

## THE PERMIAN (TATARIAN) FLORA FROM THE KOTEL'NICH VERTEBRATE LOCALITY (KIROV REGION)

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**Abstract.** --Plant remains (macrofossils and miospores) from the exposure near the town of Kotel'nich, Kirov Oblast, which is primarily known as a vertebrate locality, are considered. The macrofossil assemblage can be referred to the *Tatarina* flora, but it contains unusually abundant arthropytes. Miospores indicate an older age of the locality than previously accepted. This is supported by the position of the locality in the stratotype section of the Tatarian Stage at the Vyatka River (the Yurpalovo Beds of Forsh). The significance of the studied flora for the correlation of the stratotype section with other sections in the Russian platform and, above all, with the reference section on the Sukhona River is discussed. Taphonomic analysis of the late Tatarian flora localities suggests that this locality was formed in an extensive lake basin not far from a shore.

*Key words.* Fossil Plants, Kotel'nich, macrofossils, miospores, stratigraphy, Tatarian stage, taphonomy.

### INTRODUCTION

The outcrop on the right bank of the Vyatka River, near the town of Kotel'nich, Kirov region, has long attracted the attention of geologists (Tikhvinskaya, 1946; V'yushkov, 1953; Efremov & V'yushkov, 1955 - see this book for an extensive bibliography of earlier works; Ignat'ev, 1962; Gubin, 1989; Tverdokhlebov & Schminke, 1990; Ivakhnenko, 1994; Ochev, 1995; Tatarinov, 1995). The reasons for this are especially its enormous scale for the Russian platform (height of cliff about 30 m, stretches along the bank of the Vyatka almost without interruption for more than 30 km), as well as the fact that it involves one of the richest localities of late Tatarian vertebrates. According to the latest proposals for improving the definition of the Tatarian (Goman'kov, 1992), it falls in the stratigraphic outcrop area, and so organic remains coming from it contribute to the palaeontological characteristics (not too rich) of the section of the Tatarian group.

The fact that plants are found in the outcrop at Kotel'nich was mentioned by B.P. V'yushkov (1953), but until recently the systematic collection and study of these remains has not been carried out. Further, the exact position of the flora-rich deposits in the outcrop was not known, nor the mode of preservation of the plants, nor the systematic floristic composition of the complex.

For the first time, in 1986 we made a targeted collection of plant remains at the

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\* Original reference: Goman'kov, A.V. 1997. Permian (Tatarian) flora of the Kotel'nich

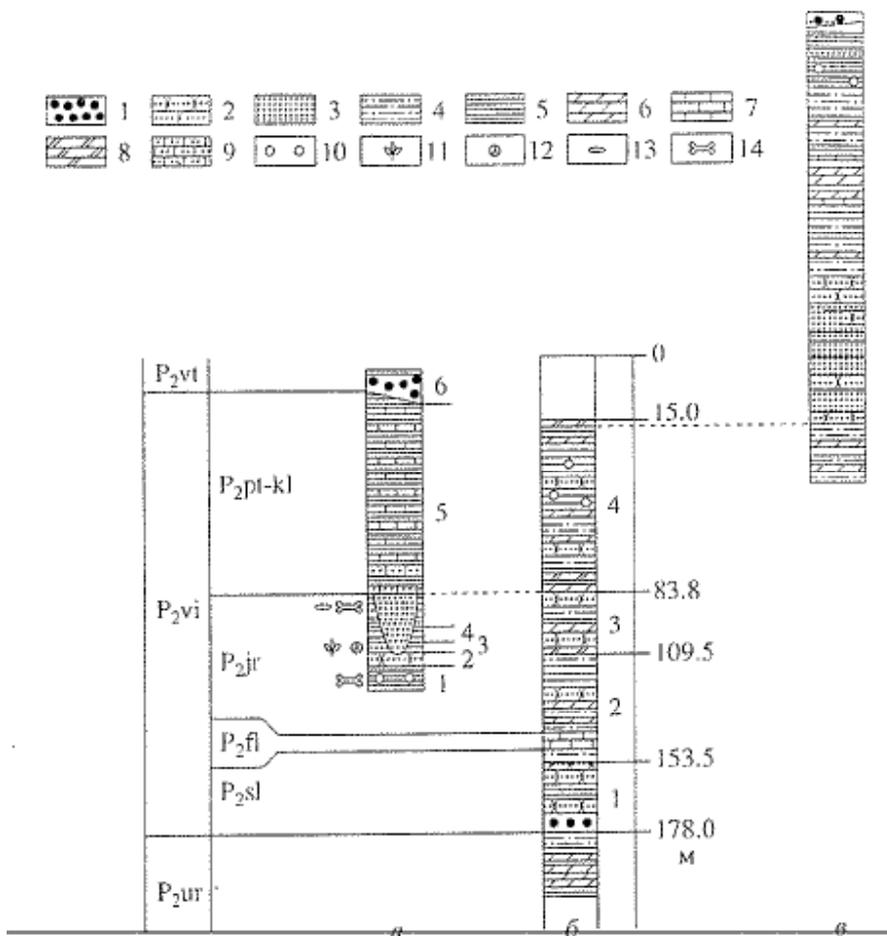
Kotel'nich locality, moreover, in addition to vegetable macrofossils from a flora-rich lens, the spore-pollen spectrum was isolated and studied. In 1992, I.D. Sukachev and A.E. Holland collected here again and they gave their collection to the author, for which he expresses his sincere appreciation to them. With the support of the geological cooperative "Stone Flower" and E.S. Bushmanova (Kirov Museum of Natural History of the Earth "Petros"), to which the author expresses his deep gratitude, he was able to re-visit the location in 1993, to find additional macrofossils and clarify the stratigraphic position of the flora-rich lens. The results of the study of the collections (of about 180 specimens with imprints of plants and spore-pollen spectrum of volume 186 grains) and served as the basis for writing this article.

