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# INTEGRATED BIOSTRATIGRAPHY OF THE TURONIAN OF ROMANIA

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**Abstract.** The first model of the Turonian integrated biostratigraphy from Romania is revised and improved with new data. The intercorrelated bioevents, that define the Turonian substages and their contents in Romania, are exposed in this paper.

**Keywords:** Romania, Turonian, intercorrelated biostratigraphy, ammonites, inoceramids, planktonik foraminifera, dinoflagellates, pollen, calcareous nannoplankton.

## INTRODUCTION

The first integrated biostratigraphical model for the Turonian from Romania, by using the ammonites, inoceramids (L.S.), planktonik foraminifera (J.I.), dinoflagellates, pollen (E.A.) and calcareous nannoplankton (M.C.M.) was elaborated by us (Ion et al., 1997, emended in thies paper) (Figs. 1, 2). The biostratigraphical data are the result of our studies on the sedimentary successions from the South and East Carpathians and North Dobrogea (Babadag Basin). The main biostratigraphical data/key sections for the Carpathian domain are from the post-tectonic cover of the Median Dacides major tectonic unit, respectively from some basinal deposits preserved in the Haţeg, Bănița and Ţara Bârsei Basins, Perşani Mountains and Maramureş area. The studies were carried out by using the all mentioned fossil groups in the Carpathian area, while in the North Dobrogea only macrofauna and planktonic foraminifera were used. The charts with the location of the biostratigraphical sections are in Ion & Szasz (1994), Ion et al. (1996-unpublished report), Szasz et al.(1992-unpublished report).

To add that only a table, with integrated biozonations and other one, which displays vertical distribution (especially of the marker species and the categories of the bioevents as chronostratigraphical significance for Tethys, the general/global, regional and local bioevents) were published so far (Ion et al., 1997); a short report, regarding the new separated and emended biozones, was also published (Ion et al., 1998). The detailed biostratigraphical data, the presentation of the biostratigraphical key sections and some stages concerning the integrated biozonation are mentioned in the following publications: Ion, 1983, 1993; Szasz, 1986; Szasz & Ion, 1984,1988; Ion & Szasz 1989, 1994; Ion et al., 1987, 1996 and Szasz et al., 1992 (unpublished reports). As additional paleontological and/or biostratigraphical works about the one fossil group can be mentioned: ammonites - Pop & Szasz, 1973, Szasz, 1986 ; inoceramids – Szasz, 1982; planktonic foraminifera – Ion, 1983; nannofloras - Melinte 1999; dinoflagellate - Antonescu (in press).

In this work, the integrated biostratigraphy for the Turonian of Romania is revised (especially following the conclusions of the Second International Symposium on Cretaceous Stage Boundaries, Brussels 1995) and improved with new data. The purpose of this work is especially to expose the intercorrelated bioevents that define the Turonian and its substages and its content in Romania.

In accordance with the informal but well established usage [also accepted in the conclusions of Bengtson (coord.) et al., 1996, following the Brussels Symposium, 1995] the Turonian of Romania was divided by us in three substages.

## EARLY TURONIAN

In the biostratigraphically studied deposits from the Carpathians and North Dobrogea, there is no record of ammonite and inoceramid faunal succession for a biostratigraphy at the Cenomanian-Turonian boundary. The late Late Cenomanian and the basal/earliest Early Turonian are lacked of the macrofauna. The first Lower Turonian macrofauna, represented by the *Mytiloides ex gr. labiatus* Inoceramid Assembage Zone, known in the North Dobrogea and in the Carpathians, as well as the *Paramammites polymorphus* and *Chaffaticeras pavilieri* Ammonite Assemblage Zone, with which it is associated in the northern East Carpathians, characterize the Early Turonian, excepting its basal/lowermost segment. Because in both zonal assemblages the typical taxa for the basal/earliest Early Turonian do not exist; respectively the fauna of the *Watinoceras devonense* Ammonite Zone and of the *Mytiloides puebloensis* Inoceramid Zone from the Pueblo-Rock Canion section. This section was proposed (Brussels, 1995) as Global Boundary Stratotype and Point (GSSP) for the base of the Turonian stage (Bengston et al., 1996; Kennedy et al., 2000). In these circumstances, the Cenomanian-Turonian boundary in Romania is situated below the base of the *P. polymorphus and Ch. pavillieri* Ammonite Assemblage Zone and of the *My. ex gr. labiatus* Inoceramid Assemblage Zone, into a pile of strata devoid of macrofauna, but including a characteristic microflora and planktonic foraminifera. In these strata, the boundary would have marked by

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the following several concomitant proxy/secondary bioevents. In microfloristic terms: the first occurrence (FO) of the dinoflagellate *Subtilisphaera pontis-marie* (DEFLANDRE) LENTIN & WILLIAMS (=the beginning of the *S. pontis-marie* Zone) or (only in the open sea facies) of *Xenascus ceratioides* (DEFLANDRE) LENTIN & WILLIAMS (=the beginning of the X. *ceratioides* Zone), both as bioevents of local chronostratigraphical significance for Tethys; the FO of the pollen *Complexiopollis christae* (VAN AMERON) KEDVES (=the beginning of the *C. christae* Zone) as bioevent of regional chronostratigraphical significance for Tethys. These bioevents were documented in the Carpathians (the Brebina Valley-Bârsa Valley key section). In planktonic foraminifera terms (bioevents marking the middle part of the *Dicarinella imbricata* Zone): in both Carpathians and North Dobrogea areas, the FO of *Marginotruncana elenae* ION (bioevent of local chronostratigraphical significance for Tethys), the last occurrence (LO) of *Thalmanninella greenhornensis* (MORROW) (bioevents of regional chronostratigraphical significance for Tethys) and of others *Rotalipora s.l.*, as *Th. brotzeni* SIGAL and *Th. globotruncanoides* (SIGAL) (as bioevents of regional chronostratigraphical significance), *Th. porthaulti* ION , *Th. jaquesigali* ION, *Th. caroni* ION and *Th. oresti* ION (as bioevents of local chronostratigraphical significance; only in the Carpathians, the later FO of *W. archaeocretacea* PESSAGNO (in North Dobrogea having the FO towards the late Late Cenomanian) as bioevent of regional chronostratigraphical significance. In the Carpathians the key sections for these bioevents are: on the Brebina Valley - Bârsa Valley (Ţara Bârsei Basin), Dâljii Valley (Bănița Basin). In North Dobrogea, these bioevents are situated at minimum 1.5 m above the base of the *D. imbricata* Zone (that starts from the late Late Cenomanian) in: the Caraburun Hill - Zmeica Lake, West Caucagia - Bal Bair Hill, Babadag and Cap Dolojman key sections (the same as for the late Late Cenomanian). The choice of these bioevents as potential proxy markers for Cenomanian-Turonian boundary is supported /controlled by the fact that in the Turonian stratotype area (Robaszynski et al., 1982) and in other several areas (e.g.: SE France, Medus et al., 1980; eastern USA, Christopher 1979, Thchudy 1981; other areas, Goczan et al., 1967), the FO of *Complexiopollis christae* is situated at the base of the Turonian and it is a good index species for Turonian stage. In some Tethyan areas, LO of *Th. greenhornensis* is lied just below of the Cenomanian-Turonian boundary.

