

Multi-Medium, Multi-Element Regional Geochemical Mapping in the European Arctic: The Kola Ecogeochemistry Project

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(Geological Survey of Norway)

Kola Ecogeochemistry



Legend

- ✕ Mine, in production
- ✕ Mine, closed down
- Important mineral occurrence, not developed
- ⚙ Smelter, production of mineral concentrate
- ▲ City, town, settlement
- └ Project boundary

Survey area (regional mapping, 1995), pilot project area (1993), location of catchments (1994 catchment study – 1 - 8)

Project Partners:
Central Kola Expedition (CKE),
Geological Survey of Finland (GTK),
Geological Survey of Norway (NGU)

Kola Ecogeochemistry



Dwarf shrub tundra, near coast of Barents Sea

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121



Forest tundra, Finmarksvidda, Norway

Kola Ecogeochemistry

441

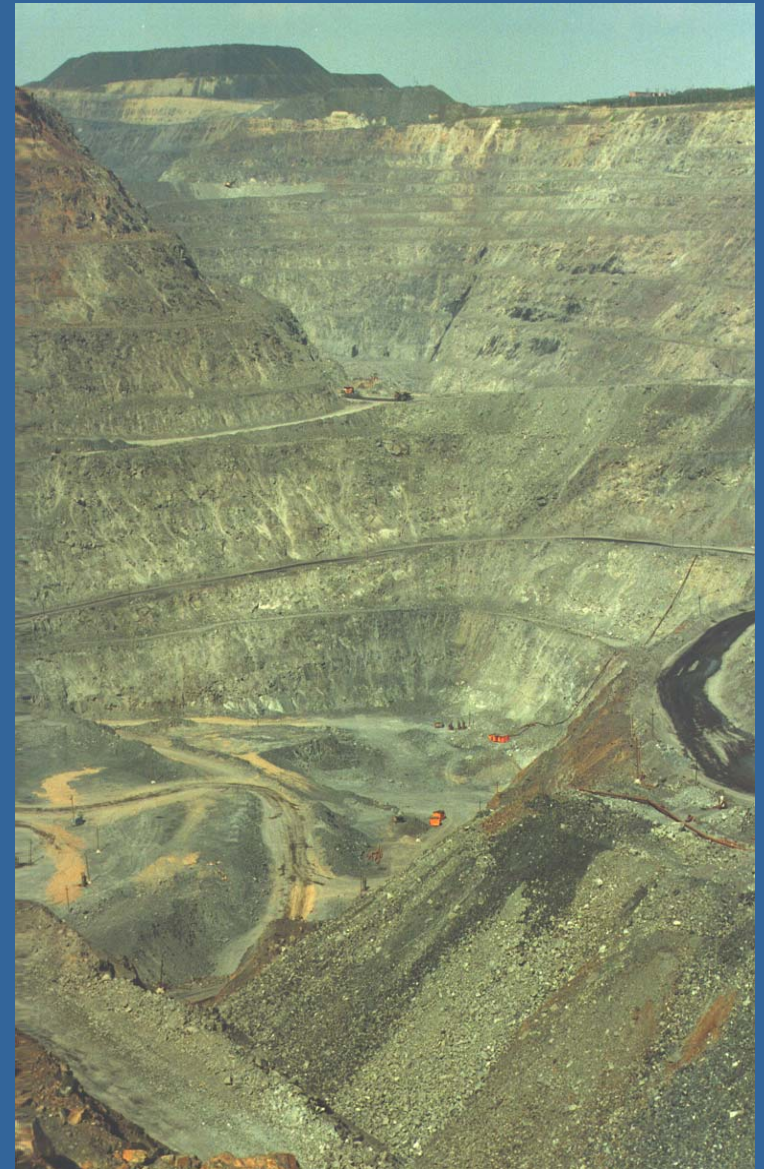


Northern boreal forest near Arctic Circle, Russia

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Zapoljarnij Cu/Ni-mine
– 6 mill. t of ore are
mined here
annually.

Nickel smelter at Nikel.



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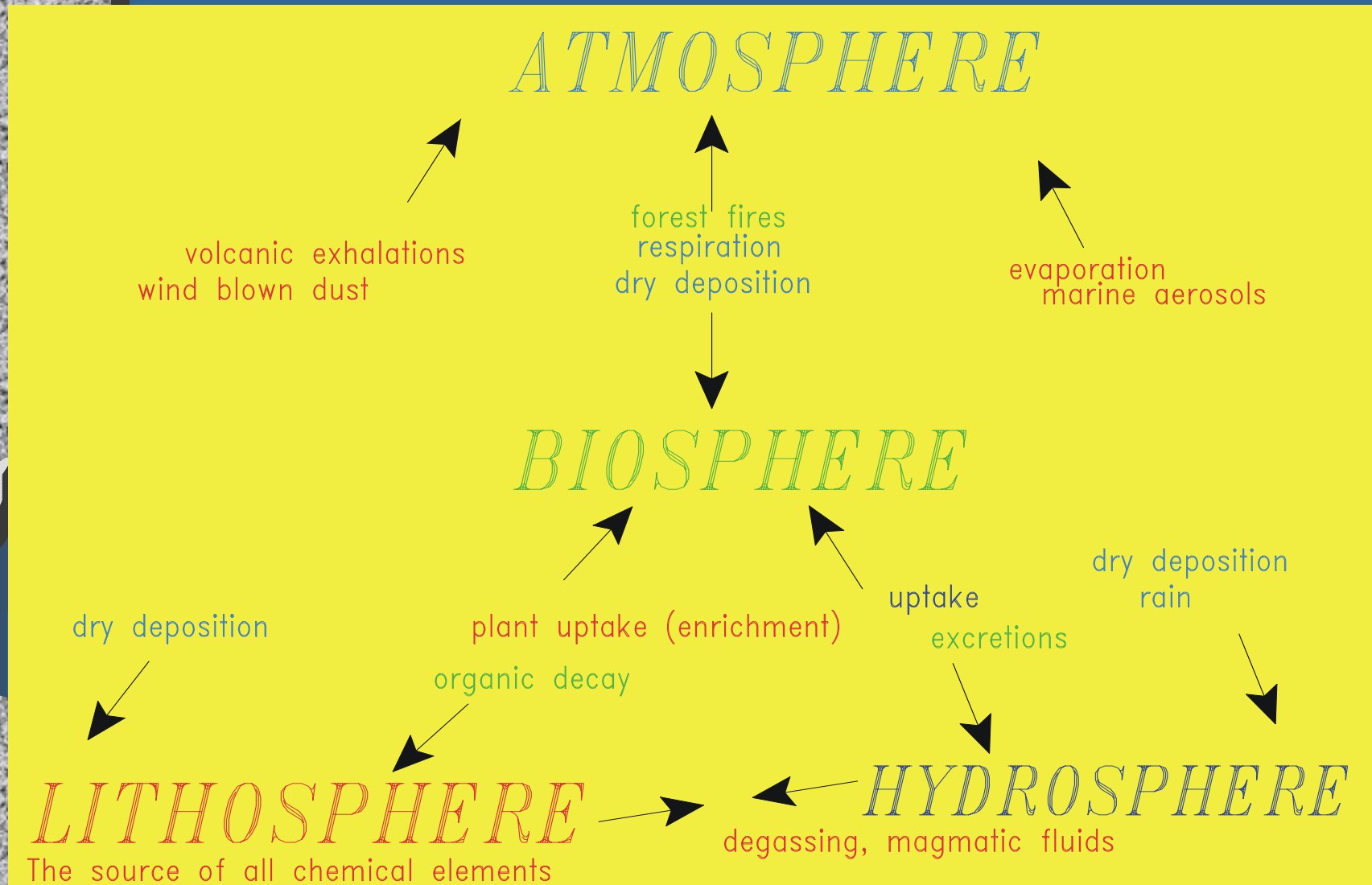
Emission figures for 1994 (in t a⁻¹):

	SO₂	Ni	Cu
– Nikel	129,000	136	82
– Zapoljarnij	69,000	161	81
– Monchegorsk	98,000	1620	930
SUM	296,000	1917	1093 (+ many other elements, e.g. Ag, Au and PGE's)

METAL VALUE (US\$)

16Mil. 3 Mil.

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Project idea: documentation of the whole ecosystem.

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MULTIMEDIA STUDY:

SAMPLE MEDIUM	PILOT PROJECT 1992/3	CATCHMENT STUDY 1994	REGIONAL SAMPLING 1995
SNOW (filterresidue and meltwater)	X	X	
RAIN		X	
STREAMWATER	X	X	
LAKEWATER			X
GROUNDWATER		X	
TERRESTRIAL MOSS	X	X	X
LICHEN			X
OTHER VEGETATION		X	
TOPSOIL (0-5 cm)	X	X	X
HUMUS (0-3 cm)			X
PODZOL PROFILES (5 horizons)		X	X
STREAM SEDIMENTS	X		
ORGANIC STREAM SEDIMENTS		X	
OVERBANK SEDIMENTS	X	X	
QUATERNARY DEPOSITS		X	
BEDROCK		X	

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THREE (FOUR) SAMPLE MEDIA FINALLY SELECTED FOR REGIONAL MAPPING:

- **TERRESTRIAL MOSS** (*Hylocomium splendens* & *Pleurozium schreberi*), representing
 - **THE ATMOSPHERE**
- **HUMUS (O-horizon)**, 0-3cm, <2mm, representing exchange between:
 - **ATMOSPHERE, BIOSPHERE, PEDOSPHERE**
- **B&C-horizon** of Podzol Profiles, representing:
 - **THE PEDOSPHERE (THE LITHOSPHERE)**

Giving the possibility to study element exchange, cycling, enrichment, and depletion between different compartments of the ecosystem on a regional scale in an area with a large gradient.

