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Pollen record and integrated high-resolution chronology of the early Pliocene Dacic Basin (southwestern Romania)

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Abstract

An integrated stratigraphic study has been performed on four early Pliocene fssections in the western Dacic Basin, including the long reference section of Lupoaia. Based on the integration of Mediterranean nannoplankton assemblages, the regional lignite stratigraphy, records of large and small mammals, large climatic fluctuations according to pollen grains, and climatostratigraphic relationships at the European scale, it has been possible to establish a magnetostratigraphic correlation of the different sections to the Geomagnetic Polarity Time Scale (GPTS). This correlation suggests that all normal episodes of the early Pliocene (from Thvera to Cochiti chrons) are recorded. Hence, the complete pollen record covers an almost continuous time span from about 5.33 to 4.30 Ma. In addition, the regional Dacian/Romanian stage boundary in the Dacic Basin is located in the Nunivak (C3n.3n) episode with an age of 4.55 ± 0.05 Ma. Our chronologic calibration, combined with high-resolution pollen data, results in a detailed record of paleoclimate in which the ~100 kyrs and ~400 kyrs eccentricity cycles are clearly identified.
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1. Introduction

The western part of the Dacic Basin contains one of the most important stratigraphic successions of Pliocene lignites in Southern Europe. Nevertheless, an accurate and reliable chronology for these deposits – with respect to the global standard timescale – is still lacking. Intense mining exploitation and drilling exploration have led to a complete inventory and mapping of the productive

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lignite layers. There are twenty-two main lignite beds (called A to D and I to XVIII), but their thicknesses vary according to geographic location. The lower part of these lignite beds (A to VII) corresponds to the regional Dacian stage, the upper layers (VIII to XVIII) belong to the regional Romanian stage (Marinescu and Papaianopol, 1995; Ţicleanu and Diaconiţa, 1997). The lignite succession is best expressed and most regular in the depocenter of the basin, i.e. in the area delimited by the Carpathians, the Danube and the Olt Rivers (Fig. 1).

In the last decade, several efforts have been made to precise the chronological framework of the Dacic Basin, including fossil mammal studies (Rădulescu et al., 1993), palaeomagnetic measurements (Rădan et al., 1996) and the first systematic pollen analysis (Drivaliari et al., 1999). High-resolution magnetostratigraphic studies on the Lupoaia reference section have been successively performed by Rădan and Rădan (1998) and Van Vugt et al. (2001). They both recorded two normal and two reversed intervals, and correlated the normal intervals to the Nunivak (C3n.2n) and Cochiti (C3n.1n) episodes of the GPTS. Recently, however, this correlation has been questioned by Popescu (2001), who proposed an alternative correlation of the same normal intervals of Lupoaia to the Sidufjall (C3n.3n) and Nunivak (C3n.2n) episodes. This latter correlation is supported by a better and more complete use of mammal records and large-scale climatic relationships (Popescu, 2001).

The present paper aims to extend palaeomagnetic measurements to some other reference sections of the Dacic Basin (Hinova, Husnicioara, Valea Vişenilor; Fig. 1) in order to provide a more accurate chronology for the entire early Pliocene in the area. In addition, high-resolution pollen records have been established for the same sections. Three aspects will be successively displayed and discussed: (1) regional lignite stratigraphy, (2) magnetostratigraphy, (3) climato- and cyclostratigraphy according to pollen records.

2. Regional lignite stratigraphy

The Pliocene of the Dacic Basin, i.e. Dacian–Romanian in regional stage names, consists of a more than 200 m thick succession of almost regular alternations of clays and lignites. It overlies the clayey bottomset beds and the sandy foreset beds of an outstanding Gilbert delta type system, which is perfectly exposed downstream from the Iron Gates of the Danube River near Turnu Severin (Clauzon et al., 2005). The horizontal topset beds of this Gilbert delta system characterize the continental accretion. The silty bottomset beds outcrop downstream near Hinova, where a thin layer supplies a mollusc assemblage of Bosphorian age (late Pontian) and nannoflora characteristic of the earliest Pliocene (zone NN12) (Clauzon et al., 2005). The Pliocene lignite–clay alternations of the west Dacic Basin, may also include some fluvial sands which can be relatively thick such as at Husnicioara. The condition of deposition of these lignites has long been a topic of discussion, but the recent discovery of the Gilbert delta of Turnu Severin on the western border of the Dacic

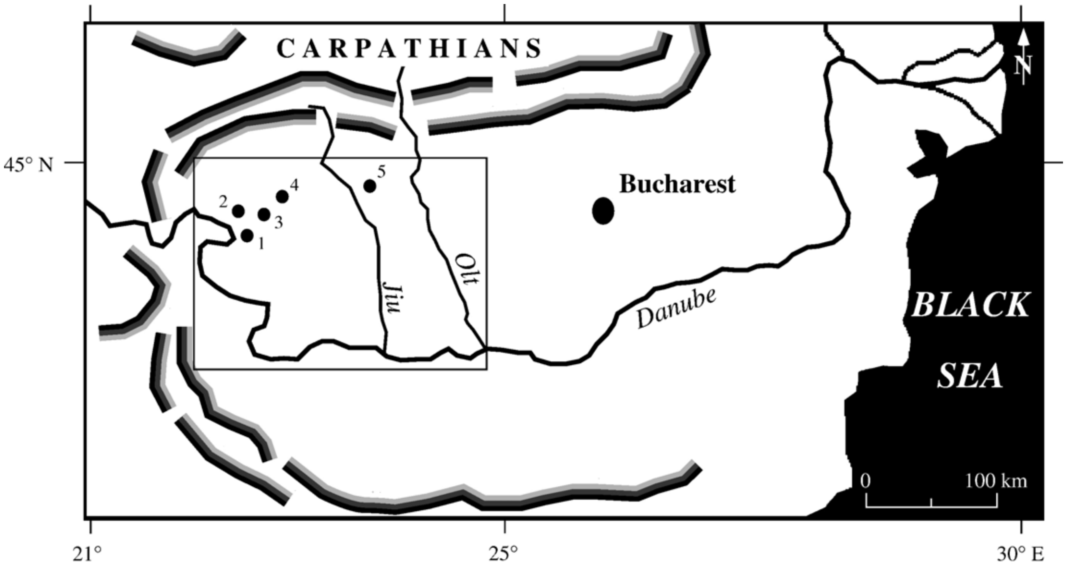


Fig. 1. Location map of the studied localities in southwestern Romania. 1, Hinova; 2, Husnicioara; 3, Valea Vişenilor; 4, Lupoaia; 5, Ţicleni. Rectangle refers to Fig. 2.