In conclusions, for the Early Turonian of the East, South Carpathians and North Dobrogea we distinguished: (1) a basal/lowermost part devoid of macrofauna and (2) the rest of the Early Turonian with ammonite and inoceramid zonal fauna.

(1) The basal/earliest Turonian would occupied the time interval of the *Watinoceras devonense* (ammonite) and *Mytiloides puebloensis* (inoceramid) Zones, from the Pueblo-Rock Canion GSSP (ammonite zonation by Kennedy & Cobban 1991, see in Kennedy et al., 2000; inoceramid zonation by Walaszczyk in Kennedy et al., 2000). In Romania, the basa/earliest Turonian is biostratigraphic represented by the concomitant zonal contents: the approximate middle segment of the *Dicarinella imbricata* Planktonic Foraminifera Zone; basal/lowermost parts of the *Complexiopollis christae* pollen Zone and of the *Subtilisphaera pontis-marie* dinofagellate Zone (or, only in the oppen sea facies, the basal/lowermost parts of the *C. christae* Pollen Zone and of the *Xenascus ceratioides* Dinoflagellate Zone); the uppermost part of the *Microrhabdulus decoratus* Nannoplankton Zone, having the same zonal content as in the Late Cenomanian. The middle segment of the *D. imbricata* Zone shows a distinct assemblage characterized by the beginning of the *Marginotruncana elenae* range and the absence of *Thalmanninella greenhornensis*, *Th. brotzeni*, *Th. globotruncanoides* and of others *Rortalipora s.l.* (*Th. porthaulti*, *Th. jaquesigali,* etc.); the persistence of *Th. reicheli* (MORNOD), *Rotalipora cushmani* (MORROW), *R. turonica* BROTZEN, *R. turonica expansa* CARBONNIER, etc.; the presence of *Whiteinella archaeocretacea* PESSAGNO, etc.;

(2) The Early Turonian without its basal/lowermost part is represented by the *Paramammites polymorphus* and *Choffaticeras pavillieri* Ammonite Assemblage Zone and/or the *Mytiloides* ex gr. *labiatus* Inoceramid Assemblage Zone. The tentative correlation of these assemblage zones with the equivalent zones from NW European zonations and Pueblo GSSP is drawn in Fig. 2. Only in the Maramureş area (near the locality Baia Borşa and in northern of the Bârgău Mountains) from the northern of the East Carpathians, both ammonite and inoceramid assemblage zones co-occurs. In North Dobrogea there is only the *My.* ex gr. *labiatus* Assemblage Zone. Here, the ammonite fauna is represented only by isolated specimens of *Lewesiceras* in the lower part of the strata of this inoceramid assemblage. In other areas of the East and South Carpathians, only isolated specimens of ammonites and inoceramids are reported for the Early Turonian excepting its basal/lowermost part. For instance: *Mammites nodosoides zeibaensis* COLLIGNON in Haţeg Basin (mentioned by Pop & Szasz, 1973 as *Kamerunoceras* cf. *lecointre* COLLIGNON and revised by Szasz, 1986 as *M. nodosoides zeibaensis*) located in the middle part of the Early Turonian; specimens of *My. labiatus* (SCHLOTHEIM) occurring at varied levels of the Early Turonian, in Postăvaru and Perşani Mountains.

The *P. polymrphus and Ch. pavillieri* Assemblage Zone from Maramureş area occupied a succession

of 10m in thickness. Its detailed content is presented in Fig. 1 and at the synthetical account regarding the Lower Turonian Romanian biostratigraphy. As additional date it is to remark: we appreciate that the succeeding FO of *Choffaticeras* and *M. nodosoides* in Romania have the same chronostratigraphical position as in Pueblo GSSP and in Kalaat Senan area (Tunisia, Robaszynski et al., 1990)

Concerning the *My. ex gr. labiatus* Assemblage Zone, this is well represented in the Carpathians (by a pile of strata of 7-8m thickness), in Maramureş area. It begins at 2-3m above the base of the *P. polymorphus* and *Ch. pavillieri* Ammonite Ass. Zone and co-occurs with this ammonite fauna in the following 7-8m beds. But the *My*. ex gr. *labiatus* Ass. Zone is the best exposed in North Dobrogea, where the pile of strata, with the whole extension of the zone, has approximately minimum 10–20m thickness. The first levels of the *My. ex gr. labiatus* Ass. Zone are situated at minimum 2-3m to 6m above the Cenomanian-Turonian boundary marked by the planktonic foraminifera proxy bioevents. It is to remark that in the Early Turonian of the Carpathians and North Dobrogea, as well as in other areas from Europe (e.g. acc. Szasz, 1986: in Germany, Tröger, 1967; France, Sornay in Robaszynski et al., 1982), the *Mytiloides kossmati* Zone and the subsequent *My. labiatus* Zone (in the zonation of Kauffman, 1977, 1978 or Kauffman et al., 1978) or the *My. kossmati* Zone and *My. mytiloides* Zone (from Pueblo-Rock Canion GSSP, Walaszczyk in Kennedy et al., 2000a) could not be separated. This is due to the fact that in the Carpathians and North Dobrogea, in the whole *My. ex gr. labiatus* Ass. Zone the specimens of *My. labiatus, My. kossmati* (HEINZ), *My. mytiloides* (MANTELL), plus the intermediate forms between *My. labiatus* and *My. kossmati* (from North Dobrogea), co-occured. It is to note that specimens only with the similar ornamentations of *Mytiloides hercynicus* PETRASCHECK co-occur, in North Dobrogea, with *My. labiatus* or/and *My*. *kossmati* in the *My. ex gr. labiatus* Ass. Zone.

The Early Turonian planktonic foraminifera, microflora and nannoflora general content from Romania is presented in Figs. 1 and 2. The microfloras and nannofloras are documented only in the Carpathians. The direct correlation of the nannoplankton with macrofauna and microfauna is yet insuficiently documented.

In North Dobrogea has been possible a more thorough macrofaunal data (inoceramids) as chronostratigraphical support for the biostratigraphy (here on the basis of the inoceramid and planktonic foraminifera). In the Carpathians the direct macrofaunal control for the integrated biostratigraphy (on the basis of macrofauna, planktonic foraminifera, microflora and nannoflora) is non complet:the sandy facies with the *P.polymorphus* and *Ch.palillieri* Ass. Zone and the *My. ex gr.labiatus* Ass. Zone from Maramureş area being unaprochable for micropaleontological studies; in other Carpathians areas the studied Lower Turonian successions included only rare pointed inoceramids or ammonites.

