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CLASSIFICATORY DISCRIMINANT ANALYSIS OF POLLEN DATA IN NORTHEASTERN ITALY - II. MAPPING OF HOLOCENE VEGETATION

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ABSTRACT - *Classificatory discriminant analysis of pollen data in north-eastern Italy. II. Mapping of Holocene vegetation* - Il Quaternario, 7(2), 1994, 627-642 - Maps of late-glacial and Holocene vegetation for NE Italy are developed for the period 14-0 Ka BP, at intervals of 2 Ka, along an uncalibrated radiocarbon timescale. Block-diagrams, with selected sites arranged along the timescale and an altimetric gradient, outline the dynamics of the main vegetation types identified.

RIASSUNT O -*Analisi classificatoria discriminante di dati pollinici dell'Italia nord-orientale - II. Mappe della vegetazione olocenica* - Il Quaternario, 7(2), 1994, 627-642 - Sono state sviluppate le mappe della vegetazione tardiglaciale ed olocenica dell'Italia nord-orientale per il periodo 14-0 Ka BP, ad intervalli di 2 Ka, lungo una scala temporale non calibrata al radiocarbonio. La dinamica dei principali tipi vegetazionali identificati viene descritta tramite diagrammi a blocchi, per specifici siti distribuiti lungo l'asse temporale ed un gradiente altimetrico.

Key words: Vegetation, palynology, maps, late glacial, post-glacial, NE Italy
Parole chiave: Vegetazione, palinologia, mappe, tardi-glaciale, post-glaciale, Italia NE

1. INTRODUCTION

Mapping of Holocene vegetation is a descriptive tool useful for different purposes in different disciplines, its primary purpose being to outline the spatial variability in existing paleo-vegetational data. Numerous examples from Europe and North America are now available at different scales, from continental (CLIMAP, 1981; Huntley & Birks, 1983; Delcourt & Delcourt, 1987; COHMA,P 1988; Birks, 1990; Overpeck *et al.*, 1991; Prentice *et al.*, 1991) to regional. The latter primarily describe local-scale variations and anthropogenic influence, which need to be set into perspective with continental-scale patterns.

The present paper describes a set of regional-scale maps of late-glacial and Holocene vegetation for North-eastern Italy, developed from palynological data; discussions on the structure of identified units and their significance will be made elsewhere (Evans, in preparation).

2. MATERIALS

Palynological data from ~85 spectra (Table 1) developed from peat bogs, lacustrine basins and rock shelters in North-eastern Italy between 1930-1986 (Fig. 1) are evaluated using cluster analysis, the objective being the identification of dominance structures in pollen-identified vegetation.

The structure of the data set is described elsewhere (Evans, 1992a). Sites are divided into 2 sets identified as "pre-1958" and "post-1958" on the basis of the number of pollen-identified woody species: in the pre-1958 period (8) species are identified; this number increases up to (25) in the post-1958 period.

The temporal framework is derived from a statistical classificatory procedure described in detail elsewhere (Evans, 1992a), which uses radiocarbon-dated pollen levels present in the set as the basic temporal structure. The method is based on classical multivariate analysis techniques and is intended to provide the objective dating, along the radiocarbon timescale, of undated pollen levels. Radiocarbon-dated observations are classified into one of a number of predefined groups (time units of 2 Ka uncalibrated radiocarbon years, starting from 14 Ka BP) on the basis of one or more numerical variables; for each observation a discriminant criterion is developed using either a linear or a quadratic discriminant function; the discriminant criteria are then applied to a second data set containing all undated pollen levels, and are used to classify the latter set devoid of the classificatory numerical variable (i.e. the radiocarbon date); techniques estimating the probability of correct classification are implemented. The resulting sites available for each time period are given in Figures 2-8.

3. METHODS

The statistical procedure adopted for the classification is described and validated elsewhere (Evans, 1992b; 1992c). A non-hierarchical clustering procedure is used to classify pollen levels on the basis of multivariate structure.

Each set ["pre-1958" and "post-1958"] is subjected

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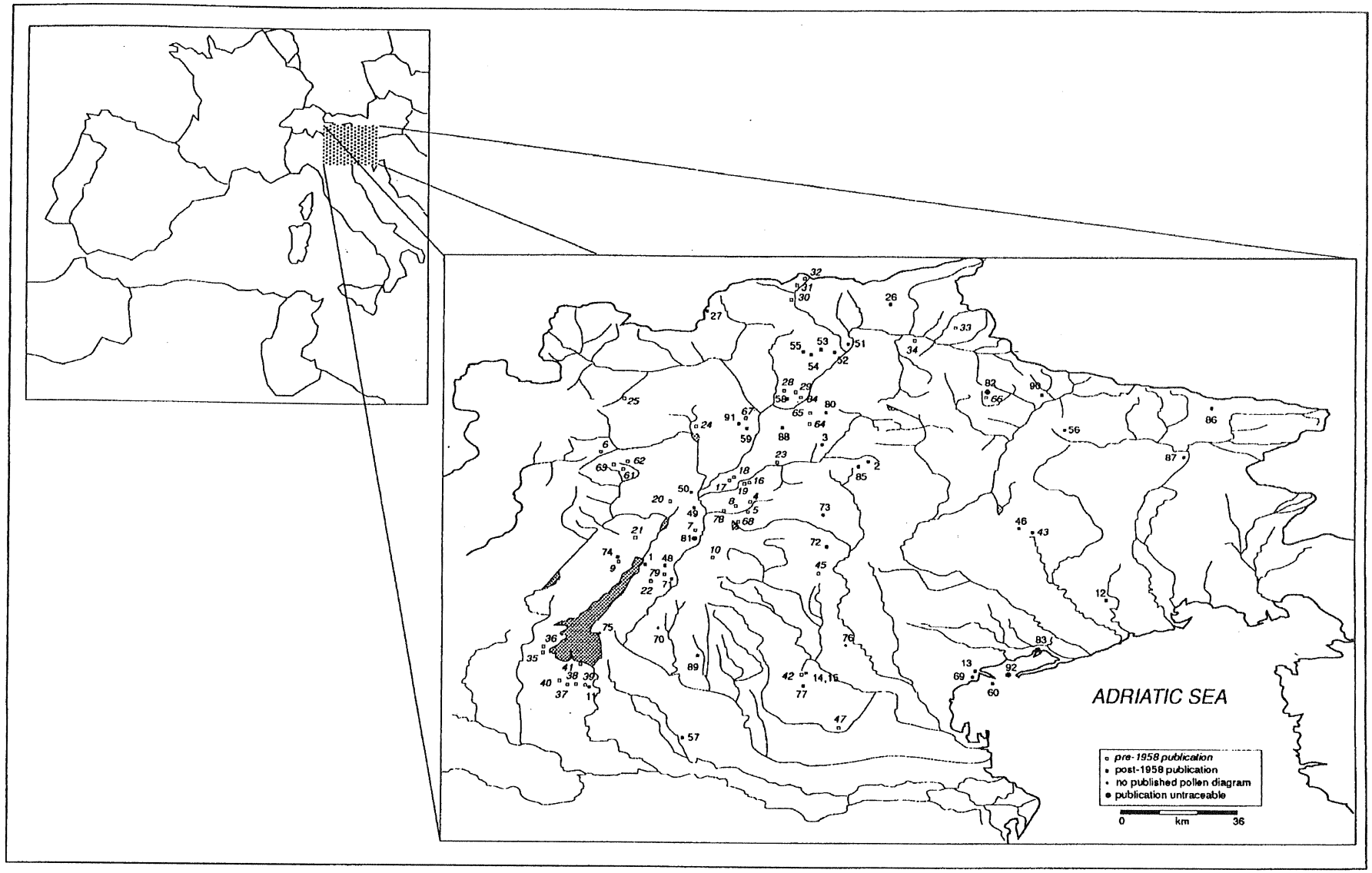

Fig. 1 - North-eastern Italy. Distribution map of sites sampled for palynological purposes in the 1930÷1986 period.
Italia nord-orientale. Carta di distribuzione delle località campionate per analisi polliniche nel periodo 1930÷1986.

