THE COAL-GENERATING NEOGENE FORESTS FROM THE DACIAN BASIN

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Abstract. Small or more extended Neogene intra and extra-Carpathian Coal Deposits are known in Romania, either related to a lacustrine environment or to the evolution of the Dacian Basin, one of the last remnants of the Central Paratethys. Here we made a short synthesis and a re-evaluation of all the previous research studies, part of them of the authors. As main results, beside the quantitative evaluation of coal resources in the basin, it is demonstrated that the most important Neogene coal-genesis within the Dacian Basin developed during the early Dacian to the late Romanian, and covered almost all the western part of the basin with large quantities of brown woody coal (lignite). It is also demonstrated that there can be outlined specific associations in the coal-generating vegetation living in the marsh and lake areas, and around, typical for each specific biotope and which gave specific lithotypes with specific technical properties. Also, an obvious cyclicity in the coal-genesis was observed during a sustained subsidence, the vegetal material being accumulated during four steps: fluvial, fluvio-lacustrine, telmatic and finally, lacustrine. And this was several times repeated, because more than twenty two coal seams, sometimes thicker than two meters, are known in the western part of the Dacian Basin.

Keywords: coal-generating forest, coal seam, palaeoenvironment, palaeoclimate, cyclicity.

Rezumat. Pădurile neogene carbogeneratoare din Bazinul Dacic. În România sunt cunoscute zăcăminte de cărbuni neogeni mai mici sau mai extinse în spaţiul intra şi extracarpatic, fie în relaţie cu medii lacustre, fie cu evoluţia Bazinului Dacic, unul din ultimele rămăşiţe ale Paratethysului Central. Am făcut aici o scurtă sinteză şi o revedere a tuturor cercetărilor anterioare, parte din ele şi ale autorilor. Ca principal rezultat, pe lângă evaluarea cantitativă a resuselor de cărbune în bazin, se demonstrează că cea mai importantă carbogeneză din Bazinul Dacic s-a desfăşurat în intervalul Dacian inferior - Romanian superior, acoperind aproape toată partea vestică a bazinului cu mari cantităţi de cărbune brun lemnos (lignit). Se demonstrează, de asemenea, că în cadrul vegetaţiei carbogeneratoare se pot contura asociaţii specifice, trăind în arii mlăştinoase sau lacustre şi împrejurul lor, tipice pentru fiecare biotop specific, şi care dau litotipi specifici, cu proprietăţi tehnice specifice. De asemenea, s-a observat o ciclicitate evidentă de-a lungul unei subsidenţe susţinute, materialul vegetal fiind acumulat în cursul a patru paşi: fluvial, fluvio-lacustru, telmatic şi, în sfârşit, lacustru. Iar aceasta s-a repetat de mai multe ori, deoarece mai mult de 22 strate de cărbune, uneori mai groase de doi metri, sunt cunoscute în partea vestică a Bazinului Dacic.

Cuvinte cheie: pădure carbogeneratoare, strat de cărbune, paleomediu, paleoclimat, ciclicitate.

INTRODUCTION

During the Neogene, within the Romanian Carpathians area, coal deposits were formed within three coal-generating phases: the first phase - developed during the Early Sarmatian (Volhynian), the second phase developed during the Early-Middle Pontian and the third phase, the most important one, developed during the Pliocene (Figs. 1, 2), in most favourable conditions for the accumulation of vegetal remains created into the Dacian Basin, especially between the Danube and the Olt rivers, i.e. Oltenia region (Fig. 1).

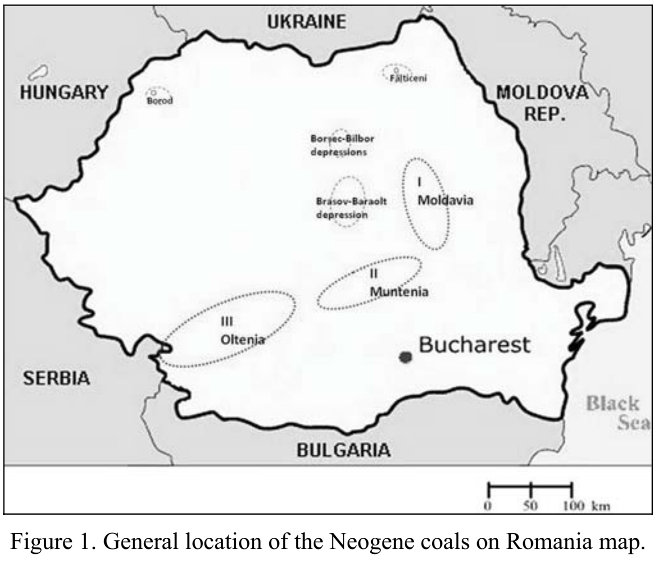

Figure 1. General location of the Neogene coals on Romania map.

Over 3 billion tons of brown woody coal (lignite) has been evaluated within this coaly region situated in the western part of the Dacian Basin. Oltenia is the most important Late Neogene coaly region (with Motru-Rovinari and Dedoviţa-Husnicioara-Pinoasa areas), followed by Muntenia (with Schitu-Goleşti area), and with numerous exploitations as mines or open pits (Figs. 1, 3).

Researches were done and numerous scientific papers were written on the Neogene coals from the Carpathian area and on their genesis by RĂILEANU (1963); PREDA et al. (1981); PAULIUC & BARUS (1982); PETRESCU et al. (1987); BARUS (1987); PAULIUC et al. (1988); ŢICLEANU (1986a, b, 1992a, b, 1995a, b, 2006); ŢICLEANU & ANDREESCU (1988); ŢICLEANU & BIŢOIANU (1988, 1989); ŢICLEANU & DIACONIŢA (1997); ŢICLEANU et al. (1982b, 1985, 1988, 1999, 2001, 2004); DIACONU (2000a, b, c, 2001, 2002b, 2004a, b, c, 2005, 2006a, b, c, 2008).

