THE MEDITERRANEAN BASIN: THE LAST TWO CLIMATIC EXTREMES

EXPLANATORY NOTES OF THE MAPS

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THE VEGETATION AROUND THE MEDITERRANEAN BASIN DURING THE LAST GLACIAL MAXIMUM AND THE HOLOCENE CLIMATIC OPTIMUM

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The mapping of the vegetation around the Mediterranean at 18±2 ka BP and 8±1 ka (radiocarbon uncalibrated years BP) is based on data concerning both pollen and plants macro-remains. The distribution of these data is sometime irregular, particularly in Northern Africa, and extrapolations were necessary.

For the Last Glacial Maximum (LGM), because of the scarcity of well dated sequences, it was also necessary to generalize the existing data to large areas, taking into account the regional topographical characteristics. The dominant taxa represented in the pollen spectra were taken into account to define the main vegetation types represented by basic colours. Nevertheless, rare taxa considered as significant of regional stands of trees were also represented by symbols as well as trees determined from plant macro-remains.

For the Holocene Climatic Optimum, the available pollen data allowed to define of the main vegetation types, represented by basic colours. Rare but representative tree taxa were also indicated by symbols. In regions such as North Africa, the Black Sea surroundings and the Middle East, the scarcity of data have imposed hypothetic reconstructions.

On the basis of the available pollen and macro-remains data, twenty different facies were initially defined to represent the diversity of the vegetation cover during the two considered periods. Technical reasons, especially the legibility of the final maps, have imposed to select only seven dominant vegetation types: tundra, tundra-steppe and taïga parkland; steppe and deserts; non mediterranean forests, mediterranean vegetation .

1 - DEFINITION OF THE SELECTED FACIES

Tundra and Tundra-steppe

In the northern Hemisphere, the typical tundra is developed to the north of the taiga, along the coasts of the Arctic Ocean and its islands. It is characterized by a small amount of solar radiation, especially during the winter when they are negligible. Because of the short growing-season, low precipitation and rate of evaporation, freezing temperature, permafrost and extensive swamps, it is a treeless landscape where sedges, mosses and lichens are dominant, associated to flowering plants.

If the short growing-season is a common feature within the high altitude ecosystems, the low solar radiation is specific of the high latitudes. For this reason, the term tundra might only be used to define this northern biome. However, numerous species abundant in the southern and typical tundra are also components of the present-day high mountains communities, from northern to southern Europe, andare often considered as relictual of the Last Glacial Period, which suggests that, at middle and high elevations, tundra-like communities have existed during the Last Glacial Maximum, which and enables us to use the term alpine-tundra.

Pollen spectra from the Mediterranean region dated to the LGM are dominated by relatively high values of *Artemisia*, Poaceae, Chenopodiaceae, Caryophyllaceae, Compositae and other heliophilous taxa. These spectra are interpreted as an evidence for the existence of steppe-like and/or meadow-like communities, generaly dominant at low altitudes.

Finally, considering the present distribution of circum-polar and arctic species at high elevation in the mountain ranges, it can be assumed that tundra-like communities were probably more abundant than nowadays at medium and high altitudes, in the vicinity of the relictual glaciers and neves. A mosaïc of

communities probably existed close to and far from the glaciated or snow-covered areas. Their floristic characteristics depended on soil drainage, *pH* and slope exposure. When available, the low pollen percentages and pollen concentrations suggest a sparse vegetation cover in the mountains: it was defined in the text as alpine tundra.

The transition zone between steppe-like and tundra-like communities was probably complex, depending on soil and exposure. The fossil pollen spectra cannot indicate such a complex ecotone. Refering to cold zones, the term tundra-steppe is a proposal to summarize this complexity.

The Taïga and Taïga parkland

This present-day landscape corresponds to a more or less open forest, observed in the regions where the cold season lasts longer than 6 months and when the daily average temperature of more 10°C drops below 120 days. Except for human impact, the opening of the forest mostly depends on wind exposure, fires and soil, particularly permafrost. In the western european taïga, the dominant species are Norway spruce (*Picea abies*), pine (*Pinus sylvestris*), birch (*Betula pubescens*), juniper (*Juniperus communis*). From pollen data, macroscopic charcoal and trunks, it was demonstrated that during the LGM, plant communities also including larch (*Larix decidua*), *Salix, Carpinus betulus, Corylus, Quercus* and *Ulmus*, were also present in the northern side of the circum-mediterranean area.

Steppes

The term steppe is generally used in a widest sense to define a treeless vegetation with a more or less dense herbaceous vegetation, mainly composed of perennial species (Freitag, 1977). In the Mediterranean area, this biome concerns semi-arid and arid bioclimatic zones as well as, in the high Mediterranean mountains, zones with cold temperatures and relatively high precipitation (Quézel and Barbéro, 1982; Quézel and Médail, 2003). As can be observed in the flat areas of Northern Africa, in the Central Ebro Basin of northeastern Spain, Poaceae (e.g.*Stipa tenacissima*) and *Artemisia* (e.g. *Artemisia herba-alba*) are the two most characteristic species.