Lake water was additionally collected in Russia.

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ELEMENTS MAPPED IN THE PROJECT

Multimedia analysis		Red:		Harmful (moderate to highly toxic, carcinogenic or radiotoxic)																											
* Isotope analysis (only topsoil)		Underlined:		Essential																											
		Italic:		Essential for some organisms																											
H																	He														
Li	Be																	B	C	N	O	F	Ne								
Na	Mg																	Al	Si	P	S	Cl	Ar								
*K	Ca	Sc	Ti	<u>V</u>	<u>Cr</u>	Mn	Fe	<u>Co</u>	<u>Ni</u>	<u>Cu</u>	Zn	Ga	Ge	As	<u>Se</u>	<u>Br</u>	Kr														
Rb	Sr	Y	Zr	Nb	<u>Mo</u>	Tc	Ru	Rh	<u>Pd</u>	Ag	<u>Cd</u>	In	<u>Sn</u>	<u>Sb</u>	Te	<u>I</u>	Xe														
*Cs	Ba	La	Hf	Ta	W	Re	Os	<u>Ir</u>	<u>Pt</u>	Au	<u>Hg</u>	<u>Tl</u>	<u>Pb</u>	*Bi	Po	At	Rn														
Fr	Ra	*Ac																													
																		Only catchment study 1994													
																		Ce	Pr	Nd	Pm	Sm	<u>Eu</u>	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
																		Th	Pa	<u>U</u>	Np	<u>Pu</u>	*Am	Cm	Bk	Cf	Es	Fm	Md	No	Lw

Only catchment study 1994



Multi-Element Study

Kola Ecogeochemistry



FOREST ECOSYSTEM STRUCTURE

Trees layer:

Spruce (*Picea abies*),
Scots pine (*Pinus sylvestris*),
Birch (*Betula pubescens*)

Dwarf shrubs layer:

Crowberry (*Empetrum spp.*),
Bilberry (*Vaccinium myrtillus*)
Cowberry (*Vaccinium vitis-idaea*)
(*Vaccinium uliginosum*)
Heather (*Calluna vulgaris*)



Moss-lichen layer:

Mosses:

Pleurozium shreberi
Hylocomium splendens
Politrichum commune
Dicranum spp.

Lichens:

Cladonia spp.
Cetraria spp.

Soil

Field documentation: 3 photographs/site

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O-horizon organic
litter and humus

E-horizon
leached

B-horizon
enrichment of Fe
and other elements

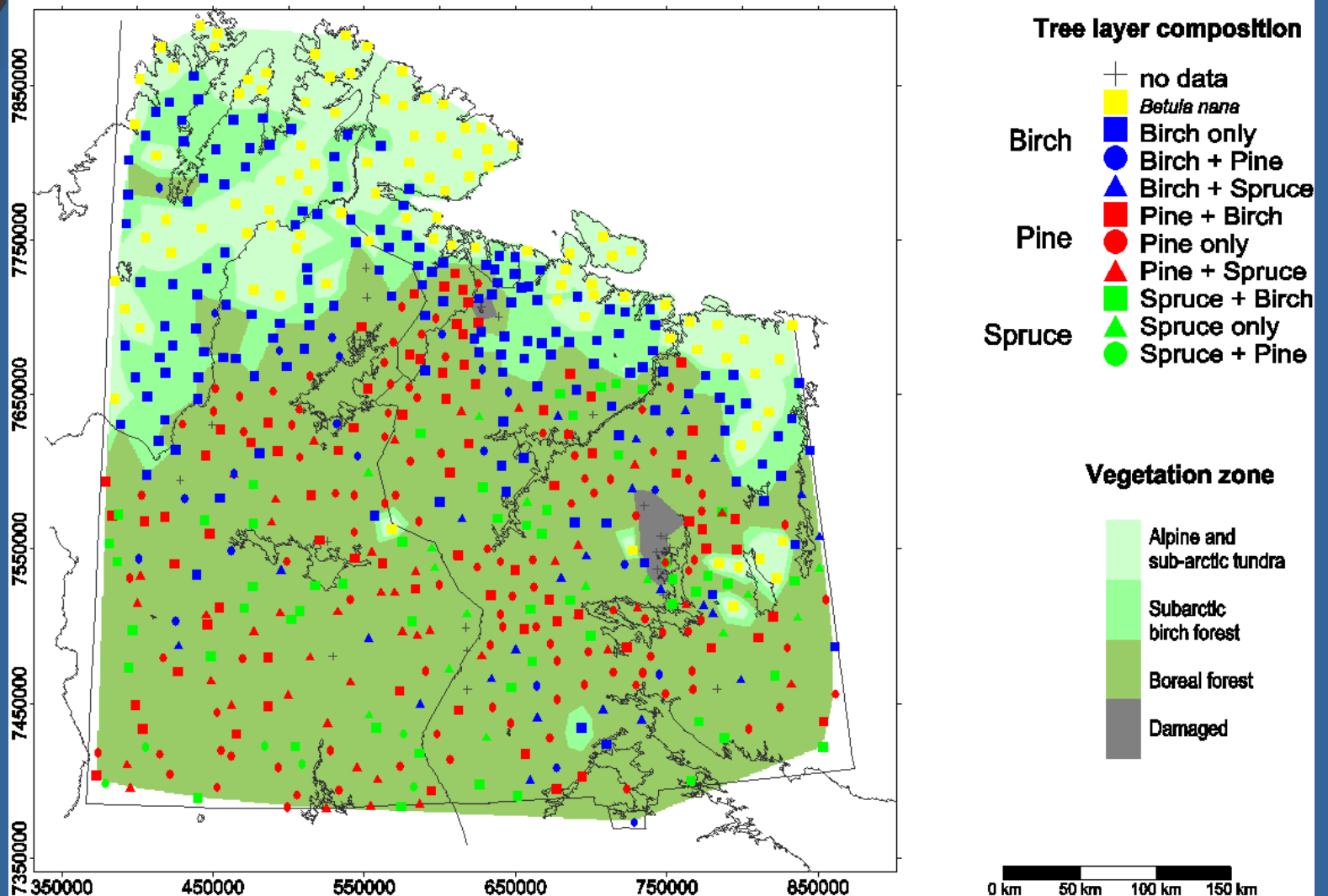
BC-horizon
border zone B to C

C-horizon
Unaltered till



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Vegetation zones and forest composition



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Caledonian rocks

Quartzite, meta-arkose, dolostone, phyllite, greywacke, gabbro

Neoproterozoic

Conglomerate, gritstone, sandstone, siltstone, mudstone, in places enriched in phosphorous

Palaeoproterozoic

Basaltic volcanites, subordinate 'black schist', conglomerate, quartzite, dolostone, gabbro

Andesite, picrite, basalt, greywacke, 'black schist', chert, limestone

Granite, granodiorite, rappakivi granite, gneiss, greywacke, marble

Gabbro

Granite, granodiorite, alkaline granite

Archaean

Felsic/mafic granulite

Gneiss, granite, tonalite, iron quartzite, amphibolite

Tonalite, granite/gneiss, tonalite, amphibolite

Basalt, komatiite

Palaeoproterozoic to Palaeozoic

Alkaline/ultramafic alkaline igneous rock

- Deposit
- Occurrence
- Ag
- Au
- Cr
- Cu
- Fe
- Mn
- Ti
- Ni
- Co
- Pt, Pd
- W
- Mo
- Zn
- Pb
- U
- Th
- Nb
- Ta
- Zr
- Apatite
- Muscovite

Lithology and mineral deposits and occurrences

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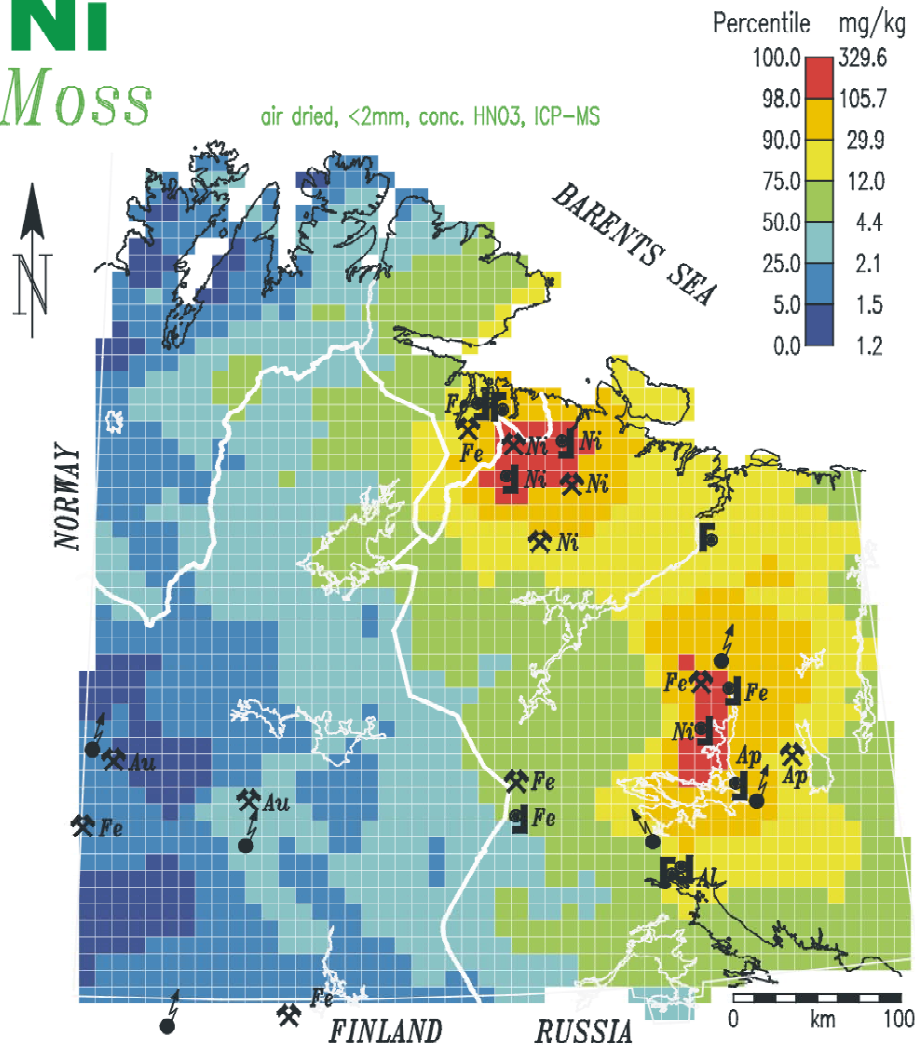


