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## The Impact of Radiocarbon Dating on Old World Archaeology: Past Achievements and Future Expectations

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## THE IMPACT OF RADIOCARBON DATING ON OLD WORLD ARCHAEOLOGY: PAST ACHIEVEMENTS AND FUTURE EXPECTATIONS

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### INTRODUCTION

Half a century since radiocarbon was first used in the archaeology of the Old World, it seems that the expectations of W F Libby may be becoming a reality. In 1952 (Libby 1952:97), he wrote:

Archaeologists, geologists and palynologists are continually searching for the means to improve methods of counting time. The . . . relative chronologies lack precision and direct correlation with the calendar, except when they may be checked with, . . . for example, the calendar based on tree-ring counts.

Two achievements that have gone some way towards realizing this goal are the use of accelerator mass spectrometry (AMS) techniques (e.g. Taylor 1997) and of calibration curves (e.g. Stuiver et al. 1993, 1998). We are still only at the threshold of seeing the impact of these two crucial advances on some strongly debated archaeological issues.

Since the end of the 18th century, some basic questions that cannot be answered without accurate dates have been at the heart of archaeological research. Practice has demonstrated that the long sequence of human evolution, from the time hominids created durable remains, the early colonization of Eurasia or even the first dispersals of Modern humans, are beyond the upper reach of  $^{14}\text{C}$  techniques.

During the last five decades, traditional  $^{14}\text{C}$  dating techniques have made numerous contributions to the archaeology of the Old World. These are evidenced in a vast literature that reports and discusses the evolution of social and cultural entities recorded from over the last 40,000 years. Terminologies may vary across Eurasia and Africa, but in the most encompassing definitions, this is a world that shifted from foraging lifestyles to farming and herding modes of production, which were then followed by the emergence of urbanism and the ensuing industrial revolution.

During these 50 years, archaeologists, geoarchaeologists, and archeobotanists have used the services of an ever-increasing number of  $^{14}\text{C}$  laboratories. In many of them, one notes a growing awareness of the need for the active participation of an experienced field archaeologist throughout the entire process, from collecting the samples and the gathering of relevant information, through laboratory operations, and the final evaluation and write-up of the results. While all this is known to the readers, and the contributions that are being made to various archaeological questions are important, there are, in the author's view, two major concerns in Old World archaeology that are of common interest to a majority of archaeologists and world historians. The advancements in dating these past events or processes will have a far-reaching impact on the interpretation of cultural history.

The two main problems are the transition from the Middle to the Upper Paleolithic, a cultural revolution which has also been labeled a "creative explosion" (Pfeiffer 1982), and the origin of plant cultivation in the two presumed centers of early agriculture, namely, the Levant in Western Asia and the middle Yangtze region of China. Precise dating of archaeological contexts and assemblages of plants and animal bones derived from well-excavated sites in these two centers will undoubtedly facilitate the resolution of long-lasting debates concerning the "where" and "when" issues of these events. The more controversial aspect of both inquiries, the "why" question, will undoubtedly

remain open to scholarly opinions as diverse as there are approaches to world cultural history. Each of these major transitions is summarized below, followed by a brief discussion incorporating future expectations.

### **The Middle to Upper Paleolithic Revolution**

Almost no one is seeking the origins of the Middle/Upper Paleolithic revolution in Western Europe, although everyone, including the media, is using the archaeological record from this region to characterize the differences between two populations—the Neandertals and Cro-Magnons. Most writers who present their views on this transition consider it to be a technological and cultural revolution (e.g. Gilman 1984; Gamble 1986; Mellars 1989; White 1989; Stringer and Gamble 1993; Mellars 1996a, 1996b; Mithen 1996; Marshack 1997; White 1997). A few follow the suggestion (Klein 1995, 1999) that it was triggered by a neurological change in the “near-Modern Humans” some 50,000 years ago, which has recently gained further support from a genetic study (Quintana-Murci et al. 1999). However, there are others (e.g. Clark 1997; Straus 1997) who regard the transition as a gradual change that took place on a regional scale. Several scholars suggest that the latest West European Neandertals had demonstrated their innovative capacities before encountering the incoming Cro-Magnons. The arguments for one or another of the alternative interpretations rely heavily on the available  $^{14}\text{C}$  dates, a proposed synchronization between TL, ESR and  $^{14}\text{C}$  dates, and the drive to reach a calendrical chronology (D’Errico et al. 1998; Zilhão and D’Errico 1999a *contra* Mellars et al. 1999; see also Van der Plicht 1999 *contra* Van Andel 1998).

Elsewhere, I have suggested that by employing models that explain the Neolithic revolution we may gain insights into the techno-cultural revolution that occurred some 50,000–40,000 years earlier (Bar-Yosef 1992, 1994, 1998c). This analytical procedure would be similar to employing studies of the Industrial Revolution as sources for testing hypotheses concerning the Neolithic revolution.

The common denominators for all three of these revolutions include the emergence of new technology in a “core area,” and its dispersal (with or without the cultural baggage) by migrating groups, or by diffusion. Study of the historical process can determine “where” and “when” techno-cultural changes occurred and how long it took for the ensuing diffusion, migration, and impacts to affect the neighboring regions. The “why” question remains within the domain of speculation. In all cases, the precise dates play an important role, and it is in this field that the various dating techniques can make major contributions.

Currently, there are only a few archaeological indications that East Africa (Ambrose 1998a, 1998b; Klein 1999), South Africa, the Nile Valley (Van Peer 1998), or the Levant (Sherratt 1997) may have been the original locus of the Middle/Upper Paleolithic revolution. Other proposals point in the direction of central Asia or Anatolia (e.g. Otte 1998). The paucity of field research in East Africa and dated sites in the Nile Valley, however, must leave all options open.

