PEATLANDS IN GIURGEU DEPRESSION AND THE RECONSTRUCTION OF TARDIGLACIAL AND HOLOCENE PALEOLANDSCAPE

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Abstract: The current geographical landscape of Giurgeu Depression in the Oriental Carpathians is the result of its spatio-temporal evolution on account of the evolution of the natural complex analysed correlatively, systematically relying on the latest alterations occurred a posteriori the Quarternary Glaciation and the recent ones determined by the anthropic pressure. In the case of the depression, there have been mapped 17 eutrophic peat bogs with a total volume of approximately 9 millions m^3 extended throughout 476 ha. These wetlands have formed due to the existence of a very small slope of Mureş meadow and most of these are of euthropic type with oligotrophic nuclei which move to peripheric areas in the transition stage becoming soligenic peatlands with hygrophile hay meadow sites. The correlation of observations and conclusions of the sporo-pollinic studies with the findings of the morphoclimatic, dendrochronological and dendrometric analyses provide specific conclusions on the spatial and temporal evolution of the geographical tardiglaciar and holocene landscape of the analised basin, exhibiting significant topoclimatic features obvious in the vegetal floor which has succeeded till the present one.

Keywords: geographical landscape, Giurgeu Depression, Mureş meadow, Quarternary Glaciation, sporo-pollinic studies

Introduction:

The current emergence of the geographical landscape of Giurgeu Depression is the result of its spatio-temporal progress driven by the evolution of the natural complex, analysed correlatively and systematically, on the latest changes occurring during post-Quaternary glaciation and the recent ones caused by human pressure. From a geographical and evolutionary approach, the quantitative analysis of the landscape has relied on the map of the current land use, representative for the spatio-temporal evolution (Schreiber et al. 2003). On a general level, the evolution of Giurgeu Depression paleolandscape in Tardiglacial and Holocene is part of the general conditions of the evolution of the Eastern Carpathians geosystems. 17 eutrophic wetlands with a total of about 9 millions m^3 of peat extended throughout about 476 ha have been mapped within the depression (Paraschiv 2014b; Raţiu 1971; Schreiber et al. 2003; Swizewski 1980). These wetlands were formed as a result of Mureş low-gradient riverbed (Bandrabur et al. 1974) and are mostly eutrophic, with oligotrophic cores, going through a transition phase in peripheral areas and becoming soligene swamps, with hydrophilic meadows, such as those from Voşlăbeni,

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Joseni and Remetea, which are also the largest (Paraschiv 2014b).

Materials and methods:

Reconstruction of climate during Holocene based on the interpretation of spore and pollen analysis of peat deposits in the upper meadow of Mureş offers the image of the geomorphological paleolandscape evolution, since the late Pleistocene and up to present. The relationship pollen - vegetation is not linear because of the calculations percentage and the long-distance effects of pollen from other regional sources (Gaillard et al. 2010), named the allochthonous pollen. Linking observations and conclusions from spore-pollen studies with results and conclusions of morphoclimatic dendrochronological and dendrometric analysis (Sidor 2009), is an important basis for scientific substantiation and evolutionary analysis of Tardiglacial and Holocene natural paleolandscape. A multi-criteria modelling is fundamental in such research (Alexandre 1987; Antonsson et al. 2008; Gaillard et al. 2010; Schreiber 2003).

Results and discussion:

The progress of Holocene lowland Carpathian forest landscape had a historical development reconstituted on the basis of peat profiles analysis interpreted by Pop at Borsec in 1931 and Bilbor in 1943 (Pop 1944), by Raţiu at Joseni, Voşlăbeni and Remetea in 1969 and 1970 (Raţiu 1971), by Fărcaş et al. (1997) at Topliţa-north, as well as other paleontologists. Raţiu (1971) performed a correlative analysis between 1969 and 1970 on the pollen samples collected from the central-northern part of Eastern Carpathians and established the evolution of forest landscape in Giurgeu Depression studying the wetlands from Voşlăbeni, Remetea and Joseni.

