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ASPECTS OF ROMANIAN EARLY JURASSIC PALEOBOTANY AND PALYNOLOGY. PART III. PHYTOSTRATIGRAPHY OF THE GETIC NAPPE

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Abstract. The phytostratigraphy of the Lower Jurassic deposits belonging to the Getic Nappe, South Carpathians is characterised by several biozones indicating Hettangian, Sinemurian, Pliensbachian and Toarcian-Aalenian stages. The assemblages are well defined and typical for Romania: first, the Assemblage zone with *Thaumatopteris brauniana* (Hettangian) is followed by the Acme zone with *Nilssonia* cf. *orientalis* (Sinemurian), by the Range zone with *Carpolithes liasinus* (Pliensbachian-Toarcian) and by the Range zone with *Brachyphyllum expansum* (Upper Toarcian - Aalenian - Lower Callovian). No Rhaetian indicators could be found so far, as *Lepidopteris ottonis*, the marker of this stage, is absent within the Romanian deposits. The previous phytostratigraphical ideas and the equivalent European zones are discussed in this paper.

Keywords: Macroflora, microflora, Early Jurassic, phytostratigraphy, Getic Nappe, South Carpathians, Romania.

INTRODUCTION

The Lower Jurassic deposits of the Getic Nappe include continental alluvial, fluvial, lacustrine and even marine facies within three main basins: Resita, Holbav and Cristian Basins (Fig. 1). Deposits of sure continental origin belonging to these basins are Hettangian-Sinemurian in age, while the deep lacustrine or marine facies are Pliensbachian - Toarcian in age. The Hettangian-Sinemurian succession begins in all basins with a basal conglomeratic member, followed by a sandstone dominated, coal bearing sequence resembling the Austrian Gresten facies. This finer succession is very rich in vegetal remains, represented by compressions, permineralised woods and by microflora. This succession is everywhere overlaid by deep lacustrine or marine deposits that gain their carbonatic character since the Late Toarcian.

METHODS

During field work in Liassic Plant Localities (LPLs), precise sampling was used for better preservation of the stratigraphical and paleoecological data regarding the collected flora. Without detailed sampling, any discussion or conclusion on the phytostratigraphy is simply not possible; this was the case for papers dealing with revisions of previous collections, stored in various museums (Timisoara, Resita, Oradea, Budapest and partly Bucharest museums), for which precise sampling data are unknown.

The sampling is usually done after recording the detailed log of the outcrops, underground mining galleries or extraction chambers, with centimetric precision. Often, the occurrence within the layer is recorded (base, top or middle part), together with the sedimentary structures that occur.

By far the best, ideal possibilities are encountered within Anina area, where a great deal of open cast mines, natural outcrops, underground directional and transversal galleries, climbers or extraction chambers could be surveyed, obtaining not only the vertical image of the flora successions but their lateral, bi-dimensional distribution as well (Fig. 5). The data gathered since 1990 permit now a three-dimensional assessment of the flora distribution within the volume of the Steierdorf Formation.

Cuticular analysis, palynological treatment of the microflora samples (dispersed and in situ), thin sections and peel techniques for the silicified woods were used for better identification of the taxa.

LITHOSTRATIGAPHY OF THE EARLY JURASSIC DEPOSITS OF THE GETIC NAPPE

In the Resita Basin, the entire Alpine cycle begins with the detritic, Lower Jurassic deposits of the Steierdorf Formation (Bucur 1991) and continues without interruption with marly-limestone and limestone deposits beginning with the Upper Toarcian up to the Aptian. The limestone successions present carbonate platform features during the Early Cretaceous.

The Steierdorf Formation (Fig. 2, Table 1) represents the productive formation for the Liassic coal extraction within the whole Resita Basin. It corresponds to a succession of sandstones, conglomerates, clays and coal seams of continental origin, resembling the typical Gresten facies described in Austria. It overlays unconformably on the crystalline basement towards the borders of the basin or the Variscan mollase deposits, especially the Permian sequences, in the middle areas of the basin. The uppermost boundaries are given by the occurrence of marly - limestone deposits belonging to the Dealul Zinei Formation. This formation yields plant compressions as well.

The base of the Steierdorf Formation is a coarse sequence of conglomerates, microconglomerates and rare clays, slightly different of the usual lithology of the Gresten type deposits included to this formation and assigned to the Dealul Budinic Member. The middle, main succession is represented by sandstones, microconglomerates, clays and coals, yielding a rich land flora approached in this paper, described as the Valea Tereziei Member (Table 1). The upper succession is represented by black, bituminous clays of possible lacustrine origin, named Uteris Member, all names being given by Bucur (1991, 1997).

The intraformational sedimentary variability is high, as a result of the continental, alluvial, fluviatile or lacustrine origin of these sediments. The lateral, facial changes are frequent and widespread, previous authors describing a "torrential" sedimentology of this formation, especially with regard to its first two members. The thickness of the first two members taken together varies

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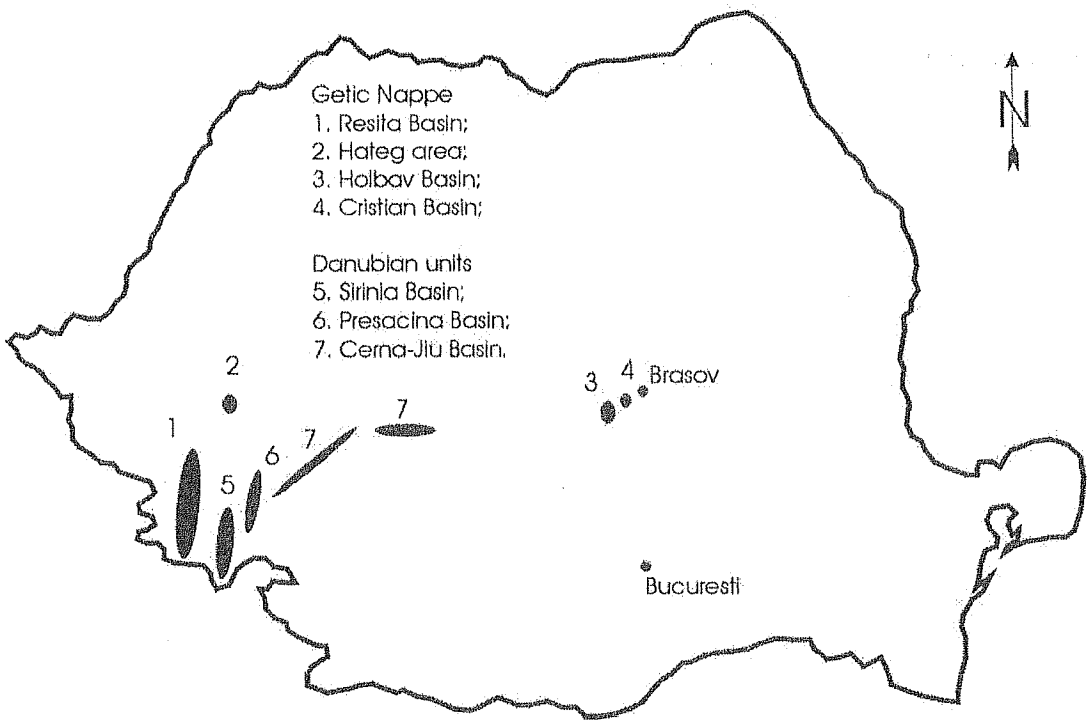

Figure 1 - Basins confined to the Getic Nappe and danubian units within Romania

between 70 and 250m from south towards north, due to the continental sedimentation.

