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DEPOSITIONAL STAGES AND CORRELATION OF THE PALEOGENE FROM THE GRABEN BASINS IN SOUTHWEST BULGARIA

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ABSTRACT
The Paleogene basinal successions record transgressive-regressive fluvial-lacustrine/marine-fluvial depositional cycles. The graben basins and a basal gray colored, terrigenous, continental-marine association were formed during the Middle Eocene. Mature and "hot" grabens with cyclic deposition of a red-and-gray colored continental-marine and related dacite-rhyodacite association are typical of the Late Eocene–Early Oligocene stage. The Rupelian-Early Chattian and Middle Chattian–early Early Miocene stage is characterized by expanding sedimentation realm and deposition of a cyclic, gray colored coal-bearing, fluvial-lacustrine association.

INTRODUCTION

The Middle Eocene–Early Miocene terrigenous and Late Eocene-Early Oligocene volcanic-sedimentary successions, varying in thickness from 0,5 to 3 km, were formed and now exposed in graben depressions in Southwest Bulgaria (SWB). Major basins are: Mesta basin (MeB), related to the homonymous fault and river valley, Sandanski (SaB), Brezhani (BrB), Simitli (SiB) and Bobovdol basins (BoB), related to Struma fault and river valley; the basins located along the northeastern periphery of the Serbo-Macedonian massif and within the Strouma zone – Padezh (Suhostrel) (PaB), Kamenitsa (Prekolnitsa) (KaB), Poletinci (PoB) and Pianets (PiB), related to homonymous faults or fault belts; the basins west of Rila block in the Rhodope region or massif (RR) and west of Struma fault – Bobovdol (BoB) and north of it in Sredna Gora Zone – Pernik basin (PeB).

The aim of the present paper is, based on complex analysis, to correlate the basins, to define the main stages or tecto-sedimentary cycles and phases in sediment accumulation and to unravel their relationships with characteristic regional and global events. M. Vatsev, who has studied all mentioned basins, has written the paper. New horizons of marine sedimentation were established in Padezhq Poletinci and Mesta basins. S. Dzuranov did the micropaleontological studies. Some unpublished data of B. Kamenov were used in the basin correlation.

STRUCTURAL AND STRATIGRAPHIC FRAMEWORK

Structural framework

The Paleogene graben (trough) basins in SWB are superimposed on Precambrian basement of the RR and on folded Paleozoic and Mesozoic complexes of the neighboring parts of Struma and Morava units, and the Srednogorie. The grabens are linearly elongated mainly in NNW-SSE direction and vary in size – 30-70 km in length and 5-20 km in width.

These basins are elements of the Late Cretaceous-Paleogene collisional tectono-magmatic activation of the RR. Some authors describe them as post-collisional structures (Dabovski et al., 1991). The origin and development of the grabens is related to the progressive growth of domes cored by Late Cretaceous-Paleocene plutons (Zagorchev, Moorbath, 1987; Soldatos, Christofides, 1986; Christofides, 1998; Kamenov et al., 1999; Arnaudov, Lilov, 1998; etc.), break-up of the upper parts of the crust during the Middle and Late Eocene and formation of rift-related grabens and depression in the peripheral parts of the domes. The newly formed faults were controlled by pre-existing faults and inhomogeneousness. The grabens accumulated coarse-terrigenous and terrigenous sediments of molasse type that were accompanied by rocks of a dacite-rhyodacite association (Ivanov et al., 1971; Ivanov, Zidarov, 1968; Bozhkov et al., 1976; Vatsev, Nedyalkova, 1984; etc.). The intrusive magmatism is represented by Paleogene-Early Miocene granite plutons (Zagorchev, Moorbath, 1987; Christofides, 1998; Kamenov et al., 1998; etc.).

Stratigraphic framework.