Paleo-bioclimatic studies recently published by Tanţău (2006), have brought new and valuable scientific contributions on the evolution of paleo-landscape in this period in the entire Carpathian area without specific customizations on the analysed depression area. Even if pollen analyses investigated by Tanțău refer to "resorts / sites" located in the proximity of Giurgeu Depression, on the correlative level the new determinations benefited from scientific recalibration of previous studies that have been reconfirmed over time. Thus the Tardiglacial landscape (14000-10000 years BP) was determined by high amplitude climatic oscillations that occurred on regional scale while on zonal scale oscillations were somewhat moderate (Litt 2003, in Tanțău 2006; Walker and Lowe 1990, in Tanțău 2006) (Tab. 1, Annexes).

Forest vegetation during Dryas I (Oldest Dryas) was reconstituted and established by the absolute dating at 13,880±90 years, being an opening for our country. The dominant vegetation was the steppe with *Artemisia* and *Poaceae*, plus a reduced arboreal and shrub vegetation. The main plant element was the pine (*Pinus*), followed by the birch (*Betula*). *Hippophae*, *Juniperus* and *Salix* associations are also documented in the mountainous area completing the natural vegetation landscape of that period. In the early Holocene, due to climatic warming, the expansion of mesophilic forest formations occured very slowly due mainly to consequences of cold climate in recent Dryas (Tab. 1, Annexes). Forest and weight trees vary from one period to another and reflect, to a significant extent, the expansion of each taxon according to the area of refuge, including the potential – very reduced indeed - human influence (beech, hornbeam, quercinee) (Huntley and Birks 1983, in Tanțău 2006; Gaillard et al. 2010). Spruce had a new post-tardiglacial expansion, since the early Holocene, probably on the existence of a number of glacial refugia or due to the propagation from a small number of isolated refuges ever since the Tardiglacial interstage (Ungur 2008). We believe that the lower part of Giurgeu basin, through which the actual Mureş slowly meanders on its lower slope, was never covered by forests in the period

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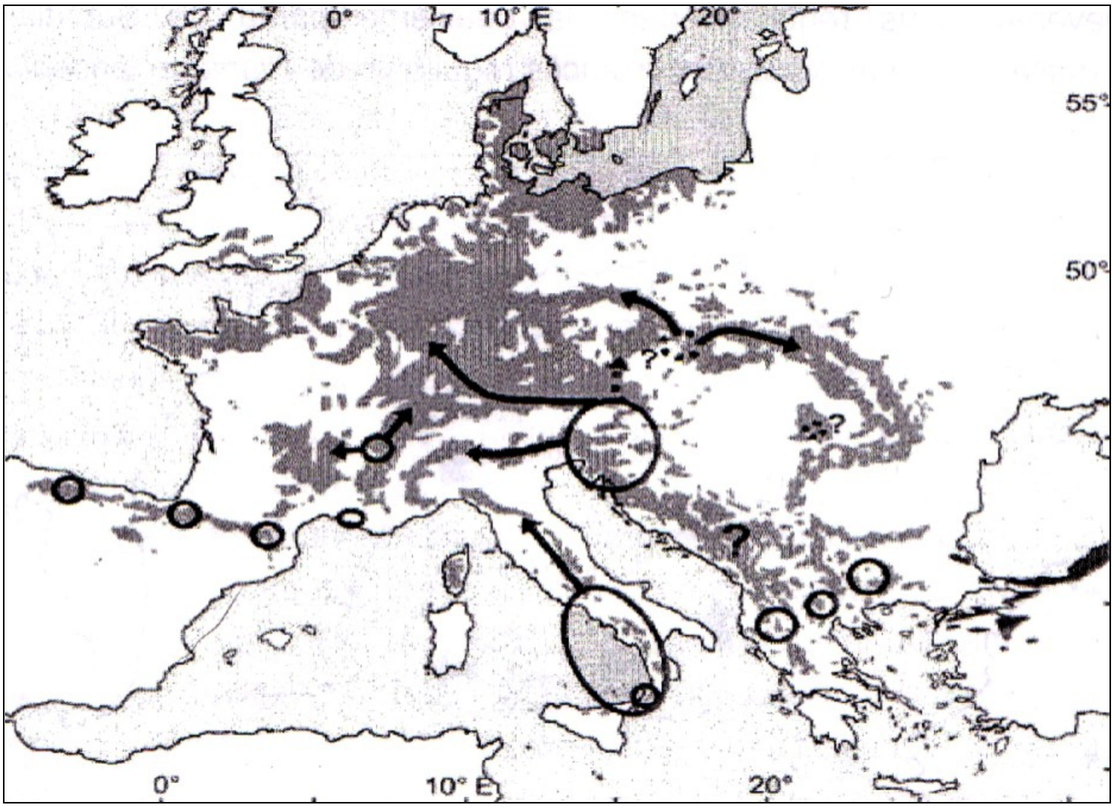
under review, fact correlated with actual soils. Holocene climatic optimum, hot and humid, started in Boreal and continued in Atlantic, allowed the accumulation of peat in the altitude swamps throughout the Carpathians. In the Atlantic the abundance of the two indicator taxa of mild and wet winter – *Hedera* and *Viscum* - was spore and pollen attested. Marshes formed in that period are considered the main natural components of the current environment and peculiar indicators for dating and reconstruction of paleo-landscape conditions in the basin's hearth. The surge of the human factor in the Subatlantic corresponded to the beech dominance on the basin slopes, settling on continental level, direct correlation between the geographical space humanization and the development of beech forests (Paraschiv 2014b) (Fig. 1). Grain crops were representative throughout this period and characterized the established "agricultural optimum".

