupied areas for each chronological period. Chronological variation in the intensity of occupation, measured in terms of artifact density, is subsequently discussed independently.

When land-use intensity is taken into account along with areal extent, it is apparent that there is a change from a more dispersed to a more aggregated pattern of land use. Middle and Upper Paleolithic land use exhibits an extensive, dispersed pattern. Areas of comparatively intensive land use, indicated by high SII values, are small and scattered across the survey area, with localities of highest intensity land use in both upland and lowland settings. Also, the distribution pattern of Middle and Upper Paleolithic land use is very similar, although Middle Paleolithic land use seems a little more intensive (i.e., more grid squares with comparatively high SII values).

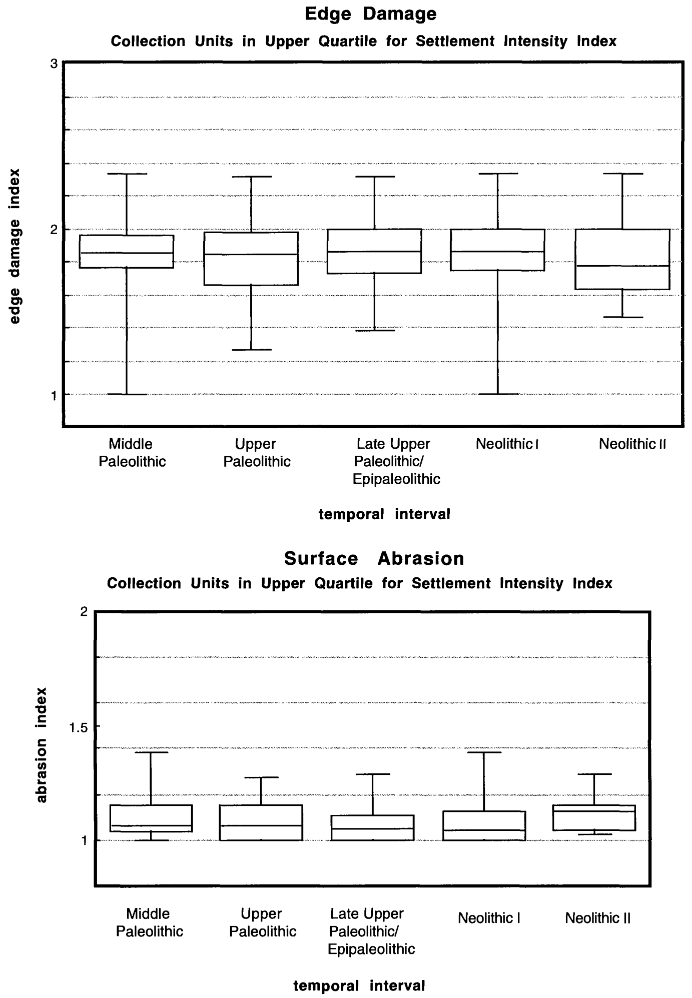
By the Late Upper Paleolithic/Epipaleolithic, evidence for the most intensive land use within the survey area seems to be focused in fewer, more intensively occupied localities, based on the area occupied by high SII values. However, there is still evidence for significant land use in many of the intervening areas, and at least a few of the dispersed and areally restricted localities that typify the earlier Paleolithic also are apparent for the Late Upper Paleolithic/Epipaleolithic. This trend continues into the Neolithic I. Land-use centers on four or five localities along the Río Polop paleodrainage, but with little evidence for significant use of intervening areas. Only a single locale in the north-central valley (left center of Figure 7d) resembles the small dispersed settlements of the Paleolithic.

The most striking change in land-use patterns appears with the Neolithic II, where artifact distribution suggests that most land use in the valley coalesced into a single settlement (center of Figure 7e). Two small outlier areas of human activity/occupation are located at opposite ends of the valley, but there is minimal other evidence of land use. This is a very different pattern from that seen for the Paleolithic.

Land Use and Taphonomy

It is likely that taphonomic processes, in addition to prehistoric land-use patterns, played a role in creating the distributional patterns discussed above. Erosion can remove or disperse all or parts of discard assemblages; colluvial and fluvial transport also can interact with natural and cultural features of the landscape to accumulate assemblages of artifacts (e.g., Wainwright 1994); agriculture can redistribute artifacts. To understand prehistoric settlement, it is necessary to evaluate the relative importance of these different processes for accumulating artifacts.

