Stratigraphic structure of the B1 Tertiary tectonostratigraphic unit in eastern Slovenia

Stratigrafska zgradba terciarne tektonostratigrafske enote B1 v vzhodni Sloveniji

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Abstract

High inconsistency and incoherence in the stratigraphy of the Slovenian upper Paleogene and lower Miocene have remained unsolved in the past 150 years. To solve the problem, we tried to rigorously conduct the authentic Galilei's scientific method. Steps of logical and empirical verification confirmed the existence of the posited B1 Tertiary tectonostratigraphic unit, and a general chronostratigraphic model of new positional relationships of lithologic units resulted from rather good biochronostratigraphic resolution achieved by nannoplankton and planktonic foraminifera biostratigraphy. The application of principles of newly developed fields in science helped us to avoid errors in transmission of messages (to reduce noise) from the source (rock) to the concept formation, which had been done previously. This in turn has strongly reduced inconsistency and incoherence (high information entropy = uncertainty). The released amount of information enabled us to answer also questions that reached beyond the original difficulty, e.g.: is the tectonostratigraphic structure of eastern Slovenia a manifestation of plate tectonics processes, and of which ones, are theories of continental escape in the Alps and associated dissection and offset of the formerly uniform Slovenian-Hungarian Paleogene basin tenable or not, are then there in the B1 stratigraphic equivalents of the Hungarian Paleogene basin formations, where are the important Eocene / Oligocene, Paleogene / Neogene, Rupelian / Chattian and Kiscellian / Egerian boundaries in Slovenia, and is there a continuation of the B1 in Croatia and in the Mid-Hungarian tectonic zone?

Kratka vsebina

Visoka inkonsistenca in inkoherenca sta bili 150 let prisotni v stratigrafiji zgornjega paleogena in spodnjega miocena Slovenije. Problem smo rešili tako, da smo poskušali strogo izpeljati avtentično Galileievo raziskovalno metodo. Postopek logične in empirične verifikacije je potrdil obstoj terciarne tektonostratigrafske enote B1. Z nanoplanktonsko in planktonsko foraminiferno biostratigrafijo smo dosegli primerno biokronostratigrafsko ločljivost za postavitev novega splošnega kronostratigrafskega modela pozicijskih odnosov med litološkimi enotami. Načela novih znanstvenih disciplin so nam pomagala preiti napake v prenosu sporočila (zmanjšati šume) od vira (kamenine) do oblikovanja koncepta, ki so problem povzročile. Tako nam je uspelo zelo zmanjšati inkoherenco in inkonsistenco (visoko informacijsko entropijo = nedoločenost znanja). Sproščena količina informacije nam je omogočila odgovoriti tudi na pomembna vprašanja, ki so presegala začetni prob-

Yellow

lem, npr.: ali je tektonostratigrafska zgradba vzhodne Slovenije posledica procesov tektonike plošč in katerih, ali obstajajo stratigrafski argumenti proti teoriji kontinentalnega pobega in razdvojitvi prvotno enotnega Slovensko-madžarskega paleogenskega bazena med pobegom, ali v B1 obstajajo stratigrafski ekvivalenti formacijam v Madžarskem paleogenskem bazenu, kje so v Sloveniji pomembne kronostratigrafske meje eocen / oligocen, paleogen / neogen, rupelij / katij in kiscellij / egerij, ali se B1 nadaljuje na Hrvaško in v Srednjemadžarsko tektonsko cono?

INTRODUCTION

In solving the stratigraphic inconsistency and incoherence of upper Paleogene and lower Miocene beds of eastern Slovenia (fig. 1, 2), we strove to satisfy the starting-point criteria of scientific research. Two among these criteria are the explanatory power of results and contributiveness of new postulates. The tendency was demonstrated by the significant explanatory power of new results and by the further fertile postulation process. One of the postulates concerns the existence between the Donat and Celje tectonic zones of a Tertiary tectonostratigraphic unit marked TTU B1 by us that differs in the stratigraphic structure from the northerly extending TTU A2 unit and the southerly TTU B2 unit (fig. 1b, 3) (J e l e n et al., 1992, 1993). Since this postulate, however,
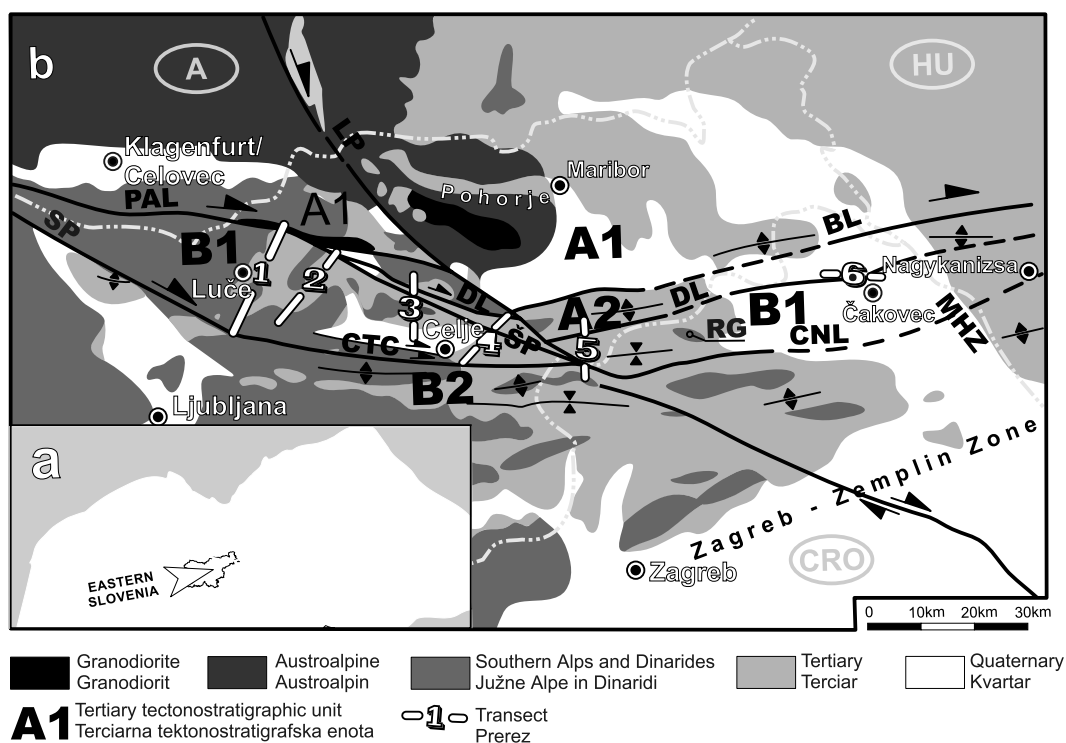

Fig. 1. a Location map of the study area in the Pannonian basin. b Geologic sketch-map of the study area and surrounding regions featuring the extension of Tertiary and major tectonic lines, showing the position of modelled cross-sections. BL Balaton line, CNL Celje-Nagykanizsa line, CTC Celje tectonic zone, DL Donat line, MHZ Middle Hungarian tectonic zone, PAL Periadriatic line, RG Ravna gora, SP Sava fault, ŠP Šoštanj fault

Sl. 1. a Lega raziskovanega območja v Panonskem bazenu. b Geološka skica raziskovanega območja in sosednjih območij prikazuje položaj modeliranih prerezov čez predlagani stratigrafski model. BL Balatonska linija, CNL Celje-Nadžkaniža linija, CTC Celjska tektonska cona, DL Donačka linija, MHZ Srednjemadžarska tektonska cona, PAL Periadriatski lineament, RG Ravna gora, SP Savski prelom, ŠP Šoštanjski prelom
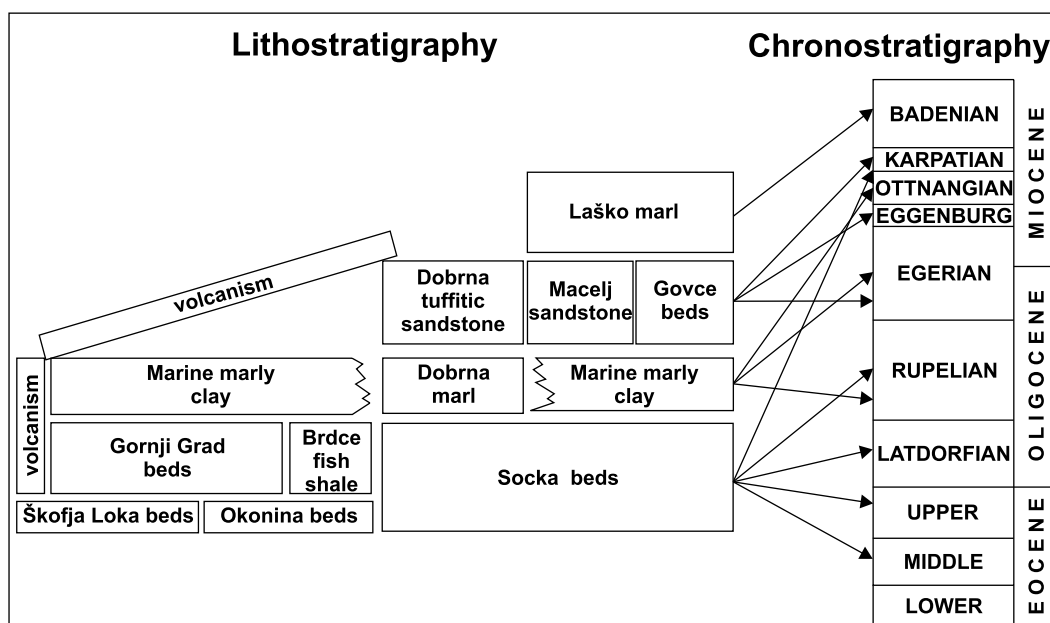
Fig. 2. Example of the chronostratigraphic inconsistency in the Tertiary of eastern Slovenia. To Socka beds five different ages were attributed. This created an unacceptable stratigraphic conflict, especially since other lithologic units with various age attributions were included into lithostratigraphic column at will.

Sl. 2. Primer inkonsistence v stratigrafiji terciarja vzhodne Slovenije.
Soteškim plastem smo na primer pripisovali pet različnih starosti. To je s pripisovanjem različnih starosti tudi drugim litološkim enotam, poljubno sestavljenih v litostratigrafijo, povzročilo nesprejemljivo stratigrafsko navzkrižje.

does not contain any assurance of its reality, although it was deduced from objective empirical observations, we tried to derive the well known method for confirming the existence or non-existence of TTU B1.

On the previously highly uncertain stratigraphic correlation between the Hungarian and Slovenian Paleogene basins two theories were set up that essentially influenced the understanding of kinematics and geodynamics in the region of the present Alps, Carpathians and the Pannonian basin: the theory of continental escape in the Alps (Kázmér, 1984) and the theory of separation of the originally unique Paleogene basin into the Slovenian and Hungarian Paleogene basins during the continental escape (Csontos et al. 1992), the design of which can be found in Báldi (1983). The research thus also represented a part of integral falsification of the starting-point stratigraphic argument of the two theories. In this the following research questions arose:

do in the B1 exist stratigraphic equivalents to formations in the Hungarian Paleogene basin, where in Slovenia do occur important chronostratigraphic boundaries Eocene / Oligocene, Rupelian / Chattian, Kiscellian / Egerian and Paleogene / Neogene, and does the B1 continue to Croatia and into the Mid-Hungarian tectonic zone?