Figure no. 1 Expansion of beech in Europe (after Tanţău, 2006)



The main human indicators used to establish the impact of prehistoric agriculture on the geographic environment and pre-existing paleo-geographic landscape were based on the analyses of the relationship between growing plants and grazing such as Cerealia - *Plantago lanceolata* and Cerealia - Poaceae (Lange 1975, 1976, in Tanţău 2006; Paraschiv 2014b).

Most likely the human impact in this period was extremely low, concluded on spore-pollen interpretations derived from peat profiles, restrictive climatic conditions and lack of proper agricultural space.

In recent years many attempts have been undertaken to reconstitute the Holocene climate and landscape using climate modeling. Climate model reconstituted with a simulation model of the climate over the past 9000 years in Scandinavia showed that it was mainly determined by solar characteristics and suggested a less warm and dry climate in the mid Holocene, than its reconstruction by modeling (Antonsson 2008). As an additional explanation for the reconstituted climate, this was analyzed taking into consideration the climatic trend at the beginning of the Holocene, from wet to dry, reinforcing the idea that it was caused by a change in atmospheric circulation, while in mid Holocene, the anticyclonic circulation of summer become prevalent. An extreme manifestation of anticyclonic conditions is the blocking of atmospheric pressure at heights that often causes long, very dry periods and hot weather during summer – the so-called "Indian summers" (Antonsson 2008), a similar situation to that happens nowadays, especially after 2004 (Paraschiv 2014a). Release of the carbon cycle in the atmosphere and change of barometric centers can cyclically, spatio-temporally return if synoptic conditions require it.

A good example is the last volcanic eruption in Iceland (March – April 2010, Eyjafjallajökull; May 2011, Grimsvötn) that caused rapid changes in the air circulation on continental scale and influenced the characteristics of climatic parameters, obviously with effects on our country. This hypothesis has timeless reverberations on the landscape functioning during the Quaternary post-volcanic period of the analysed depression. If the carbon concentration increased on acount of Holocene volcanism, nowadays the increasing carbon in the atmosphere is largely by virtue of human activity (Paraschiv 2014b). The argument is "tested" using the recordings of temperature and daily precipitation in central Sweden, as well as an objective classification of movement based on the surface air pressure between 1900 and 2002. The conclusion was that the differences between precipitation and temperature in climates are due to anticyclones and non- anticyclones synoptic developments that are significant. In addition, the combination of heat and dry spells as indicated by climate modeling reconstructions to mid Holocene is a typical pattern in anticyclonic conditions (Gaillard et al. 2010) that could be prevalent over the northern part of the Eastern Carpathians and implicitly its internal depression area, which would explain the spatio-temporal evolution of the landscape at that time.