The first two members of the Steierdorf Formation include continental deposits of intramontaneous depression, characterised by alluvial, fluvial, marsh and lacustrine features, described previously by Hálavats & Schreter (1915), Raileanu et al. (1964) and Bucur (1991, 1997) as deposited under limnic conditions. Taking into account these aspects, the facial lateral variations appear normal as well.

Several Liassic subfacies of the Budinic and Valea Tereziei members were recorded by Nastaseanu et al. in two geological reports (1981, 1982) and refined by Bucur (1991, 1997), as lateral variations of the continental facies in the Resita Basin.

In the Holbav Basin, the Lower Jurassic deposits belong to the Holbav Formation (Dragastan & Popa 1997), and they include two members, a basal, Concordia Member (Hettangian) and an upper, Piriul Crucii Member (Hettangian-Lower Pliensbachian), as shown in Fig. 2 and Table 2.

The basal, Concordia Member is a coarse, detritic member, represented by breccia and conglomerates reworked from the crystalline basement. The Piriul Crucii Member is represented by various types of detritic rocks, such as sandstones, conglomerates, all types of clays, etc., yielding a rich compressive flora. The volcano-sedimentary sequences yield a rich conifer silicified flora (Vilceanu, 1960, Popa, 1997a) as well.

The Cristian Basin has Sinemurian continental deposits overlying the Hettangian, marine sediments which are dated on ammonite faunas (Jekelius, 1923, Semaka, 1965). They are represented by detritic sediments, including coal seams explored until the first half of the XX-th century. The flora is both compressed and permineralised.

Lower Jurassic deposits have been recorded within the Hateg Depression, close to Cioclovina cave, in an area separated of the Resita Basin (Laufer, 1925) but still belonging to the Getic Nappe. Only one taxa list was published but the original material has not been found yet within the collections of the Geological Museum, so no conclusions can be discussed yet. No other vegetative remains could be recorded from the Liassic deposits of the Hateg area so far.

Table 1. General lithostratigraphy of the Steierdorf Formation Bucur 1991

No.	Member & age	General lithology	Depositional environments
3	Uteris (Pliensbachian - Middle Toarcian)	Black bituminous shales, fine black sandstones	Euxinic, anoxic deep lake or possible marine origin
2	Valea Tereziei (Hettangian-Sinemurian)	Sandstones of all types, clays (refractory, coaly, etc.), coals, micoroconglomerates, conglomerates	Fluviatile (possible both braided and meandered), marsh, back swamp, flooding plain, lake
1	Budinic Member (Hettangian)	Conglomerates, microconglomerates, sandstones and rare clay lens, sometimes resembling red beds	Alluvial fans

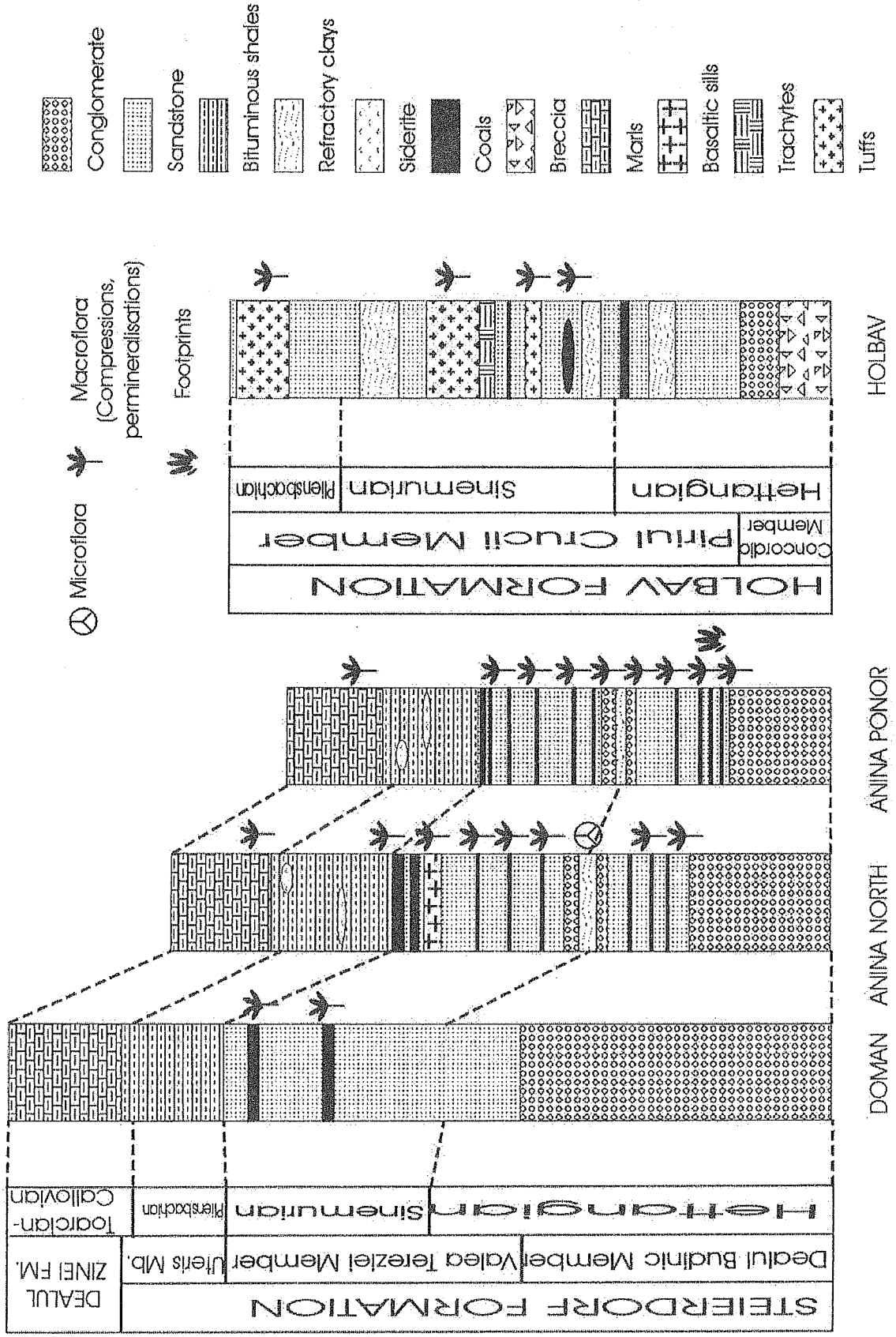

Figure 2 - Synthetic logs for Reşiţa and Holbav basins, Getic Nappe.

