Pollen Analysis and Environment

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Abstract: As well known pollen analysis method is using widely in different fields of knowledge, including of geology. In this paper authors has introduced an absolutely new criterion–Similarity Index (SI) for assessment of fossil spore-pollen spectra. The use of the SI enables us to make a reliable assessment of fossil spore-pollen spectra and, consequently, to make a correlation of deposits, containing them, therefore providing for more reliable palaeofloristics, phytostratigraphic evidence, reconstruction of change of environment in time and in space. It would be showed, that the using of this index let us to brush up the technique of pollen analysis method at nowadays level and thus will give to this important method a new very fruitful way in different fields of knowledge of natural sciences.

Keywords: Environment and pollen analysis method, fossil spore-pollen spectra, recent spore-pollen spectra, new method of assessment, similarity index, holocene, taymyr peninsula, Russia.

1. INTRODUCTION

The method of pollen analysis has been widely used in geology, e.g., in phytostratigraphy, palaeofloristics, palaeoecology and palaeogeography [1-4] and so on. In recent years pollen analysis has attained growing significance in economic geology, especially oil and gas geology. As have been shown by G. Erdtman [1], the first contact the economic geology and palynology in the form of pollen analysis was made as early as the last year of World War I.

This method, as discussed by K. Fegri and J. Iversen, is based on the actuality principle: “There is only one fact in pollen analysis that always holds true: a pollen grain of plant species came from a specimen of that species.” [2: 137]. It is needed to stress here that there is one more fact also holding always true: this is the fact that plants` pollen and spores, setting down on the Earth`s surface form spore-pollen spectra (SPS). What is pollen-spore spectrum? This notion is still interpreted by different authors differently. As to us, we think that the most precise definition of this notion have been done by V.P. Grichuk and E.D. Zaklinskaya [3]. Under the spore-pollen spectrum they understand a totally of plants` pollen and spores, both shed on the modern Earth surface and found in the fossil state, expressed in the form of percentage of components. Consequently, the taxonomic composition of SPS reflects the composition of vegetation cover (flora and vegetation) of this or that region of the Earth. It is actually this paradigm, this serves as a base of spore-pollen analysis method. According to R.G. West [10], the taphanomy of macro and pollen assemblages is fundamental to the interpretation of the paleoecology.

Data of the study of SPS composition of modern surface samples are used for the assessment of such connection. A lot of authors have established in their works that a connection of such kind really exists. This connection, however, is not simple; it is multiform and depends on a number of both objective and subjective factors, including the researches` professionalism. In the cases when the composition of surface samples is studied, taking consideration the flora and vegetation of this or that area of research, the connection between the SPS composition of surface samples and the vegetation, forming them, can be traced really. It is established that even at the depth of 1.5-2.0cm from the modern surface of the earth recent SPS become sub-fossil, and then fossil. Thus, the connection between the SPS composition of modern surface samples and the fossil spore-pollen spectra composition undoubtedly exists, and therefore there must be a criterion, reflecting this connection. And nevertheless, such kind of criterion has not been found up to now.

Thinking over the problem of connection between fossil and modern SPS again and again we understood that it could only be solved by means of quantitative assessments. Of course, one can talk a lot about of a similarity and difference between natural phenomena and events, but without quantitative characteristics, confirming their similarity or difference, it would be rather difficult to prove or disprove this similarity or difference in words only. Finally, when new representative data of conjugated analysis of surface samples and modern vegetation were received the road what we should take became clear to us. In the end, the new method have been developed, which

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enabled us to express a connection existing between fossil spore-pollen spectra components and spectra components of modern surface samples, through the Similarity Index (SI) [5].

2. METHOD

The following procedure is to be used to get the SI:

(1) The 'General composition' of the fossil SPS and the 'General composition' of the SPS of surface samples are to be divided into four groups, corresponding to the four groups of plants life forms: (1) trees pollen, (2) shrubs and small shrubs pollen, (3) grasses and dwarf shrubs pollen (*Cassiope, Dryas, Vaccinium* and other dwarf shrubs), (4) spores of spore plants.

(2) Dominants and co-dominants in the composition of the fossil SPS and in the composition of the SPS of surface samples are to be detected.

