We are IntechOpen, the world's leading publisher of Open Access books
Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

The Paleogene Dinoflagellate Cyst and Nannoplankton Biostratigraphy of the Caspian Depression

Olga Vasilyeva[1] and Vladimir Musatov[2]
[1]Institute of Geology and Geochemistry Ural Branch RAS,
[2]Lower Volga Institute of Geology and Geophysics,
Russia

1. Introduction

The Pricaspian Depression in the southeast of the East European Platform is one of the deepest depressions formed over the Baikal folded basement. The sedimentary cover consists of four structural levels corresponding to the major stages of its formation. The Riphean and the Vendian beds constitute the first structural level. The second one comprises deposits from the Devonian to the Upper Triassic. This includes the Lower Permian plastic salt-bearing beds. The post-salt deposits of the second structural level are up to 4-5 km thick. The third structural level of the sedimentary cover is composed of the Triassic-Oligocene beds, with the total thickness as high as 2.5 km; in some sections, the Paleogene sediments are over 1000 m thick. The principal accumulations of oil, gas and potassium salts are confined to the second and the third structural levels of the Pricaspian Depression.

For lack of any core drilling, no biostratigraphic exploration of the sedimentary cover, the Paleogene beds included, has been made in the region since the middle of the past century. The biostratigraphic method has been substantially improved during that period: zonal scales from nannoplankton (Aubri, 1986; Martini, 1974; Okada & Bukri, 1980; Perch-Nielsen, 1985; Varol, 1998) and foraminifers (Berggren et al., 1995) have been refined, a standard zonal scale has been developed from the dinocysts (Luterbacher et al., 2004; Powell, 1992), that have never been studied in that region before.

The latest micropaleontologic examinations of the Paleogene beds from the Northern Pricaspian have shown the sediments to comprise organic-walled microphytoplankton (dinoflagellate cysts) and calcareous nannoplankton that potentiate detailed division and dating of Paleogene sequences (Vasilyeva & Musatov, 2010a). Examination of dinoflagellate cysts and nannoplankton from the Central Pricaspian is promising in terms of zonal scales direct comparisons from those groups, correlations with the adjacent areas and West Siberia; the latter region is known for the Paleogene beds to be represented exclusively by siliceous terrigenous bodies. Furthermore, dinoflagellate cyst occurrences and analyses of palynologic remains distribution over the water area of the Pricaspian paleobasin are interesting in terms of studying fluctuations of the sea level, reconstructing the paleoecologic environment, evolution of the extensive marine basin in the Cenozoic,

formation of local residual reservoirs upon lowering of the world ocean level. The present paper aims at (1) biostratigraphic division of the Paleogene section in the Central Pricaspian Region (the Elton key well) and dating the regional lithostratons; (2) correlating of the beds from the Central and the Northern Pricaspian Regions; (3) summarizing and making direct comparisons of the zonal scales from dinocysts and nannoplankton in the Pricaspian Region; (4) diagnosing fluctuations of the sea level by means of analyzing paleoecologic characteristics of the phytoplankton associations.

2. Geological setting

During the Cenozoic, the Pricaspian Depression belonged to the northern margin of the Peri-Tethys region and used to be a major epicontinental basin connected with both, the Paleo-Atlantic and the seas of northwestern Europe and with Paleo-Arctic through the Turgaj strait and the West Siberian sea basin. An extensive region of the Pricaspian Depression used to plunge in the Cenozoic, with the northern Uzeni-Utvinskaya structural zone remaining more stable (Zhuravlev, 1970). The structure of the Pricaspian Depression is peculiar for vast occurrences of geomorphologic features of the Permian salt-dome tectonics. Salt domes, up to ten kilometers in height and across, lie fairly close over the depression and create substantially dissected relief of the surface of sedimentation (Zhuravlev, 1970). Development of major positive geomorphologic structures was sure to affect the processes of sedimentogenesis and the hydrologic regime of the basin in the Cenozoic epoch. The most complete sections of the Paleogene have been penetrated in the inter-dome areas of the Volga and Ural central interfluve (Grachev et al., 1971; Pechenkina & Kholodilina, 1971). During the Cenozoic, the basin used to remain deep there. For that matter, the lithologic sequences there are described as being monotonous, with dominating fine clayey gaize-like rocks; carbonate interlayers occur in the lowermost and in the upper part of the section.

3. Pilot stratigraphic study

Complex investigations of the numerous wells drilled in the 50-70-ties of the last century failed to provide any uniform understanding of the region's suite stratigraphy. To make stratigraphic divisions of the Paleogene sections, either the North Caucasian scheme, based on high similarity of the faunal complexes (Pechenkina & Kholodilina, 1971; Razmyslova & Nikitina, 1975), or isochronous foraminifer strata with geographic names were used (Grachev et al., 1971). The insufficiently elaborate foraminifer scale of that period did not allow to date the Paleogene sequences unambiguously. Nevertheless, principal stratigraphic levels of the subseries and the corresponding faunal complexes have been outlined.

To assess the complexity of a section lithologic division, we made use of V.G. Grachev's lithostratigraphic chart (Grachev et al., 1971). A series of lithostrata may be traced in the Paleogene from the central part of the Pricaspian Depression. The Danian is represented by a clayey-marl sequence of the Algai formation, with a complex of foraminifers *Acarinina inconstans, Globoconusa* sp. ("the Furmanovskian" layers according to V.G. Grachev) and by the Cygan formation (gray calcareous clays with marl interlayers, saturated with glauconite) with foraminifers *Globorotalia angulata*. The Upper Paleocene is composed of dark gray, low calcareous gaize-like clays and gaizes with mollusk fauna. This sequence corresponds to the lower member of V.G. Grachev's Kaztalov layers, with foraminifers *Spiroplectammina*

spectabilis (Grachev et al., 1971). The subseries upper part corresponds to the clay sequence - argillite-like, gaize-like, calcareous, with marl and sandstone interlayers; this is distinguished as the upper member of the Kaztalov layers. It comprises siliceous microbiota and foraminifers *Acarinina subsphaerica* (Grachev et al., 1971). In the Lower Eocene, the Bostandyk formation is recognized (clays – aleuritic, low calcareous, with glauconite) with complexes of foraminifers *Globorotalia subbotinae* and *G. marginodentata*. The Eocene middle subseries is represented by the Kopterek formation, with the foraminifer fauna of *Truncorotalia aragonensis* and *Acarinina crassaformis* (Grachev et al., 1971). The nannoplankton pilot study in the Volga-Pricaspian Region has been made by V.A. Musatov (Musatov, 1996).

4. Material and methods

4.1 Lithologic structure of the Paleogene section from the Elton key well

The Elton key well was drilled in 1960 in the administrative territory of Kazakhstan, between the lakes of Elton and Aralsor, 50 km east of Elton (the Aralsor field) (Fig. 1). The section has penetrated the Paleogene beds from the Danian to the Ypresian (thickness of 165 m) within the dome arch, that's why the lithostrata are relatively thin, probably partially eroded. The Paleogene deposits lie discordantly over the light gray Maastrichtian pelitomorphic marls (839–785 m). From the bottom upwards, the Paleogene section is represented by the following lithostratons.
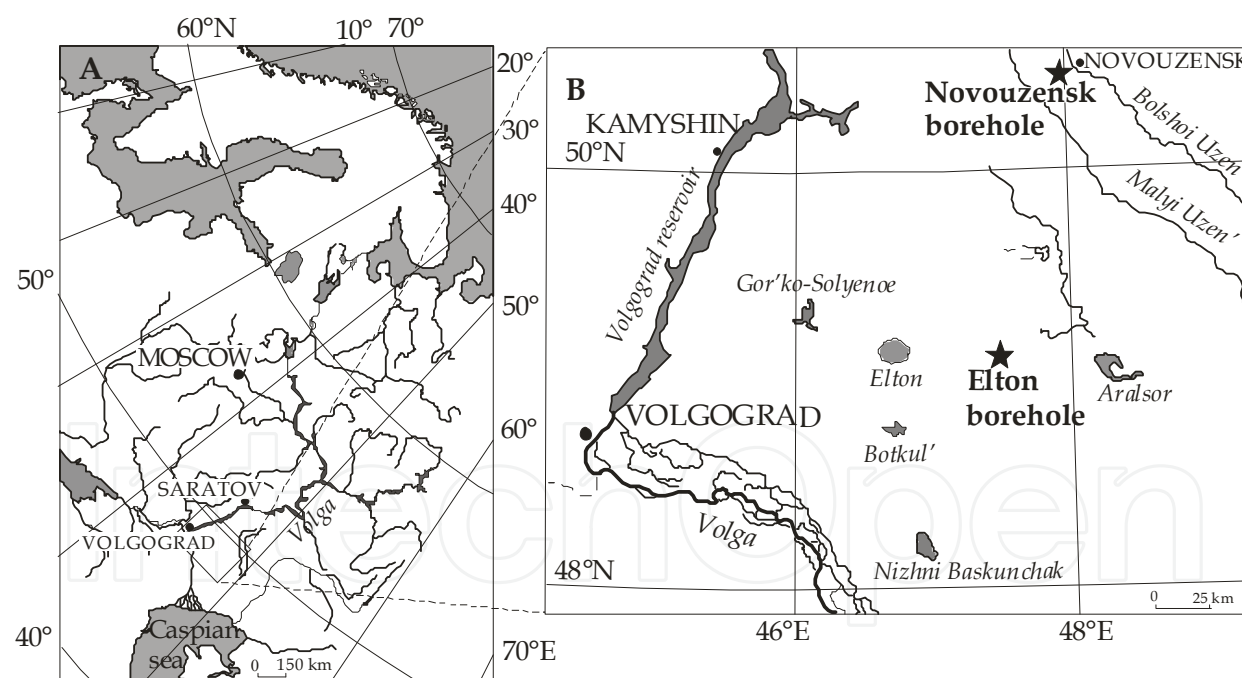

Fig. 1. Geographic location of the region studied (A), the Novouzenk key well and the Elton well (B).

4.1.1 The Danian. The Cygan formation

785–763 m – clays: gray, calcareous, occasionally sandy, laminated, with glauconite. A marl interlayer (0.1 m) lies in the lower part of the interval. In the upper portion, the clays are bioturbated, with macrofauna remains and fish scales.

763–749 m – clays: light gray, greenish, calcareous, sandy; in the upper part – bioturbated, with fish scales and macrofauna remains. The content of aleurite material increases in the interval lower part. Marl, about 1 m thick, occurs in the base of the interval.

4.1.2 Selandian–Thanetian. The Kaztalov formation

749–711 m – clays: dark gray, almost black, dense, gaize-like, silty, micaceous, occasionally low calcareous, intensely bioturbated, in the upper part – with macrofauna, fish scales and bones. The rock carbonate and sand contents increase in the suite lower interval.

711–695 m – clays: gray, dense, non-calcareous, slightly gaize-like.

695–690 m – alternating interlayers of glauconite sandstones (0.3–1.5 m thick), clays – dark gray, gaize-like, sandy, low calcareous (0.3–1.3 m thick) and marls – sandy, finely laminated (0.5 m thick). Clay interlayers contain vegetable remains and fish scales.

4.1.3 The Ypresian. The Bostandyk formation

690–680 m – clays: dark gray, black, gaize-like, sandy, occasionally calcareous, micaceous, contain vegetable detritus and fish scales. In the basement, the clays are laminated, with lenses and sprinkles of aleurite material.

680–669 m – alternating clays – dark gray, black, dense, shaly and sandy, with macrofauna fragments and fish scales. The rocks are low calcareous.

669–660 m – clays: dark gray, black, sandy, occasionally calcareous, with lenses and nests of sandy-aleurite material. Microfauna, macrofauna detritus and fish scale occur.

660–630 m – clays: black, dense, micaceous, calcareous, occasionally finely laminated, in the basement – with patches and nests of sandy material, macrofauna and fish scales.

630–620 m – clays: dark gray, black, gaize-like, homogenous, in the upper part of the interval – sandy. In the uppermost of the interval, the clays contain vegetable detritus and microfauna.

4.2 Sampling

The material for the operation consisted of 70 samples from the Paleogene and the Upper Cretaceous sections, selected for nannoplankton and dinocyst analyses. By the moment of sampling, the core was 70-50% intact. The average of 4-8 samples was taken from each 10-m interval, thus, the sections micropaleontologic description was fairly detailed (Fig. 2).