METHODS OF RESEARCH

The core of the stratigraphic research model set up for solving the problem of high inconsistency and incoherence in Slovenia is the scientific method after Galilei (Koyre, 1978). In research of TTU B1 the procedure of *modus tollens* of this method was applied. New consequences for stratigraphic structure were attempted to be deduced through this procedure.

The consequences that passed the logical verification procedure of reasoning, of con-

sistency and coherence, and by this also the procedure of elimination, were subjected to the procedure of empiric verification. The procedure of empiric verification was performed by the selected aimed sampling of constructively modelled lithostratigraphic relationships, by biostratigraphic analysis, biochronostratigraphic correlation and by correlation with sequence chronostratigraphy after A b r e u & A n d e r s o n (1998). For biostratigraphic tool the calcareous nannoplankton and planktonic foraminifers were selected. The nannoplankton and planktonic foraminifer biochronology permits also in the marine development of Tertiary of Central Paratethys the maximum possible biochronostratigraphic resolution and direct correlation with the standard geologic time

scale. High chronostratigraphic resolution and capability of direct correlation with the standard geological time scale were the necessary condition for performing the empiric verification.

The present upper Paleogene to lower Miocene basins in Slovenia are all strongly deformed postdepositional basins. The stratigraphic architecture of original sedimentation basins was radically or entirely destroyed by the tectonic-structural evolution. In addition, the synsedimentation tectonics created its complex stratigraphic architecture. Owing to these states the two verification procedures requested a time-wise very demanding modelling method, first of lithostratigraphic and then of chronostratigraphic relationships, the method being known
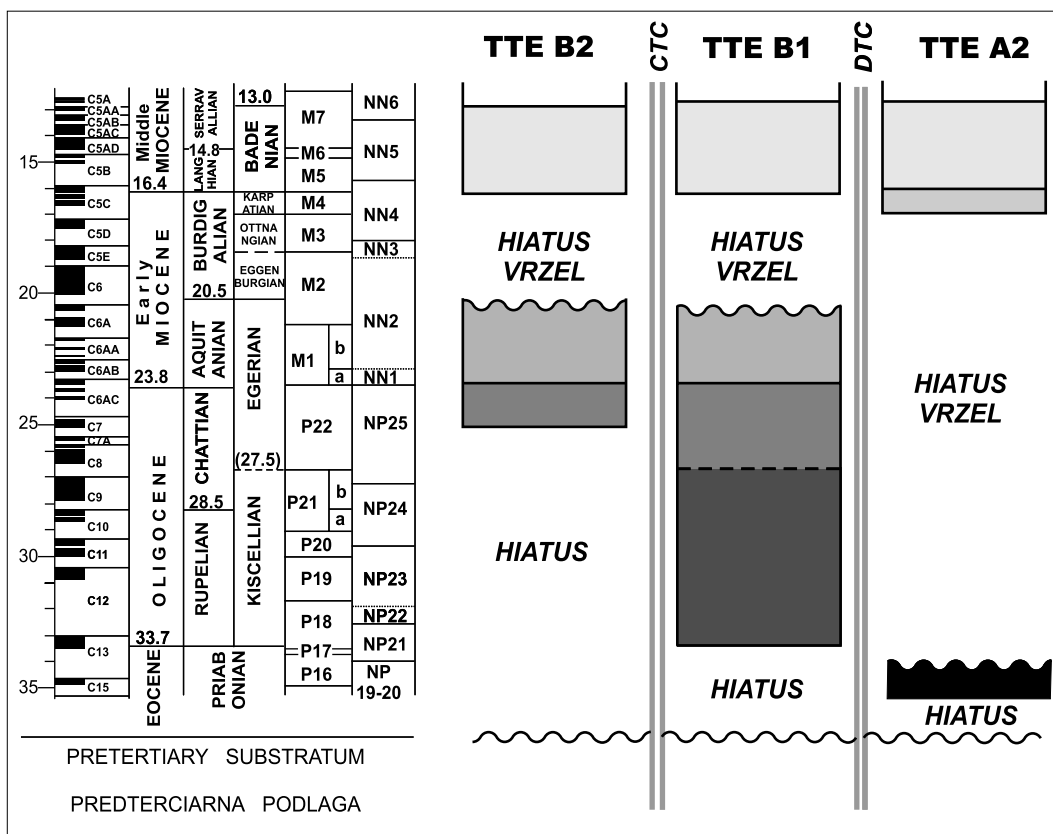

Fig. 3. Tectonostratigraphic correlation of the posited Tertiary tectonostratigraphic unit (TTU) B1, compared with the TTU A2 and TTU B2. CTC Celje tectonic zone, DTC (= DL) Donat tectonic (transpression) zone

Sl. 3. Tektonostratigrafska korelacija zahtevane terciarne tektonostratigrafske enote (TTE) B1 s sosednjima TTE A2 in TTE B2. CTC Celjska tektonska cona, DTC (= DL) Donačka tektonska (transpresivna) cona

in physics as constructive modelling (N e r - s e s s i a n, 1992). Since financing of the scientific research projects is not appropriate for performing of complex scientific research, the verification of such complex stratigraphic structure could not be carried out to its end. Therefore the physical and chemical methods of calibration with the standard geologic time scale that are extraordinarily important for verification were not performed. Likewise limited was the volume of dating by nannoplankton that was performed with financial means of Dr. Mária Báldi-Beke. Although for calcareous nannoplankton 83 samples were analyzed and the same number for planktonic foraminifers, a complete statement for the TTU B1 stratigraphic model could not be accomplished. Consequently, for the moment only the presentation of the general model of TTU B1 stratigraphic structure could be made, but not the verified specific model.

At present the science is more interested in relationships between objects and events than in the objects and events themselves, which is very close to stratigraphy. Relationships are rather mapped than measured, and they are attempted to be ordered in invariable associations, which is again close to stratigraphy. We followed this direction and we tried to set up a model of stratigraphic relationships with the least variable associations. For constructing the model the observations, results of analyzes and of reasoning have to be arranged into a stratigraphic system as a system pattern of the ordinal order. The pattern should represent a new formalization with the help of logic (a logic form) that would abolish the existing stratigraphic inconsistency and incoherence. In this case the »form« means structure, or the way things are put together.

That the structure of concepts depends upon our reasoning has been known for long also in stratigraphy (e.g. R o d g e r s, 1959; B l o w, 1979), and therefore in the research we tried to apply principles of logic at four levels: of stratigraphy, geology, science and of formal logic. This represents the multilogical approach. In the research we abandoned the formalization of lithostratigraphy, because it is nowadays in stratigraphy an anachronism (conf. M i a l l, 1990) which belongs in formal logic to logical fallacies.

We try to advance in the research model several new scientific valuable insights into problems studied. One among them is the statement that a problem cannot be solved on the same level as it was created, or, that is not the most important to achieve the result but to recognize the way how to achieve it. There are the epistemologic cognition and question of economy of thought that are the important parts of any scientific discipline. The existence of a scientific discipline requires namely the object of research and the methods of research. In any research method the empiric and rational methods complete each other – only ones of the two do not suffice – , and they must be based on logic in order to make the process of achieving new knowledge ordered, economical, meaningful and valid.

RESULTS

By considering the basic principles of logic in formalization of the system, i.e. intelligibility in understanding, simpleness, economy and generality, a simple model of the TTU B1 stratigraphic structure was achieved, so: (1) that from the standpoint of the systems theory it displays its individuality, i.e. separateness and difference with respect to other TTU in eastern Slovenia. Individuality has been actualized otherwise than with other TTU, as a quasiautonomous part of the whole; (2) that the information content of it, from the standpoint of information theory, considerably reduces the uncertainty in understanding the Tertiary stratigraphic system of eastern Slovenia, and performs organizing work by abolishing a larger part of inconsistency and incoherence of this system and confirms its high degree of dependence upon the mobility of the area and the region; (3) that its content represents a better approximation to reality (a higher verisimilitude: P o p p e r, 1979) than did the contents of earlier statements. On all questions to which the content of earlier statements gave answers, the content of the present model gives better answers, and on questions that remained unanswered by content of earlier statements the content of the model does provide answers, and it also can be explained in terms of all four logical sys-

tems. The model has consequently a higher degree of certainty, a higher explanatory power and higher potential for the general; and (4), it considerably reduces the uncertainty of stratigraphic correlation on the regional and global levels. (5) In B1 exist the following stratigraphic equivalents to formations in the Hungarian Paleogene basin: the Szépvölgy Limestone, Buda Marl, Tard Clay, Kiscell Clay, Szécsény Schlier, and coarse-grained clastic formations as for example the Törökbalint, Tura or Eger Sandstone. For the time equivalent of the Kiscell Clay the Smrekovec volcaniclastic sequence was proposed by us. (6) Important chronostratigraphic boundaries were detected: the Eocene / Oligocene, Kiscellian / Egerian and Paleogene / Neogene (= Oligocene / Miocene) boundaries that occupy in the stratigraphic equivalents the same position as in the Hungarian Paleogene basin. (7) The tectonostratigraphic structure of eastern Slovenia continues to the territory of Republic of Croatia and into strike-slip duplexes of the Mid-Hungarian tectonic zone. (8) The new information do not contradict either K á z m é r ' s (1984) or C s o n t o s ' et al. (1992) theories.

The individuality of TTU B1 is illustrated by chronostratigraphic relationships between major lithologic units in the model.

From here on the terms will be used that mean: NP – Paleogene nannoplanktonic biochronozone, NN – Neogene nannoplanktonic biochronozone, P – planktonic foraminifer biochronozone, SB – biozone of large Oligocene and Miocene foraminifers (shallow benthic), FAD – first dated appearance of taxon (first appearance datum), LAD – last appearance datum of taxon, FA – first appearance of taxon, LA – last appearance of taxon.

Thicknesses of lithologic units are very variable. They depend upon sedimentation circumstances, present gravitational movements and very strongly upon tectonic deformations. Therefore the given estimates of thicknesses of the lithologic units are very hypothetic.

Rocks were determined macroscopically.

Lithologic unit 1 (LE 1), fig. 4, 5: to LE 1 the medium to light grey massive, poorly bedded and medium to thick bedded limestones with discocyclinas and nummulites in the base of the first Tertiary succession of TTU B1 are attributed. Their thickness amounts to ~50 m. Upwards the unit passes to LE 2. The transition is observable. In outcrops it was detected in the Smrekovec basin

(in the sense of F o d o r et al., 1998), on Ravna gora and in Višnjica in Croatia (conf. Č o s o v i ć et al., 2000a, 2000b). The chronostratigraphic position of the unit is marked by discocyclinas, nummulites and by calcareous nannoplankton and planktonic foraminifera dated LE 2. Correlation with sequence chronostratigraphy demonstrated that it belongs to the start of a transgression sequence between the Pr 4 / Ru 1 and Ru 2 sequence boundaries. However, the transgression in our case started earlier (fig. 10), which better approaches the H a q ' s (1987, 1988) sequence chronostratigraphy. At a 10 cm/1000 years deposition rate for carbonates the transgression might have started already at the NP 21 / NP 19-20 boundary or at P 16. We do not see the problem so much in the difficultly solvable complex of local, tectonically induced and eustatic sea level oscillation as rather in the problem of GSSP (Global Stratotype Section and Point) of the Eocene / Oligocene boundary (conf. B e r g g r e n et al., 1995). On the basis of nummulitic fauna *Nummulites vascus* Joly et Leymerie and *Nummulites germanicus* (Bornemann) determined at Podvolovljek (F e r j a n č i č & P a v l o v e c, 1979) and with respect to inverse lithostratigraphy, as recognized by the authors, we presume the diachronicity of LE 1 (fig. 5). This fauna determines the lower part of SB 21, i.e. approximately the Oligocene part of P 18 (C a - h u z a c & P o i g n a n t, 1997). We consider LE 1 as stratigraphic equivalent of Szépvölgy Limestone in the Hungarian Paleogene basin.

