On the biostratigraphy and cyclostratigraphy of the Moscovian Stage in the type area

Marya Kh. MAKHLINA
Geocentre Moscow,
Varshavskoye shosse, 39a, 113105 Moscow (Russia)

Marya N. SOLOVIEVA † & Natalia V. GOREVA
Geological Institute of the Russian Academy of Sciences,
Pyzhevsky per., 7, 109017 Moscow (Russia)

Makhlina M. Kh., Solovieva M. N. & Goreva N.V. 1997. — On the biostratigraphy and cyclostratigraphy of the Moscovian Stage in the type area, *in* Crasquin-Soleau S. & De Wever P. (eds), Peri-Tethys: stratigraphic correlations, *Geodiversitas* 19 (2) : 235-245.

KEY WORDS
Moscovian,
Carboniferous,
biostratigraphy,
cyclostratigraphy,
Moscow Syncline.

ABSTRACT
Moscovian Stage deposits are widespread in Russia. The stage was established in 1890 by Nikitin. It is subdivised in four horizons: Vereya, Kashira, Podol'sk and Myachkovo. The subdivisions of the stage are based on studies of brachipods, foraminifera, conodonts, ammonites, bivalves, rugosans and plants. In this paper, new data are due to the correction of the standard section of the Moscovian Stage and its new interpretation. Cyclostratigraphy analysis based on the geological history of the region and its eustatics is a new aspect of the research presented in this paper.

MOTS CLÉS
Moscovien,
Carbonifère,
biostratigraphie,
cyclostratigraphie,
synclinal de Moscou.

RÉSUMÉ
Les dépôts du Moscovien sont largement répandus en Russie. Cet étage a été défini en 1890 par Nikitin. Il est subdivisé en quatre horizons : Vereya, Kashira, Podol'sk et Myachkovo. Les subdivisions de l'étage sont fondées sur l'étude des brachiopodes, foraminifères, conodontes, ammonites, bivalves, rugueux et plantes. Dans cet article, les nouvelles données proviennent de la révision de la coupe standard de l'étage et de ses nouvelles interprétations. L'analyse cyclostratigraphique fondée sur l'histoire géologique de la région et de son eustatisme est un nouvel aspect de la recherche présenté ici.

The Moscovian Stage deposits as well as the Middle Carboniferous ones as a whole are widespread in Russia and mineral deposits, including oil and gas, are rather common in these sediments. Subdivision and correlation of the Moscovian polyfacial deposits connected with different climatic zones (subtropical and boreal) represent the essential element of geological mapping and exploitation. Tendency to adequate reliability, precision of stratigraphic scales and high degree of correlations achievement caused the necessity to reinvestigate of the stage and substage stratotypes.

The Moscovian Stage was established by Nikitin in 1890 in the vicinity of Moscow. The upper limit of the stage was defined at the base of Gzhelian limestones.

The Moscovian, according to the ideas of Ivanov (1926) who had established the fundamental principles of the modern views on the volume of this stage and its subdivisions based on the studies of the depositional sequence in the southern part of the Moscow Syneclise, was subdivided into four horizons: Vereya, Kashira, Podol'sk and Myachkovo. The Tegulifera Horizon (the Kasimovian Stage) was considered to be a part of the Upper Carboniferous. Faunal assemblages of the Moscovian as a whole, as well as those of its subdivisions based on studies of brachiopods, foraminifers, conodonts, ammonites, bivalves, rugosans, plants, are relatively well known, zonal scales being established on the basis of some of these studied groups. Numerous publications are devoted to the Moscovian Stage in the type area, which most important are those by Ivanov (1926), Ivanova & Khvorova (1955), Rauser-Chernousova *et al.* (1951). Some papers are published during the last 20 years by Shik (1971), Makhlina (1972, 1976), Makhlina & Shik (1983), Makhlina *et al.* (1984), Goreva (1984), Solovieva (1984, 1986).

New data included in the present paper were obtained by the correction of the standard section of the Moscovian Stage and its new interpretation.

The lower boundary of the Moscovian Stage, according to the traditional views, coincides with the lower boundary of the Vereya Horizon. Changes in the standard section interpretation were caused by the discovery of a gap in the stratotype section of the Kashira Horizon, where deposits of the Tsna unit, established by Solovieva (1984, 1986) in the Tsna River basin (Ryazan-Saratov depression) in the eastern part of the Moscow Syneclise, are absent. Cyclostratigraphical analysis of the Moscovian Stage based on the geological history of the region and its eustatic tectonics is the new aspect of the research presented in this paper.

The Moscovian Stage in the type area is represented by marine deposits, *i.e.* by continuous series of transgressive deposits (130-150 m thick), in which sands and clays are gradually replaced by clayey and pure limestones. Subhorizontal bedding and cyclicity of deposits give opportunity to identify and follow up horizons, formations and relatively small subdivisions (subformations and members) in this region, and to identify cycles of different order.

If the Carboniferous system is considered to be a cycle of the third order, Middle and Upper Carboniferous (Pennsylvanian) are cycles of the fourth order. The Middle Carboniferous corresponds to a tectono-eustatic cycle of the fifth order, the Moscovian and Kasimovian stages to cycles of the sixth order (Table 1). According to Tikhomirov (1988), the latter includes the three units corresponding to three phases of the transgression: initial (α), maximum (β) and terminal, or regressive phase (γ). Cycles of the sixth order may be complete or shortened, the former consisting of three cycles of the seventh order, the latter of two cycles of the same order, the initial phase being absent. These cycles could be followed up in different facies throughout a region, and their formation corresponds to the maximum tectono-eustatic changes of basin level. The Aza, Vereya and Tsna subdivisions apparently correspond to the cycle of the seventh order, or to the initial phase of the transgression (α) (Table 1). The combined Kashira, Podol'sk and Myachkovo horizons correspond to the cycle of the seventh order, or to the maximum phase of the transgression (β), whereas three horizons of the Kasimovian Stage of the Upper Carboniferous correspond to a regressive phase (γ). Within the cycles of the seventh order there

TABLE 1. — Subdivision of the Moscovician of the Russian Platform.