Therefore, the absence of thermophilic and megaterme species or their insignificant participation in the cenosis structure of associations and dominance of cryophilic and microterme species denotes a climatic condition for the evolution of arctic-alpine relict elements (Ungur 2008). The generalized reconstruction of climate with an effect on the landscape of the Eastern Carpathians shows a transition climate from the continental climate specific to Eastern Europe, to the Mediterranean one specific to South Europe and oceanic climate specific to Western Europe. In conclusion we can frame the Giurgeu Depression by a humid temperate mountainous climate (Coldrea 1991, in Tanțău 2006) dominated especially in winter, by temperature inversions, with annual average values between 2-7 ^{o}C and precipitation between 800-1200 mm/year and the annual number of days featuring snow, variable, between 150-200. The presence of mineral waters loaded with dissolved chemical elements (bicarbonate ferruginous sulfated) at Voşlăbeni, Suseni, Ciumani, Ditrău, Remetea and Toplița have contributed to a good nutrition of swamp plants which dominate the alluvial plain landscape of Mureș (Fig. 2). In the evolution of post-glacial forest landscape in Giurgeu Basin the main sylvan phases described by Gaillard et al. (2010) and Rațiu (1971) have been identified, however with certain local peculiarities triggered by the manifestations of paleo-topoclimate typical of a depressionary area.

Figure no. 2 The sundew (*Drossera rotundifolia*) in Voşlăbeni swamp (June 2009)

Sylvan phases of identified Tardiglacial and Holocene forest landscape were based on the post-Pliocene paleo-landscape identified and described by the profile from Borsec (Pop 1931, in Flavia Raţiu 1971), that highlighted the presence of Atlantic elements (*Pinus strobus*, *Populus latior*, *Myrica lignitium*, *Fagus attenuata*, *Acer trilobatum* etc.), followed by Mediterranean components (*Pinus halepensis*, *Pinus nigra*, *Castanea vesca*) and the Balkan elements (*Pinus pence* and *Quercus roburoides*). Basically, in the mountainous region of the studied area, considering the sporo-pollen studies on Pliocene, we confirmed that the vegetation was dominated by Microterme coniferous: *Abies*, *Picea*, *Keteleeria*, *Tsuga* etc., but after the installation of glaciation we can speak of a criocratic landscape, with temperatures between 0 şi -5 ^{o}C on slopes and much colder in the depression's hearth, a cold steppe (Bojoi 2000, in Paraschiv 2014b).

Conclusions:

Tardiglacial and Holocene evolutionary phases have the following sequence with effect on forest paleo-landscapes that succeeded in space and time and had direct effects on the morphodynamics of the basin slopes:

A. Pine phase – based on the spore-pollen analysis of marshy complex profile from Voşlăbeni, correlated with other profiles in the nearest area, such as those in Şineu (Remetea, Izvoru Mureşului, Topliţa, Bilbor, Mohoş, Ruţ), includes the following sub-phases and episodes:

a. The sub-phase of arid pine forests with 3 climatic episodes:
   - a_1 episode of old dry pine forests;
   - a_2 episode of *Pinus-Picea*;
   - a_3 episode of new dry pine forests.

According to Bilbor, the episode of pine forests with birch is missing, in the 270-150 cm soil horizon. But forest landscape of pine forests was dominant in the conditions of an arid climatic optimum (Bojoi 2000, în Paraschiv 2014b).

b. Less arid pine forests sub-phase, in the ongoing of which we could delineate only the episode of pine forests with rich spruce forests (140-90 cm horizon). The ample development of pine phase suggests a Tardiglacial age for these dominant pine forests.