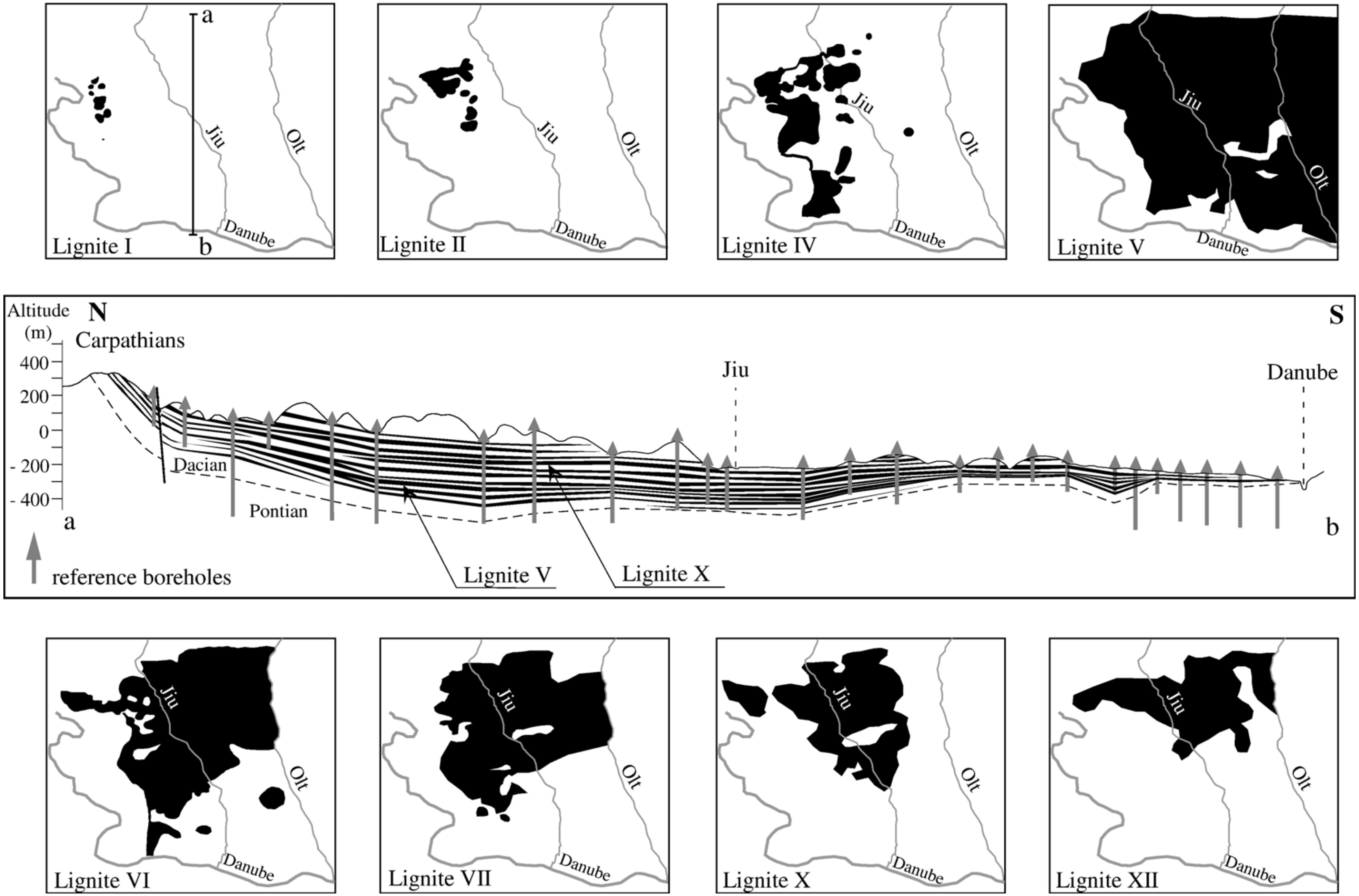


Fig. 2. Stratigraphic and geographic distribution of the most important lignites (in black) in the western Dacic Basin (document from the Romanian Lignite Company). (a–b) North–South profile with reference boreholes.

Basin (momentarily connected to the Mediterranean Sea) now confirms its fluvial origin (Clauzon et al., 2005) as previously suggested by Ţicleanu (1995). Ţicleanu (1995) has distinguished several types of lignites, based on both their mineral and floristic composition. He considers that the coastal vegetation was very complex and that various modes of lignite formation were controlled by the nature of plants (trees, herbs, and water plants) and by their distribution with respect to the aquatic areas (Ţicleanu and Diaconiţa, 1997). This has been supported by pollen analysis, which evidenced a continuous competition between swamps (made of trees growing over few centimetres of water) and marshes (made of herbs growing over some 50–150 cm of water) (Popescu et al., 2006-this volume). According to Ţicleanu (1995), the geographic extension of the lignites was forced by local physiography, water depth, hydrological regime, and possibly also by tectonics. In contrast, however, it has been shown by Popescu (2001) and Popescu et al. (2006-this volume) that also climate played an important part in lignite deposition and, probably, in space distribution as well.

Despite the ongoing debates on the origin and age of lignite formation, a regional nomenclature of the lignite succession has been established for the mining exploitation, based on the detailed sequences exposed in several quarries and through a dense network of boreholes (every 200 m). This is summarized in Fig. 2, which displays the distribution of the most significant lignite beds in the western part of the Dacic Basin. This regional lignite stratigraphy has consequently been applied to our studied sections (Fig. 3) which start at lignite A (Hinova) and end at lignite XV (Husnicioara). The three uppermost lignite layers (XVI–XVII) are only developed in the central area of the basin (Ţicleanu and Diaconiţa, 1997). This means that an almost complete vertical succession of the early Pliocene has been recovered in the western Dacic Basin, on which