The age of the terrigenous and volcanic rocks of the discussed basins is Late Eocene-Oligocene as indicated by fossils found in the water-basin sediments (Zagorchev et al., 1989; etc.) and by radiometric data for the volcanic (Palshin et al., 1974; Pecskay et al., 1991). In the course of our studies, biostratgraphic evidence for a Middle Eocene rocks in PaB, PiB and MeB (in this work down) and an early-Early Miocene – Aquitanian age of the uppermost part of the successions in BrB (Gaudant, Vatsev, in press) and in BoB and PeB has been established but the data are still not published. Most of the basins are coal-bearing and were studied by many coal experts, which in this short paper can not be mentioned. The stratigraphic data of the study basins are based of: PeB – B. Kamenov (1964), R. Beregov (1936), Zaharieva (1950) and unpublished materials of M. Vatsev; BoB - B. Kamenov (1959), S. Chernjavska (1977; etc.) and unpublished materials of M. Vatsev; PoB – S. Moskovski (1971) and unpublished materials of M. Vatsev; KaB - B. Kamenov (1942), R. Ivanov et al. (1971), M. Andelkovich et al. (1991) and unpublished materials of M. Vatsev; PiB – E. Belmustakov (1948), S. Moskovski, V. Shopov (1965), P.Mandev, S Zafirov (1967), S. Chernjavska (1977; etc.) and unpublished materials of M. Vatsev; PaB - E. Belmustakov (1948), I. Zagorchev et al. (1989) and unpublished materials of M. Vatsev; BrB and SiB – M. Vatsev (1984, 1991b) K. Zaharieva (1950), E. Palamarev (1967), J. Gaudant and M. Vatsev (in press) and unpublished materials of M. Vatsev; SaB – I. Bozkov et al. (1976, etc.) and unpublished materials of M. Vatsev; MeB – M. Vatsev (19778a, b, 1991a), M. Vatsev, S. Nedyalkova (1984) and unpublished materials of M. Vatsev. The summary stratigraphic sections of basin successions and correlate chart (Figure № 1) is prepare of M. Vatsev.

The age of the rhyodacites in the area of Kozhuh Height (Bozhkov et al., 1976, etc.) is 30 Ma (unpublished data of the former State Enterprise "Rare Metals"). This is an indication for the Late Eocene-Early Oligocene age of the rocks that are intersected by the volcanics. These rocks are red-colored, altered and silicated coarse-terrigenous and terrigenous sediments topped by opalized, probably rhyodacite tuffs.

The composition, structure, origin and correlation of the basinal successions allow distinguishing different stages in their stratigraphic-sedimentary evolution that are common for all basins. The basinal stratigraphic successions and data on their composition, structure, genesis and fossil content are summarized in Figure 1.

DEPOSITIONAL CYCLES

The Paleogene rocks are diverse conglomerates, sandstones, mudstone or argillites and minor limestones that form characteristic sequences. Their lithological compostion, fossil content, structure and genesis mark the development of transgressive-regressive depositional cycles (TRC), i. e. 3^{d} (A-K) and 2nd order cycles (Fig. 1). The boundaries of these cycles are distinct wash-out and clear lithological contacts. The wash-out character of boundaries was related mainly to changes of the temporally base level, to higher suuply of coarse terrigenous material and re-distribution of the depositional areas within the grabens and region. The changes of the base level in the discussed continental basins were related to the subsidence, the depositional rates, the formation and with drawal of water basins – lakes, lake-lagoons and marine bays. These changes were controlled by tectonic movements, eustatic changes of the World Ocean level and their combination in time. The lack of well expressed deep erosional carving and the relatively small size of the morphologically linked basins, allows to assume that there were no essential depositional breaks and that the boundaries of the 3^{d} order TRC or the cyclites (Karagodin, 1986) were nearly isochronous. There are also 2nd order cycles that integrate two to four 3^{d} order TRC. They are divided by unconformities related to more intensive tectonic movements and changes in the depositional area of the basins. Individual sedimentary autocycles may be also traced – proluvial, alluvial (fluvial), alluvial-lacustrine-swamp, etc. that indicate increasing textural maturity in the transgressive successions and decreasing – in the regressive ones.