Table 2. General lithostratigraphy of the Holbav Formation Dragastan & Popa, 1997

No.	Member & age	General lithology	Depositional environments
2	Piriul Crucii Member (Hettangian - Early Pliensbachian)	Sandstones of all types, clays (refractory, coaly, etc.), brown coals, micoroconglomerates, conglomerates, tuffs, magmatic rocks	Fluvial, telmaro-paralic facies, volcanic-sedimentary facies
1	Concordia Member (Hettangian)	Breccia, conglomerates, rare clay interlayers	Alluvial fans

PREVIOUS PHYTOSTRATIGRAPHIC INFORMATION OUTSIDE ROMANIA

Northern America, Europe and Middle East, the first attempt to characterise the phytostratigraphy of Upper Triassic - Lower Jurassic deposits belong to Harris (1937) who described in East Greenland (Scoresby Sound, Jameson Land) two different floristic assemblages, a Rhaetian assemblage with *Lepidopteris ottonis* and a Hettangian assemblage with *Thaumatopteris schenkii*. These assemblages were recorded later in Sweden (Harris, 1937, Lundblad, 1950), Germany, in Franconia (Weber, 1968), Hungary (in work by M. Barbacka), Iran and Afghanistan (Schweitzer, 1978; Schweitzer et al. 1996). A general, revised discussion on this succession was given by Vakhrameev (1991). Separate Rhaetian or Hettangian assemblages alone were found in France, England, Poland, Austria, Yugoslavia, Bulgaria and Romania. It is not by mistake these occurrences belong to northern, mid latitude areas during the break-up of Pangea and they are frequent coal generating associations.

The best documented record of the Rhaetian-Hettangian floristic boundary appears to be in East Greenland and Sweden. Harris (1937) defined the Rhaetian assemblage marked by the peltaspermal pteridosperm *Lepidopteris ottonis*, associated with *Stachyotaxus elegans*, *Dictyophyllum exile*, *Anomozamites minor*, *Ptilozamites nilssoni*, *Neocalamites hoerensis*, *Amphorispermum ellipticum*, *Ctenis minuta*, *C. nilssoni*, *Pterophyllum pilum*, *P. schenki*, *P. zygotacticum*, *P. pinnatifidum*, *Baiera minuta*, *Equisetites grosphodon*, *Hartzia tenuis*, *Furcula granulifer*, etc.

The Hettangian assemblage is marked by *Thaumatopteris schenkii*, associated with *Thaumatopteris brauniana*, *Ctenis stewartiana*, *Lobatannularia carcinoides*, *Gleichenites nitida*, *Czekanowskia hartzi*, *Sphenobaiera spectabilis*, *Ginkgoites hermelini*, *Phlebopteris muensteri*, *Dictyophyllum nilsoni*, *Lycostrobus scotii*, etc. Ash (1986) discussed in detail the floral successions for the Rhaetian and Liassic deposits from Northern America and Europe.

In China, Zhou established an assemblage zone marking the Hettangian, dominated by Dipteridaceous ferns (such being the case of the Romanian deposits as well), naming it the *Dictyophyllum-Clathropteris* zone, recorded within the Sinian maritime (southern) province. This zone is coeval with the *Thaumatopteris* zone of Harris and the arguments of Zhou for this name change regarded mainly the disputed taxonomical status of the genus *Thaumatopteris*, considered by some authors as a junior synonym of *Dictyophyllum*. The Chinese Early Jurassic flora is discussed in detail by Zhou (1997). The same phytostratigraphic macrofloral successions were described by Kimura & Ohana (1990) and Sato & Westermann (1991) for Japan and South-East Asia.

For the Pliensbachian and Toarcian stages, the phytostratigraphic assemblages began to differ within the various provinces of the Boreal continents. There is no general assemblage for the whole Upper Liassic interval, as Vakhrameev (1991) noted.

PREVIOUS PHYTOSTRATIGRAPHIC INFORMATION INSIDE ROMANIA

For Romania, serious phytostratigraphic papers are briefly presented here. Semaka approached for the first time the subject, discussing the phytostratigraphy of Romanian Lower Jurassic deposits in comparison with deposits of the same age in Europe, in papers ranging between 1962-1970. Another interesting author is Humml (1969), who gave underground occurrences within Anina mines. His data match very well with the new data discussed in this paper and in Popa (1992). Dragastan & Popa (1997) and Popa (1992, 1997a, b) detailed the phytostratigraphic information for both the Resita and Holbav basins.

Semaka (1962) approached for the first time the phytostratigraphical aspects of the Lower Jurassic deposits, for both the Getic Nappe and Danubian units (Table 3). He considered as Rhaetian (Infraliassic) flora the assemblage with *Stachyotyaxus lippoldi*, *Equisetites muensteri*, *Podozamites mucronatus*, *Czekanowskia rigida*, *C. nathorsti*, *Laccopteris angustiloba*, *Nilssonia acuminata*, *Czekanowskia nathorsti*, *Palyssia braunii* and *P. sternbergi*. This assemblage was recorded by him within the basal Liassic successions from Doman (Getic Nappe) and from Bigger (Sirinia Basin) and Mehadia (Presacina Basin) of the Danubian units.

Unfortunately, some objections must be raised with regard to this age attribution. First, no *Lepidopteris ottonis* could be recorded so far, so from the beginning the age identification is a problem. Secondary, there are no true remains of *Equisetites muensteri*, *Stachyotaxus lippoldi*, *Nilssonia acuminata*, *Podozamites mucronatus*, *Palyssia braunii* and *P. sternbergi* in the Semaka collection, as I could personally verify this during the revision of this collection stored within the Geological Museum in Bucharest. As stated already in detail (Popa, 2000), systematically *E. muensteri* is an unidentifiable *Equisetites* sp., *S. lippoldi* is a true *Ptilophyllum* sp. by having several parallel veins along the pinnules, *N. acuminata* is usually *Ctenozamites cycadea* or unidentifiable ?*Nilssonia* sp., while *Palyssia braunii* and *P. sternbergi* are similar to *Pagiophyllum* sp. and *Elatides* sp. twigs. *Podozamites mucronatus* is usually *P.* cf. *distans*. It must also to be stated here that Semaka, for unknown reasons, never used cuticular analysis for his identifications but fortunately, as the attentive worker he actually was, his mis-identifications are always systematic. As to the other, correctly identified taxa, such as *Phlebopteris angustiloba* and *Czekanowskia rigida*, their occurrence is not an argument for any Rhaetian age identification; they can just as well be Liassic in age. Semaka (1965) re-discussed his arguments on the Rhaetian age but

Table 3. Lower-Middle Jurassic phytozones for the South Carpathians. Previous and proposed nomenclature

Stage	Previous phytozones	Proposed phytozones
Aalenian - Callovian	Assemblage zone with *Nellostrobus inconstans*	Range zone with *Brachyphyllum expansum*
Toarcian		
	Assemblage zone with *Carpolithes liasinus*	Range zone with *Carpolithes liasinus*
Pliensbachian		
Sinemurian	Assemblage zone with *Nilssonia orientalis*	Acme zone with *Nilssonia* cf. *orientalis*
Hettangian	Assemblage zone with *Thaumatopteris schenkii*	Assemblage zone with *Thaumatopteris brauniana*
Rhaetian	Assemblage zone with *Lepidopteris ottonis*	Not recognised

without adding significant data. Semaka (1970) again stated this age for the area between Anina and Doman, considering that his cited taxa may indicate even alone the Rhaetian age within the basal conglomerates (Dealul Budinic Member).