If we correlate the European periodization we can say that the two sub-phases described above developed in time and space, at the end of Old Dryas, respectively in Bölling and Alleröd interstage (Firbas 1949, in Raţiu 1971), or in Recent Dryas and partially in Preboreal (Ciobanu 1960; Blytt-Sernander 1956, in Flavia Raţiu 1971).

B. Pine-spruce transition phase is still dominated by pine forests but the competition between the two species is not sufficiently conclusive in all analyzed samples. Taking into account that spruce is a less pollen producing tree compared to pine, the dominance interpretation in the spore-pollen diagrams is less subjective. Chronologically, this phase is attributed to Preboreal and Early Boreal (90-70 cm horizon, Voşlăbeni). The pollen of broadleaved such as *Betula*, *Alnus*, *Quercus*, *Tilia*, *Ulmus* feature also modest values, which show a milder and less arid climate, conditions that have led to the gradual installation of spruce in the depression's hearth. In the Early Holocene, *Picea* recorded a large number of glacial refuges spread throughout Central Europe (Tanțău 2006), the likelihood of such a refuge in the Eastern Carpathians being yet difficult to determine, though it certainly existed in our opinion. The "shelter" paleo-climates confirmed by the bibliography show how deviations from generality occurring in environmental conditions imposed by topoclimates (eg "Suardi shelter") had the functionality of shelter in space and time for Tardiglacial and Holocene vegetation (Paquereau 1976, in Cârciumaru 1980) (Fig. 1).

C. Hazelnut tree with spruce and mixed oakery phase followed the final installation of spruce as dominant species in the depression. The spruce development provides the climatic evolution frame of the following sylvan phases, the pollen spectra from Șineu swamp, located northwest of Remetea, is sufficiently convincing. However, a spatio-temporal dilemma arises, identical to that of the pine, between maximum and minimum of spruce pollen fraction, where there is a broken line (440-230 cm horizon). Rațiu (1971) considers this "pollen incident" as a landlocked installation of pine and not as a climate-influenced competition, especially as mixed quercinee records a slight ascension. Spruce pollen maximums (86%) in the middle horizon and the fact that not even in the upper half of pollen profile its weight does not fall below 70% is a convincing argument on the dominance of this forest species. The existence and persistence of temperature inversions due to embossing topography is apparent from the comparative analysis of Șineu swamp profile in the hearth of Giurgeu Depression (810 m altitude) and from Ruţ swamp in Harghita Mountains, located at 950 m altitude, on the dominance of forest elements (Ciobanu 1960). It should be noted that on a global perspective, the comparative analysis of the two spore-pollen sites approximates the stability and local evolution of climatic conditions, as Ruţ swamp is located on the western end of the volcanic plateau in Harghita Mountains, at the boundary with the Transylvanian Hilly Depression and at about 20″ south latitude of Șineu swamp. Therefore, at Ruţ, the climatic influences of western winds are more persistent than the depression's hearth, fact also beheld in the benchmarking pollen diagrams. The beginning of sedimentation of Ruţ swamp is dated to the end of Preboreal (Ciobanu 1960). The positive differences from Ruţ resort to Șineu resort bring confirmations on climatic rigors and on the different evolution stages and types of forest landscape, with considerable greater values: very high for hazelnut phase, higher for mixed oakery and the insignificant participation of fir-tree to the composition of Tardiglacial forest landscape. At Șineu, the mixed oakery has maximum values, of 21.33% (190 cm horizon), while at Ruţ is more than double, having 47.52% (435 cm horizon). If we make correlations with higher extra-depressionary resorts, north and northeast of Giurgeu, we notice some important differences, for instance the actual oak forest near Tulgheş is deemed as a witness of continuity of Tardiglacial landscape (Tofan 2012).