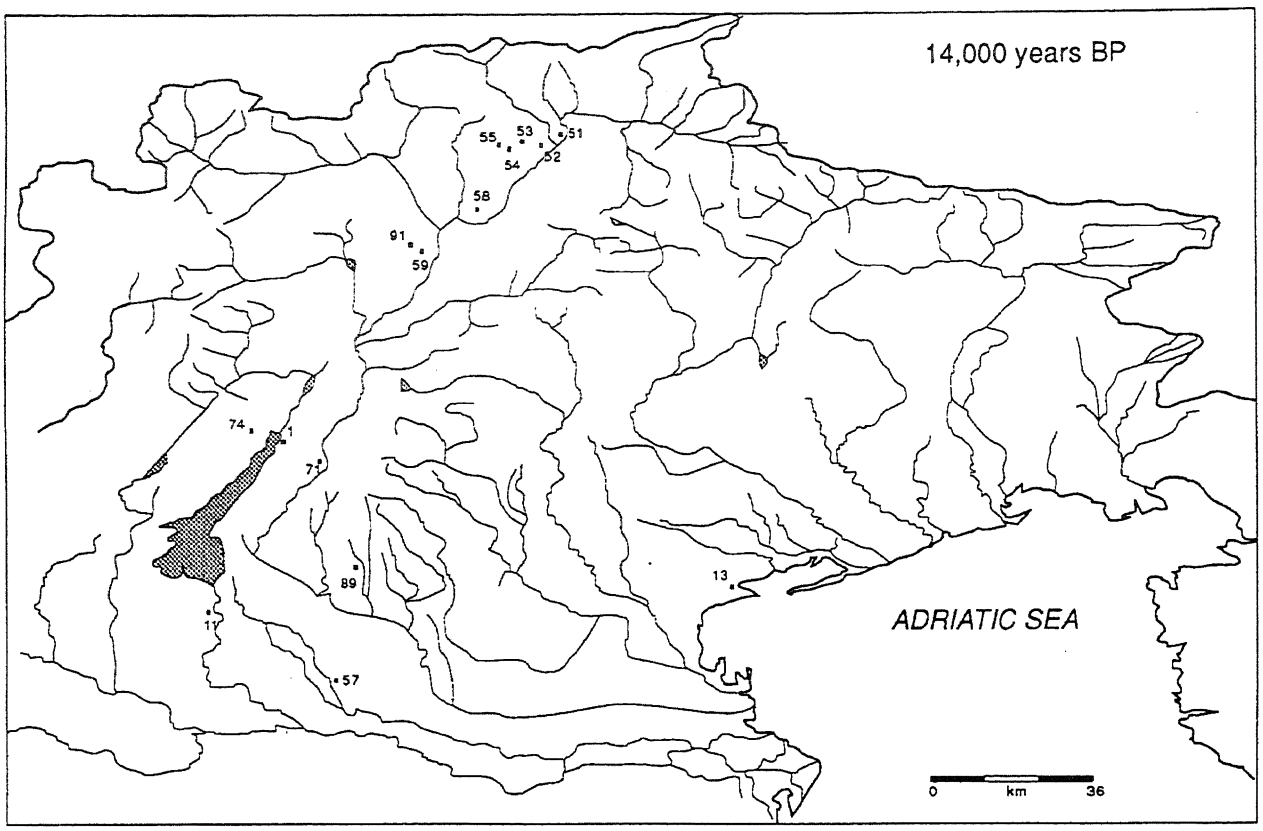

Fig. 2 - Distribution of sites in the period 14,000-13,000 years B.P.
Distribuzione dei siti nel periodo 14.000-13.000 anni B.P.

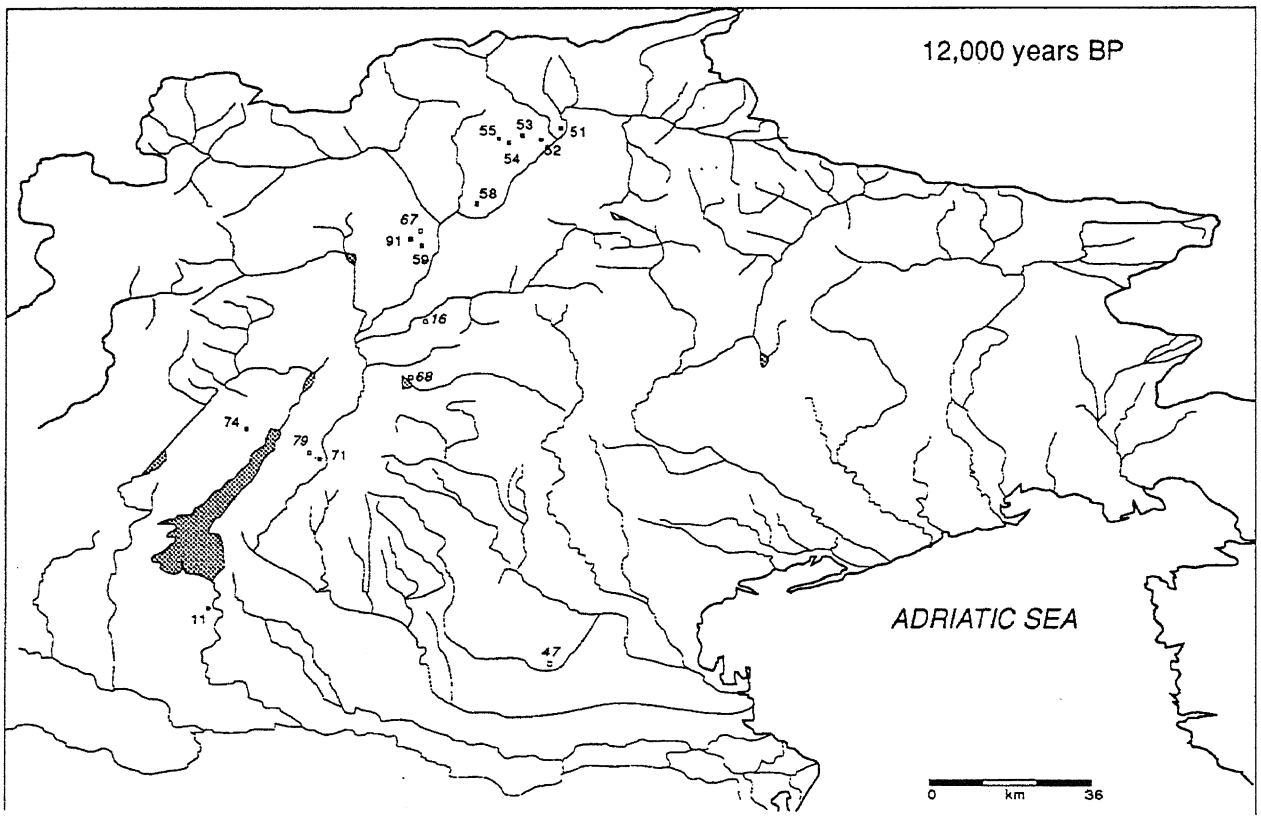

Fig. 3 - Distribution of sites in the period 12,000-11,000 years B.P.
Distribuzione dei siti nel periodo 12.000-11.000 anni B.P.

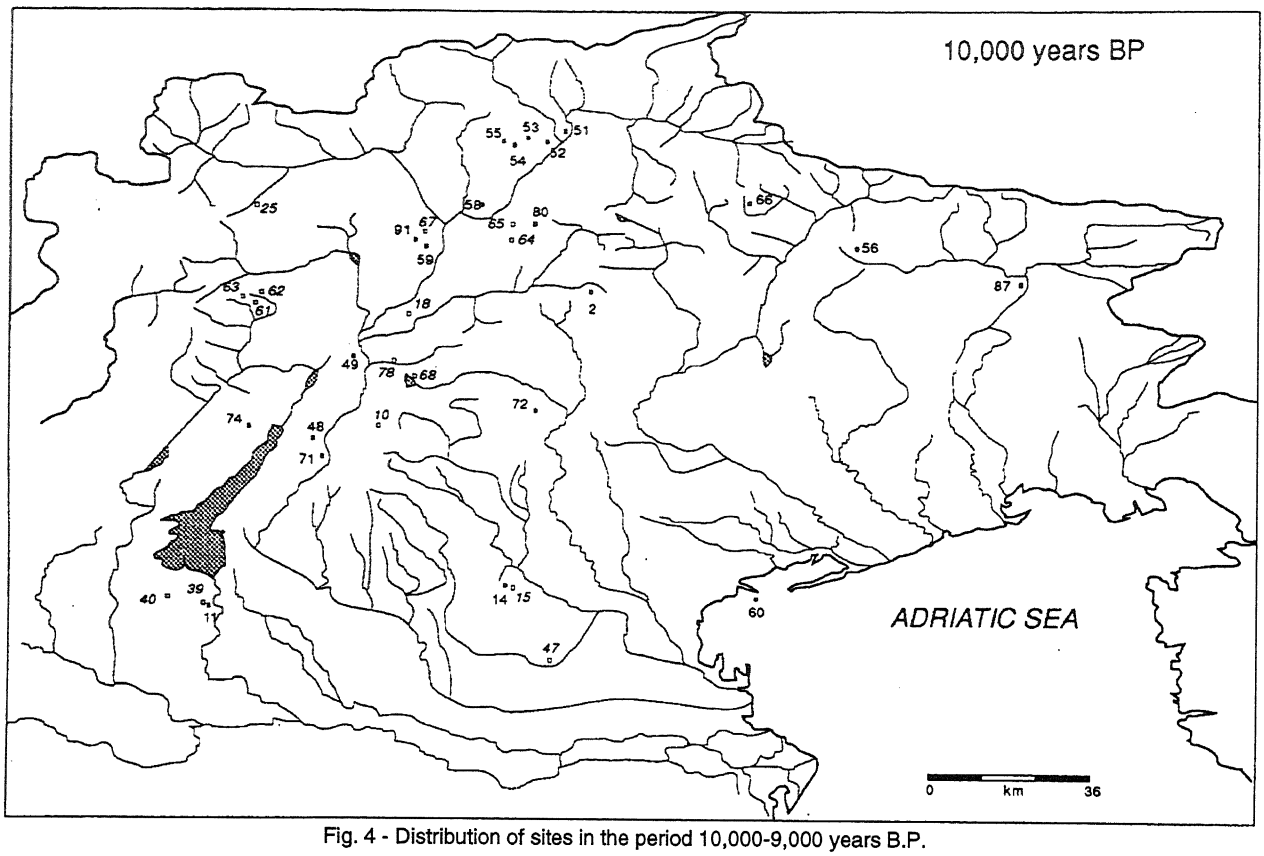

Fig. 4 - Distribution of sites in the period 10,000-9,000 years B.P.
Distribuzione dei siti nel periodo 10.000-9.000 anni B.P.