Semaka (1962, 1965) brilliantly recognised the Hettangian ("Lias α") assemblage with *Thaumatopteris schenkii* (Table 3) on the grounds of the following assemblage: *Phlebopteris brauni*, *P. muensteri*, *Matonidium goepperti*, *Thaumatopteris brauniana*, *Todites denticulata*, *Camptopteris nilssoni*, *Pterophyllum jaegeri*, *Anomozamites inconstans*, *Ginkgoites taeniata*, together with taxa identified only at generic level. This was a great step forward in the knowledge of the floral successions from the South Carpathians, although identifications were not always correct, leaving apart nomenclatorial aspects. His *Pterophyllum jaegeri*, (a Middle Triassic taxon) are actually basal frond fragments of *P. longifolium*, while *Anomozamites inconstans* was proved to be a cycadalean after cuticular analysis was applied. *Thaumatopteris brauniana* and *Matonia braunii* (*P. brauni*, *P. muensteri* and *Matonidium goepperti* sensu Semaka) were correctly recognised, just as well *Dictyophyllum nilsoni* (*Camptopteris nilssoni*) and *Cladophlebis denticulata* (*Todites denticulatus*, but never found fertile in Semaka collection during my revision). *Ginkgoites taeniata* could not be found. Moreover, there are systematic misidentifications of *Aninopteris formosa*, considered to be *T. brauniana*, in spite of fundamental differences in venation, reproductive structures and base of pinnules.

The Hettangian *Thaumatopteris* assemblage was recognised by Semaka at Anina, Doman, Holbav (Vulcan-Codlea) and in various Danubian LPLs (Jeliseva, Bigar, Buschmann, Speranta, Stanca and Pietrele Albe galleries, Rudaria). At Jeliseva, he cited (Semaka, 1964, 1970) a Hettangian assemblage in deposits yielding *Schlotheimia angulata*.

One of the major contributions of Semaka (1962, 1964, 1965, 1970) in the field of phytostratigraphy was his definition of the Sinemurian Assemblage zone with *Nilssonia orientalis* ("Lias β", Table 3). He identified first (Semaka, 1962) at Bigar (Danubian, Sirinia Basin) an assemblage with *Nilssonia orientalis*, *Clathropteris meniscioides*, *Cladophlebis browniana*, *C. rumana* (!), *Taeniopteris taenuinervis*, *T. haidingeri*, *Otozamites schmiedelii* and *Ginkgoites taeniata* (!) that could be compared later (Semaka, 1965) to a lateral, marine assemblage with *Waldheimia numismalis*, *Gryphaea cymbium*, *Gresslya trajani*, *Belemnites paxilosus*, *Cardinia gigantea*, *Terebratula grestenensis*, *T. punctata*, *Rhynchonella variabilis* pointing to the Sinemurian age. This intuition, in spite of its inherent problems, proved to be valuable not only for the Danubian area but for the entire South Carpathians. To this assemblage he added from Bigar, Anina and Doman (Semaka, 1965) the following taxa: *Sphenopteris obtusifolia*, *S. modesta*, *Cladophlebis haiburnensis*, *Todites denticulatus*, *Thaumatopteris brauniana* (!), *Pterophyllum longifolium*, *P. brevipenne*, *P. jaegeri* (!), *P. magoti*, *Taeniopteris muensteri*, *Williamsonia pecten*, *Williamsonia wittata*, *Anomozamites schaumburgensis*, *Nilssonia banatica*, *Sphenobaiera rarefurcata*, *Stachyotaxus lippoldi* (!!), *Phoenicopsis angustifolia*, *P. media*, *P. potoniei*, *P. speciosa*, *Czekanowskia rigida*.

A series of reconsiderations are imposed here. First, the occurrence of Rhaetian or Hettangian taxa (sensu Semaka) considered by Semaka as belonging also to the Sinemurian *Nilssonia orientalis* assemblage. To this, a thorough stratigrapher may object that it is the definition of assemblage zones to have trespasser taxa, indicating a specific age only by their association. But in the way they are used in previous definitions, they can indicate in assemblage any age, from Rhaetian to the Sinemurian. Secondly, misidentifications played their role again, even with the marker, *Nilssonia orientalis*. The leaves attributed to *N. orientalis* show only rarely an obtuse base (typical for *N. orientalis*), preserving again very rarely good cuticles. However, they constantly show characters that were not encountered to any younger or older *Nilssonia* leaf species: typical density of conspicuous secondary veins, cuticle characters, when occur (that enabled Givulescu, 1998, to attribute some of them to sure *N. orientalis* species), size, shape and least but not last, a remarkable boom in several localities, especially in Anina LPLs and Doman. This is why for the moment I consider this taxon as *Nilssonia* cf. *orientalis* (Popa, 2000, with details and proves). *Cycadopteris obtusifolia* (*Sphenopteris obtusifolia* ANDRAE 1855, emended in Popa, 2000) is actually a typical Upper Toarcian – Aalenian - Callovian taxon, as it has been recorded only within the marls of Dealul Zinei Formation. *Cladophlebis haiburnensis*, *Thaumatopteris brauniana* are confined remarkably and constantly to the basal part of the Valea Tereziei Member (Hettangian), while *Cladophlebis denticulata* is a Hettangian - Sinemurian trespasser. Semaka's *Cladophlebis haiburnensis* and *C. ingens* from Anina and Vulcan - Codlea are actually *C. denticulata* with simple, once forked secondary veins (and not with twice forked secondary veins as in *C. haiburnensis*); his revised material was published as well (Semaka, 1956, 1962).