4.3 Palynologic maceration

The sample palynologic processing was carried out in the laboratory at the West Siberian Institute for Oil and Gas Problems (Tyumen) in accordance with the standard procedures accepted at the Russian Academy of Sciences (Petrova, 1986). (1) A 150g rock sample was treated with 10% hydrochloric acid to dissolve calcium carbonates, with subsequent washing of the residue to neutral reaction. (2) The residue was treated with tetrasodium pyrophosphate ($Na_4P_2O_7x10H_2O$) for dispersion of clay and washed several times for

elimination of argillaceous material. (3) The residue was centrifuged with heavy liquid (K$_2$CdI$_4$) (specific gravity of 2.25) to isolate palynologic remains. (4) The macerate was treated with 10% hydrofluoric acid, with subsequent flushing to remove the fluorosilicate compounds. The glycerine macerate was examined under the Karl Zeiss Jena microscope, with incident light and magnification of x400, x600.
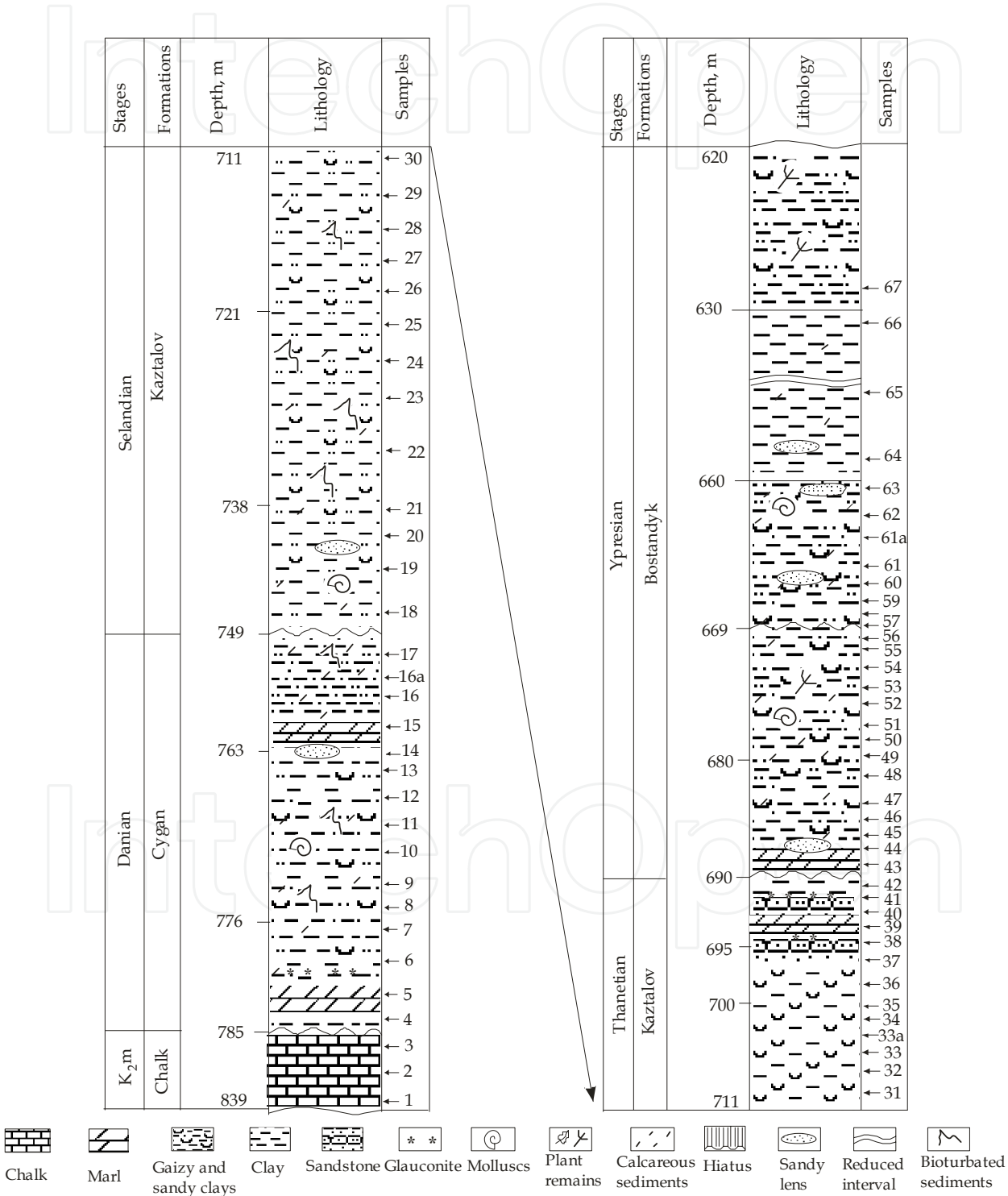

Fig. 2. The Elton well lithologic structure and sampling for dinocysts and nannoplankton

4.4 Palynologic diagnostics and investigation techniques

Species diagnostics of dinoflagellate cysts was performed in accord with the dinocyst catalogue summarized by Fensome & Williams (2004). The section biostratigraphic division according to dinocysts was accomplished in accord with the standard zonal scale accepted for the Paleogene of Northwestern Europe (Luterbacher et al., 2004). For the Maastrichtian, several alternative zonal scales have been developed from dinocysts (Kirsch, 1991; Marheinecke, 1992; Schiøler & Wilson, 1993; Slimani, 2001). The sequences of the zonal species in the Elton section allow to compare them to the chart by P. Schiøler and G. Wilson, established for the Maastrichtian from Denmark (Schiøler & Wilson, 1993).

The results thus obtained were analyzed as follows. (1) Counting all the palynologic fragments, i.e. microphytoplankton (a), pollen and spores (b) (up to 200–250 specimens if possible), to determine relative contents of palynologic remains of ecologically heterogeneous geneses and to diagnose the proximal-distal signals of associations in accord with the methods proposed by some workers (Brinkhuis, 1994; Powell et al., 1996; Stover & Hardenbol, 1994; Wall et al., 1977). (2) Composition analyses of the microphytoplankton complex: the number of dinocyst species (a), the number of species of dinocyst gonyaulacoid morphotypes (b), perodinioid ones (c), prasinophytes and acritarchs (d) were used to determine the basin transgressive-regressive impulses.

The possibility of interpreting the species composition and the diversity of phytoplankton complexes as the reflection of sea level fluctuations in the Pricaspian Region is provided by two principal provisions. (1) According to Haq et al. (1988), the most pronounced features of a rhythm are manifested on the inner and on the middle shelf. Those are associated with substantial depth fluctuations, with accumulation of differentiated sediments, shelf exposure during the stage of low sea level (SB1 boundary type), changing contours of the shore line. Drastic depth fluctuations and the changes of the photic layer water mass were sure to affect the organic-walled plankton (dinoflagellate cysts) composition in the inner shelf zone. Substantial lowering of the sea level is interpreted as a stress situation for plankton paleophytocoenoses; this is manifested in decreasing species diversity of associations (Dale, 1996; Pross, Schmiedl, 2002). (2) Current studies of the Eocene deposits have shown the compositions of organic-walled phytoplankton on the shelf to have differentiated structure (Brinkhuis, 1994). In open marine basins, gonyaulacoid dinoflagellate cysts show the tendency to genera distribution from the inner neritic zone to open oceanic settings (Brinkhuis, 1994; Crouch & Brinkhuis, 2005; Dale, 1996; Pross & Schmiedl, 2002), demonstrating proximal-distal signals. In case of transgressive movement of the water masses in an epicontinental basin, the share of taxa of the outer neritic zone grows in the littoral parts.

An extensive group of gonyaulacoid cysts represents neritic water masses (from the inner to the outer ones): *Spiniferites, Achomosphaera, Fibrocysta, Cleistosphaeridium, Cordosphaeridium*. Representatives of *Areoligera/Glaphyrocysta, Cordosphaeridium* are frequently associated with transgressive phases in the neritic zone (Crouch & Brinkhuis, 2005; Guasti et al., 2006; Habib et al., 1992; Iakovleva et al., 2001; Powell et al., 1996; Toricellii et al., 2006). Of the gonyaulacoid cyst category, *Impagidinium* and *Nematosphaeropsis/Cannosphaeropsis* genera are clearly distinguished; those occur in the shelf outer zone and oceanic settings and are characteristic of

oligotrophic conditions (Brinkhuis, 1994; Dale, 1996; Sluijs et al., 2005). A group with opposite paleoecologic features is represented by peridinioid dinocysts. In the Paleogene sections from West Europe, this group of organic plankton is peculiar for the shore-nearest settings associated with lagoons and bays, i.e. zones with the environment of advanced eutrophic properties. Similar paleoecologic adaptations in peridiniods are generally related with metabolism types, aptitude to heterotrophic and mixotrophic nutrition (Powell et al., 1996). It should be added that peridinioid dinocysts constitute the core of organic-walled plankton associations in the Paleogene interior (epicontinental) seas of Eurasia (Andreyeva-Grigorovich et al., 2011), particularly in the Pricaspian basin (Vasilyeva & Musatov, 2010a, b). The transgressive-regressive phases there are peculiar for dynamics of dinocyst species diversity and changing taxonomic compositions of principal paleoecologic groups of organic-walled phytoplankton.

4.5 Nannoplankton

Calcareous nannoplakton has been revealed in all the intervals represented by marls and calcareous rocks. No coccolithophorids have been recognized in the middle part of the Kaztalov formation. Nannoplankton was studied from the preparation made of rock powder alcohol suspension, without any enrichment. Biostratigraphic division of most of the section was made according to Martini scale (Martini, 1971); in the upper section, Okada and Bukry zonal scale (Okada & Bukry, 1980) was used. Fractional zonal divisions, similar to those in the scale developed by Varol (1998), are not always acquirable due to obviously poor species compositions of the nannoplankton complexes or total absence of nannoplankton from the section intervals. All the biozones in the section have been recognized either from the first appearance or from vanishing of the index species, according to the standard definition of zonal divisions (Martini, 1971; Okada & Bukry, 1980). The species were determined under the AxioPlan 2 (Karl Zeiss) microscope.

5. The section biostratigraphic division

5.1 Dinocysts

Dinoflagellate cysts have been revealed practically from all over the section; those are represented by diversely composed complexes of various saturations. The most productive and rich associations have been revealed from the Maastrichtian, Danian and Ypresian section intervals. Stratigraphic occurrences of some dinocyst taxa, zone intervals and the most significant biostratigraphic events are shown in Fig. 3.

5.1.1 *Triblastula utinensis* zone

The dinocyst complex from the Maastrichtian marls (839–785 m interval) is described from FO *Triblastula utinensis*, *Isabelidinium cooksoniae* and the lack of *Alterbidinium acutulum*, which allows to distinguish the *Triblastula utinensis* zone and its upper subzone *Cannosphaeropsis utinensis* (Schiøler, Wilson, 1993) in that interval of the section. The zone is dated as the upper part of the Lower Maastrichtian – the lowermost of the Upper Maastrichtian (Schiøler & Wilson, 1993).

Fig. 3. Stratigraphical occurrences of certain dinocyst and acritarch species in the Elton section. Most important dinocyst events (first occurrence, last occurrence, akme) and their ages are shown (from Luterbacher et al., 2004; Williams et al., 2004). For lithological legend see Fig. 2.

5.1.2 *Hafniasphaera cryptovesiculata* zone

The 785–776 m interval is referred to the *Hafniasphaera cryptovesiculata* (Hansen, 1977) zone from FO *Hafniasphaera cryptovesiculata*, *H. graciosa*. The biostraton has been originally recognized by J. Hansen in the Danian limestones from Denmark; it correspondsв to the upper part of the *Damassadinium californicum* (*Danea mutabilis*) zone (Hansen, 1977). The D2a zone may be directly correlated with the nannoplankton scale and corresponds to the nannoplankton zones NP3 (part)–NP4 (part) (Costa & Manum, 1988; Luterbacher et al., 2004; Powell, 1992;). Characteristic taxa from the Pricaspian complex: *Hafniasphaera hyalospinosa, Palaeocystodinium australinum, Tectatodinium rugulatum, Xenicodinium lubricum*. Availability of *Palaeocystodinium australinum* suggests that the biozone corresponds to the upper part of the D2a biochron from the standard zonal scale (Luterbacher et al., 2004) and is referred to the Late Danian.

5.1.3 *Palaeocystodinium bulliforme* zone

The 778–749 m interval is referred to the D2b *Palaeocystodinium bulliforme* zone from the appearance of the zonal species (Luterbacher et al., 2004). *Senegalinium iterlaaense, Hystrichokolpoma bulbosa, Cerodinium striatum, Laciniadinium petaloidum* appear in the interval basement. Within the interval (samp.12), FO *Palaeotetradinium minusculum, Alisocysta circumtabulata, Palaeocystodinium benjamini* is recognized. In the upper part of the interval (samp.16a), FO *Alisocysta reticulata*, LO *P. benjamini, A. circumtabulata* is pronounced. In the top of the interval, LO *Tectatodinium rugulatum, Xenicodinium lubricum, X. reticulatum, A. reticulata* occurs, appearance of small forms of *Alterbidinium* spp. is recorded, inclusive of *A. dilwynense*. The biozone corresponds to the following biochrons: *Cerodinium striatum* in J. Powell scale for northwestern Europe (Powell, 1992), DP2 (Ekofisk Fm, Maureen Fm) of the zonal chart for the North Sea basin (Mudge & Bujak, 2001), a part of the D2 (Costa & Manum, 1988); it correlates with a part of the NP4 nannoplankton zone (Luterbacher et al., 2004). The zone is referred to the Late Danian.

5.1.4 *Cerodinium depressum* zone

The 749–730 m interval corresponds to the zone D3b *Cerodinium depressum* (Heilmann-Clausen, 1985; Luterbacher et al., 2004), zone *Cerodinium speciosum* (Powell, 1992) from FO *Cerodinium depressum, C. speciosum* and the lack of *Damassadinium californicum*. The interval is described from LO *Hystrichokolpoma bulbosa, Cerodinium diebelii, Spiniferites supparus* (samp.19), *Palaeocystodinium australinum, P. bulliforme* (samp.20), *Laciniadinium petaloidum* (samp.21). Solitary *Spinidinium densispinatum* occur in the interval basement. According to Heilmann-Clausen (1985), the zone is indirectly correlatable with the nannoplankton zones NP4 (part)–NP5 (part). Characteristic species in the Elton section comprise *Palaeotetradinium minusculum, Palaeocystodinium australinum, P. lidiae, Membranosphaera maastrichtica, Laciniadinium petaloidum*. The *Cerodinium depressum* zone is referred to the Selandian.

5.1.5 *Isabelidinium*? viborgense zone

The 730–711 m interval is distinguished as the *Isabelidinium*? *viborgense* zone, as an interval from FO to LO *I.*? *viborgense*. The taxon has been first recognized in the upper part of the Kerteminde formation, within the mass of the overlying non-carbonate Selandian clays from

the section of the Viborg 1 well (Viborg zone 2 –Viborg zone 3) (Heilmann-Clausen, 1985). The bioevent *I.? viborgense* is manifested in the upper part of the zone *Cerodinium speciosum* (Powell, 1992), *Cerodinium depressum* (Luterbacher et al., 2004), traced in the North Sea basin (Heilmann-Clausen, 1994), in the sections from West Siberia (Amon et al., 2003), Povolzhye-Pricaspian region (Aleksandrova, 2001; Vasilyeva & Musatov, 2010a). The *Isabelidinium? viborgense* species was proposed by A. Köthe (2003) in Germany as an additional marker of the *Cerodinium speciosum* zone. In the Northern Pricaspian, the interval of that species occurrence is limited by the NP5 nannoplankton zone (Vasilyeva & Musatov, 2010a). LO *Palaeoperidinium pyrophorum, Cerodinium striatum, C. speciosum* is observed in the upper part of the zone in the Elton section. The *I.? viborgense* zone is referred to the Selandian (the middle part).