Lithologic unit 2 (LE 2), fig. 4, 5: the unit was composed of the 2/1 and 2/2 members. The lower 2/1 member represents an alternation of dark grey medium thick to thick bedded laminated silty to fine sandy marlstones and medium grey medium to very thick bedded allodapic limestones. Their thickness amounts to ~45 m. The upper 2/2 member consists of medium light grey silty marlstones interrupted by beds of medium light grey medium to very thick bedded allodapic limestones. 2/2 is composed of two partial profiles. Since we do not know whether the partial profiles do overlap or not, the thickness estimate of ~70 m is very hypothetical. Geometric reconstruction resulted to 120 m of thickness, which, however, is not
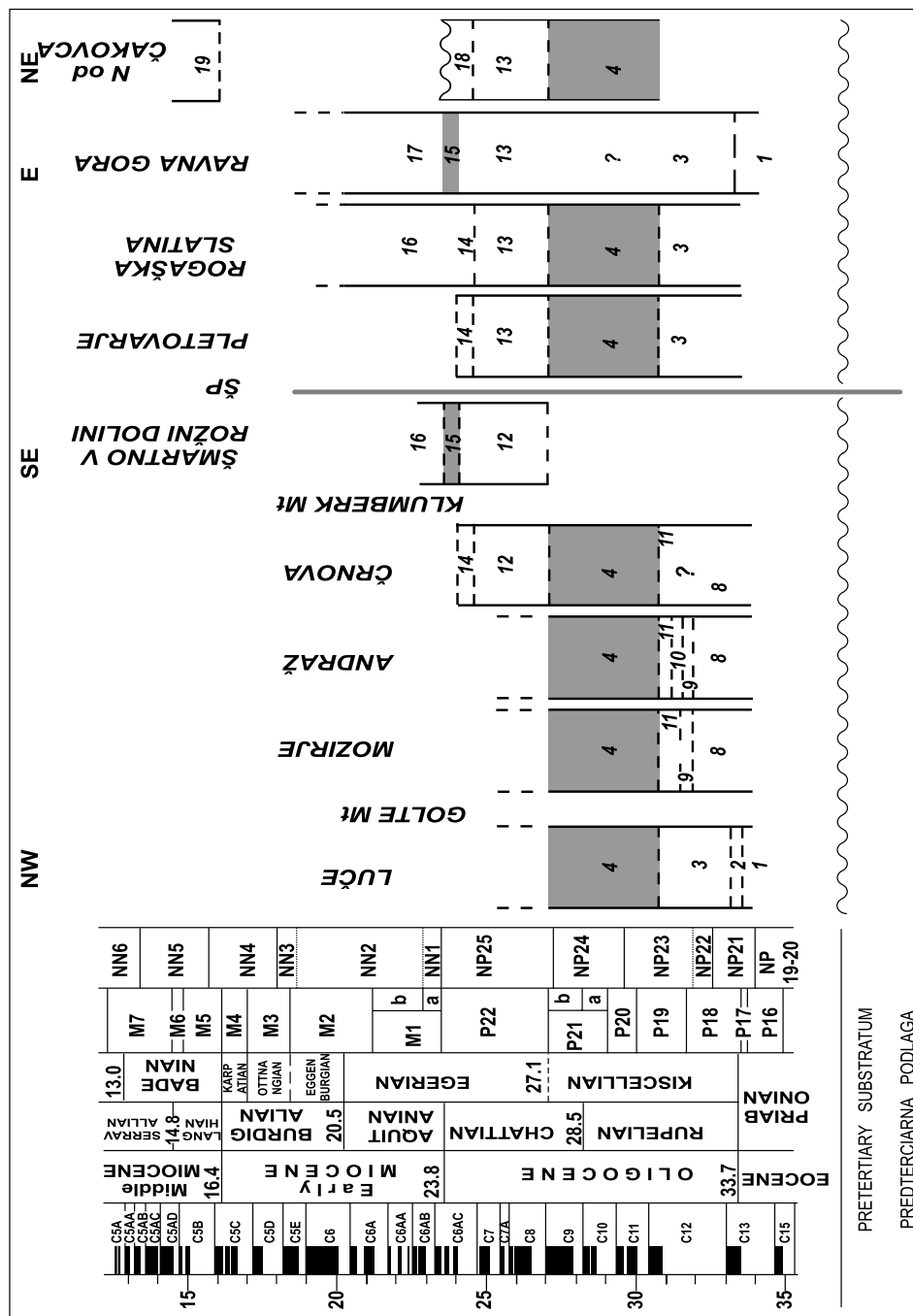
Fig. 4. W – E cross-section through the suggested stratigraphic model.
Chronostratigraphic framework represents the modelled positional relationships of lithologic units 1 – 19. The isochrony of boundaries of lithologic units depends on the achieved biochronostratigraphic resolution. For explanation see text.

Sl. 4. Prerez čez predlagani stratigrafski model prikazuje modelirane kronostratigrafske pozicijske odnose litoloških enot 1 – 19 v smeri W – E. Izokronost mej litoloških enot je odvisna od dosežene biokronostratigrafske ločljivosti. Razlaga je v tekstu.
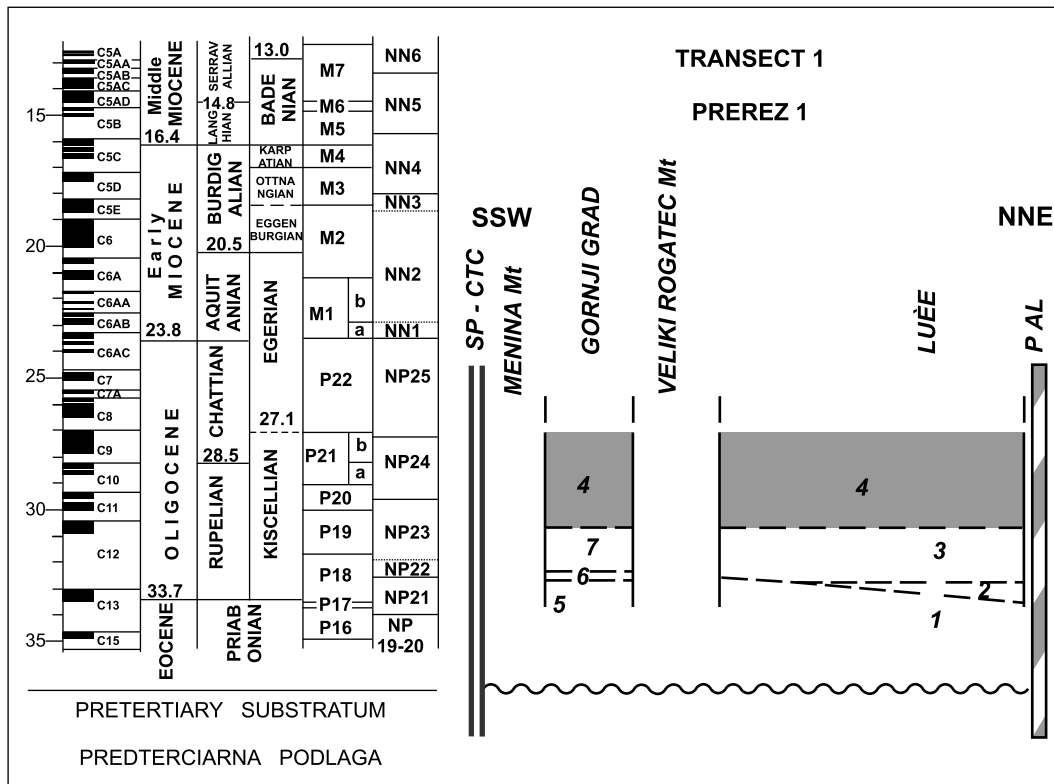
Fig. 5. Transect 1 represents the chronostratigraphic positional relationships of lithologic units (LE) LE 1 – LE 7 of the Smrekovec basin. It cuts across the Gornji Grad branch and the Luče syncline up to the Periadriatic Lineament (PAL). PAL accommodated the major part of the offset during the continental escape. Isochrony of the LE 4 lower boundary throughout the basin depends on how successfully the problem of its dating was solved. For account of the problem see the section Discussion.

Sl. 5. Prerez 1 prikazuje kronostratigrafske pozicijske odnose litoloških enot (LE)

Smrekovškega bazena LE 1 – LE 7. Prereže gornjegrajski krak in Lučko sinklinalo do PAL. Ob PAL se je zgodil glavni premik med kontinentalnim pobegom. Izokronost spodnje meje LE 4 v bazenu je odvisna od uspešnosti datiranja. O problemu datiranja glej text.

probable owing to tectonic deformations. The members are separated by ~20 m of medium to light grey thick bedded biomicritic limestones in which fragments of calcified red algae prevail. Above, the biomicrites are replaced by calcruditic calcarenites. 2/2 passes upward to LE 3. The transition is not well visible. At the surface LE 2 was detected in the Smrekovec basin only. In the lower part of 2/2 the start of the acme zone of nannoplanktonic species *Lanternithus minutus* Stradner and *Zygrhablithus bijugatus* (Deflandre) and the first appearance of *Reticulofenestra* aff. *lockeri* Müller were determined. The beginning of *Lanternithus minutus-Zygrhablithus bijugatus* Acme-zone and

the first appearance of *Reticulofenestra* aff. *lockeri* Müller occurs in the NP 21 close to the NP 19-20 / NP 21 boundary (B á l d i – B e k e, 1977, 1984; N a g y m a r o s y, 1992). Below the beginning of *Lanternithus minutus-Zygrhablithus bijugatus* Acme-zone, still in the lower part of 2/2, appears for the last time the planktonic foraminifer genus *Globigerinatheka*. The above biostratigraphy is the same as biochronology at the Eocene / Oligocene GSSP where the extinction of the last species of genus Globigerinatheka coincides with NP 19-20 / NP 21 boundary, followed by an increase in abundance of *Lanternithus minutus* Stradner (C o c c i o n i et al., 1988). In the LE 2 unit the planktonic