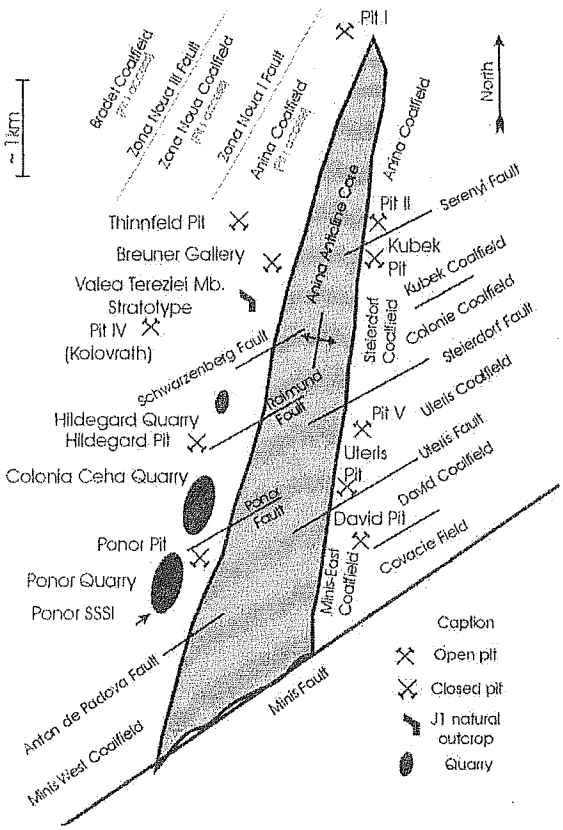

Figure 3 - Anina Coalfields, pits, quarries and outcrops, together with the main faults within Anina and Brădet structures

The successes of Semaka's vision for the *N. orientalis* zone in the South Carpathians are categorically the following: the permanent occurrence in Sinemurian of *Nilssonia banatica*, *Ginkgo rarefurcata* (*Sphenobaiera rarefurcata* SEMAKA 1962), *Ptilophyllum* sp. (from Doman, where it has a boom together with *N.* cf. *orientalis* and considered again by Semaka as *Stachyotaxus lippoldi*), *Czekanowskia rigida*, ?*Phoenicopsis* sp. and *P. potoniei* (in Holbav Basin, considered by Semaka as *Phoenicopsis* div. sp.) and of *Clathropteris meniscioides* (only in Holbav). The taxon *Zamites schmiedelii* (with the satellites *Z. aninaensis*, *Z. andraeanus*, later wrongly considered by him as *Otozamites* species, *Weltrichia alfredi* and *Weltrichia* div. sp.) is never earlier than Sinemurian. The LPLs with Sinemurian flora, demonstrated with valuable arguments, were Anina, Doman, Vulcan-Codlea, Cristian (Getic Nappe), Pietrele Albe, Stanca galleries, Dragosella East, Dragosella West, Bigar (Sirinia Basin, Danubian Authochtonous).

For the Pliensbachian - Toarcian stages, represented within Resita Basin by the Uteris Member (black, bituminous shales), Semaka (partly in 1958, 1970) introduced the zone with *Carpolithes liasinus* (Table 3). This was another success of him, as this zone remains well defined till today.

The zone with *Nellostrobus quadraticus* was introduced by Semaka (partly in 1958, 1962, 1970) for the Upper Toarcian – Aalenian - Callovian marly deposits of the Dealul Zinei Formation in the Resita Basin. To this assemblage he attributed *Equisetites* cf. *burchardti*, *Sphenopteris obtusifolia*, *Pterophyllum longifolium*, *Anomozamites spectabilis*, *Otozamites pterophylloides*, *O. reglei*, *O. decorus*, *Brachyphyllum* sp., *Nellostrobus quadraticus*, *N. inconstans*, *Nellostrobus* sp. Clearly, *Cycadopteris obtusifolia* and *Brachyphyllum expansum* (*Brachyphyllum* sp. of Semaka) belong to this assemblage, together with what could be conifer shoots named by Semaka *Nellostrobus quadraticus*, *N. inconstans* and *Nellostrobus* sp. Although I can not give sure assignments for his *Nellostrobus* species, for the moment it looks uncertain if they are real cones, considered so in one of Semaka's earliest papers (1958).

The Early Jurassic microflora of the Resita Basin was studied first by Antonescu (1973), who analysed a sample from the refractory clay seam in Anina, between the Coal seams no. 3 and 4. His results showed a Hettangian – Sinemurian asemblage with species that "are common for the entire Liassic", lacking any Rhaetian or Upper Liassic species. Details of later palynological analysis were shown by Popa (1997a), on samples collected from the same refractory clay seam in underground mining horizons of the Zona Noua Coalfield, Anina. These results look perfectly normal, as this lithological marker represents the boundary between the Hettangian and Sinemurian stages.

NEW DATA ON THE LOWER BOUNDARY OF THE HETTANGIAN STAGE IN THE GETIC NAPPE

The Lower Jurassic deposits within the Resita Basin overlay unconformably the Variscan mollase deposits (Upper Carboniferous-Lower Permian in age) or the crystalline basement (Lower Palaeozoic Sebes-Lotru Series). The lack of the Rhaetian marker, *Lepidopteris ottonis*, within the lower assemblage, unables any age attribution to this stage of the basal deposits of the Getic Nappe's Mesozoic detritic deposits.

However, an interesting find may be the basal, non fossiliferous macroscopically conglomerates and sandstones of the Budinic Member within the area of Ponor and Colonia Ceha Quarries, showing characters that resemble very well red beds facies. The green and red clay interlayers have been sampled for future palynological analysis.

NEW DATA ON THE HETTANGIAN / SINEMURIAN BOUNDARY IN THE GETIC NAPPE

In Anina, the highest data resolution permitted to identify the boundary between Hettangian and Sinemurian stages as occurring close to the refractory clay seam. The refractory clay seam has lacustrine origin and its lateral development is remarkably good, being recorded in all the mining works, from Minis West Coalfield to Anina Coalfield (Figs. 3, 4, 5). Its stratigraphic position is also constant between the Coal seams nos. 3 and 4, or their equivalents, as their lens shapes induce large thickness variations within the central area of the Resita Basin. Nevertheless, although these coal seams, as actually all coal seams in the area, deplete or increase their sizes laterally, they can be recognised in almost all sequences.

For the central area of the Resita Basin, other lithologic markers can be used for correlation. The most important are the red, tough sandstones close to the Coal seams nos. 7 and 8, the very rich mica bearing sandstone level over the Coal seam no. 5, and the white conglomeratic beds with rounded elements under and over the refractory clay seam (Fig. 2). Secondary stratigraphic markers are the Coal seam no. 1 itself