The comparative analysis between Șineu swamp and Mohoş marsh, located at about 70 km south and 1050 m altitude, on the eastern flank of Harghita Mountains, shows that the mixed oakery pinnacle Mohoş reaches a ratio of 70% (Pop and Diaconeasa 1967, in Rațiu 1971), 3 times higher than at Șineu, reconfirming the manifestation of temperature inversions during that time, with stable effect on the forest landscape of the slopes. At Mohoş, as at Ruţ, the elm dominance in the mixed oakery shows a milder climate, more favorable to forest landscape development, with the mentioned broad leaved at the altitudes at which these marshes are located, in comparison to the hearth slopes of Giurgeu Depression, mostly dominated by spruce, on the background of a harsh climate with pronounced temperature inversions.

D. Spruce and hornbeam phase. In all spore-pollen spectra of Giurgeu Depression the hornbeam presence has been constant since Late Atlantic and throughout Subboreal. At Șineu, the recorded maximum of hornbeam pollen fraction is very low, of only 14% (40-20 cm horizon). This leads us to the argument that in Giurgeu Depression *Carpinus* was a sporadic presence during the Boreal forest phase and the climate coordinates of the depression were not favorable to the development of broadleaves.

E. Spruce and beech phase. The entire Subatlantic period is marked by the reigning background of spruce, beech having small percentages, because the topography and altitude of Giurgeu Basin did not provide optimal conditions for beech forest development, since the temperature inversions were the main limiting factor of their progress. From the analysis of swampland southwest of Joseni, located at Mureş-Belcina confluence, we ascertain two beech maximums, below 30% (120-80 cm horizon), after which the values drop below 10%.

We must point out that in the recently reviewed pollen spectrum from the periglacial swampy areas parasitizing the pastures and hayfields in the plain and terraces of the depression the pollen fraction of beech has not exceeded 12% (Rațiu 1971, fact reconfirmed by subsequent analyses in 2009). Observed and comparatively analyzed the two swamps - in Joseni and Ruţ - mark a clear difference at Ruţ, after the spruce and hornbeam phase, on the background of a wet and cold climate, when the beech has become dominant (55%) in the Subatlantic forest landscape in the western part of Harghita Mountains, while in the hearth of Giurgeu Depression, there was a colder and not too wet climate, restrictive for beech forests (Fig. 1).

We had in mind a transverse profile over Giurgeu Depression, on a correlative level, which would also include the swamp Trei Fântâni Depression (Hăghimaș Mountains), located to the east on the same latitude, which is drained by an active ferruginous spring flowing into Bicăjel river. So, we might have had two marginal mountain profiles, with Ruț swamp to the west, and the Trei Fântâni swamp to the east, also correlated with those in the depression's hearth. Unfortunately, time and material aspects did not allow us the achievement of this profile, but we hope it will be accomplished in the near future. Alder forests have been a constant presence since hazelnut with spruce and mixed oakery phase till nowadays. Giurgeu Depression confirms the phenomenon of "van Post's return" specific to central and northern Europe during Subatlantic (Rațiu 1971) (Fig. 1). The entire post-glacial evolution of forests in Giurgeu Depression was dominated as spruce, which provided the necessary conditions of preservation of flora glacial relicts (Fig. 2). Out of this space-time evolution we take out the climatic coordinates of evolution, knowing that forest formations, which are climax associations, give us indications on the evolution of the climate in which the forest landscape has developed (Rațiu 1969). We believe that not even throughout the hipsotherme period of post-glacial climate, the Giurgeu Depression did not meet the thermal environment conditions that favored the dominant development of broadleaves. The peat structure in Voșlăbeni swamp confirms depressionary climate features, shown by the peat thickness with *Sphagnum* (Fig. 3, Annexes). The paleo-landscape of primary natural grasslands in Mureș plain, alternating with eutrophic swamps and the Holocene forest landscape could function and adapt throughout Quaternary, as "islands" of vegetation, and subsequently by the relative mildness of climate favored in time the settling of population in the subsequent historical periods to the evolution of present vegetation. We can say the swamps and bogs in the southern, higher area of Giurgeu Depression could serve as refuges for some of the flora of the Glacial Period and their feed was achieved exclusively by pluvionival sources. But this hypothesis must be reconfirmed by further systematic investigations and correlations of all the natural constituents of landscape, be they primary or derived, as the influence of post-volcanic events on the microclimate of shelter and the use of scaling method for the preservation of present climate variability.