In the surrounding regions of the Mediterranean during the LGM and the Late Glacial, taxa such as *Artemisia, Ephedra*, Chenopodiaceae-Salsolaceae and Poaceae are used to define the steppes. The same taxa, especially *Artemisia*, Chenopodiaceae and *Ephedra*, are also used to define cool deserts from pollen data (Tarasov *et al.*, 1998). Significant pollen percentages of *Artemisia* (20% - 35%), Chenopodiaceae (2-3% - 10-12%) and *Ephedra* (3%-10%) associated to Poaceae and Asteraceae, define semi-desert according to Combourieu-Nebout *et al.* (1998). These remarks illustrate the difficulty to describe the different biomes during the LGM and to estimate the rate of vegetation cover, using pollen data.

In the present work, pollen spectra from low altitudinal zones dominated by the taxa cited above were considered as significant of steppes submitted to a water stress (drought stress). They include the cold steppes, the periglacial steppes, dominated by european and touranian elements, the forest-steppes corresponding to a transition zone between the grassy-steppe and the deciduous or coniferous forest, the mediterranean steppes, steppe-maquis and the semi-deserts. Symbols representing trees were added to the base color when their pollen types were observed in the fossil spectra and plant macro-remains discovered, or when strong phytogeographic arguments allow to expect a possible past presence.

Deserts

Desert environments are characterized by very low annual precipitation, generally around or below 150-100mm. Considering the arid steppes of northern Africa, Le Houerou (1995) proposes the threshold 100mm ± 50 as a limit between the arid steppic zone and the hyper-arid desertic zone where appears a scattered vegetation characteristic of the true deserts. However, the author emphasizes the role of soil, which also determines the more or less scattered aspect of the vegetation cover.

Noticeable differences exist in the present desert zones. However, despite their climatic and floristic differences, central asiatic deserts and northern african deserts are submitted to similar ecological constraints, favouring comparable responses of the vegetation cover. Ephemeral, as well as long-lived and drought tolerant species, are present because of the low precipitation rate. Diurnal and annual fluctuations of temperature determine the presence of species able to tolerate both high and low temperatures. Geology and soil characteristics strongly favour a more or less sparse vegetation dominated by psammophilous, halophilous or gypsophilous communities. *Artemisia* and Chenopodiaceae are the dominant taxa abundant in the present-day desert-steppes of the Middle East (Freitag, 1977). Considering how difficult it is to define even in the present-day vegetation covers, the limits between the different biomes of the arid zones, it is obvious that the rough fossil pollen data cannot solve the problem for the past. If *Artemisia* and Chenopodiaceae, are the dominant pollen taxa associated to heliophilous forbs and shrubs, they cannot be determined at a specific level. This excludes or limits detailed palaeophytogeographical and palaeoecological interpretations.

Therefore, deserts were mapped taking into account both their present distribution, the regional topography and soils, and the available pollen data.

Mediterranean vegetation

This unit concerns the forests of low and middle altitude dominated by sclerophyllous trees, especially evergreen oaks, in which broad-leaved deciduous trees and Gymnosperms are also present. The Mediterranean climate is

characterized by regular annual summer drought and precipitation during the relatively colder seasons (autumn, winter, spring).

The present-day sclerophyllous forests have an optimal development in the meso-mediterranean stage (Quézel and Barbero, 1982), although they are also well represented in the thermo-mediterranean stage and in altitude, in the supra-mediterranean stage. In northern Africa, *Quercus ilex* subsp. *rotundifolia* is present around 3000m a.s.l. in the western High Atlas where it forms the upper forest limit (Médail and Quézel, 2003).

At low altitudes in the meso- and thermo-mediterranean stages, stands of deciduous oaks are present with evergreen oaks. *Quercus pubescens, Q. cerris* and *Q. frainetto* mainly distributed on the northern side of the Mediterranean have submediterranean affinities (Médail and Quézel, 2003). When they grow under mediterranean climatic conditions, the summer water stress is corrected by local water supply. Therefore these stands are generally on deep soils or situated near brooks or rivers. Out of these favourable zones, they are abundant under sub-humid and mainly humid bioclimates, in the supra or sub-mediterranean stages, where summer drought is irregular or short and of low intensity and generally corrected by favourable soils conditions. Deep soils, atmospheric humidity and favourable exposures also explain the presence of stands of *Quercus robur, Q. petraea* and other broad-leaved trees such as *Fagus, Corylus, Alnus, Carpinus, Ostrya, Castanea*, limited by summer drought.

The non mediterranean forests

According to altitude, they are essentially composed of deciduous broad-leaved trees and Gymnosperms. They develop under climatic conditions characterized by mild winters, warm and wet summers.