The Monchegorsk Cu-Ni-refinery and its surroundings

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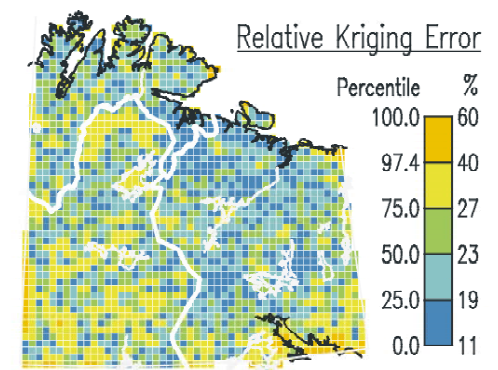
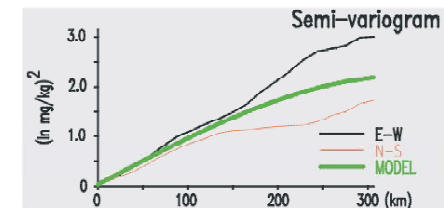
Ni Moss

air dried, <2mm, conc. HNO₃, ICP-MS

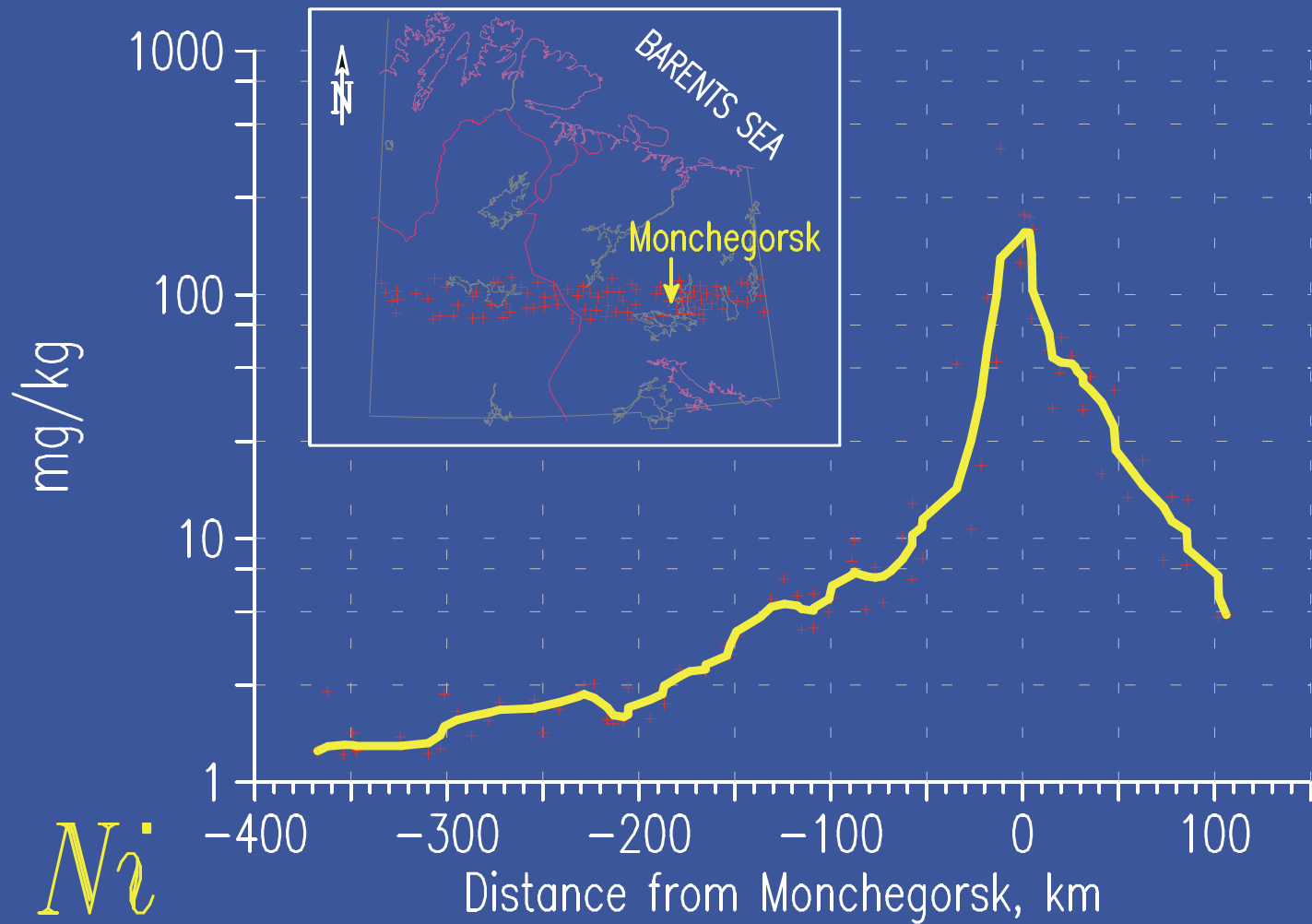


Emissions from Monchegorsk and Nikel/Zapoljarnij

- Smelter or production of mineral concentrates
 - Mining
 - Thermal power station
 - Other metal industry
 - Nuclear power station
- Al: Aluminium, Ap: Apatite, Au: Gold, Fe: Iron, Ni: Nickel/Copper

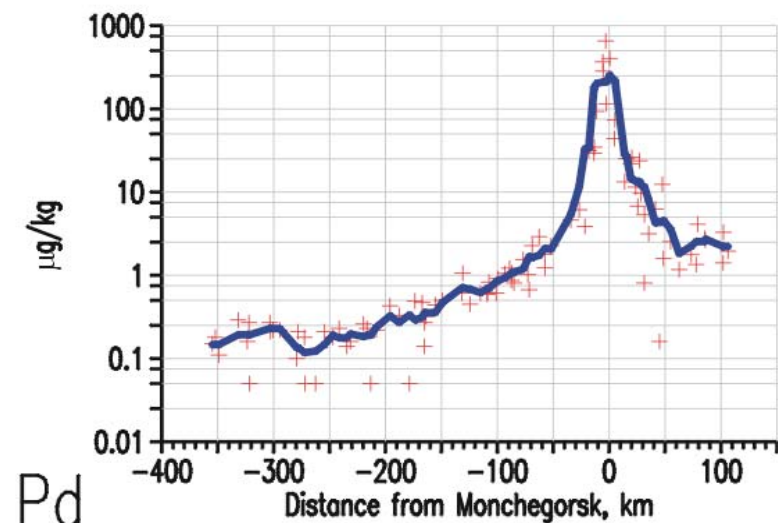
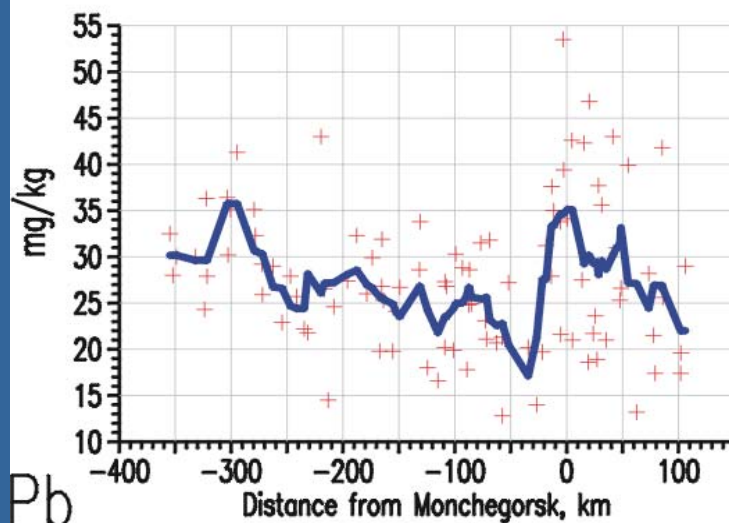
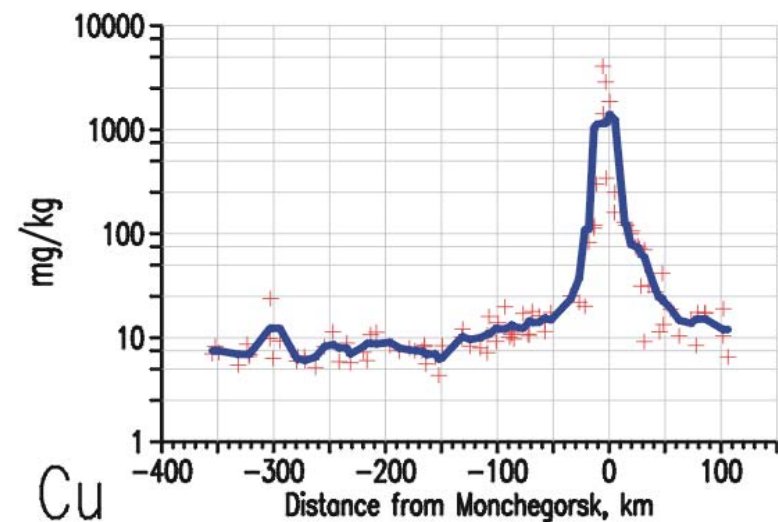
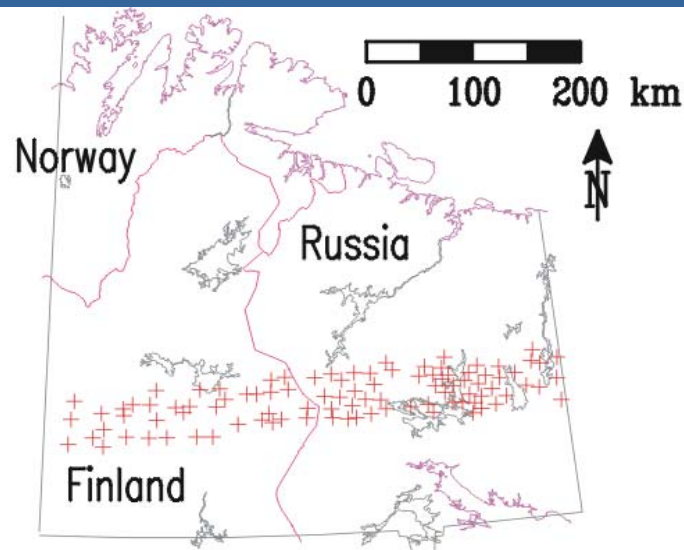