Regional scale	Local scale Moscow Synclise			Cyclostratigraphy scale order of cycles						
				IX	VIII	VII	VI	V	IV	III
Horizon	Formation	Subformation	Member	Horizon (Formation)	Substage		Stage	Series	Subsystem	System
Krevyakino	Krevyakino	Voskresensk		Krevyakino	Krevyakinian	γ	Kazimovian	Upper	Pennsylvanian	Carboniferous
		Suvorovo								
Myachkova		Peski		Peski	Myachkovian $\beta 3$	β	Moscovian	Lower		
		Novlinskoe		Novlinskoe						
Podol'sk	Podol'sk	Shchurovo		Shchurovo	Podolskian $\beta 2$					
		Ulitino		Ulitino						
		Vas'kino		Vas'kino						
Kashira	Kashira	Smedva	Smedva	Smedva	Kashirian $\beta 1$					
			Rostislavl'							
		Lopasnya	Lopasnya	Lopasnya						
			Khatum							
		Nara	Nara	Nara						
			Polustova Gora							
		Tsna		Tsna	Tsnian? $\alpha 3$	α				
Vereya	Vereya	Upper	Ordynka		Vereyan $\alpha 2$					
			Alyutovo							
		Lower	Shat							
Melekess	Aza			Aza	$\alpha 1$					

are smaller cycles - those of the eighth order, corresponding to separate horizons (substages in the proposed cyclostratigraphic scale, Table 1) and those of the first order, corresponding to subformations (horizons in the proposed cyclostratigraphic scale, Table 1).

Every stratigraphic unit of any rank can be subdivided into two parts: lower, corresponding to the transgressive phase of sedimentation, and upper, corresponding to the regressive phase. Contemporaneous stratigraphic units of different facies, which were formed in the paleobasin as a lateral sequence of rocks reflect, near-shore, periferal, shallow-water and relatively deep-water environments. Periodicity in the distribution of faunal assemblages, which always show maximum diversity in a transgressive part of a cycle and low diversity in its regressive part (Makhlina & Shik 1983), is a characteristic feature of all simultaneously formed polyfacial stratigraphic units corresponding to the cycles (Figs 1-3). Boundaries between these units correspond to historico-geological changes of sedimentation patterns, *i.e.* to changes in abiotic environment taking place simultaneously in the whole region (Makhlina 1996).

The main criteria for distinguishing and tracing of transgressive-regressive cycles in which combination form stratigraphic units (formations, subformations) are the following: sedimentological and faunistic content, features of texture, periodicity in the distribution of all groups of fauna in the section, as well as biostratigraphical characteristics for the definition of the geological age of the units. The sufficient methodical significance of the lithological-palaeoecological criteria, elaborated by Osipova & Belskaya (1967), should be emphasized in this respect.

Leaving aside the problem of the lower boundary of the Moscovian Stage, that is still discussed (Solovieva 1986; Alekseev *et al.* 1994), let us give brief characteristics of the stratotype sections of the horizons (formations, subformations), *i.e.* of units of the regional and local scales of the Moscovian Stage, accepted in Russia (Anonymous 1988, Table 1).

The Vereya Horizon (Formation), in order to reinvestigate the stratotype, was studied near the village Alyutovo on the right bank of the Pronja river, where it is lying transgressively on Lower Carboniferous deposits (Solovieva 1986) (Fig. 2-I). Red sand and clays, glauconite sandstones can be found in the base of the section, crinoid-bryozoan sandy limestones with foraminifers, as well as interbedding of crinoid limestones, variegated clays, marls with brachiopods and bryozoans overlying them (Ivanova & Khvorova 1955). The thickness of the formation in this section is 10 m, and in the region it changes from 10 to 35 m. The Vereya Formation is subdivided into two subformations, lower and upper (Anonymous 1988). Solovieva (1986) proposed the foraminiferal *Profusunella cavis, Aljutovella aljutovica, Al. artificialis* Zone. The typical assemblage of the Vereya Horizon (Formation) is represented by the following species of foraminifers: *Eostaffella mutabilis, Schubertella pauciseptata, Pseudostaffella subquadrata, Profusulinella cavis, P. parva, Aljutovella aljutovica, A. artificialis, A. scelnevatica, A. cubaea, A. elongata.*

Deposits of the Vereya Horizon (Formation) correspond to the conodont *Idiognathoides tuberculatus, Id. marginodosus* Zone. Characteristic species of the zone are *Idiognathoides donbassicus, Id. sinuatus, Id. fossatus, Id. corrugatus, Idiognathodus incurvus, Neognathodus atokaensis, N. bassleri, Diplognathodus coloradoensis, D. orphanus, Streptognathodus parvus.*

According to Solovieva (1984) and Alekseev (1994), the Vereya Formation *sensu* Ivanov (1926) is only characterized by the Alyutovo fusulinid and conodont assemblages. The overlying and underlying Shat and Ordynka members (Table 1) do not contain any other faunistic complex except Alyutovo age.