European *Quercus* (*Quercus robur* and *Q. petraea*) and other broad-leaved trees such as *Corylus* and *Ulmus* were widely developed during the Holocene climatic optimum. But other deciduous oaks (withering leave oaks also called sometime semi-deciduous (*Quercus humilis* Miller (*Q. pubescens* Willd), *Quercus. pyrenaica, Quercus cerris, Q. frainetto, Q. faginea* and *Q. canariensis*) were also probably present and abundant during this period with other deciduous taxa present but not still developed (e.g. *Tilia, Alnus, Fraxinus, Fagus, Castanea*).

On the northern side of the Mediterranean, *Q. pubescens, Q. cerris* and *Q. frainetto* are widely distributed and are mainly sub-mediterranean types. To the east of the Mediterranean basin, several species are present, especially *Q. infectoria* vicariant of *Q. faginea* (Quézel and Médail, 2003). As emphasized by these authors, most of these oaks need sufficient soil water supply and deep soils, even if some species (*Q. pubescens* subsp. *anatolica*) can grow on the high Anatolian plateau under semi arid bioclimates (400-600 mm), without any soil or atmospheric compensation. To the north of the Mediterranean basin, they have their optimal development under sub-humid, humid and even per-humid bioclimates (respectively mean annual precipitation 600-800mm; 800-1000mm; > 1000mm. To the south and in southern Spain, they are present under humid bioclimates or in local microclimates with sufficient soil water supply (Quézel and Médail, 2003). Those are associated to the Mediterranean *groupe P. halepensis / P. brutia* widely distributed around the Mediterraneand and the two species have close ecological characteristics. Other species: *Pinus maritima* and *Pinus pinea*, mainly developed in the western Mediterranean, and *Pinus nigra* especially abundant in the Balkans and eastern Mediterranean, are also represented under sub-humid and humid bioclimates, but are not strictly distributed in the Mediterranean area. Similarly, *Pinus sylvestris* is abundant in the western Mediterranean and in the mountains under cold sub-humid and humid bioclimates. The ecological characteristics of *Pinus* are not strictly mediterranean, the problematic specific determination of its pollen limits the paleoclimatic reconstructions. The extant species could survive during the LGM.

In altitude *Pinus* and *Betula* were also well developed as well as, especially in the alpine range, *Picea, Abies* and *Larix* at places. The alpine meadows higher in altitude were not represented on the maps.

Meadow-type vegetation is present when moisture is sufficient. They do not dry out during the summer and grow until the autumn. For the considered periods, in the western Mediterranean, it can be assumed that they were natural ecosystems, essentially submitted to the impact of wild herds. At low altitude, meadows corresponding to a lowland herb vegetation with patches of deciduous trees (Bulgaria), could have also existed.

2 - REGIONAL VEGETATION COVER

From the west to the east we shall consider the northern side of the Mediterranean, the Black Sea area and the Near East, northern Africa.

The Iberian peninsula and southern France

Around 18000 BP, in the Pyrenees, glacial tongues only existed in the valleys (Mardones and Jalut, 1983; Andrieu *et al.*, 1988). An alpine tundra existed only on the deglaciated zones close to the neves and still glaciated areas. Similar situations prevailed in the Massif Central where *Betula nana* was present. The present-day arctico-alpine species of Alps and Jura (*Betula nana* on the peat-bog of Frasne) demonstrate that a comparable tundra-like vegetations also existed in these moutains.

Despite unfavourable climatic conditions, numerous refuges have existed in diverse situations. In the present submerged zones of the Gulf of Lion, former deep valleys were considered as possible refuges for thermophilous trees, close to the rivers (Triat-Laval, 1978). On the continent, pollen spectra, but especially anthrocological data, demonstrate the existence of such refugia (Jalut *et al.*, 1975;

Bazile Robert; Uzquiano, 1992). They concern both present-day species such as deciduous and evergreen oaks, *Corylus, Fagus, Abies, Salix, Buxus*, and extinct species such as *Picea* (Hérail and Jalut, 1986; Uzquiano, 1992; Andrieu, 1991). Pollen data suggest the dominance of steppes, the components of which differed according to topography, soil exposure, altitude and latitude, or wooded steppes with *Pinus*. *Juniperus* (possibly *J. thurifera* and others) and isolated stands with deciduous taxa (Jalut *et al.*, 1988; Reille and Andrieu, 1995; Pons and Reille, 1988; Montserrat Martí, 1992; Sánchez-Goñi and Hannon, 1999; Valero-Garcés *et al.*, 2000; Carrión *et al.*, 2003; González-Sampériz *et al.*, 2003).