Figure 8 compares the effects of erosion on the locales of most significant land use for each of the time periods examined here. The degree of erosion varies only minimally by time period. A one-way analysis of variance indicates that the probability that the differences seen here are due to chance is about .14 ($F = 1.76$, $df = 4$). This is a higher chance of committing a type 1 error than is generally con-



Figures 9a and 9b. Box and whisker plots (showing median, mid-spread, and range) of mean intensity of edge damage and rounding of flake scar ridges for lithic assemblages from collection units with Settlement Intensity Index values in the upper quartile for each chronological period. ANOVA results for edge damage: df=4, F=.1690266, p=.9538484. ANOVA for ridge rounding: df=4, F=.7447714, p=.5631146.

sidered acceptable in archaeology (with $\alpha = .10$ or $\alpha = .05$ more normal, although there is no inherent reason for using these values [see Cowgill 1994]). Even if we accept this difference as meaningful, the most intensively used Middle Paleolithic and Neolithic II units experienced the most erosion, while the most intensively used Upper Paleolithic through Neolithic I units experienced the least. This does not account for the apparent pattern of dispersed Paleolithic land use and clustered Neolithic land use.

Edge damage and the presence of surface abrasion (reflected in notable smoothing or rounding of ridges between flake scars on the exterior surfaces) on lithic artifacts are in part a function of the degree to which these stone artifacts have been damaged in postdiscard transport by natural (e.g., colluviation) and cultural (e.g., agricultural disturbance) processes.

The intensity of edge damage and surface abrasion in collection units is shown for each interval in Figure 9. All five time periods examined exhibit nearly identical amounts of both types of postdiscard damage to lithic artifacts. One-way ANOVA's indicated that the probabilities that the minimal observed differences are due to chance is .95 for edge damage ($F = .17$, df=4) and 0.56 for abrasion ($F = .74$, df = 4).

There is evidence to suggest that older artifacts are more likely to show such damage than are more recent artifacts (Bernabeu et al. 1998). However, this tendency does not seem to have differentially affected the spatial/temporal distributions of artifact accu-

Table 3. Local Density Coefficients for Grid Squares in Upper Quartile for Settlement Intensity Index at Neighborhood Radius of 200 Meters.

	Grid Squares in Upper Quartile for SII	Grid Squares in 90th Percentile for SII
Neolithic II	4.77223	4.77223
Neolithic I	2.05122	2.49933
Late Upper Paleolithic/ Epipaleolithic	1.29375	1.88684
Upper Paleolithic	1.04983	1.47232
Middle Paleolithic	1.1604	1.92414

Note: Higher values indicate more clustered distributions. Also see Figure 10.

mulations at the temporal and spatial scales employed here. Furthermore, while the majority of artifacts (63 percent) exhibit small amounts of edge damage that might be expected from limited displacement due to cultivation, only a very few (.7 percent) display a combination of surface abrasion and heavy edge damage indicative of significant alluvial transport. The lack of significant effects by erosion and transport on observed spatial patterning strengthens the case that prehistoric land use is the most important accumulating process for artifacts in the Polop Alto valley.

Evaluating Land-Use Dispersion and Aggregation

The overall impression given by the maps in Figure 7 is one of land use becoming increasingly concentrated in fewer locations, while the locales of human activity and/or settlement simultaneously become more intensive and/or larger. This visually apparent change in land-use distribution can be evaluated quantitatively by means of spatial statistics. While the nearest neighbor statistic (R) can be used to evaluate the degree to which spatially distributed objects are clustered, dispersed pairs of grid squares can produce a low R value, mistakenly indicating a highly clustered distribution (Kintigh 1990). Such patterning characterizes pre-Neolithic land use in the Polop Alto. An alternative spatial measure, local density analysis (Johnson 1984; Kintigh 1990), avoids this problem and is employed here.

Local density analysis results are shown in Table 3 and Figure 10 for grid squares with high values of Settlement Intensity Index. Higher values of the local density coefficient (especially values greater than one) indicate tighter, larger clusters. Although meaning for absolute values of the coefficient have been suggested, using them in a relative sense seems most reliable (Kintigh 1990). The results in Table 3 indicate that land use is the least clustered during Upper Paleolithic and considerably more clustered during the Neolithic II than in other temporal intervals; remaining periods display intermediate degrees of clustering with regard to land-use patterns.