The complex processes of carbo-genesis or coal genesis, usual terms in coal science signifying all the processes of genesis of the coals – (ŢICLEANU, 1992b; BERGOSSI, 2003; ZAITSEVA et al., 2004) were well understood and explained in the Dacian Basin (ŢICLEANU, 1992b, 1995a, 2006; DIACONU, 2000a, 2002a, 2004a, 2007; DIACONU & ŢICLEANU, 2008).

Thus, Oltenia region has an extended Pliocene coal-genesis, represented by more than twenty thick lignite seams, some of them largely distributed within the Dacian Basin. They were explored and partially exploited by mining or in open pit, most of them being abandoned now.

Other coal genesis phases are poorer. For example some small lenses or decimetric seams of coals were discovered within the sediments from the Meotian till the Pliocene in the Subcarpathians, in Moldavia region, between the Trotuş and the Buzău rivers (Fig. 3). Comăneşti area is more important – with Comăneşti, Asău, Dărmăneşti coal deposits – exploited by the mines Comăneşti, Lăloaia, Lapoş, Sălătruc, Larga, Leorda and Vermeşti. Less important is Focşani-Odobeşti area with some occurrences of thin levels of lignites (at Pralea-Căiuţi, Gospei-Secu, Reghiu-Poeniţa and Milcov Valley), and Buzău area (at Ojasca, Berca, Ariceşti). Also, in the Southern Subcarpathians, beside the Schitu Goleşti, which is a better developed coal deposit, some coal seams were mined at Aninoasa, Doiceşti, Şotânga, Filipeştii de Pădure and Ceptura. Almost all of these coal deposits have smaller economic importance (RĂILEANU, 1963; PETRESCU et al., 1987) and even if they were locally exploited, they were not included in a distinct coal-genetic phase (ŢICLEANU, 2006).

During the Pliocene, some intramountaineous basins developed within the Carpathians, resulting in coal deposits, locally exploited, as those from Braşov-Baraolt (or Bârsei-Baraolt) depression (at Vârghiş, Doboşeni, Căpeni, Baraolt, Herculian, Băţanii Mari, Bodoş-Aita, Vlădeni, Ilieni, Arcuş-Criş Valey, Ghidfalău), and from Bilbor, Borsec and Jolotca small depressions (Fig. 1). Nearly all of these coal deposits were subject of local exploitation by mining or quarry, beginning with the 19th century, now being abandoned.

The sediments of all these coal deposits include clayey levels providing fossilized leaves, fruits, seeds and pollen coming from the plants which lived around or in the coal-generating area. Most of the Romanian palaeobotanists focused on these sediments. They realized and published a lot of specialized studies, in an attempt to reconstruct the coal-generating palaeovegetation, the palaeoenvironment, the palaeoclimate and the palaeogeography of those final stages of the Neogene: POP (1936); BARBU (1954, 1960); GIVULESCU (1967, 1992, 1996); PETRESCU & KOLOVAS (1983); PETRESCU et al. (1987, 1989a, b); ŢICLEANU (1986a, b); ŢICLEANU & ANDREESCU (1988); ŢICLEANU & BIŢOIANU (1988, 1989); ŢICLEANU & DIACONIŢA (1997); ŢICLEANU & PARASCHIV (2000); ŢICLEANU et al. (1982a, 1985, 1988, 2002, 2004); IAMANDEI (2000); IAMANDEI & IAMANDEI (2000); DIACONU (2000a, 2002a, 2004a, 2007); DIACONU & ŢICLEANU (2008); POPESCU (2001a, b); POPESCU et al. (2006). A small synthesis of their researches on the Pliocene coals will be included in this paper.

The Dacian Basin, as a remnant of the Paratethys, was an important area of sedimentation. Here, especially during the Pliocene, ideal environmental conditions were created for the development of vegetation with a great quantitative growing and replacement ratio. This way the basin of accumulation was fed for a long time with vegetal material, within a fluvial, deltaic or lacustrine environment with specific sedimentation. Huge quantities of vegetal material, often mainly woody, were accumulated. Periodic catastrophic precipitations can be assumed, at least as a logical explanation for those lignite seams looking like “log deposits”, from Motru-Rovinari area. This is very probably, since the Messinian crisis was not only a regional event within the Mediterranean area. At least within the Carpathians, this interval corresponds with the progressive closing of the Dacian Basin, a part of the Paratethys marked by a very important Pliocene coal-generating episode. Also here, during the Pliocene, the palaeoenvironment was rapidly modifying, the Carpathians being an active zone, which is still moving. The last Pliocene volcanism was still acting, and the mountains are still arising nowadays. The last small intramountaineous basins were filled by sediments, sometimes including variably sized coal levels. All the observations and the studies done till now on these coal deposits give us an idea, not only on the palaeoenvironment and the sedimentation style, but on the vegetation of those times. Unfortunately few palaeoxylotomical investigations were done in these coals in order to clarify the taxonomic composition of the xylitic coal seams (IAMANDEI & IAMANDEI, 2000).

To have a good geochronological setting for the next discussions, it must be taken into consideration that in June 30, 2009, IUGS ratifying the “ICS Recommendation on redefinition of Pleistocene and formal definition of base of Quaternary” changed the Pliocene chronostratigraphy, since Gelasian stage go representing the Pleistocene basal (Fig. 2), so the Pliocene start from 5.332 MY with Zanclean, and goes, with Piacenzian, up to 2.588 MY (WALKER & GEISSMAN, 2009). The equivalent stages within the Central Paratethys are represented by the Dacian, which would correspond to calcareous nannoplankton zone NN12, and the Romanian which would correspond to NN13 to NN17 as well. The changes should be in Fig. 2.