In the standard of the Moscovian Stage, the position above the Vereya Formation in the case of normal sequence is occupied by the Tsna unit distinguished by Solovieva (1984, 1986). In the stratotype section (Yambirnoye Quarry, Ryazan region, Fig. 1-II) it is represented by interbedding of detrital and dolomitized fine-grained limestones with greenish clays and marls, rarely with micro-grained dolomites (Fig. 2-II). The thickness of the subformation in the stratotype is 16.5 m (Table 1, Local Scale, 1988).

Deposits of the Tsna Subformation correspond to the Zone *Aljutovella priscoidea, Hemifusulina volgensis*. This typical foraminiferal assemblage, characterized by a high degree of similarity in all regions where these deposits are represented (the Russian Platform, the Donets Basin, the Cisuralian Depression, Urals, Tien-Shan, etc.), includes the following species: *Schubertella gracilis znensis, Sch. galinae, Ozawainella digitalis, Profusulinella prisca timanica, P. nuratovensis, P. jvata, Taitzehoella prolibrovichi, T. pseudolibrovichi, Aljutovella parasaratovica, A. saratovica, A. priscoidea, A. znensis, Hemifusulina dutkevichi, H. volgensis.*

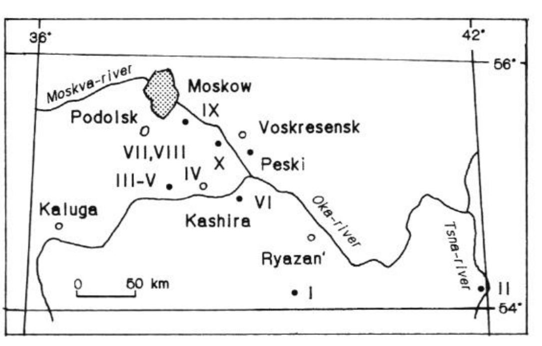

FIG. 1. — Location map of the stratotype sections (I-X) of the Moscovian Stage (for the list of the sections, see figures 2, 3).

According to the preliminary investigations, the Tsna Subformation corresponds to the conodont *Neognathodus bothrops, Streptognathodus transitivus* Zone. The lower boundary is defined by the entry of *Neognathodus bothrops*, the upper one by the incoming of *Streptognathodus dissectus*. Deposits are characterized by an impoverished conodont complex. Typical species are as follows: *Neognathodus bothrops, Streptognathodus parvus, Idiognathodus delicatus, Id. obliquus, Diplognathodus coloradoensis*.

Deposits of the Tsna Subformation have a spotty distribution due to the transgressive bedding on it of the Kashira Horizon that corresponds to the beginning of maximum transgression (β_1, Table 1).

The Nara Subformation is represented by an interbedding of poorly coloured micrograined limestones and dolomites with biodetrital limestones and clay seams. The thickness of the deposits can reach 28 m (Fig. 2-III). Materials available give an opportunity to substantiate the recognition of the local *Hemifusulina kashirica, H. moelleri, Beedeina pseudoelegans* Zone. In the eastern sections of the southern part of the Russian Platform there are numerous *Neostaffella, Profusulinella pseudolibrovichi, Pr. eolibrovichi, Pr. syzranica, Pr. mutabilis, Hemifusulina kashirica, H. pseudobochi, H. moelleri, Beedeina bona, B. ozawai, B. pseudoelegans, B.* cf. *proozawai, B. kayi*. The Nara Subformation corresponds to the conodont *Neognathodus bothrops, Streptognathodus dissectus* Zone. It is characterized by the following species: *Neognathodus bothrops, N. kashiriensis, Str. dissectus, Str. parvus. Diplognathodus coloradoensis* is very common.

The overlying Lopasnya Subformation is represented by interbedding of pinkish and greenish limestones, detrital, micrograined, with cherts, variegated marls, more rarely dolomites. Its thickness is 15-30 m (Fig. 2-IV). The subformation corresponds to the local *Moellerites lopasniensis, Beedeina ozawai, Fusulinella subpulchra* Zone (Solovieva 1986). The following complex is characteristic: *Ozawainella stellae, Fusiella praecursor paraventricosa, F. praetypica, Neostaffella larionovae, Fusulinella subpulchra, Hemifusulina moelleri, H. kashirica communis, H. splendida, Beedeina ozawai, B. paraozawai, B. pseudoelegans.*

The Rostislavl' member consists of two parts. The lower one is represented by interbedding of clays and limestones, or by unfossiliferous clays, or by dolomitic marls (bed 23, Fig. 2-IV), the upper one by sands, aleurolites, sandstones and conglomerate (bed 21, Fig. 2-V). The lower part corresponds to a regressive phase and terminates the Lopasnya Subformation, the upper part, being the transgressive one, corresponds to the base of the Smedva Subformation.