Graphs of local density coefficients for different neighborhood sizes indicate the degree of clustering at different scales. Figure 10 shows such graphs for the Polop Alto dataset. To some extent, the shape of the fall-off curves in the graph reflect relative differences in the size and tightness of clusters (see Kintigh 1990). Distributions with large, tight clusters appear as curves that begin with high local density coefficients. Their zone of most rapid fall-off tends to occur at larger neighborhood sizes. Dispersed distributions (including those with small, but dispersed clusters) have high coefficients only at very low neighborhood sizes. They fall off very rapidly to low coefficient values with increasing neighborhood sizes. Neolithic II curves for grid squares in the upper quartile and ninetieth percentile for Settlement Intensity Index are characteristic for comparatively large, tight clusters—matching the visual patterning seen in Figure 7. The Middle Paleolithic through Late Upper Paleolithic/Epipaleolithic curves are typical for dispersed distributions or very small clusters. The Upper Paleolithic curves in Figure 10 indicate the most dispersed distribution of the various time periods. The Neolithic I curve is perhaps the most interesting. While closer to the paleolithic curves than the Neolithic II ones in both graphs, it indicates tighter, slightly larger clusters for grid squares in the upper quartile for SII, but a more dispersed pattern for grid squares in the ninetieth percentile. This reflects the decrease in the use of areas between the main centers of land use in the valley.

Differences in Land-Use Location

In addition to differential amounts of dispersion and aggregation, the location of more intensive land-use changes though time. Table 4 shows the extent of land-use overlap at different time intervals. Land-use overlap is indicated by collection units that have SII

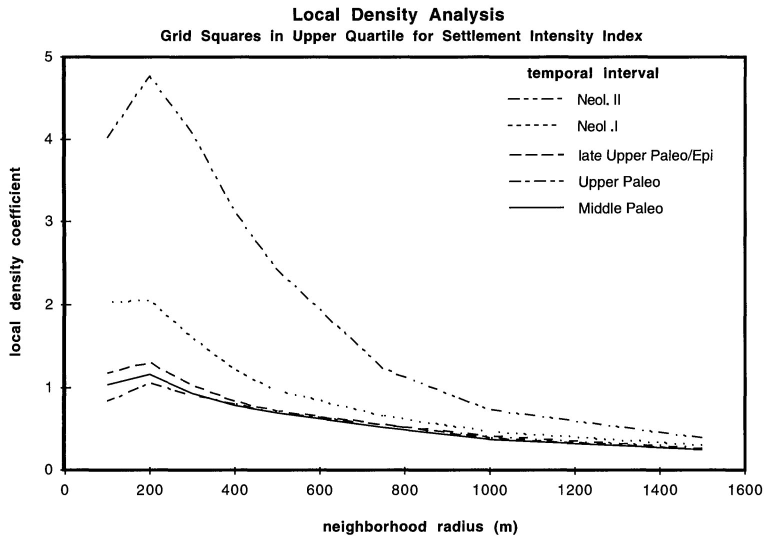


Figure 10a. Local density coefficients for different neighborhood radii. Each line represents grid squares in upper quartile for Settlement Intensity Index for each time period.

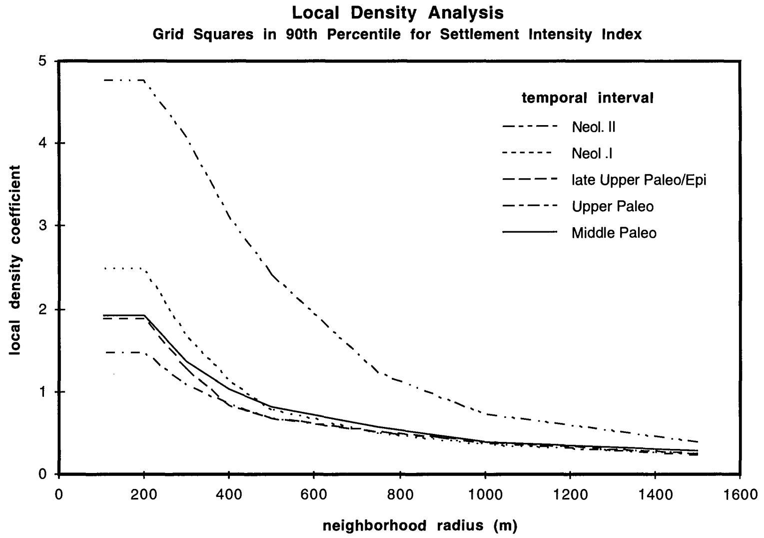


Figure 10b. Local density coefficients for different neighborhood radii. Each line represents grid squares in the ninetieth percentile for Settlement Intensity Index for each time period.

