Detailed reconstruction of the functional state of Central Yamal khasyrey as a response to local conditions and regional climate changes during the late Holocene

[1]Preis Yu.I., [1]Simonova G.V., [2]Slagoda E.A.

[1]*Institute of Monitoring of Climate and Ecological Systems of SB RAS, Tomsk, Russia*

[2]Earth Cryosphere Institute of *SB RAS, Tyumen, Russia*

- Forecasts of the natural landscape changes made on the basis of high-resolution paleoclimatic and paleoecological reconstructions are actual in light of current climate changes. Detailed reconstructions of mire functional state of Western Siberia tundra are absent.
- The goal of current work is to carry out a high-resolution reconstruction of paleophytocoenoces, water regimes and cryogenic conditions of khasyrey of Central Yamal as a response to changes of the level of the lake waters and regional climate of the late Holocene.

The study area is located in the central Yamal Peninsula, in the continuous permafrost zone, on the border of the typical and southern tundra.

The object of study - khasyrey located on the III-rd terrace of Yamal, near Sokhonto Lake (69 ° 08'57.17 "N, 84 ° 50'04" E). On the khasyrey surface convex polygons of 3-5 m size expressed. *Betula nana, Ledum palustre, Vaccinium vitis-ideae, Rubus chamaemorus, Eriophorum scheichzeri, Carex ragiflora* grow in landfills. Ground cover of sphagnum marsh (*Sphagnum majus, S. balticum, S. squarrosum*) and hypnum (*Polytrichum yuniperinum, Dicranum angustum, Oncophorus Wahlenbergii, Aulacomnium palustre*) moss is sparse.

Рис. 1. Район исследований (А) хасырея с остаточным озером (Б) в верховьях термокарстово-эрозионной долины, впадающей в озеро Сохонто.

Fig. 1. Study area (A) of khasyrey with residual lake (B) in the upper thermokarst-erosion valley, which flows into the lake Sokhonto.

- **Методы исследования**: 1)детальные (с шагом 1-3,5 см) исследования ботанического состава, физико-химических свойств торфа, $\delta^{13}C$ в целлюлозе торфа и радиоуглеродное датирование торфяных отложений; 2) реконструкция динамики фитоценозов, водных режимов и торфонакопления традиционными палеоэкологическими методами;
- 3) реконструкция геокриогенных условий по ботаническому составу и вторичному диагенезу торфов; 4) сравнительный анализ полученных данных с данными реконструкций регионального климата, солнечной активности и функционального состояния болот других зон и регионов.
- **The methods used in the study**: 1) detailed (1–3,5 cm) study of the macrofossils composition, physic-chemical properties of peat and $\delta^{13}C$ in peat cellulose, radiocarbon dating of peat deposit; 2) reconstruction of phytoceanoses and water regimes by traditional paleoecological methods; 3) reconstruction of paleocryogenic conditions on botanical composition and peat secondary diagenesis; 4) comparative analysis of the obtained data with the data of reconstructions of regional climate, solar activity and functional state of mires to other zones and regions.

Table 1. Radiocarbon and calibrated age of peat samples of Khasyrey profile

h, cm	^{14}C-age, BP	№ peat samples	Cal. 14C-age, 2δ	average
13,5-16	113 ± 0,8%	ИМКЭС–805	118…65	91,5
26,5-28,5	286 ± 67	ИМКЭС–789	501…267	384
31,5-33,5	86 ± 52	ИМКЭС–787	Modern	
33,5-35,5	31 ± 106	ИМКЭС–812	Modern	
35,5-39	639 ± 86	ИМКЭС–847	709…514	611,5
43,5-45	761 ± 51	ИМКЭС–785	786…651	718,5
72	49 ± 80	ИМКЭС–813	Modern	
72	1156 ± 122	ИМКЭС–861	1299…899	1099
79-80	1377 ± 75	ИМКЭС–782	1415…1172	1293,5

Fig. 2. Changing lake area of studied khasyrey on satellite Landsat in different years: 2003 (A) 2008 (B)

High resolution data of composition of macrofossil plant remains, degree of decomposition (R), ash-content (A), density (P) of peat and its organic matter (OM) and δ^{13}C in peat cellulose, with a step of 0,5-3,5 cm or 8-50 (77) years, are obtained for the first time for the peat cut of the Western Siberia tundra.