A synthetical report (Figs.1,2) regarding the succession of the intercorrelated biostratigraphical data for the Early Turonian in Carpathians and North Dobrogea (key sections are mentioned at the Cenomanian–Turonian boundary), is the following: (i) - in the Carpathians and North Dobrogea, the uppermost Cenomanian is devoid of ammonite and inoceramid macrofauna; the microflora and nannoflora (documented in Carpathians) are the same as in whole Upper Cenomanian Romanian deposits; the planktonic foraminiferal assemblage belongs to the lowermost part of the *D. imbricata* Zone. (ii) – The beginning of the basal/earliest Turonian without macrofauna is could be marked by the several concomitant proxy/secondary bioevents listed already at the Cenomanian–Turonian boundary. The nannofloras belongs to the *Microrhabdulus decoratus* Zone as in the Late Cenomanian. (iii) – Above the basal/lowermost Lower Turonian without macrofauna segment (minimum 2-6 m thickness), follows immediately (documented in the Maramureş area) the beginning of the *P.polymorphus* and *Ch*. *pavillieri* (ammonite) Ass. Zone, respective the level with the FO of *P. polymorphus* (as bioevents of local/regional (?) chronostratigraphical significance for Tethys), *Kammerunoceras (Schindenwolfites) inequicostatus* WIEDMANN, *Spatites (Jeanrogericeras) reveliereanum* COURTIL. (both as bioevents of regional chronostratigraphical significance for Tethys) and the presence of *S. (J.) toroiagaensis* SZASZ, *Fagesia sp. aff thevestiensis* PERON*, F. peroni* PERVINQ*., Pachydesmoceras denisonianum* STOLIC*., Baculites sp. aff. B. undulatus*, and *Watinoceras sp.* (iv) – Closely follows (documented in the Maramureş area, in the same sections that as for the point “iii”) the first presence of *Choffaticeras pavillieri* PERVINQUIERE and of *Ch. quaasi* PERON. (as bioevents of regional chrostratigraphical significance for Tethys). (v) – Not long above of the beginning of the *P. polymorhus* and *Ch. pavillieri* Ass. Zone [at 2-3m above in Maramures area, in the same key sections as for the (iii) and (iv) points], or not long above the Cenomanian-Turonian boundary defined at point “ii” (at minimum 2-3 m to maximum 6 m, in North Dobrogea in the Caraburun Hill, Bal Bair Hill, Cap Dolojman key sections), follows: in the Carpathians and North Dobrogea the FO of the inoceramid *Mytiloides labiatus* and *My*. *kossmati* (= the beginning of the *My*. *ex gr. labiatus* Ass. Zone); the first specimens of *Lewesiceras*, as ammonite event only in North Dobrogea [in Saramanchioi area]; the planktonic foraminifera *D*. *biconvexa biconvexa* has a later FO (into the uppermost part of the *D.*

*imbricata* Zone) in North Dobrogea (in Carpathians having the FO in the upper Upper Cenomanian). (vi) – Follows, into the lower part of the Early Turonian, the FO of the planktonic foraminifera *Helvetoglobotruncana helvetica* (Bolli) (as bioevent of regional chronostratigraphical sgnificance for Tethys) respective the beginning of the *H. helvetica* Zone, and probably the FO of the nannoplankton *Quadrum gartneri* PRINS & PERCH-NIELSEN (as bioevent of regional chronostratigraphical significance for Tethys) respective the beginning of the *Q. gartneri* Zone. The first occurrence of *H. helvetica* biohorizon is located in the Carpathians at 14-15m above the Cenomanian-Turonian boundary [in the sections listed at point (ii )] and sometimes in the strata with pointed presence of *My*. *labiatus* (e.g. in Tocila Valley from Ţara Bârsei); in North Dobrogea in the strata with *My. ex gr. labiatus* Ass. Zone [at 3m above the base of this ass. Zone, in Bal Bair Hill section; at 7-10m above this base in Cap Dolojman–Jurilovca (Unirea) and Caraburun Hill area/sections]. The FO of *Q. gartneri* is documented in Maramures area in the strata with *P. polymorphus* and *Ch. pavillieri* Ass. Zone and *My. ex gr. labiatus* Ass. Zone. (vii) – Higher, towards the middle of the *P. polymorphus* and *Ch. pavillieri* Ass. Zone and/or the *My. ex gr. labiatus* Ass. Zone (in Maramures area) is known the appearance of *Mammites,* while in North Dobrogea (Cap Dolojman-Jurilovca area) there are specimens of *Lewesiceras* and the FO of the planktonic foraminifera *Marginotruncana pseudolinneiana* PESSAGNO and probably of *M. marginata* (REUSS) (as bioevents of regional chronostratigraphic signifficance) as early appearances (as in boreal areas acc. to Robaszynski et al., 1979) comparative with the range known in the Carpathians. (viii) – Higher fallows (i.e. in the North Dobrogea, at 2 m above the FO of *H. helvetica* in the Bal Bair Hill section, at approx. 6m above the FO of *M. pseudolinneiana* in the Cap Dolojman-Jurilovca area) in both domains the LO of *R. montsalvensis* MORNOD and only in the North Dobrogea there is the LO (a earlier LO comparative with this from Carpathians) of the last *Rotalipora s.l.* represented by the *R. cushmani*, *R. turonica*, *R. thomei*, *Th. reicheli* (of regional chronostratigraphical significance events) and other taxa described by Ion (1983). (ix) – Only in North Dobrogea succeeds closely (e.g. at 1 m in the Cap Dolojman section) by the doubtless early presence of *M. marginata*. (x) – In the approximate upper part of the Early Turonian, in South Carpathians there is known pointed presence of *Mammites nodosoides zeibaensis* (at Malaesti and Cernatu Valley, from the Haţeg Basin) or of *My. labiatus* (the Tocila Valley, from Ţara Bârsei Basin) associated with the assemblage of the *H. helvetica* Zone. (xi) – Towards the uppermost part of the Early Turonian, only in the Carpathians there is the FO of *Sigalitruncana "schneegansi'* (SIGAL) (with one keel) (better documented on the Ghimbavului Valley from the Ţara Bârsei Basin and Lunca Ohabei Valley from Haţeg Basin), while into the strata with the *P. polymorphus* and *Ch. pavillieri* Ass. Zone and the *My. ex gr. labiatus* Ass. Zone (in Maramureş area) the ammonite *Cybolaites molenaari* and *Kamerunoceras sp*. appear. (xii) – Higher, in the uppermost Early Turonian, in both the domains (in the Carpathians, on the Ghimbavului, Brebina-Bârsa Lunca valleys; in the North Dobrogea, in strata with the *My. ex gr. labiatus* Ass. Zone, there is lied the FO of *Sigalitruncana sigali* (REICHEL) (with one keel) [as bioevent of general(?) chronostratigraphical significance for Tethys] respectively the beginning of the *S. sigali* Zone. Only in the Carpathians, at this level or immediately below it (?), the last *Rotalipora s.l.* (*cushmani, turonica, expansa, thomei, reicheli* specis and other taxa described by Ion, 1983) have the LO (a later LO comparative with in North Dobrogea) and then *M. pseudolinneiana* has a later FO (in comparison with in the North Dobrogea).