Most late Middle Paleolithic or Mousterian sites in the Levant and Northeast Africa are dated at 60 to 50/45 ka BP on the basis of thermoluminescence (TL) and electron spin resonance (ESR) measurements as well as  $^{14}\text{C}$  dates >46,000 BP (Bar-Yosef et al. 1996; Bar-Yosef 1998a; Van Peer 1998). Culturally, the end of the Levantine Middle Paleolithic is marked by the appearance of Early Upper Paleolithic (EUP) assemblages in several sites (Figure 1). When assemblages of both periods are compared across the chronological boundary, the change seems to represent a technological revolution (e.g. Marks 1993; Bar-Yosef 1998c). The paucity of bone and/or antler objects and the rarity of marine shell beads from EUP contexts have made the lithic assemblages the main source of information.

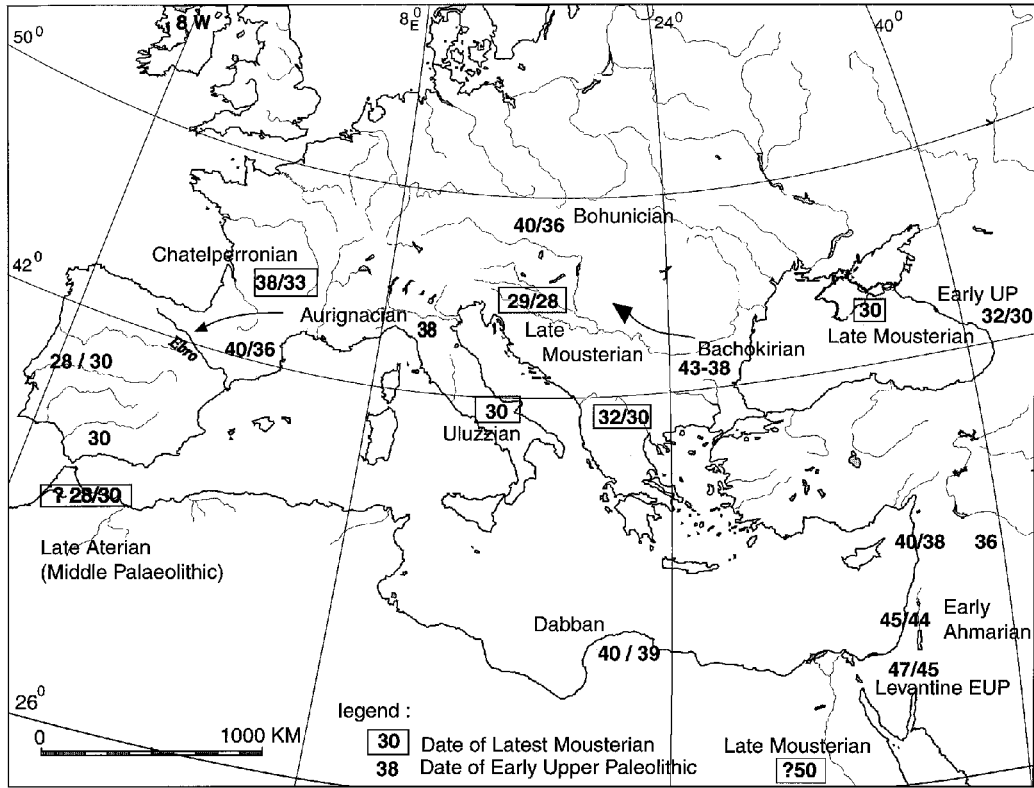


Figure 1 Map of Western Eurasia and North Africa indicating dates of the Latest Mousterian (in boxes) and Early Upper Paleolithic in various regions. The dates are a combination of TL, ESR, and radiocarbon uncalibrated readings.

The image of the pan-Levantine EUP lithic industries is rather complex, mainly due to the small number of sites, the chronological ambiguities (on which future work is required), and the presence of particular local tool types that make long distance correlations uncertain. The main sites are Ksar ‘Akil (Lebanon), Emireh cave and Boker Tachtit (Israel), Umm el Tiel (Syria), and Üçagizli (Turkey) (Garrod 1955; Marks 1983; Ohnuma 1988; Bourguignon 1996; Kuhn et al. 1999).

Boker Tachtit, in the Negev Highlands, which dated to 47 and 46 ka BP (Marks 1983), has produced cores and their refitted blanks (Volkman 1983) that demonstrate the change in how the flint knappers conceived the volume of the flint nodule. Levallois points, typological markers of the late Mousterian, were now shaped by bi-directional detachments, thus differing from their predecessors. The shift in methods of stone tool production possibly responded to a change in hafting projectiles, and the invention of spear throwers. Other special projectile points are known as Emireh points—the common tool type in Emireh cave and Boker Tachtit.

In Ksar ‘Akil, Lebanon, manufacturers preferred simpler points and special scrapers known as “chamfered pieces”, where the working edge was shaped by a side blow (Newcomer 1970; Bergman et al. 1988; Ohnuma and Bergman 1990). Similar tools were found in Abri Antelias, a neighboring site with one Emireh point, and in Abu Halka, some 30 km further north. Interestingly, the EUP of Haua Fteah cave in Cyrenaica (Libya), named the Dabban culture, is also rich in chamfered pieces,

although the precise nature of the relationship between the Libyan sites and those in Lebanon is as yet unknown (McBurney 1967).