5.1.6 *Alisocysta margarita* zone

The 711–690 m interval corresponds to the *Alisocysta margarita* biochron (Luterbacher et al., 2004). The biozone is described from FO *Alisocysta margarita, Areoligera gippingensis* in the interval basement and from the lack of the Upper Selandian zonal markers: *P. pyrophorum, P. australinum, C. striatum*. The Elton association is represented by diverse *Cerodinium: C. medcalfii, C. markovae, C. depressum, C. leptodermum, C. sibiricum*, as well as by *D. denticulata* and numerous *Fromea laevigata*. The zone is referred to the Upper Selandian – Thanetian; it correlates with the NP6–NP8 nannoplankton zones (Luterbacher et al., 2004). The lack of the Selandian zonal species makes it possible to compare the biozone with its Thanetian part (Heilmann-Clausen, 1994).

5.1.7 *Apectodinium augustum* zone

The Bostandyk formation is represented by productive dinoflagellate complexes of diverse species compositions, with numerous *Apectodinium* species in the lower part and extremely rare wetzelielloideans in the upper part of the formation. Similar distribution of wetzelielloids is not typical for Russia's interior boreal basins, but is characteristic of the Crimea-Caucasian region and of the Ukraine (Andreyeva-Grigorovich, 1991). Biozones in the upper part of the Bostandyk formation are recognized as close analogues of the standard zones in accord with the correlative taxa (Costa & Manum, 1988; De Coninck 1990; Heilmann-Clausen & Costa, 1989).

The 690-680 m interval refers to the standard D5a *Apectodinium augustum* zone (Costa & Manum, 1988; Luterbacher et al., 2004) from the appearance of the zonal taxon *A. augustum*, acme of the *Apectodinium* species. The contents of the *Apectodinium homomorphum, A. quinquelatum, A. parvum, A. hyperacanthum* species in this interval are up to 70% high, drastically reducing above the depth of 679 m. *A. homomorphum* dominates. *Wilsonidium pechoricum* is present. The D5a zone corresponds to the IETM interval (Bujak & Brinkhuis, 1998; Crouch et al., 2001; Crouch & Brinkhuis, 2005; Egger et al., 2003), corresponds to the Initial Eocene and correlates with the upper part of the NP9 nannoplankton zone (Luterbacher et al., 2004).

5.1.8 *Phelodinium magnificum* zone

The 680-669 m interval of the Bostandyk formation corresponds to the D5b *Phelodinium magnificum* zone (Luterbacher et al., 2004). The zone is specified as an interval above the top

of the D5a *Apectodinium augustum* zone to the appearance of the earliest species of *Wetzeliella* spp. (Heilmann-Clausen & Costa, 1989). In the Elton section, the biozone is described from occasional species of *Apectodinium*, inclusive of *A. augustum*, also *Cerodinium wardenense*, *Phelodinium magnificum, Deflandrea andromiensis*. No acme of *Deflandrea oebisfeldensis* is observed. The D5b *Phelodinium magnificum* zone correlates with the NP10 nannoplankton zone and is referred to the Initial Ypresian.

5.1.9 *Charlesdowniea crassiramosa* zone

The 669–655 m interval is distinguished as the D6b *Charlesdowniea crassiramosa* zone from FO *Ch. crassiramosa, Defalndrea phosphoritica*. The appearance of those species is known from the Early Ypresian D6b zone in the sections from Britain (London Clay) and northwestern Germany (Wursterheide research well) (Costa & Manum, 1988; Heilmann-Clausen & Costa, 1989). Availability of dinocysts *Trigonopyxidia ginella, Adnatosphaeridium robustum, Kallosphaeridium brevibarbatum*, acritarchs *Pseudomasia trinema* reflects common properties with the *Phthanoperidinium crenulatum* zone (middle part of the Orchies Formation in the stratotype Ypresian section from Belgium) (De Coninck, 1988). The *Charlesdowniea crassiramosa* biozone corresponds to the D6b *Wetzeliella meckelfeldensis* standard zone (Luterbacher et al., 2004) and is referred to the Early Ypresian.

5.1.10 *Eatonicysta furensis* zone

The 655–630 m interval is recognized as the *Eatonicysta furensis* zone. It is described from FO *E. furensis, Eisenackia strobiculata, Heslertonia heslertonensis, Hystrichostrogylon membraniforum granulatum, Operculodinium nanaconulum, Glapyrocysta vicina* in the interval basement. There are no wetzelielloideans within the zone. The biozone is a close analogue of the D7a (*Eatonicysta ursulae – Dracodinium solidum*) zone from the section of the Wursterheide well in Germany (Heilmann-Clausen & Costa, 1989), *Eatonicysta ursulae zone* (Roubaix formation) from the Kallo section in Belgium (De Coninck, 1988).

5.1.11 *Dracodinium varielongitudum* zone

The 630–620 m interval is recognized as the *Dracodinium varielongitudum* zone from the zonal species appearance (solitary occurrence), the presence of *Cordosphaeridium cracenospinosum, Stylodiniopsis maculatum, Membranilarnacia compressa* (Heilmann-Clausen & Costa, 1989). The biozone corresponds to the standard D7c *Dracodinium varielongitudum* biochron and is referred to the Middle Ypresian (Luterbacher et al., 2004). Some new dinocyst species from the Pricaspian Depression sections are systematically described in previous studies (Andreyeva-Grigorovich et al., 2011; Vasilyeva, 2011).

5.2 Nannoplankton

Calcareous nannoplankton complexes have been revealed practically throughout the section, with the exception of some intervals. They are fairly representative in terms of species composition, which provides reliable identification of zonal divisions. The most productive and rich associations have been revealed in the Maastrichtian, Danian, Selandian and the Early Ypresian section intervals.

5.2.1 *Nefrolithus frequens* (CC26) zone

The nannoplankton complex from the Maastrichtian marls (839–785 m) is peculiar for fairly high species diversity, inclusive of *Lithraphidites quadratus* and *Nefrolithus frequens*, which makes it possible to refer the beds to the Late Maastrichtian (zone CC26) (Perch-Nielsen, 1985; Sissing, 1977).

5.2.2 *Ellipsolithus macellus* zone

The 785–763 m interval is referred to the lower part of the *Ellipsolithus macellus* (*Coccolithus robustus*) zone (Martini, 1971) from the presence of solitary *Ellipsolithus macellus, Coccolithus robustus* and numerous *Prinsius martini* in the complex. The assemblage is principally represented by numerous *Coccolithus pelagicus, C. cavus, C. subpertusus, Cruciplacolithus tenuis, Cr. primus, Chiasmolithus danicus, Placozygus sigmoides*. Species *Lanternithus duocavus, Biantolithus sparsus, Neochiastozygus saepes, N. eosaepes* are substantially less frequent. At the level of 776 m, sparse *Chiasmolithus edentulus* appear, at the level of 770 m - rare *Ellipsolithus distichus*. Minor amounts of Cretaceous species occur throughout the section. On the basis of the species composition, this section part may be supposed to correspond to the NNTp4D-F subzones of Varol zonal scale for the North Sea (Varol, 1998).

The 763–749 m interval. At the level of ~763, fairly numerous *Neochiastozygus perfectus* and solitary small *Fasciculithus* sp. appear. Stratigraphically higher, at the level of 750, *Fasciculithus ulii, F. janii, F. magnus* appear. Besides, *Braarudosphaera bigelowii* occur quite frequently. The principal composition of the complex remains the unchanged. It should be noted that at that level all the coccoliths become substantially larger. The presence of the above mentioned species makes it possible to outline the probable level of the *Fasciculithus* first radiation at 763 m. This section interval may be compared to the upper half of the NP4 zone according to Martini (1971), or with zones NNTp5B-NNTp8 (?) specified by Varol (1998).

5.2.3 *Fasciculithus tympaniformis* zone

The 749–737 m interval is peculiar for the appearance of *Fasciculithus tympaniformis, F. ulii, F. janii, F. pileatus, Sphenolithus primus, Chiasmolithus bidens, Ch. consuetus*; in the upper part of the section *N. protenus* appear. The complex principal composition does not change as compared to the previous one, but nannoplankton productivity reduces substantially, and at the level of 738 m it disappears. This part of the section correlates reliably with the zones NP5 by Martini (1971), CP4 by Okada & Bukry (1980), NNTp9-10 by Varol (1998). It should be noted that *Sphenolithus primus* appears in the Elton key well substantially later than in the more northerly sections (Novouzensk key well, Ozinki section). No nannoplankton has been revealed in the 737–702 m interval.

5.2.4 *Heliolithus riedelii* zone

The 702–690 m interval is peculiar for appearing *Heliolithus riedelii*, drastic increase of *Fasciculithus tympaniformis* content, rare *Discoaster falcatus, D. nobilis, D.megastypus, Heliolithus kleinpellii, Chiasmolithus frequens, Neochiastozygus junctus* appear. It should be noted that in the upper part of the interval all the coccoliths are very large, overgrown,

teratic forms are frequently encountered, many of them have additional calcite knobs. This is especially characteristic *Braarudosphaera bigelowii, Sphenolithus* spp. Nannoplankton productivite, however, is insignificant, the species diversity stays at the same level as in the lower intervals: 15–20 species. This interval correlates reliably with the NP8 and CP7 zones.

5.2.5 *Discoaster multiradiatus* zone

The 690–669 m interval is peculiar for appearing *Discoaster multiradiatus, Discoaster salisburgensis*, numerous *Romboaster cuspis, R. bitrifida, R. spineus*, the content of *Neochiastozygus junctus* increases, *Campylosphaera eodela* occur infrequently. Relative to the previous interval, the nannoplakton productivity has increased substantially, but the species diversity has hardly changed. In terms of the complex species composition, this part of the section may be reliably referred to the upper part of the NP9 zone or to the CP8b subzone.

5.2.6 *Discoaster diastypus* zone

The 669–630 m interval. From the depth of 669 m, upwards in the section, gradual degrease of the nannoplankton productivity is recorded. The complexes become depleted in terms of both, species and amounts. Characteristic species *Discoaster diastypus* appears, solitary *Neococcolithus dubius*, many Paleocene species disappear, inclusive of *Heliolithus riedelii, Placozygus sigmoides, Cruciplacolithus tenuis, Ellipsolithus macellus* (occasional specimens occur only in the basement). No *Tribrachiatus bramlettei, T. contortus* have been encountered in the complex, probably due to substantial impoverishment. At the same time, no *Discoaster lodoensis* have been revealed, characteristic of the NP12 (CP10) zone. This makes it possible to compare this part of the section with the CP9 zone, without dividing it into subzones. In the 630–620 m interval, the nanoplankton complex is quite poor, thus, no zonal affiliation may be determined.

6. Rhythm successions and paleoecologic interpretations

6.1 The Danian

Beds from the Danian section are represented by well differentiated rocks comprising marl interlayers. Though boundaries of certain rhythm phases (erosion horizons, maximum flooding surface) are not clearly distinguished, the intervals recognized by the authors differ from each other, correlate positively enough with definite rhythm stages and are confirmed by characteristics of the plankton associations.

6.1.1 The 785–763 m interval

Rocks from the interval lower part (785–776 m) are represented by gray calcareous clays with patches of glauconite sand comprising a marl interlayer (0.1 m thick). The upper part of the interval (776–763 m) is composed of gaize-like sandy clays with fish scales, macrofauna remains, numerous fine burrows of deposit feeders.

In the interval base, drastic increase is observed in species diversity of dinoflagellate cysts represented mainly by gonyaulacoid forms (Fig. 4). Those are dominated by representatives of the *Fibrocysta, Fibradinium, Xenicodinium, Tectatodinium* genera – the taxa characteristic of open marine settings from the inner to the outer part of neritic zone. The occurrence of a

solitary specimen of *Impagidinium* (samp. 5) is most probably accounted for by transportation from the basin deeper outer part during the transgressive phase of the rhythm. The taxa from that association (*Spiniferites, Hystrichokolpoma, Achomosphaera, Areoligera, Hafniasphaera*) refer to cosmopolitan proximochorate cysts frequent in the well-stirred, non-stratified water masses from the neritic zone. Subsequent stepwise reduction of dinocyst species diversity (DSD) is manifested in the upper part of the interval (776–763 m). Sparse peridinioid cysts represented by the *Palaeocystodinium* species, more rarely by *Cerodinium, Palaeotetradinium, Spinidinium, Alterbidinium, Senegalinim*, demonstrate increases in the lower (samp. 6) and in the upper (samp.12) parts of the interval, but they are forced out from a major part by dinoflagellate gonyaulacoid forms. Generally, from two to four peridiniod species are present in a complex of organic-walled plankton.

Terrestrial palynomorphs are of subordinate importance in macerates. Those consist mostly of triaperturate pollen (stemma *Postnormapolles*), comparable in its organization type to modern wind-pollinated angiosperms. Such pollen grains are transported at long ranges by air streams, which doesn't disagree with interpretation of the plankton complex characterizing the open sea settings in the inner shelf conditions. Sparse prasinophyte algae and acritarchs (*Fromea laevigata*, species *Leiosphaeridia, Comatosphaeridium, Cyclopsiella, Paralecaniella, Paucilobomorpha*) indicate proximity of littoral facies.

Similar distribution of the organic plankton taxa and the interval lithologic structure may be interpreted as the highstanding system tract (HST) in the inner shelf conditions. Successive appearance of the *Hafniasphaera cryptovesiculata* (63.3 Ma), *Palaeocystodinium bulliforme* (62.2–62.4 Ma) dinocysts and *Coccolithus robustus, Ellipsolithus macellus* (63.2 Ma), *E. distichus* nannoplankton makes it possible to compare this interval with the Da-3 Danian rhythm (Hardenbol et al., 1998).

6.1.2 The 763–749 m interval

In the lower part the rocks are represented by a marl layer, about 1.0 m thick, in the upper part – by grayish green calcareous clays with burrows of deposit feeders, macrofauna remains, fish scales. The peak of dinocyst species diversity coincides with FO *Alisocysta reticulata* and the coccolithophorid first radiation including solitary small *Fasciculithus* spp. The dinocyst association is represented by roughly equal taxon participation of gonyaulacoid (species *Achomosphaera, Fibradinium, Alisocysta, Membranosphaera, Damassadinium, Cordosphaeridium, Spiniferella, Thalassiphora*) and peridinioid (species *Laciniadinium, Palaeocystodinium, Alterbidinium, Palaeotetradinium, Cerodinium*) cysts. Both groups show brief DSD peaks slightly above the marl interlayer. Terrestrial palynomorphs are of subordinate importance; they are represented by small angiosperm forms (*Triporopollenites* spp., *Aquillapollenites* spp.) and by conifers. The interval lithologic structure and dinocyst species distribution correspond to the HST stage that corresponds to the next Danian rhythm Da-4 (Hardenbol et al., 1998).