values in the upper quartile for two or more different periods. While 62 percent of the land area most intensively used in the Middle Paleolithic also was used intensively in the Upper Paleolithic, this same area of overlap comprises only 24 percent of the most intensively used part of the Upper Paleolithic landscape. This suggests, like the maps of Figures 4 and 7, that Upper Paleolithic land use was more extensive in the Polop Alto than during the Middle Paleolithic.

There is more similarity in the locations of most intensive land use during the Upper Paleolithic and late Upper Paleolithic/Epipaleolithic. Areas of overlap comprise 62 percent of the most intensively used land in the Upper Paleolithic and 48 percent for the late Upper Paleolithic/Epipaleolithic. The areas of overlap between the Neolithic I and late Upper Paleolithic/Epipaleolithic account for 60 percent of the most intensively used land areas for the late Upper Paleolithic/Epipaleolithic. This overlap comprises a

Table 4a. Area of Land-Use Overlap for Different Time Periods.

	Neolithic II	Neolithic I	Late Upper Paleolithic/ Epipaleolithic	Upper Paleolithic	Middle Paleolithic
Neolithic II	1.05	.42	.45	.52	.15
Neolithic I	.42	1.72	.65	.36	.05
Late Upper Paleolithic/ Epipaleolithic	.45	.65	1.09	.53	.11
Upper Paleolithic	.52	.36	.53	.85	.20
Middle Paleolithic	.15	.05	.11	.20	.33

Note: Values indicate the area (in square kilometers) of land with intensive use (Settlement Intensity Index values in the upper quartile) during both time periods for each pair indicated. For example, the total area of collection units with high SII values for both Neolithic II and Neolithic I is .42 km sq.

Table 4b. Area of Overlap Expressed as Percentage.

	Neolithic II	Neolithic I	Late Upper Paleolithic/ Epipaleolithic	Upper Paleolithic	Middle Paleolithic
Neolithic II	100%	41%	43%	50%	15%
Neolithic I	25%	100%	38%	21%	3%
Late Upper Paleolithic/ Epipaleolithic	41%	60%	100%	48%	10%
Upper Paleolithic	61%	43%	62%	100%	24%
Middle Paleolithic	47%	17%	34%	62%	100%

Note: In each row, values indicate the percentage of the total land intensively occupied (SII in upper quartile) during the row time period that also has evidence of intensive occupation during the time period indicated by each column. For example, 41 percent of the land intensively occupied during the Neolithic II also was intensively occupied during the Neolithic I, but only 25 percent of the land intensively occupied during the Neolithic I also was intensively occupied during the Neolithic II.

somewhat lower fraction of most used Neolithic I areas, at 38 percent. Again, this suggests that land use in the Neolithic I encompassed those areas most intensively used in the preceding period, and also added areas that were previously little used. The Neolithic I differs more strongly from the Upper Paleolithic in this respect, and Neolithic I land use is markedly distinct from that of the Middle Paleolithic—areas of overlap comprise only 17 percent of the most intensively used locales for the Middle Paleolithic and only 3 percent of those for the Neolithic I.

Interestingly, Neolithic II land use displays less similarity with the Neolithic I pattern than it does with land use at any other period, except the Middle Paleolithic. Areas of land use overlap for the Neolithic I and II, amount to 41 percent of the total area most intensively used in the Neolithic II, but only 25 percent of equivalent areas for the Neolithic I. Unlike the patterns described previously, this suggest that most intensive Neolithic II land use (as indicated by artifact discard patterns) took place on a subset of the areas most intensively utilized during the Neolithic I.

Artifact Density and Land-Use Intensity

Examining variation in artifact density by temporal interval provides additional information about land use changes though time in the Polop Alto. Figure 11 shows artifact density for collection units with high Temporal Index values, upper-quartile Settlement Intensity Index values, and SII values in the ninetieth percentile. The pattern of change in artifact density is remarkably similar in all three cases. There is a slight drop in artifact density following the Middle Paleolithic. Artifact density remains low through the rest of the Paleolithic and Epipaleolithic, possibly increasing slightly in the Neolithic I, then rises sharply in Neolithic II. ANOVA results (Figure 11) indicate that the probability that this pattern is due to chance is very low (considerably less than 0.05 for all three graphs).