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An E-W-Profile cutting Monchegorsk. Nickel in moss.
Pollution/Background-ratio: c. 200.

Kola Ecogeochemistry



An E-W-Profile cutting Monchegorsk. Copper, Pb and Pd in the O-horizon. Background is always reached at 50-200 km.

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Pollution/background-ratios (Catchment Study Results)
differ widely between different sample materials

POLLUTION/BACKGROUND-ratio

Elem.	Snow	Rain	Stream Water	Stream sed.	Moss	Crow-berry	Top-soil	O-horiz.	C-horiz.
As	21	176	4	7	6	22	60	22	16
Co	2197	1180	136	8	69	172	98	34	4
Cu	2523	453	228	735	28	95	568	383	122
Ni	1290	271	858	247	183	223	560	469	14
V	46	27	5	2	3	4	8	6	1

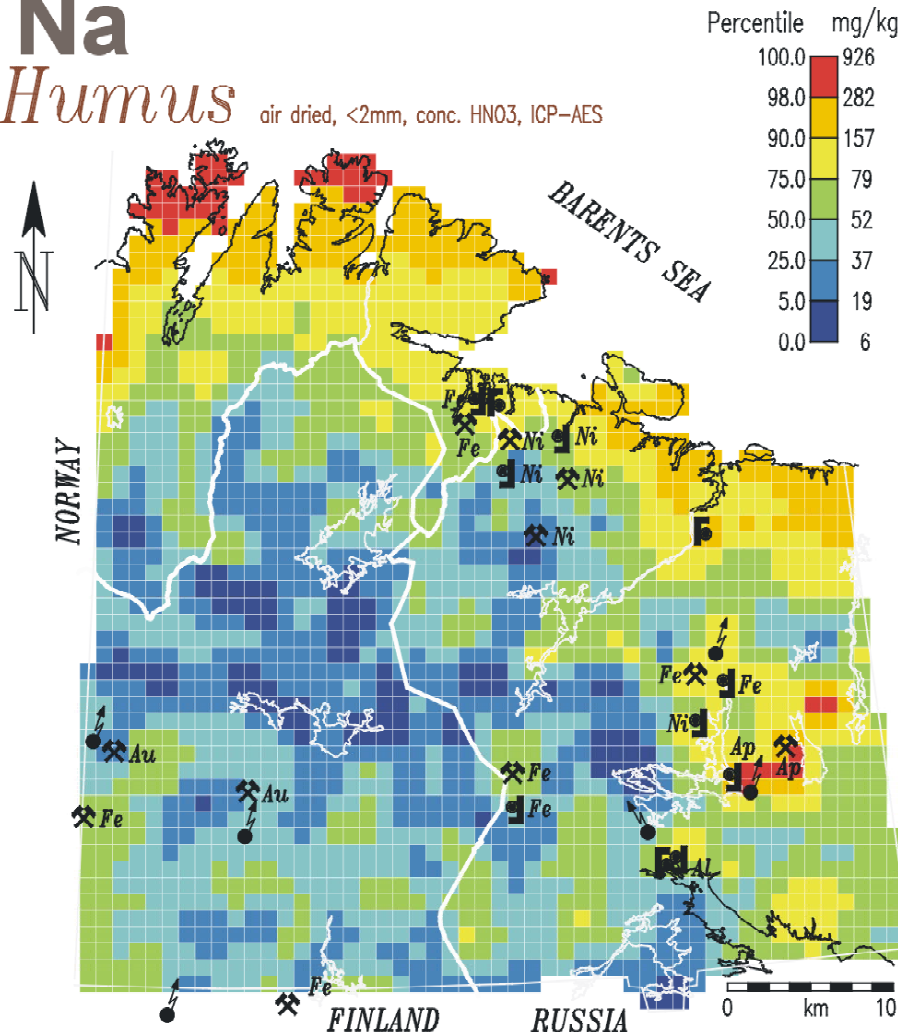
Official emission figures: Cu/Ni=0.5
 Ore feed: Norils'k ore: Cu/Ni=2
 Pechenga ore: Cu/Ni=0.5

C-horizon near Monchegorsk:
derived from basic/ultrabasic
rocks, background: gneisses

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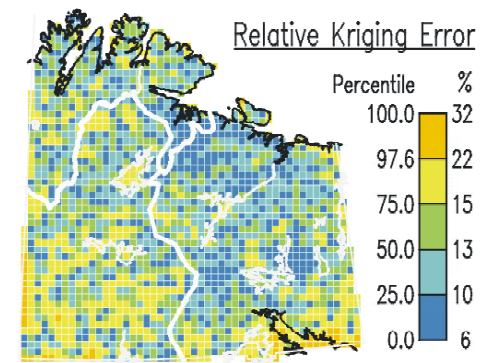
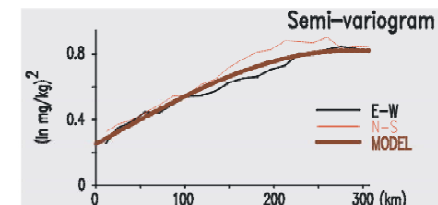
Na
Humus

air dried, <2mm, conc. HNO₃, ICP-AES



Input of Sea Spray + Mining of Alkaline Rocks

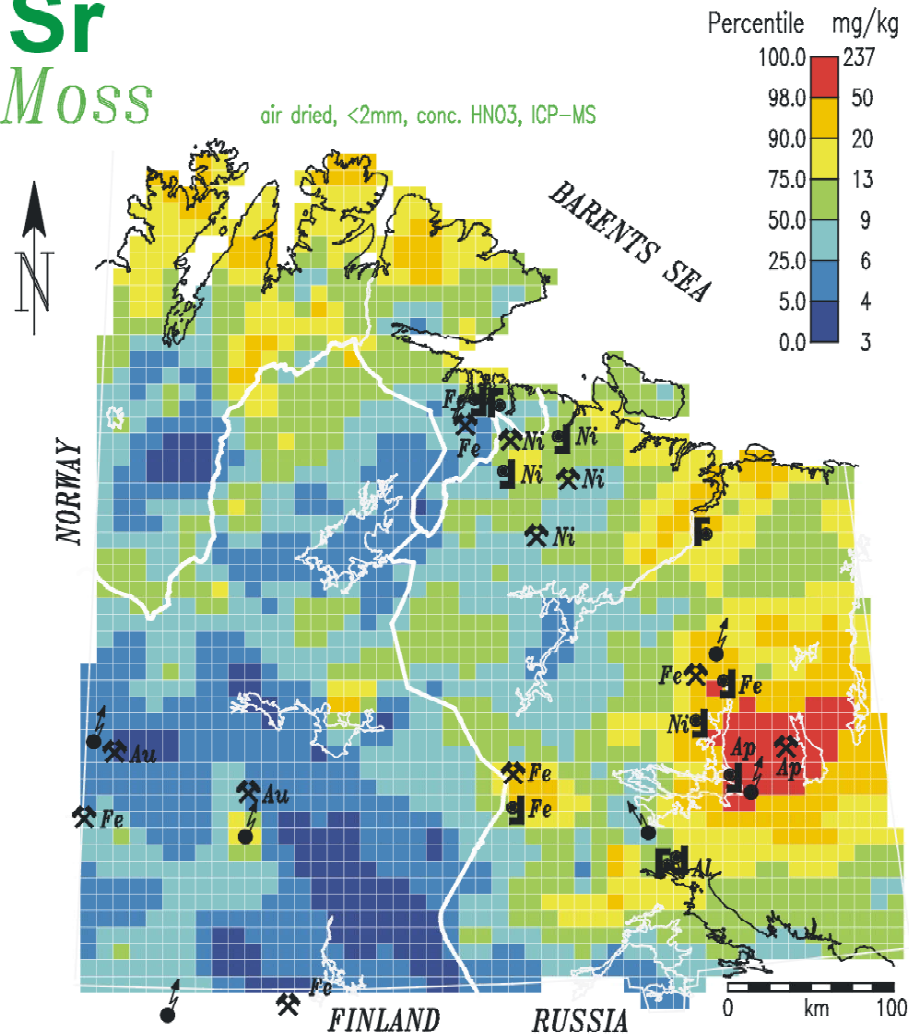
- Smelter or production of mineral concentrates
 - Thermal power station
 - Mining
 - Other metal industry
 - Nuclear power station
- Al: Aluminium, Ap: Apatite, Au: Gold, Fe: Iron, Ni: Nickel/Copper