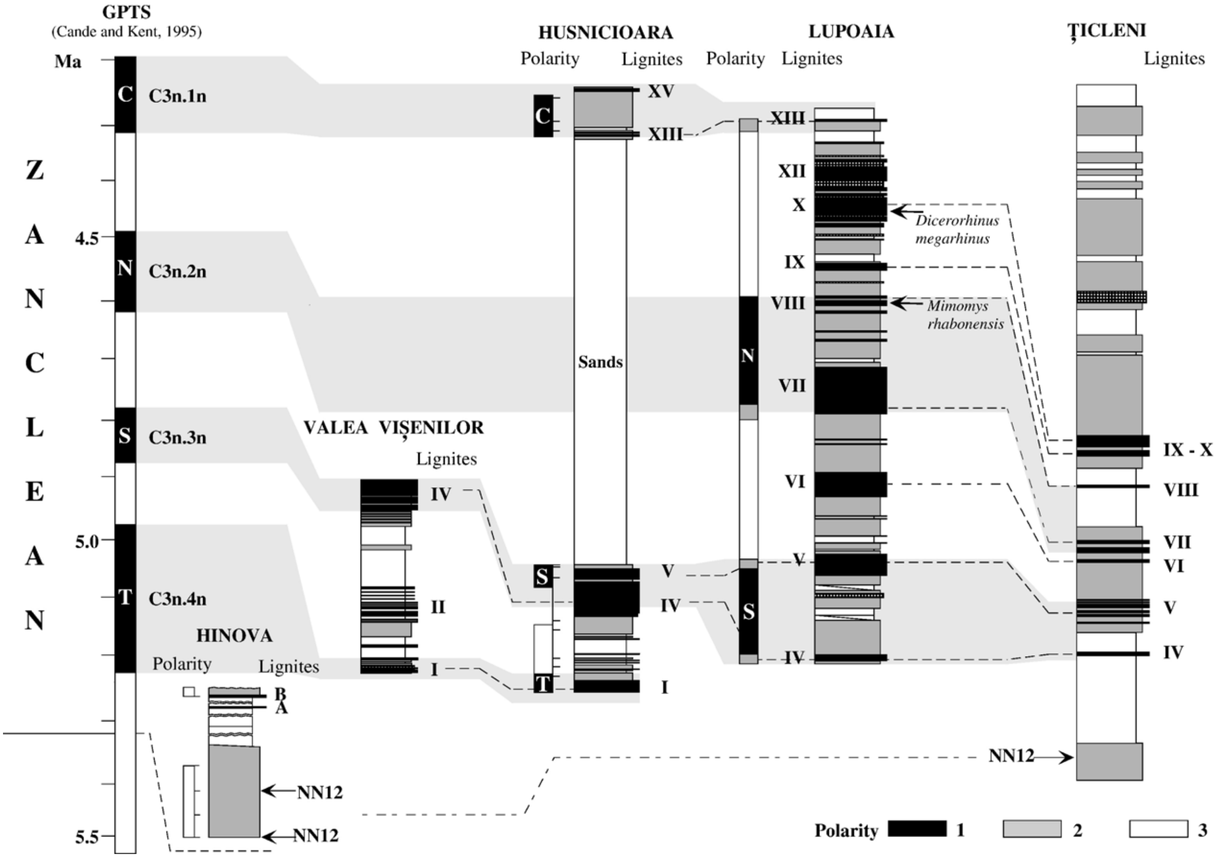


Fig. 3. Stratigraphic succession of lignites (A, B, I to XVIII) from the sections of Hinova, Valea Vişenilor, Husnicioara, Lupoaia and Ţicleni according to the regional nomenclature and chronologic assignment of the studied sections based on regional lignite stratigraphy and palaeomagnetic investigations, with additional biostratigraphic information. For Lupoaia section, the magnetic polarity column is after Rădan and Rădan (1998) and Van Vugt et al. (2001). 1, lignite; 2, lignite–clay; 3, clay; 4, sand; 5, non-recovered interval; 6, interrupted outline. T, Thvera; S, Sidujfal; N, Nunivak; C, Cochiti (Cande and Kent, 1995).

palaeomagnetic measurements and pollen analysis have been systematically processed (Fig. 3).

3. Magnetostratigraphy

To establish a magnetostratigraphic framework for the early Pliocene of the Dacic Basin, oriented handsamples have been taken from the Hinova (6 levels), Valea Vişenilor (8 levels) and Husnicioara (10 levels) sections. Previous data by Rădan and Rădan (1998) and Van Vugt et al. (2001) from the Lupoaia section are also taken into account for a general synthesis. Cores were drilled from the handsamples with compressed air at the palaeomagnetic laboratory Fort Hoofddijk. Unfortunately, the lithology of the Valea Vişenilor section appeared to be unsuitable for drilling, because of the sandy character of the samples. Hence, no palaeomagnetic results have been obtained for this section. Thermal demagnetisation was applied on the samples from Hinova and the lower part of Husnicioara with small temperature increments of 30–50 °C up to a maximum temperature of 360 °C, in a magnetically shielded furnace. Alternating field demagnetisation was applied on the samples from the upper part of Husnicioara up to a maximum field of 1 T. At least one specimen per sampling level was demagnetised. The natural remanent magnetisation was measured on a 2G Enterprises DC SQUID cryogenic magnetometer.

The samples of the Hinova section have mainly been taken from the clays of the bottom set beds of the Gilbert delta. They have relatively high NRM-intensities, ranging between 1 and 7.5 mA/m, and the NRM is generally composed of two components. First, a small viscous present-day field component is totally removed at a temperature of 150 °C. The second component has a reversed polarity, decays linearly towards to origin, and is largely removed at 360 °C (Fig. 4a,b). Similar thermal demagnetisation behaviour is observed in the samples of the Lupoaia section (Van Vugt et al., 2001). There, additional rock magnetic investigations suggested that