6.2 The Selandian

The 749–711 m interval, attributed to the Selandian, is represented by an extremely poorly differentiated clayey gaize-like sequence. Some fragments of this part of the section are represented by slightly higher calcareous rocks comprising sparse nannoplankton, or by
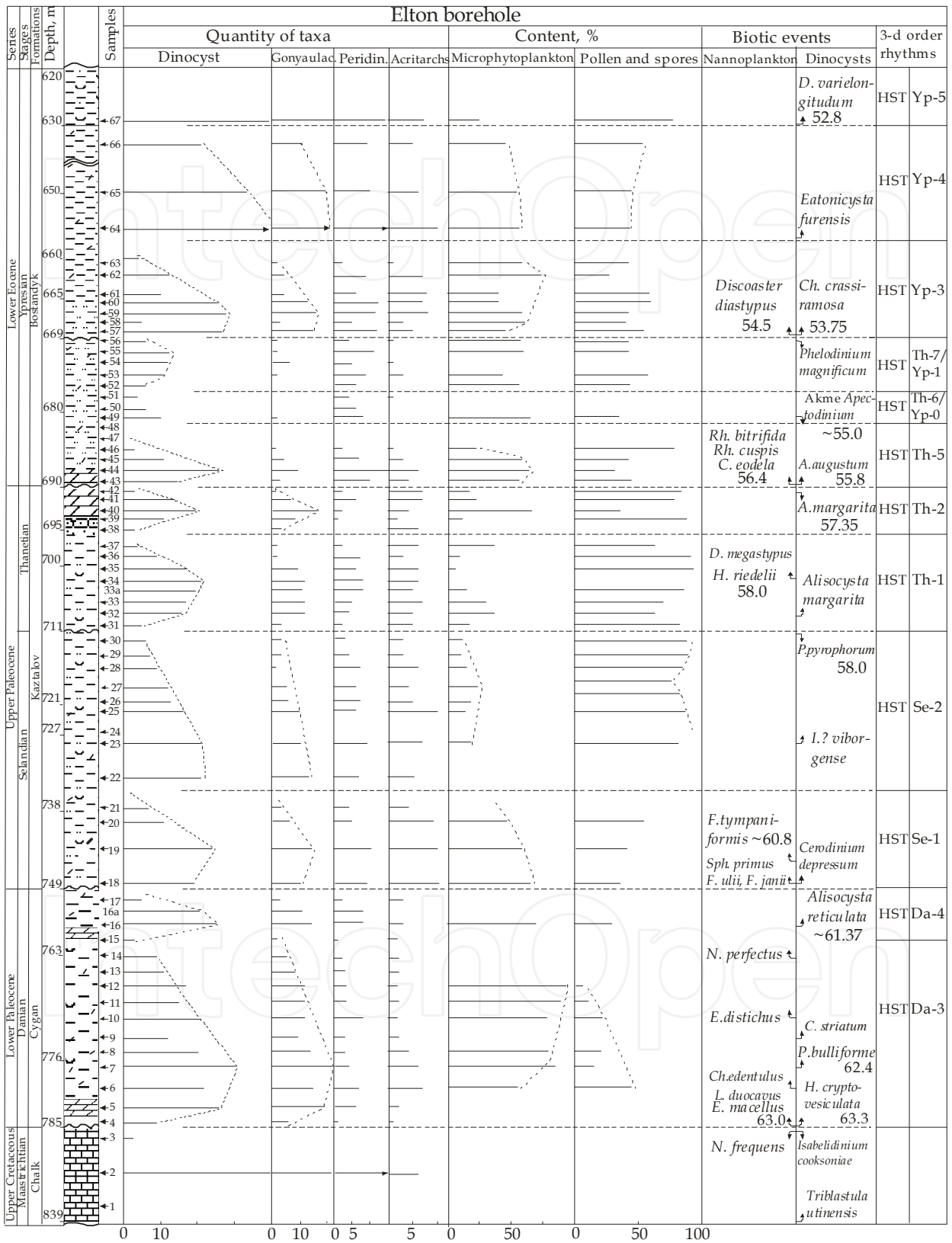
Fig. 4. Dynamic change in the palynomorphs assemblage structures and their interpretation according to Hardenbol 3-d order rhythms scale (Hardenbol, 1994; Hardenbol et al., 1998)

higher sandy clays, or by rock areas with intense bioturbation. The features of lithologic structure induce one to rely mostly on micropaleontologic evidence for rhythm recognition. Terrestrial palynomorph are absolutely dominant among all the palynologic remains (Fig. 4). They are represented by angiosperm pollen of the stemma *Normapolles* (*Trudopollis* spp., *Oculopollis* spp., *Pompeckjoidaepollenites* spp.), *Postnormapolles* (*Triatriopollenites* spp., *Subtriporopollenites* spp.) and by spore plants (*Gleicheniidites* spp., *Laevigatosporites* spp., *Cicatricosisporites* spp., *Stereisporites* spp.), with subordinate participation of Gymnosperms (*Pinaceae, Taxodiaceae*). Organic-walled phytoplankton comprises substantial amounts of non-marine plankton groups (prasinophytes and acritarchs). Prasinophyta species diversity is comparable to those of peridiniod and gonyaulacoid dinoflagellates. On the whole, dinocyst species composition is very scanty. Palynofacies composition and structure in this interval of the section are indicative of shallow-water littoral settings with low aeration of water masses. Gradual decline of connections with the open ocean is also indicated by the complexes of carbonate nannoplankton; gradual impoverishment of associations is observed starting from the 749 m level. Two distinct successive trends of DSD have been revealed in this part of the section.

6.2.1 The 749–738 m interval

The rocks are represented by dark gray, almost black, gaize-like, dense clays with rare macrofauna, microfauna and fish scales. Clays from the interval basement are higher calcareous and enriched in sandy and aleuritic materials. In this part of the interval, increase (24 taxa) and decrease (down to 7 species) of the DSD index are observed (Fig.4). Dinocysts are represented by gonyaulacoid (genera *Fibradinium, Membranosphaera, Spiniferites*) and peridinioid (genera *Palaeotetradinium, Palaeocystodinium, Cerodinium*) forms in practically equal shares. Green algae comprise *Fromea laevigata, Paucilobimorpha apiculata, Palambages morulosa, Paralecaniella identata, Botryococcus spp., Veryhachium spp., Leiosphaeridia spp., Diacrocanthidium spp.* and demonstrate dynamics similar to that in dinocysts. The first appearances of *Cerodinium depressum* dinocysts and *Fasciculithus tympaniformis* nannofossils make it possible to compare the 749–738 m interval with the Selandian first rhythm Se-1 (Hardenbol, 1994) represented by the HST stage in shallow-water littoral settings.

6.2.2 The 738–711 m interval

This section interval is composed of gray, dense, gaize-like clays. The rocks become progressively less calciferous upwards in the section. The top 6 m are composed of non-carbonate rocks with numerous deposit-feeder burrows. This part of the section is peculiar for consistent impoverishment of the dinocyst species composition (from 23 to 6 taxa), absolute dominations of *Fromea laevigata* acritarchs against the background of numerous prasinophyte algae. Palynomorphs of terrestrial origin quantitatively dominant. It is only in the lower part that impoverished complex of the *Fasciculithus tympaniformis* zone plankton occurs, coccoliths disappear entirely above the 735 m level. The interval is marked with *Isabelidinium? viborgense* dinocysts (samp. 23) appearance and *Palaeoperidinium pyrophorum* (LO in samp. 30) disappearance in the roof. We believe the interval to correspond to the Selandian second rhythm Se-2 (Hardenbol, 1994) and to correlate with the HST stage in shallow-water conditions.

6.3 Thanetian

The Thanetian beds are represented by two lithological distinct sequences: the lower, the clayey one, and the higher, the sandy-marly mass. The micropaleontologic features are similarly distinct.

6.3.1 The 711–695 m interval

The sediments are composed of gray, dense, gaize-like, non-calcareous clays with deposit-feeder burrows. The interval is close to the previous (738–711 m) in lithologic composition. A clear peak of species diversity in organic-walled phytoplankton (5–21–4 taxa) is manifested in this interval. It is formed by peridinioid (genera *Cerodinium, Palaeotetradinium, Senegalinium*), chorate and marginate (genera *Cordosphaeridium, Spiniferites, Achomosphaera, Alisocysta, Spiniferella, Areoligera, Caligodinium*) cysts. Diversity of prasinophyte algae and domination of terrestrial palynomorphs suggest that the association has been formed in littoral settings. Pollen is represented by various angiosperm taxon of the stemma *Postnormapolles*, to a lesser extent - by *Normapolles* and conifers. *Alisocysta margarita*, *Areoligera gippingensis* dinocyst and *Heliolithus riedelii* nannoplankton appearance (at the 705 m level) make it possible to refer the 711–695 m interval to the Thanetian initial rhythm (Hardenbol et al., 1998).

6.3.2 The 695–690 m interval

Drastic change of lithologic composition is observed in this part of the section. The rocks are represented by alternating interlayers of glauconite sandstones (0.75–1.5 m thick), marls (0.2–0.3 m thick) and calcareous sandy clays (0.3–1.3 m). The sediment composition is suggestive of highly dynamic sedimentation settings which has affected the phytoplankton composition, as well. The DSD impulse in the interval has been formed mostly by gonyaulacoid cysts represented by proximochorate forms – genera *Alisocysta, Spiniferites, Cordosphaeridium, Achomosphaera, Melitasphaeridium* and *Caligodinium, Impletosphaeridium*. Occurrences of those taxa are characteristic of inner neritic water masses. In the interval this association is completed with sparse peridinioids *Cerodinium markovae, C. leptodermum, Deflandrea denticulata, Lentinia wetzelii* – typical species from the shore-nearest shelf part. The observed impulse of dinocyst diversity occurs within acritarch facies, similarly to the situation in the previous interval. *Fromea laevigata* abundance disappears only in samples 39 and 40; acritarchs are substituted with chorate dinocysts there demonstrating a negative "mirror" peak. Palynomorphs of terrestrial genesis are still numerous and represented by diverse high-order taxa. The species composition of the calcareous nannoplancton complexes stays at a low level, in the range of 12-15 species; productivity increases substantially in some marl layers. This section fragment lies within the *Alisocysta margarita* (dinocysts) and *Heliolithus riedelii* (nannoplankton) zones and corresponds to the Th-2 rhythm (Hardenbol et al., 1998).

6.4 Ypresian

The Ypresian beds in the Elton section are represented by a monotonous clay mass, therefore, lithologic indices of changing rhythms are practically unpronounced. Paleoecologic changes in compositions of the plankton associations, however, are manifested most vividly in this part of the section.

6.4.1 The 690–680 m interval

The sediments in the interval are represented by low calcareous, sandy, indistinctly banded clays with lenticles of aleurite material. Clays comprise plant detritus and fish scales. There is an interlayer of dark gray marl in the basement (0.25 m thick) – with thin intercalations of aleurite-sandy material of quartz-glauconite composition.

The interval is manifested as a sharp, brief impulse of diversity in a dinocyst assemblages, mostly of wetzelielloids of the *Apectodinium* genus, inclusive of *A. augustum, A. parvum, A. quinqellatum*, and *Wilsonidium* spp. (Fig. 4). *A. homomorphum* dominates among the *Apectodinium* species. Relative content of the *Apectodinium* spp. cysts in this association is up to 70% high. The wetzelielloid group is supplemented with other peridinioid dinoflagellates, namely *Deflandrea*, inclusive of *D. andromiensis, Cerodinium, Palaeotetradinium*. Gonyaulacoids are diverse, but sparse. This group of taxa from the inner neritic zone is composed of cosmopolitan species *Achomosphaera, Hystrichokolpoma, Oligosphaeridium* and fibrose forms with thickened walles: *Kallosphaeridium, Tectatodinium, Caligodinium, Fibrocysta, Hafniasphaera*. Acritarchs and prasinophytes are solitary in this association; *Paralecaniella, Leiosphaeridia, Pterospermella, Paucilobimorpha* are permanently diagnosed. Organic-walled plankton dominated in the interval, while terrestrial palynomorphs are of subordinate importance; they are represented by fine triaperture and tricolporate pollen (*Subtriporopollenites* spp., *Triporopollenites* spp., *Tricolporopollenites* spp.). Pollen of the Stemma *Normapolles* and cryptogams are rare.

Paleophytocoenosis (690–680 m interval) developed in the conditions of inner neritic, fairly well aerated water masses. The lithologic sequence most probably reflects the HST stage within the Th-5 rhythm (Hardenbol & al., 1998), which is determined from FO *Apectodinium augustum*, acme of the *Apectodinium* spp. (dinocysts) and fairly rich nannoplankton of the CP8b subzone. The nannoplankton productivity is high enough, but its species diversity does not exceed 15–20 species. All the coccolithophores are well preserved, there are no teratic or overgrown forms. The distinct acme of *Apectodinium* spp. reflects the event of the Initial Eocene Thermal Maximum (IETM), globally correlatable about 55 million year ago (Bujak & Brinkhuis, 1998; Crouch et al., 2001; Egger et al., 2003; Steurbaut et al., 2003).

6.4.2 The 680–669 m interval

The rocks are represented by alternating low calcareous, dark gray, sandy clays and denser shaly black clays. Macro- and microfauna fragments and fish scales occur in the sediments. Associations of organic-walled microphytoplankton demonstrate two short DSD impulses and characterize different rhythms. They can't be described in detail due to material scantiness. The dinocyst complex from the interval lower part (samp. 49–51), however, belongs to the *Apectodinium augustum* zone and is represented exclusively by wetzelielloids – *Apectodinium* species, inclusive of *A. augustum*, and *Wilsonidium* spp. The upper part of the interval (samp. 52–56) reflects a mixed complex of peridiniod dinoflagellates, inclusive of the genera *Deflandrea, Cerodinium, Apectodinium, Wilsonidium, Phelodinium, Palaeotetradinium*. Species *Deflandrea andromiensis* and *D. oebisfeldensis* dominate there. Gonyaulacoids are rare; they are represented by *Diphyes colligerum, Achomosphaera crassipellis, Spiniferites ramosus*. Poor preservation of palynologic material should be noted, as well as abundance of coalified debris and numerous fragments of amorphous organic matter. The nannoplankton complex

is substantially impoverished (8–12 species), its productivity reduces. Based on palynologic features and on the occurrence frequency of marker dinocysts, one may suggest that the 680–669 m imterval reflects fragments of two successive rhythms of the Initial Ypresian: Yp-0 and Yp-1 (Hardenbol et al., 1998; Powell et al., 1996).