### LOCALITY SECTION AND FLORISTIC COMPLEXES

During the field study of the section near the town of Kotel'nich in 1986 and 1993, it was divided into several lithologically homogeneous bundles, forming the following sequence, from the bottom up (Fig. 1a).

1. Red mudstone with rare blue-grey sandy spots and numerous white calcareous concretions, sometimes irregular, forming layers along strike. This packet is determined mainly

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**Fig. 1.** Various versions of correlations of the outcrops near the town of Kotel'nich with the Kotel'nich borehole.

a – outcrop section near the town of Kotel'nich by author, numbers on the right - number of packets by the author (see explanation in text); b - upper part of the core on the Kotel'nich, according to V.I. Ignatiev.; B, sections near the town of Kotel'nich according to B.I. Ignatiev. Left - the proposed divisions of the section in accordance with the scheme of N.I. Forsch (1963): P<sub>2</sub>ur - Urzhumian Gorizont, P<sub>2</sub>vi - Vishkil' Gorizont, p<sub>2</sub>vt - Vyatkian Gorizont, P<sub>2</sub>sl - Sludkian beds, P<sub>2</sub>fl - Filinsky beds, P<sub>2</sub>jr - Yuropalovskaya beds, P<sub>2</sub>pt-kl - Putyatinskaya and Kalinin beds. 1 - Conglomerates, 2 - sandstones, 3 - sands, 4 - siltstones, 5 - mudstones, 6 - marls; 7 - limestones, 8 - sandy marls, 9 - sandy limestones; 10 - calcareous concretions, 11 - 14 - finds of organic remains: 11 - plant macrofossils, 12 - spores and pollen, 13 - ostracods, 14 - vertebrates.

by mass finds of bones of vertebrates. The apparent thickness is up to 7 m.

2. Fine-grained sandstone, quartz, brownish-orange, friable, massive or thin-bedded. In a northerly direction, these are replaced by polymictic greyish-green, coarse-grained sandstone or mudstone, similar to the overlying packet. The thickness of the packet in the central part of the outcrop (near the village of Vanyushonki) is about 15 metres. To the north and south, it gradually reduces to 1-2 m.

3. Red mudstone, massive, with numerous and very irregularly distributed patches of bluish and greenish-grey fine-grained polymictic sandstone. Thickness of 4-6 m.

4. Mudstone greyish-brown, massive, finely comminuted, with numerous bright red clay gouges along fissures separately, from which the whole packet as a whole acquires a pink colour. Thickness of 8.5 m. At the southern end of the outcrop (near the village of Nagovitsyn), the thickness of the packet is reduced to 3 m.

5. Mudstone, similar to a packet 1. Calcareous concretions usually form irregular layers of light-grey ballstone ranging from 10 cm to 1 m, making the whole packet show a "striped" appearance. At the bottom of the packet, these layers can be sandy up to the formation of bluish-grey fine-grained sandstones. This lower part of the packet (with a thickness of about 20 m)

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also contains a lens of greyish- and yellowish-green ("tobacco" colour), coarse-grained polymictic sandstones, sometimes with conglomerates at the base. The maximum thickness of these lenses can reach 15 meters, so they are incised into the underlying stack right to the top of packet 2. Such sandy lenses, and red mudstones of the lower level packets contain the bones of vertebrates. From one sand lens, a set of ostracods was identified (Tverdokhlebov & Schminke 1990). Thickness of about 90 m.

6. Conglomerate. Composed of poorly sorted pebbles of red mudstone and white limestone with a diameter of 0.5-5 cm. Cement formed from grey, coarse, polymictic sandstones. The apparent thickness is 10 m.

Actually, the plant-bearing deposits at the Kotel' nich locality are a small (approximately 10 m along strike and 1 m in thickness) lens which is composed of dark grey massive siltstone, passing facially into coarse-grained sandstones, and it occurs within three packets near the hamlet of Chizhi. In addition to plant remains, it also contains tests of ostracods, fish scales, bones and rare remnants of tetrapods.

Plant macrofossils are mostly imprints, devoid of phytolite (= carbonized plant residues) and often limonitized. Phytolite occurs mostly in the form of shapeless pieces of coal, and they survive most likely from stems of horsetails that do not exhibit resistance to maceration of the cuticle. Available for study cuticles could be obtained only from four specimens.