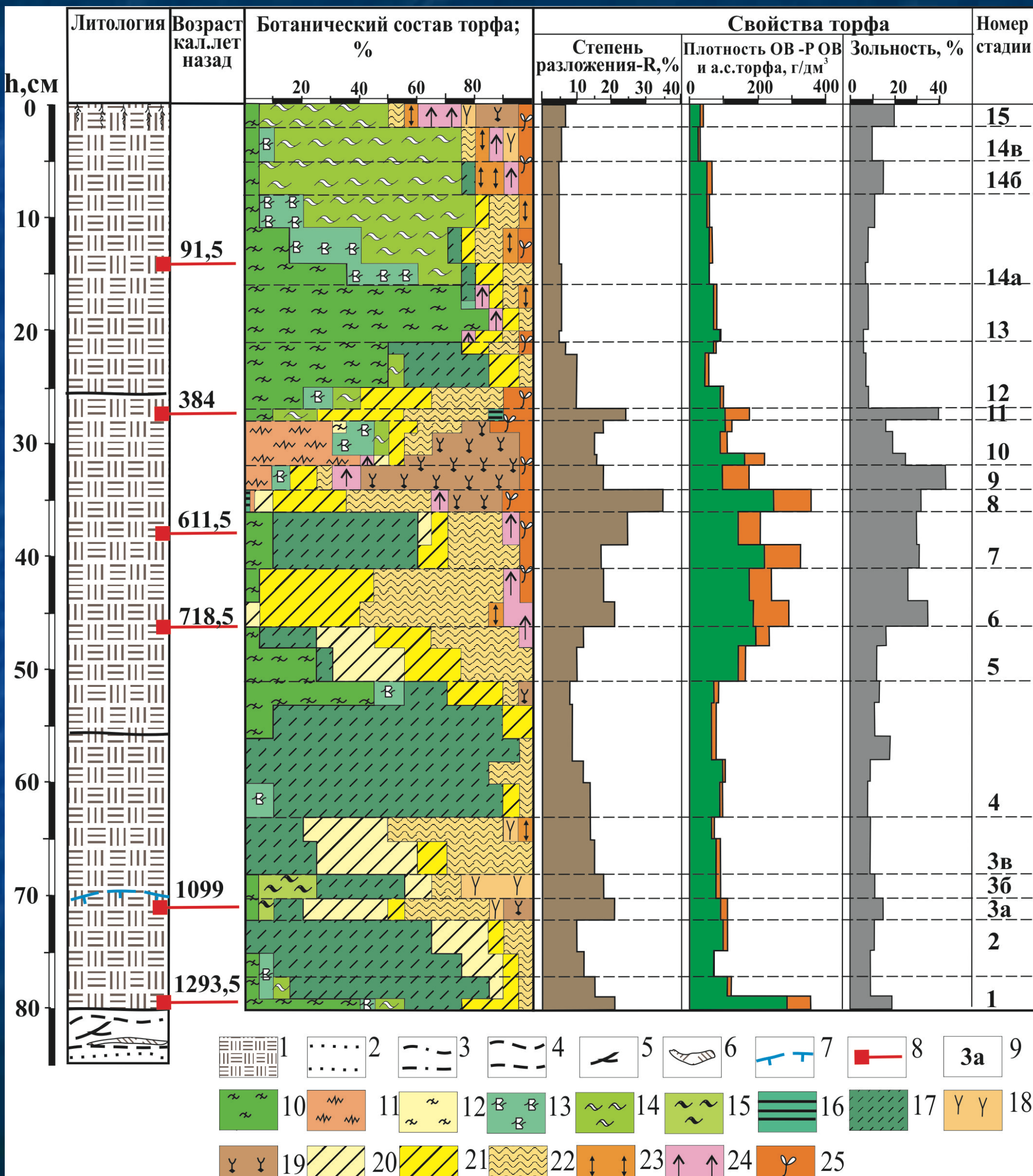


Рис. 3. Литология, ботанический состав и свойства торфа разреза Хасырей.