During the Holocene climatic optimum, in southwestern France, northern Cantabria and the Massif Central (Beaulieu *et al.*, 1982, 1984; Jalut *et al.*, 1988; Penalba, 1994; Reille and Andrieu, 1995; Sánchez-Goñi, 1996), a deciduous oak forest developed. *Pinus* was still present but generally poorly represented. *Ulmus* and *Tilia* were also present but scarce. In the Pyrenees, at medium elevation, *Pinus* and *Betula* were also important. In the Mediterranean Pyrenees, *Abies* began to develop (Jalut *et al.*, 1988). In the Alps, in the mountain stage, forests with *Quercus* then *Pinus* and / or *Larix* were present (Wegmüller, 1977; Beaulieu, 1977), at a higher altitude, *Pinus* and *Betula* occupied a significant place (David, 1997). *Abies* began to develop in the French Alps around 8800 - 8000 BP. Along the Rhône valley, at low altitude as well as to the north at low and medium elevations in the Jura and Swiss Plateau, *Quercetum mixtum* developed. Close to the Mediterranean, *Pinus* and deciduous oak forests were present, as well as generally not dominant evergreen oaks. In Languedoc and Roussillon, Mediterranean taxa were present but frequently poorly represented. Such a mixed oak forest was distributed in zones of low altitude, along Languedoc, Roussillon and the north of Catalonia, in the Oceanic-Mediterranean transition zone (Riera i Mora, 1994; Jalut *et al.*, 2000). In northwestern Spain, south of the Basque Country and in the Cantabrian Mountains Range, two types of mixed forests were dominant: a deciduous oaks one with evergreen oaks and *Pinus*, and a dominant *Pinus* one with deciduous and evergreen oaks, respectively (Peñalba, 1994; Sánchez-Goñi and Hannon, 1999). In the Ebro valley, the central plateau of Castilla, the coastal area and the Betic Cordillera, *Pinus* forests with deciduous and evergreen oaks and stands of Junipers were dominant (Múgica, 1998; Stevenson, 2000; Carrión *et al.*, 2001). To the north of Alicante, a garrigue-type vegetation was dominated by *Quercus ilex/coccifera, Olea europaea, Pistacia lenticus* and *Pinus halepensis* with *Quercus faginea* and *Arbutus unedo* (Badal *et al.*, 1994).

Corsica

Around 18000 BP, pollen data concerning this period lack and only hypothesis can be proposed on the basis of available Late Glacial pollen data (Reille *et al.*, 1997). The abundance of *Artemisia* and Poaceae indicates the wide distribution of a steppe. The values of deciduous and evergreen oaks during the Late Glacial also with *Corylus* and *Erica arborea* suggest that refuges were probably present, excepted for *Fagus* and *Abies*.

During the Holocene climatic optimum, *Erica arborea* began to develop from c. 8200 BP on, had an optimum extension between 7400 BP and 6300 BP, and formed at that time the dominant forest in Corsica. The data from Creno lake also indicate the development of *Taxus* as well as the poor representation of the deciduous oak forest. At high altitude, *Pinus nigra* ssp *laricio* was probably dominant (Reille *et al*., (1999).

Sardinia

Around 18000 BP, the lack of data make reconstruction hypothetical. It can be assumed that, because of the low altitude of the mountain, and the diversity of the topography, the dominant vegetation cover was probably a steppe with the possible presence of *Pinus*. Refuges have probably existed, especially for deciduous and evergreen oaks and broad-leaved trees.

About 8000 BP, the only hypothesis that can be proposed are based on comparisons with Corsica, Central and Southern Italy and Sicily. Dominant deciduous oak forests developed, evergreen oaks (*Quercus ilex* and *Q. suber*) being restricted and possibly localized to coastal areas.

Sicily

Around 18000 BP, only hypothesis can be proposed. According to the altitude, alpine meadows and steppe communities were dominant during this period. Both temperate, deciduous, broad-leaved, evergreen trees and Gymnosperms were also probably present in favourable habitats.

Around 8000 BP, a deciduous oak forest was dominant (*Quercus robur* type) (Sadori and Narcisi, 2001). Evergreen oaks (*Quercus ilex* type) were also well represented with lower percentages and pollen concentrations. *Q. suber/cerris* type were present but scarcer. *Ulmus, Corylus, Fagus* and Ericaceae were present as well as *Hedera, Vitis, Olea, Pistacia* and *Fraxinus ornus*. The Mediterranean taxa were probably situated near the coast, as well as inland on scattered favourable locations .

Italy

During the LGM *Artemisia*-Poaceae steppes were dominant from northern to southern Italy (Follieri *et al*., 1988; 1998; Watts *et al*., 1996; Magri, 1999; Magri and Sadori, 1999; Combourieu-Nebout *et al*., 1998). Considering the regional relief, alpine-tundra have probably existed in the northern Apeninnes and in the Italian Alps. Pollen data and plants macro-remains demonstrate the diversity of the vegetation cover. In northeastern Italy, at the Italian border of the Pre-Alps, spruce was present in the piedmont, in the Po plain, at the alpine border, as well as near the Italian-Slovenian border and partly to the north of the Adriatic depression

presently under sea-level (Ravazzi, 2002). Records from Italian Pre-Alps demonstrate the survival of *Larix, Pinus sylvestris* and *Pinus cembra* in this area during the LGM. Slightly younger, trunks of *Larix* and pollen data suggest a taiga parkland. *Picea* could also develop in the Apennines and it had a more southern distribution than at present (Follieri *et al*., 1988; Magri, 1999). Occurrences of *Abies* also suggest the presence of stands of fir in Central Italy. To the south, pollen data shows the presence of more thermophilous trees during a phase dominated by Poaceae, *Artemisia* and Chenopodiaceae steppes. In Calabria, (Grüger, 1977) pollen of *Abies, Fagus, Pinus, Betula* with deciduous, evergreen oaks and other species are present in levels attributed to the Older Dryas.