Kola Ecogeochemistry

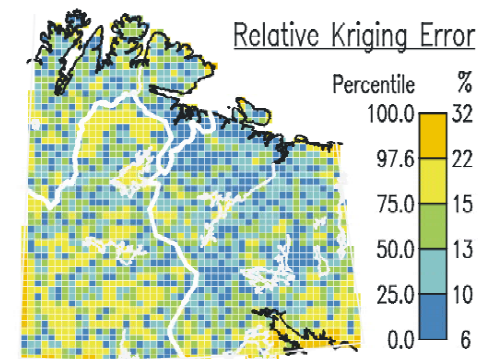
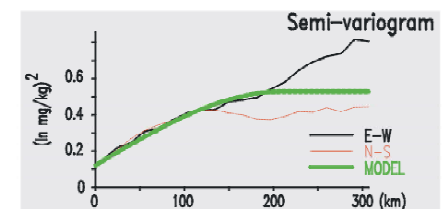
Sr Moss

air dried, <2mm, conc. HNO₃, ICP-MS



Rock Dust (Alkaline Intrusions) and Sea Spray

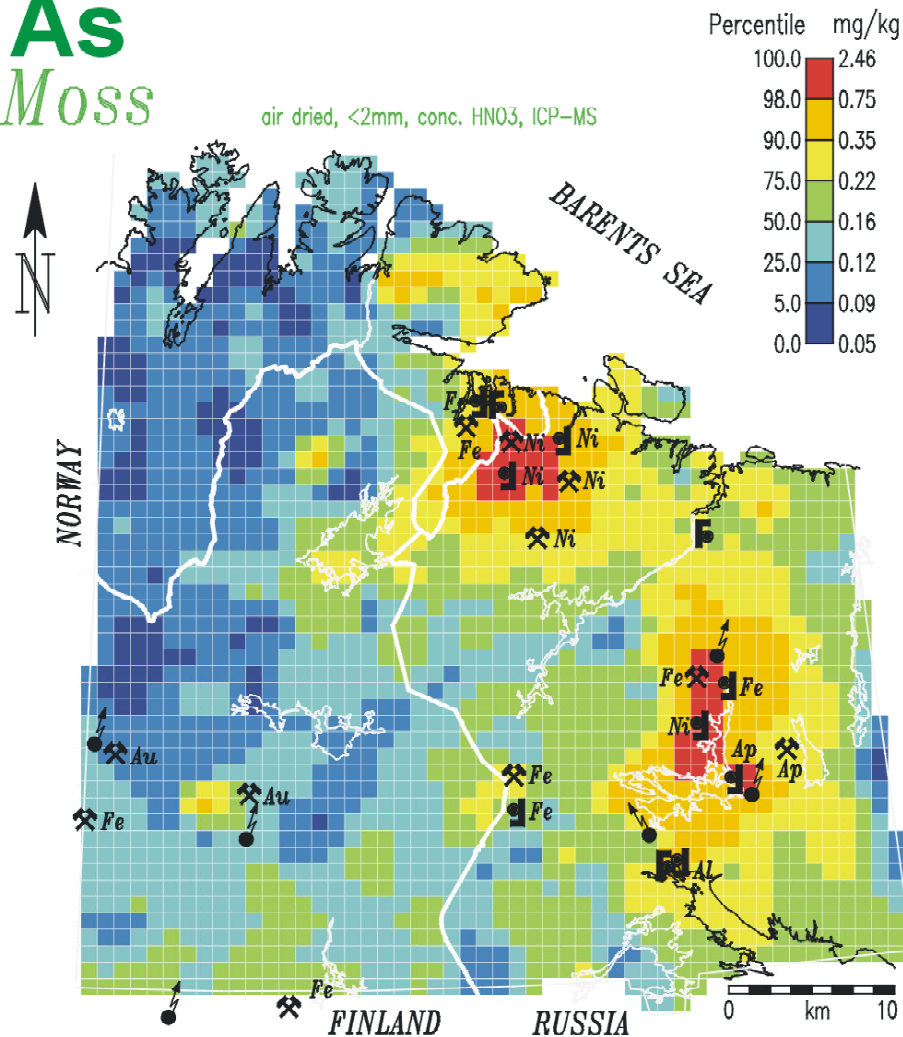
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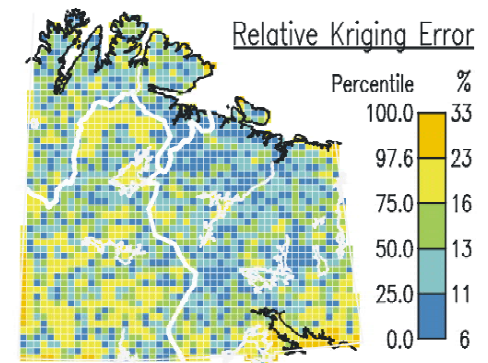
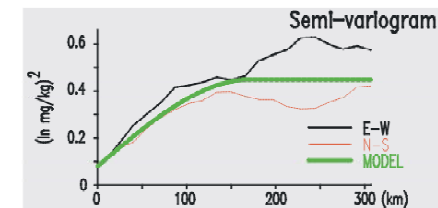
Kola Ecogeochemistry

As
Moss

air dried, <2mm, conc. HNO₃, ICP-MS



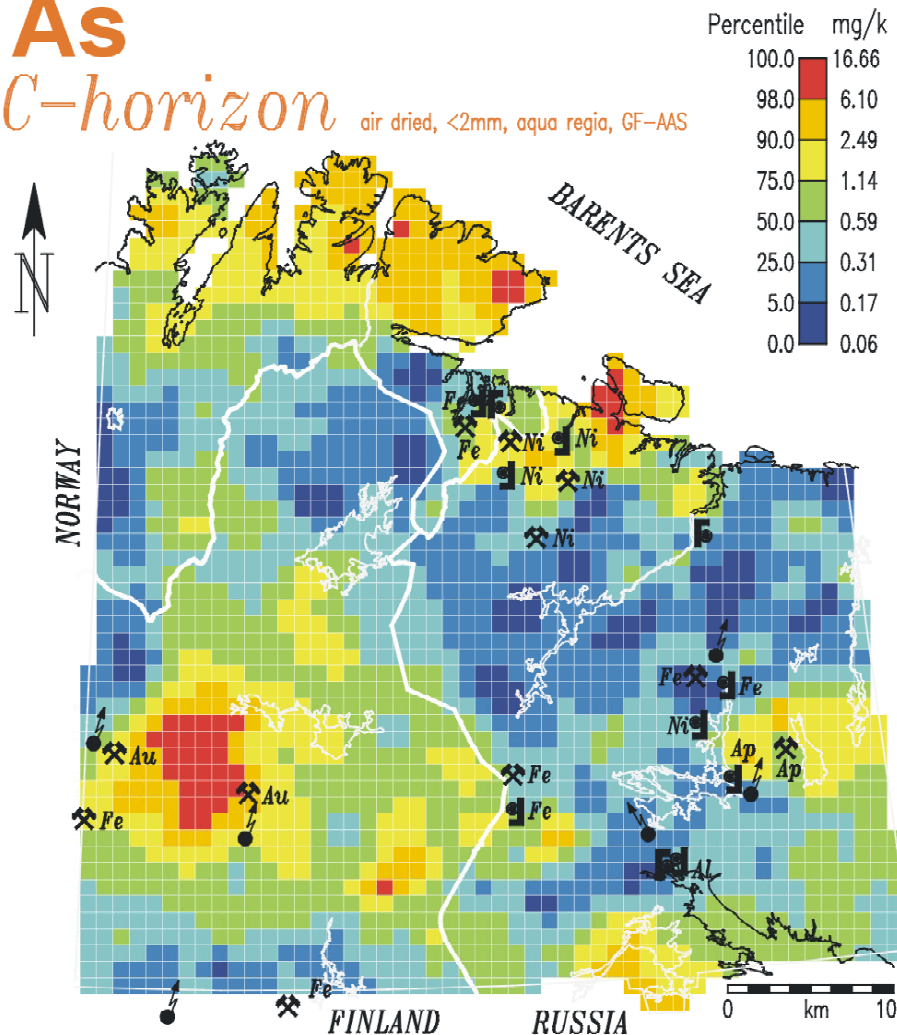
Pollution + Geogenic Sources



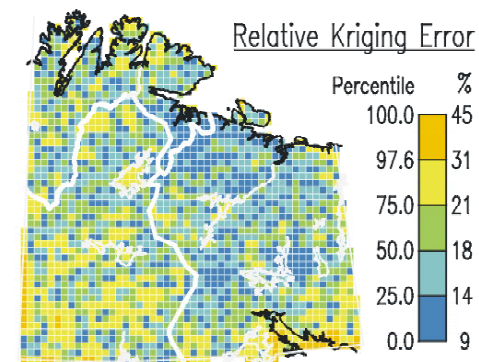
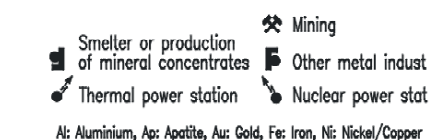
Kola Ecogeochemistry