(3) The Similarity Indices for the above-mentioned groups of the general composition, dominants and co-dominants are to be calculated. The Similarity Indices are calculated under the following formula:

X / Y= SI, where:

X – is the pollen and spores content of any plants taxon in the composition of the SPS of a fossil sample in percentages;

Y – is pollen and spores content of the same plant taxon in the composition of the recent SPS in percentages;

SI – is the Similarity Index.

The Similarity Index can be calculated for any component of fossil SPS. The calculation technique for the Similarity Indices is clearly demonstrated (Table **1**). However, this index can only be obtained if there is a conjugated study of fossil and recent samples.

3. RESULTS AND DISCUSSION

The above method is developed on the base of data obtained on study of a concrete geological section. This is a raised peat bog, 2.62m thick, on the left bank of the Fomich River in the south-eastern part of the Taymyr Peninsula, Russia (71° 42' North, 108° 03' East) (Figure **1**). This raised peat bog was being formed during the entire Holocene. Its formation stopped 500 ± 60 yrs BP (1400–1470 AD), when it was overlapped with a sand layer. The peat bog was securely dated with seven radiocarbon data. We have to stress here that there is not known a geological sections like this one on the huge territories of Taymyr Peninsula till now, as we know.

Approximately hundred meters away from this baring, a surface sample was taken in the dwarf shrub-sedge-mixed moss larch forest, which is typical of the research area. The tree level in this forest is formed by larch *Larix dahurica* ssp. *gmelinii* – d (cop 3), the height of which reaches 7 to 10m, the trunk diameter is 10 to 20cm and the trees' closeness is 0,3–0,6. The shrub

Table 1: Similarity Indices Calculated for the Tree Pollen Group in the Composition of Spore-Pollen Spectra of the Sediments from above-the-Flood-Plain Terrace 2 of the Fomich River (Ukraintseva, 2005)

Sample, Lithology	Pollen								
	Trees			*Larix Gmelinii*			Long Distance Blown Pollen of Trees		
	Contents	%	SI	Contents	%	SI	Contents	%	SI
1, surface sample	78	18,6	**1**	53	12,6	**1**	25	5,9	**1**
2, peat	91	16,0	**0,86**	68	12,0	**0,95**	23	4,0	**0,68**
3, peat	63	20,0	**1,1**	42	13,4	**1,06**	21	6,6	**1,1**
4, peat	60	13,4	**0,72**	50	11,2	**0,88**	10	2,2	**0,37**
5, peat	18	4,6	**0,25**	14	3,6	**0,28**	4	1,0	**0,17**
6, peat	14	4,3	**0,23**	12	3,7	**0,29**	2	0,6	**0,10**
7, peat	29	5,9	**0,32**	28	5,7	**0,45**	1	0,2	**0,03**
8, peat	20	4,2	**0,22**	19	4,0	**0,32**	1	0,2	**0,03**
9, loamy sand	31	5,9	**0,31**	17	3,3	**0,26**	14	2,6	**0,44**