**MIDDLE TURONIAN**

The macrofaunistical markers for the base of the Middle Turonian could be the appearance of *My. opalensis* sensu BOSE and of the ammonite *Kammerunoceras turoniense* (d'ORBIGNY) in the Carpathians, and only the appearance of the inoceramid *Mytiloides opalensis* sensu BOSE in the North Dobrogea. The both bioevents are first order proxy markers of regional chronostratigraphical significance for Tethys. In the North Dobrogea the appearance of *My. opalensis* sensu BOSE (=the beginning of the *My. opalensis* Assemblage) there is in the beds that immediately succeded the Lower Turonian strata with the *My. ex gr. labiatus* Ass. Zone. E.g., in the Caraburun Hill section (in which the specimens of *My. opalensis* sensu BOSE= *My. subhercynicus transiens* SEITZ or *My. transiens* SEITZ of Szasz & Ion, 1988). In the Carpathians, the FO of *My. opalensis sensu* BOSE and of the *K. turoniense* are known only in the Maramures area (in the northern part of the Bargau Mountains). Here, the beds with the appearance of *K. turoniensis* and of some specimens which may be of *My. opalensis sensu* BOSE, immediately succeed the Lower Turonian strata with co-occurrence of the *My. ex gr. labiatus* Ass. Zone and the *P. polymorphus* and *Ch. pavillieri* (ammonite) Ass. Zone.

The presence of the *My. opalensis* sensu BOSE is characteristically for the *Mytiloides hercynicus* Zone accepted as late Early Turonian (*e.g*. Sornay in Robaszynski et al., 1982) or as Middle Turonian in age (e.g. Kauffman 1977, Walaszcyk 1992). The second oppinion has been accepted by us for the Turonian biostratigraphy of Romania. This oppinion is in accordance with the data from the Pueblo Rock Canion GSSP (see in Bengston et al., 1996) and from other biostratigraphical zonations (e.g.

Kauffman et al. 1993 see in Kennedy et al., 1995), in which the first occurrence of *My. hercynicus* and of *Inoceramus cuvieri* (BRONGNIART)] is concomitant with FO of the ammonite *Collignoniceras woollgari* (MANT.) (proposed as global primary marker for the base of the Middle Turonian). Regarding the FO of *K. turoniense*: in some areas (e.g. fide Robaszynski et al, 1990: in Kalaat Senan, Tunisia; USA Western Interior, Cobban, 1978, 1984; Israel, Freund & Raab, 1969), this is situated in the late Early Turonian *M. nodosoides* Zone; in other areas (e.g. in France, Amedro et al., 1983) this species is mentioned only in the lowermost part (=*K. turoniense* Sz.) of the Middle Turonian with the *C. woollgari* Zone. In Romania, based on the intercorrelated macrofaunal data, we have been accepted the second situation.

Concerning the definition/position of the Lower-Middle Turonian boundary in respect to the planktonic foraminifera, it is to note: in Romania from the terminal Early Turonian to the middle part of the Middle Turonian, the planktonic foraminifera content not changed (Fig.1). Therefore, indiferent of the oppinion accepted by us regarding the chronostratigraphical significance of the first occurrence of *K. turoniense, My. hercynicus* and of *My. opalensis sensu* BOSE respectively, in the planktonic foraminifera terms the Lower-Middle Turonian boundary falls into the same zonal assemblage (of *S. sigali* Zone). In microfloristic terms (by correlation with the planktonic foraminifera zonation) only if we accept the apparence of *My. hercynicus* at the base of Middle Turonian, than the following microfloral events, as proxy markers, would pointed out (into the *S. pontis-marie* and *X. ceratitides* Dinoflagellate Zones and ito the *C. christae* Pollen Zone) the base of the Middle Turonian: the LO of the dinoflagellate *Lithosphaeridium siphoniphorum* (COOKSON & EISENACK) DAVEY & WILLIAMS emend. CLARKE-LUCAS (of regional chronstratigraphical significace bioevent for Tethys), *L. conispinum, Epellidosphaeridia spinosa* (COOKSON & HUGHES) DAVEY, *Ascodinium dacicus n.sp*. ANTONESCU and *A. ovatum* PROSSL.; the FO of the dinoflagellate gr. *Alterbia aff. acutula-Subtilisphaera sp*. A; the beginning of the abundance (as number of the species and as frequency) of the *Complexiopollis* and *Atlatopollis* pollen genera. This microflora thereshold is associated in the Ţara Bârsei Basin (e.g. on Brebina-Bârsa valleys) with a “black band” anoxic episod (C.1m). In the nannoplankton terms (documented only in the Carpathians), the base of this substage would be marked by the FO of *Eiffelithus eximius* (STOVER) PERCH-NIELSEN (of regional chronostratigraphical significance bioevent). But the chronstratigraphical significance of this boundary marker in Romania is insufficient controlled by the macrofauna.

The Middle Turonian successions of the North Dobrogea (the Caraburun Hill, Slava Rusa in northern part of the Harada Hill and the Visterna quarries key sections) produced a relative better biostratigraphy, in respect to the macrofauna; in the Carpathians, only in the lowermost segment of the Middle Turonian the macrofauna is present.

In macrofaunal terms, for the Middle Turonian of Romania, we identified three parts, although the macropaleontological data supporting the existence of this substage are sparce. These three parts, together, would correspond to the *Collignoniceras woollgari* Ammonite Zone [*sensu* Kennedy, 1984, 1986 = interval from the first presence of *C. woollgari* to the first presence of *Subpryonociclus neptuni* (GEINITZ)] from West European zonation.

(1)The lower part of the Middle Turonian is represented by the *My. opalensis* Inoceramid Assemblage (in the North Dobrogea, in the Caraburun Hill section; in the northern East Carpathians, in northern part of the Bargau Mountains respectively), co-occuring with the ammonite *K .turoniense* in the base (in northern East Carpathians); *Neoptychites cephalothus* (COUTILLER), situated into the base of this interval is known too (in the South Carpathians, in Banita Basin). This inoceramid and ammonite faunas co-occurs in the Carpathians and North Dobrogea with the same planktonic foraminifera assemblage (of *S. sigali* Zone) as for the terminal part of the Early Turonian. The microflora assemblage (of the *S. pontis – marie* Dinoflagellate Zone and of the *C. christae* Pollen Zone) is characterized (documented in the Carpathians, the Brebina Valley-Barsa Valley section) by the presence of the *Alterbia aff. acutula-Subtilisphaera sp.A* dinoflagellate group, absence of *Lithosphaeridium siphoniphorum, L. conispinum, Epellidosphaeridia spinosa, Ascodinium dacicus, A. ovatum* dinoflagellate and by the abundance of the *Complexiopollis* and *Atlantopollis* pollen. The lower part of the *Eiffellithus eximius* Nannofossil Zone would occupied the lower part of the Middle Turonian (according to the data from the Carpathians: in the Băniţa Basin and in the Dâmboviţa Valley).