The Smedva Subformation, or according to Ivanov (1926) "dolomites of Smedva", contains micrograined dolomites and detrital limestones (Fig. 2-V). It was referred to the Podolsk' Horizon by Ivanov and Solovieva, many of the subsequent authors assigned this subformation to the Kashira Horizon. "Dolomites of Smedva" represent lagoonal rocks characteristic of a regressive phase. This environment was unfavorable for fusulinids. That is why deposits of the Smedva Subformation are very poorly characterized by this group of fauna. The Lopasnya and Smedva subformations correspond to the conodont *Neognathodus medadultimus, Streptognathodus dissectus* Zone. The lower limit of the zone is defined by the incoming of *Neognathodus medadultimus*, the upper one by the entry of *N. medexultimus*. Characteristic species are as follows: *N. bothrops, N. medadultimus, N. colombiensis, Idiognathodus obliquus, I. delicatus, I. robustus, Streptognathodus dissectus, Diplognathodus coloradoensis*. This zone can be subdivided into two local subzones, each with a characteristic assemblage: Subzone *Neognathodus bothrops, N. medadultimus*, corresponding to the Lopasnya Subformation, and Subzone *N. medexultimus* corresponding to the Smedva Subformation. The volume of the former sub-zone is designated by the coexistence of *N. bothrops* and *N. medadultimus*, the characteristic complex being represented by *N. bothrops, N. medadultimus, Streptognathodus dissectus, Idiognathodus obliquus*. The volume of the latter subzone is designated by the presence of *Neognathodus medexultimus, Streptognathodus dissectus, Idiognathodus obliquus, I. robustus*.