6.4.3 The 669–660 m interval

The entire upper part of the Elton section, starting from the depth of 669 m, is represented by substantially different plankton characteristics. Well saturated and representative dinocyst complexes are peculiar for predominance of gonyaulacoid morphotypes. Moreover, the wetzelielloids that make the basis for biostratigraphic division of the Ypresian beds from Russia's epicontinental section are extremely rare or absent. At the same time, dynamics of species diversity in dinocyst associations is most distinctly manifested in this part of the section.

The 669–660 m interval is represented by dark gray, almost black, low calcareous, sandy clays with microfauna, macrofauna detritus and fish scales. Sand material occurs as lenses and superfine laminae. Sharp increase and gradual decrease of the DSD-criterion is observed in this part of the section. Dinoflagellate associations are represented by various gonyaulacoid morphotypes, mostly by chorate cysts. Representatives of *Achomosphaera*, *Spiniferites, Cordosphaeridium, Hystrichosphaeridium* occur most frequently; those are cosmopolitan taxa typical of neritic water masses. In the group of peridinioids, *Deflandrea* are the most characteristic and diverse ones. Wetzellieloids are represented by solitary specimens of *Charlesdowniea crassiramosa, Apectodinium homomorphum, A. hyperacanthum, Dracodinium* sp. 1 Heil.-Claus. Acritarchs and prasinophytes are rare. Among those, *Paralecaniella, Paucilobimorpha, Leiosphaeridia, Cymatiosphaera* occur most consistently. The relative content of organic-walled phytoplankton in this interval is generally above the amount of terrestrial palynomorphs. All the palynologic remains are peculiar for poorly preserved material. Many dinocysts are represented by fragments, the periphragm structure is damaged, frayed. Large amounts of amorphous organics and coalified debris are recorded. The nannoplankton species diversity gradually reduces upwards in the section – to 4-8 species. Finds of (FO) *Charlesdoniea crassiramosa, Discoaster diastypus* (nannoplankton) make it possible to correlate the 669–660 m interval with the first major transgression of the Lower Ypresian Yp-3 (HST stage) and the zone from the *Wetzeliella meckelfeldensis* dinocysts.

6.4.4 The 660–630 m interval

This interval of the Elton section is composed of black, dense, indistinctly laminated, low calcareous clays with minor admixture of sandy-aleurite material as patches and lenses. Microfauna, macrofauna fragments and fish scales occur in the sediments. The sharpest and the highest DSD peak is observed in this part of the section (Fig. 4). The composition of the organic-walled microphytoplankton complex is rather unexpected. On the one hand, high taxonomic diversity is observed in chorate dinocysts. Among those, representatives of the genera *Achomosphaera, Spiniferites, Hystrichsphaeridium, Cordosphaeridium* are the most common ones. Sporadically, genera *Operculodinium, Homotriblium, Fibrocysta, Cleistosphaeridium, Membranosphaera* occur, i.e. typical representatives of neritic zone. Solitary *Impagidinium dispertitum* occur, reflecting the influence of deeper settings. On the other hand, the peridinioid part of the phytoplankton spectrum is represented only by representatives of

dominating *Deflandrea* and *Cerodinium*. There are practically no wetzelielloid dinocysts present.

The most of *Deflandrea* specimens are found as fragments – endocysts. Periphragm in the preserved forms is thinned, perforated or covered with granules, spines. The preservation state of the palynologic material reflects unfavorable chemical conditions during sedimentation and, probably, the initial stage of organic matter destruction. Poor preservation is characteristic of terrestrial palynomorphs, as well. Besides, macerates contain large numbers of foraminifer inner capsules, scolecodont remains, fragments of amorphous organics, detrital material. Constant presence of *Botryococcus, Palambages, Leiosphaeridia* is characteristic of those palynofacies. Such structures of taphocoenosis and palynofacies, material preservation state and sediment compositions suggest that the paleophytocoenosis has been formed in the conditions of limited water exchange and disturbed circulation within the water column, which was, probably, caused by partial isolation of that basin part. Rise of the sea level and inflow of transgressive water masses used to provide phytocoenosis (diverse gonyaulacoid dinocysts) short-term taxonomic renovation, but closed settings favored formation of reducing environment, stagnation, development of deflandreoids and prasinophyte alga complexes representing the autochthonous biota there. The calcareous nannoplankton complexes are extremely poor, just with 5-6 species, inclusive of *Discoaster diastypus.* It is the inflow of marker dinocysts (*Eatonicysta furensis, Stylodiniopsis maculatum*) that allows correlation of the 660–630 m interval with the *Dracodinium simile* zone and the consistent Lower Ypresian rhythm Yp-4.

6.4.5 The 630–620 m interval

The sediments in the interval are represented by dark gray, uniform, low arenaceous, gaize-like clays. In some site the clays are layered, irregularly pyritized, comprise fauna detritus and plant remains.

Organic-walled phytoplankton has been examined only in one sample, since just a small core fragment from that part of the section was preserved. Association of high species diversity has been revealed compared to the complex from the top of the previous interval. The phytoplankton is represented by mixed ecologic groups. Diverse neritic gonyaulacoid forms occur. Those generally comprise representatives of genera *Achomosphaera, Cordosphaeridium, Cleistosphaeridium, Membranilarnacia, Tectatodinium. Impagidinium* and *Eatonicysta* are observed. The ecologic group from littoral settings consists of peridinioid forms of the genera *Dracodinium, Wetzeliella, Deflandrea, Senegalinium, Apectodinium.* This is supplemented with abundant plankton of prasinophyte algae and acritarchs – *Pterospermella, Paralecaniella, Cymatiosphaera, Cyclopsiella, Botryococcus.* Microforaminifer capsules, scolecodonts and fragments of amorphous organics occur substantially less frequently. Terrigenous palynomorphs represented by pollen of the Stemma *Postnormapolles*, tricolporate grains (Angiosperms), taxodians (Gymnosperms) and fern spores quantitatively dominate over plankton.

The DSD peak and appearance of *Dracodinium varielongitudum* dinocysts (52.8 Ma) allow to refer the interval to the next rhythm of the Ypresian, Yp-5 (Hardenbol et al., 1998). Peridinioid diverse composition and satisfactory material preservation state suggest that the paleoecologic conditions of this algocoenosis formation were substantially improved in that

time interval. The species composition and productivity of nannoplankton, however, has not changed as compared to the previous interval.

7. Discussion

7.1 Palynologic data interpretation

Examination of the Elton section has shown that notwithstanding some uncertainty and probable faults in counting the taxa of the species rank (different preservation of palynologic material, taxonomically understudied phytoplankton groups, divisiveness in species diagnostics of paleontologic species), making use of the criterion of dinocyst species diversity (DSD) allows clear structuring of associations in the Paleogene beds from the Pricaspian basin. The dinocyst species diversity always reduces to minimum values in the intervals with apparent lithologic evidences of hiatus. In the section intervals associated with development of calcareous facies the DSD impulses are confined to interlayers of marls and marly clays. We believe the dynamics of plankton species diversity in the Pricaspian region to reflect rhythmic fluctuations of the basin depth and the changes of the water-mass volume within the photic zone.

The necessary criterion for rhythm substantiation consists in the lithologic features of the rhythm sequential stages: determination of the lowstanding sea tract (LST), transgressive system tract (TST), highstanding basin phase (HST), shelf margin wedge (SMW), rhythm dividing surfaces and limits (Haq et al., 1988). Since the Elton section is situated in the deepest plunged part of the depression and is represented mostly by monotonous clay sequences, clear lithologic criteria of the rhythm stages are unrecognizable or partially diagnosed (in the Danian beds). Therefore, a necessity arises to compare the sections from the Elton and from the Novouzensk key well drilled in the northern, shallower shelf zone of the Pricaspian Depression (Vasilyeva & Musatov, 2010b) (discussed below).

Distribution of coalified debris (phytoclasts) – fine black and coarse brown, fossilized cuticle fragments (single-layered epidermis of higher plants) and tracheides (cells of plant conducting system) is definitely oriented in the specified intervals and may provide additional information for rhythm diagnostics. We did not count those microfossil groups or microforaminifer organic capsules or fragments of amorphous organic matter. We recorded obvious accumulations of organic-origin remains in individual levels and samples.

High contents of pollen and spores (palynomorphs of terrestrial origin) throughout the Paleogene section from the Central Pricaspian happened to be fairly unexpected while palynologic data analyses. The Elton well is over 1000 km away from the supposed shoreline of the paleobasin. Large share of all pollen and spore groups in macerates may be accounted for by the presence of major islands developed over positive geomorphologic constructions. Let us remark here, that according to the data of geophysical exploration (Zhuravlev, 1970), the entire area of the Pricaspian Depression is covered with salt-dome structures, inclusive of those up to 10 km high and across. Most probably, the islands were represented by salt domes, similar to the Elton and Baskunchak ones. An extensive system of submerged domes and islands in the shelf of the Pricaspian basin used to constitute geomorphologic constructions similar to barrier reefs. In this case, phytocoenosis of organic-walled plankton peculiar for high diversity and the presence of acritarchs, prasinophyte algae and peridinean dinocysts, looks quite accountable, as well. The depths of the basin with such paleophytocoenosis do not generally exceed 50 m.

7.2 Correlating the sections from the Elton and the Novouzensk key wells

The two section correlation allows preliminary estimation of transgressive rhythm and corresponding sediment occurrences in the shelf of the Pricaspian paleobasin (Fig. 5). Adequately detailed paleontologic sampling enables us to describe the regional paleontologic sedimentation settings and their changes in the Cenozoic.
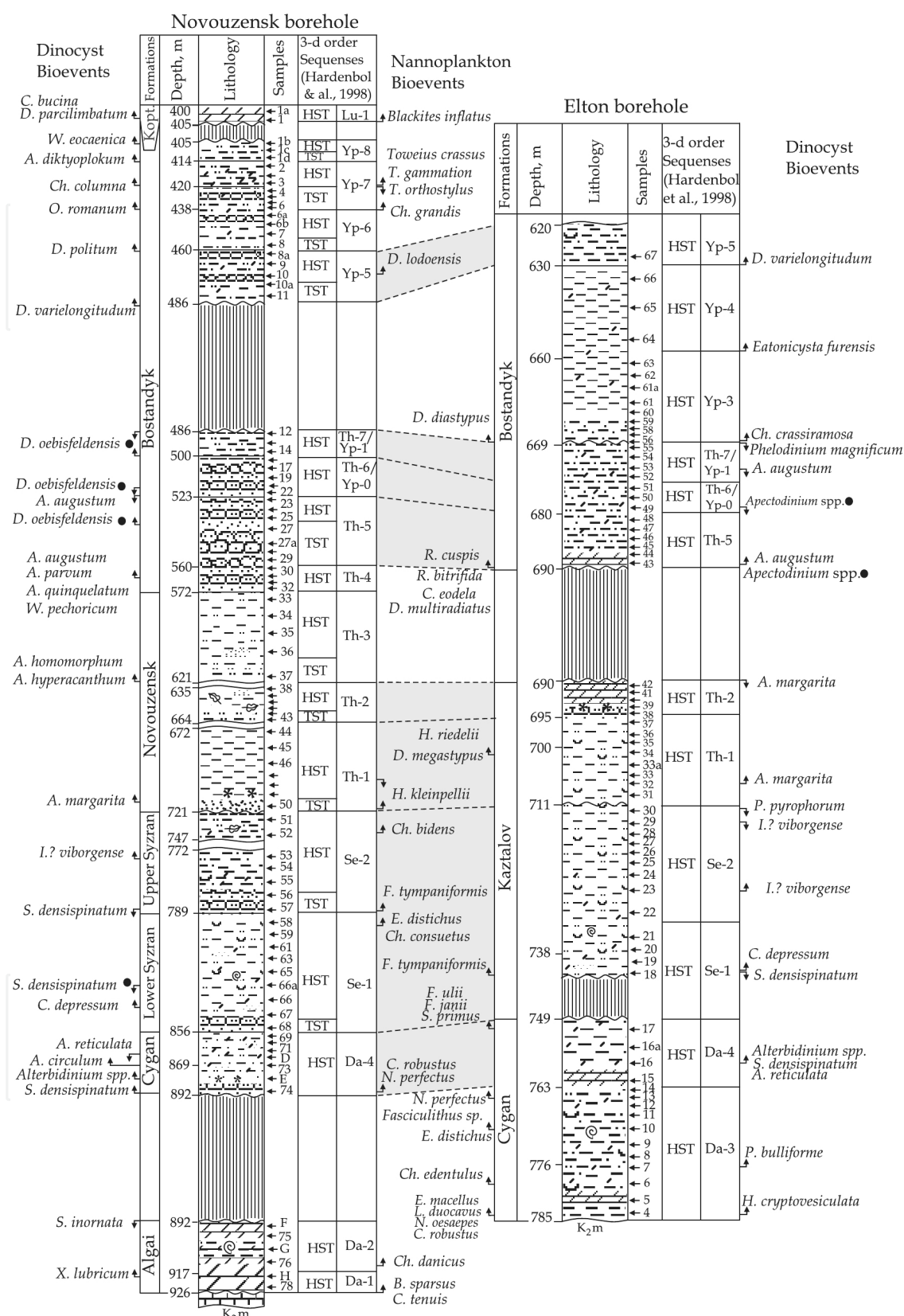
7.2.1 The Danian

The Danian beds from the Elton and the Novouzensk wells are poorly correlatable and may be rather regarded as complementary to each other. The marl sequence from the Lower Danian Algai formation is represented in the Novouzensk section, but is absent from the Elton well. The Algai formation marl pelitomorphic sediments (up to 40 m thick) are common in the Central Pricaspian region, but are locally absent from many salt-dome arches. The Algai formation is described from nannoplankton of the zones NP2 *Cruciplacolithus tenuis* and NP3 *Chiasmolithus danicus*; additional sampling from the Novouzensk well indicates that dinocysts from the D1 with *Xenicodinium lubricum* are also present.