The established 2nd order cycles developed during certain stages or episodes and 3^{d} order TRC that form the latter, are similar in composition and structure but show some individual features. The base of the 3^{d} order cycles comprises fluvial-transgressive complexes (FTC) that correspond to low base level and probably of the sea level (LS) and lack of water basins in the grabens. The basal mono- to polylithoclastic breccia-conglomerates and conglomerates originated during the early transgressive fluvial phase while the interbedded conglomerates and sandstones on top of them formed during the late-transgressive fluvial phase. Their genesis is proluvial-alluvial. The thickness of these rocks is variable and they are texturally and mineralogic-petrographic immature. The inundation-transgressive complexes (ITC) comprise mainly terrigenous rocks – polymictic and arkose sandstones and diverse mudstones that were formed in water basins – lakes, barred lagoons or open sea bays. They are characterized by higher textural and mineralogic-petrographic maturity. Coal seams are related to the sediments of the initial inundation phase while the sediments of the late inundation phase comprise mudstone and clay-carbonate rocks. These successions record the stages of transgression including also the maximum transgression of the water basins – TS. The regressive complexes (RC) correspond to high level of the basins – sea, lake – but with retreating coast – HS. RC comprise sandstones, sandy argillites and conglomerates in the lower parts that were formed during the early regressive phase. They are overlain by conglomerates and sandstones of the late regressive phase that show strongly varying quantitative relations and decreasing textural and mineralogic-petrographic maturity. This is due to erosion of rocks from the bordering, already uplifted blocks. RC was deposited from bottom rivers within the retreating water basins.

These sediments and the accompanying volcano-sedimentary rocks may be interpreted as syn-rift or syn-tectonic successions. The 3^{d} order TRC of low and middle part of the 2nd order cycles are progressive and asymmetrical and grow bigger thickness of the water-basin sediments and small of the RK. The last cycles are progressive-regressive (Karagodin, 1985) and have well developed RK. The evolution of these successions in the individual basins is similar throughout the discussed region and may be caused and explained by a combination between tectonic subsidence and long-lasting eustatic changes.

Middle Eocene 2nd order cycles – cycles A and B: Rocks of this 2nd order cycle were established in PaB, PiB and MeB. The basal conglomerate-sandstone complexes of TRC A overlie pre-Paleogene basement rocks and are related to paleo-river valleys within the grabens. ITC are represented mainly by bituminous silty shales, clayey sandstones and sandstones. Pinching-out layers of coal and coal schist occur in the basal parts. In the upper parts, the argillites are gray-green, sandy-silty, locally calcareous. In these rocks, in PaB and MeB, we have found remnants of foraminifers, gastropods and bivalves for the first time. The water basins were bay-lagoons to open bays. RC of cycle A, represented by irregularly intercalated sandstones and conglomerates, is not so well developed (10-50 m) as compared to that of cycle B (80-150 m).