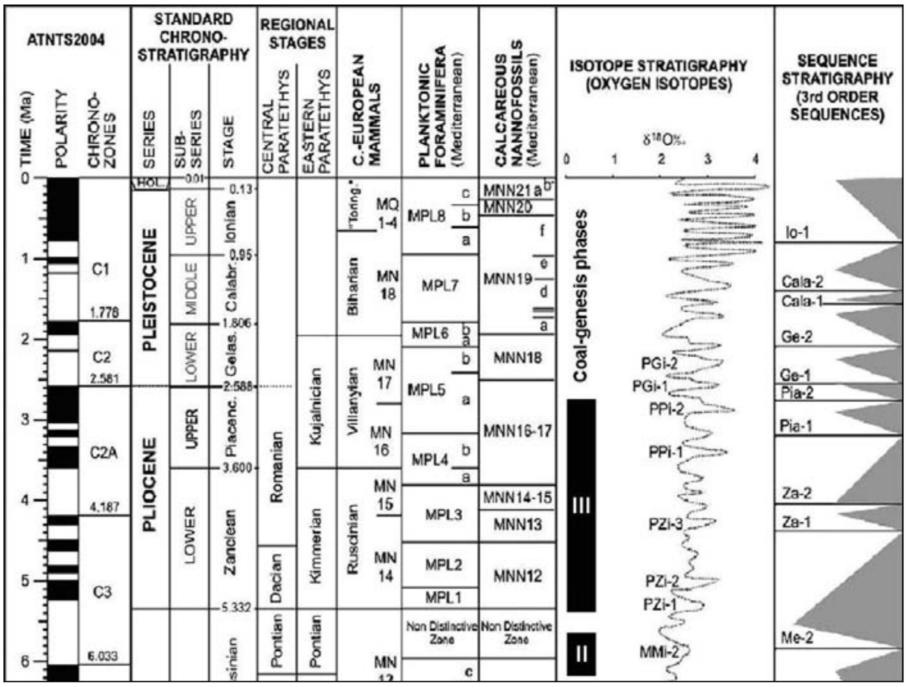

Figure 2. Pliocene chart (from HARZHAUSER & PILLER, 2007, with modifications).

COAL-GENERATING PALAEOENVIRONMENTS WITHIN THE DACIAN BASIN. THE PLIOCENE MODEL

The Dacian Basin - in Romanian it is named and orthographied "Dacic"; similarly it is pronounced as in French "Dacique", see JIPA (2006) - was a part of the late Paratethys (Fig. 3).

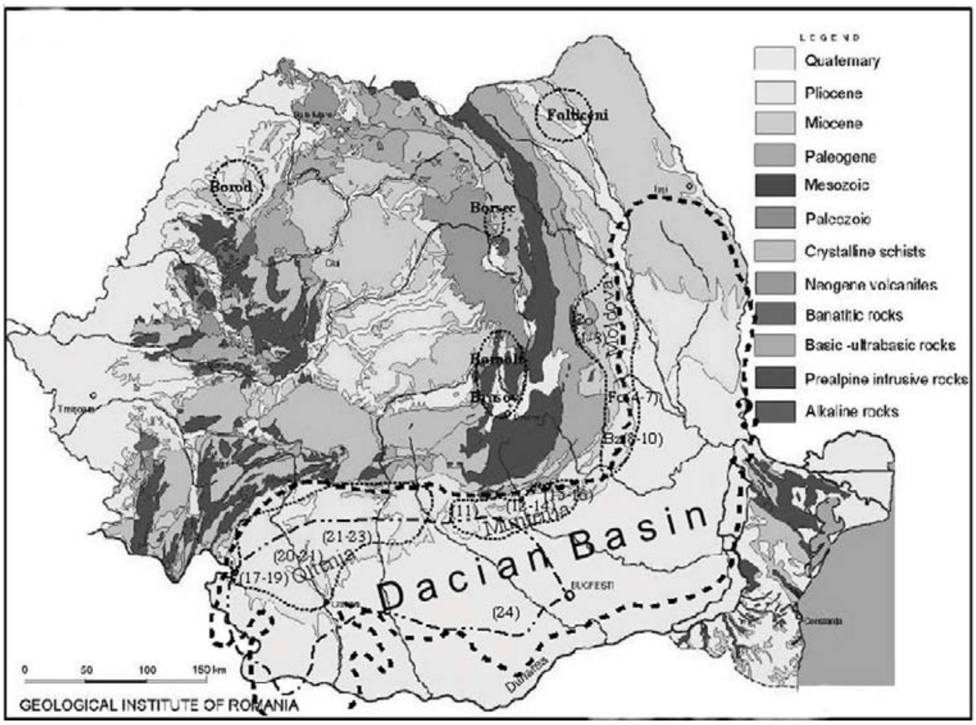

Figure 3. Areas of the main Neogene coal genesis within the Dacian Basin.
(Sketch of the Geological Map of Romania, with the extension of the Dacian Basin, modified after JIPA & OLARIU, 2009).
Moldavia region – The Sarmatian coal genesis: Fălticeni area, Co-Comăneşti area (1-Comăneşti, 2-Asău, 3-Dărmăneşti); + some Meotian to Pliocene coal occurrences: FO-Focşani-Odobeşti (4-Pralea-Căiuţi, 5-Gospei-Secu, 6-Reghiu-Poeniţa, 7-Milcov Valley); Bz-Buzău (8-Ojasca, 9-Berca, 10-Ariceşti); *Muntenia region* – The Pontian coal genesis (11-Schitu-Goleşti, 12-Şotânga, 13-Doiceşti, 14-Aninoasa); + some Pliocene coal deposits: 15-Filipeştii de Pădure, 16-Ceptura). *Oltenia region* – The Pliocene coal genesis (17-Dedoviţa, 18-Husnicioara, 19-Pinoasa, 20-Motru, 21-Rovinari, 22-Ploştina, 23-Mătăsari, 24-Deep extension).