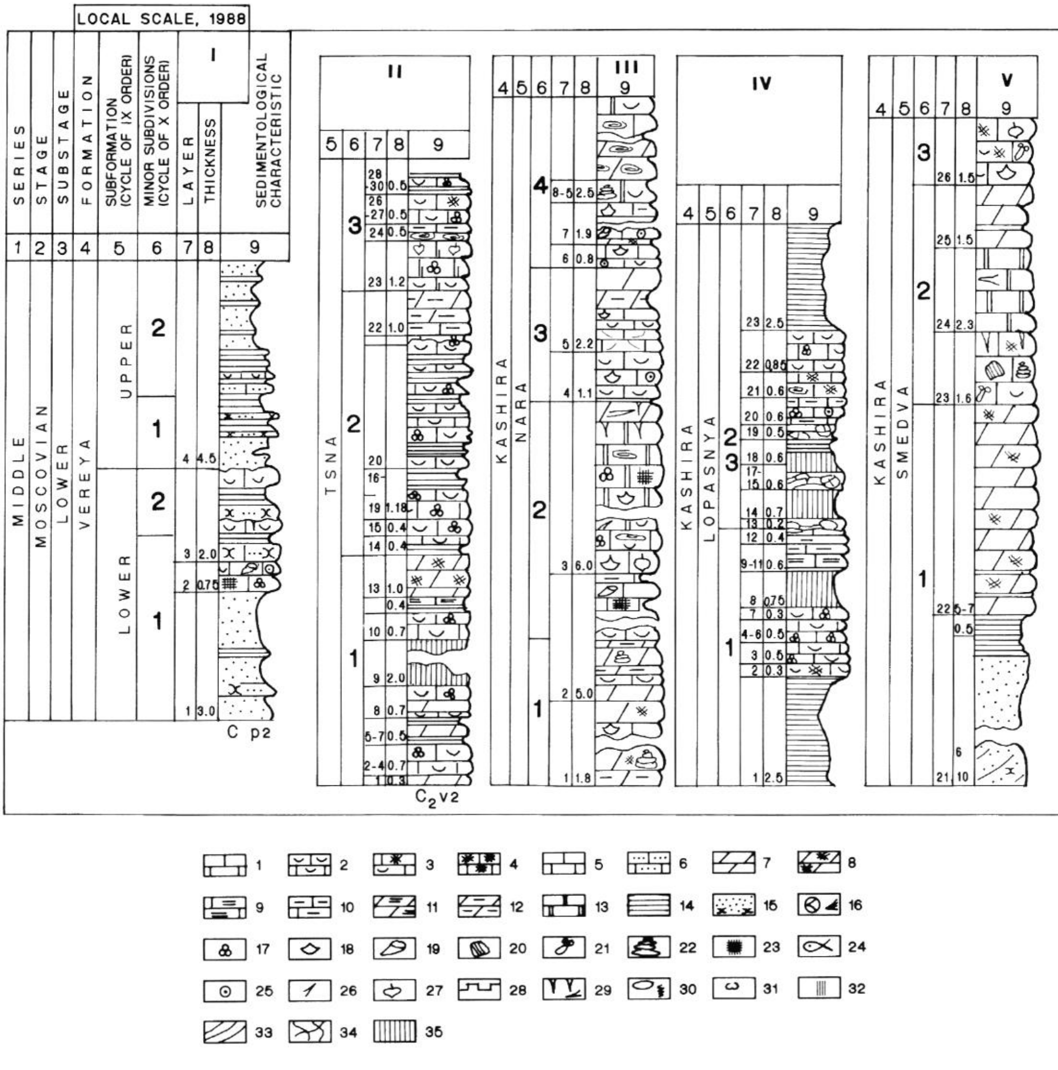

FIG. 2. — Sections of the Moscovian Stage (Vereya, Tsna and Kashira beds): **I**, outcrops near the Alyutovo village, right bank of the Pronja River (Solovieva 1986), lectostratotype of the Vereya Formation; **II**, Yambirnoye Quarry near the Yambirnoye village, left bank of the Tsna River (Solovieva 1986); the Tsna Subformation holostratotype; **III**, outcrops along the Oka, Nara, Protva, Besputa rivers; section of the Nara Subformation of the Kashira Formation (Ivanova & Khvorova 1955, fig. 13); **IV**, outcrop near the Lapino village at the left bank of the Lopasnya River (near the Khatun village) (Solovieva 1986); stratotype of the Lopasnya Subformation; **layer 1**, Khatun member; **layer 23**, Rostislavl'member, the lower part; **V**, outcrops along the Oka, Nara, Protva, Besputa rivers; sections of the Smedva Subformation of the Kashira Formation; **layer 21**, Rostislavl' member, the upper part (Ivanova & Khvorova 1955, fig. 13).
Legend for figures 2-3: Deposits **1-16**; **1**, limestone; **2**, detrital or biomorphic-detrital limestone; **3**, sludge limestone; **4**, micrograined limestone; **5**, coprolite-detrital limestone; **6**, lime sandstone; **7**, dolomite; **8**, micrograined dolomite; **9**, clayey limestone; **10**, marl; **11**, clayey dolomite; **12**, dolomite marl; **13**, dolomitized limestone; **14**, lime and dolomite clay; **15**, sand silt, sandstone; **16**, fragments of chert and limestone. Fossils **17-29**; **17**, foraminifers; **18**, brachiopods; **19**, solitary corals; **20**, colonial corals; **21**, bivalves; **22**, gastropods; **23**, bryozoans; **24**, fishes; **25**, crinoids; **26**, echinoids; **27**, algae; **28**, algae Ivanovia tenuissima; **29**, traces of mud-eaters; Secondary alterations, structure and other signs **30-35**; **30**, cherts; **31**, caverns; **32**, styliolites; **33**, cross-bedding; **34**, limestone breccia; **35**, gap.

The Podol'sk Horizon (Formation), a maximum phase of the Moscovian transgression (β_2), is represented mainly by biomorphic limestones with seams of micrograined dolomites, greenish marl and clays; the total thickness is 25-40 m. Three subformations can be identified within this formation.

The lower one (Vas'kino Subformation) is represented by micrograined limestones and dolomites with biomorphic-detrital limestone seams; the thickness is 7-12 m (Fig. 3-VI). At the base, there are conglomerates and marls that could be traced regionally. The Vas'kino Subformation corresponds to the fusulinid *Fusulinella colaniae, Beedeina elegans* Zone. The characteristic complex is as follows: *Ozawainella kurakhovensis, Neostaffella rostovzevi, N. sphaeroidea, Taitzeheella librovitchi atelica, Fusulinella colaniae, Hemifusulina splendida, Beedeina elegans, B. ozawai, B. elshanica vaskinensis, Putrella triangula.*

The overlying Ulitino Subformation is similar to the Vas'kino in the sedimentological aspect but differs in the presence of limestone seams with the algae *Ivanovia tenuissima.* The thickness of the deposits is 12-18 m (Fig. 3-VII). The subformation corresponds to the local *Fusulinella*