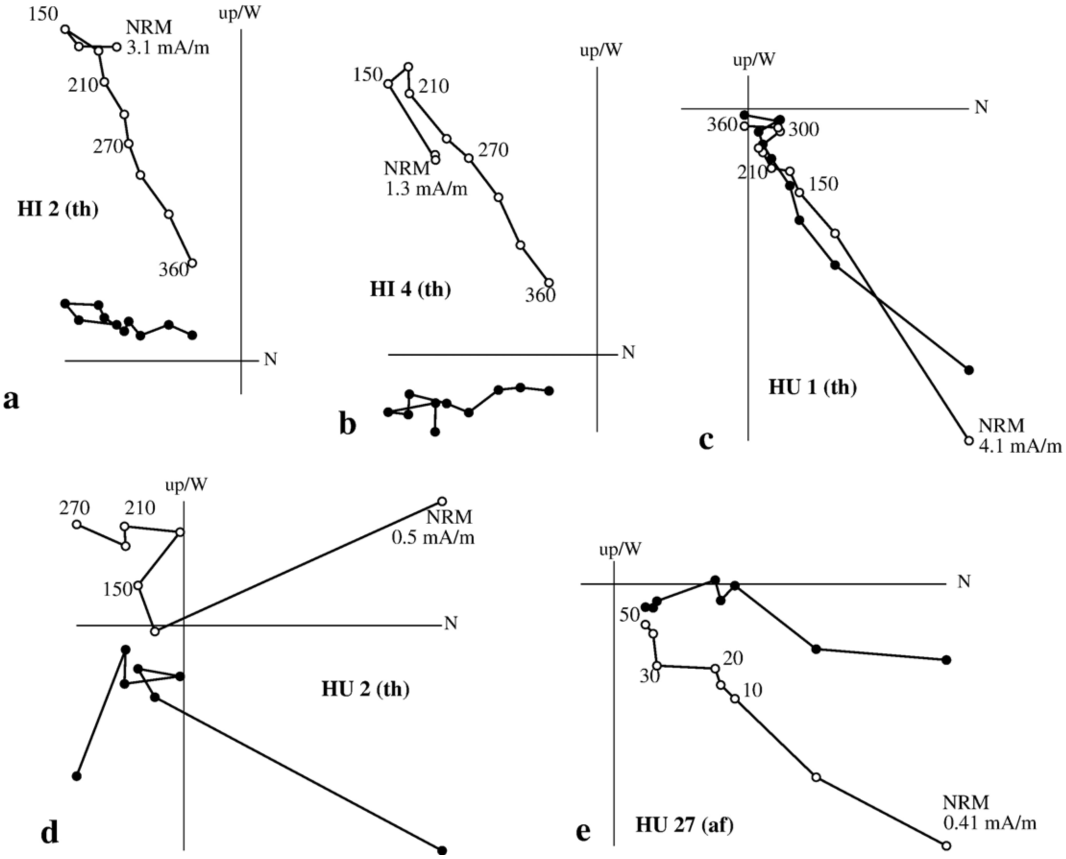


Fig. 4. Zijderveld diagrams for selected samples of the Hinova (HI) and Husnicioara (HU) sections of the west Dacic Basin. Thermal demagnetisation diagrams are indicated with (th), alternating field demagnetisation with (af). Filled symbols denote the projection of the vector end-point on the horizontal plane; open symbols denote projections on the vertical plane; values represent temperatures in °C or in mT.

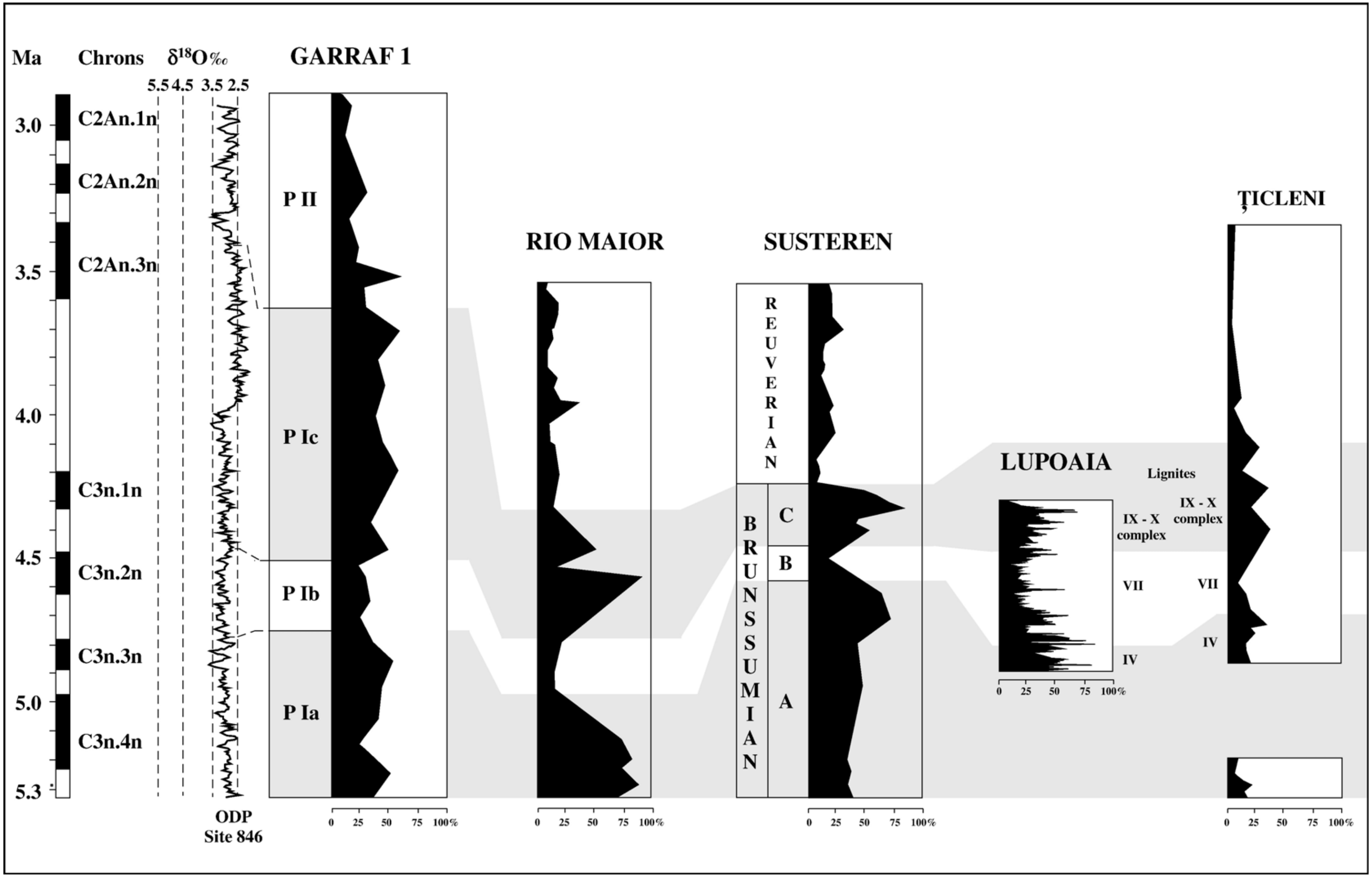


Fig. 5. Early Pliocene climatostratigraphy in Europe according to reference pollen diagrams: Garraf 1 in the Northwestern Mediterranean region (Suc and Cravatte, 1982), Rio Maior F16 in Portugal (Diniz, 1984), Susteren in The Netherlands (Zagwijn, 1960), Lupoaia (Popescu, 2001) and Țicleni (Drivaliari et al., 1999) in Romania. Climatostratigraphic relationships are based on the respective curves of subtropical trees compared to the reference oxygen isotope curve from ODP Site 846 (Shackleton et al., 1995).

the magnetic signal was carried by a ferrimagnetic iron sulphide, probably greighite, which is very common in freshwater sediments. Following Van Vugt et al. (2001), we have also interpreted this reversed 150–360 °C component in the Hinova section as a primary component of the NRM, implying that the entire Hinova section was deposited during a period of reversed polarity (Fig. 3).