In the macrofossil complex, we have identified the following taxa: *Algites* sp. AVG-1, *Phyllothea* aff. *Turnaensis* Gorelova, *Pecopteris* sp. AVG-1, *Peltaspermopsis* (?) sp., *Alicospermum* sp., *Tatarina conspicua* S. Meyen, *Phylladoderma* (*Aequistomia*) sp. indet., *Permothea sardykense* Zalessky, *Pursongia belousovae* (Radczenko) Gomankov et S. Meyen, *Geinitzia* sp. (Plate I).

In the spore-pollen spectrum obtained from the same plant-bearing deposits (Plate II), commonest are the ribbed, quasi-saccate pollen genus *Protohaploxylinus* (*P. dvinensis* (Sedova) Hart - 32,8%, other genera - 12.9%), as well as the pollen *Vitreisporites pallidus* (Reissinger) Nilsson (17.2%). There is a relatively high (8.1%) content of mono-saccate pollen, which is close to the genus *Cladaitina*. Ribbed, non-saccate pollen (the genera *Vittatina* and *Weylandites*), as well as *Vesicaspora* ex gr. *magnalis* (Andreyeva) Hart are present in small amounts (about 4%).

In the form of single grains (0.5-2%) occurs *Vesicaspora aërifera* (An-dreyeva) Hart, And that glue quasi-monosaccate pollen and spores of *Cordatinia* type and *Neoraistrickia* type.

#### ON THE NOMENCLATURE OF SUBDIVISIONS OF THE TATARIAN STAGE

Before proceeding to discuss the age of the complexes, it is necessary to make one remark about nomenclature. In composition, the Tatarian stage is traditionally divided into three horizons (from bottom to top): Urzhumian, Severodvinian and Vyatkian. It has long been known that the name of the Severodvinian Gorizont "is unacceptable for reasons of nomenclature". A.G. Olfer'evym (1974), and after him, the author of this article (Goman'kov. 1992) for the corresponding interval of the section suggested the name "Kotel'nich Gorizont," which, however, was pre-occupied by the usage of E.I. Tikhvinskaya (1946). Therefore, here to refer to the middle Gorizont of the Tatarian, we propose to introduce the name "Vishkil' Gorizont" (after the village Vishkil', Kotel'nich district, Kirov region, located at the southern end of the Kotel'nich exposure).

The Vishkil' Gorizont, with stratotypes on the River Vyatka from the mouth of the Bredekhi to the village of Arbazh district of the Kirov region are invited to understand the extent of the Slobodskaya, Filinin, Yurpalovskaya, Putatinskaya and Kalinin beds in the scheme of N.N. Forsch (1963). As the lower boundary stratotype, we propose the boundary between a layer of white massive limestone, which is crowned by a section of the Urzhumian Svita, and a monotone of red clay and sand bundle of late Tatarian age, exposed on the right bank of the Vyatka River near the village of Povoyska. For the upper boundary stratotype of the Vishkil' Gorizont, we propose the boundary between a packet of brownish-red mudstone with numerous calcareous nodules of Kalinin age and medium-grained, cross-bedded, polymict, greyish-green sandstones of the Bykov beds of Forsch, which are exposed on the right bank of the Vyatka in the former village of Putyatina, Nagorskaya district, Kirov region. With this definition, of the Vishkil' Gorizont, it turns out that the stratotypes of all three Tatarian gorizonts are within a single section on the Vyatka river, which can thus be regarded as a model for the Tatarian.

Since the Vishkil' Gorizont is actually introduced as replacement *nomenclature* for the Severodvinian horizon, its biostratigraphic study coincides with the rationale given for the Severodvinian Gorizont, the detailed palaeontological characteristics of which are contained in A.G. Olfer'eva (1974), as well as in the regional stratigraphic scheme of the Upper Permian, adopted by the MSC Anon., 1988). It should be emphasized, however, that the Vishkil' Gorizont

