

Phytoindication of Landslide Disturbances in the Central Yamal

Ksenia Ermokhina

Vegetation prodromus

Equiseto–Salicion glaucae union

differential species: *Salix glauca*, *Equisetum arvense* subsp. *boreale*

- ***Poo–Caricetum concolor association***

differential species: *Carex concolor*, *Poa alpigena* subsp. *colpodea*, *Ranunculus borealis*

- ***Bistorto-Betulion nanae association***

differential species: *Betula nana*, *Vaccinium vitis-idaea* subsp. *minus*, *Bistorta vivipara*, *Dicranum elongatum*

Vaccinio–Betuletum nanae association

differential species: *Betula nana*, *Vaccinium vitis-idaea* subsp. *minus*

Luzulo–Polytrichetum juniperinum association

differential species: *Luzula confusa*, *Polytrichum juniperinum*

Alopecuretum pratensis association

differential species: *Alopecurus pratensis*

Equiseto-Salicion glaucae union

(species with constancy classes $\geq IV$). Vaskiny Dachi

subassociation (quantity of relevés)	Salicetosum polaris (8)	Calamagrostis sum holmii (18)	Drepanodadus sum uncinati (8)	Veratretosum lobelianum (19)	Caricetosum arctisibiricae (4)	tipicum (18)	Carex lachenalii (15)	festucetosum rubrae (5)	Peltigeretosum aphthosae (4)	Veratretosum lobelianum (7)	Poetosum arcticae (4)	Eniphoretosum vaginati (5)	Poo – Calamagrostis sum holmii (14)
differential species of Equiseto-Salicion glaucae union													
<i>Salix glauca</i>	V	V	V	V	V	V	V	V	V	V	V	V	V
<i>Equisetum arvense</i> subsp. <i>boreale</i>	IV	III	V	V	IV	V	V	III	V	IV	V	III	III
differential species of Poo–Caricetum concolor and Bistorta–Betuletum nanae associations													
<i>Carex concolor</i>	III	V	IV	V	IV	IV	III	I	I	III	III	I	II
<i>Poa alpigena</i> subsp. <i>colpodes</i>	IV	III	III	III	III	III	IV	II	I	I	III	I	IV
<i>Ranunculus borealis</i>	III	IV	III	IV	III	III	V	I	IV	III	I	II	III
<i>Betula nana</i>	I	I	I	I	I	I	I	V	V	V	V	V	V
<i>Bistorta vivipara</i>	III	III	I	II	III	II	III	III	IV	IV	IV	IV	III
<i>Dicranum elongatum</i>	II	II	I	I	III	I	I	V	IV	III	III	III	IV
<i>Vaccinium vitis-idaea</i> subsp. <i>minus</i>	I	I	I	I	I	I	IV	III	III	III	III	V	III
differential species of subassociations													
<i>Salix polaris</i>	V	II	I	I	III	II	I	II	IV	V	I	I	II
<i>Dryas octopetala</i>	IV	I	I	I	II	I	I	I	II	I	I	I	I
<i>Polytrichum juniperinum</i>	IV	I	I	I	III	I	I	III	I	I	I	I	II
<i>Poa arctica</i>	IV	II	I	I	IV	II	I	I	II	III	II	V	II
<i>Calamagrostis holmii</i>	I	IV	III	III	I	III	II	II	I	III	III	I	IV
<i>Drepanodadus uncinatus</i>	I	I	V	II	I	I	I	I	I	III	III	I	II
<i>Polemonium acutiflorum</i>	II	II	V	V	I	IV	III	I	II	V	II	III	III
<i>Nardosmia frigida</i>	II	II	IV	III	II	II	II	II	II	III	I	III	V
<i>Veratrum lobelianum</i>	II	I	I	IV	I	I	II	I	I	IV	I	I	I
<i>Carex arctisibirica</i>	II	I	I	I	IV	I	I	III	I	I	I	V	I
<i>Carex lachenalii</i>	II	I	II	II	I	I	IV	I	I	I	I	I	I
<i>Alopecurus pratensis</i>	II	II	I	I	III	II	I	II	IV	I	III	III	II
<i>Festuca rubra</i> subsp. <i>arctica</i>	II	II	I	I	II	I	I	I	IV	III	II	III	I
<i>Peltigera aphthosa</i>	I	I	II	I	I	I	I	I	I	V	I	I	I
<i>Aulacomnium turgidum</i>	I	I	III	I	I	I	I	II	I	V	I	I	I
<i>Enophorum vaginatum</i>	I	I	I	I	II	I	I	III	I	I	II	I	IV
<i>Stellaria palustris</i>	I	II	I	I	II	I	I	II	I	III	I	I	IV

The main vegetation features on marine terrace slopes

Vegetation syntaxa	Equiseto-Salicion glaucae Union		Vaccinio-Betuletum nanae association	Luzulo-Polytrichetum juniperinum association	Alopecuretum pratensis association
	Poo-Caricetum concolor association (1)	Bistorto-Betulion nanae association (2)			
Differential species of associations	<i>Carex concolor</i> , <i>Poa alpigena</i> subsp. <i>colpodea</i> , <i>Ranunculus borealis</i>	<i>Betula nana</i> , <i>Vaccinium vitis-idaea</i> subsp. <i>minus</i> , <i>Bistorta viviparum</i> , <i>Dicranum elongatum</i>	<i>Betula nana</i> , <i>Vaccinium vitis-idaea</i> subsp. <i>minus</i>	<i>Luzula confusa</i> , <i>Polytrichum juniperinum</i>	<i>Alopecurus pratensis</i>
Plant community layers	shrubs, dwarf shrubs and grasses, moss-lichenous layer	shrubs (frequently), dwarf shrubs and grasses, moss-lichenous layer	draft shrubs and grasses, moss-lichenous layer	grass and moss-lichenous layers	grass layer and rarely moss layer
Dominant species	<i>Salix glauca</i> , <i>Equisetum arvense</i> subsp. <i>boreale</i> , <i>Carex concolor</i> , <i>Poa alpigena</i> subsp. <i>colpodea</i> , <i>Ranunculus borealis</i>	<i>Salix glauca</i> , <i>Betula nana</i> , <i>Vaccinium vitis-idaea</i> subsp. <i>minus</i> , <i>Equisetum arvense</i> subsp. <i>boreale</i> , <i>Bistorta viviparum</i> , <i>Dicranum elongatum</i>	<i>Betula nana</i> , <i>Vaccinium vitis-idaea</i> subsp. <i>minus</i>	<i>Polytrichum juniperinum</i> <i>Polytrichum strictum</i>	Polydominant grass community, rich in graminoids
Total projective cover (PC)	65–95%	65–90%	85%	97%	55%
Average PC of shrub layer	8–75%	0–61%	0%	0%	0%
Average PC of dwarf shrubs and grasses layer	40–64%	35–87%	50%	74%	49%
Average PC of moss component	28–80%	30–85%	84%	96%	26%
Average PC of lichen component	1–6%	0–8%	7%	2%	0%