Because artifact density serves as a proxy for land-use intensity, the slight drop in density values after the Middle Paleolithic, accompanied by the dispersed land-use pattern discussed above is not inconsistent with a shift to slightly greater residential mobility, accompanied by some combination of

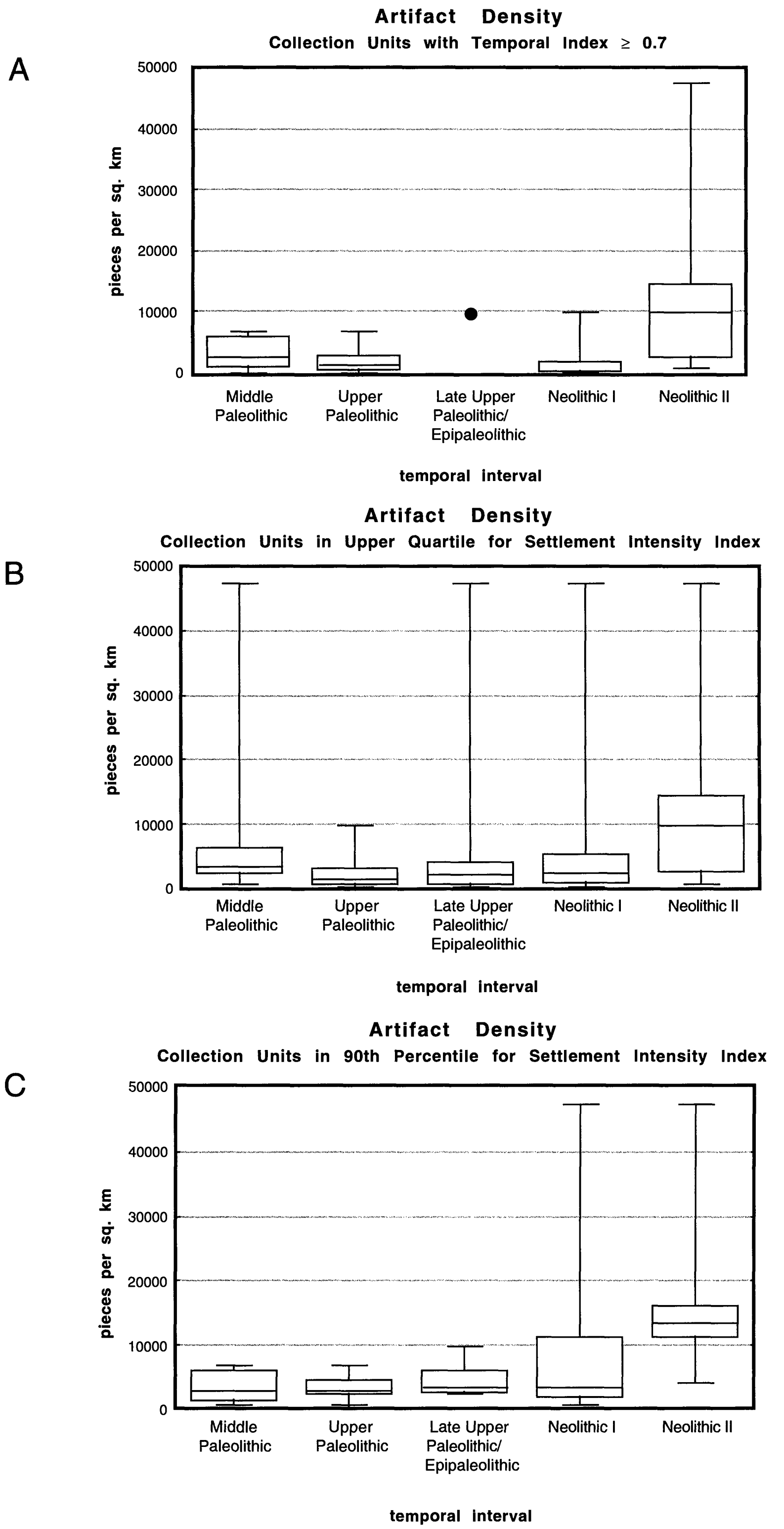


Figure 11. Box and whisker plots (showing median, mid-spread, and range) of artifact density by chronological interval. 11a: artifact density for collection units with Temporal Index ≥ .7 (ANOVA results: F=8.43, p=.00001); 11b: artifact density for collection units with Settlement Intensity Index values in the upper quartile (ANOVA results: F=3.31, p=.01); 11c: artifact density for collection in the ninetieth percentile for SII values (ANOVA results: F=5.29; p=.001). *Note*: In 11a, only one collection unit has a value of ≥ .7 for Late/Upper Paleolithic/Epipaleolithic.