Условные обозначения: 1) торф; 2) пески; 3) супеси слоистые; 4) суглинки слоистые; 5) линзы торфа из мхов; 6) намытые растительные остатки; 7) верхняя граница мерзлого торфа (28.08.2014); 8) места отбора проб на радиоуглеродное датирование; 9) границы стадий формирования хасырея; растительные остатки в торфе: 10) *Sphagnum squarrosum*, 11) *S. lenense*, 12) *S. angustifolium*, 13) *S. balticum*, 14) *S. majus*, 15) *S. platyphyllum*, 16) *S. riparium*, 17) *Warnstorfia fluitans*, *Drepanocladus sp.*, *Calliergon sp.*, 18) *Aulacomnium palustre*, *Meesia triquetra*, 19) *Polytrichum juniperinum*, *Dicranum angustum*, *Oncophorus walhenbergii*, 20) *Carex rariflora*, 21) *C. rotundata*, 22) *Eriophorum sp.*, 23) *Betula nana*, 24) *Ericaceae*, 25) *Rubus chamaemorus*.

Fig. 3. Lithology, composition of macrofossil plant remains and features of peat section of the Khasyrey.

Legend: 1) peat; 2) sands; 3) laminated sandy loam; 4) laminated loam; 5) lenses of peat moss; 6) introduced by water plant remains; 7) the upper limit of the frozen peat (28.08.2014); 8) sampling locations on radiocarbon dating; 9) borders of khasyrey formation stages; plant remains: 10) *Sphagnum squarrosum*, 11) *S. lenense*, 12) *S. angustifolium*, 13) *S. balticum*, 14) *S. majus*, 15) *S. platyphyllum*, 16) *S. riparium*, 17) *Warnstorfia fluitans*, *Drepanocladus sp.*, *Calliergon sp.*, 18) *Aulacomnium palustre*, *Meesia triquetra*, 19) *Polytrichum juniperinum*, *Dicranum angustum*, *Oncophorus walhenbergii*, 20) *Carex rariflora*, 21) *C. rotundata*, 22) *Eriophorum sp.*, 23) *Betula nana*, 24) *Ericaceae*, 25) *Rubus chamaemorus*.