Distribution of syntaxa by ecotope types

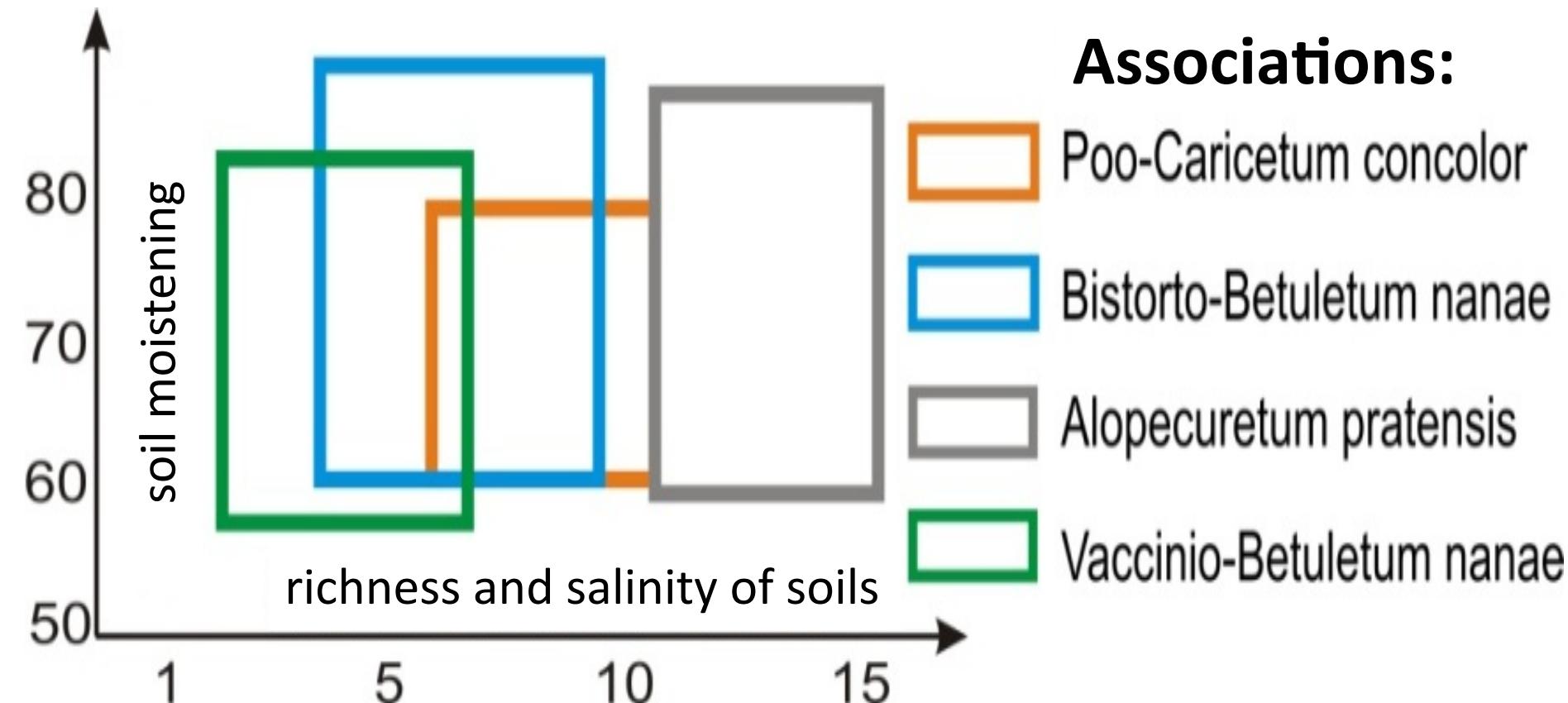
Central parts of shearing surfaces	Peripheral parts of shearing surfaces	Central parts of landslide bodies	Peripheral parts of landslide bodies	Stable slopes*	Snowbeds on stable slopes
<i>Alopecuretum pratensis</i>	<i>Poetosum arcticae</i> (2)	<i>Calamagrostietosum holmii</i> (1)	<i>Festucetosum rubrae</i> (2)	<i>Salicetosum polaris</i> (1)	<i>Luzulo-Polytrichetum juniperinum</i>
<i>Caricetosum arctisibiricae</i> (1)**	<i>Eriophoretosum vaginati</i> (2)	<i>Drepanocladetosum uncinati</i> (1)	<i>Peltigeretosum aphthosae</i> (2)	<i>tipicum</i> (2)	
<i>tipicum</i> (1)	<i>Poo – Calamagrostietosum holmii</i> (2)	<i>Veratretosum lobeliani</i> (1)	<i>Veratretosum lobeliani</i> (2)	<i>Vaccinio-Betuletum nanae</i>	
<i>Caricetosum lachenalii</i> (1)					

* Stable slopes – slopes without noticeable landslide relief (the area more than 500 m²),