foraminifera of *Turborotalia cerroazulensis group* was not found; its LAD determines the boundary of P 17 / P 18 set at 33.8 millions years, and the youngest part of Chron C13r (B e r g g r e n   e t   a l., 1995), neither the nannoplanktonic species *Discoaster saipanensis* Bramlette et Riedel and *Discoaster barbadiensis* Tan Sin Hok by whose LAD the NP 19-20 / NP 21 boundary is determined and set at ~34.2 millions years (M a r t i n i, 1971; B á l d i – B e k e, 1977, 1984; P e r c h – N i e l s e n, 1985; N a g y m a - r o s y, 1992; B e r g g e n et al., 1995). The start of the acme zone of nannoplanktonic species *Ericsonia subdisticha* (Roth et Hay) that is set at 33.3 millions years and in the oldest part of Chron C13n (B e r g g r e n et al., 1995) was determined above the begin-

ning of the *Lanternithus minutus-Zygrhablithus bijugatus* Acme-zone in the upper part of 2/2. 2/1 and the lowermost part of 2/2 are therefore attributed to the Eocene part of NP 21 and the uppermost part of 2/2 to the lowermost Oligocene. Thus in Slovenia the Eocene / Oligocene boundary is detected. The boundary is dated at 33.7 millions years, and the youngest part of Chron C13r (B e r g - g r e n et al., 1995) can be set between the determined start of the acme zone of nannoplanktonic species *Lanternithus minutus* Stradner and *Zygrhablithus bijugatus* (Deflandre), and the start of the acme zone of nannoplanktonic species *Ericsonia subdisticha* (Roth et Hay). The unit can be correlated with the transgression of sequence between the Pr 4 / Ru 1 and Ru 2 sequence
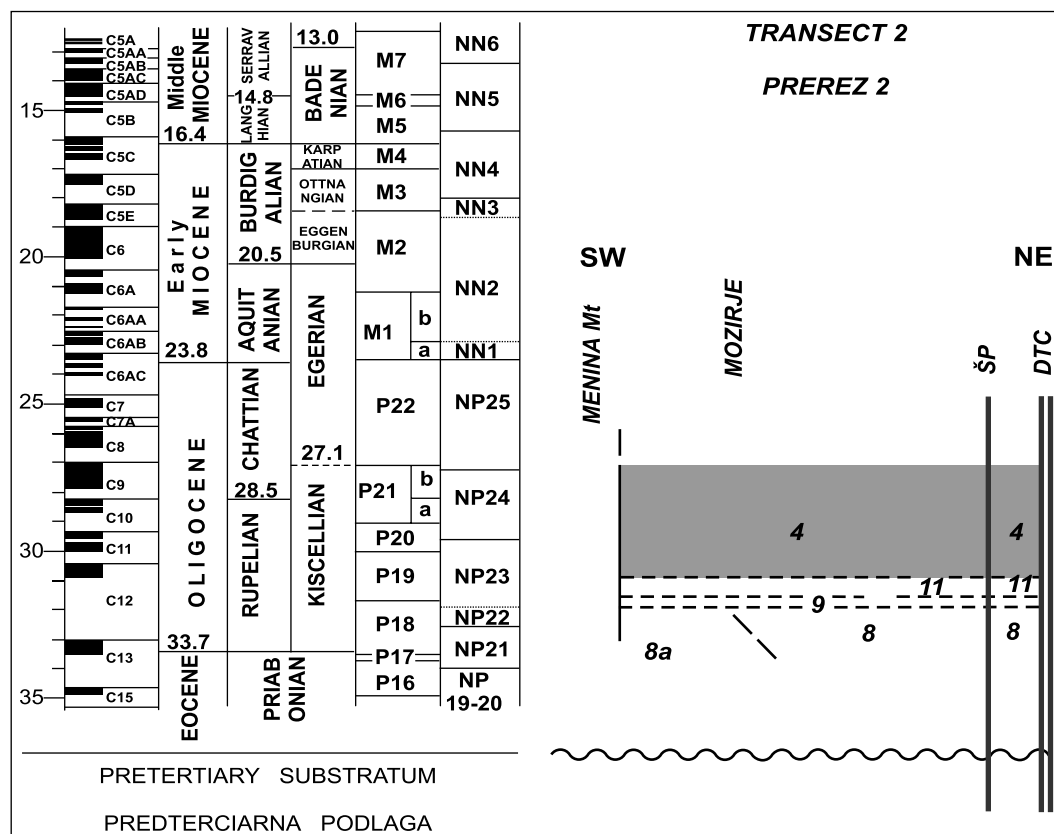

Fig. 6. Transect 2 represents the chronostratigraphic positional relationships of lithologic units LE 8 – LE 11 and LE 4 of the Mozirje area. For explanation see text.

Sl. 6. Prerez 2 prikazuje kronostratigrafske pozicijske odnose litoloških enot območja Mozirja LE 8 – LE 11 in LE 4. Razlaga je v textu.
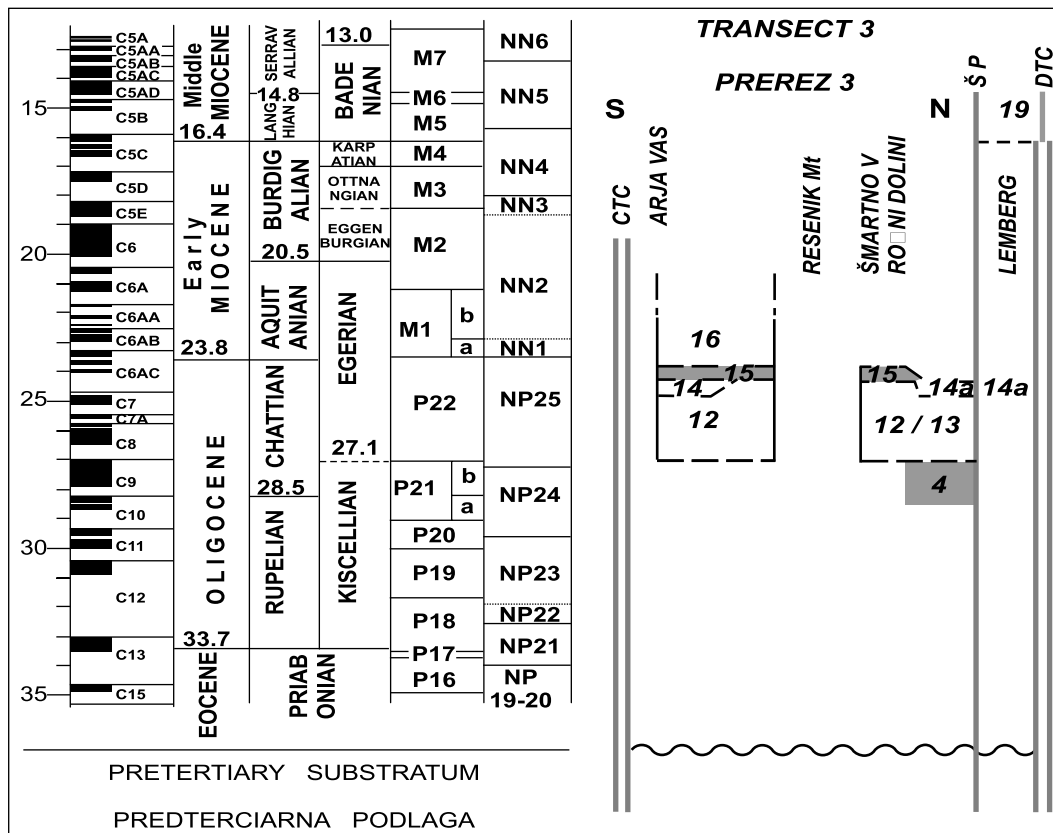
Fig. 7. Transect 3 is to represent the chronostratigraphic positional relationships more to the east, where in the south the Egerian LE 12 is transgressive over the pre-Tertiary substratum, but in the north the LE 12 / LE 13 transition grades up from the LE 4. The upper Egerian volcaniclastic sequence LE 15 is clearly separated from the Kiscellian volcanoclastic sequence LE 4 by the LE 12 / LE 13, and pinching out toward the north. For more explanation see text.

Sl. 7. Prerez 3 prikazuje kronostratigrafske pozicijske odnose litoloških enot vzhodneje, kjer na jugu egerijska LE 12 leži transgresivno na predterciarni podlagi, severno pa LE 12 / LE 13 konkordantno na LE 4. Zgornjeegerijska vulkanoklastična sekvenca LE 15 je jasno ločena od kiscellijske vulkanoklastične sekvence LE 4 z LE 12 / LE 13 in se proti severu izklinja. Več razlage je v tekstu.

boundaries (fig. 10). We consider the LE 2 unit the stratigraphic equivalent of Buda Marl in the Hungarian Paleogene basin.

Lithologic unit 3 (LE 3), fig. 4, 5: LE 3 was equally composed by us from two members. The lower member (3/1) is represented by medium dark grey silty marlstones with very rare thin calcarenite layers. Its thickness amounts to ~100 m. The upper member (3/2) consists of medium dark grey marly mudstone with very rare siltstone laminas. Its thickness is ~50 m. 3/2 passes upwards to LE 4. Transition is visible. At the surface the unit outcrops discretely between the Smrekovec basin and Ravna Gora. It comprises the upper part of NP 21, NP 22 and the lower part of NP 23. The NP 21 / NP 22 boundary was approached by us with determination of the end of the acme zone of nannoplanktonic species *Ericsonia subdisticha* (Roth et Hay) in the lower part of 3/1 and with the last appearance of the nannoplanktonic species *Cycloccolithus formosus* Kamptner in the upper part of 3/1. The lower part of NP 23 is marked by blooming of species *Raticulofenestra ornata* Müller (Báldi – Beke, 1977, 1984; Nagymarosy, 1992) in monotypic assemblage in the upper part of 3/2. The NP 22 / NP 23 boundary was not approached owing to the insuf-

ficient number of examined samples. In the lower part of 3/1 appears first the planktonic foraminifer of species *Chiloguembelina gracillima* (Andreae) the FA of which is in Paratethys at the Eocene / Oligocene boundary (C h i c h a et al., 1998). In the uppermost part of 3/1 first appear planktonic foraminifers of species *Globoquadrina globularis* Bermudez, *Globoquadrina winkleri* (Bermudez) and *Tenuitella munda* (Jenkins). The FA of the first two in Paratethys is in the middle part of lower Kiscellian, and of the third one at the lower / upper Kiscellian (C i c h a et al., 1998). 3/1 can be correlated with transgression of sequence between the Pr 4 / Ru 1 and Ru 2 sequence boundaries, and the upper part of 3/2 with transgression of sequence between the Ru 2 and Ru 3 sequence boundaries (fig. 10). Reg-

ression of sequence between Pr 4 / Ru 1 and Ru 2 sequence boundaries could not be determined due to insufficient number of examined samples. The unit is considered by us the stratigraphic equivalent of Tard Clay in the Hungarian Paleogene basin.