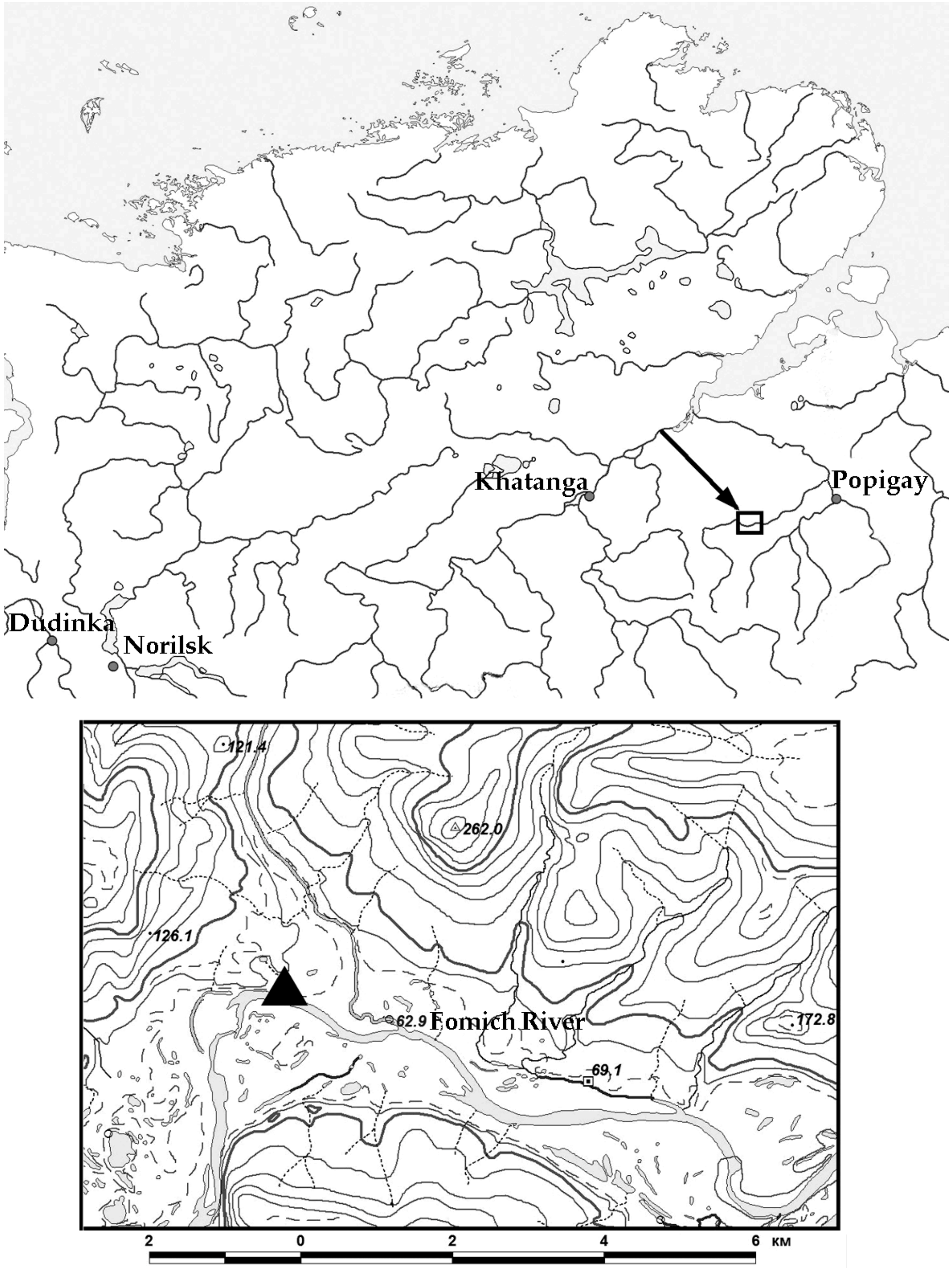

Figure 1: Scheme of the region of investigation (a square designates the location of the region of investigation; a triangle designates the location of the investigated peat bog).

level is formed by brush alder *Duschekia (Alnaster) fruticosa* (cd, cop 1, 15%), small birch *Betula exilis* (cd, cop 2, 10-20%), and *Ledum palustre* (cd, cop 2, 10-20%). The complete landscape and geobotanical description of the research area, as well as the results of the spore-pollen and radiocarbon analyses are discussed [8, 9].

According to the results of the spore-pollen analysis of the samples taken from this peat bog a spore-pollen diagram was made, which reflect the changes of a relative abundance of plants` taxa, the pollen and spores of which were detected in the sediments. The diagram allows imagining the nature of changes in the vegetation cover and the climate of the studied region during the entire Holocene (Figure **2**).