**here and further: (1) – subassociations of *Poo-Caricetum concolor* association,

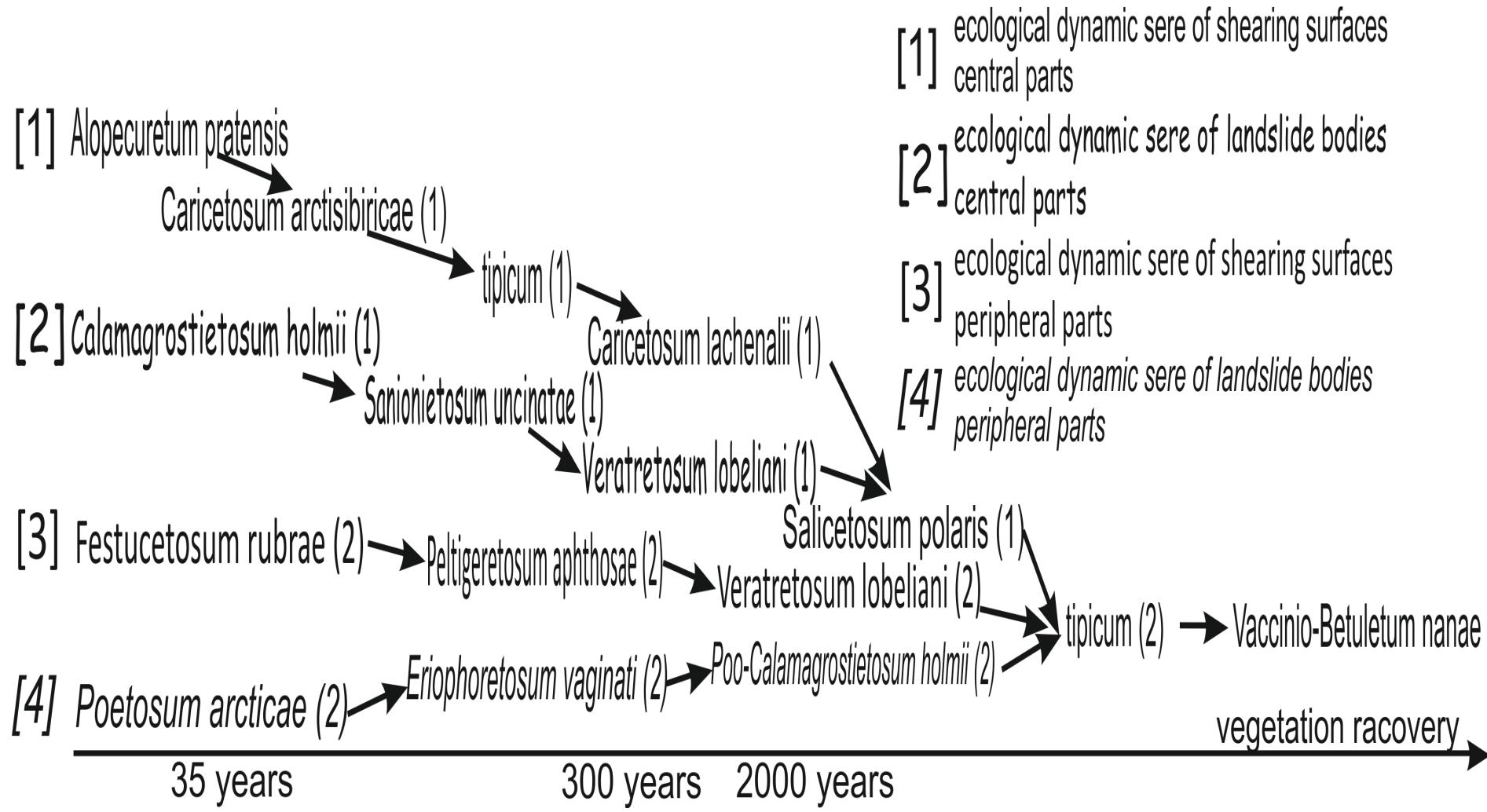
(2) – subassociations of *Bistorto-Betuletum nanae* association.