shorter stays at camps, smaller social groups, and/or a shift to longer curation of tools (*sensu* Shott 1996). These all can produce lighter density artifact scatters and accompanying dispersed land-use pattern.

The fact that this pattern of low artifact density persists through the Neolithic I, in spite of the appearance of more aggregated land-use patterns—and with larger areas of most intensive land use—is more consistent with more regular reuse of particular locales while maintaining relatively high residential mobility, than with longer stays and/or larger social groups. The dramatic rise in artifact density in the Neolithic II, along with spatial patterning indicating much more aggregated land use, best fits a model of significantly reduced residential mobility and possibly increased social group size.

Discussion

The data presented above indicate the extent to which human land use is dynamic in a number of different dimensions. These include the degree of dispersion or aggregation, the intensity that particular localities were used, and spatial shifts in the localities used most and least intensively. It must be kept in mind that, in spite of the variability examined here, we can only observe those aspects of land use that leave archaeological traces on the landscape. In this case, those traces are limited to discarded durable artifacts. Other, more recent traces of human land use include the agricultural terraces that cover the Polop Alto today and quite possibly even the modern drainage net in the valley. We mention these simply to note that those aspects of land use revealed in this study are but a part of the story. Nevertheless, they provide valuable information about prehistoric social and economic change.

In the light of the preceding discussion, the Upper Paleolithic seems to represent a period of more extensive, but less intensive land use in the Polop Alto than the Middle Paleolithic. This, in turn, suggests that Upper Paleolithic foragers engaged in more frequent moves and/or shorter stays at particular localities than did Middle Paleolithic foragers. Higher frequencies of retouched artifacts often indicate a higher degree of artifact maintenance, linked to the need to economize on essential transported items of material culture during frequent moves (Barton 1998; Kuhn 1994, 1996; Morrow 1996; Shott 1996). The mean frequency of retouched artifacts in collection units in the upper quartile of SII for the Upper Paleolithic is nearly twice the value for corresponding Middle Paleolithic units (5.4 percent vs. 3.2 percent).

However, this does not necessarily mean that Upper Paleolithic foragers were more residentially mobile overall than Middle Paleolithic foragers, although this could be the case. The pattern seen here could equally be produced by a shift from regular use of the valley by residentially mobile Middle Paleolithic foragers to sporadic visits to the valley by logistic task groups of Upper Paleolithic foragers based elsewhere (perhaps along the Río Serpís). In this respect, there is greater variation in the amount of retouch among Upper Paleolithic assemblages (CV=1.71 for Upper Paleolithic vs. CV=1.17 for Middle Paleolithic), supporting a model of more activity-specific task groups producing Upper Paleolithic accumulations and less differentiated residential camps producing the Middle Paleolithic accumulations. Both increased residential and logistical mobility—with their implications for foraging patterns, demography, and social organization—have been proposed elsewhere in the Mediterranean to help explain aspects of the Middle/Upper Paleolithic transition (e.g., Barton 1998; Marks and Friedel 1977), but a single pattern does not seem universal even within eastern Spain (Villaverde et al. 1998).

The longer time span of the Middle Paleolithic also could have played an important role in producing the observed differences between Middle and Upper Paleolithic artifact accumulations (both here and elsewhere). Longer accumulation spans could produce denser artifact palimpsests in which distinctions in assemblage composition are blurred, and would allow more opportunities for erosion and/or burial to reduce the extent of apparent Middle Paleolithic land use. These alternative explanations (different durations of accumulation and different settlement strategies) are not mutually exclusive and both processes may have contributed to differences between Middle and Upper Paleolithic artifact accumulations.