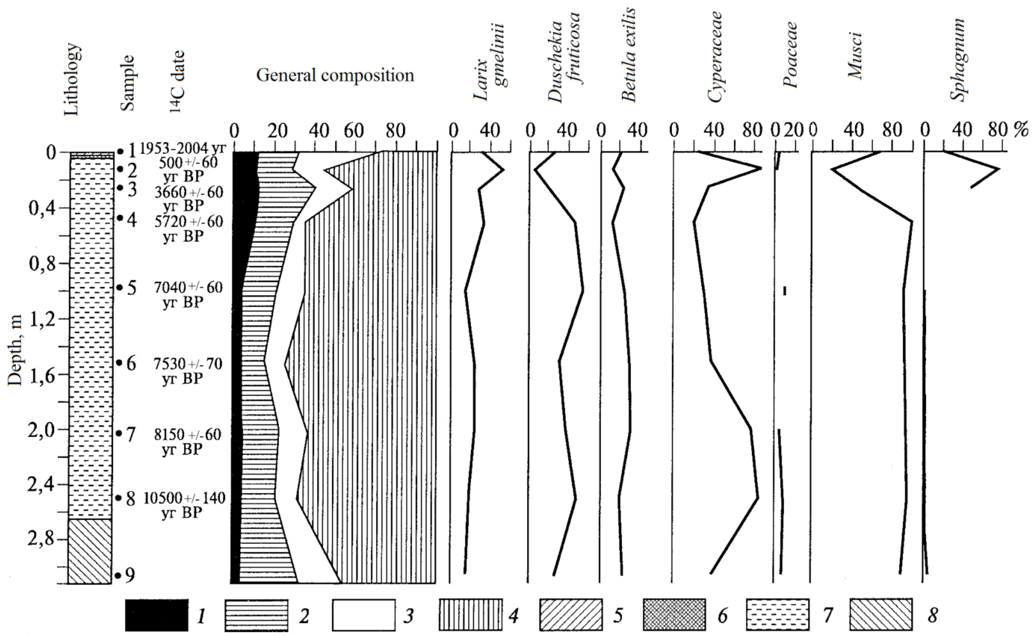

Figure 2: Spore-pollen diagram for the sediments of the 2nd upper flood-land terrace of the Fomich River, south-east of the Taymyr Peninsula.

Legend: 1 - pollen of trees, 2 - pollen of shrubs and dwarf shrubs, 3 - pollen of grasses and small shrubs, 4 - spore bearing plants; 5 - surface sample, 6 - sand, 7 - peat, 8 - loamy sand.

Table 2: Similarity Indices, Calculated for the Taxa of the Zonal and Phytoceonotic Levels in the Composition of the SPS of the Samples Taken from Peat bog 2 of the Above-the-Flood-Plain Terrace of the Fomich River

No. Sample	Radiocarbon Age (BP)/AD	*Larix Gmelinii* (Zone Level)		*Larix gmelinii* (Phytocoenotic Level)		*Duschekia Fruticosa*		*Betula Nana* S.l.		*Cyperaceae*		*Poaceae*		*Musci*		*Sphagnum*	
		%	*SI*	%	*SI*	%	*SI*	%	*SI*	%	*SI*	%	*SI*	%	*SI*	%	*SI*
1	1953-2003 AD	12,6	**1**	32	**1**	24,1	**1**	21,7	**1**	25	**1**	2,2	**1**	68	**1**	20,8	**1**
2	500 ± 60	12	**0,95**	52	**1,6**	8,4	**0,35**	17,5	**0,8**	84,8	**3,4**	1,8	**0,81**	21,5	**0,31**	76,4	**3,67**
3	3660 ± 60	13,4	**1,1**	28	**0,9**	20	**0,82**	24,7	**1,14**	35	**0**			44,6	**0,65**	48,4	**3,32**
4	5720 ± 60	11,2	**0,9**	35,2	**1,1**	43,1	**1,79**	12,6	**0,58**	22	**0**			99,4	**1,46**		
5	7040 ± 60	3,6	**0,28**	16,3	**0,5**	54,5	**2,26**	23,2	**1,06**	30	**1,4**	10	**4,54**	93	**1,36**	0,4	**0,02**
6	7530 ±70	3,7	**0,29**	24	**0,75**	30	**1,24**	32	**1,47**	36	**0**			94	**1,38**	0,8	**0,04**
7	8150 ± 60	5,7	**0,45**	24,1	**0,75**	35,7	**1,48**	33	**1,52**	74,7	**3**	4,2	**1,9**	95	**1,39**	1	**0,05**
8	10500 ±140	4	**0,31**	19	**0,59**	48	**1,99**	20	**0,92**	84	**3,36**	8	**3,63**	95,6	**1,4**	0,3	**0,01**
9		3,3	**0,26**	8,5	**0,26**	34	**1,41**	41,5	**1,9**	37,4	**1,5**	6,7	**3,04**	89,5	**1,32**	2,4	**0,11**

We have calculated the similarity indices for the taxa plants of the zonal level - 'General composition' and for a number of differentiating taxa used for making the Similarity Indices` graphs. The obtained similarity indices reflect a connection between the SPS components of the fossil samples and corresponding SPS components of a surface sample taken in the immediate vicinity of the studied peat bog section, in a larch forest of the upland type (Table **2**).