Ecological series of vegetation



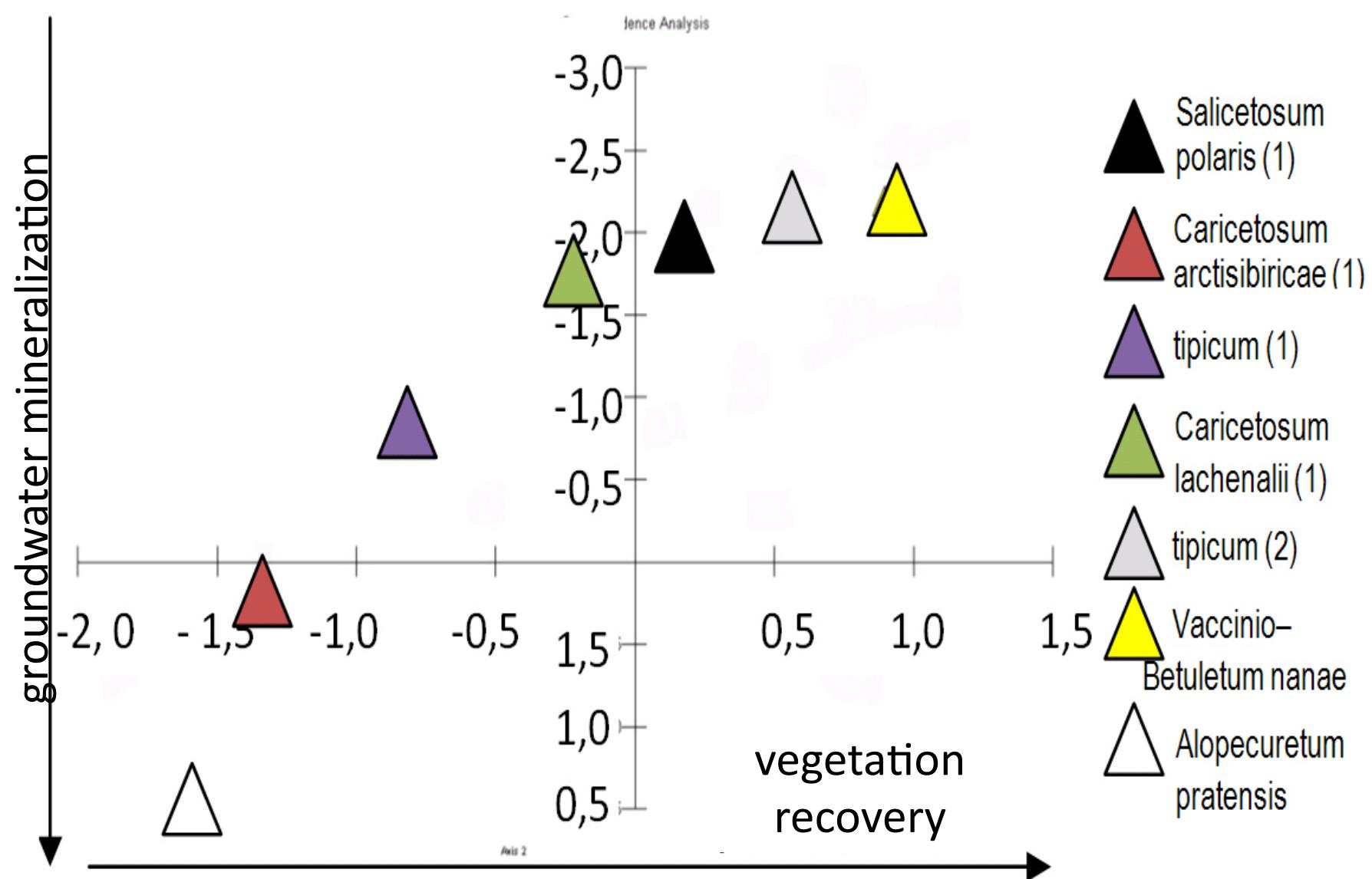
Alopecuretum pratensis → Poo–Caricetum
concolor → Bistorto-Betuletum nanae →
Vaccinio–Betuletum nanae

The seral system of vegetation for landslide's slopes of marine terraces

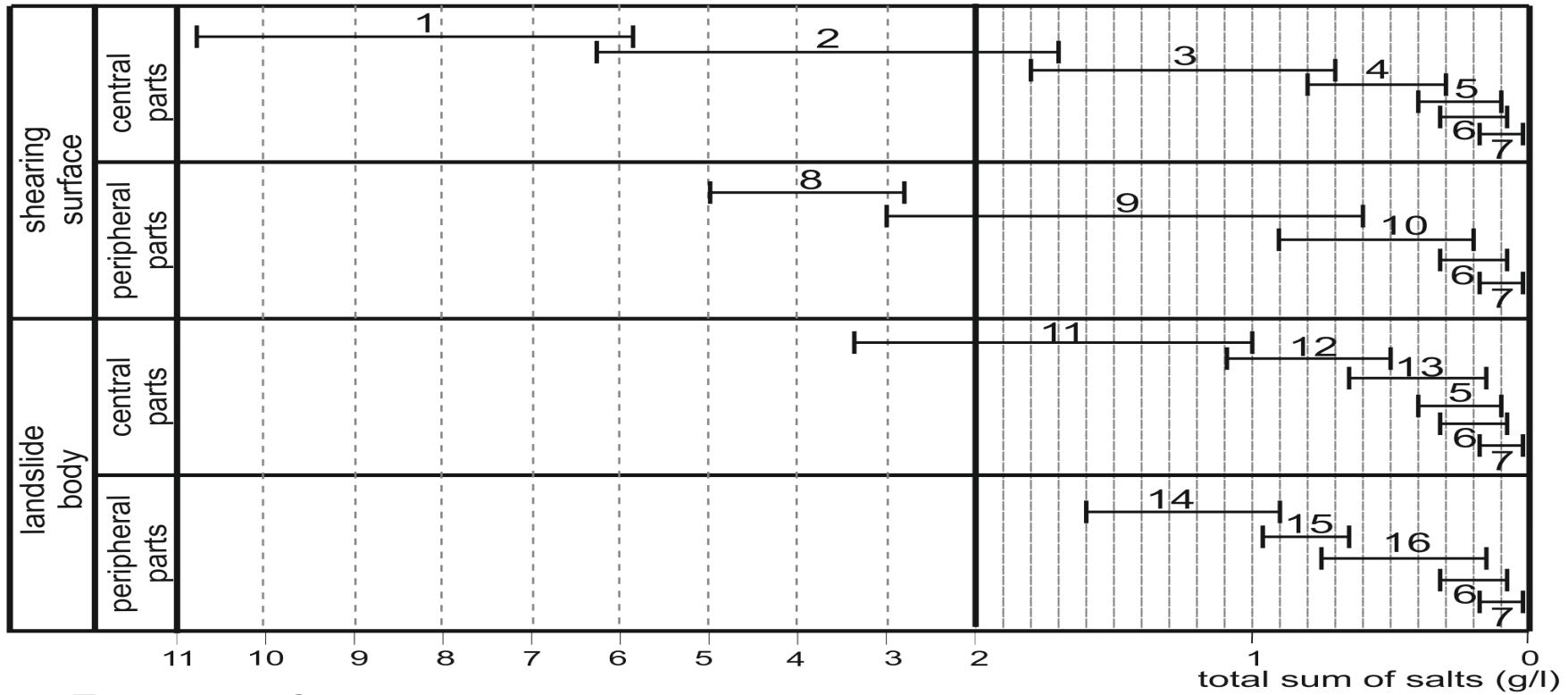


Correspondent analysis

(ecological dynamic sere of shearing surfaces central parts)