By 8000 BP, at low elevations, deciduous oak forests were dominant from northern to southern of Italy. *Quercus robur* type, *Quercus cerris* type and *Corylus* as well as *Tilia, Ulmus* and *Carpinus* suggest the development of mixed oak forests. Evergreen oaks (*Quercus ilex* type) were present but sparse. *Fagus* was also well represented on the reliefs, in the southern part of Italy and in the north-east. In eastern central Italy, *Abies* was probably very sparsely distributed (Follieri *et al*., 1988; Magri, 1999; Magri and Sadori, 1999). In the southern Alps, it began to develop around 9000 BP. Then, around 8000 BP, it spread northwards, eastwards and westwards. Similarly, spruce (*Picea abies*) began its migration toward the north and the west (Burga and Hussendörfer, 2001). Up to about 1200-1400m a.s.l. in the mountain, pines (possibly *Pinus sylvestris*) participated in mixed forests together *with Quercetum mixtum* and *Corylus*. Higher, it could be in contact with *Picea* and *Abies*. At places, at high altitudes, *Pinus cembra, Larix decidua* and *Betula* were present near the timberline which reached its highest altitude between 8000 and 5000 BP (Schneider, 1985; Wick and Tinner, 1997).

The Balkans

By 18000 BP, in the northern Carpathians, before 14800±1100 BP (Farcas *et al*., 1999) steppic communities with dominant Poaceae and *Artemisia* were probably present as well as *Pinus* and sparse stands of *Picea* at low elevation (Wolfarth *et al*., 2001; Björkman *et al*., 2002). When considering the available pollen and plant macro-remains data concerning *Pinus sylvestris* and *Pinus cembra, Picea abies, Larix decidua, Betula* and *Juniperus*, it can be assumed that the low altitudinal zones between Ukrainia to the east, the southern Alps, northern and central Apennines to the west, have presented facies similar to a taiga parkland (Sercelj, 1981-1996; Willis *et al*., 1995, 2000; Ravazzi, 2002). To the east of northeastern Carpathians, in Moldova, a similar vegetation cover with *Picea, Pinus cembra* and *Salix* also probably existed (Haesearts *et al*., 1998) while to the south of the Carpathians, a wooded lowland steppe was probably developed along the Danube valley. In the highest zones of the Carpathians, Rila and Pirin Mountains, an alpine tundra was probably present. In Rila Mountains before 12815 ± 130 BP (Tonkov, unpublished) and in the northern Pirin Mountains (Atanassova and

Stefanova, 2003) open herb communities (mountain-steppe) existed dominated by *Artemisia* and Chenopodiaceae, together with various taxa of Poaceae, Asteraceae, Apiaceae and *Ephedra* . Refuges for more thermophilous trees e.g., *Quercus, Corylus, Ulmus, Tilia, Carpinus betulus*, were present either in favourable conditions, e.g. deep soils and protected southern exposures, or within the coniferous woodlands in microenvironmental oases (Willis *et al.*, 1995, 2000). The Rhodopes Mountains were possible refuges for deciduous and coniferous trees and, to the east, the Strandza Mountains are considered as a refugial place for mixed oaks forest and *Fagus orientalis*. To the west and the south of the Balkans, at high altitudes, an alpine–tundra was possibly present. In Greece, steppes characterized by *Artemisia*, Poaceae and Chenopodiaceae were widely distributed. The regular presence of *Pinus* with high percentages and *Juniperus* also suggests the existence of wooded steppes. In the mountain regions of Greece and in southern Bulgaria (Rhodopes Mountains), the abundance of the pollen of deciduous *Quercus* and the occurrence of *Carpinus orientalis/Ostrya, Carpinus betulus, Ulmus, Tilia, Corylus, Fraxinus, Cornus mas, Pinus peuce, Taxus, Fagus, Abies* show the presence of refuges (Bottema, 1974; Bozilova et al., 1989; Huttunen et al., 1992; Tzedakis, 1993) which could exist at low and middle elevations.