(2)The middle part of the MiddleTuronian, is represented in North Dobrogea (e.g. in the Slava Rusa key section) by the *Inoceramus apicalis* Assemblage [*I. apicalis* WOODS= the specimens of *I. tenuistriatus* NAGAO & MATSUMOTO identified by Szasz (1983), Szasz & Ion (1988) in the Slava Rusă section and revised by Szasz in Ion et al., 1997}, in co-occurrence with the ammonite *Romaniceras kallesi* and *Lewesiceras spp*. (including *L. aff. peramplum* (MANTELL) cited by Szasz & Ion, 1988, in the Slava Rusa section). This macrofauna is present only in the first half of this time interval and it is associated with the same planktonic foraminifera assemblage (of the *S. sigali* Zone) as for the lower part of the Middle Turonian. In the second half without macrofauna, the planktonic foraminifera

assemblage (of the *S. sigali* Zone too) includes specimens of *Dicarinella turonica* (SAMUEL & SALAJ), as new presence, as well as the later FO (comparative with its FO in the Carpathians) of *S. "schneegansi*" (with one keel) and *S. marianosi*. In the Carpathians, for the middle part of the Middle Turonian the macrofauna is not identified. In the Carpathians, in comparison with the North Dobrogea, the planktonic foraminifera assemblage of this interval is without *M. marginata* and includes new taxa (of Ion, 1983) as *Praeglobotruncana aff. oraviensis oraviensis* SCHEIBNEROVA. The nannoplankton and dinoflagellate assemblages are the same as for the lower part of the Middle Turonian (in the Brebina Valley-Barsa Valley key section), the pollen assemblage is without the bloom of the *Complexiopollis* and *Atlantopollis* genera.

(3) The upper part of the Middle Turonian is represented in the North Dobrogea (in the Visterna quarries) by the *Inoceramus cuvieri* (?or *lusatiae*) Assemblage. In the first half it co-occurs with the uppermost part (with the same content as in the middle Middle Turonian) of the *S. sigali* Planktonic Foraminifera Zone and in the second half with the lowermost part of the *Marginotruncana coronata* planktonic foraminifera Zone plus the ammonite *Collignoniceras carolinum* d'ORBIGNY situated towards the Middle-Upper Turonian boundary. The lowermost part of the *M. coronata* Zone is characterized by the beginning of the ranges of *M. coronata* (BOLLI) and of *M. sinuosa* PORTHAULT (the both FO as bioevents of regional chronostratigraphical significance) as well as of *M. 'renzi'* (GANDOLFI) sensu PESSAGNO, 1967 (plan-convex morphotype); includes also *H. helvetica.* In the Carpathians, the upper part of the Middle Turonian is represented by the strata devoid of macrofauna, but situated imediately bellow of the Upper Turonian succession with the *Subprionocyclus neptuni* Ammonite Zone or/and the *Inoceramus falcatus* and *I. teshioensis* Inoceramid Assemblage Zone. The upper Middle Turonian planktonic foraminifera content is the same as in North Dobrogea, but in addition in the Carpathians exist: *M. angusticarinata* (GANDOLFI), with FO at the base of *M. coronata* Zone (in the North Dobrgea its first presence being in the base of the Coniacian); the lowermost part of the *M. coronata* Zone includes also new taxa (of Ion, 1983, Ion in Ion & Szasz, 1994) as *Marginotruncana tohanensis* ION, *Dicarinella jekeliana* ION, intermediate morphotype between *M. elenae* ION and *M. paraconcavata* PORTHAULT, intermediate *M. pseudolinneiana-M. spinea* (KIKOINA). The micro- and nannofloras are the same as in the middle Middle Turonian.

**LATE TURONIAN**

In Romania, the ammonite and inoceramid intercorrelated criteria for the base of the Late Turonian are: the FO of the representatives of the *Subprionocyclus* ammonite genus, as FO of *S. neptuni* (GEINITZ) (=the beginning of the S. neptuni Zone) as primary boundary marker (of regional/global? cronostratigraphical significance), *S. branneri* (ANDERSON) and *S. cf. normalis* (ANDERSON); the FO of *Inoceramus costellatus* WOODS, *I. teshioensis* NAGAO & MATSUMOTO, *I. falcatus* HEINZ (=the beginning of the *I. falcatus* and *I. teshioensis* Assemblage Zone) as of the first order proxy boundary markers (the former of regional/?global chronostratigraphical significance, the next two as of regional chronostratigraphical significance for Tethys) and of other Upper Turonian inoceramid species (see detailed data at the presentation of the key succession and in Figs. 1, 2). In the Carpathians there are the both cited ammonite and inoceramid boundary markers (on the Ion Valley from Haţeg Basin; on the Carbunelui Valley in the Perşani Montains) and co-occurring (in Persani Mountains). In North Dobrogea, these inoceramid boundary markers are well represented, but they are associated with the appearance of *Tongoboryoceras rhodanicum* (ROMAN & MAZERAN) or *Lewesiceras mantelli* WRIGHT.

Other intercorrelated proxy markers, but of secondary order/auxiliary, for the base of the Upper Turonian of Romania (documented by direct correlation with the listed macrofauna boundary criteria) are: both in the Carpathians and North Dobrogea, the FO of the planktonic foraminifera *Marginotruncana paraconcavata* PORTHAULT and *gr. Sigalitruncana - Marginotruncana undulata undulata* (LEHMANN) [the both as of local(?) or regional chronostratigraphical significance bioevents] into the *M. coronata* Zone; the FO of the nannofossil *Kamptnerius magnificus* (DEFLANDRE) (of regional chronostratigraphical significance bioevent for Tethys), documented only in the Carpathians. Concerning the microflora (documented in the Carpathians, in the Brebina Valley - Barsa Valley key section)) we have concluded: in dinoflagellate terms, for the Middle-Upper Turonian boundary (into the *S. pontis-marie* and the *X. ceratitoides* concomitant Dinoflagellate Zones) are not boundary criteria; in pollen terms, it is not documented, so far, if the FO of the *Ocuopollis*, *Vacuopollis* and *Trudopollis* genera (into the *C. christae* pollen Zone) is situated at the base of the Upper Turonian (as at the Turonian stratotype, NW France, Robaszynski et al., 1982) or little below it.