Lithologic unit 4 (LE 4), fig. 4 – 10: LE 4 represents the Smrekovec volcaniclastic sequence. M i o č (1983) named it the Smrekovec series. He estimated its thickness to about 800 to 1000 m. It passes upwards to LE 13. On the surface it extends from the Smrekovec basin to north of Ravna gora (conf. Š i m u n i č & P a m i ć, 1993). In boreholes it was established also north of Čakovec (conf. B i s t r i č i ć, 1979). We did not study its chronostratigraphy and geochronometry. We set its beginning after the blooming of nannoplankton species *Reticulofenestra ornata*
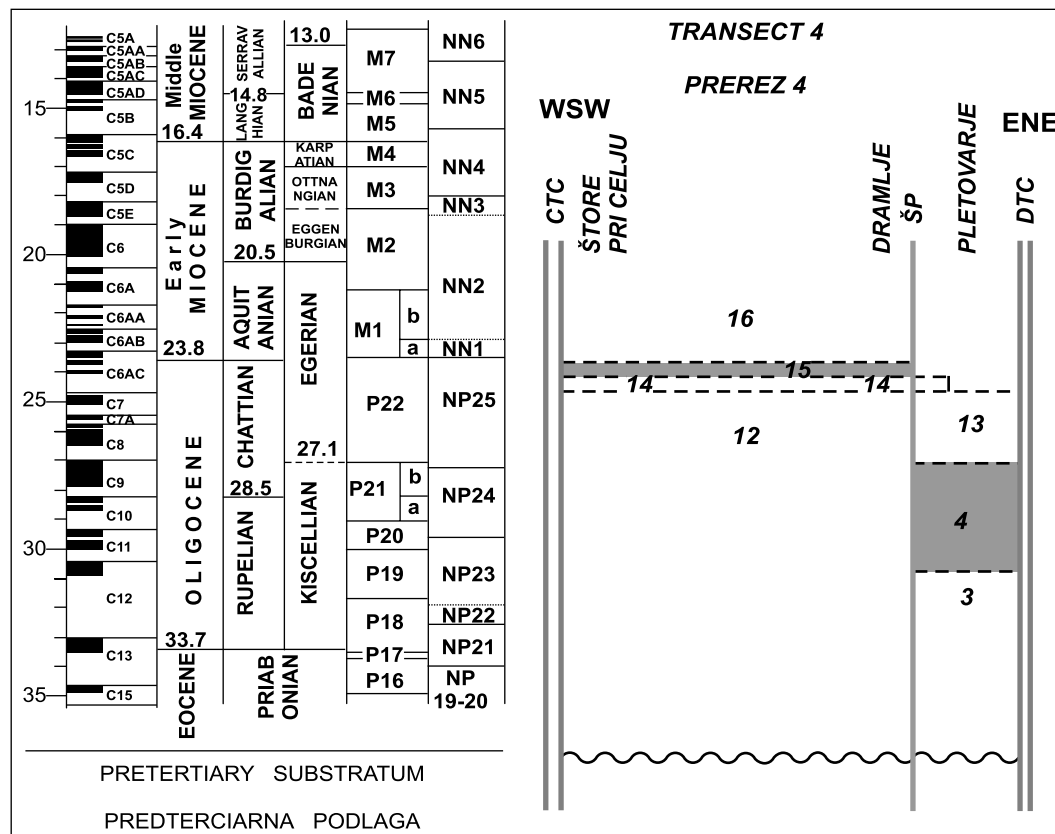

Fig. 8. Transect 4 is to represent the chrostratigraphic positional relationships of LE 3 – LE 16. North of the Šoštanj fault the LE 4 grades up into the LE 13. For explanation see text.

Sl. 8. Prerez 4 prikazuje kronostratigrafske pozicijske odnose LE 3 – LE 16. Severno od Šoštanjskega preloma LE 4 prehaja v LE 13. Razlaga je v tekstu.
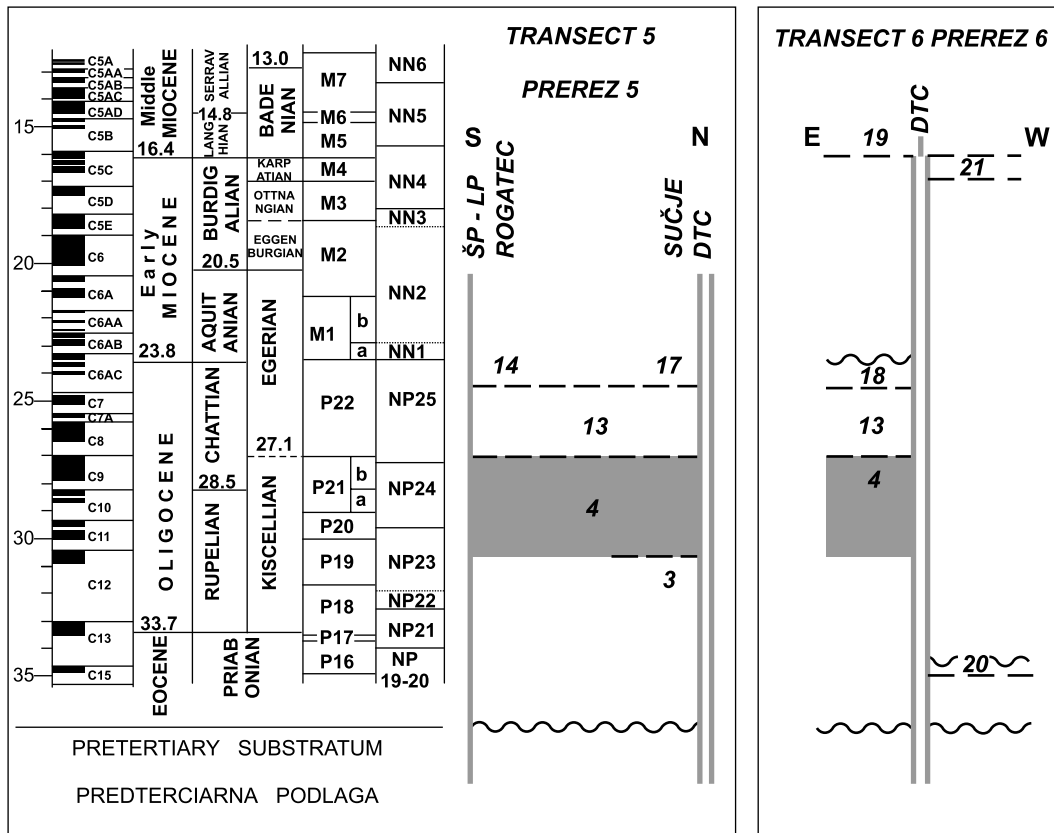
Fig. 9. Transect 5 represents the chronostratigraphic positional relationships of LE 3 – LE 17 in the area of Rogaška Slatina. Here again LE 3 grades up into LE 4 and the latter into LE 13.
Transect 6 shows the chronostratigraphic positional relationship across the Donat line (DTC) north of Čakovec in Croatia. The modelled positional relationships revealed the continuation of the tectonostratigraphic features of the Slovenian Paleogene basin into Croatia and Mid-Hungarian zone.

Sl. 9. Prerez 5 prikazuje krostratigrafske pozicijske odnose LE 3 – LE 17 na območju Rogaške Slatine. Tudi tukaj LE 3 prehaja v LE 4 le-ta pa v LE 13.
Prerez 6 prikazuje kronostratigrafske pozicijske odnose litoloških enot čez Donačko linijo (DTC) severno od Čakovca na Hrvaškem. Modelirani odnosi odkrivajo nadaljevanje tektonostratigrafske zgradbe Slovenskega paleogenskega bazena na Hrvaško in v Srednjemadžarsko tektonsko cono.

Müller in monotypic and oligotypic assemblage with 1 – 2 specimens of nannoplankton species *Reticulofenestra lockeri* Müller at the LE 3 / LE 4, LE 7 / LE 4 and LE 11 / LE 4 transition to NP 23. Its termination was set by us close to the newly proposed Kiscellian / Egerian boundary with respect to the last appearance of very rare specimens of plankton foraminifer *Paragloborotalia opima opima* (Bolli) in the lowermost part of LE 13, and according to the first appearance of large foraminifer *Nephrolepidina morgani* (Lemoine et Douvillé) at the LE 4 / LE 13 transition (R i j a v e c, 1984)

(see also at LE 13). LAD of subspecies *Paragloborotalia opima opima* (Bolli) defines the P 21 / P 22 boundary, and is calibrated to 27.1 millions years and the youngest part of Chron C9n (B e r g g r e n et al., 1995). The P 21 / P 22 boundary at 27.1 millions years has been proposed for the Kiscellian / Egerian boundary by B á l d i et al. (2000). FA of species *Nephrolepidina morgani* (Lemoine et Douvillé) occurs in the lowermost part of SB 22B that corresponds to P 21b. The beginning of its continuous appearance, however, is found in the middle part of SB 22B, i.e. in the middle part of P 21b
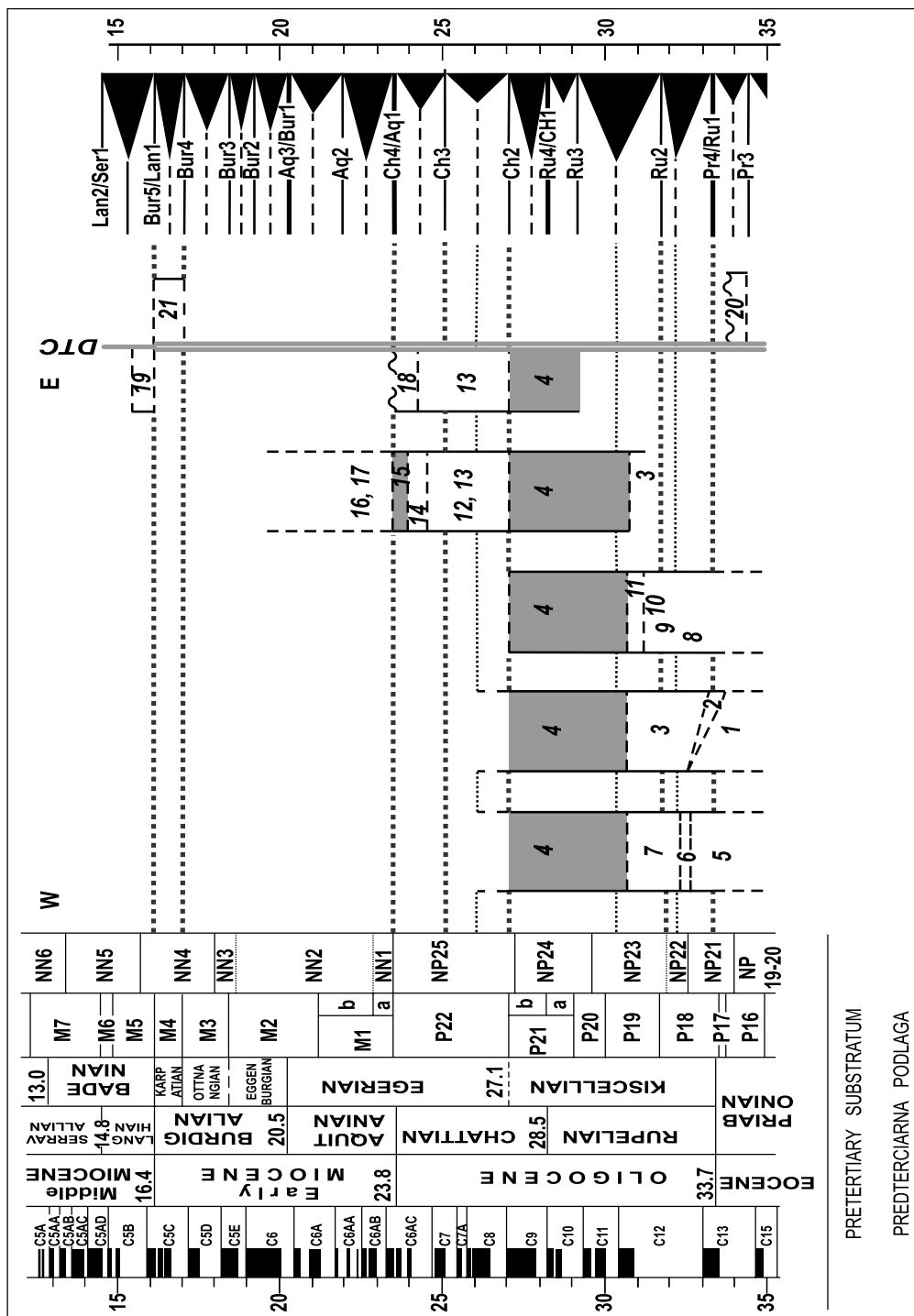
Fig. 10. Tentative correlation of the TTE B1 stratigraphic model with the sequence chronostratigraphy.