In northeast Syria, the site of Umm el Tlel produced an industry of points and blades made by unidirectional percussion. All the stone tools are, without a doubt, from the Upper Paleolithic, although the special Emireh point and the chamfered pieces are absent (Bourguignon 1996). Interestingly, the AMS date for layer III2A is  $34,530 \pm 750$  BP (Gif A-93216) and the TL date is  $36 \pm 2.5$  ka (Gif A-93215).

Additional assemblages were uncovered in Üçagizli and Kanal caves (Kuhn et al. 1999), where a blade-based industry resembles that of Umm el Tlel, with end scrapers, burins, and retouched blades. The presence of marine shell beads is noteworthy. Two AMS dates of  $39,400 \pm 1200$  BP (AA-27994) and  $38,900 \pm 1100$  BP (AA-27995) place the assemblage from Üçagizli within the range of the EUP industries of the Levant.

It is generally agreed that  $^{14}\text{C}$  dates earlier than 30,000 BP should be considered as recording minimal ages. However, Van Andel (1998) has suggested that dates older than 38/39 ka BP are again closer to the real ages and do not underestimate the true age, as is the case for dates younger than 30 ka. Van der Plicht (1999) disagrees. Additional uncertainties arise from the use of different laboratories and the possible contamination of charcoal by bioturbation. In this respect, advancements in dating techniques in recent years should allow us to synchronize TL, ESR, and  $^{14}\text{C}$  dates from late Middle and EUP sites in the Levantine sequence. Unfortunately, the size of the time difference between the uncalibrated  $^{14}\text{C}$  years and TL and ESR years has various estimates. The proposal that  $^{14}\text{C}$  dates in this range (earlier than 30 ka) are younger than the TL and ESR ages only by 3–4 ka (Mellars et al. 1999 and references therein), is in need of further testing. In one case, the  $^{14}\text{C}$  dates from Umm el Tlel are only about 2 ka younger than the TL date, and lie within the standard deviation of the latter.

Another proposal to combine the results of the two dating techniques was undertaken in Kebara cave (Bar-Yosef et al. 1996). TL measurements place the upper part of the Mousterian sequence in Kebara at  $48.3 \pm 3.5$  ka (Valladas et al. 1987), although there are no secure dates for the latest occupation. The EUP assemblages, which are definitely younger than the phase containing the Emireh points, were  $^{14}\text{C}$  dated to 43/42 ka. It was therefore suggested that a cautious estimate of 46/45 ka BP for the MP/UP transition seems reasonable, and the gap in the Kebara sequence from 46/45 ka to 43 ka lends credence to the  $^{14}\text{C}$  dates for the Boker Tachtit Level I (47 and 46 ka; Marks 1983).

Another option in dating the boundary between the Middle and the Upper Paleolithic in the Levant is to employ the dates available for the Ksar 'Akil sequence. Mellars and Tixier (1989), similarly to McBurney in his study of the cave of Haua Fteah (Libya), estimated the rate of sedimentation for this site. Eleven AMS readings of charcoal samples from Ksar 'Akil, in addition to the previously obtained  $^{14}\text{C}$  dates, allowed them to estimate the cultural transition as taking place around 50 ka. Surprisingly, the U-series disequilibrium dates on two bone samples produced earlier, by scientists who cautioned against accepting them without reservation (Van der Plicht et al. 1989), provided similar results. The bone dates are given as "surface" and "bulk" material, and are as follows: for layer XXVI (youngest Mousterian level)  $47 \pm 9$  ka (G-88174S) and  $19 \pm 5$  ka (G-88173B); and for layer XXXII (Mousterian)  $51 \pm 4$  (G-88177S) and  $49 \pm 5$  (G-88178B).

The situation in the Taurus and on the Anatolian plateau is poorly known (Yalçinkaya et al. 1993; Otte et al. 1995; Kozłowski 1998), with the exception of the latest Mousterian layers at Karain cave

(Antalya province), which were ESR dated to  $62.0 \pm 10.1$  to  $71.6 \pm 11.4$  ka (EU), or  $65.5 \pm 10.6$  to  $74.4 \pm 11.8$  ka (LU) (Çetin et al. 1994). No dates are available for the EUP in this vast region.

The state of dating in the Zagros, where several cave sites have been excavated, is not much better (Solecki 1963, 1964; Dibble 1993; Dibble and Holdaway 1993; Solecki and Solecki 1993). The  $^{14}\text{C}$  results of 46 and 50 ka from layer D in Shanidar, where several of the Neandertal remains were uncovered, could be argued as simply minimal dates, or as indicating the persistence of the Middle Paleolithic in this mountainous region. The Upper Paleolithic industry known as the Baradostian is dated by a series of readings to 33–28 ka, and in Yafteh cave to the same range (Smith 1986). The absence of the EUP from this site and the other known caves lends temporary support to this interpretation. Further north, in the Caucasus region, similar Mousterian industries seem to be of the same, late age (Kozłowski 1998; Golovanova et al. 1999; Figure 1).

Broadening the geographic scope of the present overview, namely, the dating of the late Middle Paleolithic and EUP, introduces additional evidence for what may have been a patchy colonization of Cro-Magnons across Eurasia (Figure 1). In Crimea, producers of the Mousterian industry survived until 29 ka BP, and the early EUP—dated to 30 ka BP—is interpreted as demonstrating a short coexistence of two populations (Marks and Chabai 1998; Rink et al. 1998). In Greece, the late Mousterian is dated to 32–30 ka BP by a series of  $^{14}\text{C}$  dates from Theopetra cave in Thessaly, supported by the earliest dates for the EUP in Klisoura cave 1, in the Argolid (Karkanas 1999; Kyparissi-Apostolika 1999; Koumouzelis et al. forthcoming). The late survival of Neandertals is also evidenced in the direct dates of the human bones from Vindija cave in Croatia, which place these relics at 28 ka BP (Smith et al. 1999).