As
C-horizon

air dried, <2mm, aqua regia, GF-AAS



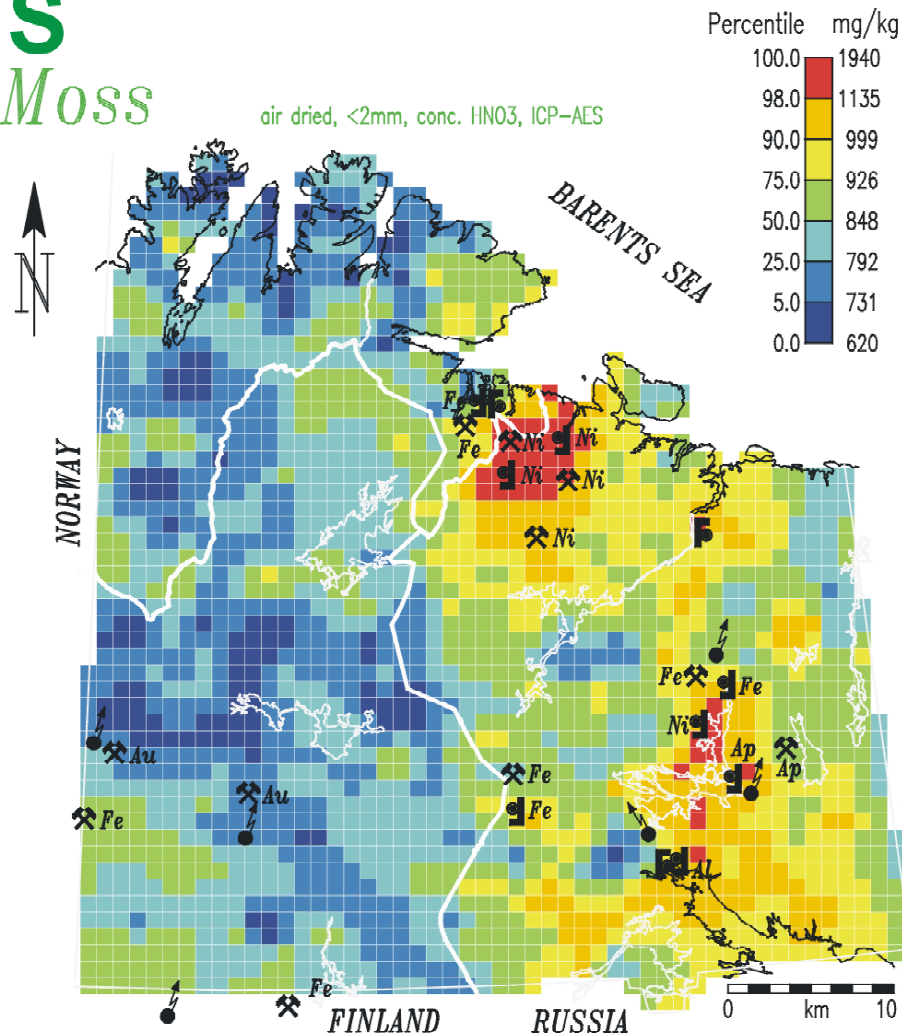
Caledonian Sediments
Cu/Ni-deposits (?)
Alkaline Intrusions
Hydrothermal System



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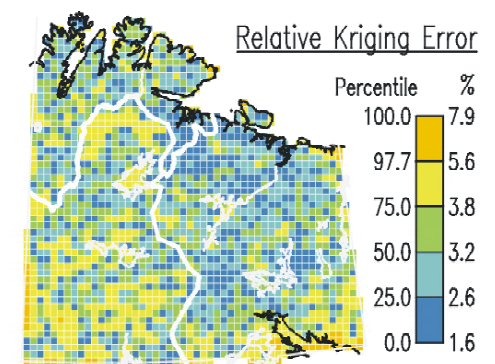
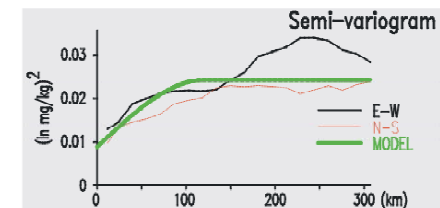
S
Moss

air dried, <2mm, conc. HNO₃, ICP-AES



**Pollution but
no sea spray!**

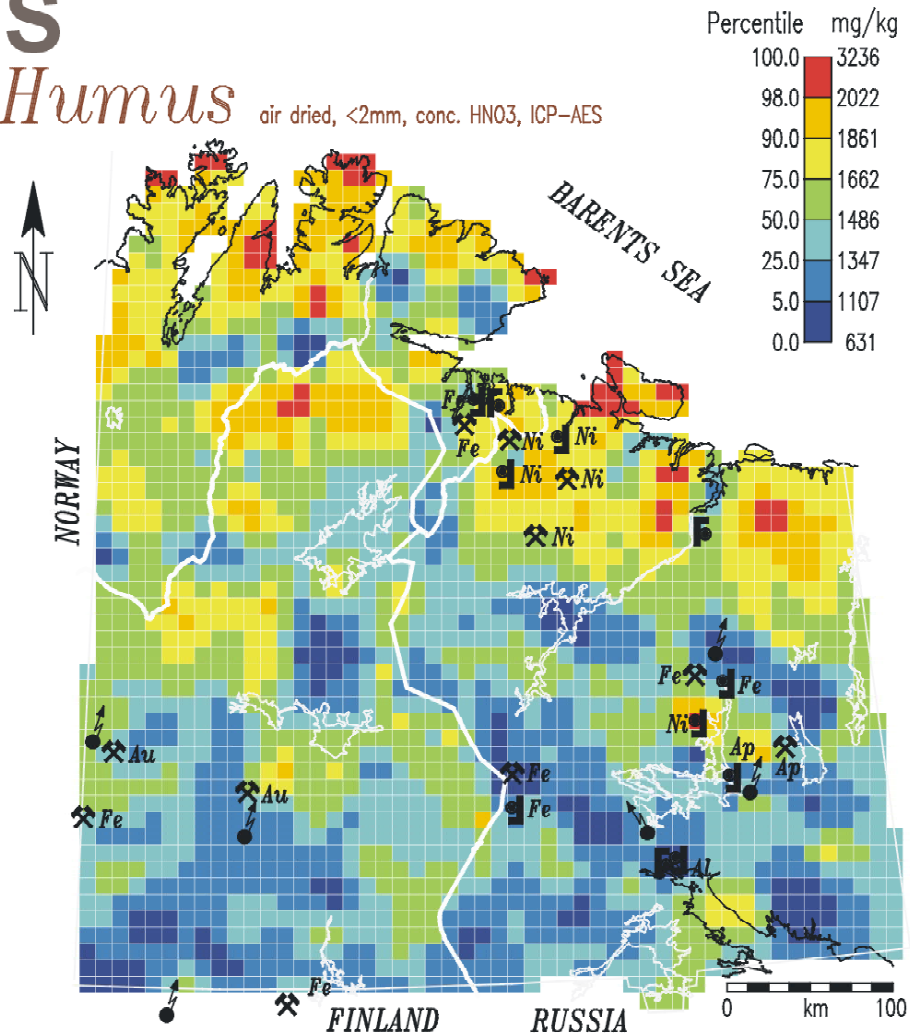
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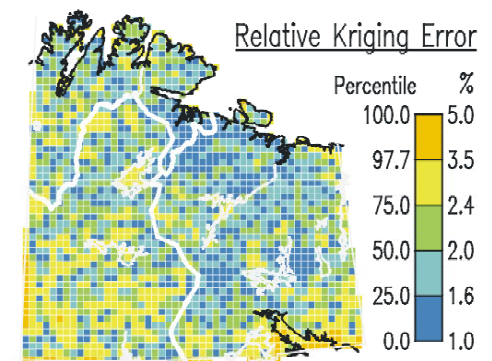
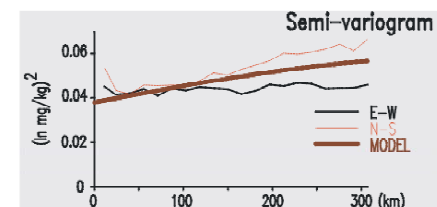
Kola Ecogeochemistry

S
Humus

air dried, <2mm, conc. HNO₃, ICP-AES

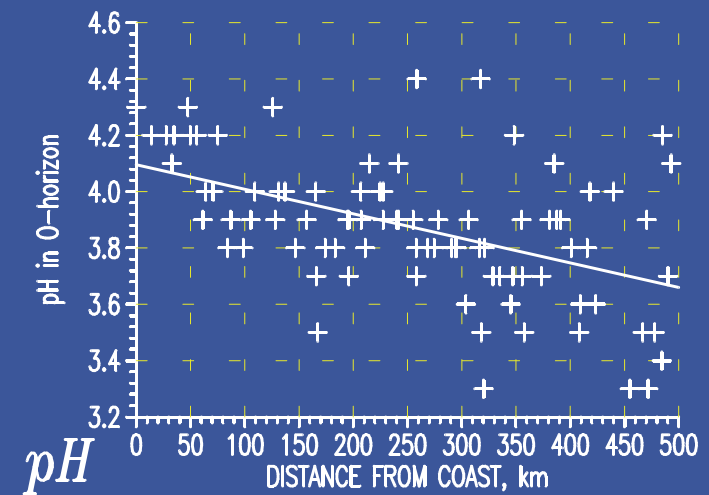
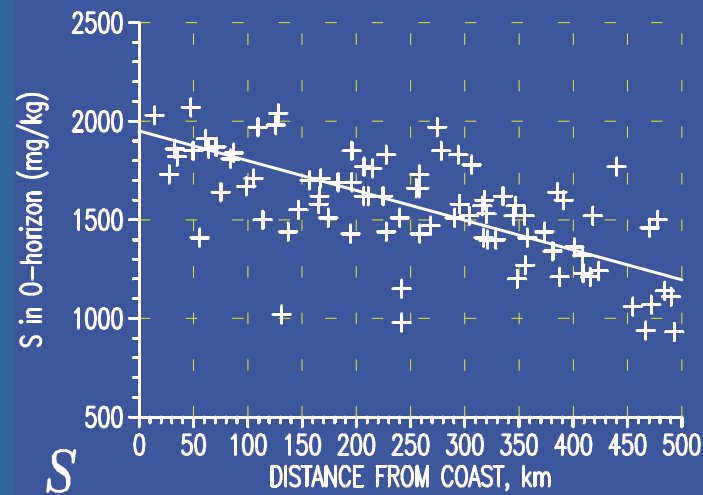
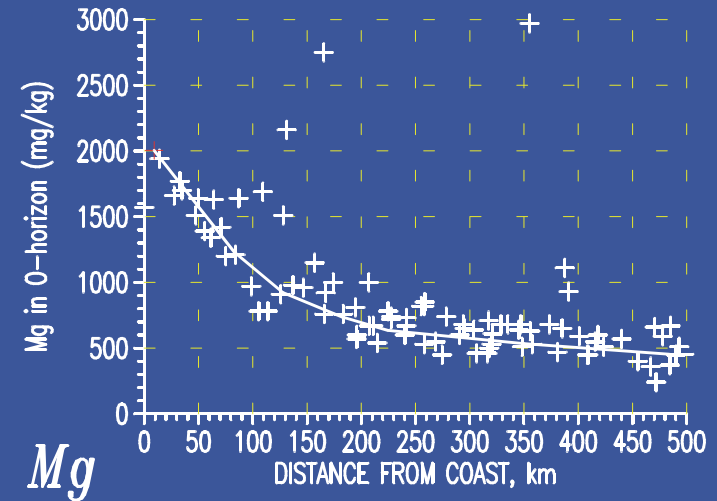