The late Pleistocene through mid-Holocene displays a different set of land-use dynamics. Beginning with the Late Upper Paleolithic/Epipaleolithic, locales with most intensive land use decline in number and slightly increase in areal extent. In the Neolithic I, small, dispersed use locales all but disappear. Throughout this time, however, there is no appreciable increase in artifact density, with one exception—the most intensively used areas in the Neolithic I (i.e., having SII values in the ninetieth percentile). There are no apparent differences in taphonomic processes to account for these changes. The light density artifact scatters of both periods suggest discard rates roughly equivalent to those of the Upper

Paleolithic and, hence, imply a similar degree of residential mobility in terms of length of stays at any one locale. However, human activities leaving artifactual debris seem to have taken place in fewer, more restricted areas. This seems best explained by a pattern of regular reuse of the same vicinities, leaving low density artifact scatters in restricted areas. In the Neolithic I, there is a slight increase in artifact density for the most intensively used areas (Figure 11c). Although ceramics were first produced at this time, they are present in such small numbers in the relevant surface assemblages that they have virtually no impact on Neolithic I artifact densities. This means that this change represents a real increase in the quantity of artifacts discarded—especially as the time span of artifact accumulation is much shorter for the Neolithic I than it is for the Late Upper Paleolithic/Epipaleolithic. This increase, in turn, could be a product of a reduced frequency of residential moves and/or slightly larger social groups occupying the locales in question. Surface staining that has indicated the presence of semi-subterranean domestic structures at Neolithic II sites (Bernabeu et al. 1994) was noted in one of the areas of most intensive Neolithic I land use. If such structures exist, they indicate an investment in the construction of living structures consistent with longer stays at a locality.

The Neolithic I marks the first clear-cut use of domesticate plants and animals in this region, but the initial effects of these new resources on land-use patterns in the Polop Alto seems minimal. Our data do provide some tentative indications of the way in which domesticates were incorporated into the local forager communities of the economies. In the Neolithic I, there is some initial use of areas not previously utilized to a significant degree. At the same time, small, dispersed land-use localities virtually disappear and artifact densities in the most intensively used locales increase slightly. Taken together, these facts suggest less effort devoted to collecting resources at some distance from primary occupation localities and more effort devoted to acquiring resources nearer to these localities. Given that a larger foraging area tends to encompass a wider variety of resources than a smaller one, such a reduction in effective foraging area could be associated with reduced diet breadth. Optimal foraging models suggest that decreased diet breadth is a result of greater returns from highly ranked resources or, similarly, the introduction of new highly ranked resources causing lower-ranked foods to be dropped from the diet (Bettinger 1991:84–90; Kelly 1995: 78–90). Hence, rather than replacing a foraging economy or directly replacing selected wild plants and animals, domesticates may have entered forager economies in the Polop Alto as relatively highly ranked food resources with the result of the loss of a suite of lower-ranked resources and concomitant decrease in diet breadth. While there is no direct evidence that the introduction of domesticates is responsible for the slight changes in land use seen in the Neolithic I, settlement strategies often are closely tied to economy (Binford 1980; Kelly 1983, 1995: 111–160).

If domesticates were added into a diverse forager subsistence economy rather than replacing it with a distinct horticultural economy, it could help to explain why significant changes in land use are not seen after the Pleistocene/Holocene boundary in the Polop until several millennia after the initial introduction of domesticates. In other words, the initial incorporation of domesticates into mid-Holocene economies in the Polop Alto did not result in new selective pressures (e.g., demographic change or time stress) that initially favored dramatically different configurations of land use and/or social organization. As with the Middle-Upper Paleolithic transition, however, it is likely the picture is even more complicated. Analysis of our survey data from other valleys suggests that the initial appearance of domesticates may have had a greater initial impact on land use elsewhere (Bernabeu et al. 1998).

The Neolithic II exhibits the most dramatic change in land use for the nearly 100,000 years of human occupation in the Polop Alto investigated here, centering on a single, well-defined locale, much larger than prior areas of most intensive land use. There are two much smaller areas of relatively intensive land use to the east and west respectively. This pattern shows up visually in Figure 7 and in the local density analysis. Furthermore, artifact density in these areas is much higher than seen for earlier time periods. This suggests that most human activities (at least those producing artifact accumulations) occurred within a very restricted spatial context, and that these activities also generated more discarded artifacts per square meter than previously. While various areas of the valley were probably utilized by the Neolithic II occupants, most durable artifacts used to carry out relevant tasks (and presumably any resources collected) were returned to the central locality and eventually discarded there. Also, most processing activities that generated discarded artifacts seem to have taken place at this central locality. Surface staining noted at the large, central locality is similar to staining identified as semi-subterranean domestic and other structures at excavated Neolithic II sites (Bernabeu et al. 1994). While a short-term occupation by a large social group could produce this pattern, it seems most parsimoniously explained by greatly reduced residential mobility—especially given the paucity of evidence for notable Neolithic II land use elsewhere in the Polop Alto.