On the other hand, an EUP industry known as the Bohunician is dated in Bohemia to 40–36 ka BP (Svoboda and Simán 1989). Further west, the earliest Aurignacian in northeast Spain dates to 40–37 ka BP (e.g. Bischoff et al. 1989, 1994; Cabrera and Bernaldo de Quirós 1996; Straus 1996; Mellars et al. 1999). The persistence of the Mousterian in southern Italy (Kuhn and Bietti, forthcoming) and in Iberia south of the Ebro valley until about 30 ka BP is, in most cases, founded on numerous  $^{14}\text{C}$  dates for the late Mousterian and EUP (Raposo and Santonja 1995; Barton et al. 1999; Zilhão and D’Errico 1999a, 1999b; Carbonell et al. forthcoming). Figure 1 presents an overall geographic summary. Although boundaries between the Neandertal and Cro-Magnon territories are not marked, the question is raised of whether Neandertal populations across southern Europe continued to be in touch with each other after 40–38 ka BP, or became isolated groups. Small populations, as modeled by Zubrow (1989), if not intermarrying with incoming groups, could disappear within a relatively short period.

There is little doubt today that the rapid cultural changes through the Upper Paleolithic times reflect the results of a major revolution. There were significant technological and social changes, but they are not easy to decipher, due to the grain of chronological resolution as presented above. As with other revolutions, the nature of the changes is better documented after a certain lapse of time, when the new cultural expressions stand in contrast to those of pre-revolutionary times. In the case of the European sequence, the proliferation of lithic blade industries, antler and bone tools, mobile art objects, and cave art (in the Franco-Cantabrian region) gives a good example. In the Near East—despite the more ephemeral character of the Upper Paleolithic sites—the evolved blade technology, the appearance of grinding tools, and the modest use of bone, antler and marine shells mark the cultural shift. That the change was rapid is clearly demonstrated by the radiometric scale. From 270/250 ka through 48/46 ka BP, Mousterian lithic industries were pre-eminent, while from 45/42 ka BP

onwards, laminar industries formed the basic stone tool-kits, and involved the use of various raw materials, while the appearance of imagery was seen.

### **Origins of Agriculture in Western Asia**

The agricultural revolution, or as it is known in the archaeological literature, the “Neolithic Revolution”, is a topic that has attracted historians, archaeologists and botanists since the 19th century. The impact of plant cultivation by sedentary communities on human diets and rates of reproduction is considered the crucial threshold that caused rapid population growth in many parts of the world during the Holocene (e.g. Bar-Yosef 1998c; Cohen 1977; Harris 1998a, 1998b; Smith 1998).

As with all important past revolutions, the emergence of plant cultivation some 11,000 years ago, followed by animal domestication, is evaluated on the basis of its outcome. Gradualists see the cultural and socio-economic changes as a slow process that took thousands of years to complete. Others view the change as radical and rapid. The question of “why” a particular change took place is often the most debated. Once there are records based on field and laboratory observations, however, archaeologists tend to agree on the “when” and “where” aspects of the studied revolution. It is in both these aspects that AMS  $^{14}\text{C}$  measurements, especially when calibrated, can revolutionize past understandings and pose additional challenges.

The Fertile Crescent of western Asia and the Yangtze River valley are considered the two oldest centers of the transition to agriculture in the Old World (Smith 1998). Like other major revolutions in history, the Neolithic revolution began in a core area. The locus of early cultivation practiced by Neolithic villagers is still uncertain. Past hypotheses placed incipient farming in the natural habitat of cereals (Braidwood 1975), or at the edges of the main distribution of the progenitors, namely, in the marginal belt where foragers experienced decreasing yields in plant food resources in the face of prolonged worsening of environmental conditions (e.g. Binford 1968; Flannery 1973).

Archeobotanical evidence of carbonized plant remains from Neolithic sites in the Levant points to the location in which cultivation began (e.g. Harris and Hillman 1989; Miller 1992, 1997; Hillman 1996; Heun et al. 1997; Harris 1998a). There is little doubt today that systematic cultivation and harvesting in the same fields year after year resulted in the domestication of plant species (Zohary 1989; Zohary and Hopf 1994; Bar-Yosef and Meadow 1995; Harris 1996a, 1996b, 1998b). Once communities of cultivating foragers were established, the domestication of goats and sheep was initiated (Legge 1996), followed later by cattle and pigs (Uerpmann 1989).

The search for the earliest farming communities began with the pioneering project of R Braidwood (1952, 1973, 1983), which targeted the hilly flanks of the Zagros, where wild cereal species grow today. His choice relied on botanical surveys that mapped the distribution of the various *Cerealia* species across western Asia (Harlan and Zohary 1966; Harlan 1977; Zohary and Hopf 1994). Unfortunately, at the time these surveys were conducted, the impact on the vegetation of Terminal Pleistocene–Early Holocene climatic fluctuations was not taken into account, a fact realized only later (Wright Jr 1993).

In the late 1990s, archaeologists and archeobotanists began to create an evolutionary scenario based on various kinds of data sets. First, information retrieved from pollen cores and the deep-sea cores from the Eastern Mediterranean provides the distribution of the paleo-phytogeographical belts (Van Zeist and Bottema 1991; Roberts and Wright Jr 1993; Baruch 1994; Bottema 1995; Rossignol-Strick 1995, 1997; Hillman 1996). Adopting the correction for hard-water effects on  $^{14}\text{C}$  dates in inland lakes, proposed by Rossignol-Strick (1995), established sound correlations between marine

and terrestrial pollen cores. According to this scheme, the Younger Dryas is signified by the abundance of Chenopodiaceae, followed by an increase in deciduous oak pollen that marks the early millennia of the Holocene and reflects the increase in annual precipitation.