The samples from the Husnicioara section have been taken at a very propitious moment when the mining excavation reached lignite I. Generally, these samples have a much lower NRM-intensity, and are commonly below 1 mA/m. Consequently, thermal and alternating field demagnetisation show less straightforward diagrams. After removing a viscous component at temperatures of 150 °C (or fields of 150 mT), most samples reveal a second component, which is removed at temperatures up to 360 °C (or fields up to 500 mT). The samples which are taken directly at the top of lignites I and V show a normal polarity component (Fig. 4c). The samples between lignites I and IV reveal demagnetisation diagrams which pass by the origin and gradually merge into the reversed quadrant of the Zijderveld diagrams, suggesting the presence of a reversed component (Fig. 4d). Alternating field demagnetisation diagrams of the samples from the upper part of the section, between lignites XIII and XV are clearly of normal polarity again (Fig. 4e). Consequently, we have interpreted the interval between lignites I and IV of being of reversed polarity, the other intervals of normal polarity (Fig. 3).

High-resolution magnetostratigraphic studies have earlier been performed on the Lupoaia section, and the reader is referred to Rădan and Rădan (1998) and Van Vugt et al. (2001) for more detailed information. The main result of these studies was that the lowermost part of the section (lignite V at that time) and the interval from lignite VII up to VIII have a normal polarity (Fig. 4). The middle and uppermost parts are reversed, with the uppermost reversed interval continuing at least up until lignite XV according to Rădan and Rădan (1998).

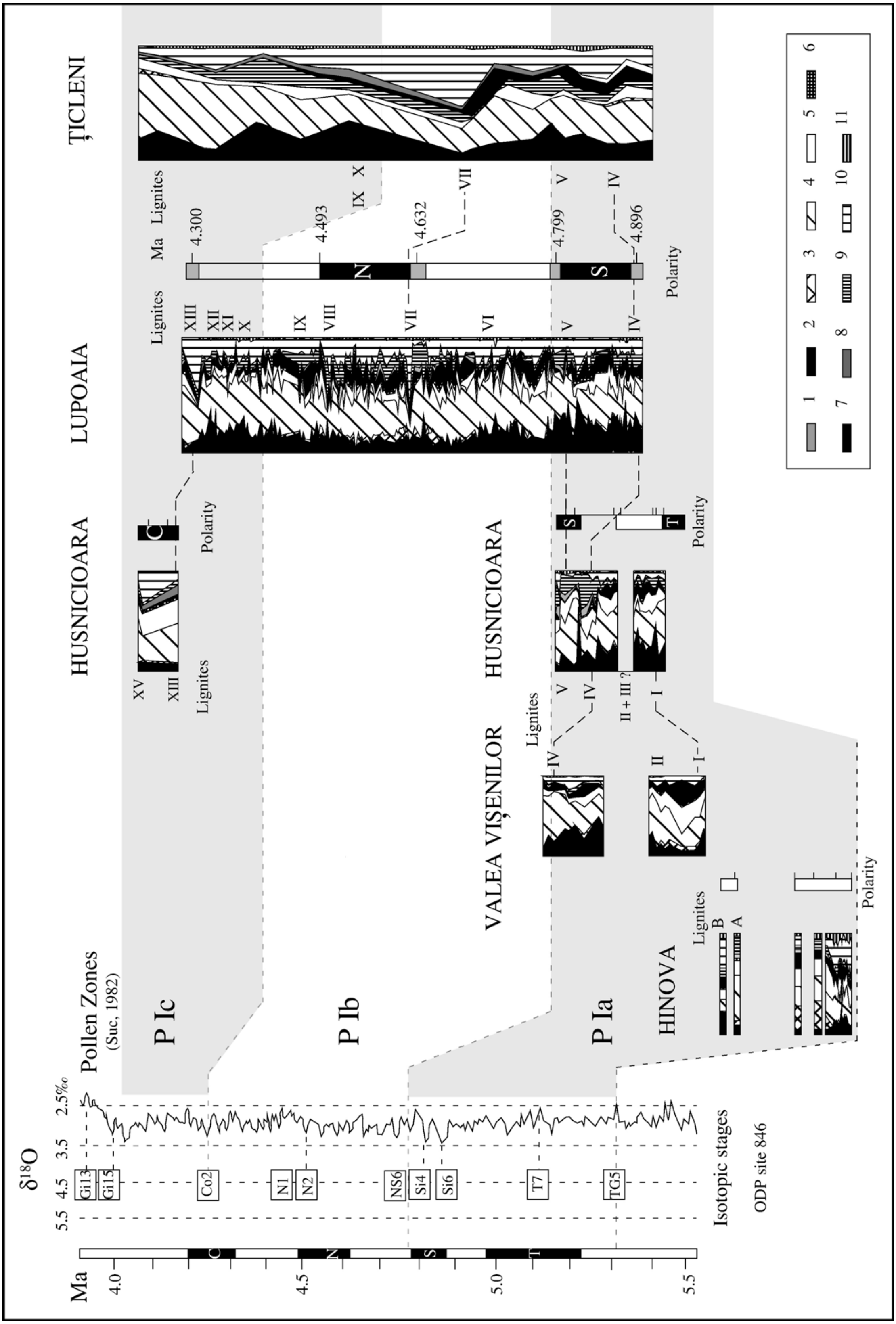
4. Correlation to the GPTS

The magnetic polarity patterns of the studied sections is generally too short to make a straightforward correlation to the GPTS. Nevertheless, there exist many additional stratigraphic constraints to achieve a best-fit correlation. This includes the detailed regional lignite stratigraphy, which allows a correlation between different sections and boreholes, and biostratigraphic constraints from nannoflora and fossil mammals.