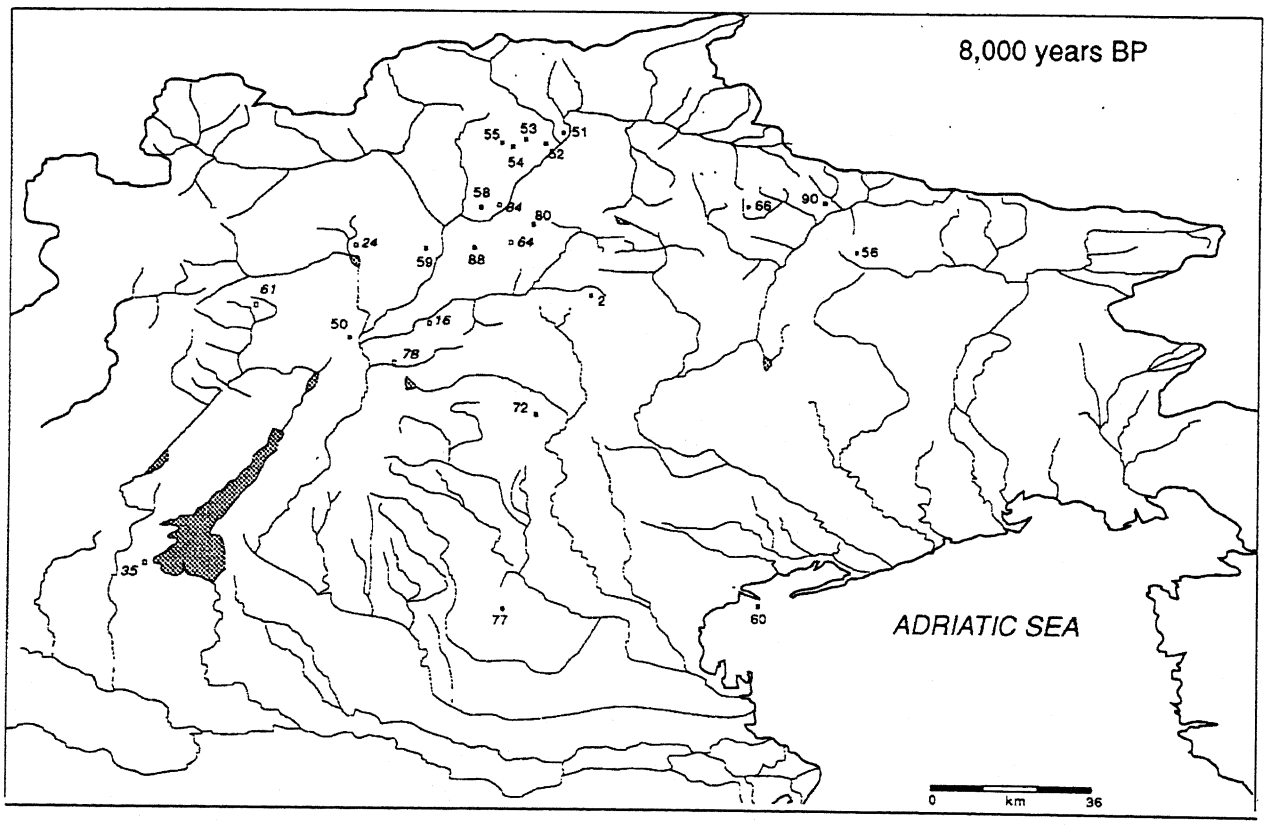

Fig. 5 - Distribution of sites in the period 8,000-7,000 years B.P.
Distribuzione dei siti nel periodo 8.000-7.000 anni B.P.

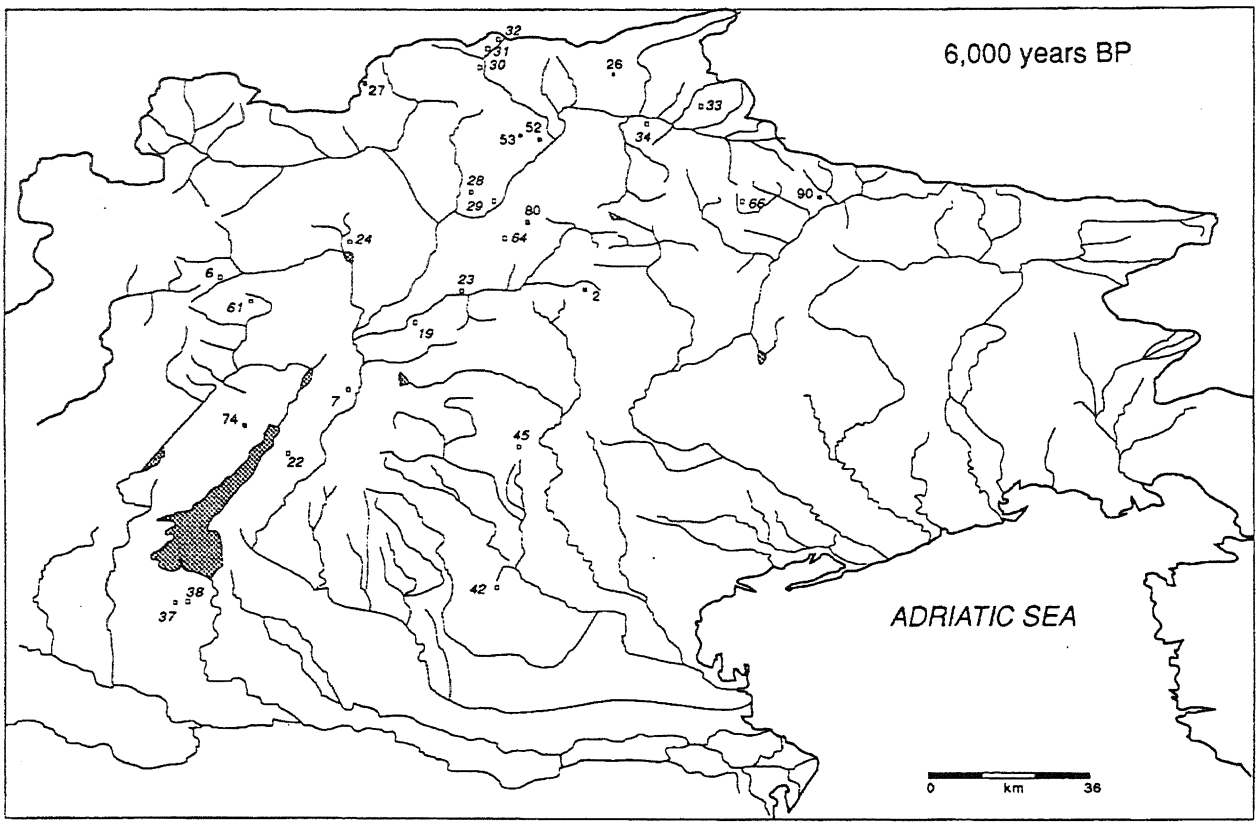

Fig. 6 - Distribution of sites in the period 6,000-5,000 years B.P.
Distribuzione dei siti nel periodo 6.000-5.000 anni B.P.

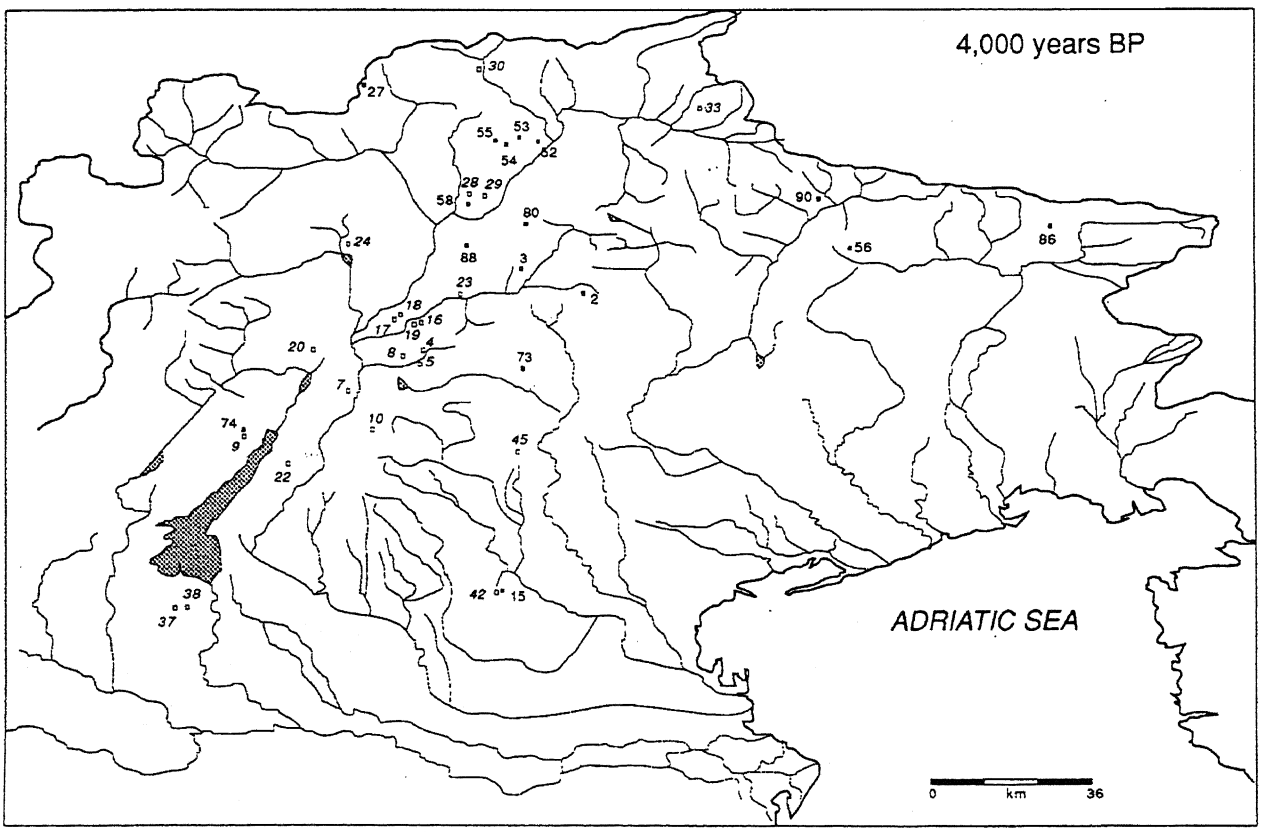

Fig. 7 - Distribution of sites in the period 4,000-3,000 years B.P.
Distribuzione dei siti nel periodo 4.000-3.000 anni B.P.