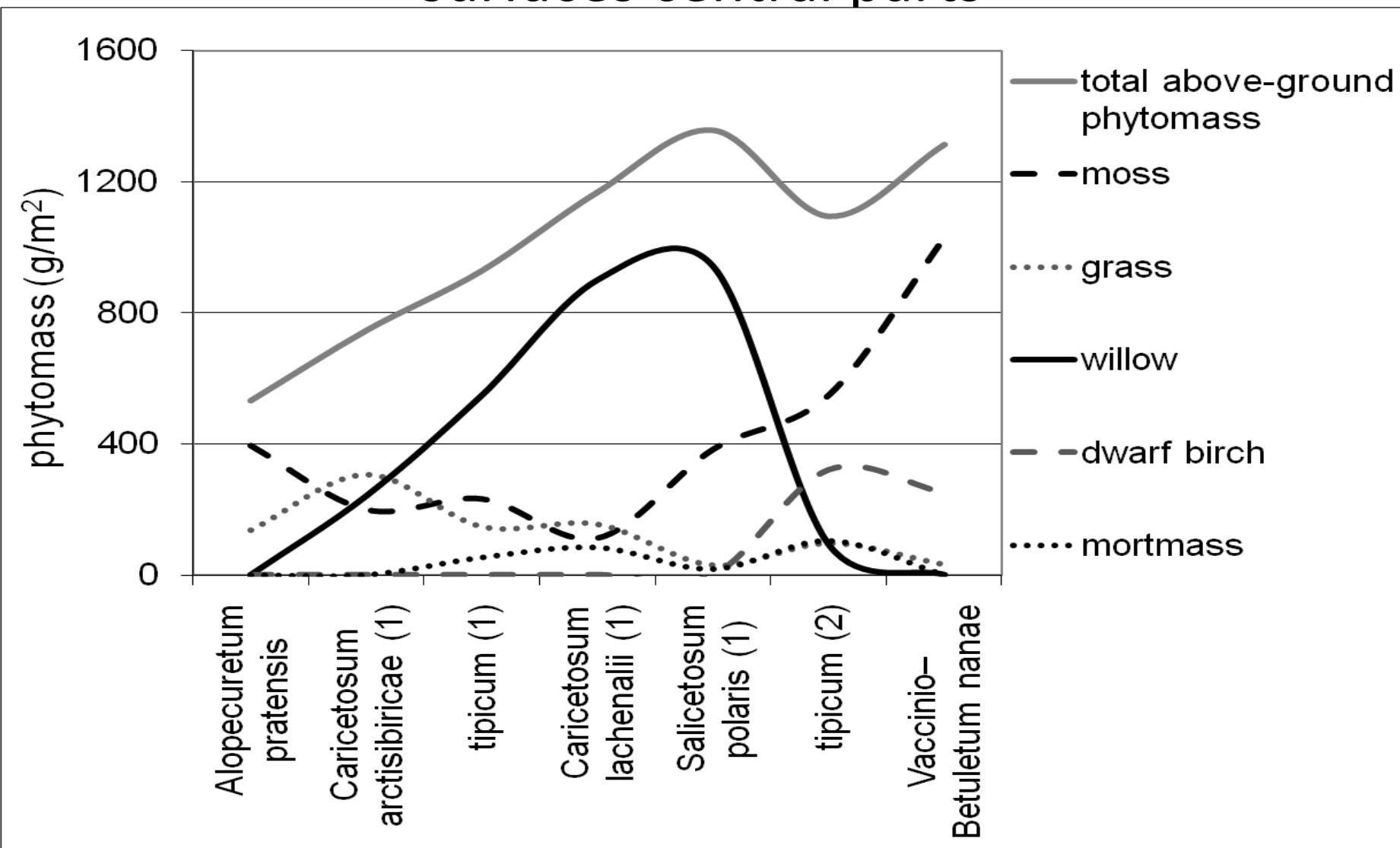
Ecological dynamic series and the change of salt content in groundwaters



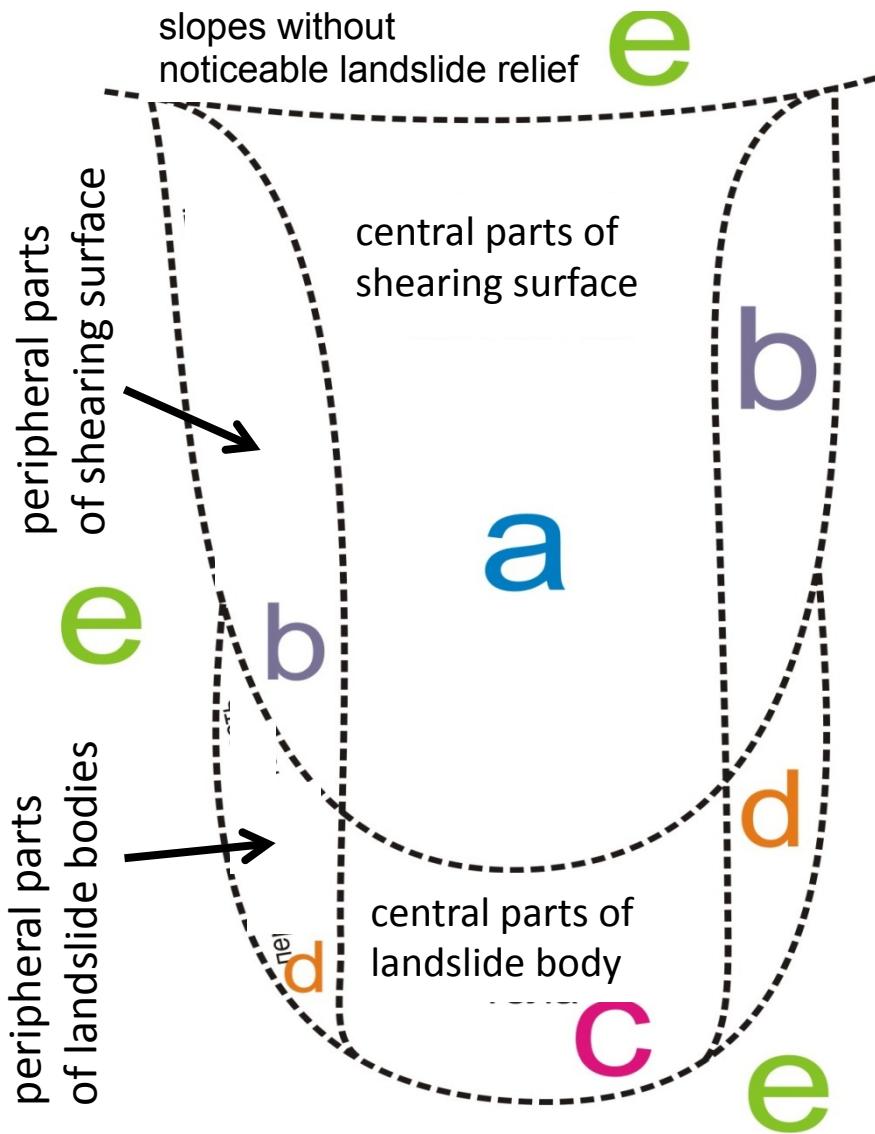
Ecotopes of syntaxa:

- 1 - as-tion Alopecuretum pratensis
- 2 - subas-tion Caricetosum arctisibiricae (1)
- 3 - subas-tion tipicum (1)
- 4 - subas-tion Caricetosum lachenalii (1)
- 5 - subas-tion Salicetosum polaris (1)
- 6 - subas-tion tipicum (2)
- 7 - as-tion Vaccinio-Betuletum nanae
- 8 - subas-tion Calamagrostietosum holmii (1)
- 9 - subas-tion Drepanocladetosum uncinati (1)
- 10 - subas-tion Veratretosum lobeliani (1)
- 11 - subas-tion Festucetosum rubrae (2)
- 12 - subas-tion Peltigeretosum aphthosae (2)
- 13 - subas-tion Veratretosum lobeliani (2)
- 14 - subas-tion Poetosum arcticae (2)
- 15 - subas-tion Eriophoretosum vaginati (2)
- 16 - subas-tion Poo-Calamagrostietosum holmii (2)

Change of average phytomass values in the communities of ecological dynamic sere of shearing surfaces central parts



Scheme of vegetation patterns on landslide-affected slopes



young landslide structures
(up to 300 years old)

- a - *Alopecuretum pratensis / Caricetosum arctisibiricae* (1)*
- b - *Poetosum arcticae* (2)
- c - *Calamagrostietosum holmii* (1)
- d - *Festucetosum rubrae* (2)

old landslide structures (300-2000 years old)

- a - *tipicum* (1)
- b - *Eriophoretosum vaginati* (2)
- c - *Sanionietosum uncinatae* (1)
- d - *Peltigeretosum aphthosae* (2)

ancient landslide structures (>2000 years old)

- a - *Caricetosum lachenalii* (1)
- b - *Poo – Calamagrostietosum holmii* (2)
- c - *Veratretosum lobeliani* (1)
- d - *Veratretosum lobeliani* (2)

subclimax stage (slopes without noticeable landslide relief)

- e - *Salicetosum polaris* (1)
- e - *tipicum* (2)
- e - *Vaccinio–Betuletum nanae*
- e - *Luzulo–Polytrichetum juniperinum*

Indication scheme of seral system of vegetation on landslide-affected slopes of the Central Yamal