In the Hinova section, for instance, the presence of Mediterranean nannoplankton from zone NN12 suggests an earliest Zanclean age. Moreover, the Gilbert type delta that developed along the Danube River was suggested to be related to the Pliocene flooding of the Mediterranean and Eastern Paratethys areas, directly following the Messinian salinity crisis (Clauzon et al., 2005). The observed reversed polarities are in good agreement with this scenario and therefore most likely correlate to the upper part of chron C3r. This implies that the Hinova section has been deposited in the interval between the Pliocene flooding at 5.33 Ma and the base of the Thvera at 5.23 Ma.

The correlation of the Lupoaia section to the GPTS has already been the subject of considerable debate. The original magnetostratigraphic correlation by Rădan and Rădan (1998) and Van Vugt et al. (2001) was that the two normal intervals correlate to the Nunivak (C3n.2n) and Cochiti (C3n.1n) episodes. The main argument for this correlation was the presence of a long interval of reversed polarities at the upper part of the Lupoaia section, from lignite bed VIII until XV. Later, however, Popescu (2001) proposed an alternative correlation of the two normal intervals to the Sidufjall (C3n.3n) and

Fig. 6. Synthetic pollen diagrams of the early Pliocene sections in the Dacic Basin and their chronological location with respect to the global polarity time-scale and the global climatic evolution. Pollen groups: 1, megathermic (i.e. tropical) elements (unidentified Euphorbiaceae, *Amanoa*, Mimosaceae including *Entada* and *Pachysandra* types, Meliaceae, Sapindaceae, Loranthaceae, Arecaceae, Sapotaceae, Tiliaceae, etc.); 2, mega-mesothermic (i.e. subtropical) elements (mainly Taxodiaceae, *Engelhardia*, *Cephalanthus*, *Distylium*, *Parrotiopsis jacquemontiana*, *Microtropis fallax*, Cyrillaceae–Clethraceae, *Leea*, *Myrica*, *Nyssa sinensis*, *Parthenocissus henryana*, *Ilex floribunda* type, Anacardiaceae, Araliaceae, *Magnolia*, etc.); 3, a lower-mid-altitude coniferous elements, *Cathaya*; 4, mesothermic (i.e. warm–temperate) elements (deciduous *Quercus* chiefly, *Carya*, *Pterocarya*, *Liquidambar*, *Parrotia persica*, *Carpinus*, *Ulmus*, *Zelkova*, *Celtis*, *Ostrya*, *Platanus*, *Juglans*, *J.* cf. *cathayensis*, *Nyssa*, *Sciadopitys*, *Buxus sempervirens* type, *Acer*, *Tilia*, *Fagus*, *Alnus*, *Salix*, *Populus*, Ericaceae, *Vitis*, *Hedera*, *Lonicera*, *Fraxinus*, *Ligustrum*, *Sambucus*, *Viburnum*, *Rhus*, *Ilex*, *Tamarix*, *Betula*, etc.); 5, *Pinus*; 6, meso-microthermic (i.e. cool–temperate) trees: *Cedrus*, *Keteleeria* and *Tsuga* growing in mid-altitude; 7, microthermic (i.e. boreal) trees living in high altitude, *Abies* and *Picea*; 8, elements without significance (Rosaceae, Ranunculaceae, unidentified pollen grains, poorly preserved pollen grains); 9, Cupressaceae; 10, herbs: Cyperaceae, Poaceae, Asteraceae, *Plantago*, Brassicaceae, Apiaceae, *Polygonum*, *Rumex*, Amaranthaceae–Chenopodiaceae, Caryophyllaceae, *Linum*, *Erodium*, *Convolvulus*, *Mercurialis*, *Euphorbia*, *Scabiosa*, *Knautia*, Malvaceae, Borraginaceae, *Helianthemum*, *Asphodelus*, Liliaceae, Cannabaceae, Fabaceae, Plumbaginaceae, *Butomus*, water-plants such as *Potamogeton*, Restionaceae, *Myriophyllum*, *Typha*, *Sparganium*, *Thalictrum*, *Nuphar*, *Nymphaea*, Oenotheraceae, *Trapa*, *Utricularia*, etc.; 11, steppe elements (*Artemisia*, *Ephedra*) (Suc, 1984).


Ma
4.0
4.5
5.0
5.5
C
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T
δ18O
5.5
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3.5
2.5‰
Gi13
Gi15
Co2
N1
N2
NS6
Si4
Si6
T7
TG5
Isotopic stages
ODP site 846
Pollen Zones
(Suc, 1982)
P Ic
P Ib
P Ia
HINOVA
Lignites
B
A
Polarity
VALEA VIȘENILOR
Lignites
IV
II
I
HUSNICIOARA
XV
XIII
Lignites
C
Polarity
HUSNICIOARA
V
IV
II + III ?
I
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Polarity
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4.300
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Nunivak (C3n.2n). This latter correlation was based on a better fit between the pollen data of Lupoaia with global climatic fluctuations provided by the oxygen isotope curves. The only problem with this revised correlation is the apparent absence of the Cochiti (C3n.1n) episode in the upward extension of the Lupoaia record. Additional biostratigraphic data at Lupoaia comes from fossil mammals, which indicate the presence of a primitive *Mimomys* (*Mimomys rhabonensis*) and *Apodemus dominans* within lignite VIII (Rădulescu et al., 1993), while *Dicerorhinus megarhinus* is observed within lignite X (Apostol and Enache, 1979). In northern Greece, the first *Mimomys* (*Mimomys davakosi*) is recorded in the Ptolemais 3 locality (van der Weerd, 1978), which correlates to the Sidufjall (C3n.3n) episode (Van Vugt et al., 1998). Unfortunately, no reliable age constraints (apart from being early Pliocene in age) can be given to the other species. Therefore, this mammal fauna of Lupoaia does not provide unambiguous chronological support to distinguish between the two different correlations.

The Husnicioara section is largely overlapping in time with the Lupoaia section, although the main part of this section consists of unconsolidated sands, which appeared to be unsuitable for a paleomagnetic study. The upper part of the Husniciaora section, however, consists of a more clay-rich interval and corresponds to the lignites XIII and XV, according to the regional lignite stratigraphy. The demagnetisation results from this interval suggest that lignites XIII–XV were deposited during an interval of normal polarity. Obviously, this is in disagreement again with the reported reversed polarities of the same interval in Lupoaia (Rădan and Rădan, 1998). So far, no unambiguous solution is found for this discrepancy, but overprinting of the magnetic signal (either normal or reversed) or errors in the lignite nomenclature (either in Husnicioara or Lupoaia) cannot be completely excluded. Nevertheless, the normal polarities of the upper part of Husnicioara are in clear support of the revised correlation of Popescu (2001) and hence they should correspond to the Cochiti (C3n.1n) episode (Fig. 3).