During the Holoceme climatic optimum, to the north of the Balkans, at low elevations, a mixed oak forest composed of deciduous *Quercus. Tilia, Ulmus* and *Corylus* were developed. Occurrences of *Fagus* indicate the presence of this tree. Needle leaved trees (*Pinus, Picea, Abies* and *Juniperus*) were very reduced (Willis *et al.*, 1995). To the southeast of the Carpathians, a mixed oak forest also dominated (Lazarova and Bozilova, 2001). Zones with xerophytic herbs were also possibly present (Tomescu, 2000). A similar vegetation cover can be supposed in the eastern piedmont of the Carpathians. In the coastal part of the Strandza Mountains, a dominant deciduous oak forest with *Carpinus betulus* and *Fagus* (most probably *F. orientalis*) was also present (Filipova-Marinova, 2003). In the high montane area of Bulgaria, the Western Rhodopes Mountains, Rila and Pirin Mountains, at mid-altitudes, a mixed deciduous forest of *Quercus robur* type and *Quercus cerris* type was developed with *Carpinus betulus* and other thermophilous trees, with possibly some *Fagus* and *Abies* in sheltered places. Similarly, *Platanus* was present in the Western Rhodopes Mountains (Kupena) around 7600 BP (Huttunen *et al.*, 1992; Bozilova and Tonkov, 2000; Tonkov *et al.*, 2002; Tonkov, 2003).

In Slovenia, at low and middle elevations, the *Quercetum mixtum* was also developed. *Fagus, Abies* and *Picea* were also present. At higher altitudes, *Picea* was the dominant tree (Sercelg, 1996).

In the Carpathians, the mixed oak forest was developed at low and middle elevations and *Corylus* was strongly represented. The *Picea* forest was dominant at middle elevations from the south to the north of the Carpathians (Farcas *et al.*,

1999; Björkman *et al.*, 2002), including the Apuseni Mounts (Bodnariuc *et al.*, 2002).

In Croatia, at low altitudes, a deciduous oak forest spread (Beug, 1961) with a significant representation of *Corylus* and *Ulmus*. The same was recorded in Albania (Denèfle *et al.*, 2000) where *Abies* was present

In Greece, at low and middle elevation the deciduous oak forests included *Carpinus orientalis/Ostrya, Carpinus betulus, Fraxinus ornus, Ulmus, Tilia* and *Corylus*. At higher elevations, *Abies* was well represented and *Fagus* scarcer. *Pinus* had an important place in the landscape (Bottema, 1974). Rare thermophilous taxa (*Quercus coccifera* type, *Phillyrea, Pistacia, Olea*) suggest that restricted Mediterranean communities existed, at low altitude, close to the sea.

The Black Sea area and Turkey

During the LGM, it can be assumed that a taiga parkland existed on the eastern slope of the Carpathians, in the transition zone between the high altitudinal zones and the Ukrainian steppes. Eastwards, a forest-steppe of european broad-leaved trees possibly formed the transition with a periglacial steppe, dominated by european and turanian elements (Grichuk, 1984). The Crimean reliefs were possible refuges for mixed coniferous-broad-leaved stands.

The reconstruction of the vegetation cover of the Pontic chain is also quite hypothetical. Western Caucasus and the Pontic chain were also possible refuge zones for coniferous and broad-leaved trees (Grichuk, 1984; Van Zeist and Bottema, 1982, 1988)

In Anatolia, steppes with *Artemisia*, Poaceae and Chenopodiaceae extended. Pollen of *Pinus* and *Quercus* also suggest the existence of scattered tree stands In southwestern Turkey an oak steppe forest (open forest vegetation) and forest steppe (steppic vegetation with sparse trees) existed with, higher, more or less open coniferous forest stands. To the east of the Konia plain, an *Artemisia*-Chenopodiaceae steppe extended. It was poor in Poaceae and *Pinus*. Pollen of *Quercus cerris*-type, *Cedrus, Betula* and *Pistacia* also suggest the presence of refuges in this part of Taurus (Van Zeist *et al.*, 1975; Van Zeist and Bottema, 1982, 1988).

In the early Holocene, the vegetation cover of the eastern Carpathians was, at middle elevation, a spruce forest in contact with a broad-leaved more or less narrow forest (european oak forest), forming a transition with the steppe zone. On the left side of river Dniestr (Ukrainia) (Kremenetski, 1995) grew a mixed oak forest. *Pinus* and *Picea* were present in the area. To the south-east, in the low Dniepr flood plain, transitional vegetation spread. Elements of the mixed oak forest were absent or very poorly represented and *Pinus* was the most important tree, while *Artemisia*-Poaceae steppe elements were abundant. In the lower part of the Don river valley, *Pinus* was also the dominant tree, heliophilous herbs forming a steppe vegetation. A wooded steppe with *Pinus* growing on the sandy terraces was the dominant vegetation cover between the Don and the Dniepr. Broad-leaved trees lived along the rivers as well as in the reliefs of southern Crimea (Kremenetski *et al.*, 1999).