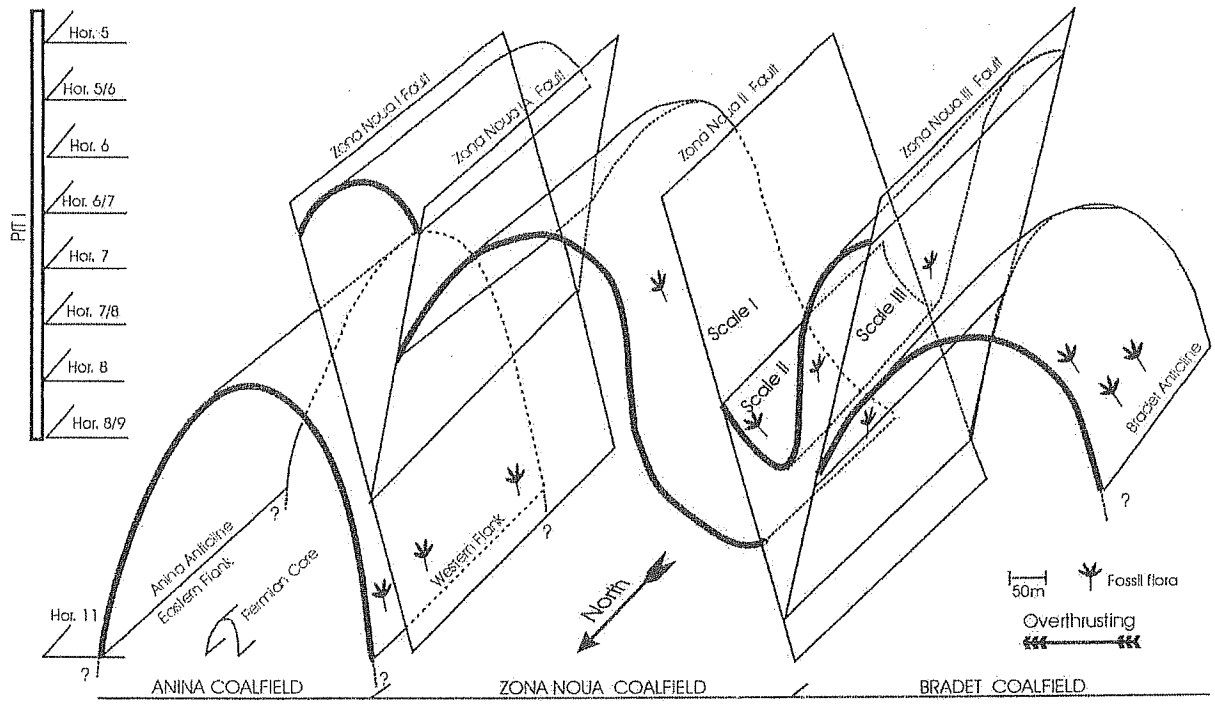

Figure 4 - Simplified structural image of the Anina, Zona Nouă and Brădet coalfields, together with the main floral collecting points within the roof of Coal seam no. 7 (Sinemurian). No galleries or other coal seams than the 7th are figured. Modified after Anescu (1985).

(clayey), the Coal seam's no. 3 roof (clayey paleosol with roots, sometimes used instead of refractory clay), the Coal seam's no. 4 roof (easily broken in cubes) and the Coal seam's no. 6 sole (fine, white, very abrasive sandstone).

Macroflora can be successfully used for correlations, together with the lithological markers or alone as well. The Hettangian macrofloral assemblage could be recorded unchanged along the western flank of the Anina Anticline, in Ponor SSSI, Colonia Ceha Quarry, close to Hildegard Quarry, Pit IV, Valea Tereziei, and within the Zona Noua Coalfield (underground mining field, Fig. 3, 4, 5). In Anina and Bradet Coalfields, the basal sequence of the Valea Tereziei Member (where the coal seams are depleted) is covered by gallery bandages, so macrofloral remains could not be collected.

This Hettangian assemblage is confined to the lower sequence of the Valea Tereziei Member, under the refractory clay seam and over the Dealul Budinic Member, the latter too coarse for preserving macroflora. The Hettangian assemblage is remarkably marked by the Dipteridaceous fern *Thaumatopteris brauniana* and includes several typical, frequent or rare taxa which are never encountered over the refractory clay seam. To them are added trespassers that cross the Hettangian / Sinemurian boundary (Fig. 5).

Within Resita Basin, the basal sequence of the Valea Tereziei Member, over the boundary with the Dealul Budinic Member and under the refractory clay seam is considered Hettangian in age on the grounds of the mentioned assemblage.

An exception within the whole Getic Nappe, the Sinemurian acidic volcano-sedimentary sequences include an entire conifer (Taxodiaceae and Cheirolepidiaceae mainly) forest that occurred on the slopes of a Liassic volcano. Neither its neck, nor its lava adduction channel are recorded, but the tuff levels are well preserved and so are the wood remains caught within them. In the case of the black silicified wood remains, the vegetative material was usually first charcoaled and secondary silicified as Gradinaru (personal communication) observed, but simple, white silicified trunks occur as well, with good anatomical structures.

PROBLEMS OF THE HETTANGIAN / SINEMURIAN BOUNDARY IN THE SOUTH CARPATHIANS

Continental deposits always put problems in stratigraphy, especially when this is done with paleobotanical means. Such problems, related to the Getic Nappe basins, are the following:

1. The general lack of dense sampling possibilities. Outcrops of the Lower Jurassic deposits belonging to the Getic Nappe are not widespread and usually they are quickly covered by vegetation. Even the galleries of underground mining horizons of the Anina coalfields are subject of continuous bandaging or damming, so unique outcrops are again lost, in the latter case, forever. Fortunately, I could survey the majority of open (under construction) galleries during their optimum time intervals, the density of sampling points being high enough for correct conclusions and for three dimensional distribution of the flora within the Lower Jurassic deposits.

2. Even the frequent, typical taxa for Hettangian or for Sinemurian can miss in some outcrops (at daylight or underground), although the assemblages fortunately remain the same. This is also a typical stratigraphical disadvantage, as ideal assemblages occur nowhere.