Sl. 10. Poskus korelacija stratigrafskega modela TTE B1 s sekvencno kronostratigrafijo.

(C a h u z a c & P o i g n a n t, 1997) at ~27.7 millions years. We propose the unit for a time equivalent of Kiscell Clay in the Hungarian Paleogene basin. Within LE 4 the sequence boundaries Ru 3, Ru 4 / Ch 1 are hidden, and probably also Ch 2 with corresponding sequences.

Lithologic unit 5 (LE 5), fig. 5: is represented by basal clastites of the second Tertiary succession of TTU B 1. Its thickness varies approximately between 0 and 200 m (S c h m i e d l et al. 2002). Upwards it passes to LE 6. Transition is observable. It was established only at the southern border of the Smrekovec basin, and is the time equivalent of LE 1, LE 2 and part of LE 3.

Lithologic unit 6 (LE 6), fig. 5: this lithologic unit was called by H a u e r (1848) the Gornjigrad beds. Its thickness varies approximately from 5 to 20m (S c h m i e d l et al., 2002). It passes upwards to LE 7. Transition is visible. We established it only in the southern part of the Smrekovec basin. Its chronostratigraphic position in the lower part of NP 22 was determined by us indirectly with regard to the first nannoplankton datation in LE 7, although it can reach also to NP 21. After correlation with the sequence chronostratigraphy the unit represents the upper part of transgression of sequence between Pr 4 / Ru 1 and Ru 2 (fig. 10).

On the Gornjigrad beds an inconstant member of dark grey finely laminated marlstone is deposited.

Lithologic unit 7 (LE 7), fig. 5: the unit is composed of three members: 7/1, 7/2 and 7/3. The lower member (7/1) is represented by light grey to olive grey silty marlstones that pass upwards to medium grey silty marls / silty clayey marls with thin beds of fine grained laminated sandstone (7/2). Upwards the marl becomes more clayey and sandstone beds thinner and rarer, ending as very rare laminas (7/3). Upwards 7/3 passes to LE 4. Passage is observable. The thicknesses of members could not be established owing to tectonics and vegetation. Thickness of LE 7 has been estimated at ~170 to ~270 m (S c h m i e d l et al., 2002). At the surface LE 7 could be detected in the southern part of the Smrekovec basin. Blooming of nannoplankton species *Braarudosphaere bigelowi* (Gran et Brrarud) in polytypic assemblage dates 7/1 to the upper part of NP 22 (B á l d i – B e k e, 1977, 1984; N a g y m a r o s y,

1992), and blooming of species *Reticulofenestra ornata* Müller in monotypic assemblage dates the lower part of 7/2 to the lower part of NP 23 (B á l d i – B e k e, 1977, 1984; N a g y m a r o s y, 1992). At the LE 7/3 / LE 4 transition we found in the oligotypic assemblage next to the rare species *Reticulofenestra ornata* the nannoplankton species *Cyclicargolithus abisectus* (Müller) (1 specimen), *Helicosphaera carteri* (Wallich) (2 specimens) and *Reticulofenestra lockeri* Müller (1 specimen). FA of species *Cyclicargolithus abisectus* (Müler) should determine the start of NP 24 (B á l d i – B e k e, 1977, 1984; P e r c h – N i e l s o n, 1985; N a g y m a r o s y, 1992), whereas at the Paleogene / Neogene GSSP in NN 2b it becomes extinct (A u b r y & V i l l a, 1996). The first rare representatives of *Helicosphaera carteri* (Wallich) in Central Paratethys occur at the top of NP 25, and become common in NN 1 (Bá l d i – B e k e, 1984). FA of species of *Helicosphaera* cf. *carteri* (Wallich) is also on GSSP somewhat below the Paleogene / Neogene boundary, but *Helicosphaera carteri* (Wallich) does not become common before the middle of NN 2b (A u b r y & V i l l a, 1996). The species *Reticulofenestra lockeri* Müller is rare up to the upper part of NP 23 (B á l d i – B e k e, 1977, 1984; N a g y m a r o s y, 1992). For explaining this, we propose the contamination of species from younger beds into older ones. Correlation with the sequence chronostratigraphy demonstrated the possibility of correlation of 7/1 with the transgression peak of sequence between the Pr 4 / Ru 1 and Ru 2 sequence boundaries, 7/2 with regression and the Ru 2 sequence boundary and start of a new transgression between the Ru 2 in Ru 3 sequence boundaries, and 7/3 with transgression of sequence between Ru 2 and Ru 3 (fig. 10). The unit is also the time equivalent of the upper part of 3/1 and 3/2, and the upper part of LE 8 to LE 11.

Lithologic unit 8 (LE 8), fig. 4, 6: to LE 8 the clastic rocks from the base of the third Tertiary TTU B1 succession are attributed. In the south the thickness of the unit is up to ~100 m, and in the north up to ~1 m. Upwards it passes to LE 9. Transition is observable. At the surface it is exposed between Mozirje in Črnova. It was dated indirectly in NP 22 and NP 21 with respect to the overlying unit LE 9 that was dated in the

lower part of NP 23. The unit is the time equivalent of LE 1, LE 2 and of the lower part of LE 3, LE 5 and LE 6.

Lithologic unit 8a (LE 8a), fig. 6: is represented by the Okonina conglomerate called so from T e l l e r (1896) on, and by breccia as the lateral development of LE 8. The thickness amounts to ~100 m. The Okonina conglomerate and breccia overlie thin bedded light brown sandstone about 2 m thick, and the latter overlies the basal coal clay. Upwards the unit passes rapidly to LE 9. Transition is observable. At the surface it was established from Mozirje to Črnova.

Lithologic unit 9 (LE 9), fig. 4, 6: also LE 9 was composed by us from two members: 9/1 in 9/2. The lower member (9/1) is represented by medium grey massive marlstones and massive allodapic limestones with nummulites, and in lateral development by medium grey massive and poorly bedded limestones with nummulites. In the south 9/1 is up to ~10 m thick, and in the north ~50 m. 9/2 is represented in the lower part by alternation of medium grey thin bedded to thick laminated silty marlstones and mudstones on which dark grey thinly laminated marlstones are deposited. In the south the 9/2 is up to ~10 m thick, and in the north ~30 m. From T e l l e r (1898) on it was called the Fish shale of Brdce. 9/2 rapidly passes to LE 11. Transition is visible. The unit appears at the surface between localities Mozirje and Andraž. With the nannoplankton species *Transvesopontis fibula* Gheta and blooming of species *Reticulofenestra ornata* Müller in monotypic assemblage the 9/1 has been dated to the lower part of NP 23 (N a g y m a r o s y, 1992). The unit is correlated with transgression of sequence between Ru 2 and Ru 3 (fig. 10).

Lithologic unit 10 (LE 10), fig. 4: to LE 10 the poorly and thinly bedded medium to coarse-grained sandstones at Andraž above Polzela are attributed that were sedimented between LE 9 and LE 11. The unit thickness is ~20 m.

Lithologic unit 11 (LE 11), fig. 4, 6: to the unit olive grey silty marls / silty marly clays are attributed that pass northwards to medium light grey silty / very thin grained sandy marls. The thickness is ~70 m. The unit passes upwards to LE 4. Transition is observable. On the surface it is exposed between Mozirje and Črnova. At the LE 11 / LE 4

transition the oligotypic nannoplankton assemblage and blooming of species *Reticulofenestra ornata* Müller were established what determines NP 23. In this assemblage in places appear with 1–2 specimens of older nannoplankton species *Cyclococcolithus formosus* Kamptner, *Isthmolithus recurvus* Deflandre and *Reticulofenestra placomorpha* (Kamptner). This appearing is interpreted by temporary recursions (conf. N a g y m a r o s y, 1992). The unit is correlated by us with transgression between the Ru 2 and Ru 3 discontinuities. It is the time equivalent of the upper part of LE 3 and LE 7.

Lithologic unit 12 (LE 12), fig. 4, 7, 8: LE 12 is represented by olive grey to light olive grey silty marls, in the base of which occur coarse clastites of small thickness deposited on Pretertiary beds. The thickness of the unit could not be estimated. Contact with LE 14 is observable and sharp. Contact with LE 15 is visible as well, but it is gradual or chaotic. On the surface it was traced from Šmartno in Rožna dolina toward Štore near Celje. The chronostratigraphic position of LE 12 is determined by occurrence of rare biochronomarker *Paragloborotalia opima opima* (Bolli) in the lowermost part of the unit. According to B e r g g r e n et al. (1995) its LAD determines the P 21 / P 22 boundary at 27.1 millions years (see also at LE 4). Nannoplankton dates the unit to NP 24 – NP 25. The unit is regarded as the stratigraphic equivalent of Oligocene part of the Szécsény Schlier in the Hungarian Paleogene basin.

Lithologic unit LE 13 (LE 13), fig. 4, 7, 8, 9: towards north the LE 12 passes to medium grey silty to very finely sandy marls of LE 13, with total thickness attaining up to ~500 m. The LE 4 / LE 13 contact is visible, and is gradual. At the LE 12 / LE 13 transition above LE 4 a submarine gravel fan is deposited, paleobathymetrically estimated to 200 m or more. The contact of LE 13 with LE 14 and LE 14a is visible, and it is sharp. It outcrops between Velenje and Ravna Gora. The unit was determined also in boreholes north of Čakovec (conf. B i s t r i č i ć, 1979). The lower chronostratigraphic boundary of unit is determined by biochronomarker *Paragloborotalia opima opima* (Bolli) established above the transition from LE 4 to LE 12-13 (see also at LE 12 and LE 4) and by large foraminifer *Nephrolepidina morgani* (Le-

moine et Douvillé) determined in borehole Tekačevo-1/75 at Rogaška Slatina (R i j a v e c, 1984) at the LE 4 / LE 13 transition. The beginning of continuous appearance of the latter is in the middle part of SB 22B, i.e. in the middle part of P 21b (see also at LE 4). Nannoplankton dates the unit to NP 24 – NP 25. The upper chronostratigraphic boundary in the upper part of NP 25 is determined by: first appearance of plankton foraminifer *Globoturborotalita connecta* (Jenkins) ~30 m below LE 14, last appearance of benthic foraminifer *Tritaxia szaboi* (Hantken) ~20 m below LE 14, and indirectly by dating of the LE 16 base by nannoplankton in the Oligocene / Miocene boundary zone. The FA of the first falls to the upper part of upper Oligocene (J e n k i n s, 1985), and the second becomes extinct towards the end of Oligocene. The unit is considered by us a stratigraphic equivalent of Oligocene part of the Szécsény Schlier in the Hungarian Paleogene basin.