The Similarity Indices graphs, what have been constructed with help of Exsel: Quick Start Program [7], give a visual presentation of evolution of the studied region's vegetation during the Holocene on the zonal and the phytoceonotic levels (Figure **3**).

As a result two types of Phytochrones have been detected: tundra (I_{1-4}) and forest (II_{1-4}). The tundra phytochrone is typical for the time interval 10500±140–

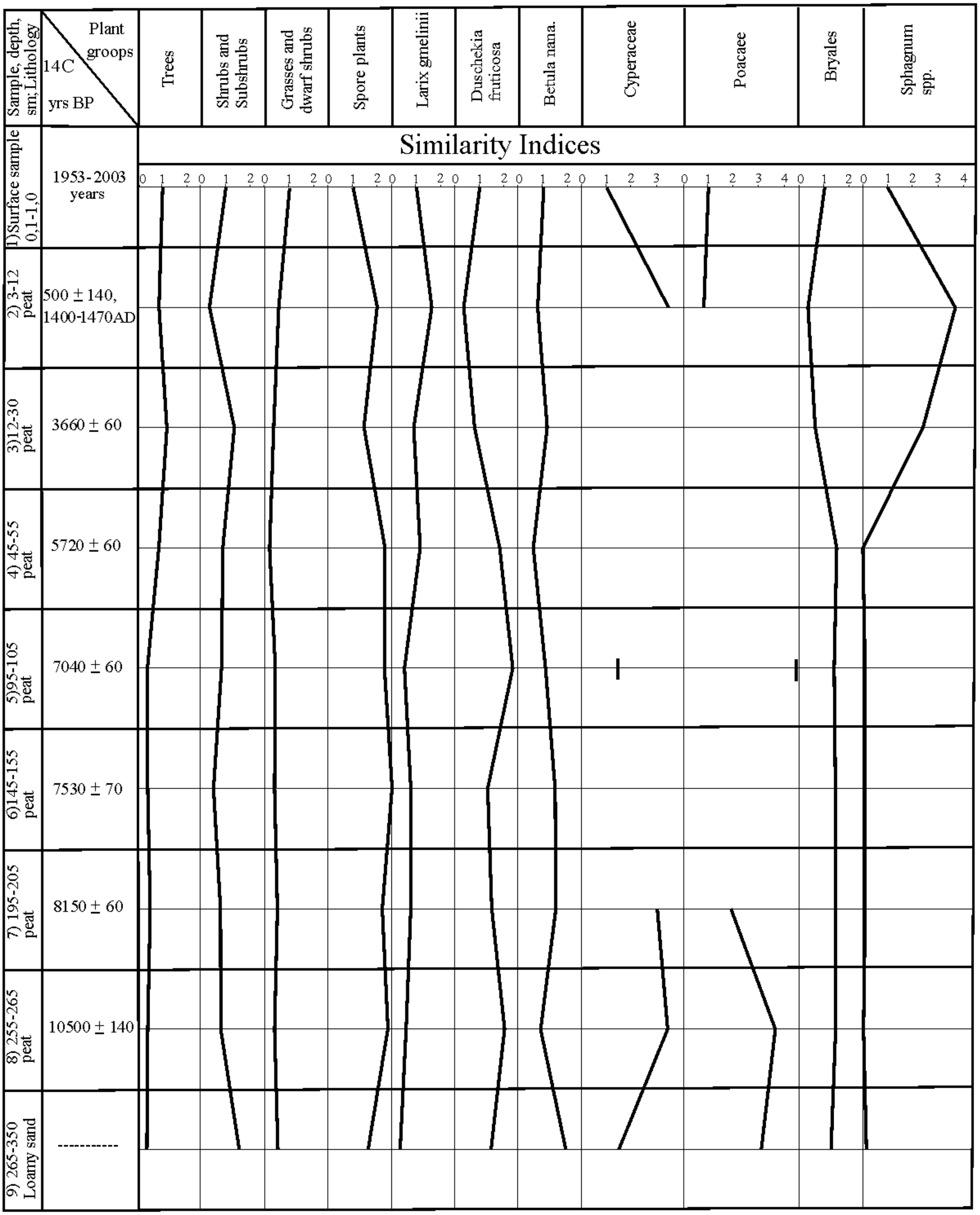

Figure 3: Graphs of the Similarity Indices for the groups of the "General composition" taxa of fossil SPS (trees, shrubs and small shrubs; grasses and dwarf shrubs; spore plants) and of the differentiating taxa (*Larix gmelini, Duschekia fruticosa, Betula exilis*, Poaceae, Cyperaceae, Musci, Sphagnum spp).