Rezumat:

TURBĂRIILE DIN DEPRESIUNEA GIURGEU ȘI RECONSTRUCȚIA PEISAJULUI GEOGRAFIC DIN TARDIGLACIAL

Peisajul geografic actual din Depresiunea Giurgeului, Carpații Orientali, este rezultatul evoluției spațio-temporale a acestuia pe fondul evoluției complexului natural analizat corelativ, sistemic, pe baza ultimelor modificări intervenite în post-glaciația cuaternară și a celor recente determinate de presiunea antropică. În cadrul depresiunii au fost cartate 17 mlaştini eutrofe cu un volum total de cca 9 milioane m^3 de turbă, extinse pe cca 476 ha. Aceste mlaştini s-au format ca urmare a pantei foarte mici a albiei Mureşului şi sunt în cea mai mare parte a lor de tip eutrofic, cu nuclee oligotrofe, care trec în zonele periferice în faza de tranziţie devenind mlaştini soligene, cu fâneţe higrofile. Corelarea observărilor şi concluziilor din studiile sporo-polinice cu rezultatele analizelor morfoclimatice, dendrocronologice şi dendrometrice, oferă concluzii concrete asupra evoluției spațiale şi temporale a peisajului geografic tardiglaciar şi holocen din bazinul analizat, cu particularitățile topoclimatice de impact reflectate în covorul vegetal care s-a succedat până la cel actual.

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Annexes:

Table no. 1 Tardiglacial and Holocene chronology (processing after Tanțău 2006)

SERII / EPOCI	VÂRSTA	SUBDIVIZIUNI INFORMALE	CRONOZONE	SUB-CRONOZONE	Datare convențională (^{14}C): Mangerud et col., 1874, 1982; Lang, 1994	Datare convențională (^{14}C): Firbes, 1954	Datare convențională (^{14}C): Burge, 1988	Datare convențională (^{14}C): Beaulieu et col., 1994	Datare precisă (^{14}C): Stuiver & Reimer, 1993
HOLOCEN		TÂRZIE; NEOGLACIAȚIE; 100 – L.I.A. – 500	Subatlantic	târziu					
				mediu	1000				
		2800 BP		timpuriu	2000				
					2500	2500/2800	2800	2700	2728-2467
		MIJLOCIE; HYPSITHERMAL	Subboreal	târziu	3000				
				mediu	4000				
				timpuriu					
					5000	4500	4800	4700	5657-5855
		5300 BP ca	Atlantic	târziu	6000				
				mediu	7000				
		TIMPURIE		timpuriu					
		8000			8000	7500	7500	8000	8672-8961
			Boreal						
					9000	8500/8800	8800	9000	9944 – 10.004
			Preboreal						
					10.000	10.100	10.200	10.200	11.008 – 11.587
PLEISTOCEN	WURM = WISCONSINIAN = WEICHSELIAN	GLACIARUL TÂRZIU	Dryas-ul nou						
					11.000	11.000	11.000	10.800	12.847 – 12.985
			Alleröd	Oscilația Gerznersee				INTERSTADIUL GLACIAR TÂRZIU	
			Dryas-ul mediu						
					12.000	12.000	11.800		13.866 – 14.126
			Bölling						
					13.000		13.000	13.000	15.280 – 15.573
			Dryas-ul vechi						
					(15.000)		cca 15.000	15.000	
		MAXIMUL ULTIMEI GLACIAȚII							

Figure no. 3 The pollen chart of Voșlăbeni swamp (after Flavia Raţiu 1969, 1971)