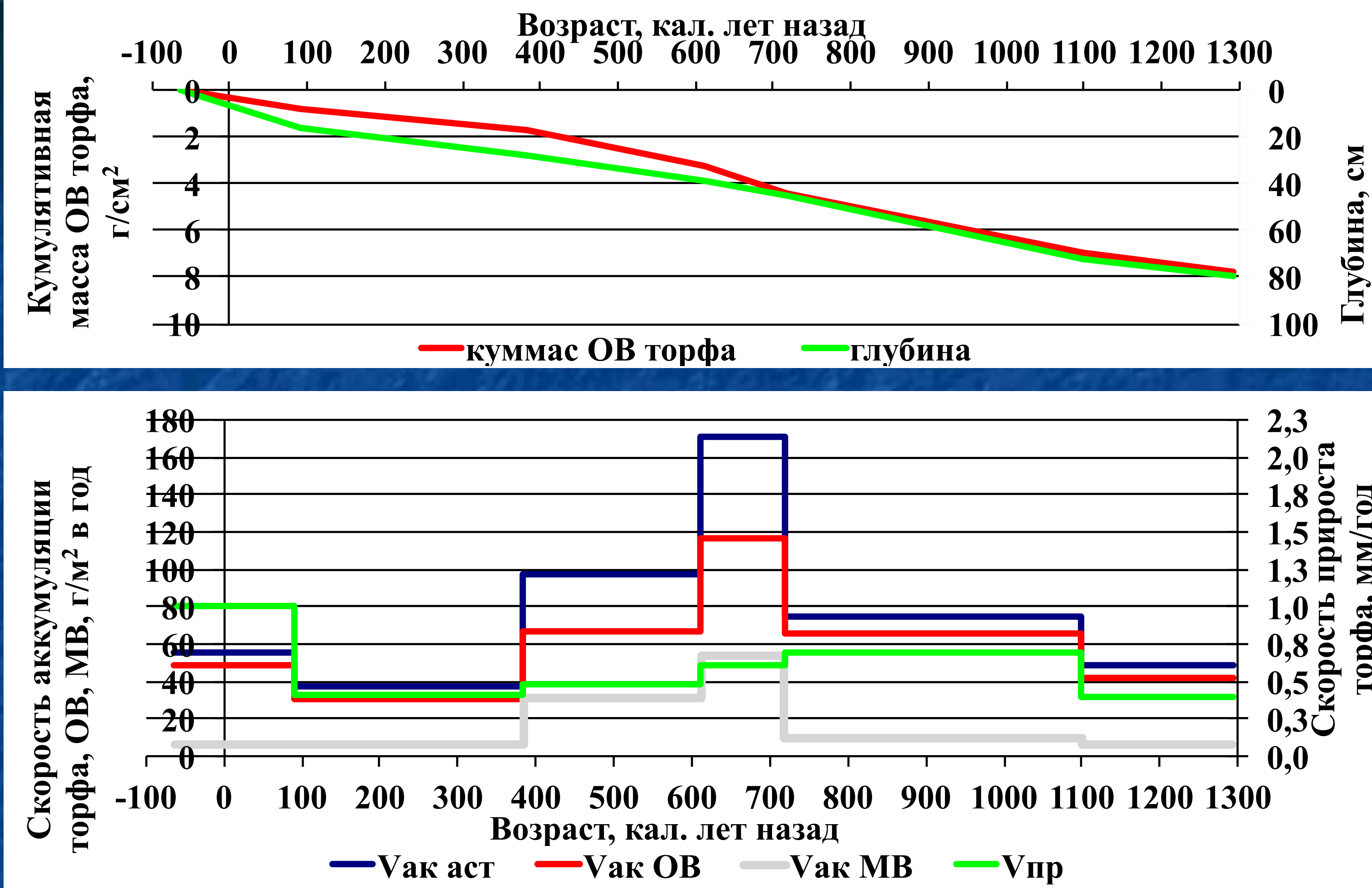


Fig. 4. Relationship between: A) age, peat depth and cumulative mass of peat organic matter, B) age, rate of growth peat, accumulation rate of peat, OM and mineral matter

The long-term rate of accumulation of organic matter of peat – 57,2 g m^{-2} yr^{-1} with a variation from 116,7 to 31,1 g m^{-2} yr^{-1} in layers.