Second, there is a general agreement on the identification of the Younger Dryas, whether in marine sediments, lake cores, or speleothems (Wright Jr 1993; Rossignol-Strick 1995; Hillman 1996; Landmann et al. 1996; Bar-Mathews et al. 1997, 1999; Lemcke and Sturm 1997; Fontugne et al. 1999; Frumkin et al. 1999). The conditions prevailing during the Younger Dryas are crucial in interpreting the archaeological remains, and, unfortunately, the dating of this period in the Near East is not without difficulties. According to the ice cores, the Younger Dryas lasted from 12.9 to 11.6 ka (Alley et al. 1993; Mayewski et al. 1996), while in the varve sequence of Lake Van in eastern Turkey (Lemcke and Sturm 1997), this cold and dry period was longer by around 800 years.

The third source of data is carbonized plant remains, which indicate “where” within the region various seeds were collected (Hillman et al. 1989; Hillman 1996; Kislev 1997). The seeds, if in secure archaeological context, often provide more precise dates for the “when” question, especially through AMS measurements. Although the number of directly dated seeds is currently rather small, the growing awareness among archaeologists and archeobotanists that this is the way forward facilitates the testing of several hypotheses in the near future. Meanwhile, available charcoal dates already provide an interesting picture, whether at the level of a particular site, or across a micro-region such as the Jordan Valley (Figures 2–5).

A brief summary of the paleoclimatic sequence of the Terminal Pleistocene, following the Last Glacial Maximum (LGM), would begin with an increase of annual precipitation and a slow temperature rise from around 15,500 BP. The typical eastern Mediterranean cycle of wet, cold winters and dry, hot summers was established during this period and not later, as was suggested previously (McCormiston and Hole 1991; Wright Jr 1993). The rapid expansion of oaks (mainly the deciduous *Q. ithaburensis*), olives, and pistachio (which is always misrepresented in the samples due to low pollen production), as well as the cereals, which were present in the region from 19,000 BP, testify to this annual climatic pattern (Baruch and Bottema 1991).

The ensuing changes are recorded in the terrestrial pollen diagrams and were plotted fairly recently by Hillman (1996) as two vegetation maps for Western Asia, for 13 and 11 ka BP (uncalibrated), respectively. These maps, although based on the terrestrial pollen cores (see above), demonstrate the expansion of three plant associations as follows: 1) forests and woodland in the Mediterranean coastal plain and hilly ranges, 2) oak-terenbinth, a mosaic of woodland and open areas dominated by annual grasses further inland, and 3) terenbinth-almond woodland-steppe that phases into the desertic Saharo-Arabian associations (Zohary 1973).

The natural stands of wild cereals are within the last two belts and often appear as grasses in the oak parkland. The expansion of the Mediterranean vegetation and especially of the natural habitats of the cereals resulted from increases in rainfall and temperatures. The prevailing climatic conditions of the Bölling/Allerød (ca. 15,000–13,000 cal BP) favored the growth of C3 plants (Sage 1995), used by Levantine foragers from at least 19,000 BP onwards (Kislev et al. 1992). The improved conditions seem to have served as an impetus for intensive exploitation of cereals and legumes, as well as fruit trees and acorns. The archaeological evidence indicates an increase in sedentism, a broad-based economy relying on extensive exploitation, and the emergence of a complex hunter-gatherer society known as the Natufian culture (Figures 2–3; Henry 1989; Belfer-Cohen 1991; Bar-Yosef 1998b).



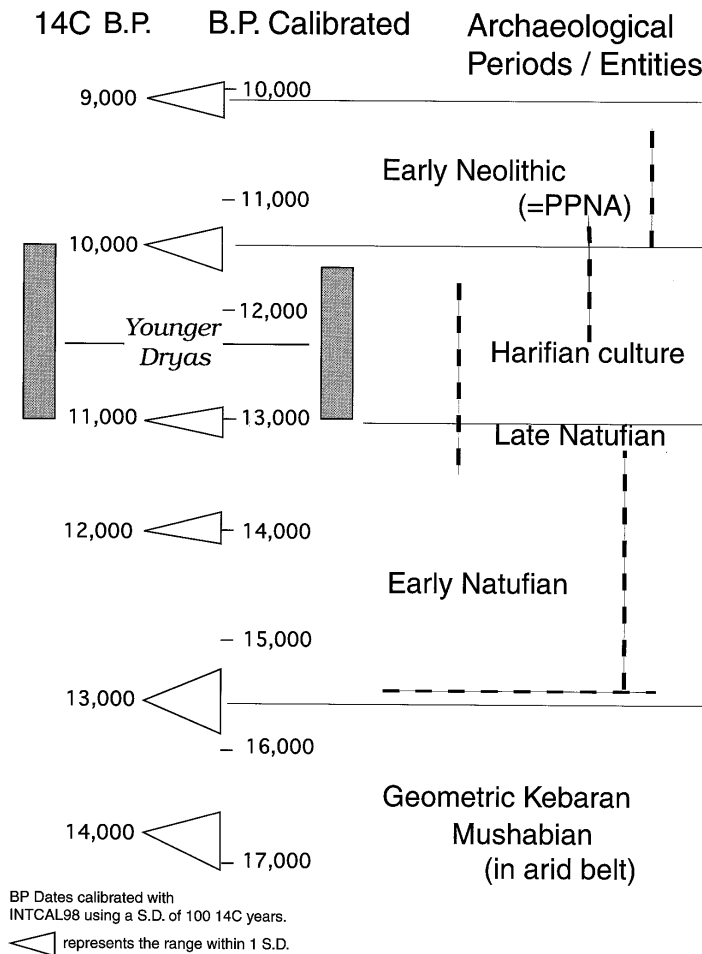


Figure 2 Calibrated generalized chronology for the Terminal Pleistocene and Early Holocene of the Levant, indicating both uncalibrated and calibrated BP dates. The figure demonstrates that the Earliest Neolithic actually began during the Younger Dryas.