Table 1 - Sites sampled for palynological purposes in the Eastern Alps. Site number, height in m a.s.l. and coordinates are given. The complete bibliography may be found in Evans (1992c).

Siti campionati a fini palinologici nelle Alpi orientali. Vengono fornti il numero progressivo, la quota s.l.m. e le coordinate. La bibliografia completa viene data in Evans (1992c).

N°.	SITE LOCATION	AUTHOR(S)	YEAR	HEIGHT m a.s.l.	COORDINATES
1	Linfano di Torbole	Paganelli *et al.*	1958	70	45.52°N10.52°E
2	Castrozza	Paganelli	1959	1475	46.16°N11.48°E
3	Vedes	Paganelli *et al.*	1981	1496	46.15°N11.18°E
4	Miola di Pinè	Lona	1941	970	46.07°N11.14°E
5	Laghestel	Lona	1941	900	46.06°N11.13°E
6	Tonale	Dalla Fior	1932	1880	46.17°N10.33°E
7	Bondone	Dalla Fior	1932	1550	45.59°N10.38°E
8	Palù dei Fornasi	Dalla Fior	1932	900	46.07°N11.10°E
9	Molina di Ledro	Dalla Fior	1932	655	45.52°N10.45°E
10	Folgaria	Lona	1946	1263	45.55°N11.10°E
11	Lago di Castellaro	Bertoldi	1968	100	45.22°N10.38°E
12	Portogruaro	Buurman	1969	26	45.47°N12.50°E
13	Motte diVolpego	Bertolani Marchetti	1965	20	45.25°N12.14°E
14	Lago di Fimon	Durante Pasa	1972	100	45.28°N11.33°E
15	Lago di Fimon	Lona	1957	100	45.28°N11.33°E
16	Lago diValda	Lona *et al.*	1944	10	46.12°N11.16°E
17	Lagabrun	Lona *et al.*	1944	1370	46.09°N11.07°E
18	Vegiose	Lona *et al.*	1944	1250	46.09°N11.07°E
19	Brusago	Lona *et al.*	1944	1100	46.11 °N11.19°E
20	Lago di Molveno	Marchesoni	1954	823	46.08°N10.57°E
21	Fiavè	Dalla Fior	1932	654	46.59°N10.50°E
22	Creer	Dalla Fior	1940	1550	45.47°N10.70°E
23	Anterivo	Dalla Fior	1940	1435	46.16°N11.22°E
24	Palù Longa di Brez	Dalla Flor	1940	1574	46.26°N11.06°E
25	Alta Val Martello	Dalla Fior	1940	2100	46.34°N10.48°E
26	Lappago	Decarli *et al.*	1982	2323	46.55°N11.48°E
27	Granati	Decarli *et al.*	1983	2076	46.54°N11 .06°E
28	Lago di Mezzo	Dalla Fior	1933	1260	46.32°N11.24°E
29	Maso Holt	Dalla Fior	1933	1350	46.32°N11.25°E
30	Stilves	Dalla Fior	1935	935	46.51°N11.29°E
31	Brennero Terme	Dalla Fior	1935	1300	46.59°N11.31°E
32	Passo del Brennero	Dalla Fior	1935	1370	47.01°N11.30°E
33	Val d'Anterselva	Dalla Fior	1935	1100	46.53°N12.08°E
34	Riscone	Dalla Fior	1935	900	46.47°N11.58°E
35	Saltarino Sotto	Keller	1931	230	45.30°NtO.30°E
36	Saltarino Sopra	Keller	1931	245	45.30°N10.30°E
37	Rande di Solferino	Keller	1931	130	45.23°N10.34°E
38	Barche di Solferino	Keller	1931	120	45.23°N10.34°E
39	Lago di Castellaro	Keller	1931	100	45.22°N10.38°E
40	Castel Venzago	Keller	1931	105	45.25°N10.31°E
41	Laghetto di Lugana	Keller	1931	74	45.26°N10.40°E
42	Lago di Fimon	Keller	1931	26	45.28°N11.33°E
43	Polcenigo	Keller	1931	36	46.01°N12.30°E
44	Lago di Massenza	Bertoldi *et al.*	1977	245	
45	Laghetto di Lumera	Lona	1949	1060	45.52°N11.30°E
46	Bosco del Cansiglio	Kral	1969	1000	46.04°N12.24°E
47	Arquà Petrarca	Lona	1957	100	45.16°N 11.42°E
48	Lago di Loppio	Bertoldi *et al.*	1965	210	45.51°N10.55°E
49	Pradestel	Cattani	1977	650	46.08°N11.04°E
50	Vatte di Zambana	Cattani	1977	650	46.09°N11.04°E
51	Sommersuss	Seiwald	1980	870	46.46°N11.39°E
52	Schwarzsee	Seiwaid	1980	2033	46.42°N11.34°E
53	Malsch. Holler	Seiwaid	1980	2050	46.42°N 11.34°E
54	Dura Moor	Seiwald	1980	2080	46.42°N 11.34°E
55	Rinderplatz	Seiwald	1980	2033	46.42°N 11.34°E
56	Malga Varmost	Kral	1982	1480	46.23°N 12.40°E
57	Nogara	Marchesoni	1959	10	45.11°N 11.04°E
58	Signater Kopf	Schmidt	1975	1260	46.31°N 11.24°E
59	Montiggler See	Schmidt	1975	492	46.25°N 11.17°E
60	Laguna di Venezia	BertolaniMarchetti	1966	-2	45.27°N 12.21°E
61	Malga Ritorta	Fischer *et al.*	1930	1670	46.13°N 10.47°E
62	Malga Patascos	Fischer *et al.*	1930	1830	46.13°N 10.47°E
63	Malga Zeledria	Fischer *et al.*	1930	1990	46.13°N 10.47°E
64	Kolbleggwiesen	Fischer *et al.*	1930	1700	46.32°N 11.38°E
65	Karer-See	Fischer *et al.*	1930	1650	46.24°N 11.35°E
66	Passo di Pramollo	Kral	1982	1770	46.35°N 12.15°E
67	Montigll	Fischer *et al.*	1930	495	46.25°N 11.16°E
88	Pergine-Vigalzano	Fischer *et al.*	1930	503	46.04°N 11.13°E
69	Porto Marghera	Paganelli	1966	0	45.26°N 12.16°E
70	Ponte di Veja	Durante Pasa	1959	602	45.35°N 10.54°E
71	Monte Baldo	Beug et al.	1960	879	45.25°N 10.60°E
72	Forcellona	Kral	1980	1330	45.57°N 11.37°E
73	Pieve Tesino	Kral	1980	1240	46.04°N 11.36°E
74	Lago di Ledro	Beug	1964	655	45.52°N 10.45°E
75	NO DIAGRAM	Paganelli *et al.*	1983	25	45.34°N 10.42°E
76	NO DIAGRAM	Paganelli *et al.*	1984	30	45.35°N11.45°E
77	Covoloni del Broion	Cattani	1977	120	45.25°N 11.33°E
78	Civezzano	Dalla Fior	1933	450	48.05°N 11.11°E
79	Grunser Buhl	Fischer *et al.*	1930	2000	45.49°N 10.58°E
80	Grosses Moor	Kral	1983	1880	46.32°N 11.40°E
81	NO DIAGRAM	Anonymous		654	45.59°N 10.38°E
82	NO DIAGRAM	Bertoldi		1770	46.35°N 12.15°E
83	NO DIAGRAM	Anonymous		5	45.59°N 10.38°E
84	Collalbo	Dalla Fior	1933	1126	46.32°N 11.26°E
85	Colbricon	Cattani	1984	1930	46.16°N 11.45°E
86	Pramollo	Kral	1982	1520	46.34°N 13.17°E
87	Cavazzo-Vuarbes	Kral	1982	270	46.20°N 13.04°E
88	Nova Ponente	Kral	1986	1290	46.24°N 11.23°E
89	Riparo Tagliente	Cattani	1987	250	45.33°N 10.59°E
90	Comelico	Krai	1986	1400	46.35°N 12.30°E
91	Langmoss-Montiggi	Schmidt	1975	500	46.25°N 11.17°E

NO DIAGRAM - article published with no pollen diagram

Lona - pre-1958 diagram Kral - post-1958 diagram

separately to K-means cluster analysis. This technique is a variant of MacQueen's (1967) basic procedure whereby an initial partition is established with a set of seed points computed as centroids of a number of clusters; each case is assigned to the cluster with the nearest seed point; cluster number is systematically reduced with initial reassignment of cases to the reduced number of groups.