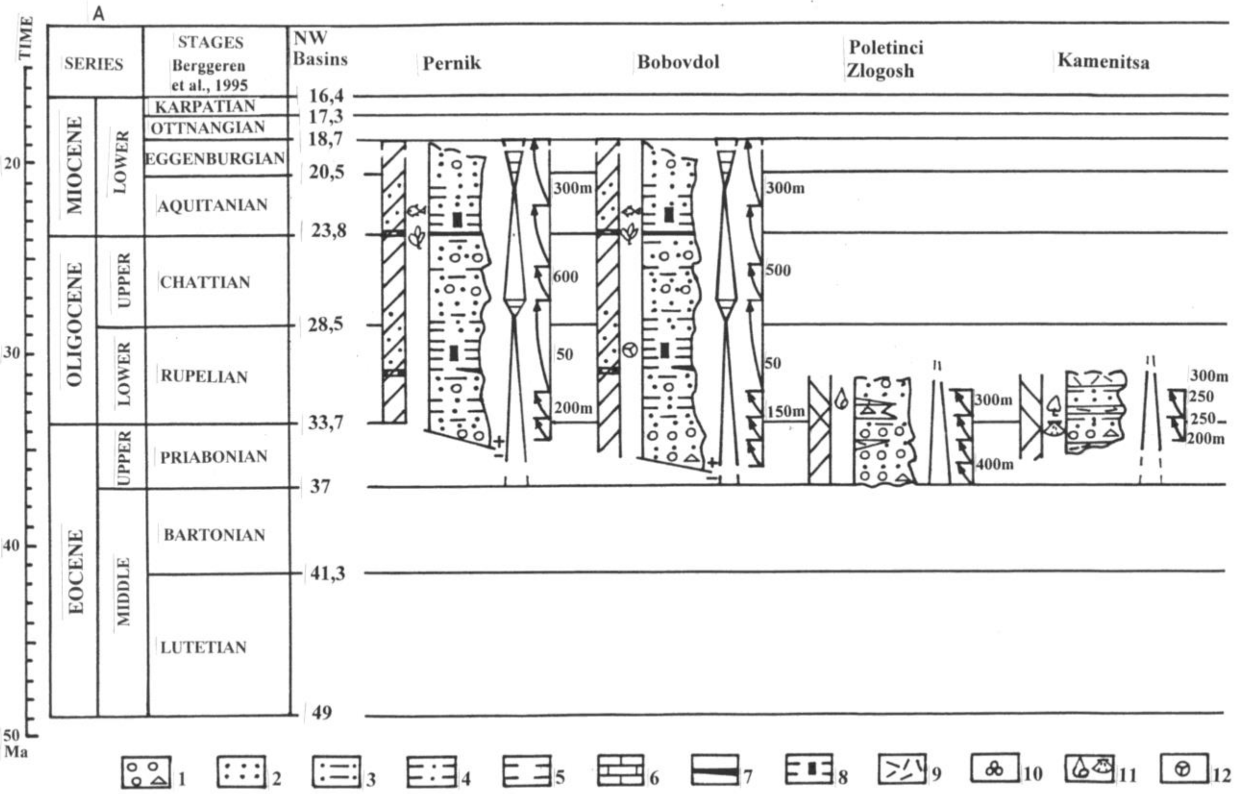


Figure 1. Correlate chart of the Paleogene successions and cycles of deposition of basins of the SW Bulgaria. Lithology: 1 – breccia-conglomerate and conglomerate; 2 – sandstone; 3 – clayey sandstone; 4 – sandy mudstone; 5 – mudstone; 6 – limestone; 7 – coal; 8 – bituminous mudstone; 9 – rhyodacites and tuffs; paleontology: 10 – foraminifers; 12 – gastropods and bivalvias ; 13 – spores and pollen; 14 – Eocene and Oligocene fossil flora; 14 – fossil fishs; environments: 15 – alluvial plain; 16 – lake; 17 – bog; 18 – bay-lagoon; 19 – marine coastal and shelf; 20 – transgressive succession; 21 – regressive succession; 22 – transgressive-regressive cycle; 23 – synsedimentary fault; 24 - synsedimentary faulting and volcanism.