The proliferation in recent years in the number of <sup>14</sup>C dates reveals that the dry and cold climate of the Younger Dryas was probably the main cause for the initiation of systematic cultivation (Bar-Yosef and Belfer-Cohen 1992; Moore and Hillman 1992; Bar-Yosef 1998a; Hole 1998). The crisis of the Younger Dryas, which lasted for about  $1300 \pm 70$  yr (Alley et al. 1993; Mayewski et al. 1993), was due to its effect on the vegetation of Western Asia. It stopped the advance of the woodland into higher altitudes inland (in the Taurus and Zagros Mountains) and reduced the belt of oak and terebinth. This reconstructed scenario is supported by the identification of carbonized plant remains from Mureybet (Van Zeist 1986; Van Zeist and Bakker-Herres 1986) and Abu Hureyra (Hillman et al. 1989; Moore and Hillman 1992; Figures 3–5), where cereals decreased; and Halan Çemi, which, on a more eastward tributary of the Tigris, by that time had no cereals present (Rosenberg et al. 1995).

Human acts are seen as the results of social decisions. It is hypothesized that the determining decision in favor of intentional cultivation was taken in the face of decreasing yields of cereals in the wild

stands, in combination with the recognition that other economic solutions, such as becoming more mobile, given the regional population densities, were not the optimal way to minimize risk. The assumed depletion in the natural yields is a testable hypothesis. It relies on the slight decrease in atmospheric CO<sub>2</sub> values during the Younger Dryas as the limiting factor in the distribution of the oak-terebinth belt, and in particular, in the declining annual returns among C3 plants such as the cereals, which had become a major source of carbohydrates for Levantine foragers (Bar-Yosef and Meadow 1995). The paleo-phytogeographical reconstruction points to a relatively narrow strip in the Levant in which the progenitors of most cereal species grew (Hillman 1996). This belt, although a series of delineated areas (Van Andel and Runnels 1995) also known as the “Levantine Corridor,” became the locus in Western Asia in which the first agricultural communities were founded (Figure 4; Bar-Yosef and Meadow 1995; Bar-Yosef 1998c). The decision for economic change was probably not an easy one. It entailed the re-organization of the division of labor, seasonal scheduling of work, allocation of energy expenditure at different times of the year, and the like. However, the stable provision of a staple food meant an increase in the fertility rates, which, despite rising infant and toddler deaths (evidenced in burials), resulted in relatively rapid population growth (Bentley et al. 1993; Bentley 1996).

The return to increasing CO<sub>2</sub> levels and higher annual amounts of precipitation during the early Holocene provided conditions suitable for successful cultivation (e.g. Araus et al. 1999). Hence, early farming communities—known archaeologically in the Levant as Pre-Pottery Neolithic A (PPNA)—and particularly their descendants—during the Pre-Pottery Neolithic B (PPNB)—flourished (Figure 5). The ensuing off-shoot villages resulted in emigration and demic-diffusion into Europe, the Mediterranean islands, northeast Africa, and southern and central Asia (Ammerman and Cavalli-Sforza 1984; Wetterstrom 1993, 1998; Van Andel and Runnels 1995; Meadow 1998). At the same time, the wetter and warming climate of the early Holocene facilitated the larger geographic dispersal of the wild-cereal progenitors, at later times reaching the current distribution.

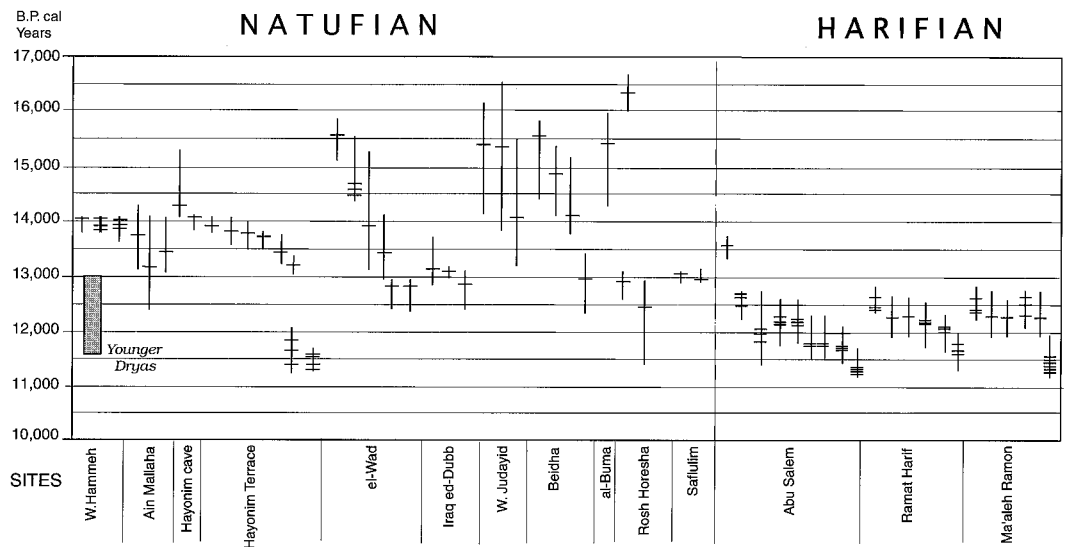


Figure 3 Calibrated dates for the Natufian (both Early and Late) and the Harifian (a desertic entity in the Negev and northern Sinai). A general correlation between the onset of the Bölling/Allerød and the emergence of the Natufian culture is suggested, as is the contemporaneity of the Natufian and Harifian with the Younger Dryas.