This basin was intensely studied from all points of view, not only because of its huge coal deposits, which were formed during the most important Neogene coal genesis within the Carpathian area, the Pliocene one. For comparison it might be useful to mention also the previous two coal genesis phases on Romania's territory, in terms of the Romanian scientific literature:

I. The Sarmatian coal genesis is represented by the early Sarmatian (Volhynian) lignite of the Borod basin (POPA, 2000; PETRESCU, 2003). Also some Volhynian occurrences were described by ŢIBULEAC (2001) in Fălticeni area (at Fălticeni, Boroaia, Bogdăneşti), on the Moldavian Platform (Fig. 1), where a coal-generator peat formed on the paralic plains of the Dacian Basin which had a typical peat vegetation with *Glyptostrobus, Myrica?, Alnus, Salix, Liquidambar* and also with *Phragmites* and *Typha*. Even if the biotic and climatic conditions were convenient, the tectonic and palaeogeographic conditions were not too favourable and therefore few coal seams of reduced thickness and extension were formed.

II. The Pontian coal genesis was developed especially in Muntenia region (Figs. 1, 3), in Schitu-Goleşti area (exploited points at: Berevoieşti, Godeni, Pescăreasa, Poienari and Jugur), as well as in some other places where thinner coal intercalations within Middle Pontian appear (in PETRESCU et al. 1987). Aninoasa and Doiceşti coal deposits could be added (other coal deposits in the same Subcarpathian region, situated much to East: Filipeştii-de-Pădure, Şotânga and Ceptura - are more recent, of Pliocene age, and were not included in this phase of coal genesis). The Pontian coal genesis developed only in the inner part of the Carpathian Foredeep, where the palaeorivers resulted in not too extended alluvial-lacustrine accumulation plains with a continuous subsidence (e.g. between the Argeş and the Topolog rivers). The wet and warm-temperate climate was favourable to a coal-generating peat and to large forests with *Glyptostrobus europaeus, Alnus cecropiaefolia, Bytneriophyllum tiliaefolia*, a. o…, as other Pontian forests in the Carpathian area show (GIVULESCU, 1967, 1992, 1996, 1997; ŢICLEANU & PARASCHIV, 2000; ŢICLEANU et al., 2002; PETRESCU et al., 2002; DIACONU, 2004a).

III. The Pliocene coal genesis developed within the Dacian Basin, which still had a large extension during the Pliocene, especially during the Dacian stage to the middle-late Romanian (Fig. 2). Some coeval deposits were developed in the intramountaineous small depressions (Fig. 3). The Dacian Basin had a fluctuant evolution in relation with the Euxinian Basin during the Dacian stage, as well as during the Romanian stage. As a result, favourable conditions were created for an extended coal genesis on the depositional plains situated at the foot of the arising Carpathians. The type of sedimentation consisted dominantly of a fluvial facies and swampy, but into the basin – a proximal (littoral) or distal (of deeper water) sedimentation can be separated. The stratigraphic columns in this area show many lignite seams: around 22 coal seams can be counted from the Early Dacian up to the Late Romanian, in Oltenia coaly region (Fig. 4).

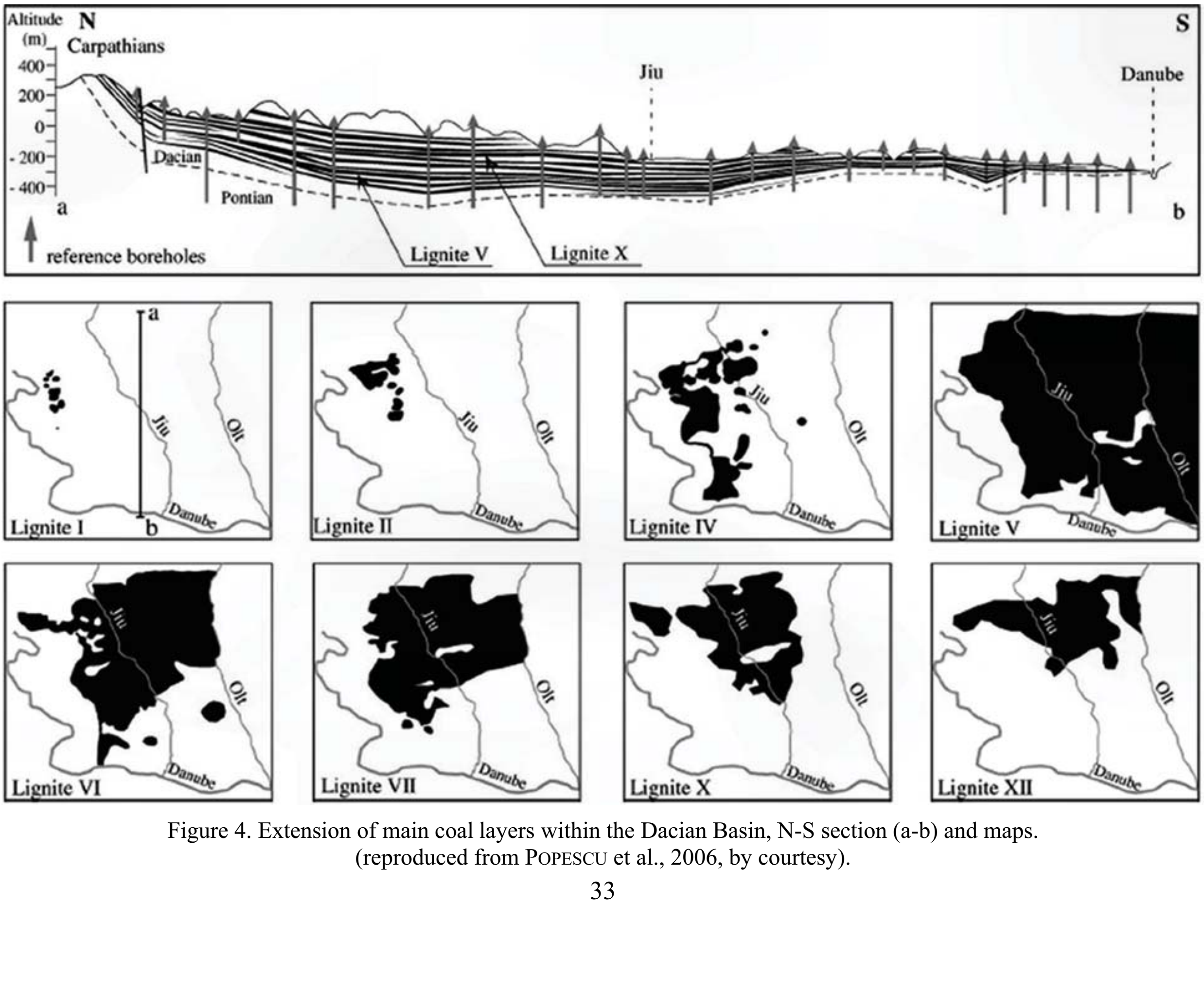

Figure 4. Extension of main coal layers within the Dacian Basin, N-S section (a-b) and maps.
(reproduced from POPESCU et al., 2006, by courtesy).