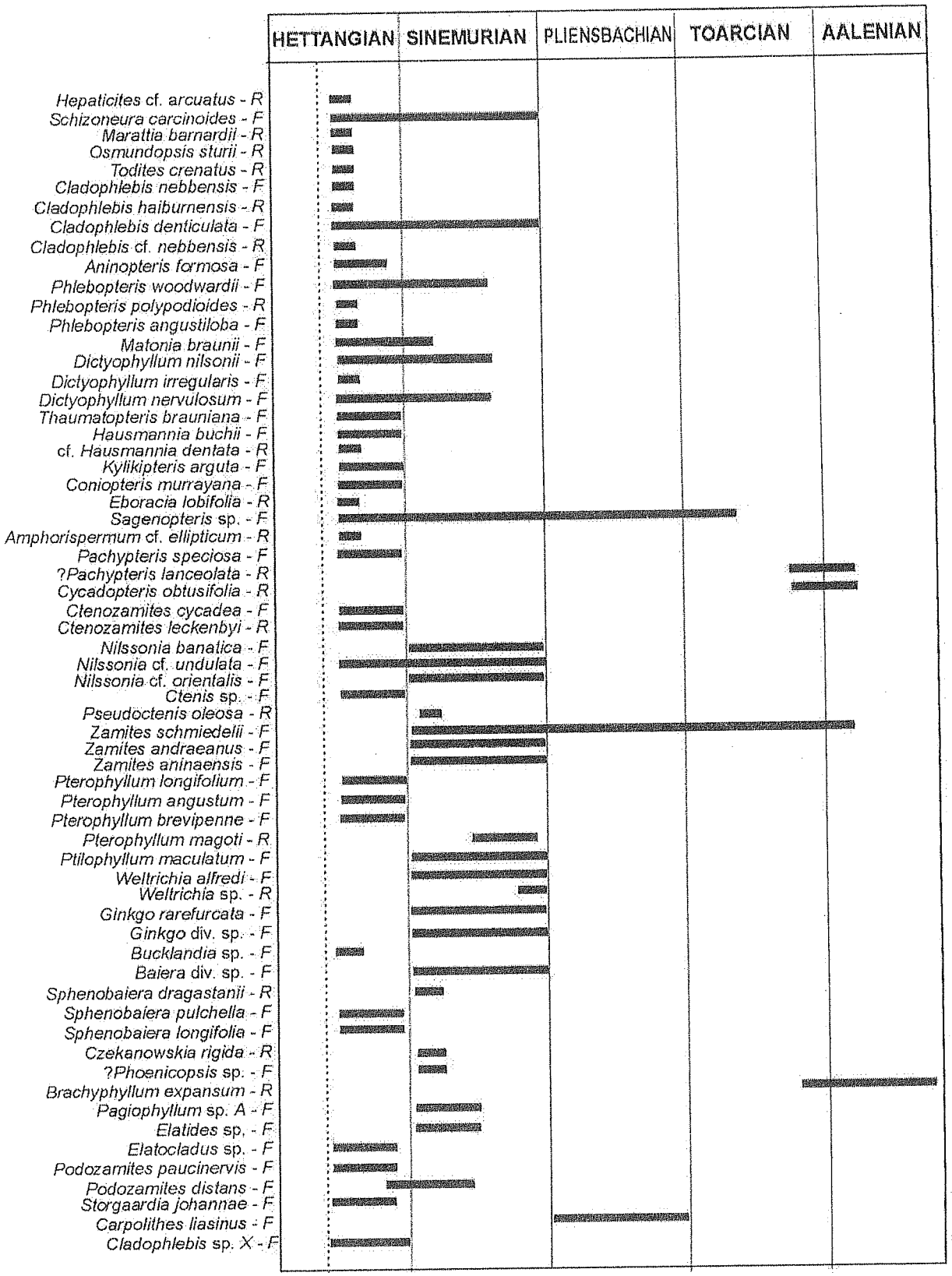

Figure 5 - Taxon ranges for the Reşiţa Basin, Getic Nappe (R - rare, F - frequent)

3. The taxonomical status of *Thaumatopteris brauniana*. I included to *T. brauniana* the taxon *T. schenkii*, as Schweitzer (1978) observed for the Iranian species. *T. schenkii* seems to be also in the Resita Basin a junior synonym of *T. brauniana*, as both morphological types currently occur together, including bipinnate leaves as well. Schweitzer (1978) also noticed that *T. brauniana* in Iran is not confined to the Hettangian stage; there, it is a ht/sm trespasser, reaching even the Middle Jurassic. But this is clearly not the case of this taxon in the Resita Basin, where it is a remarkable marker, confined strictly to the lower sequence of the Valea Tereziei Member (under the refractory clay seam).

As the original, marker taxon of the Hettangian assemblage is taken into synonymy to *T. brauniana*, it looks normal to name the Romanian Hettangian assemblage the Assemblage zone with *Thaumatopteris brauniana*.

4. The impossibility to name the Hettangian assemblage the Assemblage zone with *Dictyophyllum* - *Clathropteris*, as Zhou introduced it in China. It is true that *Dictyophyllum* species are frequent in the Basal sequence of the Valea Tereziei Member in the Resita Basin, but there occurs no *Clathropteris* species at all, while some of the *Dictyophyllum* species are trespassers into Sinemurian. *C. meniscioides* is actually a rare, rather unclear taxon, recorded only in Holbav Basin where it is Sinemurian in age, presenting affinities with *C. obovata*.

5. The ranges of some typical and frequent taxa of the *T. brauniana* assemblage in Resita Basin are Upper Liassic and even Middle Jurassic elsewhere in Western Europe or Middle Orient, although they function very well in Romania as Hettangian markers because they are so strictly confined to the mentioned lithological sequence. Clear examples are *Coniopteris murrayana*, *Eboracia lobifolia*, *Ctenozmites cycadea*, *C. leckenbyi*, etc. or *Cladophlebis haiburnensis*, *Marattia barnardii*, *Osmundopsis sturii*, *Todites crenatus*, etc. as rare taxa.

6. The difficulties of identification of *Nilssonia orientalis*, especially in Romania. Rare cuticles of *N. orientalis*, the continuous transition between obtuse to elongate, symmetric leaf bases and even the definition of the taxon puts problems in defining the Sinemurian assemblage in Romania. This is the reason for naming the Acme zone with *Nilssonia* cf. *orientalis*. Moreover, *N. orientalis* is a sure Middle Jurassic taxon through the whole Euro-Sinian Region (sensu Vakhrameev, 1991).

NEW DATA ON THE SINEMURIAN / PLIENSBACHIAN BOUNDARY IN THE GETIC NAPPE

Unfortunatelly, the almost sudden facies change between Valea Tereziei and Uteris Members unabled the preservation of the floral change, if any. The general bad preservation of the Pliensbachian macroflora is due to the deep, anoxic, aquatic environment present at that time in the Resita Basin, which actually generated the black, bituminous shales.

Together with the constant occurrence of *Carpolithes liasinus*, *Sagenopteris* cf. *nilssoniana* and other taxa can be recorded.

NEW DATA ON THE MIDDLE/UPPER TOARCIAN BOUNDARY IN THE GETIC NAPPE

The terms of the floral change at the Middle/Upper Toarcian boundary look not to be abrupt at all, although this boundary marks the contacts between Steierdorf and Dealul Zinei Formations. The occurrence of *Zamites schmiedelii* in the shallow water deposited marls of the Dealul Zinei Formation points to a smooth passage not only at this boundary, but at the Sinemurian / Pliensbachian boundary as well (Fig. 5).

Due to the unclear status of the *Nellostrobus* species, the zone marking the Upper Toarcian – Lower Callovian interval should be named the Range zone with *Brachyphyllum expansum* (Fig. 5).

CONCLUSIONS

Considered useless for stratigraphic correlations, the Early Jurassic macroflora of the Resita Basin is now proved to have marker significance when properly collected (detailed sampling within underground mining horizons or outcrops of the coal measures). Assemblage zones can be successfully defined for stages from Hettangian to Aalenian, with the most spectacular results for the Hettangian and Sinemurian. The Hettangian is marked by the Assemblage zone with *Thaumatopteris brauniana* and the Sinemurian by the Acme zone with *Nilssonia* cf. *orientalis*. A floral change is recorded close to the refractory clay seam in the central part of the Resita Basin, marking the Hettangian/Sinemurian boundary. The Pliensbachian - Middle Toarcian is marked by the Range Zone with *Carpolithes liasinus*, as Semaka (1962, 1965) defined it, and the Upper Toarcian - Aalenian - Lower Callovian by the Range zone with *Brachyphyllum expansum*.