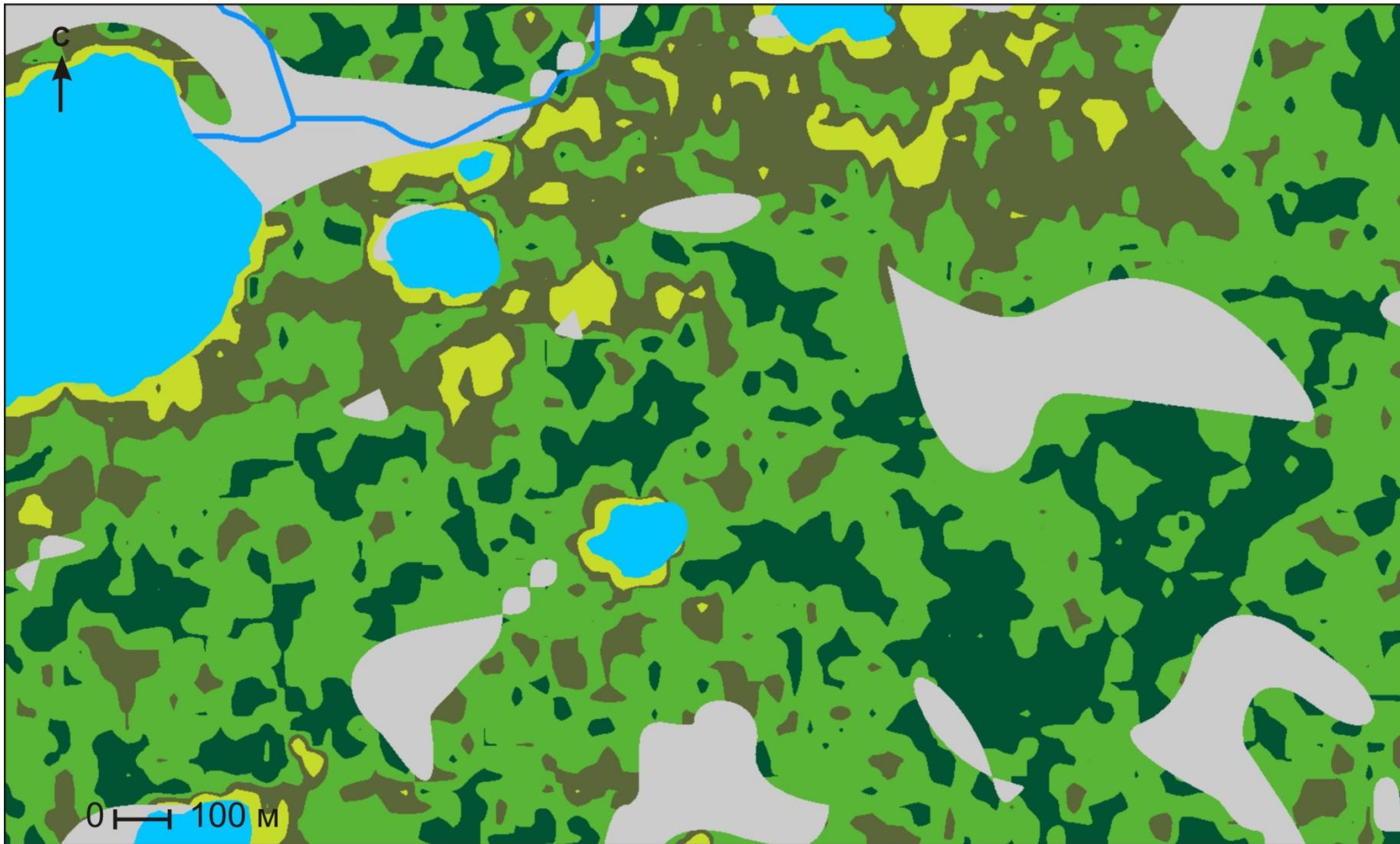
	young structures stage	old structures stage	ancient structures stage	subclimax stage	
shearing surfaces central parts	diff. species <i>Alopecuretum pratensis</i> ; sp. richness - 34; total phm - 532; willow phm - 0; moss phm - 396; ecotypes of v.p. - lrpg+lbpg	diff. species <i>Caricetosum arctisibiricae</i> (1); sp. richness - 22; total phm - 746; willow phm - 241; moss phm - 200; ecotypes of v.p. - lrpg+lbpg	diff. species <i>tipicum</i> (1); sp. richness - 42; total phm - 928; willow phm - 548; moss phm - 233; ecotypes of v.p. - lrpg+srgp+rpg	diff. species <i>Caricetosum lachenalii</i> (1); sp. richness - 36; total phm - 1167; willow phm - 900; moss phm - 113; ecotypes of v.p. - lrpg+rpg+srgp	diff. species <i>Salicetosum polaris</i> (1); ind. species - <i>Dryas octopetala</i> ; sp. richness - 46; total phm - 1356; willow phm - 941; moss phm - 384; ecotypes of v.p. - lrpg
shearing surfaces peripheral parts		diff. species <i>Poetosum arcticae</i> (2); ind. species - <i>Dupontia fisheri</i> ; sp. richness - 20; total phm - 830; willow phm - 470; moss phm - 170; ecotypes of v.p. - lrpg+hs+lbpg	diff. species <i>Eriophoretosum vaginati</i> (2); ind. species - <i>Stellaria palustris</i> ; sp. richness - 31; total phm - 1029; willow phm - 550; moss phm - 230; ecotypes of v.p. - lrpg+hs	diff. species <i>Poo - Calamagrostietosum holmii</i> (2); sp. richness - 34; total phm - 1230; willow phm - 626; moss phm - 277; ecotypes of v.p. - hs+lrpg	diff. species <i>Vaccinio-Betuletum nanae</i> ; sp. richness - 59; total phm - 1093; willow phm - 91; moss phm - 550; ecotypes of v.p. - lrpg+hs
landslide bodies central parts		diff. species <i>Calamagrostietosum holmii</i> (1); sp. richness - 46; total phm - 1016; willow phm - 898; moss phm - 26; ecotypes of v.p. - lrpg	diff. species <i>Drepanocladetosum uncinati</i> (1); ind. species - <i>Drepanocladus uncinatus</i> ; sp. richness - 38; total phm - 1329; willow phm - 1077; moss phm - 95; ecotypes of v.p. - lrpg	diff. species <i>Veratretosum lobelianii</i> (1); sp. richness - 27; total phm - 1386; willow phm - 1014; moss phm - 270; ecotypes of v.p. - lrpg	diff. species <i>Salicetosum polaris</i> (1); ind. species - <i>Dryas octopetala</i> ; sp. richness - 46; total phm - 1356; willow phm - 941; moss phm - 384; ecotypes of v.p. - lrpg
landslide bodies peripheral parts		diff. species <i>Festucetosum rubrae</i> (2); sp. richness - 35; total phm - 993; willow phm - 478; moss phm - 110; ecotypes of v.p. - lrpg+hs	diff. species <i>Peltigeretosum aphthosae</i> (2); ind. species - <i>Peltigera aphthosa</i> ; sp. richness - 25; total phm - 1324; willow phm - 520; moss phm - 388; ecotypes of v.p. - lrpg+hs	diff. species <i>Veratretosum lobelianii</i> (2); sp. richness - 42; total phm - 1725; willow phm - 800; moss phm - 446; ecotypes of v.p. - lrpg+hs	

35 years 300 years 2000 years

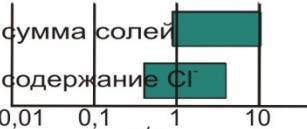
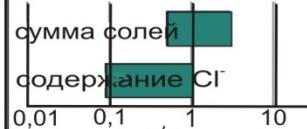
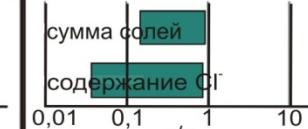
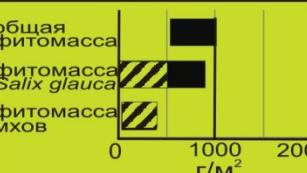
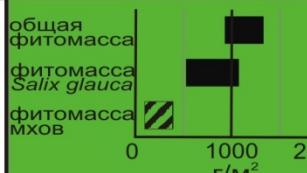
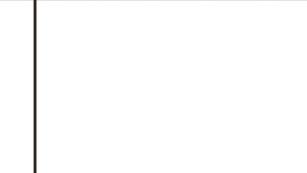
Salix glauca

phm – phytomass (g/m²), v.p. – vascular plants, lrpg – long-rhizome polycarpic grasses, hs – hemiprostrate shrubs, fbpg – firm-bunch polycarpic grasses, srgp – short-rhizome polycarpic grasses; rrgp – racemose-root polycarpic grasses; lbpg – loose-bunch polycarpic grasses with short creeping roots