The main aim of multi-sequence comparison of pol-

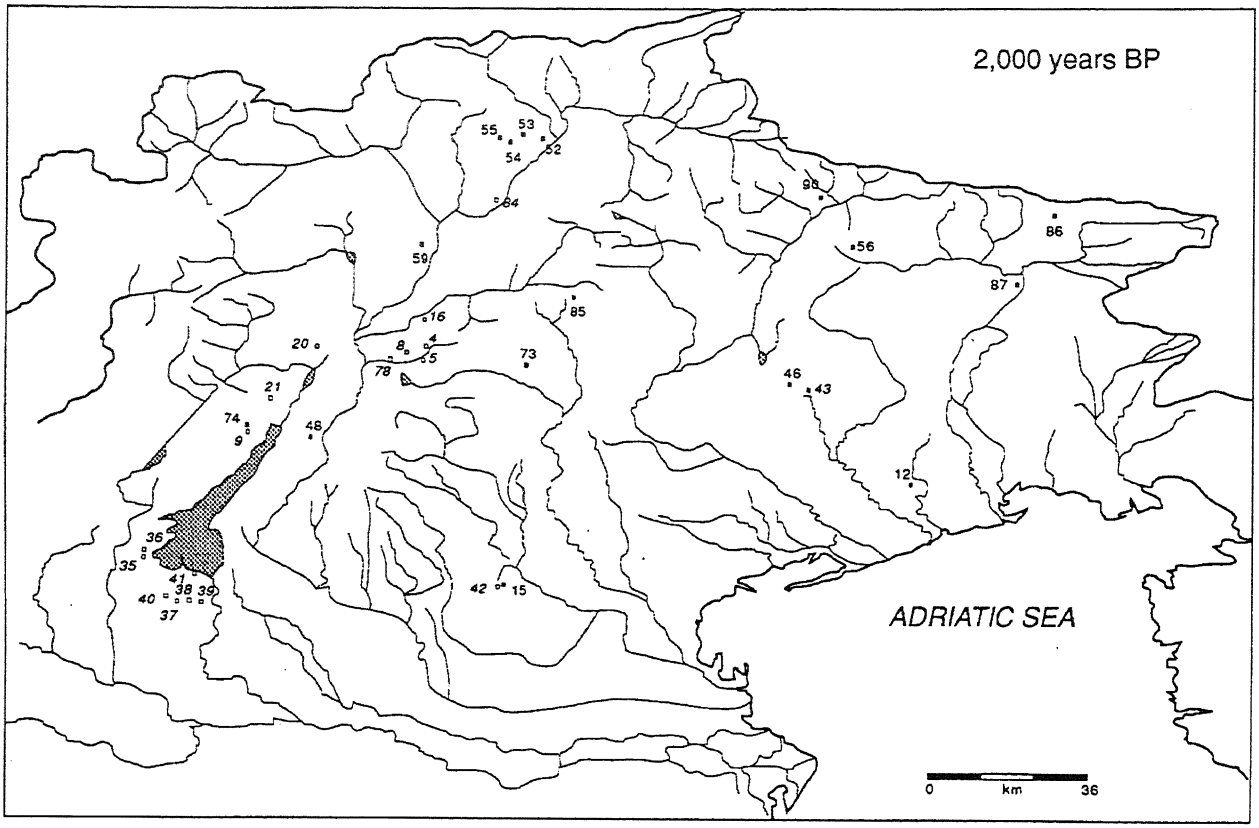

Fig. 8 - Distribution of sites in the period 2,000-0 years B.P.
Distribuzione dei siti nel periodo 2.000-0 anni B.P.

len data using cluster analysis is the identification of structurally different vegetation units in time and space. No stratigraphic constraint is imposed on the data; it is assumed that the formation of homogeneous units or "zones" is an intrinsic property of palynological data, reflecting dominance patterns present in the vegetation.

Multidimensional scaling [MDS] has also been carried out, using canonical vari-ables; Mahalanobis distance [D2] has been used to assess similarity-affinity between clus-ters (Evans, 1989). Results will be reported in detail elsewhere (Evans, in preparation); data confirms the cluster analysis technique adopted and its results, indicating a good separation between clusters.

4. RESULTS

Results are summarized in maps of vegetation spanning the period 14-0 Ka BP; the "dominance structure" of vegetation at each site during each time interval are mapped (Figures 9-15). Dominance structure identifies the three most important species characterizing cluster composition (Evans, 1992c).

Sites are also assigned to 5 vegetational belts with relative altimetric heights (in metres) above sea level (Table 2; Fenaroli & Giacomini, 1958, modified from) and positioned within two quadrants (I and II; Fig. 16), dividing the Adige valley into Southern outer Alps and Inner Alps. The purpose of assigning sites to this somewhat dated classification is only functional, since it provides a simple basis for interpreting an otherwise large data set.

Figures 17 and 18 summarize the diachronic dominance structure along the altimetric gradient for sites in quadrants I and II, respectively. For figure 18 only, homogeneous units have been grouped, and the altitudinal range is tentatively identified; a question mark [?] identifies a problem in the definition of the altimetric range for a given unit(s), due either to a lack of information, or to sites within the same belt being assigned to structurally different vegetational units. During this process preference has been given to sites in the "post-1958" set, since available information is more complete.

Table 2 - Vegetational belts and relative altimetric categories to which palynological sites have been assigned.
Fasce di vegetazione e relativa altimetria alle quali sono stati assegnati i siti palinologici.

CATEGORY	HEIGHT m a.s.l.
Planar	0-200
Lower montane sub-zone	200-1200
Upper montane sub-zone	1200-1600
Sub-alpine (or montane) zone	1600-2000
Alpine zone	>2000

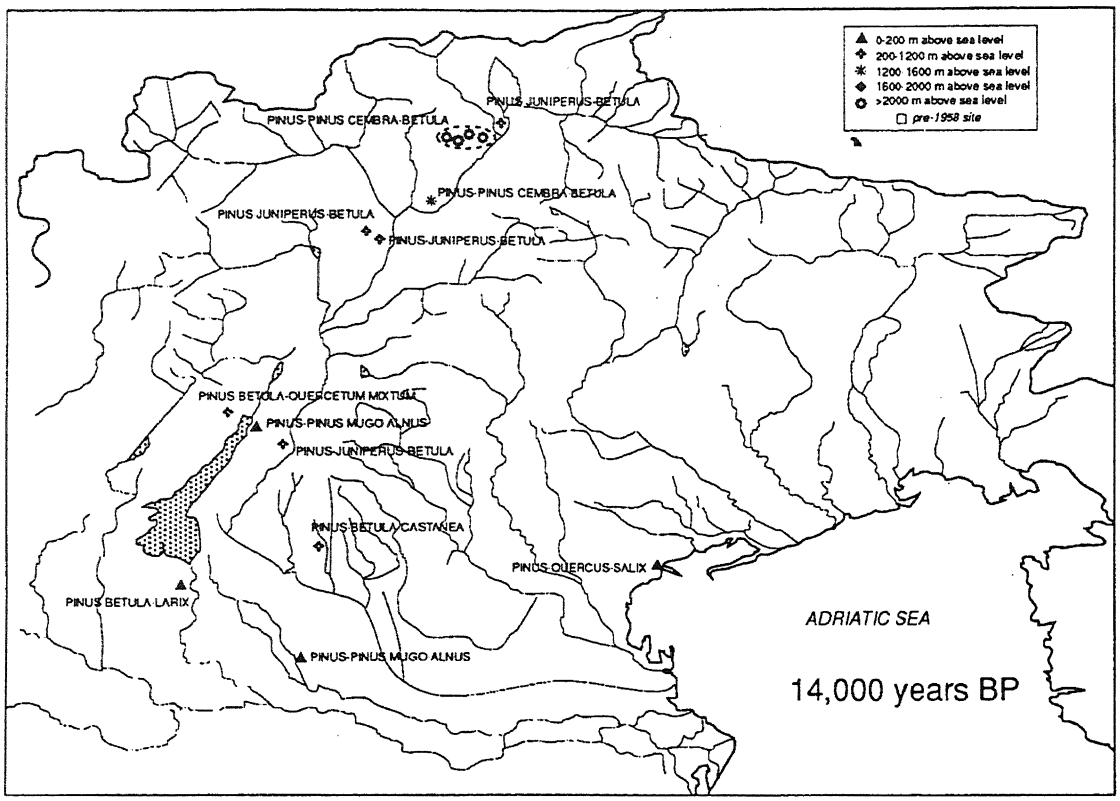

Fig. 9 - Dominance structure of vegetation in the period 14,000-13,000 years B.P.
Struttura di dominanza della vegetazione nel periodo 14.000-13.000 anni B.P.

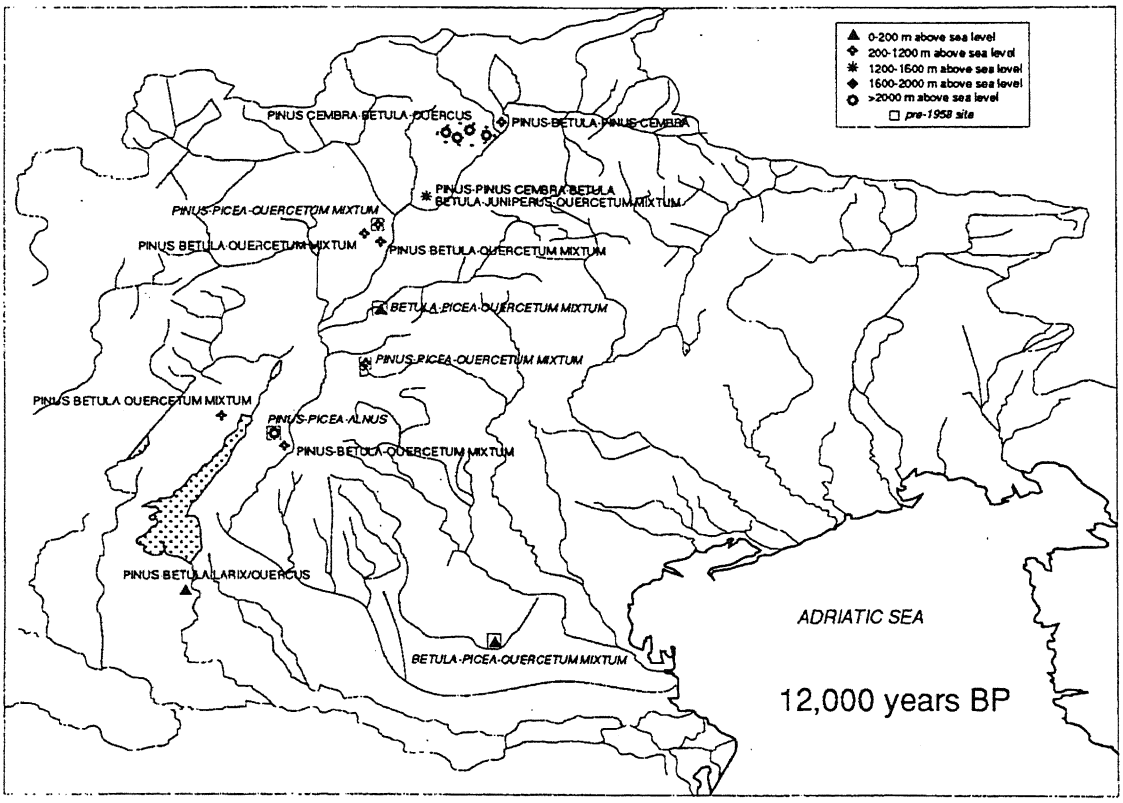

Fig. 10 - Dominance structure of vegetation in the period 12,000-11,000 years B.P.
Struttura di dominanza della vegetazione nel periodo 12.000-11.000 anni B.P.