Some small coal seams appear up to the Early Pleistocene, but of small economic importance (ŢICLEANU, 2003). It is interesting that the area covered by the lignite layers is variable. This was demonstrated on the basis of the drilling results. For example, the 5th coal seam, which is marked by a strange high level of radioactivity, is the most extended one (ŢICLEANU, 2006; Fig. 4).

There is a palaeogeographic and tectonic explanation: the Dacian Basin was a variably extended alluvial-lacustrine accumulation plain situated in front of the mountains. It had a longtime stable subsidence rate which was equal to the accumulation velocity of coal-generating vegetal material and this happened during 2,000 up to 18,000 years (ŢICLEANU et al., 2004; ŢICLEANU in JIPA, 2006).

Within the inner foredeep, the thickness of the coal layers or of the coal complex (coals ad associated sediments) is more developed than in the outer foredeep of the Carpathians, because a role in the subsidence could be paid to the differentiated compaction of the sediments (ŢICLEANU, 2003; ŢICLEANU et al., 2004). The negative relief of the platform also had much importance in the coal accumulation and again, the tabular and the compactional subsidence could be considered.

In fact, these structural and palaeogeographic conditions favoured the coal accumulation in these polygenetic accumulation-plains of fluvial, deltaic and lacustrine origin, which is characteristic of the molassic basins situated in front of the mountains.

The Dacian Basin was also filled with sediments along the entire region arising as a result of plate movements, and the lower Danube was born. In the Dacian Basin, the most important Neogene coal genesis developed between the Early Dacian and the Middle-Late Romanian and, according to ANDREESCU et al. (1985), it is composed of three coal complexes:

- Vişenilor Valley Coaly Complex is represented by some coal seams hosted by the Early Dacian Berbeşti Formation (coal seams A-D and I-IV).
- Motru Coaly Complex, the most important one, is represented by the coal seams V-XIV hosted by the Jiu-Motru Formation. It was formed during the Late Dacian to the Middle-Late Romanian. The seams V-VII and X had the best qualitative characteristics.
- Bălceşti Coaly Complex, hosted by Cândeşti Formation of the middle-late Romanian to the early Pleistocene age, developed within the central-western part of Oltenia coaly basin. It is represented by the seams XV-XVIII, having reduced economic importance.

Some coal seams are variably extended under the blanket of the Moesian Platform. As we mentioned, a coal seam of more than 4 m thickness was identified from drillings extended up to Bucharest area, at the depth 400–600 m. It is most probably synchronous with 5th coal layer from the Oltenia (ŢICLEANU, 2006; POPESCU et al., 2006a, b; Fig. 4).

Another Pliocene coal deposits resulted in a similar type of coal genesis, but at a smaller scale. They appeared in some small intramountaineous Carpathian depressions which were active during the Latest Pontian to the Dacian (GIVULESCU, 1996; 1997) as isolated lakes or fluvial corridors.

There, fluvial-lacustrine deposits with coal seams accumulated: within Braşov-Baraolt Depression, explored or mined in several points, now abandoned, and also within Bilbor, Borsec and Jolotca Depressions (BANDRABUR & CODARCEA, 1974; BANDRABUR et al., 1990).

Pliocene coal genesis related to some small intramountaineous basins associated with the Pannonian Basin also appeared within the western part of the Apuseni Mts., especially within Borod area (GIVULESCU, 1996, 1997).

However, it could be stressed that the most favourable palaeogeographic and tectonic conditions for a spatial and temporal extension of the Pliocene coal genesis were created within the Dacian Basin, a basin with large plains of sedimentation developed just in front of the Carpathians. These conditions and the coal-generating peat determined the qualitative and quantitative characteristics of coal seams.

Thus, the coal layers from Vişenilor Valley Complex were formed on upper deltaic plains, as their depositional system shows. The coal layers from Motru Complex were formed on fluvio-lacustrine accumulation plains where coal-generating peats were developed, following four distinct phases: fluvial, fluvio-lacustrine, palustrine (telmatic) and finally, lacustrine. This typical succession was also described by NEBERT (1983), within the Ebisswalder Basin, Germany, and is perfectly consistent to the theoretical model of coal-generating swamps of TEICHMÜLLER (1958, 1962) (Table 1).

Table 1. The model of a coal-generating swamps according to TEICHMÜLLER (1958, 1962).

No.	Lake areas	Type of vegetation
1.	Marginal zones	Forests with Conifers (*Sequoia, Glyptostrobus, Pinus, Sciadopytis*);
2.	Seasonally flooded zones	Swamps or marshes with *Carex* and then with hygrophytes like *Alnus cecropiaefolia, Myrica lignitum* or, latter, with *Salix* sp., *Byttneriophyllum tiliaefolium*;
3.	Already permanently flooded zones	Swampy forests with *Glyptostrobus europaeus* and/or *Taxodium dubium*;
4.	Permanently flooded zones	Vegetation with *Phragmites* and *Typha*;
5.	Free water (deep water) zones	Aquatic vegetation with *Stratiotes dacicus*, *Trapa* sp., *Nelumbo protospeciosa* and others.

Such a coal-generating swamp is characterized by a palaeophytocoenosis which is controlled by the hydrological regime, the edaphic factor, the Eh, the pH, i.e. the important parameters of the depositional environment.