Table 3: Phytochrones Established on the Basis of Spore-Pollen Data for the Lower Course of the Fomich River, South-East of the Taymyr Peninsula

		General Composition of SPS				Phytochrone		
Sample No.., Depth, cm	^{14}C Data/AD	Trees	Shrubs + Small Shrubs	Grasses + Dwarf Shrubs	Spore Plants	Name	Index	Brief Characteristics
		Similarity Index						
1,surface sample, 0-1cm	1953-2003	1	1	1	1	*Larix gmelinii*	II_4	Larch forest (*Larix. gmelinii*), density 0,3 - 0,6, height 7 - 10m, diameter – 10-20cm; small shrubs - *Betula nana + Ledum palustre*, density 0,2 - 0,5. *Musci* – d (cop. 3) – sol.
2, peat, 3-12cm	500±60, 1400-1470	0,95	0,34	0,61	1,99	*L. gmelinii,* Sphagnum *spp.*	II_3	Larch forest (*Larix gmelinii*), *Betula nana и Duschekia fruticosa* were found sporadically; *Sphagnum* spp. – d; *Musci* – condominants
3, peat, 12-30cm	3660±60,2135-2079 B.C.	1,10	1,31	0,35	1,42	*L. gmelinii, Betula exilis, Duschekia fruticosa*	II_2	Larch forest (*L. gmelinii*), in the underwood *B. nana* and *D. fruticosa* (condominants); *Sphagnum* spp. and *Musci* were represented almost in equal ratios
4, peat, 45-55cm	5720±60, 4669-4463 B.C.	0,90	0,90	0,16	2,24	*L. gmelinii, Duschekia fruticosa,* Musi	II_1	Larch forest *(L. gmelinii*), in the underwood *D. fruticosa, B. nana* (seldom); *Musci* – d; *Dryas crenulata, Huperzia selago* ssp. *arctica* were found
5, peat, 95–105cm	7040±60, 5985-5841 B.C.	0,28	0,83	0,41	2,25	*Duschekia fruticosa, Betula exilis,* Musci	I_4	Tundras – analogues of contemporary tundras of the southern type; *D. fruticosa* and *B. nana* – condominants; *Musci – d*
6, peat, 145-155cm	7530±70, 6443-6261 B.C.	0,29	0,52	0,35	2,54	*Betula exilis, Duschekia fruticosa,* Musci	I_4	Tundras – analogues of contemporary tundras of the southern type; *B. nana – d, D. fruticosa – cd; Musci - d*
7, peat, 195-205cm	8150±60, 7315-7065 B.C.	0,45	0,80	0,46	2,16	*Duschekia fruticosa, Betula exilis, Larix gmelinii* , Musci	I_3	Forest-tundra with the participation of *L. dahurica*, in the shrub layer *B. nana, D. fruticosa, Ledum decumbens; Musci* – d; some earth mosses and equisetums were found.
8, peat, 255-265cm	10500±140, 10650-10275 B.C.	0,31	0,80	0,33	2,37	*Duschekia fruticosa, Betula exilis,* Salix, Musci	I_2	Tundras – analogues of contemporary tundras of the southern type with the participation of *D. fruticosa – d, B. nana*, willows *(Salix pulchra, S. polaris); Musci* – d; earth mosses and Equisetums were found sporadically
9, sandy loam, 300-310cm		0,26	1,55	0,46	1,63	*Betula exilis, Duschekia fruticosa.,* Musci	I_1	Tundras – analogues of contemporary tundras of the southern type, *B. nana – d, D. fruticosa – cd, L. dahurica* were found sporadically; *Musci* – d; *Sphagnum* spp. and *Eguisetum* spp., *Lycopodium* spp., Botrychi*um* sp. were present.

7040±60 years BP; the forest phytochrone–for the time interval 5720±60–500±60 years BP–the present time; their brief characteristics are given (Table **3**). The term Phytochrone denotes a type of vegetation, which existed on the studied territory within a certain period of time in the past and which is characterized by a certain combination of similarity indices for pollen and spore groups of the zonal and phytoceonotic levels (Figure **4**).