The lower part of the Husnicioara section reveals normal polarities in the lignite–clay interval just below the sands. According to the regional lignite stratigraphy, this interval corresponds to lignites IV and V (Fig. 3). Moreover, these normal polarities are in good agreement with the normal polarities observed in Lupoaia between lignites IV and V (Rădan and Rădan, 1998; Van Vugt et al., 2001). Consequently, they correspond to the Sidufjall (C3n.3n) according to the correlation of Popescu (2001). The downward extension of mainly reversed polarities is in good agreement with this correlation and the normal polarity at the base of the section thus suggests that lignite I was deposited during the uppermost part of the Thvera (C3n.4n) episode.

Summarizing, it can be concluded that the studied Pliocene series of the Dacic Basin covers at least a time span from the earliest Zanclean (about 5.33 Ma) up to the Cochiti normal episode (about 4.2 Ma), including all the normal events of the concerned period (Fig. 3). The onset of lignite deposition in the Dacic Basin is dated at approximately 5.25 Ma, i.e. slightly below the base of the Thvera. This seems to be perfectly synchronous with the marked transition from the carbonates of the “Lower Formation” to the lignite-bearing sediments in the Ptolemais basin in northern Greece, which occurred one precession cycle below the Thvera, suggesting a large-scale regional control on lignite formation. Moreover, the Dacian/Romanian boundary is located between lignites VII and VIII of the Lupoaia section (Andreescu, 1981; Alexeeva et al., 1983) and thus correlates to the Nunivak (C3n.3n) episode (Fig. 3). Consequently, the age of the Dacian–Romanian boundary arrives at approximately 4.55 ± 0.05 Ma in the Dacic Basin.

5. Climato- and cyclostratigraphy

The reliability of long-distance relationships based on climatic significance of pollen diagrams has been confirmed by Suc and Zagwijn (1983) and amplified by Suc et al. (1995). At the European mid-latitudes, the early Pliocene is characterized by two warm phases [noted Brunssumian A and C by Zagwijn (1960) and P Ia and P Ic by Suc (1984)] surrounding a moderate cooling phase [Brunssumian B of Zagwijn (1960) = P Ib of Suc (1984)]. Such a subdivision is only slightly expressed in the records of the Southern Mediterranean region where aridity is intense and dominant (Suc et al., 1995). However, it is well pronounced in the records of Portugal in Southwestern Europe (Diniz, 1984) and of the Eastern Paratethys in Southeastern Europe (Drivaliari et al., 1999). The floristic composition of the numerous investigated European regions is rather different, but fluctuations within pollen diagrams are parallel and are distinctly illustrated by the curve of subtropical trees (see the listing below) (Fig. 5). In addition, this pollen curve may be compared with the oxygen isotope reference curve of the open ocean (Shackleton et al., 1995) (Fig. 5). Taking into account the relative weakness of subtropical trees and the relative importance of altitudinal trees in the middle part of the Lupoaia pollen diagram (Fig. 6), this section

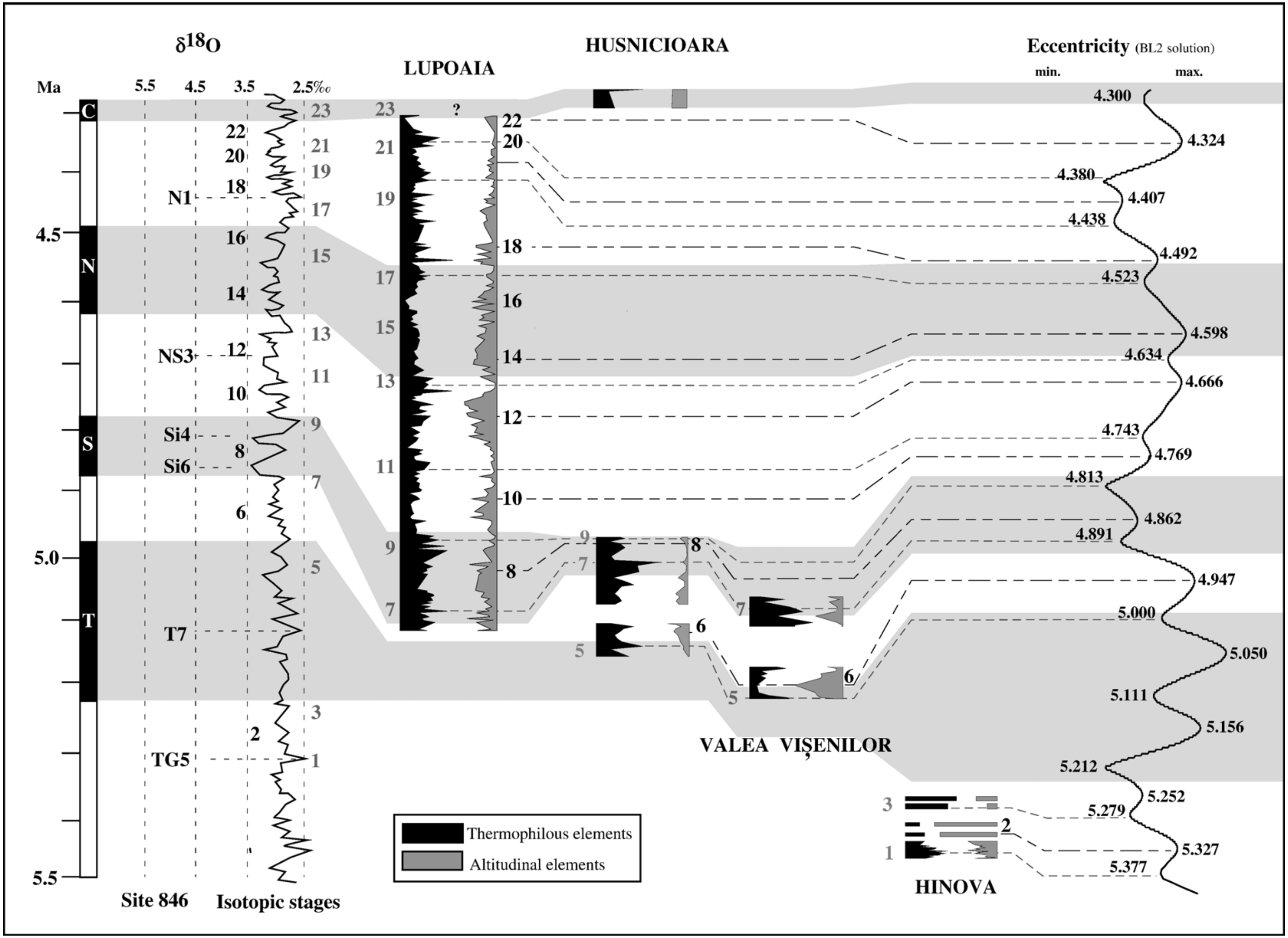

Fig. 7. High-resolution cyclostratigraphy of the early Pliocene sections in the Dacic Basin according to comparison between thermophilous vs. altitudinal element curves and the eccentricity curve (BL2 solution: Loutre and Berger, 1993).