During the fluvial transport the vegetal remains mixed with inorganic sediments, which always appear in the ash-content of the coal. Plotted on maps it indicates the direction of the inorganic input (ŢICLEANU, 2006).

Also, evaluating the pollen assemblages and diverse other macroremains studies, PETRESCU et al. (1989b, 2002), and IAMANDEI (2000) estimated a pluvial palaeoenvironment (MAP=1000-1100 mm/year) in a Cfa climate (Köppen classification in PEEL et al., 2007), for the Motru area (at least for Lupoaia lignite deposit). According to the cited authors, the swamp complex comprised a flora with *Glyptostrobus, Taxodium, Alangium,* plus *Salix, Acer, Alnus, Nyssa, Myrica* (abundant pollen), *Cyrilla, Ilex, Symplocos* - also with *Phragmites, Typha, Potamogeton, Stratiotes, Sparganium,* Poaceae div. If the open water included Nympheaceae, *Stratiotes, Salvinia, Botryococcus* and Zygnemataceae, etc., the dry peat bog was occupied by a forest of *Sequoia, Sciadopitys, Pinus* div. and ferns as *Lygodium*. More distantly, forests with *Abies*, *Cathaya*, *Cedrus, Quercus, Tilia, Ulmus, Juglans, Pterocarya, Betula, Parthenocissus, Liquidambar, Fagus, Castanea, Illex, Magnolia, Liriodendron*, etc. were present.

Repeated flooding in the coal-generating swampy peat bog brought barren epiclastic intercalations of sands of fine to medium-sized granofacies (bearing now some secondary spherical concretions – so called "*trovants"*), as well as thin levels of small-sized pebbles or clay layers with plant remains as impressions, and oblique lamination. The coaly complex includes specific lithological successions, facieses and rhythms determined by the subsidence oscillation and the fluvial divagation. Usually, after a telmatic phase of the coal-generating peat, a lacustrine one followed (ŢICLEANU, 2006), with fauna of unionids and viviparidae (MARINESCU & PAPAIANOPOL, 1987). After advanced studies on the Pliocene coals from the Dacian Basin, ŢICLEANU (1995a) made an applied discussion on the palaeobotanical data implicated in the study of the coal deposits. Based upon this, he tried to answer many questions about the genesis of the coals and the necessary premises which achieved it, and defined those phytologic, climatic and palaeogeographic premises:

- *The phytologic premises* - imply a discussion about coal-generating and palaeophytocoenotic elements and about the frequency of some taxa in the fossil vegetal remains (FVR) which can indicate the source of the coal-generating phytomass. This discussion applied to the Pliocene coal genesis perfectly corresponds to other similar situations. For example, the frequency of *Glyptostrobus europaeus* in the Neogene coal deposits in Europe was still observed by SCHIMPER (1872), then confirmed by many researchers (e.g.: TEICHMÜLLER 1958; KNOBLOCH 1973; GIVULESCU 1992, 1996; ŢICLEANU 1986a), pointing out coal-generating vegetal communities. ŢICLEANU (1995b) concluded that, at least from the middle Miocene to the late Pliocene, about 90 taxa can be considered as furnishing coal-generating phytomass and he selected the most important ones (Table 2).

Table 2. Main taxa phytomass coal-generators (after ŢICLEANU, 1995b).

Taxa	Chronostratigraphic Units				
	Vh	Bs	Me	Po	Dc+Ro
Osmunda regalis					+
Taxodium dubium			+	+	+
Glyptostrobus europaeus / Glyptostroboxylon tenerum	+	+	+	+	+
Sequoia abietina	+		+		+
Liquidambar europaeum	+		+	+	+
Alnus kefersteini		+		+	
Alnus cecropiaefolia		+		+	
Betula macrophylla	+	+		+	
Salix div.sp.	+		+	+	+
Bytneriophyllum tiliaefolium	+	+		+	+
Myrica lignitum	+	+	+		
Phragmites oeningensis	+	+	+	+	+
Typha latissima	+	+		+	+
Vh – Volhynian; Bs – Bessarabian; Me – Meotian; Po – Pontian; Dc – Dacian; Ro – Romanian.					

Even if many angiosperms could be considered coal-generators, it seems that especially some taxodiaceous gymnosperms with deciduous leaves (*Taxodium, Glyptostrobus* and *Sequoia*) had the most important contribution in coal genesis during all the Neogene, as big phytomass generators. Also, some monocots such as *Typha, Phragmites* may be considered phytomass generators, usually growing directly in the peat.

- *The climatic premises* - the temperature and especially the humidity – are essential to determine the quantity of phytomass. The mean annual precipitations (MAP) were evaluated by ŢICLEANU (1995b) to over 1500 mm/year, considering especially some hygrophytic indicators based on the presence of *Glyptostrobus, Bytneriophyllum* and *Salix*. This can be correlated with a positive temperature, which determined a big phytomass quantity. In Recent times for example, the phytomass vary from 189 t/ha within the boreal zones to 342-366 t/ha in the temperate zone, and up to 440 t/ha at the tropics (WALTER & WIESER, 1973).

- *The palaeogeographic premises* - imply large areas of low eutrophic swamps which are subject to subsidence, inclusively of compactional type, whose rate is quite equal to the accumulation rate of the vegetal material originating in the vegetal communities of the swamps. Such conditions can be achieved in the same palaeogeographic situation as in a paralic basin, or in intracontinentally accumulation plains of fluvial, lacustrine, deltaic origin or combined (WILSON, 1976). The control factors of the variety of palaeophytocoenosis within the coal generating swamps are represented by hydrological regime, edaphic factor, Eh, pH, etc. These factors help create a good reconstruction of the depositional environment (ŢICLEANU, 1995a, b). The models of coal-generating swamps given by TEICHMÜLLER (1958) comprise marginal, seasonally flooded, almost permanently flooded, and permanently flooded and free water zones of a basin (i.e. pond, more or less extended lake, etc.). They can be recognized in many coal deposits because each zone is characterized by the presence of some taxa, or associations of taxa, adapted to the respective conditions. For example, they can be recognized in the western and north-western part of the Dacian Basin (Table 3).