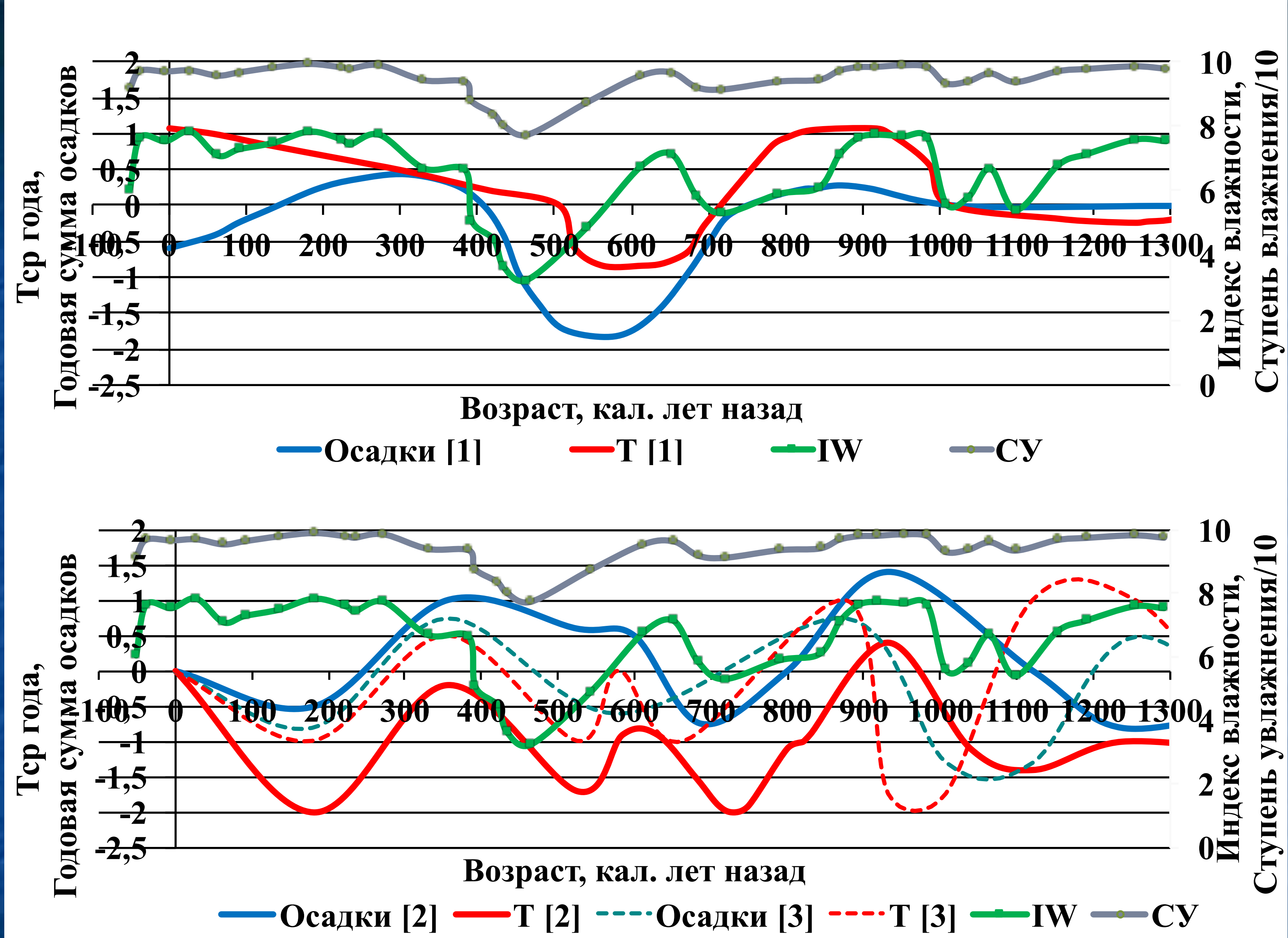
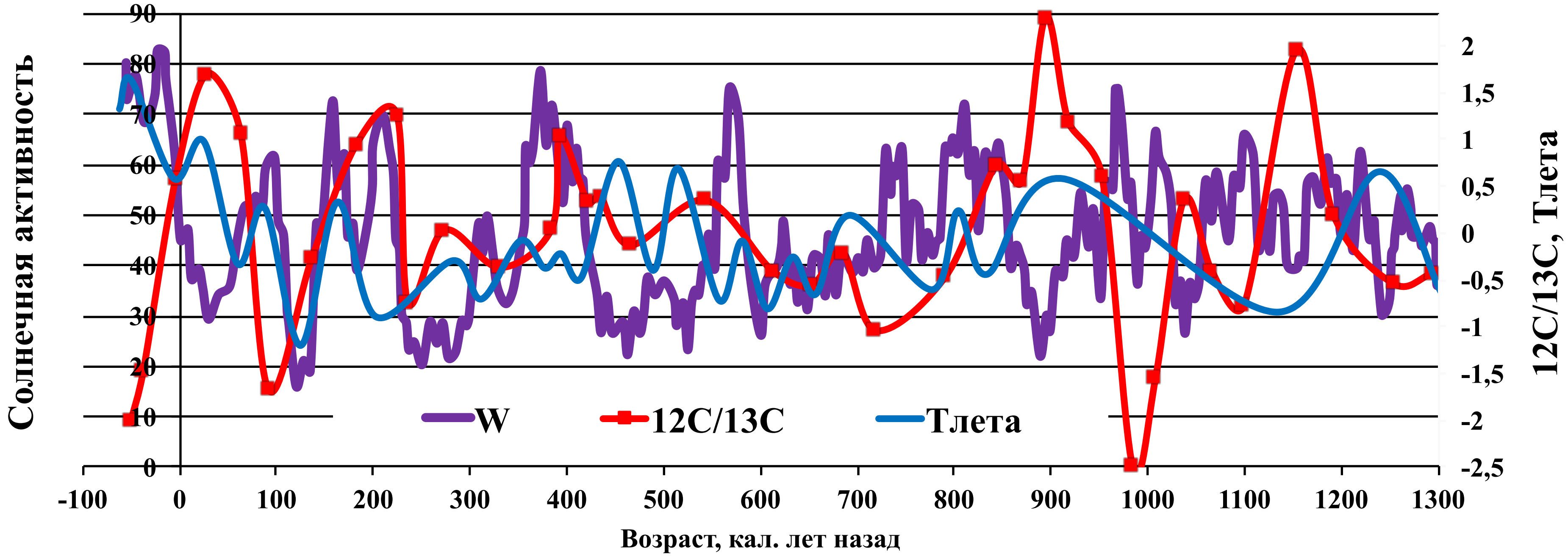