No pollution!
Sea Spray (?)



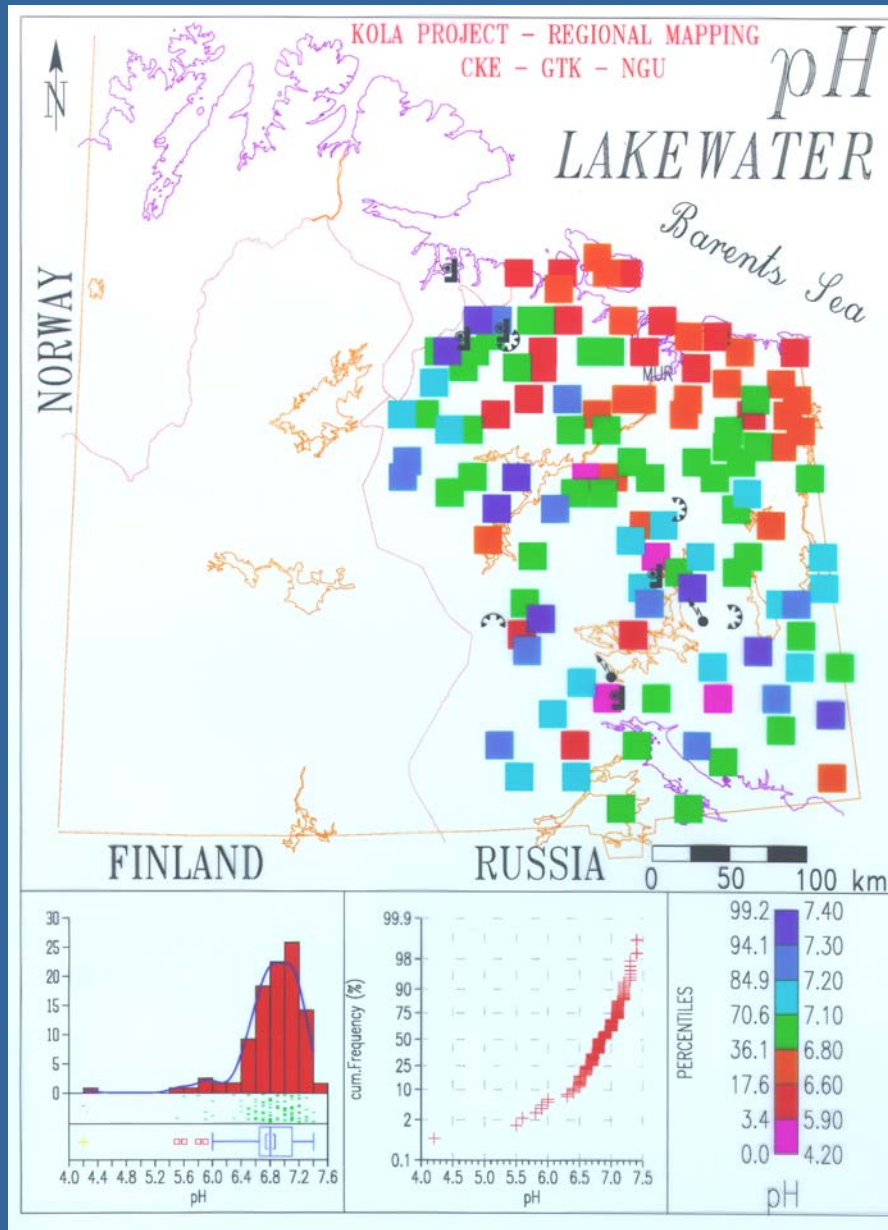
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N-S-profiles at the western project border (background).



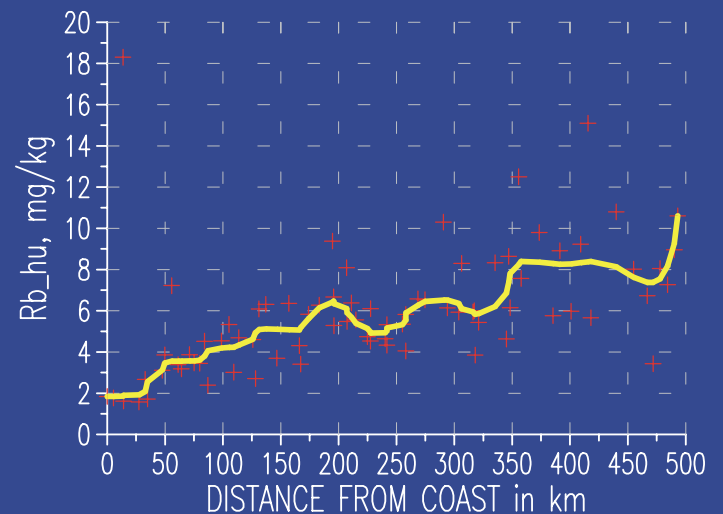
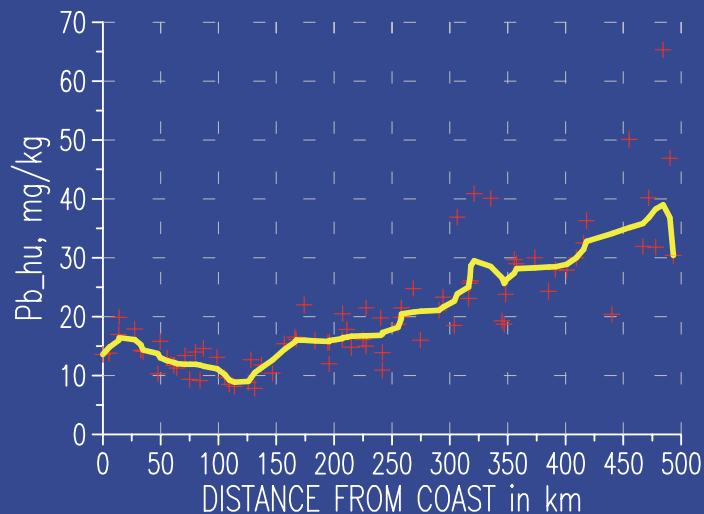
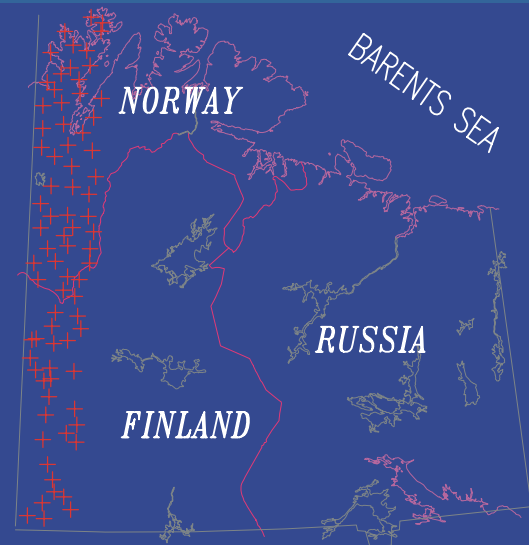
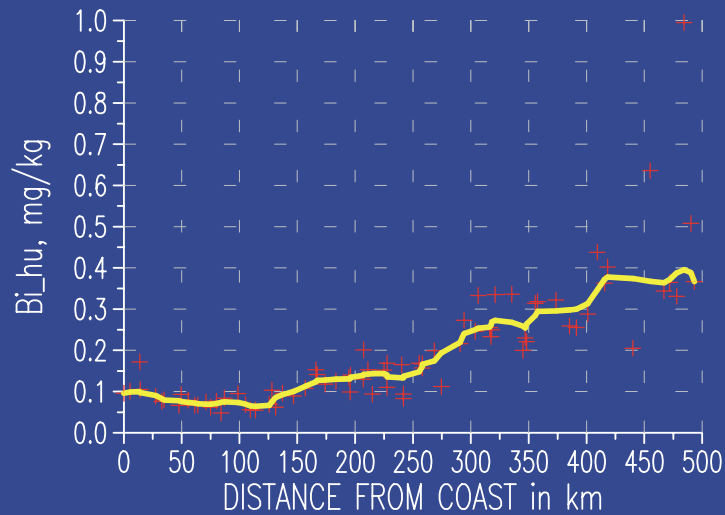
The highest pH occurs near coast together with the highest S-concentrations.