The siliciclastic units that follow are in the studied region very heterolithic and heteropic. Their heterolithicity and heteropicity were not studied in detail. They only were separated at the first differentiation level. We consider them the stratigraphic equivalent to coarse-grained Törökbalint, Tura or Eger formations in the Hungarian Paleogene basin.

Lithologic unit 14 (LE 14), fig. 4, 7, 8, 9: to LE 14 massivne and bedded conglomerates and sandstones of various grain size and lithification grade are attributed. The thickness amounts to ~40 m. On the surface extends the unit in the Sava-Celje tectonic zone from NW of Kamnik to the territory of Republic of Croatia. Its chronostratigraphic position in the upper part of NP 25 is determined indirectly by first appearance of species *Globoturborotalita connecta* (Jenkins) and by last appearance of species *Tritaxia szaboi* (Hantken) in the uppermost part of LE 13, and by nannoplankton dating of the base of LE 16 to the Oligocene / Miocene boundary zone (see also at LE 13 and LE 16).

Lithologic unit 14a (LE 14a), fig. 7: to LE 14a thin to thick bedded strongly lithified glauconitic sandstones and conglomerates are attributed that represent the lateral development of LE 14. The thickness amounts to ~70 m. Upwards the unit is in sharp con-

tact with LE 15, or it passes to LE 16. It is intermittently exposed between Velenje and Rogaška Slatina. Its chronostratigraphic position is determined indirectly by the position between LE 13 and LE 15.

Lithologic unit 15 (LE 15), fig. 4, 7, 8: it is represented by volcaniclastites that are in the Celje tectonic zone ~100 m thick, and that pinch out towards north. North of the Šoštanj fault they were not found any more. The unit passes upwards rapidly to LE 16. Transition is visible. They outcrop between Peračica in Upper Carniola and Lepoglava in Croatia (conf. Š i m u n i ć & P a m i ć, 1993), and probably at Ravna gora. The stratigraphic position of the unit in the uppermost part of NP 25 is determined indirectly by dating of the base of LE 16 to the Oligocene / Miocene boundary zone. In Croatia they are attributed to the Egerian / Eggenburgian boundary and to Eggenburgian (Š i m u n i ć & P a m i ć, 1993, Š i m u n i ć, 1996).

Lithologic unit 16 (LE 16), fig. 4, 7, 8: it is a very heterolithic and heteropic unit. It consists of variously lithified conglomerates and sandstones with or without glauconite, sands, marl clay, bentonite clay, silty, sandy and gravelly clay and sandy marl. The thickness could not be determined, but it probably amounts to several 100 m. Above it follows a hiatus (fig. 3). It is exposed along and in the Sava-Celje tectonic zone from NW of Kamnik to the territory of R Croatia. At the LE 15 / LE 16 transition we approached the Oligocene / Miocene boundary determination. An approximation to the boundary is represented by the first appearance of nannoplankton species *Rhabdosphaera pannonica* (Báldi-Beke) and *Helicosphaera carteri* (Wallich) the FA of which lies in the uppermost NP 25 (B á l d i – B e k e, 1984) (see also at LE 7). The first appears at the LE 15 / LE 16 transition, and the second one ~5m above the transition to LE 16. About 50 m above the LE 15 / LE 16 transition first appear nannoplankton species similar to *Sphenolithus belemnos* Bramlette et Wilcoxon and *Discoaster aulakos* Gartner. According to M a r t i n i (1971) the form similar to *Sphenolithus belemnos* Bramlette et Wilcoxon is restricted to NN 1, and according to B e r g g r e n et al. (1995) to Chron C6C. The second species was described in lower Miocene, but its chronostratigraphic distribution is unknown. According to R i j a v e c

(1984) and A n i č i ć & J u r i š a (1985) this unit extends also to Eggenburgian.

Lithologic unit 17 (LE 17), fig. 4, 9: to it medium thick and thick bedded sandstones alternating with medium to very thick beds of sandy marl are attributed. Thickness of the unit is not determinable. In outcrops it is determined north of Rogaška Slatina. Its chronostratigraphic position in the uppermost part of Oligocene and/or in the lowermost Miocene is determined by appearance of species *Tritaxia szaboi* (Hantken) in sandy marl below it.

Lithologic unit 18 (LE 18), fig. 4, 9: LE 18 has been separated on the ground of the paper by B i s t r i č i ć (1979). It is represented by lithothamnian limestones at the top of the Oligocene lithologic succession as determined in boreholes north of Čakovec: andesitic tuff, dark grey sandy marls, and lithothamnian limestones. Above the limestone follows hiatus. The chronostratigraphic position of the unit is determined by the large foraminifer *Miogypsinoides formosensis* Yabe et Hanzawa whose FA occurs in the middle part of SB 23 which corresponds to the middle part of P 22 (C a h u z a c & P o i g n a n t, 1997), respectively to the upper part of NP 25.

We believe that for an attempt of correlation of lithologic units LE 12, LE 13, LE 14, LE 16, LE 17 and LE 18 with sequential stratigraphy too little information was collected. In addition, in the complex it would be probably covered by the tectonic sequence, so that the eustatic sequence would be difficultly perceived.

Lithologic unit 19 (LE 19), fig. 4, 9: above hiatus in the boreholes north of Čakovec on LE 18 calcarenitic subgreywacke and lithothamnian limestone are deposited, both of Badenian age (B i s t r i č i ć, 1979) (fig. 9). The unit is correlated with transgression of sequence between the Bur 5 / Lan 1 and Lan 2 / Ser 1 sequence boundaries (fig. 10).

Lithologic unit 20 (LE 20), fig. 9: in the borehole Dravsko Središče-2 (DS-2) upper Eocene limestone was determined (Š i m u - n i ć et al., 2000) followed by a hiatus. Limestone is correlated by us with Priabonian limestone of TTU A2 which is of NP 19-20, i.e. P 16 age (fig. 3), and with the sequence between the Pr 3 in Pr 4 / Ru 1 sequence boundaries (fig. 10).

Lithologic unit 21 (LE 21), fig. 3, 9: in

borehole DS-2 above the hiatus follows sandy marl. According to our chronostratigraphic interpretation of foraminifer fauna the marl is of Karpatian age. It is correlated with the sequence between Bur 4 and Bur 5 / Lan 1 (fig. 10).

DISCUSSION

From standpoint of information theory the former investigations created a state that could be described as one with a high information entropy. High inconsistency and incoherence signify high uncertainty, and high uncertainty means high information entropy (uncertainty of knowledge). By abolishing a large part of inconsistency and incoherence in the stratigraphic structure of the upper Paleogene and lower Miocene of eastern Slovenia, the information entropy was strongly diminished. The information theory considers also the source of message, and we can say in this regard that we now much better know the source and the message (probability of message is increased) it communicates.

At the research level »investigation and understanding of the problem« we investigated the disturbances (noise or distortions) that occurred in transmission of the message from source to destination (from construction of the information channel, release of message to reception of message). Discussion of events that intensified the problem after the Second World War, when also in our country the micropaleontologic revolution occurred, is beyond the frames of this paper. All disturbances can be explained by the S c h u m m ' s (1991) statement that the geologists show a remarkable lack of interest for scientific mode of thinking (conf. J e l e n, 1993). Among the disturbances we list only some simpler, but frequent examples of logical fallacies, as we emphasized in the chapter Methods of research the role of logic that assures the formal form, logical certainty and validity of knowledge. For verification of logical certainty and possible logical fallacies the arguments were evaluated according the structure and the content. For verification of the truthfulness of arguments we utilized the method of critical thinking (J e l e n, 1996). Well constructed and clear arguments were rare. Prevailed unclear, complicated and hidden arguments. The eva-

luation of arguments detected two sound arguments at most, others were unsound, invalid or uncogent.

The majority of them were valid arguments in which, however, the premises only apparently supported the conclusion, as, for example, when the chronostratigraphic conclusion was derived from the faunistic facies or B u c k m a n ' s (1902) faunizone, later called cenozone or assemblage-zone (H e d b e r g, 1976), which has chiefly an ecological meaning.

Even before T a n s l e y (1935) defined the concept of an ecosystem in the sense of a system in physics, the environmental control of organisms was a generally accepted idea (e.g. P e t e r s e n, 1924). The contradiction between the evolutional and environmental control of distribution of fossils in space and time was an obstacle to stratigraphy (W i l l i a m s, 1905) which already B u c k m a n (1893) started to solve. Philosophically the problem was solved by a clear separation of stratigraphy from chronology (B u c k m a n, 1893; W i l l i a m s, 1901; T e i c h e r t, 1950, 1958), and methodologically by the biochronologic procedure and the datum concept (B o l l i, 1957, 1959; B l o w, 1957). After this followed propositions for formal stratigraphic procedure, nomenclature and standard classification (H e d b e r g, 1961, 1976; A m e r i c a n   C o m m i s s i o n   o n   S t r a t i g r a p h i c t e r m i n o l o g y, 1961).

A special kind of logical fallacy is represented by the so-called extended arguments. The first part of argumentation in these cases was the most often a valid and sound P a p p's (1955, 1960, 1975) argument. The second part of argumentation was, however, represented by unjustified inductive generalization that predicts only weak probability. All weak arguments are, however, uncogent.

There were several examples of hasty arguments. Also factual errors were detected in spite of facts that they can least be pardoned in any epistemological system. One of these, erroneous attribution of important chronostratigraphic value to the species *Tritaxia szaboi* (Hantken), had a key role in the origin of stratigraphic inconsistency. Already H a n t k e n (1873, 1875, 1884) established the distribution of this species not only in the Kiscell Clay but also in the un-

derlying Ofen (= Buda) Marl and in the Bryozoan Marl, underlying the latter, in northern alpine Eocene and in Eocene of northern Italy. To Bryozoan Marl the Eocene age was correctly attributed already by H o f f m a n (1871). The question of already then disputable chronostratigraphic value of species *Tritaxia szaboi* Hantken was solved by H a g n (1956) by the determination of its stratigraphic distribution (range-zone) from middle Eocene to upper Oligocene.

After P a p p ' s (1955, 1960, 1975) sound argument the following sound chronostratigraphic argument is represented by a part of the argument of D r o b n e et al. (1985, 89), while their other part of the argument is an example of an unjustified inductive generalization.