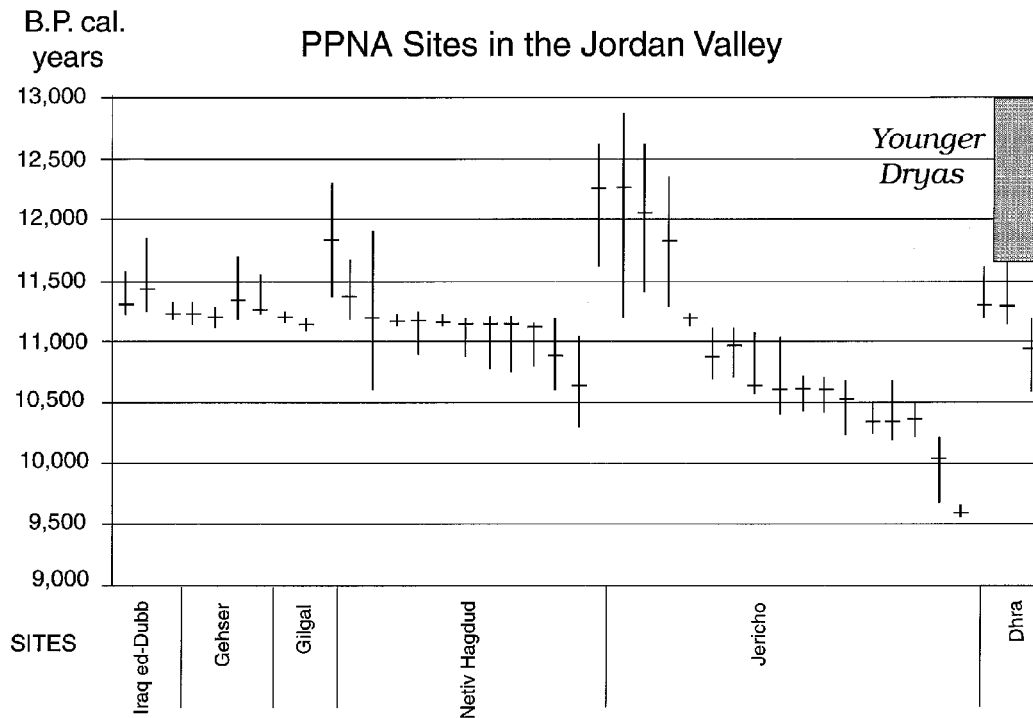


Figure 4 Calibrated dates of Early Neolithic sites in the Jordan Valley and the neighboring hilly areas indicate that the large communities such as Jericho, Netiv Hagdud, and Gilgal were probably the result of the emergence of intentional cultivation during or immediately at the end of the Younger Dryas.

## DISCUSSION

In the previous sections, only two issues from the endless number of archaeological investigations were chosen for presentation. In both cases the demand and need for accurate dating have a major impact on the social interpretation of the data. However, there are other domains in which AMS  $^{14}\text{C}$  measurements seem to revolutionize our interpretations, and one of these is the study of cave art. This is not only a subject that continues to interest specialists, but is also a topic in art history, and continues to be studied by students of human cognition and its intricate evolution. Even a cursory survey will demonstrate that brain scientists and social psychologists, among others, cite and interpret prehistoric cave art (mostly from the Franco-Cantabrian region) as evidence for symbolic behavior. In addition, mobile objects that fall under the category of imagery are being considered as such (e.g. Marshack 1972, 1997; Donald 1991; Mithen 1996; Conkey et al. 1997; Deacon 1997; Klein 1999). It is, therefore, worth noting that direct AMS dating of samples carefully removed from paintings has enabled investigators to test previous hypotheses concerning their age, and in particular, to confirm that the earliest cave paintings, in the site of Grotte Chauvet, date back to 32–30 ka and in Cosquer Cave to 28–26 ka (Clottes et al. 1995; Clottes 1996a, 1996b). These dates tally well with the even older mobile art objects and body decorations known from the Aurignacian, and support the contention that this culture differs entirely from the Mousterian and thus signifies the techno-cultural revolution of the Middle to Upper Paleolithic.

Another well-known historical example is the dating of the famous Shroud stored in the Cathedral of St John the Baptist in Turin, Italy. In this case, the three series of AMS dates carried out indepen-

dently by three laboratories support the history of this object as first noted in the mid-14th century AD. The calibrated  $^{14}\text{C}$  dates suggested a range of the late 13th to 14th centuries AD (Damon et al. 1989; Taylor 1997).

The calibration of conventional  $^{14}\text{C}$  ages has already had some major impacts in archaeology. The first all-encompassing attempt to evaluate the impact of the calibration curve on archaeological interpretations was made by Renfrew (1973). In this influential survey, the chronological paradigm of G Childe—which was based on artifact and assemblage correlations across the Mediterranean and Europe—was used, with the Egyptian timetable as a basic yardstick. However, when the available  $^{14}\text{C}$  dates for various cultural manifestations from Greece through Britain were calibrated, non-diffusionist explanations were put forward. Today, correlations between Egypt and Greece are considered well established. Models based on diffusion and migrations are back in fashion (e.g. Anthony 1990), and like other explanations, propose that the expansion of farming from the Near East to Western Europe can be correlated with the dispersal of Indo-European languages (Renfrew 1987).