The Upper Danian is represented by calcareous clays from the Cygan formation. In the Central Pricaspian region, its thickness ranges from 20 to 140 m, increasing in the interdome downfolds. The Cygan formation is 36 m thick in the Elton well. The phytoplankton paleontologic analysis shows the formation to have been formed within two successive rhythms of the Upper Danian – Da-3 и Da-4. In the Elton section, sediments corresponding to the Da-3 rhythm are represented by black, calcareous, sandy clays (HST); they correspond to the nannoplankton zone NP4 *Ellipsolithus macillus* (*Coccolithus robustus*) and sequential appearances of the *Hafniasphaera cryptovesiculata* and *Palaeocystodinium bulliforme* dinocysts (zones D2a and D2b). Only the Da-4 rhythm beds may be traced in both wells. In the submerged part of the Pricaspian region, they are composed of greenish gray calcareous clays (14 m thick) with a marl interlayer in the basement; in the northern marginal part (Novouzensk well) – of black sandy clays (36 m thick). Sediments of the Da-4 rhythm are peculiar for the appearance of dinocysts *Alisocysta reticulata* (FO and LO), *Spinidinium densispinatum* (FO), *Alterbidinium circulum* (FO). Supposedly, the level of fascicullite first radiation (small *Fasciculithus* sp.) begins to show there. This level is not traceable in the North Pricaspian region, probably due to the development of an island barrier of salt domes and hampered water exchange. In the Danian, the Pricaspian region used to be an open warm-water sea basin inhabited by rich complexes of heat-loving biota (foraminifers, brachiopods, sea urchins, nannoplankton, dinocysts). The tendency to shoaling became obvious by the end of the Danian.

7.2.2 Selandian and Thanetian

Selandian and Thanetian beds are consistently traceable in both wells. They are represented by low calcareous, gaize-like clays of mostly terrigenous genesis. Two Selandian rhythms correlate consistently in the Central and in the North Pricaspian regions. In the Central Pricaspian, the Se-1 and Se-2 beds are lithologically manifested as a uniform sequence of gray, gaize-like clays of Kaztalov formation. In the basin northern marginal part – as differentiated bodies of the Lower Syzran and the Upper Syzran subformations separated with an erosion horizon. The appearance sequence of *Cerodinium depressum* (FO) dinocysts

Fig. 5. Correlation of the rhythms in the sections from the Northern and Central Caspian Depression (the Novouzensk key well and the Elton well) based on micropaleontological data. Legend as in Fig. 2.

characterizes the Se-1 rhythm, while FO and LO *Isabelidinium? viborgense*, LO *Palaeoperidinium pyrophorum* - the Se-2 rhythm. The stratigraphic gap between the Danian and the Selandian is clearly manifested in the Elton well. The successive change of dinocyst assemblages there is most comparable with the Danian-Selandian transition in the Viborg 1 section, Denmark (Heilmann-Clausen, 1985).

In the Elton section, the basement of the Kaztalov formation coincides with the appearance of a series of nannoplankton species of the genus *Fasciculithus* (*F. pileatus, F. ulii, F. janii,*), i.e. with the clearly manifested second radiation of fascicullites. The zonal species *F. tympaniformis* appears several meters higher. This biotic event marks the basement of the Selandian stage. In the Novouzensk section, the nannoplankton complexes are poorer and *Fasciculithus tympaniformis* is recorded only in the basement of the Upper Syzran subformation (Se-2 rhythm). During the Selandian, the sea basin remained warm, shallow-water, and was affected by substantial drift of siliceous material from the continent; that was probably associated with general sinking of the continental margin and widening of the water area. Note, that substantial part of the Volga Uplands is composed of a thick sequence of gaizes and siliceous clays. A vast system of islands, shoals and deeper straits favored formation of organic-walled biota phytocoenoses with peridinioid dinocysts and prasinophyte algae. Nannoplankton associations are poor and in some intervals (Kaztalov formation) have not been revealed at all.

The Lower Thanetian is represented by two lithologically differentiated sequences corresponding to two Thanetian rhythms: Th-1 and Th-2. The lower clay sequence (the upper part of the Kaztalov formation from the Elton section and the lower part of the Novouzensk formation in the Novouzensk section) is described from the appearance of *Alisocysta margarita* dinocysts. It corresponds to the Thanetian first rhythm manifested in the shallow-water settings of the inner neritic zone. Organic plankton associations are represented by peridinioids with numerous prasinophytes and acritarchs. Nannoplankton is absent from most of the beds. Some finds of *Heliolithus kleinpellii* coccoliths in the basement of the Novouzensk formation and *Heliolithus riedelii* in the uppermost of the Kaztalov formation make it possible to date that rhythm quite clearly.

The upper sandy sequence corresponds to the Thanetian second rhythm Th-2. This is manifested by formation of highly dynamic beds in the top of the Kaztalov suite in the Central Pricaspian region and black sandy clays in the North Pricaspian region. Paleontologically, it corresponds to the *Alisocysta margarita* zone (dinocysts) and NP8 *Heliolithus riedeii* (nannoplankton). The Upper Thanetian beds (Th-3 rhythm) are represented in the North Pricaspian region, but are missing from the Elton section.

7.2.3 Ypresian

Lithostratigraphic sequences of the initial Ypresian are fairly consistent in the Pricaspian Depression. In the Central Pricaspian region, they are represented by sandy-clayey, low calcareous sediments from the Bostandyk formation (Th-5, Th-6/Yp-0, Th-7/Yp-1), in the northern marginal part – by a thick sandstone sequence with subordinate clay interlayers. It is remarkable, that two sections separated by 150 km differ so drastically in the contents of organic-walled phytoplankton at that stratigraphic level. Both associations refer to the *Apectodinium augustum* zone. But while acme of the *Apectodinium* species is observed in the

depression central, submerged part, in the littoral zone, the Early Eocene climate maximum (IETM) is manifested by acme of *Deflandrea oebisfeldensis,* with subordinate participation of *Apectodinium* spp. We believe this to be associated with depth differences and diverse adaptations of wetzielloid and deflander dinocysts to the physical-chemical properties of the environment within the inner shelf. Note, that in the basin northern marginal part, no nannoplankton has been revealed at that level; in the central part it is represented by diverse-species complex of the CP8b zone.

Certain significant events occur in the Early Ypresian. In the Central Pricaspian region, the Lower Ypresian is represented by a thick sequence of black, shaly, low calcareous clays formed during the Yp-3 and Yp-4 rhythms. There are no corresponding beds in the Novouzensk well. The Early Ypresian associations of organic-walled phytoplankton and calcareous nannoplankton in the Elton section reflect the features of unfavorable paleoecologic settings, stagnant, reducing environments. One may suppose that the stratigraphic gap revealed in the Novouzensk section was not of local, but of regional character. If the northern marginal part of the depression is accepted to have experienced tectonic uplift, the basin inner, submerged parts happened to become partially isolated; thus, suppressed plankton associations were formed (dinocysts and nannoplankton). Most probably, open interconnections with the Tethys and normal marine sedimentation were restored in the Middle Ypresian, during the Yp-5 rhythm, peculiar for appearance of *Dracodinium varielongitudum* dinocysts in both, northern and central parts of the Pricaspian Depression.

Subsequent biostratigraphic sequences of nannoplankton and dinocysts, inclusive of the Lower Lutetian, have been revealed only in the Novouzensk well. Sandy-clayey non-calcareous rocks occur in the Elton section above the 620 m depth. The core is in bad condition, highly curtailed and unsampled.

We believe that the Novouzensk and the Elton sections complement each other and may constitute the basis for biozonal division of the Pricaspian Depression Paleogene from dinocysts and nannoplankton (Fig. 6). The proposed chart covers the interval from the Lower Danian to the Lower Lutetian and is based on direct correlations of dinocysts and nannoplankton.

8. Conclusion

Examination of the Elton key well has shown that practically entire Paleogene section from the Central Pricaspian region (from the Upper Danian to the Middle Ypresian) is described from productive complexes of dinocysts and nannoplankton. Zonal nannofossil complexes have not been revealed only in a portion of the Upper Selandian and in the lowermost of the Thanetian. The Cygan formation from the basement of the section is referred to the Upper Danian.

It is represented by nannoplankton of the zone NP4 *Ellipsolithus macellus* (*Coccolithus robustus*); in its upper part, small *Fasciculithus* spp. appear. Successive appearances of dinocysts (FO) *Hafniasphaera cryptovesiculata, Palaeocystodinium bulliforme, Alisocysta reticulata* are peculiar for the Cygan formation. The Kaztalov formation is represented by nannoplankton of the zones NP5 *Fasciculithus tympaniformis* (in the lower part) and NP8 *Heliolithus riedelii* (in the top) and corresponds to the Selandian and a part of the Thanetian.

Fig. 6. The chart of the Danian-Lower Lutetian zonal division from nannoplankton and dinoflagellate cysts in the Caspian Depression

Age (Ma)	Series	Stages	Polarity Chrons	Zones NP (Martini, 1971)	Zones D (Luterbacher et al., 2004)		Caspian Depression North region	Central region	Nannoplankton	D...
	Eocene	Lute-tian		NP14↑	D9	b	Kopterek	Kopterek	NP14 Discoaster sublodoensis	Costacys...
49			C22				Bostandyk			Wetzeliel... Areosphaeridium
50				NP13		a			NP13 Discoaster lodoensis	
51		Ypresian			D8	c		Bostandyk		Dracodini... Charlesdown...
52			C23	NP12		b			NP12 Marthasterites tribrachiatus (CP10 Tribrachiatus orthostylus)	
						a				Dracodinium
53				NP11		c			CP9 (NP10-11) Discoaster diastypus	Eatonicy...
54					D7	b				Charlesdow...
				NP10	D6	b				Phelodinium magnificum
55			C24			a	Bostandyk		NP9 Discoaster multiradiatus	Apectodiniu...
					D5	b		Campylosphaera eodela		
				NP9		a				
56										
57		Thanetian				c	Novouzensk	Chiasmolithus bidens		Apectodinium
			C25	NP8	D4	b			NP8 Heliolithus riedelii	Alisocysta marg...
58				NP7				Kaztalov	no plankton	
									NP6 Heliolithus kleinpellij	
59				NP6		a			not established	not e...
60	Paleocene	Selandian	C26	NP5	D3	b	Syzran		NP5 Fasciculithus tympaniformis	Isabelidini...
61										Cerodinium
						a				Spinidinium
62		Danian	C27	NP4	D2	b	Cygan	Cygan	NP4 Ellipsolithus macellus (Coccolithus robustus)	Alterbidini...
										Palaeocystod...
63						a				Hafniasphaera
64			C28	NP3	D1	c	Algai		NP3 Chiasmolithus danicus	Xenicodin...
65			C29↓	NP2		b			NP2 Cruciplacolithus tenuis s.s.	not stu...
				NP1		a		unknown		

First occurence of a number of fasciculites (*F. ulii, F. janii*), that are predecessors of the zonal species - *F. tympaniformis,* markes the base of the Kaztalov formation. Sequences of dinocysts FO *Cerodinium depressum*, FO and LO *Isabelidinium*? *viborgense*, LO *Palaeoperidinium pyrophorum*, FO *Alisocysta margarita* represent the Kaztalov formation. This is separated from the underlying and from the overlying sequences with a gap. The Bostandyk formation from the top of the Elton section is referred to the Ypresian. The Bostandyk formation is characterized from successive dinocyst events, inclusive of FO *Apectodinium augustum*, acme *Apectodinium* spp., LO *Phelodinium magnificum*, FO *Charlesdowniea crassiramosa*, FO *Eatonicysta furensis*, FO *Dracodinium varielongitudum*. Nannoplankton of the CP8b, CP9 and CP10 zones has been revealed in that formation. Section correlations in the North and Central Pricaspian regions (from the Novouzensk and the Elton key wells) make it possible to present a chart for biostratigraphic division of the Paleogene section from dinocysts and nannoplankton.

Comparison of the organic-walled microphytoplankton complexes from the region shows the dinocyst species diversity to grow substantially in the Central Pricaspian relative to the basin northern marginal part. At that, the share of gonyaulacoid dinoflagellates within the plankton composition increases appreciably. This group is represented mostly by cosmopolitan chorate forms (*Achomosphaera, Spiniferites, Cordosphaeridium, Fibrocysta*), supplemented by species *Xenicodinium, Tectatodinium, Kallosphaeridium, Impletosphaeridium*. Distribution of peridionioids within the Pricaspian inner shelf demonstrates fairly well defined trends during the Ypresian. The wetzelielloid group is inclined to occur in more open marine facies, while deflandroids occur ubiquitously and are preserved in disturbed marine environment determined by restricted sea circulation. Diversity of prasinophyte algae and acritarchs within the phytoplankton denotes formation of local shallow-water, freshened, low-current settings.

Paleoecologic analyses of the organic-walled microphytoplankton complexes and correlations of the two thoroughly dated sections make it possible to reveal cyclicity corresponding to the third-order rhythms and to trace the dynamics of the Pricaspian basin evolution in the Early Cenozoic. Both sections belong to the inner shelf zone, but the Elton section is represented by the deeper facies, farther remote from the shoreline. Breaks in both sections generally correspond to dropout of one or two definite rhythms, which is caused by local tectonic movements.