To avoid such logical mistakes, a guarantee for substantiation of truth of biochronostratigraphic conclusions has to be found. The first author had good luck that Dr. Mária Báldi-Beke accepted co-operation with him, and that Dr. Fred Rögl accepted the advisership of the second author. Nevertheless, especially the possibility of hasty biochrostratigraphic generalization remained considerable, since the number of samples for nannoplankton analysis is limited, and among the planktonic foraminifers numerous chronomarkers were missing. Therefore e.g. the justifiability of LE 7 age remains disputable, and with it the question of age of this unit becomes essential for the Tertiary stratigraphy of eastern Slovenia. We attributed LE 7 to the interval from upper part of NP 22 to part of NP 23, whereas P a v š i č (1980) and B r i c e l & P a v š i č (1991) put the lowermost part of the same lithologic unit to NP 23, and the remaining part of the unit on the basis of presence of species *Cyclicargolithus abisectus* (Müller) at Hom by Radmirje and at Nova Štifta to NP 24. They, however, did not consider the question of dating the start of the Smrekovec volcaniclastic sequence. The species *Cyclicargolithus abisectus* should have its FA at the NP 23 / NP 24 boundary and its LA in lower Miocene (NN 2b). In our case this species appeared once with a single specimen in the profile of Gornji Grad at the LE 7 / LE 4 transition, and not alone, but together with 2 specimens of species *Helicosphaera carteri* (Wallich), FA of which is in the uppermost NP 25. Therefore the common appearance of

both species was explained by us with contamination of older beds from the younger ones. Since two contradicting propositions belonging to the same system cannot be at the same time true, we accepted the supposed contamination and also in this case we attributed the transition from LE 7 to LE 4 to NP 23 (see also at LE 7). S c h e r b a c h e r (2000) and S c h m i e d l et al. (2002) solved the age problem of LE 7 in a different way. In part they followed P a v š i č (1980), J e l e n (1980) and B r i c e l & P a v š i č (1991). They attributed LE 6 to NP 22, LE 7 to NP 23, NP 24 and based on K/Ar dated age of 28 millions years even to the lower part of NP 25 (S c h e r b a c h e r, 2000), while they put the start of LE 4 with a question mark to NP 25 (S c h e r b a c h e r, 2000), or to NP 24, at the Rupelian / Chattian boundary (S c h m i e d l et al., 2002). If excluding the contamination, the start of LE 4 must be put even higher, at least to the Oligocene / Miocene boundary zone. By attributing the LE 7 / LE 4 transition to NP 25 or higher, the beginnings of LE 4 and LE 15 become approximately isochronous, which creates a new biochronologic contradiction, and the illogicality (invalidity) of this system becomes evident (cf. Fig. 4).

Since for every research step theoretical orientation is required, among the established logical fallacies also incorrectly posited questions and anachronisms occurred. We attribute the first error to the poor definition of the problem (M a y e r, 1983) which is a consequence of insufficiently directed thinking (G i l h o l y, 1982). One of the consequences of this state was that adequate and important questions could not be asked, as for example, the question of chronostratigraphic boundaries. Only in D r o b n e et al. (1985, 83) we find the perception of this problem: «The Oligocene beds are deposited discordantly on the older rocks. Concordant transition from Eocene beds into Oligocene beds was not yet established in Slovenia.» The orderliness of the research process permitted us to locate in Slovenia three very important chronostratigraphic boundaries: Eocene/Oligocene, Kiscellian / Egerian and Paleogene / Neogene (= Oligocene / Miocene) boundaries. The Eocene / Oligocene boundary was examined by the second author. We showed the best exposed profile with the boundary at Dupeljnik to a group of professors and students from Tübingen who did research in the environs of Gornji Grad in our best intention, thinking that they are fully aware of academic and research ethics. However, a researcher of this group simply published it with other co-workers (N e b e l s i c k, B a s s i & D r o b n e, 2000).

A further very important question could not be formulated: the question of association of stratigraphy and its inconsistency with plate tectonics processes. It is very unusual that the plate tectonics as the essential paradigmatic shift in geology still could not find its way among us.

We presume that the second error was conditioned by the philosophic standpoint of the line Werner – Beaumont – Kober-Stille, the influence of which on Slovenian geology could still be felt, as distinguished from the philosophic line Hutton – Lyell – (Suess) – Wegener-Argant. The deep philosophic distinction between the two orientations was not as it could be thought in fixism and mobilism, but rather in the similar philosophic distinction as it existed between the classical (Newton – Laplace – Einstein) and modern (Bohr – Heisenberg) physics. Both first mentioned lines are deterministic, and both second ones probabilistic. In geology the first orientation argued for temporal and spatial regularity, and the second one for randomness in tectonic events (Ş e n g ö r, 1982). The first orientation became established in our Tertiary stratigraphy with Teller and Petraschek (J e l e n, 2000a). Here we met the role of K u h n ' s (1970) paradigm (J e l e n, 1994, 2000b) and S e n g ' s (1990) mental models in research and thinking (J e l e n, 1996). We cite two examples of the old and the new scientific paradigm. Earlier researchers examined according to the old paradigm outcrops and profiles and tried to compose the whole from them, like from construction elements, while they created the process from the structure, forces and mechanisms. Both these made the problem worse. In the team we tried to establish the principles of the new scientific paradigm. We researched the whole, and then we tried to understand the interdependent associations of individual parts of the whole. And the process created us the structure.

In order to understand and explain the

individuality of TTU B1, we followed the later paradigmatic shift and investigated the process of individualization.

The origin of TTU B1 is associated in the south with the continental escape of the AL-CAPA block of Earth's crust in lower Miocene south of the Periadriatic lineament (PAL), and in the north along the SEMP lineament towards the east (F o d o r et al., 1998; J e l e n et al., 2000). The continental escape of the part of Earth's crust or squeezing out of the ALCAPA block is a part of postcollisional processes in the Alps. The right lateral displacement affected also the Southern Alps. South of PAL at least two fragments of Earth's crust formed that were moved relatively in different ways eastwards. On the ALCAPA block TTU A1 was deposited, on the 1st fragment (South Karavanke) delimited by PAL and Donat tectonic (transpressive) zone (DTC) TTU A2 was deposited, on the 2nd fragment (Savinja Alps) delimited by DTC and the Celje tectonic zone (CTC) the TTU B1 deposited, and south of CTC the TTU B2 was deposited (fig.1, 3). In addition to that, the tectonic processes till the end of Lower Miocene (end of Karpatian) very differently influenced the stratigraphic structure of every tectonostratigraphic unit. Thereof resulted the individuality of TTU B1 and its different actualization than those of other Tertiary tectonostratigraphic units. Owing to these two reasons we proposed the tectonostratigraphic solution of the existing inconsistency of upper Paleogene and lower Miocene beds of Slovenia (J e l e n et al., 1992).

The new stratigraphic system of eastern Slovenia Tertiary can be explained by the theory and terminology of the system. With the former system this was not possible. The former system was also not compatible with the stratigraphic system of Central Paratethys. Therefore the Hungarian researchers tried to establish the compatibility of the two systems (B á l d i, 1984; K á z m é r, 1984; R o y d e n & B á l d i, 1988; N a g y m a r o s y, 1990; C s o n t o s et al., 1992). The new stratigraphic system reinstated the desired compatibility and possibility of correlating geologic processes and events in Central Paratethys as well as globally (fig. 10).

Tectonic and stratigraphic correlation between Slovenia and Hungary (F o d o r et al, 1998; J e l e n et al. 1998a, 1998b) indi-cated the structural and stratigraphic continuity from the Slovenian shear zone between PAL and the Sava – Celje tectonic zone over Croatia to Mid-Hungarian shear zone between the Balaton and »Paleogene« tectonic lines. It is further indicated that stratigraphic correlation and correlation of the original structure between the Slovenian and Hungarian Paleogene basins, that lie at present south of PAL and north of the »Paleogene» tectonic line, are possible. New information does not contest either K á z-m é r's (1984) or C s o n t o s's et al. (1992) theories. With this we must take in consideration the shift to dynamic stratigraphy. Therefore, present are not equal developments, but equivalent products of processes that manifested themselves at the basin level at various scales as stratigraphic records that are dynamically associated and temporally correlative between each other.

With the listed examples we tried to show a part of efforts for understanding the epistemological process with the aim of better controlling it later. Namely, the way in which we perceive the phenomena depends upon the way of observation, and the way of observation also directs the processes we observe. And our propositions and conclusions depend upon the way how we collected the data and the form into which the data are cast. Therefore the present idea that epistemology must become a part of any scientific discipline. If in the understanding of the process of generation of knowledge the Cartesius's absolute and final certainty was substituted by the upper relative and approximative process (conf. M a t u r a n a & V a r e l a, 1988), the importance of logic and critical reasoning as well as intersubjectivity becomes even greater. We hope that we succeeded to control the process of research to the degree that we did not commit heavier errors. L a n g m u i r ' s (1989) example shows how a researcher in spite of his ideal motivation with truth, rationality, integrity and modesty (P o p p e r, 1979; F o x & F o x, 1990) can find himself in a paradoxal situation. This Nobel price winner in his paper Pathological Science stated: »To me it is extremely interesting that men, perfectly honest, enthusiastic about their work, can so completely fool themselves«. It is even more paradoxal, however, that it was found that also Langmuir was mislead in his research.

Does then exist the dilemma whether to publish new results, or not and dwell upon further verification?

CONCLUSIONS

1. The research question of existence or of non-existence of the Tertiary tectonostratigraphic unit B1 was solved and explained with 5th and 6th steps of the Galilei's scientific method. On the level of derivation of conclusion, and not on the level of rigorous proving the 5th level confirms the existence of TTU B1, and the 6th step explains its origin in the postcollisional process of continental escape in the Alps.

2. Based on principles of logic we constructed and formalized the stratigraphic model of B1 that abolishes a larger part of former inconsistency and incoherence, and has high verisimilitude, explanatory power and potential for the general.

3. We attained a degree of biochronostratigraphic resolution and correlation with sequence chronostratigraphy high enough to permit a better and more reliable intraregional stratigraphic correlation than before. Thus we discovered the continuation of B1 across Croatia to Mid-Hungarian tectonic zone, and in the Slovenian Paleogene basin the stratigraphic equivalents to formations of the Hungarian Paleogene basin: Szépvölgy Limestone, Buda Marl, Tard Clay, Szécsény Schlier, and Törökbalint, Tura or Eger Sandstone. The Smrekovec volcaniclastic sequence was proposed as time equivalent of Kiscell Clay.

4. In these equivalents the first in Slovenia approached chronostratigraphic boundaries have the same position as in Hungary: the Eocene / Oligocene boundary in the equivalent of Buda Marl, Kiscellian / Egerian approximately at transition from equivalent of Kiscell Clay to equivalent of Szécsény Schlier, and the Paleogene / Neogene or Oligocene / Miocene boundary in coarse clastic lithologic units.

5. Next to correlation of intraregional geologic processes also correlation with global geologic processes is possible.

6. All our partial stratigraphic criteria: stratigraphic structures of TTU A1, A2, B1 and intraregional stratigraphic correlation and complementary structural, tectonic and paleomagnetic criteria do not contradict the theories of dissection and offset of the originally unique Slovenian-Hungarian Paleogene basin and of continental escape in the Alps, but they complete them.

7. The research process must be completely organized. Since financing of research and its realization did not assure this, additional empiric verification is needed, especially calibration of the research results with standard geological time scale by physical methods.

8. Not only the researcher, but also the society through the scientific management and by respecting the integrity of the research process (B e r n a l, 1939; N a t i o n a l A c a d e m y   o f   S c i e n c e, 1993) strongly influences the reliability and validity of the knowledge.

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