Fig. 6. Paleogidrological regime dynamics of the Khasyrey peat section and paleoclimatic curves of annual average temperature and annual precipitation for the forest zone of Westrn Siberia: 1 – Volkova et al., 2002, 2 – Blakharchuk, Klimanov, 1986, 3 - Blakharchuk, 2013

A)



B)

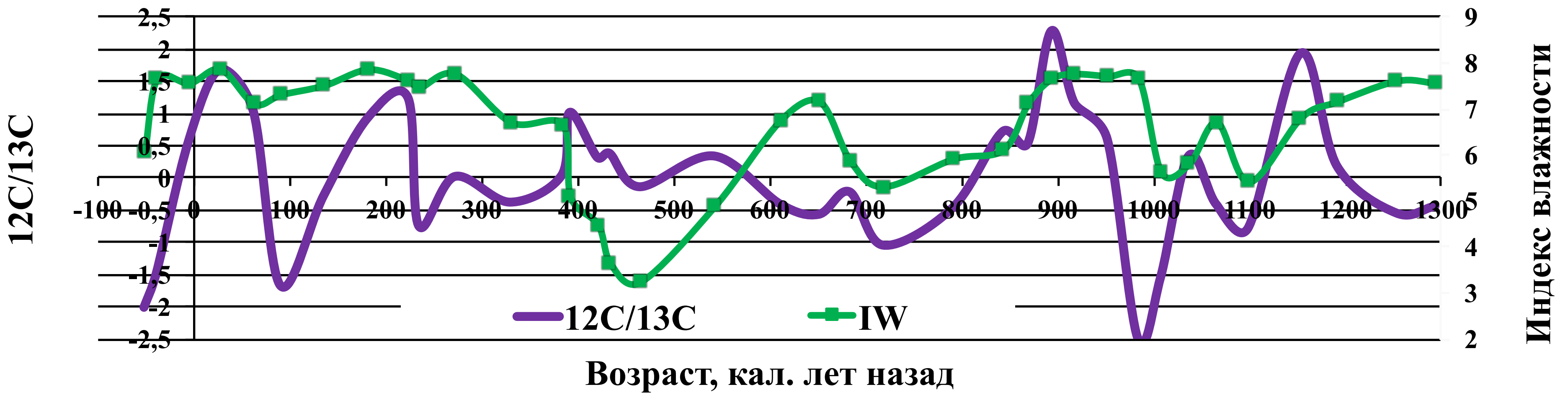
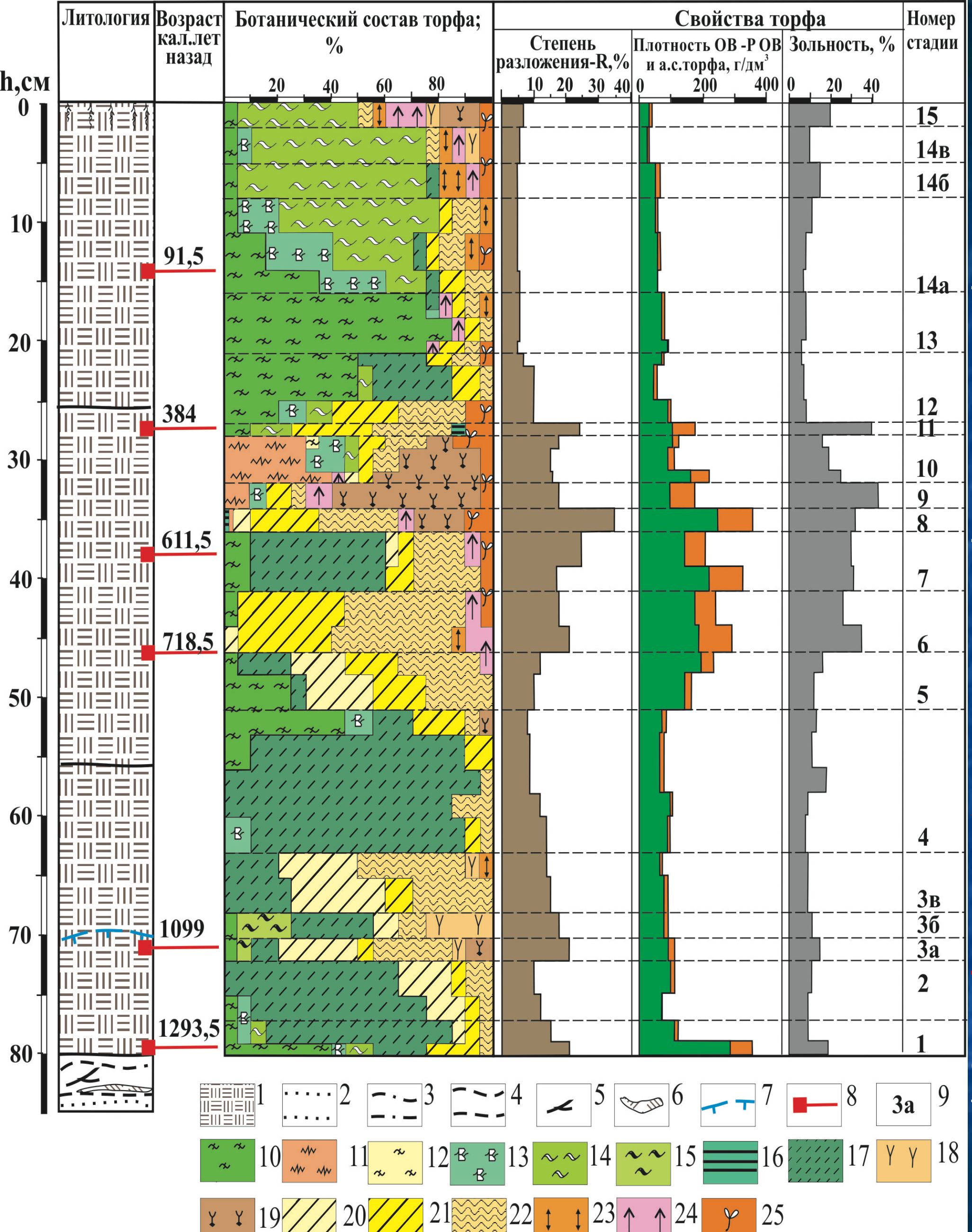