The using of the FO of *S. neptuni* as primary boundary marker for the base of the Late Turonian of Romania, is in accordance with the point of view of Wright & Kennedy (1981), Kennedy et al. (1982), etc. As ammonite criterion for defining the base of the Late Turonian, other point of view prevailing is the appearance of *Romaniceras deverianum* (d'ORBIGNY).This is the galic historical criterion

(from the stratotype area and respectivelly for the Western Europe) of Grossouvre (1901), Collignon (1962), accepted by Amedro et al. (1982), Robaszynski et al. (1982, 1983). In the conclusions (Bengston et al., 1996) following the Second International Symposium on the Cretaceous Stage Boundaries (Brussels, 1995), there is no proposal for a Global Boundary Stratotype Section and Point (GSSP) and the ammonite boundary criterion for the Middle-Upper Turonian bundary. There are problems in choosing the ammonite boundary criterion, e.g. the relative position of the FO of the *R. deverianum* and *S. neptuni* species is uncertain. The FO of *Inoceramus costellatus* WOODS, which is situated near the FO of *S. neptuni*, is proposed to be studied as an alternative proxy marker for this boundary.

Only in the North Dobrogea, in the quarries situated at the South of Visterna locality, outcrops a succession with macrofauna (ammonites and inoceramids) in the uppermost Midde Turonian and the Late Turonian (beginning from its base): (i) – The topmost Middle Turonian beds (C. 1.6-2 m) with the ammonite *C. carolinum* and the planktonic foraminifera assemblage of the lower part of the *M. coronata* Zone; (ii) – At 0.3m above follows the first Upper Turonian pile of strata (of 4-5m thickness), its start being marked by the concomitant FO of the ammonite *T. rhodanicum*, the *Inoceramus costellatus, I. falcatus, I. teshioensis, I. parvus* (=the beginning of the *I. falcatus* and *I. teshioensis* Ass. Zone) bivalves and the FO of the planktonic foraminifera *M. paraconcavata* and *gr. S.-M. undulata undulata* (into the *M. coronata* Zone). Also, as inoceramid bivalve includes *Mytiloides lusatiae* ANDERT, *Inoceramus longealatus* TROGER, *Cremnoceramus waltersdorfensis (*Andert*)*(?) (which in Romania occur in the Late Turonian and in the Coniacian too), *I. inequivalvis* SCHLUTER, *I. tenuistriatus* NAGAO & MATSUMOTO and *I. apicalis* WOODS (the all three species coming from the Middle Turonian), *I. lusatiae brandenburgensis* KAUFFMAN.These macro- and microfauna occur in the entire this pile of strata, excepting *Cr. waltersorfensis*? that there is only in its uppermost part. (v) – The following second Upper Turonian pile of strata (of 3.5 m) is devoid of macrofauna and contains the same planktonic foraminifera assemblage as in the first part. (vi) – The FO of the *Marginotruncana tarfayensis* (LEHMANN) that follows immediately, marks the beginning of the Early Coniacian.

Usually, in the North Dobrogea and Carpathians, bellow the first levels with the Upper Turonian, the macrofauna was not found. These uppermost Middle Turonian levels are known only in the planktonic foraminifera terms, of the lowermost part of the *M. coronata* Zone in co-occurrence (documented only in the Carpathians) with the nannoplankton (with *Eiffellithus eximius* and *Quadrum gartneri*) of the *E. eximius* Zone; the microflora has not been suficiently investigated. Thus, in North Dobrogea, in the Cosarul Mic outcroups (situated at SE of Slava Rusa) and in SE part of the North Dobrogea, the uppermost Middle Turonian beds contain the planktonic foraminifera of the lowermost part of the *M. coronata* Zone. Above follows the Upper Turonian strata (10-14 m in Cosaru Mic section) with the planktonic foraminifera assemblage of the middle and upper part of the *M. coronata* Zone, and as macrofauna exposing in Cosaru Mic outcrops: (i) – *Romaniceras* sp. and *Inoceramus* ex gr. *fragilis* White – *perplexus* Whitfild, in the base of the exposure/in the lowermost segment of the Early Turonian. (ii) – At 10 m above, towards the topmost Late Turonian, there are the levels (1 m thickness) with *Mytiloides dresdensis*, *My*. *carpahicus* (SIMIONESCU), *Pachydesmceras linderi* GROSSOUVRE, *Gaudryceras denseplicatum* (JIMBO), *Parapuzosia mobergi* GROSSOUVRE. *G. denseplicatum* and *P. linderi* are known in the Matera Hill too. (iii) - The topmost part (approximate 3.5 m) is devoid of macrofauna, but contains the planktonic foraminifera of the *M. coronata* Zone as in underlying beds. (iv) –Iimmediately follows the base of the Early Coniacian (see Ion et al, 1997,1999).

In the SE part of the North Dobrogea, respectivly in the outcroups from the Caramanchioi - Jurilovca (Unirea) area and in the south bank of the Zmeica – Sinoe Lake, the Upper Turonian succession contains as macrofauna: *Lewesiceras mantelli, L. aff. vaju, Puzosia intermedia* (in the south bank of the Zmeica Lake) or *Inoceramus costellatus, I. falcatus* (of the *I. falcatus* and *I. teshioensis* Ass. Zone) and *G. denseplicatum* (at Cap Dolojman).

In the Carpathians (the Carbunelui Valley from Persani Mountains and Ion Valley from Hateg Basin), the biostratigraphical data of the Upper Turonian are: (i) – The topmost Middle Turonian beds devoid of macrofauna and with the planktonic foraminifera assemblage of the lowermost part of the *M. coronata* Zone and the nannoplankton of the topmost part of the *E. eximius* Zone. (ii) – The base of the Late Turonian is marked by the concomitant: the first presence of the ammonite *S. neptuni* associated with *Romaniceras sp., Scaphites cf.geinitzi* (d"ORBIGNY) (on the Ion Valley); or (on the Carbuneui Valley) the FO of the ammonite *S. neptuni, S. branneri* and *S. cf. normalis*, associated with *Lewesiceras sp*., *Damesites sugata* (FORBES), *Baculites sp*.; the first presence of *Inoceramus costellatus*, *I. falcatus*, *I. teshioensis, I. parvus, I. ex gr. glatziae* FLEGEL, *I. lusatiae*, the presence of *I. globosus* SIMIONESCU, *I. inequivalvis* SCHLUTER; the FO (into the *M. coronata* Zone) of the planktonic foraminifera *M. paraconcavata, gr. S.-M. undulata undulata* (into the *M. coronata* Zone), *Praeglobotruncana hilalensis* BARR, as well as of the *Marginotruncana aff. M. pseudoinneiana* (on the spiral side with the chambers in "*G. obliqua* type"

form), *M. aff. M. angusticarinata* (with very involute chambers on the spiral side) and *M. aff. S. marianosi* (with two fine keels on the first 1-3 chambers of the last whorl) as new morphotypes (on the Carbunelui and Ion vallies); the FO of the nannofossil *Kamptnerius magnificus* (=the beginning of the *K. magnificus* Zone) (in Carbunelui Valley). The strata with the co-occurrence of the *S. neptuni* Zone and *I. falcatus* and *I. teshioensis* Ass. Zone are extended on approximate 5m thickness (on the Carbunelui Valley) and into theirs lower part (iii) – the nannoplankton *Marthasterites furcatus* and *Lucianorhabdus maleformis* have the FO (=the beginning of the *M. furcatus* Zone and of the *L. maleformis* Subzone). (iv) – The following Upper Turonian sequence (of 10-15 m, on the Carbunelui Valley) is devoid of macrofauna and contains the same planktonic foraminifera and nannoplankton as in the lowermost Upper Turonian underlying strata. (v) – Follows the base of the Early Coniacian (see in Ion et al., 1999).