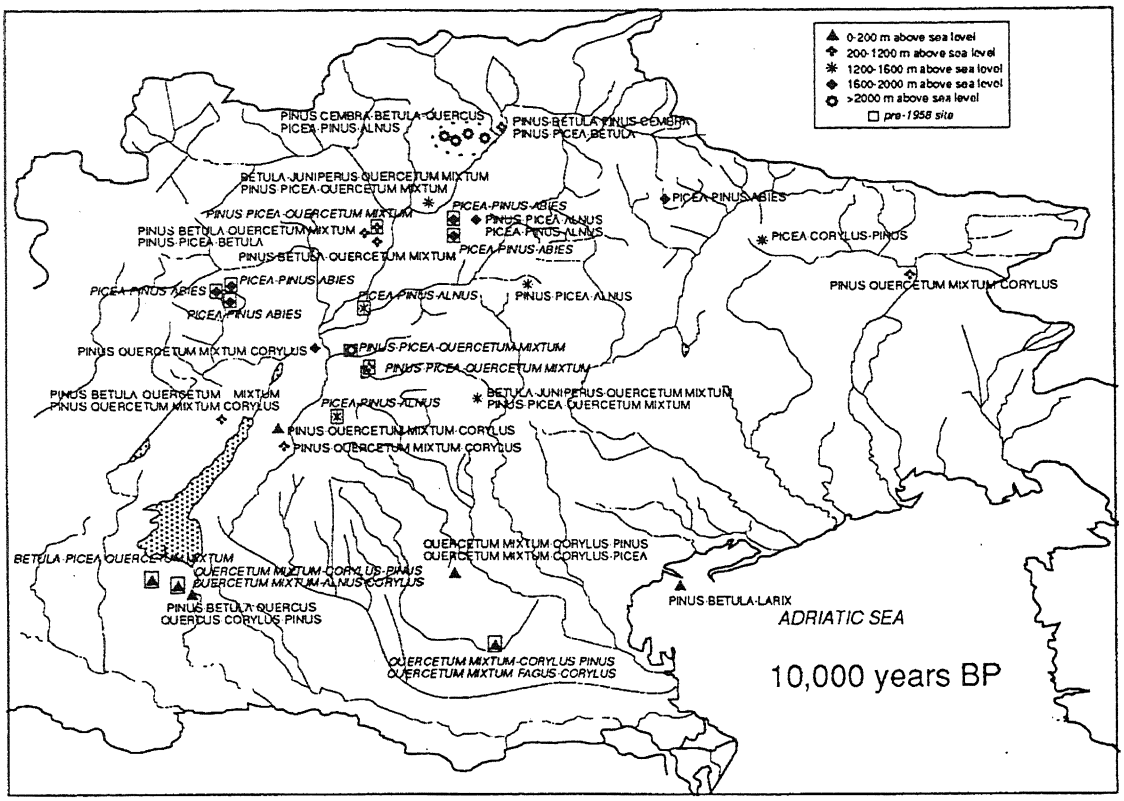

Fig. 11 - Dominance structure of vegetation in the period 10,000-9,000 years B.P.
Struttura di dominanza della vegetazione nel periodo 10.000-9.000 anni B.P.

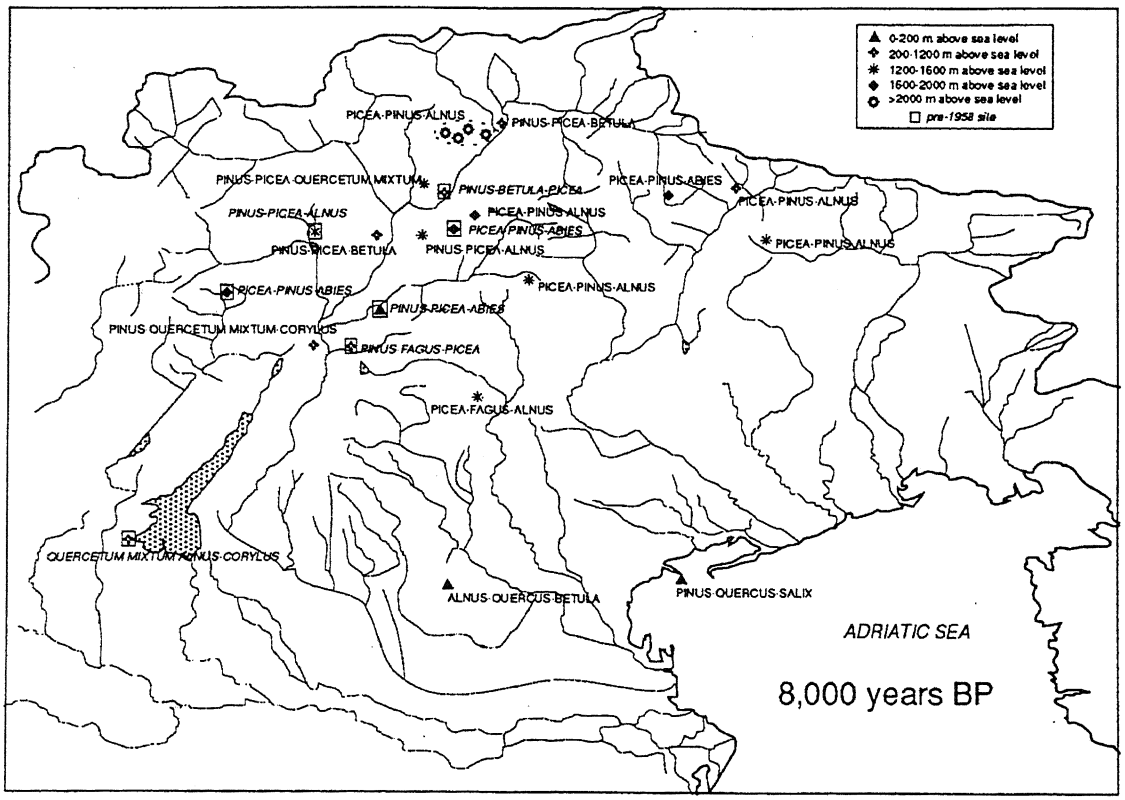

Fig. 12 - Dominance structure of vegetation in the period 8,000-7,000 years B.P.
Struttura di dominanza della vegetazione nel periodo 8000-7.000 anni B.P.

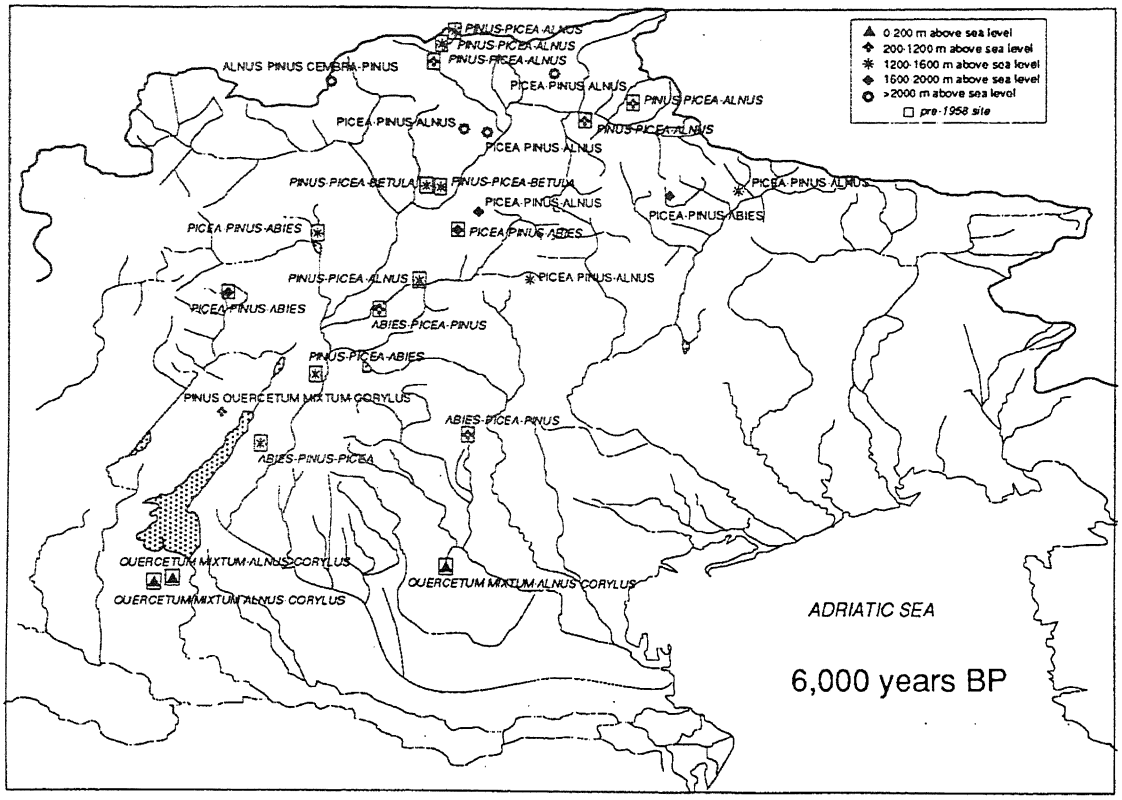

Fig. 13 - Dominance structure of vegetation in the period 6,000-5,000 years B.P.
Struttura di dominanza della vegetazione nel periodo 6.000-5.000 anni B.P.