Table 3. Pliocene vegetal communities in the western part of the Dacian Basin (according to DIACONU & ŢICLEANU, 2006).

Nr. crt.	Vegetal communities
1	Dry forest with *Sequoia* sp.;
2	Swamp with *Carex* div. sp. and *Pandanus* sp.;
3	Swamp with *Salix* sp. and *Myrica* sp.;
4	Swamp with deciduous hydrophytes forest with two variants (with *Salix* div. sp., *Liquidambar europaeum, Acer tricuspidatum, Alnus* sp., *Carya aquatica, Juglans barbui*, etc., or with *Byttneriophyllum tiliaefolium*);
5	Swamp of forest with *Glyptostrobus europaeus* associated or not with *Taxodium dubium* and/or *Nyssa* sp.;
6	Associations of *Phragmites* sp. and *Pandanus* sp. with or without *Typha latissima, Sparganium* sp., etc.
7	Aquatic plants associations with monocoenoses dominated by one of the taxa: *Stratiotes dacicus*, *Nelumbo* sp., *Nymphaea* sp., *Ceratophyllum* sp., etc.

These associations, typical for each specific biotope, determined specific lithotypes with specific technical properties (ŢICLEANU et al., 1999). For example, by analyzing the almost permanently flooded zones in the evolution of the Dacian Basin, the mid-Miocene association with *Taxodium dubium* evolved to a very developed one with *Glyptostrobus* during the Pliocene (Table 1). The permanently flooded zones dominated by *Phragmites* and *Typha* comprise also other aquatic taxa as *Stratiotes, Potamogeton, Ceratophyllum, Nelumbium* etc. (ŢICLEANU, 1995a, b). Extended areas of coal seams have been emphasized by a net of boreholes and by open cast which found all the concentric zones of TEICHMÜLLER (1958). We already specified that a special situation occurs at the 5th layer which is the most extended and comprises also the delta plain of river Lom which is coming from Bulgaria, as ŠIŠKOV & ANGELOV (1984) estimated.

According to the already known classic theoretical model of coal genesis and to his previous observations coupled with other researches (ŢICLEANU, 1992a, b; 1995a), a new model was imagined, valid at least for the Pliocene coal genesis from the western part of the Dacian Basin (ŢICLEANU & DIACONIŢĂ, 1997), as a result of the combined action of more factors:

- *the tectonic factors* - determining subsidence, accumulation velocity, diving velocity, results, rhythms, phase, active and compactional subsidence, plicative or ruptural tectonics;
- *the palaeogeographic and depositional factors* - referring to the peat bogs developing and the coal-generating basins as areas of sedimentation;
- *the biotic factors* - represented by the macroflora (the vegetation), plus the microflora and the microfauna of the peat bog which give the qualitative characteristics of coal seams and define the genetic model of coal accumulation (ŢICLEANU, 1995a) producing specific lithotypes with specific technical properties (ŢICLEANU et al., 1999);
- *the climatic factors* are very important, their analysis enabling the reconstruction of areal palaeogeography and palaeoclimate;
- *the coaly facieses factors* - as the vegetal communities, i.e. the coal-generating vegetation, the indicators of depositional environment (nutrients, pH, Eh, peat temperature, bacteria) determining the accumulation type;
- *the physical and mechanical factors* - which determine the differentiated compaction;
- *the geothermal factors* - which determine the coal metamorphism.

Surely, several palaeophytogeographic, ecologic and phytocoenotic considerations can be extracted from the analysis of these factors. Knowing well the action of each of these factors, the whole process of coal genesis can easily be reconstructed.

Among the scientific researches on coal genesis, firstly one must consider the sedimentological and the palaeobotanical studies which help us reconstruct the fluvial, deltaic, fluvio-lacustrine, or simply lacustrine palaeoenvironment and the coal-generating vegetation, especially the woody vegetation which is basic for a coal deposit formation. Sometimes, beside the vegetal fossils, vertebrate remains also can appear (CODREA & DIACONU, 2003, 2007; DICA et al., 2007).

Therefore, by prospection, exploitation works and scientific studies done within the Dacian Basin, more than 22 coal seams were identified. Distributed to some coaly complexes, they represent the rhythmic character of the sedimentation within the basin. Important data about the distribution and thickness of strata were studied and also on their morphology and on their petrography, defining the lithotypes. Their microscopic constituents as macerals and their qualitative characteristics were studied, and the process of coal genesis was reconstructed based on them [ŢICLEANU & BIŢOIANU (1989), ŢICLEANU & DIACONIŢĂ (1997), ŢICLEANU et al. (1999)].

Also, the researches of climatostratigraphy applied to Lupoaia open pit (Motru area) showed repetitive clay-lignite alternations which were interpreted as corresponding to cyclic changes in climate (POPESCU, 2001b), forced by cycles of eccentricity, giving an age of 4.9-4.3 MY (Chrons C3n.3n-3n.1n) for the layers IV-XIII.

As already shown, in Oltenia area, the Pliocene coaly series was known from exploration and exploitation works and from systematic drillings. The stratigraphy of the region comprises successions of detrital rocks and numerous coal seams with various spatial and temporal extensions interpreted by DIACONU (2000b) and POPESCU (2001a, b) mostly as deltaic sediments.

Trying to reconstruct the coal-generating palaeoenvironment for the coal seams I-IV, in the western part of the Dacian Basin (Husnicioara area), DIACONU & ŢICLEANU (2006) analysed the palaeobiotopes and these vegetal communities, representing the terminal Pontian (probably) and the Earliest Dacian. In this way they defined various coal facieses and some palaeophytocoenoses were separated (Table 3) due to the vertical alternation of them, related to the modifications of the water depth in time and to the subsidence rate or to floods.