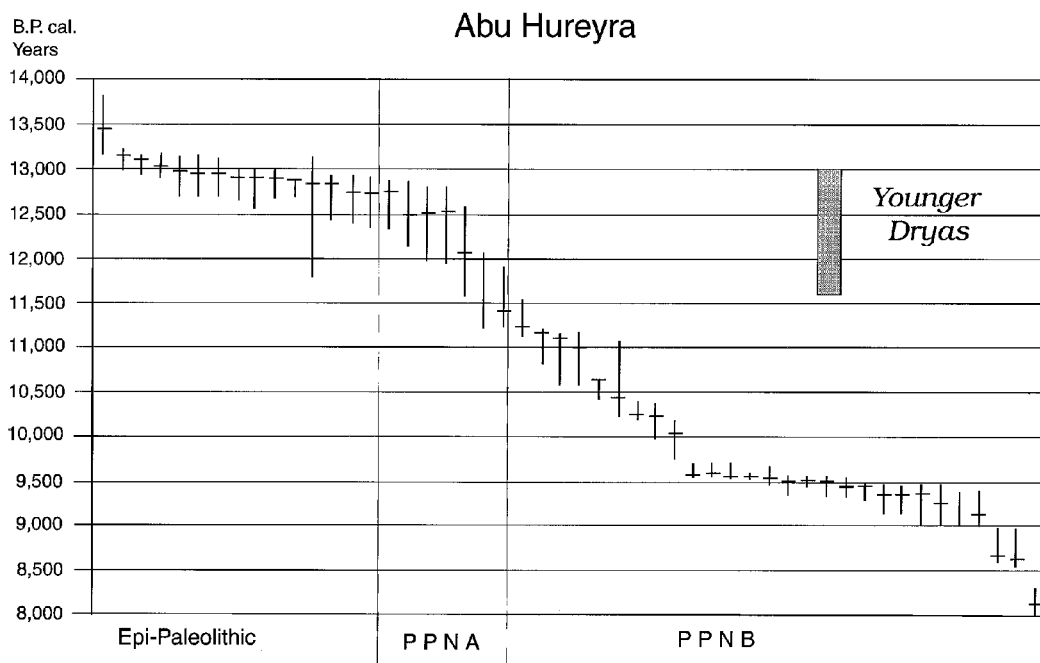


Figure 5 The radiocarbon calibrated chronology of Abu Hureyra on the Middle Euphrates River (Moore et al. 1986), from which carbonized plant assemblages were recovered. The dates indicate that the emergence of the farming community was either during or at the beginning of the PPNB.

Chronologies earlier than the third millennium BC in the Near East are dependent on  $^{14}\text{C}$  dates. Time estimates employed by archaeologists to evaluate whether a socioeconomic or cultural change was rapid or slow relied until now on non-calibrated  $^{14}\text{C}$  dates. Correlations with Ice Core chronology, which is calendrical, require the calibration of dates derived from archaeological contexts. This would, for example, be the only way to test hypotheses that climatic changes triggered cultural changes in a given region. However, everyone who uses the calibration curve is familiar with the existence of "plateaux" when even a date with a rather small standard deviation could indicate several potential calendrical dates (e.g. Hajdas et al. 1995). Unfortunately, the time of the origins of agriculture also seems to coincide with one of these plateaux.

Archaeologists should be able, in forthcoming years, to resolve the issue of chronological ambiguities. A potential way to overcome the problem of a “plateau” in the calibration curve is to obtain past climatic information from well-stratified, dated samples. Previous work has demonstrated that carbonized plants preserve the original ratios of  $^{16}\text{O}/^{18}\text{O}$  and  $^{12}\text{C}/^{13}\text{C}$  (Marino and DeNiro 1987; Marino and McElroy 1991). Similar investigations in the Near East provided promising results. For example, wood samples from the first century AD rampart in Masada, or on carbonized cereal grains from PPNB Tel Halula indicate the wetter climate or higher level of water availability during the lifetime of the plants (Araus et al. 1999; Yakir et al. 1994). This approach requires that carbonized seeds be collected with special attention paid to their stratigraphic position from sites that span the time of the Late Natufian and Early Neolithic, that is, from 13,000 to about 10,000 BP (calibrated). The isotopic information from a stratified sequence could be then compared with the climatic curve of the ice cores, although it is expected that the  $^{14}\text{C}$  dates will fluctuate between older and younger readings (e.g. Hajdas et al. 1998). Such a research project would force archaeologists to indulge in an as yet very uncommon standard of behavior: that of publishing the sections of the sites and indicating from where the samples were taken (see for example Bar-Yosef et al. 1996). This kind of information, when accompanied by a report on the site’s micromorphology, a study that would clarify the amount of disturbance, often of biogenic origins, would enable readers to evaluate the integrity of the so-called “archaeological context” (Courty et al. 1989; Goldberg and Bar-Yosef 1998). The cumulative experience of field archaeologists indicates that “clean” contexts are not easy to trace in Early Neolithic sites, however, given their potential in resolving important historical questions, the additional efforts would be worthwhile.

In sum, the last decade of  $^{14}\text{C}$  dating has already made a significant impact on archaeological and historical interpretations. In an atmosphere of improved cooperation between scientists and archaeologists, new avenues of research can bring us revolutionary answers to old questions.

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