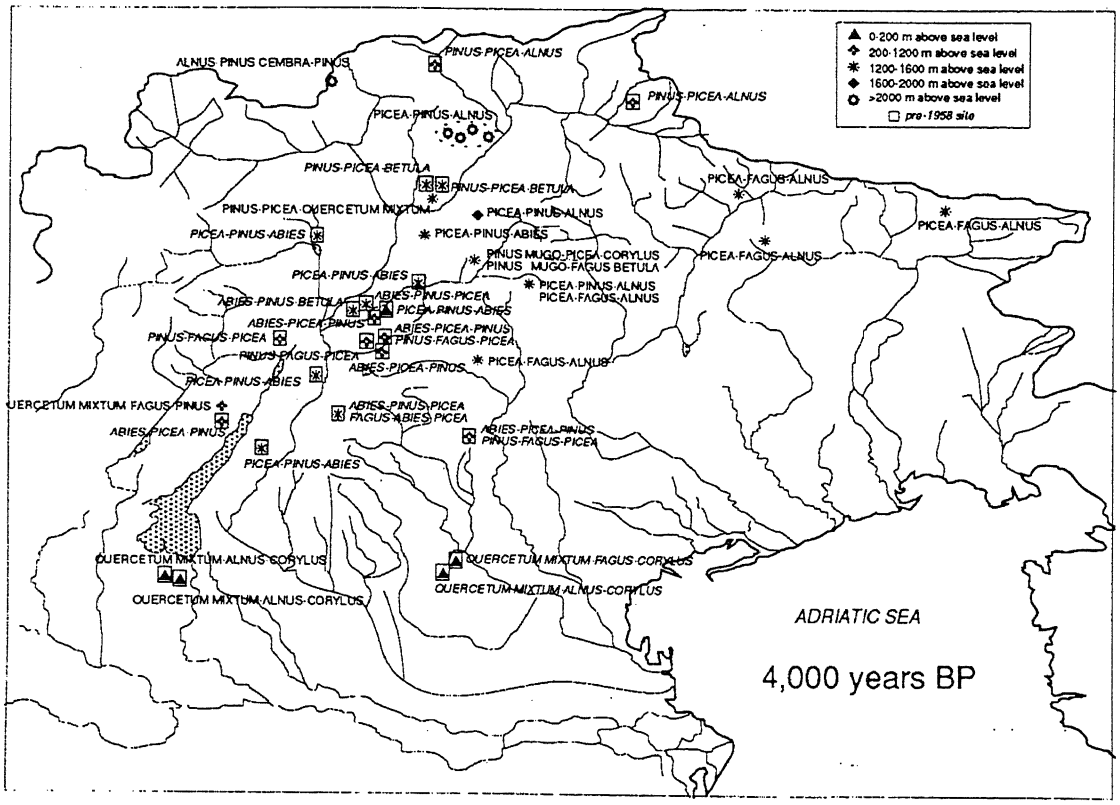

Fig. 14 - Dominance structure of vegetation in the period 4,000-3,000 years B.P.
Struttura di dominanza della vegetazione nel periodo 4.000-3.000 anni B.P.

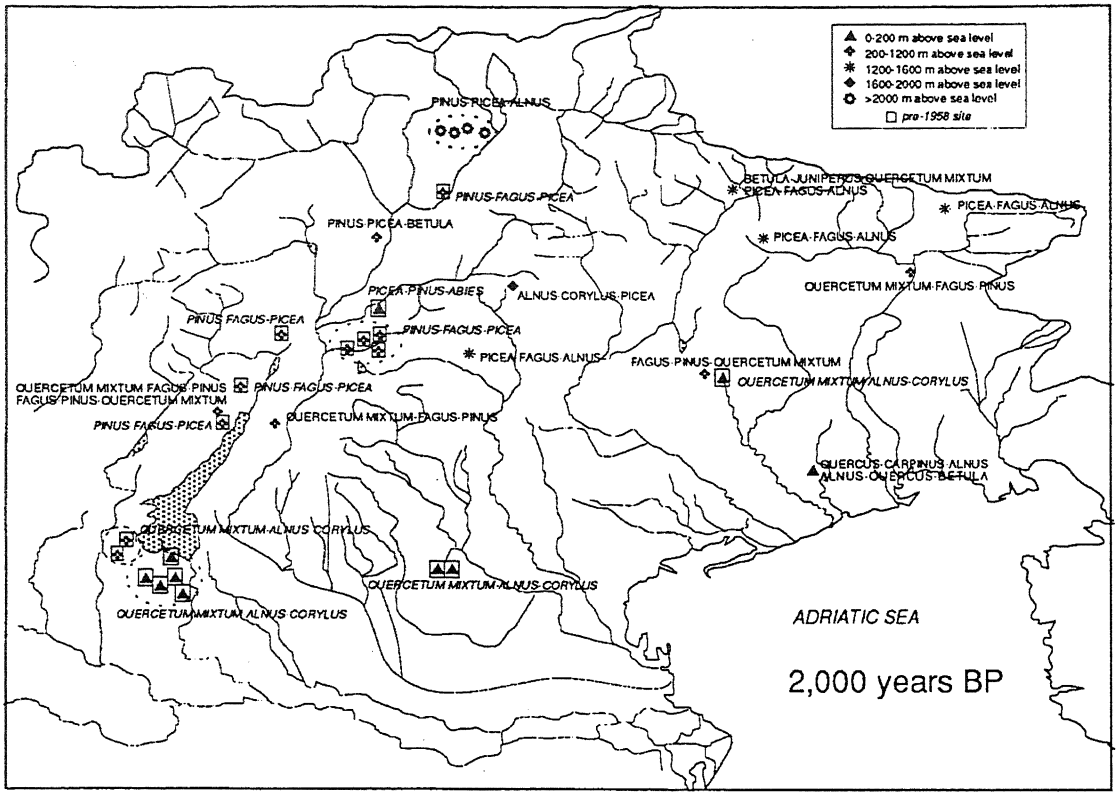

Fig. 15 - Dominance structure of vegetation in the period 2,000-0 years B.P.
Struttura di dominanza della vegetazione nel periodo 2.000-0 anni B.P.

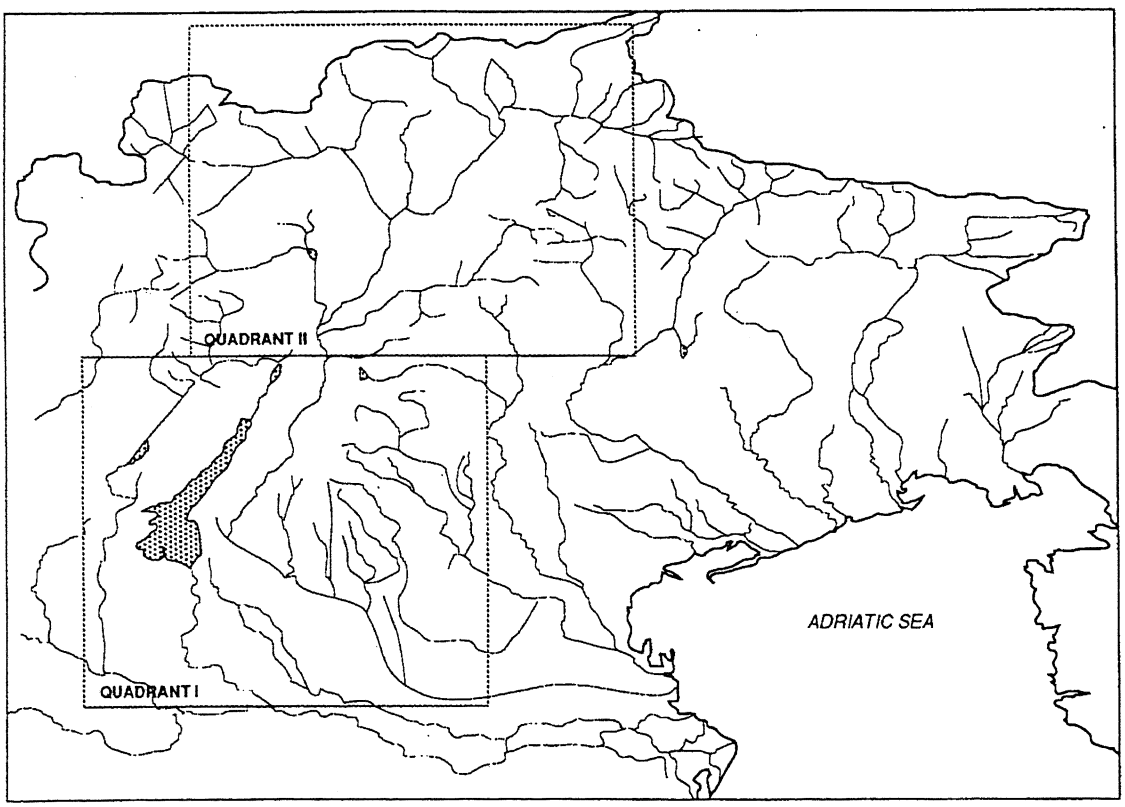

Fig. 16 - Quadrants within which diachronic vegetation reconstruction is proposed.
Quadranti all'interno dei quali viene proposta una ricostruzione diacronica della vegetazione.