Using the Similarity Indices for assessment of fossil spore-pollen spectra allowed us to develop a new method of reconstruction of climates past and prediction of future climatic changes. This new a rather fruitful method is discussed in detail [9].

CONCLUSIONS

(1) The Similarity Index, introduced first for the assessment of spore-pollen spectra, is a quantitative characteristic. This characteristic allows assessing the composition of fossil SPS in comparison with the SPS composition of

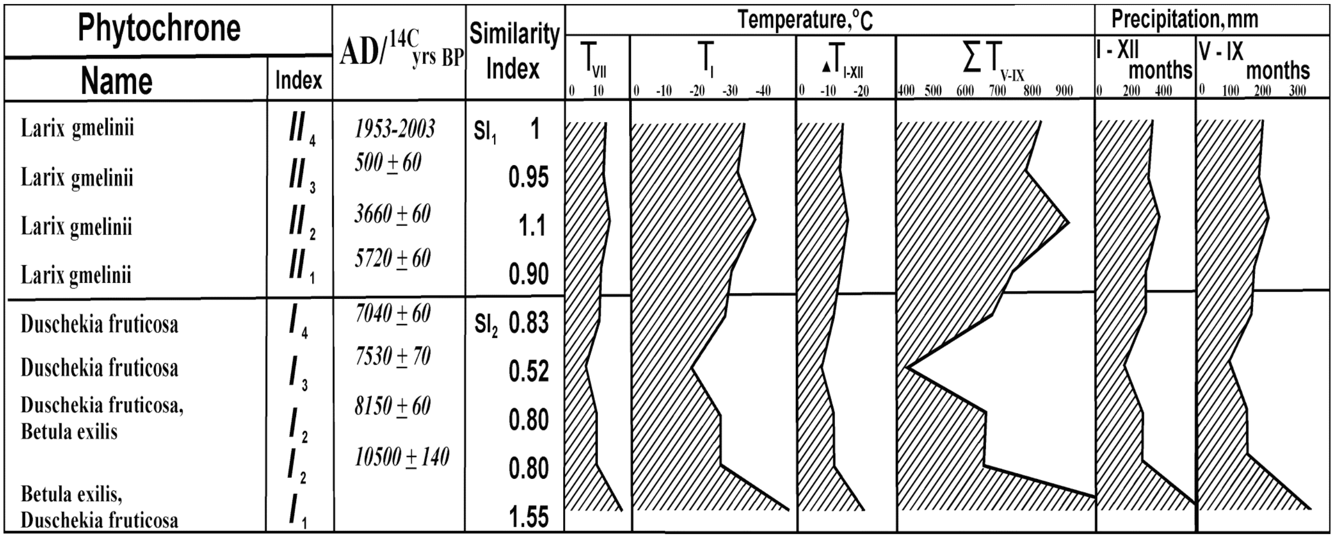

Figure 4: Graphs illustrating the character of warmth and moisture availability in the basin of the Fomich River during the last 10 500 years.

modern surface samples–a model, reflecting the character of modern vegetation of this or that research area.

(2) The Similarity Index can only be obtained if the investigation of fossil SPS, the spectra of modern surface samples and modern vegetation is carried out in conjugation or recent vegetation district of research is known a rather well.

(3) The introduced index allows making a reliable correlation of fossil SPS on the zonal and phytocoenotic levels.

(4) The Similarity Indices graphs give, in our opinion, more information than traditional spore-pollen diagram, since the Similarity Indices reflect more an objective connection existing between fossil SPS and modern surface samples' spectra. These graphs are more visual and compact in comparison with traditional spore-pollen diagrams, what enable us to make a correlation of paleobiogeographic phenomena and events in time and space with more confidence, and, consequently, to make a correlation of sequences of deposits of the same age. And nevertheless, it is needed to construct both the spore-pollen diagram and the similarity indices graphs to obtain more useful of geological and paleobiogeographical information. This method seems to be applicable for the diatom analysis, for the phoraminifer analysis and in the study of other groups of organisms of organic origin.

(5) As regards the assessment of climates of the past and modeling forecasts of climatic changes in future, the use of Similarity Indices method can make a real contribution in the solution of this one of most important modern problem. Supposedly this is the most radical approach and it must attract attention of climatologist.

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