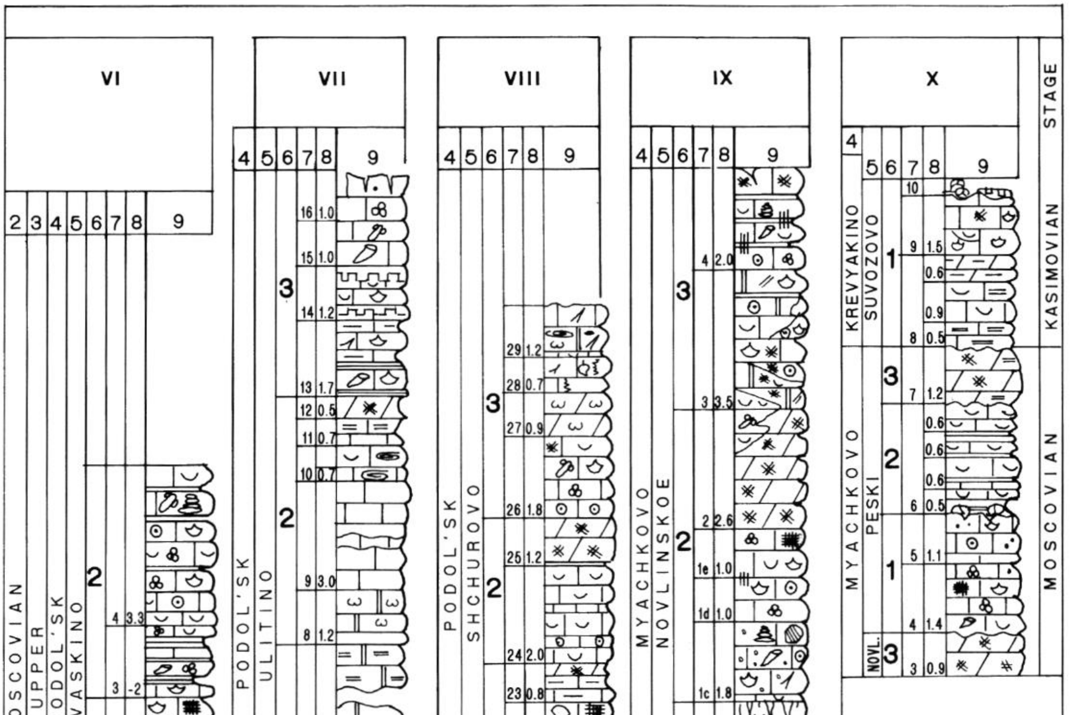

FIG. 3. — Sections of the Moscow Stage (Podol'sk, Myachkovo horizons): **VI**, sections in the basin of the Oka River east of the Kashira town, near Bolshoye Runo village, pogost Rostislavl', and near Vas'kino village; section of the Vas'kino Subformation of the Podol'sk Formation (Ivanovan & Khvorova 1955, fig. 20); **VII**, Quarry near the town Podol'sk; stratotype of the Podol'sk Formation (Ulitino Subformation) (Ivanova & Khvorova 1955, fig. 23); **VIII**, Quarry near the town Podol'sk, stratotype of the Podol'sk Formation (Shchurovo Subformation) (Ivanova & Khvorova 1955, fig. 23); **IX**, Quarry near the town Podol'sk hypostratotype of the Novlinskoe Subformation of the Myachkovo Formation (Ivanova & Khvorova 1955, fig. 23); **X**, Afanasievo Quarry near the Afanasievo village on the right bank of the Moskva River; section of the Myachkovo-Krevyakino boundary layers (Middle/Upper Carboniferous boundary); **layer 6**, "lower conglomerate"; **layer 7**, "dolomite of Turaevo"; **layer 8**, "garnasha"; **layer 9**, "sharsha"; **layer 10**, "upper conglomerate". Hypostratotype of the Peski Subformation of the Myachkovo Formation; it is near Peski railway station, on the left bank of the Moskva River (Makhlina *et al.* 1972, 1984).

vozghalensis, *Fusulina litinensis* Zone, the following complex being considered as a characteristic one: *Fusiella pulchella*, *Neostaffella ozawai*, *Ozawainella mosquensis*, *Fusulinella vozhgalensis*, *Hemifusulina stabilis*, *H. polasnensis*, *Fusulina ulitinensis*, *F. panconensis*, *Putrella brazhnikovae*.

The uppermost part of the Podol'sk Formation is identified as the Shchurovo Subformation represented by dolomites, biomorphic limestones with greenish marl and clayey limestone seams. Limestones are often dolomitized and siliceous. The thickness of the deposits is 8-12 m (Fig. 3-VIII). The Shchurovo Subformation corresponds to *Beedeina kamensis*, *Putrella brazhnikovae*, *Ozawainella mosquensis* Zone with accompanying characteristic complex of *Fusulinella bocki*, *F. vozghalensis*, *B. elegans*, *B. shellwieni*, *B. elshanica*.
Deposits of the Podol'sk Horizon correspond to the conodont *Neognathodus medexultimus*, *Idiognathodus podolskensis* Zone. The lower limit of the zone is defined by the entry of these two species, the upper one by the incoming of *Neognathodus roundyi*. The conodont complex as a whole is not characteristic enough, the following species being typical: *Idiognathodus podolskensis, I. magnificus*, *I. delicatus*, *Neognathodus medadultimus*, *N. medexultimus*.

The Myachkovo Horizon (Formation) accomplishes the maximum phase of the Moscovian transgression (β_3). It is represented by biomorphic limestones with micrograined dolomite seams and lightcoloured marl lenses. The total thickness of the deposits is 17-37 m. The formation is divided into two subformations.

The lower one, Novlinskoe Subformation, is represented by various limestones (detrital, biomorphic-detrital) with micrograined limestone and dolomite seams, coral-fusulinid limestones being typical of its lower part (Fig. 3-IX). The thickness of the deposits is 10-23 m. Deposits of the subformation correspond to *Fusulinella bocki*, *F. rara*, *Beedeina samarica* Zone. The characteristic complex includes *Schubertella myachkovensis*, *Fusiella typica*, *Neostaffella paradoxa*, *N. sphaeroidea*, *Fusulinella bocki*, *F. bocki pauciseptata*, *F. fluxa*, *F. mosquensis*, *F. rara*, *Beedeina samarica*, *Pulchrella pulchra*, *Hemifusulina bocki*, *H. stabilis*, *Fusulina cylindrica*.

The upper one, Peski Subformation, is represented by biomorphic-detrital limestone with lenses of lightcoloured marls and clays. "Turaevo" micrograined dolomite at the top accomplishes the maximum phase of the Moscovian transgression. The thickness of the deposits is 7-15 m (Fig. 3-X). Deposits of the Peski Subformation correspond to the local *Fusulinella podolskensis*, *F. cylindrica domodedovi* Zone. The data available, especially those concerning fusulinid distribution (Makhlina *et al.* 1972) give an opportunity to indicate complex typical of the deposits of the Peski Subformation: *Schubertella mjachkovensis*, *Ozawainella mosquensis*, *Fusulinella bocki*, *F. rara*, *F. podolskensis*, *F. helenae*, *F. mosquensis*, *F. kumpani*, *Hemifusulina bocki*, *Fusulina cylindrica domodedovi*, *F. mosquensis*, *F. mjachkovensis*, *F. pachrensis*, *F. fortissima*.

The Myachkovo Horizon (Formation) corresponds to the conodont *Neognathodus roundyi*, *Streptognathodus cancellosus* Zone. The lower limit of the zone is defined by the entry of *Neognathodus inaeuqualis*, *N. roundyi*, the upper one by the incoming of *S. subexcelsus*, *Idiognathodus fisheri* and by the disappearance of *Neognathodus* species. Index species are dominating in this complex, *N. medexultimus*, *N. inaequales*, *Idiognathodus delicatus*, *I. trigonolobatus* being characteristic ones. The zone is subdivided into two parts considered nowadays to be local subzones. The Novlinskoe Subformation corresponds to the *Neognathodus inaequales* Subzone, characterized by the acme of the index species. The Peski Subformation corresponds to the *N. roundyi* Subzone, *i.e.* to the period of *N. roundyi* mass development and incoming of *N. dilatatus* and *Idiognathodus trigonolobatus*.