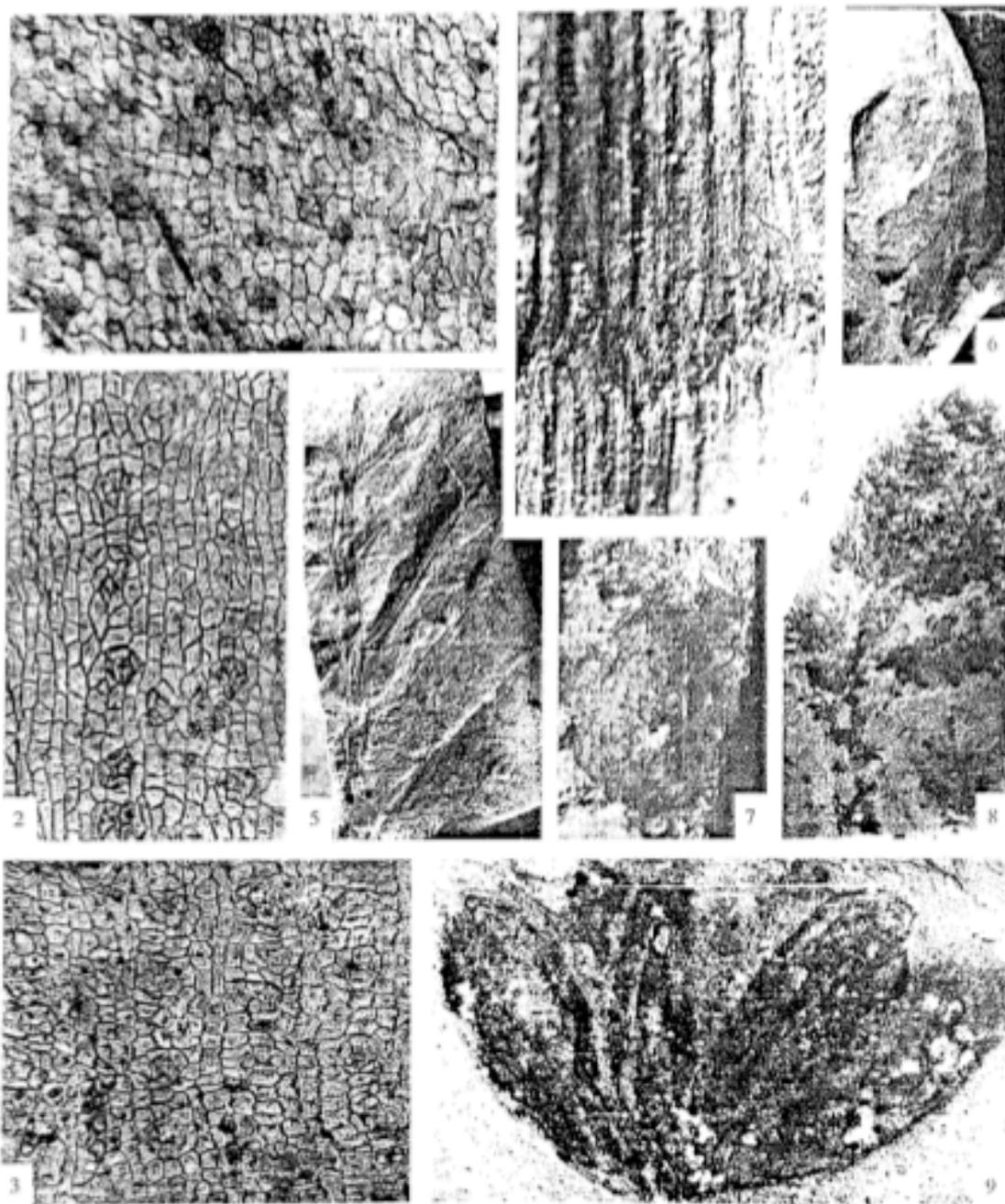


Plate I. Plant macrofossils from the Kotel'nich locality (originals stored in the Paleofloristic Laboratory GIN RAS).

1 - *Phylladoderma* (*Aequistomia*) sp., left epidermis, prep. № 4388/675-2, x 100; 2, 3 - *Tatarina conspicua* S. Meyen, prep. № 4388/675-1, x 100: 2 - upper leaf epidermis, 3 - lower leaf epidermis; 4 - *Paracalamites* sp., imprint on the surface of pith cavity, spec. № 4388/554, x 10; 5 - *Phyllothea* aff. *turnaensis* Gorelova, leafy shoot, spec. № 4388/615A, x 2, 6 - *Pursongia beloussovae* (Radczenko) Goman'kov et S. Meyen, pith cavity, spec. № 4388/557, x 1; 7 - *Alicospermum* sp., imprint of seed, spec. № 4388/601, x 5, 8 - *Geinitzia* sp., leafy shoot, spec. № 4388/658, x 2, 9 - *Permothea sardykense* Zalessky, flower, spec. № 4388/669A, x 10