Fragment of phytoindication map of landslide process



Legend of phytoindication map

		сумма солей и содержание Cl ⁻ в грунтовых водах (г/л)	сумма солей и содержание Cl ⁻ в грунтовых водах (г/л)	сумма солей и содержание Cl ⁻ в грунтовых водах (г/л)	сумма солей и содержание Cl ⁻ в грунтовых водах (г/л)	сумма солей и содержание Cl ⁻ в грунтовых водах (г/л)
а	микрокомбинации сообществ синтаксонов сукцессионной системы растительности склонов морских террас					
	серии и комплексы: Alopecuretum pratensis Caricetosum arctisibiricae (1) Poetosum arcticae (2) Calamagrostietosum holmii (1) Festucetosum rubrae (2)					
б	комплексы: tipicum (1) Eriophoretosum vaginati (2) Drepanocladetosum uncinati (1) Peltigeretosum aphthosae (2)					
	комплексы: Caricetosum lachenalii (1) Poo-Calamagrostietosum holmii (2) Veratretosum lobeliani (1) Veratretosum lobeliani (2)					
в	комплексы: Salicetosum polaris (1) tipicum (2) Vaccinio-Betuletum nanae					
	NDVI	0,00 - 0,27	0,34 - 0,40	>0,40	0,27 - 0,34	
	стадии восстановления растительного покрова после схода криогенного оползня скольжения	начальная стадия	промежуточная стадия (до 300 лет)	поздняя стадия (до 2000 лет)	стадия субклимакса	

(1) - субассоциации ассоциации Poo-Caricetum concolor, (2) - субассоциации ассоциации Bistorto-Betuletum nanae



водотоки



водоемы



растительные сообщества сукцессионной системы
растительности склонов морских террас отсутствуют

Legend of phytointication map

Сукцессионная система растительности склонов морских террас

Alopecuretum pratensis

Caricetosum arctisibiricae (1)

tipicum (1)

Calamagrostietosum holmii (1)

Drepanocladetosum uncinati (1)

Veratretosum lobelianii (1)

Salicetosum polaris (1)

Festucetosum rubrae (2)

Peltigeretosum aphthosae (2)

Veratretosum lobelianii (2)

tipicum (2)

Vaccinio-Betuletum nanae

Poetosum arcticae (2)

Eriophoretosum vaginati (2)

Poo-Calamagrostietosum holmii (2)

Союз *Equiset-Salicion glaucae* (дифференциальные виды - *Salix glauca*, *Equisetum arvense* subsp. *boreale*):
 (1) - субассоциации ассоциации *Poo-Caricetum concolor* (дифференциальные виды - *Carex concolor*, *Poa alpigena* subsp. *copeloea*, *Ranunculus borealis*)
 (2) - субассоциации ассоциации *Bistorto-Betuletum nanae* (дифференциальные виды - *Betula nana*, *Vaccinium vitis-idaea* subsp. *minus*, *Bistorta vivipara*, *Dicranum elongatum*)

Эколого-динамические ряды:

эколого-динамический ряд сообществ центральных частей склонов скольжения

эколого-динамический ряд сообществ центральных частей оползневых тел

эколого-динамический ряд сообществ периферических частей оползневых тел

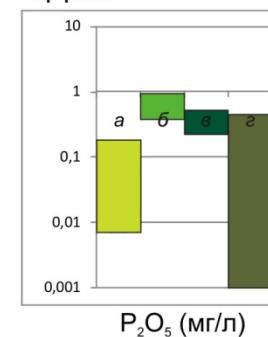
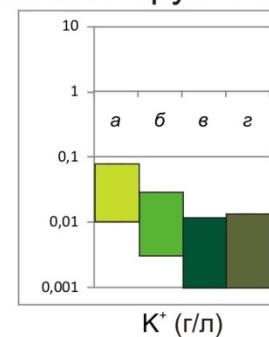
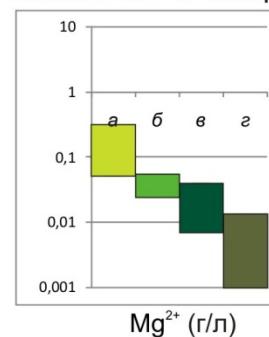
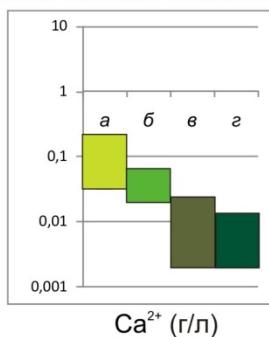
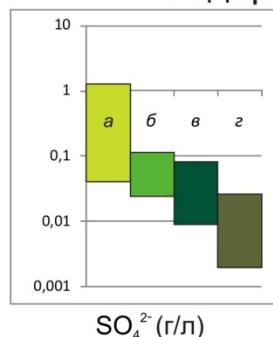
эколого-динамический ряд сообществ периферических частей склонов скольжения

35 лет

300 лет

2000 лет

Содержание химических элементов и соединений в грунтовых водах



Landslide-affected area

stages of the process	% of area of landslide development (1014,6 km ²)	% of mapped area (4037 km ²)
young landslide structures	13,31%	3,35%
old landslide structures (up to 300 years old)	41,53%	10,44%
ancient landslide structures (300 – 2000 years)	26,59%	6,68%
subclimax stage (slopes without noticeable landslide relief)	18,57%	4,67%