No data are available for western Caucasus. Along the northern slope, mixed deciduous broad-leaved-coniferous forests probably developed, with a transition towards the steppe. On the southern slope and along the Pontic chain, most of present species were probably present. To the south, in the mountains of western Anatolia and in the western Taurus Mountains; forests were also well developed. *Cedrus* and *Pinus* were the dominant trees, deciduous taxa being scarcer and *Abies* rare but present. *Artemisia*-Chenopodiaceae- Poaceae steppes were also developed. In other cases, deciduous *Quercus* and *Pinus* were the most abundant trees, *Juniperus* and *Cedrus* being also represented (Van Zeist *et al.*, 1975; Van Zeist and Bottema, 1988; Eastwood *et al.*, 1999).

In the Eastern Taurus, deciduous *Quercus* (*Quercus cerris* type) and *Pinus* were dominant. *Cedrus* and *Juniperus* were also well represented as well as herbaceous taxa, mostly Poaceae. *Artemisia* and Chenopodiaceae were less developed but present.

Steppes were mainly developed in the central and the easten part of Anatolia that (Van Zeist and Bottema, 1988; Van Zeist and Woldring, 1978). The low but regular values of *Pinus, Betula* and *Quercus* suggest a great scarcity of the tree stands.

The Middle East: Syria, Lebanon, Israel, Jordan

During the LGM, in Syria, steppic elements dominate with Poaceae, *Artemisia* and Chenopodiaceae. Due to the increasing humidity in altitude, trees could survive in this area despite drought and temperature decrease (Bar-Matthews *et al.*, 1997). Pollen data demonstrate the presence of *Quercus*, especially evergreen (*Q. calliprinos* type), *Pinus, Juniperus* and *Cedrus*. Other taxa such as *Carpinus orientalis/Ostrya* type, *Olea, Pistacia* and *Phillyrea* were also present but rare. The Alaouite mountains harboured tree stands due to cool and sufficiently moist climate, cooler and moister than during the Holocene (Van Zeist and Woldring, 1978; Van Zeist and Bottema, 1982, 1988; Yasuda *et al.*, 2000). Similarly, it can be assumed that, because of their elevation and topography, *Cedrus libani* also survived in the mountains of Lebanon.

To the south, in the Hula Basin, near the northeastern border between southern Lebanon and northern Israel, (Baruch and Bottema, 1999), the vegetation cover was dominated by Poaceae. *Artemisia* and Chenopodiaceae were present but less important. In this open landscape, deciduous *Quercus* (mainly *Q. ithaburensis* type) and evergreen oaks (*Q. calliprinos* type) were also represented. Around 1000m a.s.l., in northern Golan (Weinstein, 1976), the pollen data also indicate that Gymnosperms (*Abies* and *Cedrus*) were present in the vicinity.

According to altitude and ecological situations, a mosaic of vegetation cover existed from the north to the south of the considered region. In the driest places, at low and middle altitudes, steppe, forest-steppe or steppe-forest were probably widely developed. Data from Soreq cave, near Jerusalem, reinforce this hypothesis and suggest that the vegetation cover was composed of C3-and C4-type plants forming a bush-type vegetation (Bar-Matthews *et al.*, 1997)

Thermophilous mediterranean species formed more or less scarce Mediterranean stands. Along the eastern slope of the reliefs, a more steppic vegetation cover extended in contact with semi-desert and desert areas. At higher elevations, stands of deciduous broad-leave trees could survive as well as Gymnosperms such as *Cedrus libani*.

To the south, steppes dominated by Irano –Turanian species were probably developed, followed, towards the Red Sea, by a Saharo-Arabian desert vegetation submitted to an extremely arid climate.

In the early Holocene, in Syria, (Van Zeist and Woldring, 1980; Van Zeist and Bottema, 1988) a deciduous oak forest (*Quercus cerris* type) was dominant and evergreen oaks (*Quercus calliprinos* type) were less abundant. *Pinus* was also present as well as *Cedrus* with lower values. When considering the oak forest history, the pollen data demonstrate that around 8660±100, a marked decrease of the curve is recorded both in percentages and pollen concentration. It is associated to an increase in fern spores, charcoal particules, *Pinus*, evergreen oaks and *Olea* percentages. This abrupt fall is attributed to a forest clearance by populations belonging to the Pre-Pottery Neolithic B (PPNB) (Yasuda *et al.*, 2000).

In the vicinity of Lake Hula (Baruch and Bottema, 1999), deciduous oaks (*Quercus ithaburensis* type) were dominant on evergreen Mediterranean species (*Q. calliprinos, Pistacia* and *Olea*). Southwards and eastwards, this mosaic of vegetation was probably progressively replaced by steppe-maquis, steppe then desert.

Northern Africa

The available data are rare and very irregularly distributed which makes the mapping very hypothetic.

During the LGM, *Artemisia*, Chenopodiaceae, Poaceae steppes were widely developed at low and middle altitudes in this part of the Middle Atlas as probably in numerous other areas (Lamb *et. al.*, 1989).