The position of the upper boundary of the Moscovian Stage, *i.e.* the Middle/Upper Carboniferous, is still discussed at present time. This boundary was established by Ivanov (1926) in outcrops and quarries along the Moskva river and its tributaries (in Myachkovo, Suvorova Gora, Krevyakino and other localities). All these localities are connected to a separate synsedimentary elevation in the Moscow zone of elevations and are characterized by varying facies of the boundary beds, as well as by numerous erosional surfaces with an intraformational conglomerate interbed. Some marker beds traced by Ivanov (1926) in the boundary beds in this region got their own names: bed 7 - "svinya", or "dolomite of Turaevo" (Makhlina *et al.* 1972) (Fig. 3-X) - lightgreen argillaceous micrograined dolomite; bed 8 - "garnasha" - interbedding of green, red clays and marls, limestones, sometimes with conglomerate interbeds. In some sections, this member is replaced by dolomitic marls and argillaceous limestones (Fig. 3-X); bed 9 - "sharsha" - white micrograined nonhomogeneous "conglomerate-like" limestone with caverns.

The position of the upper boundary of the Moscovian Stage, according to the conclusions based on brachiopods and foraminifera studies, is changing within the interval from "the lower conglomerate to the base of the upper conglomerate", *i.e.* within the interval from bed 6 to bed 10 on Fig. 2-X (Ivanov 1926; Ivanova & Khvorova 1955; Bolkhovitinova 1937; Rauser-Chernousova & Reitlinger 1954; Makhlina *et al.* 1972). Further studies of the lower conglomerate interbed (bed 6 on Fig. 3-X) underlying "dolomite of Turaevo" showed that this conglomerate was from intraformational origin and not of interstagial one, because all these interbeds contained fusulinids of *Fusulina cylindrica* Zone, indicating the Myachkovo (Peski Subformation) age of the "lower conglomerate" (Makhlina *et al.* 1972).

The complex of foraminifers above the "dolomite of Turaevo" (in beds 8-9, *i.e.* in "garnasha" and "sharsha") is represented by numerous small foraminifers and fusulinids with a wide vertical distribution, *Ozawainella angulata*, *Globivalvulina* ex gr. *granuloza*, *Schubertella mjachkovensis*, *Endothyra* sp. among them. Recently, few oppressed *Obsoletes obsoletes* were found in these beds. Mass *Obsoletes* enter above the bed 9 ("sharsha"). Therefore, we draw the boundary between the Myachkovo and the Krevyakino horizons (*i.e.* the Middle/Upper Carboniferous boundary) at the top of the "dolomite of Turaevo" (bed 7 on Fig. 3-X) between the two conglomerates, the lower one and the upper one.

Conodont distribution in the boundary beds demonstrates that the "garnasha"-"sharsha" beds should be assigned to the Kasimovian stage, *i.e.* to the local Subzone *Idiognathodus arendti* of the *Streptognathodus oppletus* Zone (the Krevyakino Horizon). The lower limit of the subzone is defined by the incoming of *Idiognathodus arendti, I. fisheri, Streptognathodus subexcelsus, S. oppletus,* the upper one by the entry of *S. sagittalis* and the disappearance of *Idiognathodus trigonolobatus.* Characteristic species are as follows: *Streptognathodus subexcelsus, S. oppletus, S. excelsus, S. cancellosus, Idiognathodus trigonolobatus, I. fisheri, I. arendti.*

The upper boundary of the Myachkovo Horizon (Formation), established on the basis of cyclostratigraphic analysis at the top of the "dolomite of Turaevo", is proved not only by faunal distribution data but by also sedimentological and geochemical data. Bed-by-bed comparison of detrital limestone microstructures on the Myachkovo-Krevyakino boundary demonstrates that in the former cloddy pelletal cement structures dominate, whereas in the latter (the Suvorovo and Voskresensk subformations) micrograined ones dominate. Comparison of the geochemical coefficients in the boundary beds also demonstrates the difference in the quantitative content of microelements: in carbonate rocks and in clays and marls in the Novlinskoe and Peski subformations, it is respectively 10 and 2000 times more, than in similar rocks of the Suvorovo and Voskresensk subformations. This level, therefore, designates the end of the Moscovian transgression maximum phase (β_3) and the beginning of a regressive phase (γ). It corresponds to the Kasimovian time, characterized by the terrigenous supply with the microelemental content, different from the Moscovian, by facies variability in the zone of synsedimentary elevations, followed by the erosion and prevailing of unfavorable environments for many groups of fauna, particularly foraminifers (Makhlina 1976; Makhlina *et al.* 1972).

Based on the data obtained from cyclostratigraphical analysis of the Middle/Upper Carboniferous deposits in the type area, one may conclude that the Kasimovian/Gzhelian boundary was more significant than the Moscovian/ Kasimovian one, because the Kasimovian Stage represented the terminal phase of the Moscovian transgression, whereas the Gzhelian Stage corresponded to the maximum phase of the following, the Gzhelian/Asselian transgression (both the Moscovian and the Gzhelian/Asselian transgressions represent cycles of the sixth order). This cyclostratigraphical boundary supports the views of Nikitin (1890), who proposed to draw the boundary between the "Moscow Series" and the Gzhelian Stage below the limestones of Gzhel.