Fig. 7. Changes of: A) solar activity (Levi et al., 2012), summer temperatures (Hantemirov, 2009), 12C/13C, B) Index of humidity



We obtained 15 stages of paleophytocoenoces, water regimes and cryogenic conditions changes intra century and century scale of are revealed for the 1300-year period of khasyrey formation.

The khasyrey surface was **wet maximally** : 952-843 (Medieval Max); 273 cal. yr. BP - ca 2003-2008 yr. (from Maunder Min) and was **drained maximally**: 1099-1065 and 1037-984 (dry cooling); 719-652 (beginning of Wolf Min); 542-434 cal. yr. BP (beginning of Spörer Min).

The **low palsa** short formation took place: 1099-1065; 1008-984 and 719-652 cal. yr. BP.

Formation of **polygonal peatland** took place during 542-434 cal. yr. BP.

From 434 cal. yr. (from warming between minima Spörer and Maunder) **increase in the depth of seasonal thawing** began, and from 330 cal. yr. – the **melting of ice veins** to form a **convex polygon**.

Between 136 ... 91 cal. yr. (Minimum Dalton), there has been a **decrease in the depth of seasonal thawing**.

Drainage of a khasyrey surface in a consequence of **dumping of waters of the khasyrey lake** during the **wet warm periods** took place between 1153 and 1099, 869 and 843 cal. yr. BP; ca. 2003-2008 yrs.

Рис. 5. Стадии и подстадии функционального состояния Хасырея.

Fig. 5. Stages and substages of the Khasyrey functional state .

CONCLUSIONS

1. Khasyreis of Western Siberia tundra have a sensitive response to Holocene climate change. These peat deposits can be used for high-resolution reconstructions and forecasts of changes of the khasyreis functional state and climate.
2. The data of water regimes and cryogenic conditions of formation stages of khasyrey of Western Siberia tundra in cooling are in good agreement with data of regional climate reconstructions and some solar activity periods, water regimes and paleocryogenic conditions of mire of Western Siberia forest zone and cryolitozones of Eastern and Western Europe, North America.
3. Zone feature of khasireis development - a manifestation of cryogenic processes even in wet periods of warming due to the sharp drainage of the surface due to the overflow of lakes and discharge their waters.
4. Climate changes in the Western Siberia tundra were the main cause of pulsating nature of khasyreis in contrast to the more southern areas. Climate influence was direct, through the hydrothermal regime, and indirect, through cryogenic processes in peat deposit and the water table regime of the lake.

Thanks for attention!