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REFERENCES

Anescu, D., 1985, Documentatia geologica a Cimpului minier Anina, 200pp., geological report, technical use, Anina archives.

Antonescu, E., 1973, Quelques donnees sur la palynologie du Lias sous facies de Gresten de Roumanie, Palynology of the Mesophyte, Proc. 3rd Intern. Palynol. Conf., Moscow.

Ash, S., 1986, Fossil plants and the Triassic-Jurassic boundary. In Padian, K. (Ed.), The beginning of the age of dinosaurs, p. 21-30, Cambridge Univ. Press.

Bucur, I.I., 1991, Proposition pour une nomenclature lithostratigraphique formelle des depots paleozoiques et mesozoiques de la zone de Resita – Moldova Noua (Carpathes Meridionales, Roumanie), Studia Univ. Babes-Bolyai, Geologie, XXXVI/2, p. 3-14.

Bucur, I.I., 1997, Formatiunile mesozoice din zona Resita – Moldova Noua (Muntii Aninei si estul Muntilor Locvei), 214p., Presa Universitara Clujeana.

Dragastan, O.N. & Popa, M.E., 1997. Early Jurassic phytostratigraphy of the Holbav Formation, Getic Nappe, Brasov County. Rev. Roum. Geologie, 41: 51-60.

Givulescu, R., 1998, Flora fosila a Jurasicului inferior de la Anina, Rom. Acad. Publ. House, 90pp.

Halavats & Schreter, 1915. Die Umgebung von Fehertemplom Szaszkabanya und Omoldova. Erl. geol. spez. Land., XXV.

Harris, T.M., 1937. The fossil flora of Scoresby Sound, East Greenland; Part. 5: Stratigraphic relations of the plant beds. Meddelelser om Gronland, 2(112): 1-114.

Humml, H., 1969. Contributii la flora fosila a Liasicului inferior de la Steierdorf-Anina. Stud. Cerc. Geol. Geofiz. Geogr. (Geol.), 14(2): 385-404,.

Jekelius, E., 1923. Zacamintele de carbuni din Romania, Fasc. 1, Carbunii liasici din imprejurimile Brasovului, Inst. geol. Rom., 30 p.

Kimura, T. & T. Ohana, 1990. Triassic-Jurassic plants in Japan. In Pre-Cretaceous Terranes of Japan, IGCP Project 224, pp. 371-379, Osaka.

Laufer, F., 1925. Contributiuni la studiul geologic al imprejurimilor orasului Hateg. Anuarul Inst. Geol. al Romaniei, X: 301-333.

Lundblad, B., 1950. Rheto-Liasic floras and their bearing on the Stratigraphic of Triassic- Jurassic rocks. Acta Univ. Stockholmiensis, Stockholm contributions in Geology, 3(4): 83-102.

Nastaseanu, S., Popescu, I. & Gheorghean, D., 1981. Harta paleogeografica a Jurasicului inferior din zona Resita, in vederea stabilirii posibilitatilor de conturare a noi zone de interes pentru huila, geological report, IPEG Archive.

Nastaseanu, S., Popescu, I. & Bitoianu, C., 1982, Cercetarea complexa a formatiunilor purtatoare de de carbuni si sisturi combustibile: Carpatii Meridionali, zona Svinita-Resita. Harta paleogeografica a Jurasicului inferior din zona Resita in vederea stabilirii posibilitatilor de conturare a noi zone de interes pentru huila, geological report, IPEG Archive.

Popa, M.E., 1992, The Early Liassic of Anina: New Paleobotanical Aspects, Documenta Naturae, 74: 1-9.

Popa, M.E., 1997a. The Liassic continental flora of Romania: Systematics, Stratigraphy and

Paleoecology. Acta Botanica Horti Bucurestensis, 1997-1998, p. 177-193.

Popa, M.E., 1997b. Corystospermal pteridosperms in the Liassic continental deposits of Romania. Acta Palaeontologica Romaniae(1): 81-87.

Popa, M.E., 2000, Early Jurassic land flora of the Getic Nappe, Romania, PhD thesis, 257 p., 118 pls. Bucharest University.

Raileanu, G., Nastaseanu, S. & Boldur, C., 1964, Sedimentarul Paleozoic si Mesozoic de pe Domeniul Getic din SW Carpatilor Meridionali, An. Com. Geol., XXX (2), p. 6-72.

Sato, T. & Westermann, G., 1991. Jurassic Taxa Ranges and Correlation Charts for the Circum Pacific. Newsletters on Stratigraphy, 24: 81-108.

Schweitzer, H.J., 1978. Die Rhato-Jurassischen Floren des Iran und Afganistans. 5. Todites princeps, Thaumatopteris braunlana und Phlebopteris polypodioides. Paleontographica B, 168 (1-3): 17-60.

Schweitzer, H.J., J.H.A. Van Konijnenburg - Van Cittert & J. Van der Burgh , 1996. The Rhaeto-Jurassic flora of Iran and Afghanistan. 10. Bryophyta, Lycophyta, Sphenophyta, Pterophyta - Eusporangiatae and Protoleptosporangiatae. Palaeontographica Abt. B, 243: 103-192.

Semaka, A., 1956. Contributii la flora Liasica de la Vulcan-Codlea. Nota a-II-a. Bul. St. Sec. Geol. Geogr., 1(1-2), p. 107-121.

Semaka, A., 1958. Nellostrobus n. g. (Coniferales) din Aalenianul de la Doman (Banat). Stud. Cerc. Geol. Acad. RPR, III(3-4): 201-206.

Semaka, A., 1962. Observatii asupra florei Toarcian-Aalenianului din Banat. D.S. Com. Geol., LXVI: 225-237.

Semaka, A., 1964. Einige Bemerkungen zur paleobotanischen Grenze Rhat-unter Lias-Mittellias im den Nilssonia orientalis Flora in den Sud Karpaten. Acta Paleobotanica Polonica, V: 27-39.

Semaka, A., 1965. Zur Kenntnis der Nilssonia orientalis-Flora in den Sudkarpaten. Acta Paleob. Polonica, VI(2), 27-39.

Semaka, A., 1970. Geologisch - Paleobotanische Untersuchungen in S.O. Banaten Danubikum, 79 pp.

Vakhrameev, V. A., 1991, Jurassic and Cretaceous floras and climates of the Earth, Cambridge University Press, 318 p.

Vilceanu, P., 1960, Contributii la cunoasterea geologica a regiunii Codlea, Stud. Cerc. Geol., Tome V, no. 1, Bucharest.

Weber, R., 1968. Die Flora der Rhat-Lias-Ubergangsschichten von Bayrenth (Oberfranken) under besonderer Beriicksichtigung der Coenologie. Erlangen geol. Abh, 72(73): 73.

Zhou, Z., 1997. Jurassic flora, Chapter 8, p. 343-410.