Taking into account everything mentioned above, one may come to the conclusion that almost each of the subdivisions of Kashira, Podol'sk and Myachkovo horizons (formations) are characterized by zonal conodont and fusulinid assemblages, and can be traced in different facies all over the major part of the Moscow Syneclise and other regions of the Russian Platform, and also outside of it. It gives the opportunity to raise the rank of these subdivisions and to regard them as the horizons (cycles of the eighth order) of the Russian Platform Regional Scale (Table 1). We believe also that the horizons established by Ivanov in 1926 (the Vereya, Kashira, Podol'sk and Myachkovo - cycles of the eighth order) correspond to stages, as it has been demonstrated by Ivanova in 1955 and proved by numerous data, obtained during the following years. However, in May 1995, the Interdepart-mental Stratigraphic Committee of Russia decided to consider horizons of the Moscovian Stage of the Global Scale as substages with their own names. As to the Tsna Subformation, the problem of its rank still remains debatable (should it be a horizon or a substage?). Solovieva considered the Tsna beds to be of a stage rank. It can be traced in the Russian Platform, as well as in Tien-Shan, Donets Basin, Urals and other regions.

REFERENCES

Anonymous 1990. — *Decision of the Interdepartmental Regional Stratigraphic Conference on the Middle and Upper Paleozoic of the Russian Platform (Leningrad, 1988). Carboniferous System.* Léningrad, 95 p. [in Russian].

Alekseev A. S., Barskov I. S. & Kononova L. I. 1994. — Stratigraphy of the Lower Moskovian Substage (Middle Carboniferous) from Central Russia according to conodont investigation. *Vestnik MGU*, Serie 4, Geologia 2: 33-46 [in Russian].

Bolkhovitinova M. A. 1937. — Myachkovo section according to new paleontology data. *Thesis of report in XVIII session of International Geological Congress*, Moscow: 295 [in Russian].

Goreva N. V. 1984. — Conodonts of the Moscovian Stage in the Moscow Syneclise. *Sbornik "Paleontological characteristics of stratotypical and base Carboniferous sections in the Moscow Syneclise"*, Moscow: 44-122 [in Russian].

Ivanov A. P. 1926. — Middle-Upper Carboniferous deposits of Moscow province. *Bulletin MOIP*, volume 4: 13-180 [in Russian].

Ivanova E. I. & Khvorova I. V. 1955. — Stratigraphy of the Middle and Upper Carboniferous in the western part of the Moscow Syneclise. *Trudy Paleontologischeskyi Institute Academy Nauk USSR*, Moscow, tome 53: 1-281 [in Russian].

Khvorova I. V. 1953. — Evolution of Middle and Upper Carboniferous Basin in the western part of the Moscow Syneclise. *Trudy PIN*, tome XLIII, Moscow, 220 p. [in Russian].

Makhlina M. Kh. 1976. — Comparative characteristics of the structure of Moskovian, Kasimovian and Gzhelian-Asselian stages of the Upper Paleozoic in Podmoskovye. *Izvestya VUZov. Geologia i razvedka*, No. 6: 3-10 [in Russian].

— 1996. — Cyclic stratigraphy, facies and fauna of the Lower Carboniferous (Dinantian) of the Moscow Syneclise and Voronezh Anteclise, *in* Recent Advances in Lower Carboniferous Geology, *Geological Society*, Special Publication, No. 107: 359-364.

Makhlina M. Kh., Koulikova A. M. & Bourkovsky V. P. 1972. — New data about a detailed comparison of stratigraphic sections. *Izvestya VUZov, Geologia i razvedka*, No. 10: 13-20 [in Russian].

Makhlina M. Kh. & Shik E. M. 1983. —Cyclostratigraphic method for a detailed investigation of Upper and Middle Carboniferous deposits in Podmoskovye. *Izvestya VUZov. Geologia i razvedka*, No. 2: 3-14 [in Russian].

Makhlina M. Kh., Isakova T.N. & Joulitova V.E. 1984. — Upper Carboniferous in Podmoskovye. *Vestnik sbornik Verhni Carbon SSSR*, Nauka: 5-14 [in Russian].

Nikitin S. N. 1890. — Carboniferous deposits of the Moscow area and artesian waters in the vicinity of Moscow. *Trudy Geologischeskyi Com.*, tome 5, No. 5: 1-181 [in Russian].

Osipova A. I. & Belskaya T. N. 1967. — An experience of a lithological-palaeoecological study of the Visean-Namurian deposits in the Moscow Syneclise. *Lithologia i polezn. iskop.*, No. 5: 118-142 [in Russian].

Rauser-Chernousova D. M., Kireeva G. D. & Leontovich G. E. 1951. — Middle Carboniferous fusulunids of the Russian Platform and adjacent areas. *Spravochnik-opredelitel' AN SSSR*, No. 3: 1-380 [in Russian].

Rauser-Chernousova D. M. & Reitlinger E. A. 1954. — Biostratigraphic distribution of foraminifers in Middle Carboniferous deposits of the Podmoskovnaya depression. Southern limb. *Regionalnaya stratigrafia SSSR*, Goskomizdat., Moscow, tome 2: 7-120 [in Russian].

Shik E. M. 1971. — Carboniferous System. Middle series. *Geologia SSSR,* Nedra, Moscow, tome 4, part 1: 258-290 [in Russian].

Solovieva M. N. 1984. — The Middle Carboniferous of Eurasia (biogeographical differentiation, zonations). *27th International Congress Stratigraphy Section C.01. Reports*, volume 1, Nauka, Moscow: 73-78 [in Russian].

Solovieva M. N. 1986. — Zonal fusulinids scale of the Moscow Stage by revision of the stratons interstage subdivisions. *Voprosi micropaleontologii*, volume 28: 3-23 [in Russian].

Tikhomirov S. V. 1988. — The second edition of the manual "Historical geology" 1986. I. On the methods of Historico-Geological Analysis. *Izvestya VUZov, Geologia i razvedka*, No. 10: 122-135 [in Russian].

Submitted for publication on 15 January 1996;
accepted on 1 October 1996.