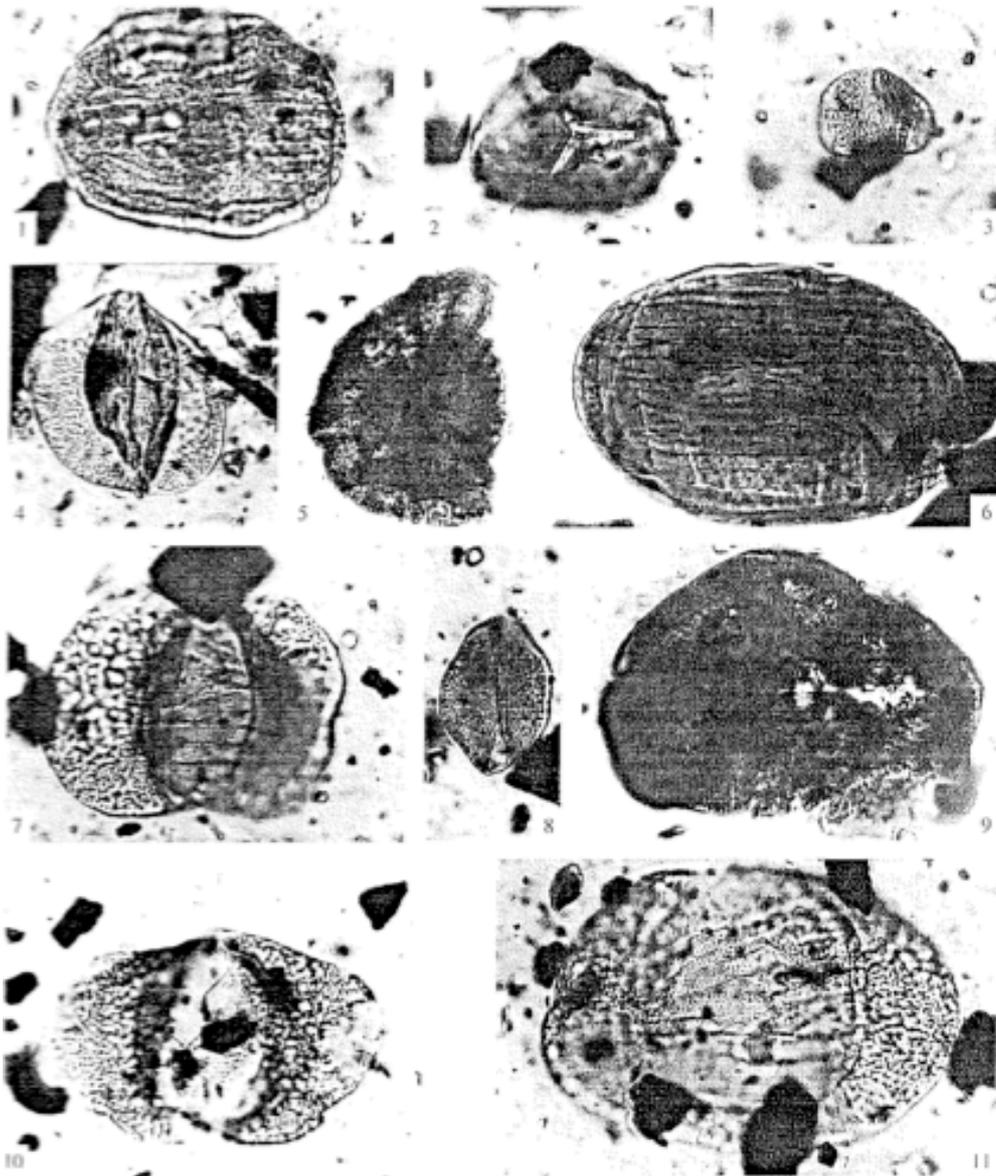


Plate II. Spores and pollen from the from the Kotel'nich locality (originals stored in the Paleofloristic Laboratory GIN RAS).

1 – *Vitattina subsaccata* f. *connectivalis* Sauer ex Warjuchina, spec. № 4.188/507-73, x 1000; 2 - *Neoraistrickia* (?) sp., spec. № 4388/507-83, x 1000; 3 – *Vitreisporites pallidus* (Reissinger) Nilsson, spec. № 4388/507-40, x 1000; 4 – *Vesicaspora aërifera* (Andreyeva) Hart, spec. № 4388/507-130, x 1000; 5 *Cordaitina* sp., spec.. № 4388/507-37, x 500; 6 – *Weylandites tataricus* Goman'kov, spec. № 4388/507-154. X 1000; 7 – *Striatopodocarpites* sp., spec. № 4388/507-39, x 1000; 8 - *Cladaitina* (?) sp., spec. № 4388/507-80, x 1000; 9 – *Lueckisporites virkkiae* Potonié et Klaus, spec. № 4388/507-36, x 1000; 10 - *Vesicaspora* ex gr. *magnalis* (Andreyeva) Hart, spec. № 4388/507-79, x 1000; 11 – *Protohaploxypinus dvinensis* (Sedova) Hart, spec. № 4388/507-26, x 1000.

is defined in this work not by a zonal method (i.e. by specifying the attributes that provide its identity), but through its stratotype (the Vishkil' Gorizont is called the stratotype of the Vishkil' Gorizont and everything that is synchronous with it), which, in principle, can be correlated with other sections on any grounds available for observation in it as relevant, and those that might be discovered in the future.

#### AGE OF THE FLORAL LAYER

The complex of plant macrofossils of the Kotel'nich locality has a typical upper Tatarian appearance, and is sure to be assigned to the Tatarian flora (Goman'kov & Meiyen, 1986). Only two taxa in its composition – *Algites* sp. AVG-1 and *Phyllothea* have not been reported previously from this flora. However, the presence of the genus *Phyllothea* might be expected, since this bed includes leafy shoots of articulates, the trunks of which are attributable to the genus *Paracalamites*, very common in the Tatarian flora.

With regard to the Kotel'nich spore-pollen spectrum, compared to other well-known spectra of the upper Tatarian Substage (understood as the combination of the Vishkil' and Vyatkian gorizonts) it seems rather "archaic." The relatively high content of pollen of the *Cladaitina* type especially gives it this appearance. This pollen is produced by cordaites with the foliage *Rufhoria* (Maheshwari & Meyen, 1975), which in the macrofossil complex does not occur above the Lower and Upper Tatarian (Kon'kov, 1967). The relative antiquity of the Kotel'nich spectrum is apparently also indicated by its lack of the pollen *Scutasporites unicus* Klaus, produced by the conifers *Quadrocladus* – *Sashinia* – *Dvinostrobus* (Goman'kov, 1986). As these conifers and the *Scutasporites unicus* pollen are very characteristic of the Tatarian flora, but were not observed in the sediment, it is certainly older than upper Tatarian. An archaic element of the Kotel'nich spectrum can probably be considered the spore type *Neoraistrickia*, still not noticed by us in the upper Tatarian of the Russian platform, but quite usual for the Upper Permian deposits of Siberia, which also contain *Cladaitina* and *Rufhoria* and are usually considered as late Tatarian. The abundance of the pollen *Vitreisporites pallidus* (in the older works often referred to as "*Caytonia* pollen") in the Kotel'nich spectrum can be compared with a set of layers defined by N.I. Umnova at Uglich, Kostroma region, corresponding to the middle part of the Vishkil' Gorizont ("Upper and Lower Triassic deposits ...", 1984).