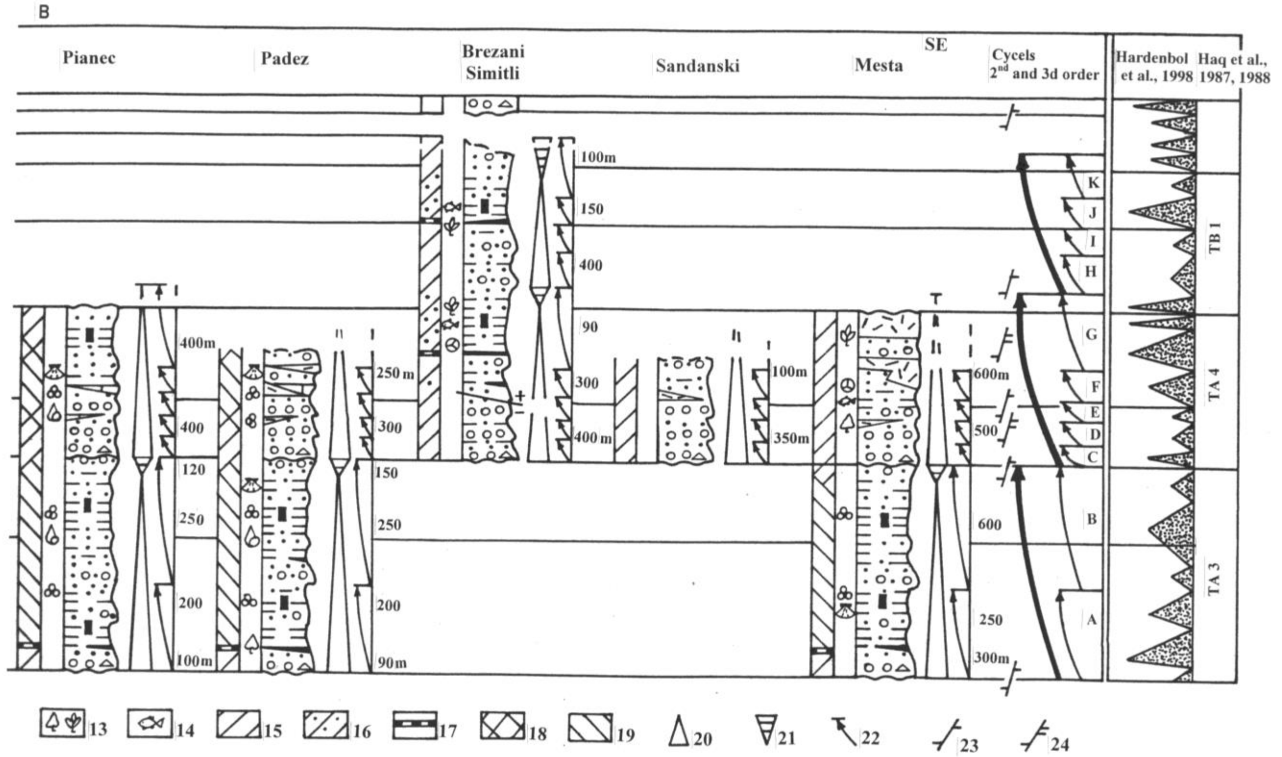
This witnesses a more complete development of the discussed 2nd order cycle. As a whole, the succession of TRC A and B is a gray-colored terrigenous, continental-marine association and has complicated structure.

Foraminifers for the first time were found in gulf-lagoon bituminous shale of the Suhostrel Formation (Zagorchev et al., 1989) of PaB, in bituminous shale of the Pelatikovo area of PiB and Dobrinishte Formation (Vatsev, 1978a, 1991a) of MeB. In PaB in middle part of theTRC A they are at four level. In their larger part, the associations are composed of plankton foraminifers. The following species were defined: *Acarinina bullbrooki* (Bolli), *A. spinuloinflata* (Bandy), *A. primitiva* Morozova, *A. rugosoaculeata* Subb, *Pseudohastiregirina micra* (Cole), *P. danvilensis* (Howe & Wallace), *Subotina eocaena* (Gumbel), *S. linaperta* (Finlay), *Globigerina senni* Beckman, *G. medizzai* Toumarkine& Bolli; and others. This association proves Middle Eocene age of the rocks.

In middle part of the TRC B at two level foraminifer and Radiolaria associations were found. The foraminifer association is almost fully composed of plankton foraminifers. The following species were defined: *Acarinina bullbrooki* (Bolli), *A. spinuloinflata* (Bandy), *A. pentacamerata* Subbotina, *Subotina eocaena* (Gumbel), *Pseudohastiregirina micra* (Cole); and others. These taxa determine Middle Eocene age of the rocks. The foraminifers from MeB still did not study.