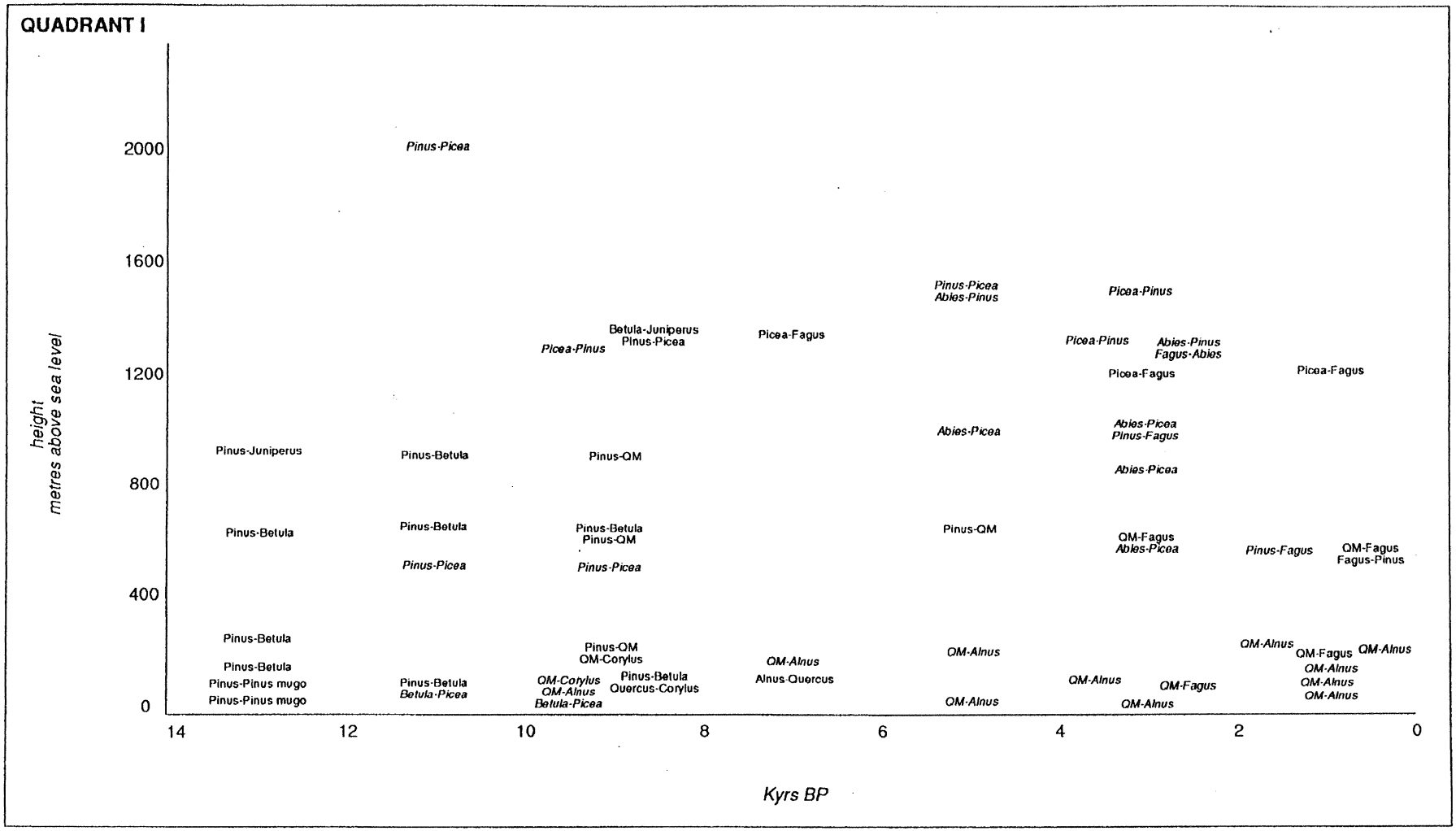

Fig. 17 - Quadrant I. Diachronic reconstruction of dominant vegetatioin (14-0 Ky B.P.) along an altimetric gradient.
Quadrante I. Ricostruzione diacronica della vegetazione dominante (14-0 Ka B.P.) lungo un gradiente altitudinale.

The same has not been attempted for sites along the southern fringe of the Alps, since available information is incomplete, and relies primarily on sites in the "pre-1958" set.

5. CONCLUSIONS

Available palynological data from North-eastern Italy have been used to develop maps of late-glacial and Holocene vegetation at 2 Ka intervals, starting from 14 Ka BP. Maps may be used by geologists, palæoecologists and archæologists to identify:

— sites for which palynological data is available and its quality, viceversa sites for which no data is available;

— the structure of dominant vegetation at specified sites and time periods;

— the structure of vegetation at dif-ferent altimetric heights.

A tentative scheme outlining the diachronic development of vegetation units in the Inner Alps is proposed; a number of gaps are apparent, both geographical and for time periods during which anthropic activity becomes an important factor in landscape transformation. This scheme updates the previous work of Schneider (1985), in which not all available sites have been taken into consideration.

No scheme has been proposed for the southern fringe of the Alps given the limited coverage of the time span considered and a preponderance of data developed in the "pre-1958" period.

As outlined in Evans *et al.* (1994) data will sucessively be compared to present-day vegetational units in order to:

— identify types with no analogues in present-day vegetation;

— identify types with analogues in present-day vegetation and outline changes in their altimetric distribution;

— develop maps identifying the direction and migration rate of single species.

ACKNOWLEDGEMENTS

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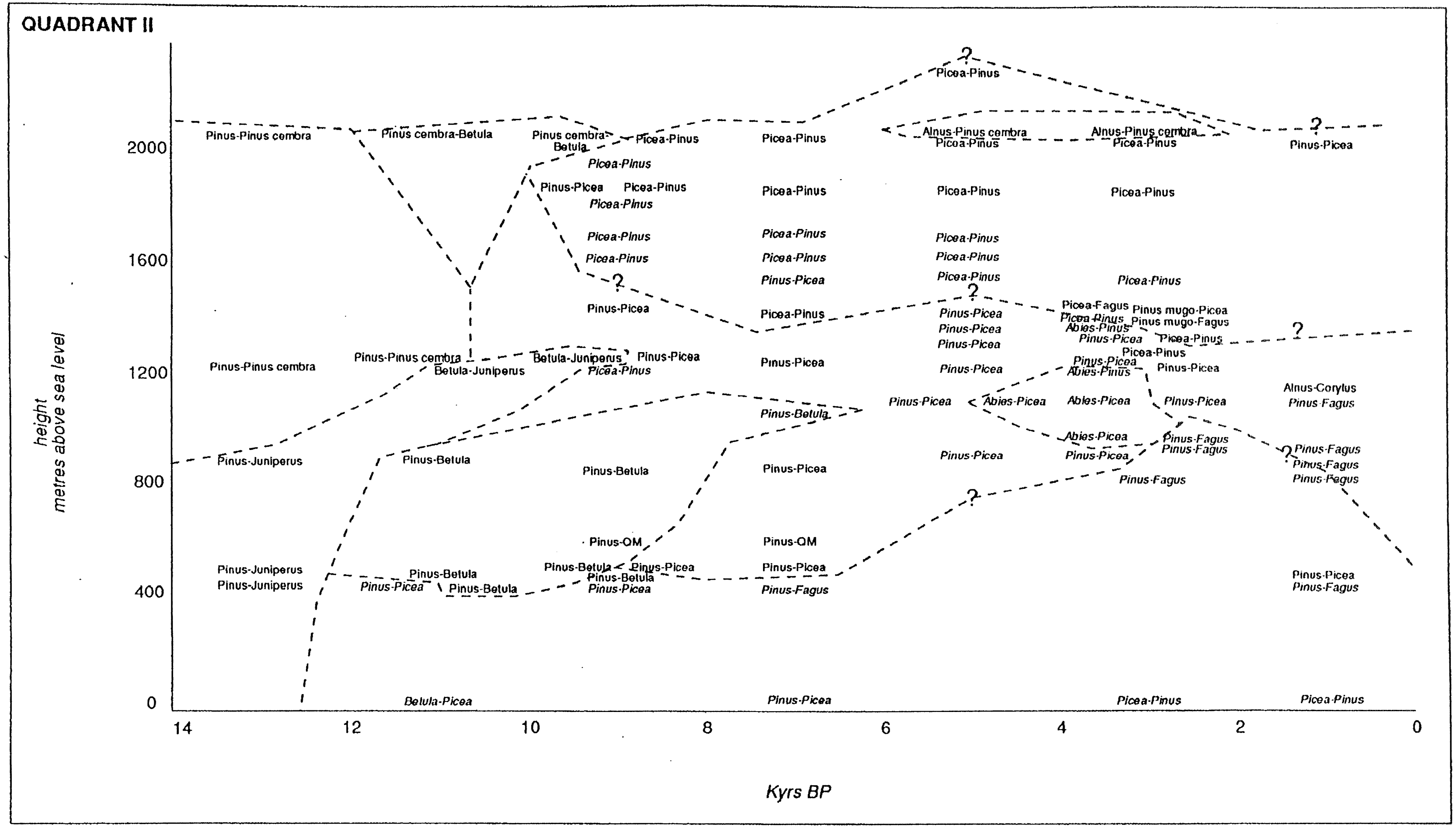

Fig. 18 - Quadrant II. Diachronic reconstruction of dominant vegetatioin (14-0 Ky B.P.) along an altimetric gradient. Homogeneous groups are tentatively identified.

Quadrante II. Ricostruzione diacronica della vegetazione dominante (14-0 Ka B.P.) lungo un gradiente altitudinale. Vengono identificati gruppi omogenei.

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