9. Appendix – List of micro- and nannoplakton

A. Dinoflagellate cysts

Achomosphaera crassipellis *Deflandre & Cookson, 1955) Stover & Evitt, 1978*
Adnatosphaeridium robustum *(Morgenroth, 1966) De Coninck, 1975*
Alisocysta circumtabulata *(Drugg, 1967) Stover et Evitt, 1978*
Alisocysta reticulata *Damassa, 1979*
Alisocysta margarita *(Harland, 1979) Harland, 1979*
Alisocysta *sp. 2 Heilmann-Clausen 1985*
Senegalinium ?dilwynense *(Cookson & Eisenack, 1965) Stover & Evitt, 1978*
Alterbidinium acutulum *(Wilson, 1967) Lentin & Williams, 1985*
Alterbidinium *spp. (including* A. prominense *Vassilyeva,* Alterbidinium compactum *Vassilyeva in Andreyeva-Grigorovich et al., 2011)*

Apectodinium homomorphum *(Deflanre & Cookson, 1955) Lentin & Williams, 1977*
Apectodinium hyperacanthum *(Cookson & Eisenack, 1965) Lentin & Williams, 1977*
Apectodinium quiquelatum *(Williams & Down, 1966) Costa & Downie, 1979*
Apectodinium parvum *(Alberti, 1961) Lentin & Williams, 1977*
Apectodinium augustum *(Harland, 1979) Lentin & Williams, 1981*
Areoligera gippingensis *Jolly, 1992*
Biconidinium *sp.*
Caligodinium aceras *(Manum & Cookson, 1964) Lentin & William,s 1973*
Cannosphaeropsis utunensis *O. Wetzel, 1933*
Cerodinium depressum *(Morgenroth, 1966) Lentin & Williams, 1987*
Cerodinium diebelii *(Alberti 1959) Lentin & Williams 1987*
Cerodinium leptodermum *(Vozzhennikova 1963) Lentin & Williams 1987*
Cerodinium markovae *(Vozzhennikova 1967) Lentin & Williams 1987*
Cerodinium medcalfii *(Stover 1974) Lentin & Williams 1987*
Cerodinium sibiricum *(Vozzhennikova 1967) Lentin & Vozzhennikova 1990*
Cerodinium striatum *(Drugg 1967) Lentin & Williams 1987*
Cerodinium speciosum *(Alberti 1959) Lentin & Williams 1987*
Cerodinium speciosum *subsp. glabrum (Gocht 1969) Lentin & Williams 1987*
Cerodinium dartmoorium *(Cookson & Eisenack 1965) Lentin & Williams 1987*
Cerodinium wardenense *(Williams& Downie 1966) Lentin & Williams 1987*
Charlesdowniea crassiramosa *(Williams & Downie 1966) Lentin & Vozzhennikova 1989*
Cladopyxidium saeptum *(Morgenroth 1968) Stover & Evitt 1978*
Cordosphaeridium ?cracenospinosum *Davey & Williams 1966*
Cordosphaeridium inodes *(Klumpp 1953) Eisenack 1963*
Cleistosphaeridium polypetellum *(Islam 1983) Islam 1993*
Damassadinium californicum *(Drugg 1967) Fensom et al., 1993*
Deflandrea andromiensis *Vozzhennikova 1967*
Deflandrea denticulata *Alberti 1959*
Deflandrea oebisfeldensis *Alberti 1959*
Deflandrea phosphoritica *Eisenack 1938*
Diphyes colligerum *(Deflandre & Cookson 1955) Cookson 1965*
Dracodinium varielongitudum *(Williams et Downie 1966) Costa et Downie 1979*
Dracodinium *sp. 1 Heilmann-Clausen in Heilmann-Clausen & Costa 1989*
Eatonicysta furensis *Stover & Evitt 1978*
Eisenackia ?strobiculata *Morgenroth 1977*
Fibrocysta lappacea *(Drugg 1970) Stover & Evitt 1978*
Glaphyrocysta ?vicina *(Eaton 1976) Stover et Evitt 1978*
Hafniasphaera cryptovesiculata *Hansen 1977*
Hafniasphaera graciosa *Hansen 1977*
Hafniasphaera hyalospinosa *Hansen 1977*
Heslertonia heslertonensis *(Neale & Sarjeant 1962) Sarjeant 1966*
Homotriblium tenuispinosum *Davey & Williams 1966*
Hystrichokolpoma bulbosum *(Ehrenberg 1938) Morgeroth 1968*
Hystrichostrogylon membraniphorum subsp. granulatum *Heilmann-Clausen in Heilmann-Clausen & Costa 1989*
Hystrichosphaeridium tubiferum *(Ehrenberg 1938) Wetzel 1933*

Isabelidinium cooksoniae *(Alberti 1959) Lentin & Williams 1977*
Isabelidinium? viborgense *Heilmann-Clausen 1985*
Impagidinium dispertitum *(Cookson & Eisenack 1965) Stover & Evitt 1978*
Kallosphaeridium brev*ibarbatum De Coninck 1969*
Laciniadinium petaloidum *Vassilyeva in Andreyeva-Grigorovich et al., 2011*
Lentinia ?wetzelii *Morgenroth 1966*
Membranilarnacia compressa *Bujak 1994*
Membranilarnacia glabra *Agelopoulus 1967*
Membranosphaera maastrichtica *Samoilovich in Samoilovich et Mtchedlishvili 1961*
Melitasphaeridium *sp.*
Operculodinium nanaconulum *Islam 1983*
Oligosphaeridium *sp.*
Palaeoperidinium pyrophorum *(Ehrenberg 1938) Sarjeant 1967*
Palaeocystodinium australinum *(Cookson 1965) Lentin et Williams 1976*
Palaeocystodinium bulliforme *Ioannides 1986*
Palaeocystodinium benjamini *Drugg 1967*
Palaeocystodinium golzowense *Alberti 1961*
Palaeocystodinium lidiae *(Gorka 1963) Davey 1969*
Palaeotetradinium minusculum *(Alberti 1961) Stover et Evitt 1978*
Phthanoperidinium cre*nulatum (De Coninck 1975) Lentin & Williams 1977*
Rottnestia borussica *(Eisenack 1954) Cookson & Eisenack 1961*
Senegalinium iterlaaense *Nohr-Hansen & Heilmann-Clausen 2001*
Spinidinium densispinatum *Stanley 1965*
Spiniferites supparus *(Grugg 1967) Sarjeant 1970*
Systematophora *sp. 1 Heilmann-Clausen*
Stylodiniopsis maculatum *Eisenack 1954*
Tectatodinium rugulatum *(Hansen 1977) McMinn 1988*
Tectatodinium pellitum *Wall 1967*
Triblastula utinensis *O. Wetzel 1933*
Trigonopyxidia ginella *(Cookson & Eisenack 1960) Down & Sarjeant 1965*
Thalassiphora pelagica *(Eisenack 1954) Eisenack & Gocht 1960*
Thalassiphora delicata *Williams & Downie 1966*
Wilsonidium pechoricum *Iakovleva & Heilmann-Clausen 2010*
Wilsonidium *sp.*
Xenicodinium lubricum *Hansen 1977*

B. Prasinophyta and Acritarcha

Botryococcus *sp.*
Comasphaeridium *sp. Staplin et al., 1965*
Cyclopsiella *sp. Drugg & Loeblich Jr.1967*
Diacrocanthidium *sp. Deflandre & Foucher 1967*
Fromea ?laevigata *(Drugg 1967) Stover & Evitt 1978*
Leiosphaeridi*a sp. Eisenack 1958*
Paralecaniella identata *(Deflandre & Cookson 1955) Cookson & Eisenack 1970*
Palambages morulosa *O. Wetzel 1961*
Paucilobimorpha ?apiculata *(Cookson & Eisenack 1962) Prössl 1994*

Pseudomasia trinema *De Coninck 1969*
Veryhachium *sp.*

C. Nannoplankton

Biantholithus sparsus *Bramlette & Martini, 1964*
Braarudosphaera bigelowii *(Gran & Braarud, 1935) Deflandre, 1947*
Campylosphaera eodela *Bukry & Percival, 1971*
Chiasmolithus (Sullivania) danicus *(Brotzen, 1959) ex van Heck & Perch-Nielsen, 1987*
Chiasmolithus bidens *(Bramlette & Sullivan, 1961) Hay & Mohler, 1967*
Chiasmolithus (Sullivania) consuetus *(Bramlette & Sullivan) Hay & Mohler, 1967*
Coccolithus (Ericsonia) cavus *Hay & Mohler, 1967*
Coccolithus robustus *(Bramlette & Sullivan, 1961) Wise et al., 2002*
Coccolithus pelagicus *(Wallich, 1877) Schiller, 1930*
Coccolithus subpertusus *(Hay & Mohler, 1967) Wei & Pospichal, 1991*
Cruciplacolithus tenuis *(Stradner, 1961) Hay & Mohler, 1967*
Cruciplacolithus primus *Perch-Nielsen, 1977*
Cruciplacolithus frequens *(Perch-Nielsen, 1977) Romein, 1979*
Discoaster araneus *Bukry, 1971*
Discoaster diastypus *Bramlette & Sullivan, 1961*
Discoaster multiradiatus *Bramlette & Riedel, 1954*
Discoaster megastypus *(Bramlette & Sullivan, 1961) Bukry, 1973*
Discoaster nobilis *Martini, 1961*
Ellipsollithus distichus *(Bramlette & Sullivan, 1961) Sullivan, 1964*
Ellipsolithus macellus *(Bramlette & Sullivan, 1961) Sullivan, 1964*
Fasciculithus tonii *Perch-Nielsen, 1971*
Fasciculithus tympaniformis *Hay & Mohler, 1967*
Fasciculithus janii *Perch-Nielsen, 1971*
Heliolithus riedelii *Bramlette & Sullivan, 1961*
Markalius inversus *(Deflandre in Deflandre & Fert, 1954) Bramlette & Martini, 1964*
Neochiatozygus eosaepes *Perch-Nielsen, 1981*
Neochiastozygus junctus *(Bramlette & Sullivan, 1961) Perch-Nielsen, 1971*
Neochiastozygus perfectus *Perch-Nielsen, 1971*
Neochiastozygus saepes *Perch-Nielsen, 1971*
Neococcolithes dubius *(Deflandre in Deflandre & Fert, 1954) Black, 1967*
Placozygus sigmoides *(Bramlette & Sullivan, 1961) Romein, 1979*
Prinsius martinii *(Perch-Nielsen, 1969) Haq, 1971*
Rhomboaster bitrifida *Romein, 1979*
Rhomboaster cuspis *Bramlette & Sullivan, 1961*
Rhomboaster spineus *(Shafik & Stradner, 1971) Perch-Nielsen, 1984*
Sphenolithus primus *Perch-Nielsen, 1971*
Lithraphidites quadratus *Bramlette & Martini 1964*

10. Acknowledgments

11. References

Aleksandrova, G.N. (2001). Palynological Characteristics of Paleocene Deposits in the Lower Volga Region (Borehole 28, town of Dubovka). *Stratigraphy and Geological Correlation*, Vol. 9, No. 6, pp. 529-602, ISSN 0869-5938

Amon, E.O., Vasilyeva, O.N. & Zhelezko, V.I. (2003). Stratigraphy of the Talitsa Horizon (Paleocene) in the Central Trans-Urals. *Stratigraphy and Geological Correlation*, Vol. 11, No 3, pp. 278-292, ISSN 0869-5938

Andreyeva-Grigorovich, A.S. (1991). Phytoplankton (Dinocysts and Nannoplankton) Zonal Stratigraphy of the Paleogene of southern USSR (thesis). Kiev (Ukraine); Geological Institute, 47 p (in Russian)

Andreyeva-Grigorovich, A.S., Zaporozhec, N.I., Shevchenko T.V., Aleksandrova G.N., Vasilyeva O.N., Iakovleva A.I., Stotland, A.B. & Savitskaya, N.A. (2011). *Atlas of Paleogene Dinocysts of Ukraine, Russia and adjacent countries,* Naukova dumka, ISBN 978-966-00-1044-4, Kiev, Ukraine (in Russian)

Aubri, M.-P. (1986). Paleogene calcareous nannoplankton biostratigraphy of Northwestern Europe. *Palaeogeography, Palaeoclimatology, Palaeoecology*, Vol. 55., pp. 267–334, ISSN 0031-0182

Berggren, W.A., Kent, D.V., Swiher, C.C. & Aubry, M.-P. (1995). A revised Cenozoic chronology and chronostratigraphy, In Berggren, W.A., et al. (Eds.), *Geochronology, Time Scales, and Global Stratigraphic Correlation*, SEPM (Society for Sedimentary Geology) Special Publication, Vol.54, ISBN n.d., pp. 129-212

Brinkhuis, H. (1994). Late Eocene to early Oligocene dinoflagellate cysts from the Priabonian type-area (northeast Italy): biostratigraphy and palaeoenvironmental interpretation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, Vol.107, pp. 121–163, ISSN 0031-0182

Bujak, J.P. & Brinkhuis, H. (1998). Global warming and dinocysts changes across the Paleocene/Eocene boundary, In: *Late Paleocene–Early Eocene biotic and climatic events in the marine and terrestrial records,* M.-P. Aubry et al. (Eds.), pp. 277–295, New York: Columbia Univ. Press, ISBN n.d

Costa, L.A. & Manum, S.B. (1988). The description of the interregional zonation of the Paleogene (D1-D15) and Miocene (D16-D20). *Geologisches Jahrbuch*, Reihe A, Helt 100, pp. 321-330, ISSN 0341-6399

Crouch, E. & Brinkhuis, H. (2005). Environmental change across the Paleocene–Eocene transition from eastern New Zealand: a marine palynological approach. *Marine Micropaleontology,* Vol.56, pp. 138–160, ISSN 0377-8398

Crouch, E.M., Heilmann-Clausen, C., Brinkhuis, H., Morgans, H.E.G., Rogers, K.M., Egger, H., & Schmitz, B. (2001). Global dinoflagellate event associated with the late Paleocene Thermal Maximum. *Geology*, April 2001, Vol.29, No.4, pp. 315–318, ISSN 0091-7613

Dale, B. (1996). Dinoflagellate cysts ecology: modeling and geological applications, In: *Palynology: principles and applications,* J. Jansonius, & D.C. McGregor. (Eds.), pp. 1249–1276, American Association of Stratigraphic Palynologists Foundation, Vol.3, ISBN 9-931871-03-4, USA

De Coninck, J. (1988). Ypresian organic-walled phytoplankton in the Belgian Basin and adjacent areas. *Bulletin de la Societe Belge de Geologie*, Vol.97, No.3–4, pp. 287–319, ISSN 0-772-9464

Egger, H., Fenner, J., Heilmann-Clausen, C., Rögl, F., Sachsenhofer, R. & Schmitz, B. (2003). Paleoproductivity of the northwestern Tethyan margin (Anthering section, Austria) across the Paleocene–Eocene transition, In: *Causes and consequences of globally warm*

climates in the Early Paleogene, S.L. Wing et al. (Eds.), pp. 133–146, Geological Society of America Special Paper, Vol.369, ISSN 0072-1077

Fensome, R.A. & Williams, G.L. (2004). The Lentin et Williams Index of Fossil Dinoflagellates. *American Association of Stratigraphic Palynologists*, Contributions Series, No.42, 909 p, ISSN 0160-8843

Grachev, N.V., Zhizhchenko, B.P., Kolyhkalova, L.A. & Kholodilina, T.S. (1971). Paleogene sediments in the central Volga and Ural rivers basin, In: *Cainozoic Stratigraphy and Paleogeography of the south USSR gas and oil-bearing regions*, B.P. Zhizhchenko, V.A. Ivanova (Eds.), VNIIGas Publications, No. 31/39–32/40, pp. 36-45, Nedra, Moscow (in Russian)