This 2nd order cycle may be correlated with supercycle TA 3 (Haq et al., 1987, 1988; Hardenbol et al., 1998).

Late Eocene-Early Oligocene 2nd order cycle – cycles C, D, E, F and G: A typical feature of FTC is that they are build up almost entirely (up to 80%) of red-colored breccia-conglomerates, conglomerates and sandstones. At the same time, they form the dominant (60-80%) part of cycles C and D. Those two cycles are progressive asymmetrical. The rocks of cycle C overlie unconformably the basement or older Paleogene sediments. ITC comprises sandy argillites and clayey sandstones with interbeds of fine conglomerates and sometimes in the upper part – limestones. They were deposited in lakes (SaB), lakes or bay-lagoons and marine bays (PiB, KaB, PaB, MeB). Late Eocene and Oligocene bivalves and gastropods were found in KaB (Kamenov, 1942). Lithothamnian algae, ehinids, corals, nummulites and planctonic foraminifers are known from PaB and PiB (Belmustakov, 1948, Zagorchev et al., 1989; etc.). A progressive increase (from 15-30 to 150 m) in the thickness of the conglomerate and sandstone succession is typical for RC of TRC. TRC C, D and E are characterized by a progressive increase of the thickness and persistence of ITC and RC. Cycle F and G are progressive-regressive.



The upper parts of cycle D, E and F comprise rhyodacites and tuffs. The volcanic activity provoked some disturbances in the structure and development of the sedimentary and volcano-sedimentary successions. The volcanic activity terminated probably during the Early Oligocene but a dated cover of sedimentary rocks is lacking. It must be pointed out that the development of KaB and the neighboring Pchin basin in SE Serbia (Andelkovich, et al., 1991) commenced with volcanic activity. The early volcanic rocks and their sedimentary cover are exposed along the Tlamina Ridge, directly west of the Bulgaria-Serbia border. As a whole, this is a red-and-gray colored terrigenous, continental-marine succession with related normal calc-alkaline, dacite-rhyodacite association (Ivanov et al., 1971; Ivanov, Zidarov, 1968; etc.). The sequences of the TRC F and G of BrB, BoB and PeB do not contain volcanic rocks and are presented of coal-bearing formations; their short characteristic is in lower part.

Extremely rich foraminifer association were found at several levels and place in the upper part of the cycles D and E in PaB. Prevailing in them ate the Benthic foraminifers. Plankton taxa are also present in the smaller fractions. The following species were defined: *Globigerina officinalis* Subbotina, *G. yeguaensis* Weinzierl & Applin, *G. praebulloides* Blowq, *G. officinalis* Subbotina, *Subbotina eocaena* Gumbel, *Trurborotalia cerr. pomeroli* (Toumarkine & Bolli) and others. As a whole this association proves Upper Eocene age of the rocks of cycle C, D (Komatinitsa and Logodazh Formation) and lover part of E. In upper part of section of the Padezh Formation is presented different Late Eocene-Early Oligocene fauna (Belmustakov, 1948, Zagorchev et al., 1989; etc.). Analysis of the biostratigrafical materials in this short paper can no be do. The age of this 2nd order cycle, incidences Komatinitsa, Logodazh and Padezh Formation (Zagorchev et al., 1989) on the basis of new and published data is Late Eocene-Early Oligocene.

This 2nd order cycle may be correlated with supercycle TB 4.

Late Oligocene-early Early Miocene 2nd order cycle – cycles H, I, L and K: The rocks of this 2nd order cycle and cycles F and G were deposited in new graben basins or in lateral branches of old ones. The volcanic rocks absence in these grabens. The successions of the 3d order TRC F-G and H-K have analogical structure and development. Their first cycles are progressive asymmetrical incomplete. FTC of those 3rd order cycles are represented by alluvial conglomerates and sandstones, the letter dominating. Their thick is variable. Their ITC consist of irregularity alternation of sandy-silty shales and clayey sandstones and are wash away. The upper TRC are progressive-regressive. Their ITC are composed of bituminous clay shales, clayey sandstones and calcareous shales (70-150 m). The coal seams are developed in their base and are mined in BrB (cycle G), BoB and PeB (cycle J). The RC comprise of fluvial sandstones, sandy argillites and conglomerates.