In favour of the relative antiquity of the flora under consideration is the presence of *Algites* sp. AVG-1, previously known only from lower Tatarian deposits (Goman'kov 1995).

From the above, we can conclude that the plant-bearing deposits near the town of Kotel'nich belong to the upper Tatarian, but to a lower stratigraphic level than all other known locations of the Tatarian flora characterized by miospores. The oldest of these localities is Isady on the Sukhona River (Fig. 2) and Alexandrov in the Orenburg region, having Vishkil' age (Goman'kov, & Meiyen, 1986). Judging by the position of the Isady locality on the Sukhona section ("Reference section ...", 1981), it corresponds to about the middle of the Vishkil' Gorizont, so that the Kotel'nich flora suggests an assignment of its host sediments to the base of this gorizont.

Despite the fact that the Kotel'nich outcrops are within the stratotype of the Tatarian, the age of the exposed rocks has long been a subject of controversy (see, for example, the discussion in V.I. Ignat'ev, 1962, pp. 222-223). Recently, researchers have converged on the fact that these

deposits belong to the upper Tatarian, but their exact stratigraphic position still remains uncertain. The deposition of layers in this outcrop was considered horizontal. Therefore, despite the great lateral extent of the exposure, the stratigraphic interval of the exposed sediments seems relatively small, which has hindered an analysis of their lithological variation up and down the section, and hence determines their position in the composite section of the upper Tatarian Substage. Based on the representations of the occurrence of horizontal bedding also suggests that the exposed part of the section mostly corresponds to the section in the Kotel'nich borehole, which revealed its boundary with the lower Tatarian Substage at a depth of 178 m. This comparison of the section and the exposure revealed by the borehole is shown in particular by V.I. Ignat'ev (1962).

On the Vyatka in the upper Tatarian everywhere are two megarhythms, each of which begins with a powerful burst of a great deal of sandstone, and ends mostly with fine-grained clay-carbonate sediments (particularly characteristic of clay with a large number of calcareous concretions). These two megarhythms answer to two horizons, allocated to the upper Tatarian Substage: the Vishkil' and Vyatkian. The Kotel'nich borehole exposed, in fact, only one of these

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**Section on the Sukhona River**

**Section on the Vyatka River**

Subdivision by N. A. Pakhsutova		Flora localities	Gori-zont	Beds from N. N. Forsch	Flora localities
Bed	Packet				
Komaritskie		Aristovo	Vyatkian	Nefedovskie	
Ustyugskie				Bykovskie	Mulino
Gremyachevskie	Teymtasskaya				
	Lower Fedorovskaya				
Klimovskie	Rovdinskaya	Kalikino	Vishkil'	Kalininskie	
	Erogodskaya			Putyatinskie	
	Kalikinskaya			Yurpalovskie	Kotel'nich
Mutovinskie	Kichugskaya			Filinksie	
	Purtovinskaya	Isady, Opoki Mukulino		Slobodskie	Slobodskoy
Opokskie	Isadskaya		Syr'yanskie		
	Strelenskaya		Urzhumian	Belokholunitskie	
Mikulinskaya	Navoloki	Il'inskie			
Niuksenitskie				Maksimovskie	
Dmitrievskie			Kazanian Stage	Shikhovo-Chirki, Donaurovo	
Upper Toz'menskie		Kopylovo II			
Shardinskie		Vostroe, Kopylovo I, Bobrovskoe			
Karpogorskie					
Mar'egorskie					

**Fig. 2.** Breakdown of the sections of the Tatarian Group on the Vyatka and Sukhona rivers, and positions of localities for fossil flora in these sections.

megarhythms - obviously the lower one, i.e. corresponding to the Vishkil' Gorizont. Besides, the distribution of sand and clay-carbonate rocks in the drill core is also confirmed by the presence at a depth of 140-145 m of the limestone packet corresponding to the Filiny beds of Forsch, which are a good marker in the lower part of the predominantly sandy Vishkil' Gorizont.

Thus, if we start by a comparison with Ignat'ev (reproduced in our Fig. 1b, c), the sand packets exposed at the surface (our packets 2-4 and the bottom of packet 5) should be considered as the basis of the second megarhythm and classified as Vyatkian Gorizont (Bykovskaya Svita of Forsch), which contradicts the dating given above based on plant fossils. However, the selection of the above packages and tracking them across the exposure has revealed that the layers in the outcrop are not always horizontal. In particular, there is a significant dip of the beds from the village Shabalin north of the town of Kotel'nich, and then to the mouth of the River Molomy, making the whole of the cliff at Kotel'nich, and the area *between* Kotel'nich and the mouth of the Molomy, the extremely complex packets 5 and 6. Therefore, we can assume that the deposits exposed in the central and southern parts of the outcrop (at a considerable distance from Kotel'nich) did not build on top of the section of the Kotel'nich borehole, but were deep enough to correspond to part of it, namely packets 2 and 3 of Ignat'ev, i.e. the tops of the sand strata of the Vishkil' Gorizont, or the Yurpalovskaya Svita of Forsch. On this basis, the Vyatkian Gorizont can also be considered as a combination of our six packets, exposed north of Kotel'nich

#### STRATIGRAPHIC SIGNIFICANCE OF THE KOTEL'NICH FLORA

The fact that the Kotel'nich locality is almost the oldest of all known localities of the Tatarian flora allows us to make another step towards the construction of a fractional

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stratigraphy of the upper Tatarian Substage on a floristic basis.