In Eastern Morocco (Oujda region), according to Wengler and Vernet (1992), the last Glacial was a dry period within a semi-arid climate. Pollen data from Northern Tunisia (Ben Tiba and Reille, 1982) demonstrate that in the studied area, at this altitude (780m a.s.l.), steppe was not the dominant vegetation cover. Deciduous *Quercus* (*Quercus canariensis* type) were dominant and numerous other tree taxa were represented (e.g. *Pinus, Cedrus, Abies, Juniperus, Quercus* type *ilex, Q. suber*). Steppic elements were rare. Therefore, such a vegetation cover was not the dominant vegetation of the area, but more probably the one of a protected zone with sufficient water supply.

Other protected areas also existed between the Middle Atlas and northern Tunisia. To the north of Oujda (Morocco-Algeria border,) *Quercus*, *Cedrus atlantica* and *Juniperus* possibly *J. thurifera* were present (Santa, 1958-1959; Couvert and Roche, 1977-1978). To the east, in Algeria, in Djurdjura Kabylia, *Abies* was also present.

Nevertheless, during this dry period, a steppe-like vegetation was probably dominant. The expansion of the Sahara was at its maximum, reaching into the Atlas region to the north and the latitude of about 14°N to the south (Petit Maire, 2002).

To the east of the Maghreb, according to regional ecological situations, steppe-like vegetation, semi-desert or desert dominated the landscape.

In the early Holocene, in the Maghreb, both evergreen and deciduous oaks were developed (Lamb *et al.*, 1989). The evergreen oak forest was dominant, also including *Phillyrea* and *Pistacia*.

In the Oujda Moutains, around 1000 a.s.l., *Tetraclinis articulata, Pistacia lentiscus, Pinus* cf. *halepensis* and cf. *Juniperus* were present (Wengler and Vernet, 1992).

In Grande Kabylie, around 1225m a.s.l. (Salamani, 1991), a deciduous oak forest was locally dominant. *Quercus suber* was poorly represented and *Quercus ilex* very rare. *Cedrus atlantica* was also briefly well represented.

Despite their scarcity, the pollen and charcoal data from the Maghreb demonstrate a diversity in the vegetation cover which already corresponded to a clear regional climatic diversity.

CONCLUSION

During the Last Glacial Maximun, steppic environments were widely distributed. However, the pollen data as well as plant macro-remains also demonstrate that other vegetation types have existed.

Tundra-like vegetation was distributed at higher altitudes in wet and cold zones, the glaciated and snow-covered areas. Taiga and taiga-parkland were also well developed in some regions. In the concerned areas, the duration of the growing season was favourable for trees as well as soil conditions. Flood plains were possibly forested zones.

The presence of thermophilous trees within the coniferous woodland (Willis *et al.*, 1995) emphasizes the role of the favourable exposures and soil conditions during this episode. Taking into account both pollen data and plant macro-remains, it is also obvious that numerous refuges sheltering deciduous and conifrous trees existed at places with a favourable microclimate, in all parts of the considered

zone. If steppes were a major component of the landscape, trees were also present in such environments forming, as defined by Van Zeist *et al.* (1975) either open forest vegetation or dominant steppic vegetation with sparse trees.

During the Holocene climatic optimum, the pollen data demonstrate the wide distribution of broad-leaved trees, forming the dominant deciduous oak forests. Evergreen forests developed under a mediterranean climate seem to have been developed in only two regions: southeastern Spain (Jalut *et al.*, 2000) and the Maghreb. In this latter region, the pollen and charcoal demonstrate that humid and sub-humid bioclimates also prevailed in some zones as palaeolacustrine evidence shows. In the eastern Mediterranean, Sapropel phase S1 (Fontugne *et al.*, 1994), climate data from Soreq Cave (Bar-Matthews *et al.*, 2000), high lake levels (Roberts *et al.*, 2001), pollen data (Van Zeist and Woldring, 1980) demonstrate that the 8000 BP period was moister than the following one. The data from Soreq Cave define the period corresponding to sapropel S1 as very wet, with frost-free winters and drought-free summers (Bar-Matthews *et al.*, 2000), which does not correspond to a Mediterranean climate defined by summer drought and rainfall during the cold seasons. Under these conditions, the climate of the considered period might have been rather of sub-mediterranean type (Horvat *et al.*, 1974), with irregular or short and limited summer drought, with high mean annual temperatures and abundant precipitation distributed in autumn, winter and spring. This would explain the dominance of deciduous broad-leaved trees commonly forming the forests in areas with mild winters, warm and wet summers.

In numerous regions, pine was also an important component of the vegetal cover, both at low and medium altitudes and in the mountains. From their refuges, the climatic optimum favoured not only the expansion of deciduous *Quercus* and their associated broad-leaved trees (*Ulmus, Corylus, Tilia, Fraxinus*), but also, according to the regions, that of *Abies, Picea* and *Larix*. Beech, *Fagus sylvatica* in Italy and *F. orientalis* in the Balkans, were also well represented. Taxa of the Mediterranean Mountain stage also began to develop, both in Turkey, the Middle East and northern Africa. Generally, the extension and the distribution of the main tree species were not depending on any human impact except for the Middle East where its consequences began to appear.

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