Otherwise DIACONU (2008) published the newly identified taxa within Husnicioara association and made a detailed analysis and reconstruction of the coal-generating Pliocene palaeoenvironment within the Dacian Basin. She identified the following forest association within Husnicioara coal deposit area: *Glyptostrobus europaeus*, *Ceratophyllum* sp. aff. *C. demersum*, *Platanus platanifolia*, *Carpinus betulus*, ?*Myrica lignitum*, *Quercus* sp., *Carya denticulata*, *Byttneriophyllum tiliaefolium*, *Salix* sp., *Pandanus austriacus*, *P. trinervis*, *P. barbui*, *Phragmites oeningensis*. She also indicated that most of these taxa belong to the dominant group of the coal swamps, in which the three mangrove species of *Pandanus* were firstly found in Romania's Pliocene. *Pandanus* was also mentioned by PALAMAREV & UZUNOVA (1969) within the Bulgarian Pliocene deposits, and they were considered as most presumably Oligo-Miocene relicts.

After MAI (1995) *Pandanus* lives in a mean annual temperature between 15º and 20ºC, in tropical-subtropical climate, specifically to the SE Asia. For this reason DIACONU (2008) concluded that the Early Dacian climate was warm enough and characterized by precipitations of about 1400 mm/year, almost uniformly distributed, with a summer peak higher than 150 mm. However, interpreting the palynological content of the same interval, PETRESCU (2003) gave another resolution: MAT= 13ºC, MAP=1300 mm/year, values rather consistent to other previous evaluations.

ŢICLEANU (1992) evaluated MAT (mean annual temperature) at least for the late Dacian and the Romanian as between 14º and 15ºC, based on the presence of *Glyptostrobus europaeus* and *Byttneriophyllum tiliaefolium*. Once again, considering the macroflora and palynoflora described in the Motru area (from Ţicleni, Roşia, Peşteana, Lupoaia, a.o.) for the same interval, PETRESCU (2003) evaluated, with poor variations, more decreased values for MAT to 13-14ºC and for MAP to 1000-1100 mm.

CONCLUSIONS

This paper tries to synthesize and re-evaluate the previous researches, part of them of the authors. It is focused on the reconstruction of the palaeoenvironment and of the favourable conditions of coal genesis during the Pliocene time. The research demonstrated that the most important Neogene coal genesis within the Dacian Basin developed during the Early Dacian to the Late Romanian. It covered almost all the western part of the basin with large quantities of brown woody coal (more than 3 billion tons of lignite estimated).

The Pliocene coaly series comprise in Oltenia region at least 22 coal seams which present various spatial and temporal extensions, and constitute three coaly complexes: Vişenilor Valley, Motru and Bălceşti. On the basis of the systematic works of research and exploitation, the stratigraphy of the region is quite clarified comprising successions of detrital rocks and coal seams, interpreted mostly as a deltaic sedimentation. Compared with the previous phases of coal genesis from the Dacian Basin as they are known within the Romanian literature, it is obvious that the Pliocene phase (the 3rd) developed in Oltenia region was the most important. The early-middle Pontian (the 2nd) had a medium development within Muntenia region. The early Sarmatian phase (the 1st) had only local development (Fălticeni, Borod areas), and a reduced economic importance.

Evaluating the three Neogene coal genesis phases from coal resources point of view, it can generally be observed that the most important one is the Pliocene coal genesis, developed in the Western part of the Dacian Basin, in Oltenia coaly region. In the second place, Muntenia coaly region with Pontian coals can be considered. The early Sarmatian coal genesis was less developed and offered few coal resources. Few other small intramountaineous coal genesis developed small coal deposits of more reduced importance (Comăneşti, Baraolt, Borsec areas).

The coal genesis needs some spatial, temporal, tectonic, climatic and vegetation conditions to develop. The Dacian Basin offered the best conditions for this, during the Pliocene: alluvial-lacustrine plains of sedimentation at the foot of the Carpathians, stable and continuous rate of subsidence for a long period of time, accompanied by a compactional one locally augmented by the negative relief where important pellitic deposits were accumulated.

The contemporaneous flora shows favourable climatic conditions for a big and continuous production of phytomass, related to some cyclicity. In fact all these represent the necessary inferences for coal genesis, which are of phytologic, climatic and palaeogeographic nature.

Thus, as a result of the combined action of more factors of tectonic, palaeogeographic, biotic, climatic, faciesal, physical, mechanical and geothermal nature, a new model of coal genesis, valid in the western part of the Dacian Basin, was imagined.

It is therefore obvious that the main scientific researches on coal genesis could be both sedimentological and palaeobotanical, in order to reconstruct the palaeoenvironment and the coal-generating forestry vegetation, especially the woody vegetation, which was basic for a coal deposit genesis. The specific associations typical for each specific biotope produced specific lithotypes with specific technical properties. Knowing these, you can perform interpretations and reconstructions, extract conclusions on palaeogeography and further for economic evaluations.

From other point of view an obvious cyclicity in the coal genesis was observed during a sustained subsidence, the vegetal material being accumulated during the four known steps: fluvial, fluvio-lacustrine, telmatic and finally, lacustrine. On the other hand, researches of climatostratigraphy showed a repetitive clay-lignite alternations which were interpreted as corresponding to cyclic changes in climate, forced by cycles of eccentricity and which gave an age interval of 4.9-4.3MY (Chrons C3n.3n-3n.1n) for the layers IV-XIII.

Evaluating the flora and palynoflora identified in Oltenia region during the Pliocene coal genesis Ţicleanu (1992) estimated MAT = 14-15ºC and a wet weather, considering at least the presence of *Glyptostrobus europaeus* and *Byttneriophyllum tiliaefolium* within the vegetal association. However DIACONU (2008), finding some *Pandanus* species in Husnicioara area (west of the Dacian Basin) considered that, at least for the early Dacian, MAT could be of up to 15ºC or more and MAP of about 1400 mm/year, with a summer peak higher than 150 mm. Interpreting the palaeobotanical and palynological content only in Motru area, PETRESCU (2003) estimated MAT=13-14ºC and MAP=1300 mm/year during the early Dacian, and more decreased values for MAT, maybe under 13ºC, and for MAP, to 1000 mm/year, during the late Dacian and the Romanian.

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