According to fossil flora (Palamarev, 1964; Vatsev, 1984; Zakharieva, 1957), spores and pollen (Chernjavska (1977; etc.), fossil fishes – *Barbus macrurus,* Ag., of PeB and BoB (Beregov, 1936), *Barbus steinheimehsis* Quenst (Zakharieva, 1957) and other of BrB (Gaudant, Vatsev, in press) the rocks of cycle F-H are of Rupelian-Early Chattian age. The rocks of cycles I-K are dated as Late Chattina-Aquitanian on the basis of fossil fishes and flora in BrB (Vatsev, 1984; Gaudant, Vatsev, in press); the age of these succession in BoB and PeB is analogous but the data are still not published. According to stratigraphic position, the age of the RC of cycle K is probably late Late Aquitanian-Egenburgian and the depositional break occurred during the Ottnangian age. The cover is of Carpathian sediments of the SiB (Vatsev, 1991b) and BrB (Vatsev, 1984). In general, the Early Oligocene successiin of TRC H-G and this of cycles H-K Late Oligocene-early Early Miocene is a complex cyclic, gray colored, coal-bearing, terrigenous fluvial-lacustrine association.

This 2nd order Late Chattian-early Early Miocene cycle may be correlated wit supercycle TB 1.

DISCUSSION AND CONCLUSIONS

The analysis of the Middel Eocene-early Early Miocene successions and the basin history suggests several stages in their formation, evolution and sediment accumulation: 1) The formation of the Middle Eocene sedimentary graben basins was related to the Illyrian tectonic phase; a gray colored, terrigenous-marine association deposited in the conditions of a warm and humid climate. 2) The Late Eocene-Early Oligocene 2nd order cycle was controlled by the Pyrenean phase under conditions of expanding basins, deep and narrow fault zones, development of elongate mature and "hot" grabens with deposition of a red-and-grey colored continental-marine and related dacite-rhyodacite association accompanied by granite intrusions. The volcanic activity and the related growth of thermo-tectonic domes as well as the intrusion of granite plutons resulted in essential changes in the character and size of depositional areas during the Early Oligocene. 3) The LateOligocene-early Early Miocene 2nd order cycle was related to the Pyrenean and Savian phases; typical features are development of new graben basins, expanding depositional area, deposition of a gray colored, coal-bearing, fluvial-lacustrine association, changes in the geodynamic regime during the Early Miocene from extension and subsidence to compression, block-dome uplift and termination of the sediment deposition, onset of plastic deformations mainly around the periphery of the grabens as a result of general horizontal compression and block movements. In general, this 2nd order cycle (stage) is characterized by development of new graben depressions and formation of a gray colored, fluvial-lacustrine association. The bordering horst blocks were not highly uplifted and were covered by vegetation under conditions of a warm and humid climate. These data indicate a general crustal stabilization. 4) The differences between succession 3rd order TRC cycles and the 2nd order cycles which they form are interpreted as a result of the subsidence in different affiliated graben basins to form wide depressions of similar type resulting from sediment loading, thermal cooling, crustal stabilization and their combination with eustatic changes. 5) A link between depositional cycles and changes in the World Ocean level can be established (Haq et al., 1987, 1988; Hardenbol et al., 1998) – the development of water basins (lakes and marine bays) in the grabens correlates well with episodes of high World Ocean level but at present a more accurate correlations are not possible due to insufficient information concerning a more detailed biostratigraphic dating of the successions and the boundaries between the cycles. 6) As a whole, in the interval Middle Eocene – Early Miocene and later, the discussed region of SWB suffered a progressive, irregular expansion, complicated by unperiodic compressional impulses and related block displacements, cyclic volcanism and intrusions of granite plutons.

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