obviously refers to the three Zanclean climatic phases: the upper part of P Ia, the entire P Ib, the lowermost part of P Ic (Figs. 5 and 6). These climatostratigraphic relationships support the magnetostratigraphic assignments discussed above and are wholly consistent with the regional lignite stratigraphy (see relationships between Lupoaia and Țicleni: Fig. 5). Consequently, it is proposed to correlate the pollen diagrams of the southwestern Romanian sections to obtain climatostratigraphic relationships, thereby including the magnetostratigraphic age constraints and taking into account the regional lignite stratigraphy (Fig. 6).

Detailed pollen counts are deposited at the Laboratory “PaléoEnvironnements et PaléobioSphère” (University Claude Bernard – Lyon 1) and will be shortly on the “Cenozoic Pollen and Climatic values” database (C.P.C.) on the Medias-France website (http://cpc.mediasfrance.org). Synthetic pollen diagrams have been used in which taxa are grouped with respect to their climatic and ecological significance (Suc, 1984; Suc et al., 1995). The eleven taxa groupings are given in Fig. 6.

The complete Hinova and Valea Vişenilor sections, the lower part of Husnicioara and the lowermost part of Lupoaia, belong to the P Ia warm phase (Fig. 6). The warmest period is recorded at Valea Vişenilor, Husnicioara and mostly at Lupoaia in correspondence with lignite V which, in addition, shows the largest geographic extension; Fig. 2). The middle part of Lupoaia belongs to the P Ib cooling phase. The coolest period is recorded at Lupoaia around lignite bed VII, although here it is not so clearly reflected in its geographical extension. The uppermost parts of Lupoaia and Husnicioara belong to the beginning of the P Ic warm phase (Fig. 6). The Țicleni borehole contains the three climatic phases, which are depicted at a considerably lower resolution but evidently show the “cooler” interval straddling lignite VII (Fig. 6).

Synthetic pollen diagrams can be summarized into two opposite curves, the thermophilous elements (i.e. the megathermic elements plus the mega-mesothermic elements plus the Cupressaceae) on the one hand, the altitudinal elements [*Cathaya* plus meso-microthermic elements (*Tsuga* and *Cedrus*) plus microthermic elements (*Abies* and *Picea*)] on the other hand. Such curves provide very good possibilities of comparison with the oxygen isotopic reference curve, maxima of thermophilous elements (warming events) corresponding to $\delta^{18}O$ minima and maxima of altitudinal elements (cooling events) corresponding to $\delta^{18}O$ maxima (Popescu, 2001; Popescu et al., 2006-this volume). In total, 23 major climatic points have been identified both on the oxygen isotope reference curve and on the pollen records, which have been correlated within the magnetostratigraphic frame during the early Pliocene time window corresponding to the studied sections (Fig. 7). Even numbers indicate cooler events, odd numbers indicate warmer events. The continuous opposition between the two pollen groups evidenced at Lupoaia (Popescu, 2001) is recurring within the entire basin, whatever the lithology that discards a possible influence of pollen transport. It has been demonstrated by Popescu (2001) and Popescu et al. (2006-this volume) that alternations between these pollen groups were forced by 100 kyrs cycles of eccentricity: maxima of thermophilous elements related to minima of eccentricity, maxima of altitudinal elements related to maxima of eccentricity. As a consequence, relationships between pollen curves and the eccentricity curve provide a high-resolution chronology to the Early Zanclean sediments of the Dacic Basin between 5.33 and 4.30 Ma. All the eccentricity cycles have been correlated with pollen records, except those comprised between 5.230 and 5.00 Ma which correspond to sands separating lignites B and I (Țicleanu and Diaconița, 1997) (Fig. 7); i.e. the lowermost top set beds of the Turnu Severin Gilbert delta (Clauzon et al., 2005). In addition, 400 kyrs cycles are also obvious: phases of increasing thermophilous elements are exaggerated during the lowest eccentricity minima (climatic events 3, 7 and 9, 19 and 21; Fig. 7), while the altitudinal elements are enriched during the highest eccentricity maxima (climatic events 10, 12, 14 and 16; Fig. 7). This suggests that the large-scale climatic subdivisions proposed by Zagwijn (1960), Suc (1984) and Diniz (1984) and which allow long distance climatostratigraphic relationships (Suc and Zagwijn, 1983; Suc et al., 1995), are dominantly forced by the ~400 kyr eccentricity cycles.

6. Conclusions

Several ways for dating the early Zanclean sediments of the Dacic Basin have been successively used. Mediterranean nannoplankton of zone NN12 immediately overlies a strong erosional surface, which was suggested to have a relation with the Messinian salinity crisis in the Mediterranean (Clauzon et al., 2005), and thus correlates to the earliest Zanclean. The normal polarities of the lignite I and of the lignite XIII–XV interval at Husnicioara seem to confirm the chronological re-calibration of the Lupoaia reference section to the Sidufjall and Nunivak episodes (Popescu, 2001). This correlation is very consistent with the pollen records and the resulting climatostratigraphy. In addition, palaeomagnetic measurements have been understood within the frame of the regional lignite stratigraphy and show the presence of the four successive normal events of the Gilbert Chron (Thvera to Cochiti). Consequently, an almost continuous pollen record of the western Dacic Basin is provided for the early Pliocene interval between about 5.33 and 4.30 Ma. Two very significant and still opposite pollen curves (thermophilous elements vs. altitudinal elements) allow a direct comparison with the reference oxygen isotopic curve and with the 100 kyrs and 400 kyrs eccentricity cycles in the astronomical curve. Recognition of 400 kyrs cycles offers large climatostratigraphic subdivisions as previously proposed by Zagwijn (1960), Suc (1984) and Diniz (1984). Recognition of 100 kyrs cycles only depends on time resolution of pollen analyses. This emphasizes once again the importance of very high-resolution pollen sampling.

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