As a general characterization, we report that the Upper Turonian of Romania is biostratigraphic represented by the co-occurrence of (Figs. 1 and 2): - the *S. neptuni* Ammonite Zone, known only in the Carpathians, or some equivalent ammonite assemblages in North Dobrogea; - the *I.falcatus* and *I. teshioensis* Inoceramid Assembage Zone (in the Carpathians and North Dobrogea); - the approximate middle and upper part of the *M. coronata* Planktonic Foraminifera Zone. The Upper Turonian zonal assemblage, in both the Carpathians and North Dobrogea, is marked by *M. paraconcavata* and *gr. S. - M. undulata undulata*, as new presences and *H. helvetica* occurs throughout the *M. coronata* Zone (in Romania occurring to in the Early Coniacian). Only in the Carpathians in addition as new presences occur *M. marginata* (a later beginning of its range in compareson with in North Dobrogea), *Praeglobotruncana hilalensis*, as well as new morphotypes (see at the key sections); - as nannoplankton (documented only in the Carpathians), the entire *K. magnificus* Zone followed by the the lowermost part of the *M. furcatus* Zone (=the lower part of the *L. maleformis* Subzone respectively); - the same dinoflagellate assemblage (of the concomitant *S. pontis-marie* Zone and *Xenascus ceratioides* Zones) as for the Middle Turonian( documented in the Carpathians); - the pollen assemblage (of the *C. christae* Zone) with the *Oculopollis*, *Vacuopollis* and *Trudopollis* genera (as new presences) and the abundance of the *Alterbia aff. acutula-Subtilisphaera sp*. A group (documented in the Carpathians). The *Didymotis* bivalve genus, in the Carpathians and North Dobrogea do not occured in the Upper Turonian deposits; it is present only in the Lower Coniacian (see detailed data in Ion et al., 1999).

Excepting for its uppermost part, the Late Turonian is controlled in the North Dobrogea by the inoceramid and/or ammonite fauna; in the Carpathians (in the Persani Mountains and Hateg Basin), only its approximate lowermost/lower part is with macrofauna. The characteristic assembage of the *S. neptuni* ammonite Zone of Carpathians contains: *S. neptuni, S. cf. normalis, S. branneri*. The equivalent of ammonite assembllages from the North Dobrogea contain species, as *T. rhodanicum* and *L. mantelli*, that in the West Europe are found usually in the *S. neptuni* Zone (e.g. Wright, 1979, in the England and South France) or in the typical Upper Turonian assemblage. Other ammonites known in the Carpathians and North Dobrogea are mentioned at the key successions and in Fig.1.

In both the Carpathians and North Dobrogea areas, the *I. falcatus* and *I. teshioensis* Ass. Zone is characterized by the presence of the nominate species plus *I. costellatus* and *I. parvus* (TROGER). They are the Upper Turonian index species geographically wide-spread [ cf. Troger (1967, 1971), Keller (1982), Ernst et al.(1983) and Sornay in Robaszynski et al. (1982), the all cited by Szasz, 1986 b]. Together with these species there are numerous other inoceramids mentioned in Fig. 1 and in the text for the key sections. Also concerning the content of the *I.falcatus* and *I. teshioensis* Ass. Zone it is interesting to remark: has a unitary (a detailed zonation no permitting) and common content in both the Carpathians and North Dobrogea; the presence of *Cremnoceramus waltersorfensis* (in the uppermost Late Turonian) is uncertain; not contains the species *Mytiloides incertus* (JIMBO), in Romania this species appearing in the base of the Early Coniacian (see Ion et al., 1997,1999); not contains the inoceramid of large size from the *Cremnoceramus crassus* (PETRASCHECK) – *Cr. deformis* (MEEK) group and *Cr. rotundatus* (sensu TROGER non FIEGE) (in the Carpathians and North Dobrogea these having the appearance in the Early Coniacian, see Ion et al., 1997, 1999).