The Upper Tatarian floristic complex of the Russian Platform (Tatarian flora), until recently, was considered to be stratigraphically and geographically undifferentiated (Goman'kov & Meyen, 1986). This opinion was based mainly on the similarity between the location of the complex macrofossils of Vyazovka in the Orenburg Ural region, whose age was considered to be Severodvinian (i.e. Vishkil' in our understanding), and a complex of the Vyatkian Aristovo locality on the Malaya Severaya Dvina River. Both complexes are characterized by the presence of species such as *Tatarina pinnata* S. Meyen et Goman'kov and *Peltaspermopsis buevichiae* (Gomankov et S. Meyen) Goman'kov (another species of the genus *Peltaspermopsis* - *P.* ? sp. AVG-3, known only from Vyazovka, morphologically very similar to *P. buevichiae*). Recently it was shown that the Vyazovka floristic complex has Vyatkian, and not Vishkil' age, and this paved the way for the dismemberment of the single upper Tatarian complex and a return to the point of view of S.V. Meyen (1971) that two floristic complexes existed in the upper Tatarian Substage of the Russian Platform, voiced also at the initial stage of study of the Tatarian Flora (Tverdokhlebov et al., 1989). For the lower of these complexes (Alexandrov of S. Meyen) is characterized by the presence of sulcial cordaites (in the Urals region of Orenburg), species *Phylladoderma (Aequistomia) rastorguevii* S. Meyen, *P. (A.) tichophora* S. Meyen, *Quadrocladus schweitzerii* S. Meyen, as well as peltoids with large oval seeds, pitted (*Peltaspermopsis* sp. AUS-1), while the upper (Vokhmian) complex is characterized by the presence of peltoids with small and rounded seed scars (type *Peltaspermopsis buevichiae*) and

taxa such as *Tatarina mira* Gomankov, *T. raristomata* Gomankov, *T. pinnata*, *T. (?) furcata* Gomankov, *Stiphorus biseriatus* S. Meyen, *Glossophyllum permienne* S. Meyen, *Phylladoderma (Aequistomia) aequalis* S. Meyen, *P. (A.) tatarica* S. Meyen, *Quadrocladus dvinensis* S. Meyen, and *Q. borealis* S. Meyen.

Differences between floristic complexes are manifested in the composition of the spore-pollen spectra. Thus, in the Vyatkian spectra there are usually very low pollen counts of *Vesicapsora aërifera* (pollen of sulcial cordaites - see Goman'kov, 1986), but a number of new taxa unknown in the Vishkil' Gorizont: *Falcisporites* sp., *Cycadopites* sp. nov., *Mulinopollenites bonus* Gomankov, *Punctasporites* sp., and *Brevitriteles subangaricus* Gomankov.

The Kotel'nich flora may represent the third floristic complex in the upper Tatarian, more ancient than both the higher ones. It is characterized by: among macrofossils - no conifers of *Quadrocladus* type and abundance of articulates [= sphenopsids], and among miospores - no *Scutasporites unicus*, high content of *Vitreisporites pallidus*, the relatively highest pollen, close to the genus *Cladaitina*, and presence of spores of *Neoraistrickia* type.

The exact correlation of the flora from the Kotel'nich locality in the scheme of Forsch can be clarified by some points of correlation of the Vyatkian stratotype with reference sections on the Sukhona River, which are of fundamental importance for the entire stratigraphy of the Tatarian (Reference section "...", 1981, "Upper Permian and Lower Triassic deposits ...", 1984; Goman'kov & Meyen, 1986). The analogue of the Kotel'nich locality on the Sukhona River may be the Strel'na locality, also characterized by its numerous articulates. Interestingly, both these localities are associated with deposits of pure quartz sandstone, generally quite rare in the upper Tatarian of the Russian Platform (N.I. Strok, 1987), and links their formation to the Baltic supply province, in contrast to conventional polymictic sandstones, deposited by the rivers that flowed from the Urals. We can assume that on the basis of this association (quartz sandstones and phyto-oryctocoenosis, rich in articulates) in the upper layers of the Yurpalovskaya Svita of Forsch and their analogues can identify the marker horizon, similar to the "the old clays" horizon, known at the contact of the Bykovskaya and Nefedovskaya svitas (Borozdima & Olfieriev, 1970, "Upper Permian and Lower Triassic sediments ...", 1984; Goman'kov & Meyen, 1986).