Guasti, E., Speijer, R., Brinkhuis, H., Smit, J. & Steurbaut, E. (2006). Paleoenviromental change at the Danian-Selandian transition in Tunisia: Foraminifera, organic-walled dinoflagellate cyst and calcareous nannofossil records. *Marine Micropaleontology*, Vol.55, pp. 1–17, ISSN 0377-8398

Habib, D., Moshcovitz, S. & Kramer, C. (1992). Dinoflagellate and calcareous nannofossil response to sea-level change in Cretaceous–Tertiary boundary sections. *Geology*, Vol. 20, pp. 165–168, ISSN 0264-8172

Hansen, J.M. (1977). Dinoflagellate stratigraphy and echinoid distribution in Upper Maastrichtian and Danian deposits from Denmark. *Bulletin Geological Society Denmark*, Vol. 26, August 1977, pp. 1-26, ISSN 0011-6297

Haq, B.U., Hardenbol, J. & Vail, P.R. (1988). Mesozoic and Cenozoic chronostratigraphy and cycles of sea-level change. In: *Sea-level changes: an integrated approach*, Society of Economic Paleontologists and Mineralogists, Special Pubication No.42, pp. 71-108, Tulsa, Oklahoma (USA), ISBN 0-918985

Hardenbol, J. (1994). Sequence stratigraphic calibration of Paleocene and Lower Eocene continental margin deposits in the NW Europe and US Gulf Coast with the oceanic chronostratigraphic record, *Meeting Procceedings "Stratigraphy of the Paleocene"*, ISBN n.d., GFF, Vol. 116, pp. 49-51

Hardenbol, J., Thierry, J., Farley, M.B., Jacquin T., Graciansky P.-C. & Vail P.R. (1998). Mesozoic and Cenozoic sequence chronostratigraphic framework of European basins, In: *Mesozoic and Cenozoic sequence stratigraphy of European Basins,* P.-C. Graciansky, J. Hardenbol, T. Jacquin, P.R. Vail (Eds.) Society of Economic Paleontologists and Mineralogists, Special Publication No.60, Tulsa, Oklahoma, USA, ISBN 0-918985

Heilmann-Clausen, C. & Costa, L.I. (1989). Dinoflagellate Zonation of Uppermost Paleocene? to Lower Miocene in the Wursterheide Research Well, NW Germany, *Geologisches Jahrbuch,* A 111, pp. 431-521, ISSN 0341-6399

Heilmann-Clausen, C. (1985). *Dinoflagellate stratigraphy of the uppermost Danian to Ypresian in the Viborg 1 borehole, central Jylland*, *Denmark.* Danmarks Geologiske Undersøgelse. S. A. No.7, pp. 1–69, ISBN n.d

Heilmann-Clausen, C. (1994). Review of Paleocene dinoflagellates from the North Sea region. *Meeting Proceedings "Stratigraphy of the Paleocene"*, GFF, Vol. 116, pp. 51–53, ISBN n.d

Iakovleva, A.I., Brinkhuis, H., & Cavagnetto, C. (2001). Late Paleocene–Early Eocene dinoflagellate cysts from the Turgay Strait, Kazakhstan: correlation across ancient seaways. *Palaeogeogaphy, Palaeoclimatology, Palaeoecology*, Vol. 172, pp. 243–268, ISSN 0031-0182

Kirsch, K.-H. (1991). *Dinoflagellatenzysten aus der Obekreide des Helveticums und Nordultrahelveticums von Oberbayern*, Munchner Geowissenchaftliche, Abh.22, 306 p, ISBN n.d., München

Köthe, A. (2003). Paleogene Dinoflagellates from northwest Germany – Biostratigraphy and Paleoenvironment. *Geological Jahrbuch*, A 118, pp. 3-111, ISSN 0341-6399

Luterbacher, H.P., Ali, J.R., Brinkhuis, H., Gradstein, F.M., Hooker, J.J., Monechi, S., Ogg, J.G., Powell, J., Rohl, U., Sanfilippo, A. & Schmitz, B. (2004). The Paleogene Period, In F.M. Gradstein, J.G. Ogg, Smith A. (eds.) A Geologic Time Scale. Cambridge (UK): Cambridge University Press, pp. 384–408, ISBN n.d.

Marheinecke, U. (1992). Monographie der Dinozysten, Achritarcha und Chlorophyta des Maastrichtium von Hemmoor (Hierdersachsen). *Palaeontographica*, Abt. B, Vol.227, Lfg. 1-6, August 1992, pp.1-173, ISSN 1846-1933

Martini, E. (1971). Standard Tertiary and Quaternary calcareous nannoplankton zonation. *Proceedings of the Second Planktonic Conference*, Farinacci A. (Ed.), Roma, pp. 739–785, ISBN n.d

Mudge, D.C. & Bujak, J.P. (2001). Biostratigraphic evidence for evolving palaeoenvironments in the Lower Paleogene of the Faeroe-Shetland Basin. *Marine and Petroleum Geoogy*, Vol.18, pp. 577–590, ISSN 0264-8172

Musatov, V. A. (1996). *The Paleogene Nannoplankton Biostratigraphy of the Lower Volga Region (thesis)*, Saratov (Russian Federation): Lower Volga Institute of Geology and Geophysics, 25 p (in Russian)

Okada, H. & Bukry, D. (1980). Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation (Bukry, 1973, 1975). *Marine Micropaleontoogy*, Vol.5, pp. 321–325, ISSN 037-8398

Pechenkina, A.P. & Kholodilina, T.S. (1971). Some data on Paleogene deposits stratigraphy from Volga and Ural rivers basin based on Foraminiferas, In: *Cainozoic Stratigraphy and Paleogeography of the south USSR gas and oil-bearing regions*, B.P. Zhizhchenko, V.A. Ivanova (Eds.), VNIIGas Publications, No. 31/39–32/40, pp. 25-36, Nedra, Moscow (in Russian)

Perch-Nielsen, K. (1985). Cenozoic calcareous nannofossils. In: *Plankton Stratigraphy*, H. Bolli, J. Saunders, K. Perch-Nielsen (Eds.), pp. 427–554, Cambridge University Press (UK), ISBN 0 521 23576 6

Petrova, I.A. (1986). *Recommendations for methods of palynological preparation of sediments.* VSEGEI Publications, Leningrad, 77 p (in Russian)

Powell, A.J. (1992). Dinoflagellate cysts of the Tertiary System, In: *A stratigraphic index of Dinoflagellate cysts*, A.J. Powell (Ed.), pp. 155–251, London: British Micropaleontol. Soc. Ser., Published in 1992 by Chapman & Hall, ISBN 0412-362805, London (UK)

Powell, A.J., Brinkhuis, H. & Bujak, J.P. (1996). Upper Paleocene-Lower Eocene dinoflagellate cyst sequence biostratigraphy of southeast England. *Correlation of the Early Paleogene in Northwest Europe*, R.W.O'B. Knox, R.M. Corfield, R.E. Dunay (Eds.), Geological Society Special Publication, London. Vol.101, pp. 145–183, ISBN 0305-8719

Pross, J. & Schmiedl, G. (2002). Early Oligocene dinoflagellate cysts from the Upper Rhine Graben (SW Germany): paleoenvironmental and paleoclimatic implications. *Marine Micropaleontology*, Vol.45, pp. 1–24, ISSN 0377-8398

Razmyslova, S.S. & Nikitina, J.P. (1975). The Caspian Depression, In: *Stratigraphy of USSR. Paleogene system*, D.V. Nalivkin (Ed.), pp.204-219, VSEGEI Publications, Nedra, Moscow (in Russian)

Schiøller, P. & Wilson, G.J. (1993). Maastrichtian dinoflagellate zonation in Dan Field, Danish North Sea. *Review of Palaeobotany and Palynology*, Vol.78, pp. 321-351, ISSN 0034-667

Sissingh, W. (1977). Biostratigraphy of Cretaceous calcareous nannoplankton. Geologie en Mijnbouw, Vol.56, No.1, pp.37-65, ISSN 0016-7746

Slimani, H. (2001). Les kystes dinoflagellésdu Campanian au Danien dans la region de Maastricht (Belgique, Pays-Bas) et de Turnhout (Belgique): biozonation et corrélation avec d'autres regions en Europe occidentale. *Geologica et Paleontologica*, Vol.35, August 2001, pp. 161-201, ISSN 0344-659X

Sluijs, A., Pross, J. & Brinkhuis, H. (2005). From greenhouse to icehouse: organic-walled dinoflagellate cysts as paleoenvironmental indicators in the Paleogene. *Earth-Science Reviews*, Vol.68, pp. 281–315, ISSN 0012-8252

Steurbaut, E., Magioncalda, R., Dupuis, C., van Simaeus, S., Roche, E & Roche M.-I.E. (2003). Palynology, paleoenvironments, and organic carbon isotope evolution in lagoonal Paleocene-Eocene boundary settings in North Belgium, In: *Causes and consequences of globally warm climates in the Early Paleogene*, S.L. Wing, P.Gingerich, B. Schmitz, E. Thomas (Eds.). Geological Society of America, Special Paper No.369, pp. 291–317, ISSN 0072-1077

Stover, L.E. & Hardenbol, J. (1994). Dinoflagellates and depositional sequences in the lower Oligocene (Rupelian) Boom clay formation, Belgium. *Bulletin de la Societe Belge de Geologie*, Vol. 102, No.1–2, pp. 2–77, ISSN 0379-1807

Torricelli, S., Knezaurek, G. & Biffi, U. (2006). Sequence biostratigraphy and palaeoenvironmental reconstruction in the Early Eocene Figols Group of the Tremp-Graus Basin (south-central Pyrenees, Spain). *Palaeogeography, Palaeoclimatology, Palaeoecology*, Vol.232, pp. 1–35, ISSN 031-0182

Varol, O. (1998). Palaeocene calcareous nannofossil biostratigraphy, *Proceedings of the International Nannofossil Association Conference (Nannofossils and their applications)*, pp. 267-310, ISBN 0-7458-0237-0, London (UK), 1987

Vasilyeva, O.N. (2011). New wetzelielloidae dinocyst species (Dinophyceae) from Eocene deposits of Eastern Pricaspian. *IGG UrB RAS Publications*, Vol.158, pp. 14-20, ISBN 978-5-94332-090-3, Available from *http://www.igg.uran.ru/Publications/Tr158_2011/Tr158_Contents.htm* (in Russian)

Vasilyeva, O.N. & Musatov, V.A. (2010a). Paleogene Biostratigraphy of the North Circum-Caspian Region (Implication of the Dinocysts and Nannoplankton from the Novouzensk reference borehole), Part 1: Age Substantional and Correlation of Deposits. *Stratigraphy and Geological correlation*, Vol.18, No.1 (January-February 2010), pp. 83-104, ISSN 0869-5938

Vasilyeva, O.N. & Musatov, V.A. (2010b). Paleogene Biostratigraphy of the North Caspian Region based on Dinocysts and Nannofossils from the Novouzensk borehole. Article 2: Biotic events and Paeoecological Settings. *Stratigraphy and Geological correlation*, Vol.18, No.2, (March-April 2010), pp. 177-199, ISSN 0869-5938

Wall, D., Dale, B., Lohmann, G.P. & Smith, W.K. (1977). The environmental and climatic distribution of dinoflagellate cysts in the North and South Atlantic and adjacent seas. *Marine Micropaleontology*, Vol. 30. pp. 319–343, ISSN 0377-8398

Williams, G.L., Brinkhuis, H., Pearce, M.A., Fensome, R.A. & Weegink, J.W. (2004). Southern Ocean and global dinoflagellate cyst events compared: Index events for Late Cretaceous–Neogene. In: *Proceedings of the Ocean Drilling Program, Scientific Results, Vol.189*, N.F. Exon, J.P. Kennett, M.J. Malone (Eds.), Available from *http://www-odp.tamu.edu/publications/189_SR/107/107.htm*

Zhuravlev, V.S. (1970). The Caspian Depression, In: *Geology of USSR, Vol. XXI, Western Kazakhstan*, Part I (Geological description), Book 2, A.V. Sidorenko (Ed.). pp. 108-165, Nedra, Moscow (in Russian)
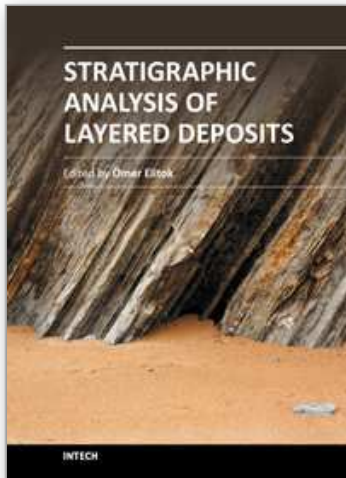
Stratigraphic Analysis of Layered Deposits

Edited by Dr. Ömer Elitok

Stratigraphy, a branch of geology, is the science of describing the vertical and lateral relationships of different rock formations formed through time to understand the earth history. These relationships may be based on lithologic properties (named lithostratigraphy), fossil content (labeled biostratigraphy), magnetic properties (called magnetostratigraphy), chemical features (named chemostratigraphy), reflection seismology (named seismic stratigraphy), age relations (called chronostratigraphy). Also, it refers to archaeological deposits called archaeological stratigraphy. Stratigraphy is built on the concept "the present is the key to the past" which was first outlined by James Hutton in the late 1700s and developed by Charles Lyell in the early 1800s. This book focuses particularly on application of geophysical methods in stratigraphic investigations and stratigraphic analysis of layered basin deposits from different geologic settings and present continental areas extending from Mexico region (north America) through Alpine belt including Italy, Greece, Iraq to Russia (northern Asia).

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Olga Vasilyeva and Vladimir Musatov (2012). The Paleogene Dinoflagellate Cyst and Nannoplankton Biostratigraphy of the Caspian Depression, Stratigraphic Analysis of Layered Deposits, Dr. Ömer Elitok (Ed.), ISBN: 978-953-51-0578-7, InTech, Available from: http://www.intechopen.com/books/stratigraphic-analysis-of-layered-deposits/the-paleogene-dinoflagellate-cyst-and-nannoplankton-biostratigraphy-of-the-caspian-depression

INTECH
open science | open minds