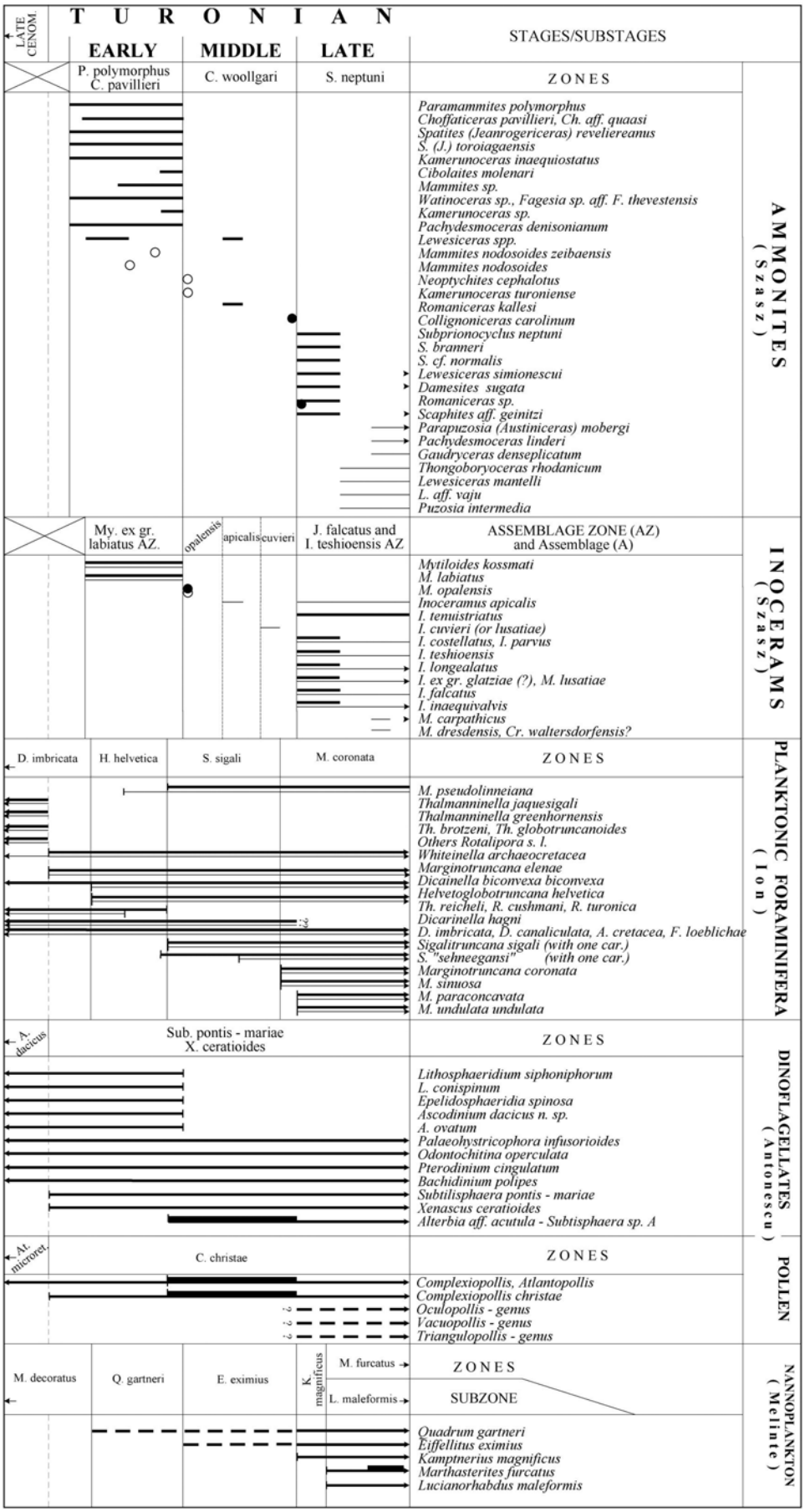


Fig. 1 Intercorrelated vertical distribution of the main biostratigraphical taxons in the Turonian of Romania
— and ○ in Carpathian; —— and ● in North Dobrogea; ▬ bloom

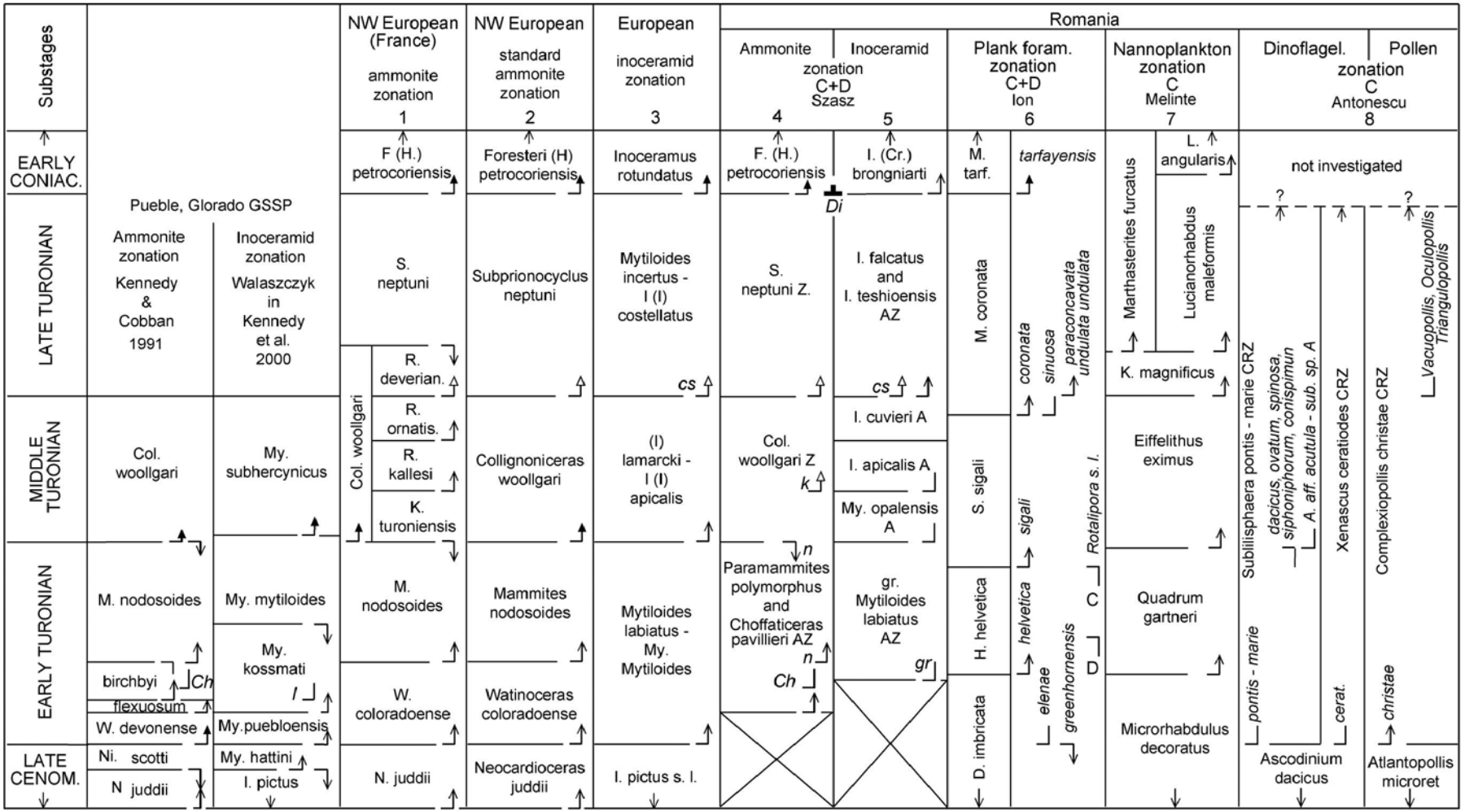


Figure 2 Integrated biostratigraphy for the Turonian of Romania and tentative correlation with the ammonite and inoceramid zonations for NW Europe and for Pueblo, Colorado, GSSP.

Legende: 1, Amedro et al. (1983); 2, Kennedy (1986); 3, Matsumoto & Noda (1986); 4, Szasz (1986); 5, Szasz, (1984), Szasz in Ion et al. (1997, 1998); 6. Ion (1989, 1993); 7, Melinte in Ion et al. (1997, 1998); 8, Antonescu in Ion et al. (1997, 1998); C, Carpathians; D, North Dobrogea; CRZ, Conccurrent Range Zone; Z, Zone; SZ, Subzone; AZ, Assemblage Zone; A, Assemblage; primary boundary marker bioevent, ⊥ first occurrence; potential primary boundary marker, ⊥ first occurrence; secondary bioevent of first order, first occurrence ⊥, last occurrence ⊤; secondary/auxiliary bioevent, first occurrence ⌋, last occurrence ⌈; first occurrence of Didymotis (in North Dobrogea) $\frac{+}{Di}$; *Ch, Choffaticeras; cs, I. costellatus; gr, My. gr. labiatus; k, R. kallesi; l. My. labiatus; n, M. nodosoides.*

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