The Strel'na locality on the Sukhona relates to the Isadsky packet of N.A. Pakhtusova or to the upper packet "a" in the scheme of the SSU geologists ("Reference section ...", 1981), and with the overlying Purtovinskaya packet of Pakhtusova or packet "b" of the Saratov geologists linked to the already mentioned Isady locality, related to the Alexandrov floristic complex and dedicated to the famous Isadsky lens. In light of the foregoing, this lens can be compared with lenses exposed in the Kotel'nich area at the bottom of our packet 5 and in the upper Yurpalovskaya Svita of N.N. Forsch or Putyatinskaya Gorizont of B.I. Ignat'ev (1962). Thus, we can assume that the change from the Kotel'nich floral complex to the Alexandrov happens just below the top of the Yurpalovskaya Svita (at the base of the Putyatinskaya Gorizont of Ignat'ev).

## MODE OF PRESERVATION OF THE PLANT FOSSILS

Turning to a discussion of the taphonomy of the Kotel'nich locality, it should be noted that many aspects of it become clearer when compared with other localities macrofossilily plant in Upper Tatarian in the northern Russian platform. In the overall palaeogeographic situation in the space-time data limits, we believe the interpretation given by N.I. Strok (1987), according to which the

territory of the Moscow syncline in late Tatarian time was a lake-alluvial plain with low-lying topography and a large number of relatively shallow-water lake types, connecting to an extensive network of rivers flowing mainly from the Urals and to a lesser extent from the Baltic Shield. It is assumed (Gomankov, 1992; Verzilin et al., 1993) that climatic conditions in this plain were arid. The geographic and stratigraphic position of localities mentioned below can be found in A. Goman'kov & S.V. Meyen (1986).

Taphonomic types of the flora in most upper Tatarian localities on the Russian platform can be organised by the degree of preservation of organic matter, related most likely to the amount of oxygen dissolved in the water, which is determined in turn apparently by the size of the reservoir where burial took place as well as by the remoteness of the shore. The first in this series of taphonomic types is the location of the previously mentioned 'ancient clays' horizon' (except the Mulino locality). They are confined to dark grey or black clay-silt rocks contained within thick lenses, composed of polymictic sandstones. Plant remains in these localities are very numerous, varied and are mostly well-preserved phytoliteims, sometimes replaced with pyrite. These locations were formed apparently in very small ponds of stagnant type with great lack of oxygen. The most suitable model for such a reservoir may be a river oxbow (sand lenses with which these localities are related, we are against the opinion of N.N. Verzilin and co-authors (1993) who regard them as alluvial, since they contain well preserved plant fossils completely eliminates anything other than their transport by water).

The Mulino locality, although it corresponds stratigraphically and lithologically completely to the same ancient horizon, it was formed apparently in somewhat different conditions. Plant fossils are much more monotonous (almost exclusively leaves the genus *Tatarina*), and they are represented only by phytoliteim cuticles virtually free of any carbonaceous matter, although the morphological preservation is good. Obviously, the burial of plants occurred there in conditions of a more open body of water with greater access to oxygen, but still near the shore. The formation of this locality can be associated with the underwater part of a river delta, as indicated by its morphology and the enclosing sand lens: this lens has a flat sole and convex roof, that is, it is convex-upwards. Changes in taxonomic composition of the complex probably arise for geobotanical reasons: the emergent vegetation of the delta, through which the locality is mainly formed, was apparently more uniform than the actual vegetation of the river valleys at a considerable distance from the mouth.

The third taphonomic type is represented by the Kotel'nich locality discussed in this article. The lithological type of the sediments (grey siltstone in association with "tobacco" polymict sandstones) are similar to the previous location, and yet the siltstone is not enclosed within the sandstone, but is only "adjacent" to it. Phytoliteims (= carbonized layers) occur only rarely, often plant fossils are observed limonitised (instead of pyritization). All this indicates that the reservoir in which burial took place, was more open and well aerated. An indirect confirmation of this is also the presence at Kotel'nich of the plant species *Algites* sp. AVG-1, unusual for the Tatarian flora. By this view the remains of algae are known hitherto from only one lower Tatarian locality, Kichkas in the Orenburg region. Sediments containing *Algites* sp. AVG-1 in this locality, accumulated in a very extensive body of water (perhaps even in the sea - Minikh et al, 1992; Gomankov, 1995) and at a considerable distance from the shore. It is possible that the Kotel'nich locality was associated with the peripheral part of a submarine delta, although the amount of "river" material (grey siltstone and "tobacco" sandstone) is relatively small.

Finally, the fourth taphonomic type is represented by the localities Mikulino and Opoki. Phytoliths are completely absent. Plant fossils take the form of prints (usually highly fragmented, often limonitised or covered with a calcite crust) mainly of red mudstones and sandstones. Such

burials were formed apparently in vast lacustrine

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waters at a considerable distance from shore. The observed poverty of their taxonomic composition is related in this case probably to the fact that not all plant remains withstood long-range transport.

Thus, the taphonomic features of the Kotel'nich locality, considered in the context of other late Tatarian localities of the northern Russian platform, suggest it was formed under a vast lake basin, but at a relatively small distance from the shore.

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*Translator's notes*

Лимонитизированными = limonitized

Одномешковой = mono-saccate

Фитолеймы = 'phytoleim', the thin carbon layer on a plant compression

Членистостебельных = horsetails

[translated by Mike Benton, April 2011]