The two, compact outlying locales are exceptions to the tendency to discard artifacts at the central settlement. Both are located along the primary paleodrainage of the valley and, in both instances, very restricted areas were visited repeatedly or were occupied for sufficient time to produce significant artifact accumulations. A reasonable (although admittedly speculative) explanation for these localities is that they represent places where a few individuals regularly visited while working or watching agricultural fields.

The overall objective of our research project in eastern Spain is to gain a better understanding of the spatial and temporal dynamics of human land use in the late Pleistocene and early Holocene. Archaeologists have long recognized that land use provides important clues to economic and social organization. However, initializing research programs to systematically study land-use dynamics has been difficult in many cases (Dunnell 1992). In the Polop Alto and the other valleys we are studying in eastern Spain, we are developing methodological and analytical tools to study prehistoric human land use from a landscape rather than a site-focused perspective. We do not claim that these methods are applicable everywhere, but they are well suited to modern landscapes characterized by small fields and a long history of agriculture—settings common throughout much of Europe (e.g., Zvelebil et al. 1992) and in many other parts of the world. Human activities are played out at a regional scale rather than at a single site. Dynamic modeling of regional land-use patterns will help us to better interpret the information derived from excavated sites, and better understand the processes responsible for social change.

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Notes

1. Dates in uppercase (i.e., "B.C.") are in calibrated years B.C. Those in lowercase (bc or bp) are uncalibrated.

2. The aerial photographs were analyzed in NIH Image imaging-processing software to isolate and smooth zones of the bright white marls. The greyscale photos (256 shades) were thresholded at pixel values of 20 to isolate the most eroded areas. The image was then inverted and filtered through several smoothing operations (2 "dilations" followed by 2 "closes"). This produced an image of the eroded areas which was imported into MapInfo where the eroded zones were digitized. The digitized, eroded zones were then overlayed over the collection unit polygons and used to cut out the areas where they overlapped. The areas of the resultant, smaller collection unit polygons were then used to calculate artifact density for those areas. The reasoning behind this procedure was the observation that all prehistoric artifacts were found only in uneroded areas. Hence, computing their density on the basis of the uneroded part of collection units is more realistic than computing density on the basis of both eroded (i.e., lacking artifact) and uneroded parts.

3. Collection units were grouped into 6 quantiles according to artifact frequency. In addition to addressing the noncomparability of raw values for SII among different time

intervals, it served to reduce the effects on SII of a few outlier units with extreme values for artifact density. The groups were units with no artifacts (assigned a value of 0), units with frequencies in the lowest 25th percentile for all collection units (assigned 0.25), units in the 26–50th percentile (assigned 0.50), units in the 51–75th percentile (assigned 0.75), units in the 75–90th percentile (assigned 0.90), and units in the 90th percentile (assigned 1.00). The assigned quantile group values for artifact density were multiplied by the TI value for each unit for each chronological period. In this way, a collection unit could have a high SII value for one or more periods and low values for others; it also could have equally high values (if it had many artifacts and clear temporal signals) or low values (few artifacts and/or ambiguous temporal signals) for all periods. While this procedure does not allow us to divide an artifact assemblage from a collection unit into temporally distinct components, it does allow us to quantitatively estimate the relative contribution to that assemblage of temporally distinct episodes of artifact deposition. This, in turn, makes it possible to model variation in occupational intensity (and associated artifact discard) for collection unit through time and, at a regional scale, to model changing land-use patterns in the Polop Alto valley.

4. The grid size chosen, 100 x 100m, is close to the minimum collection unit size so as not to greatly exceed the resolution of the original data. SII values were assigned to grid squares on the basis of a proportional area weighted average of the SII values of the underlying collection units. Grid squares wholly overlaying a single collection unit were assigned the SII value from that unit; those overlaying more than one unit were assigned an average value of the underlying units, weighted by the percent area of the square that overlay each unit. This has the added benefit of spatially smoothing SII distribution and making the visual recognition of spatial patterning easier.

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