Kola Ecogeochemistry



Only single lakes near industry are acidified. The effect of the steady input of marine aerosols near coast plays the more important role for lake water pH.

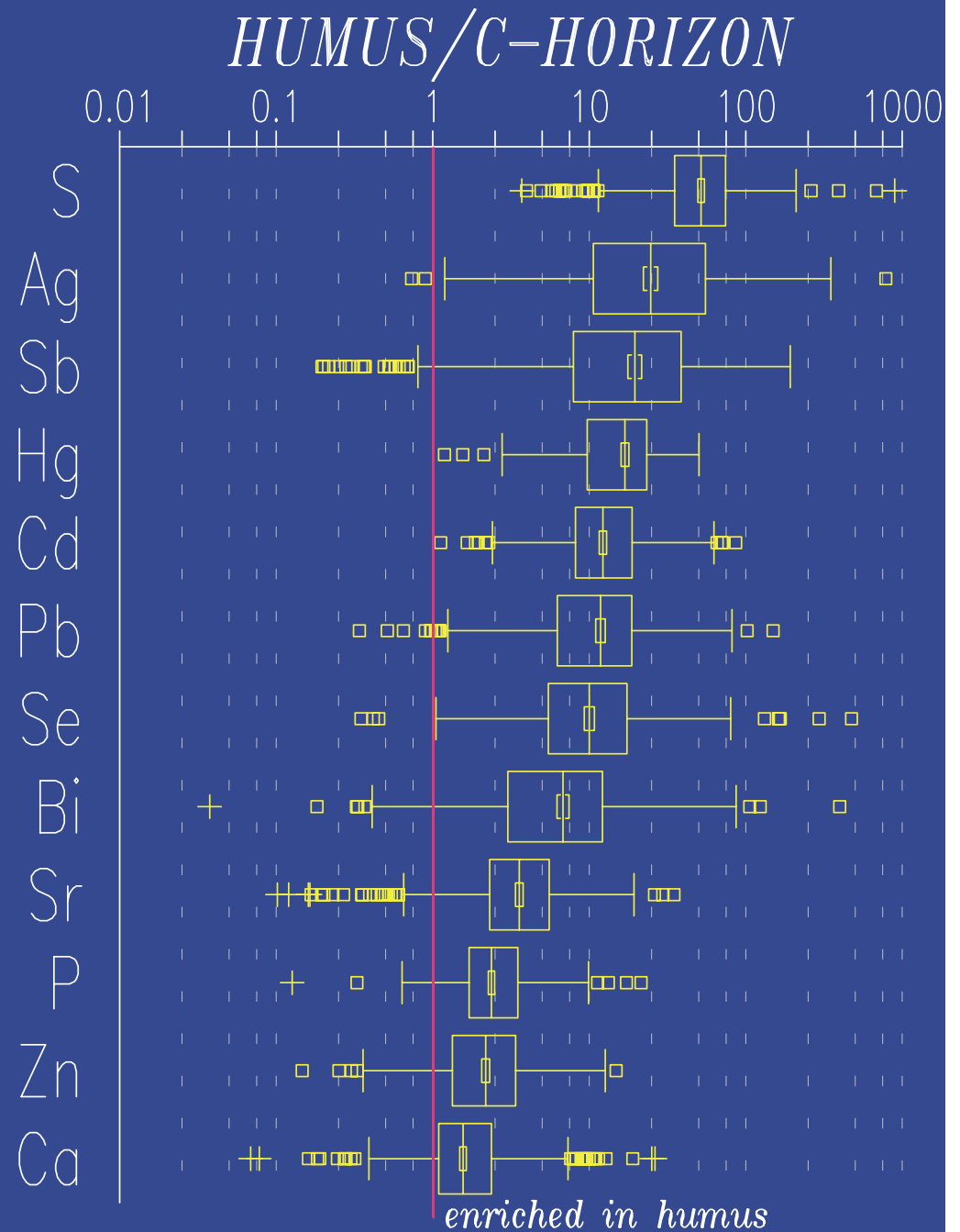
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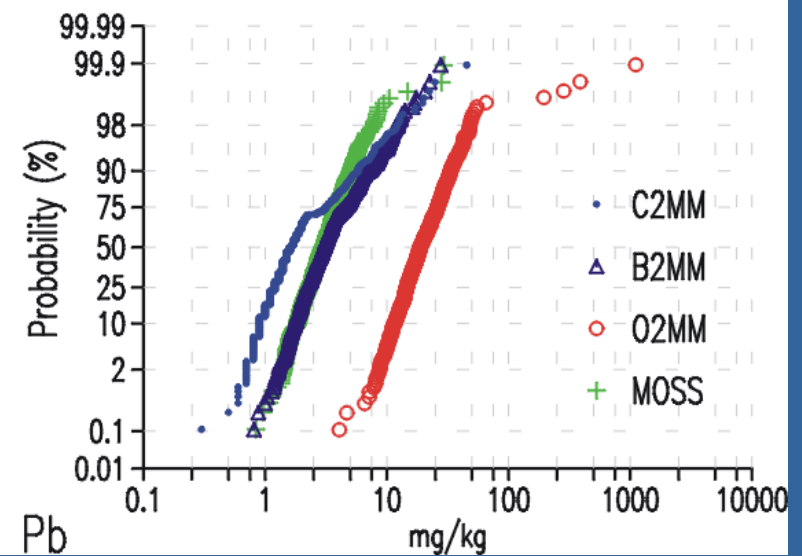
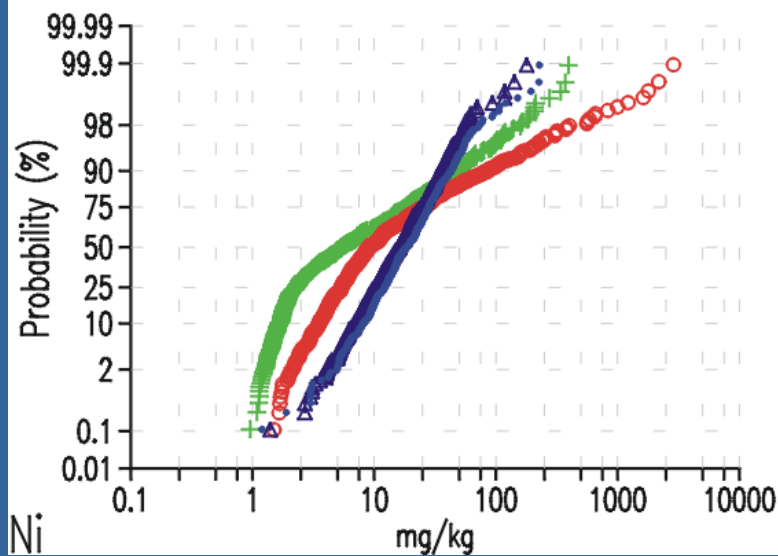
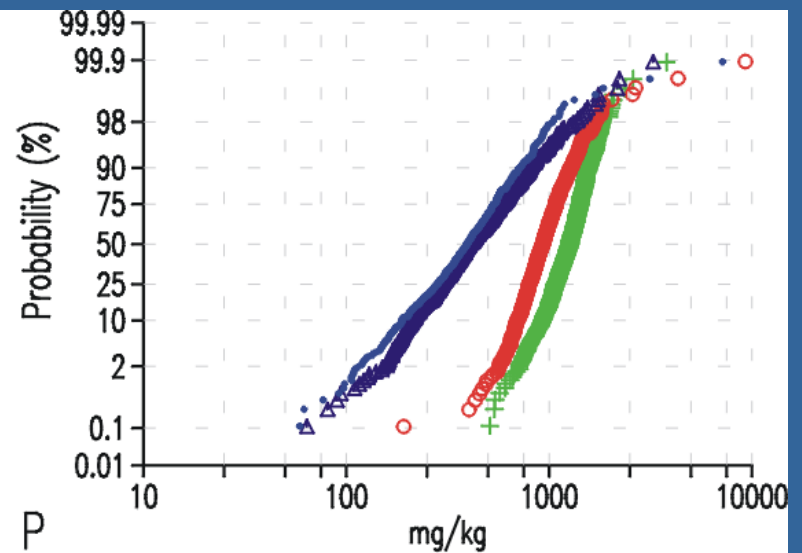
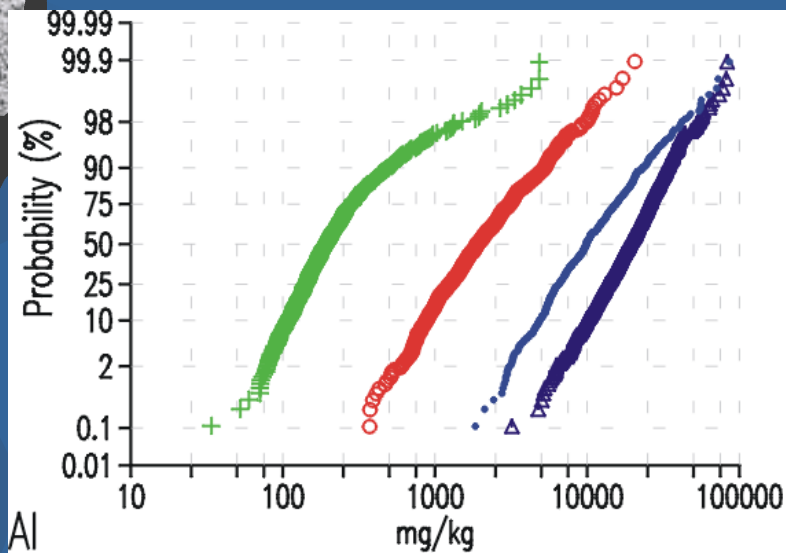
Some elements display a striking N-S-gradient

Kola Eco-geochemistry

Elements enriched
in the O-horizon.
Where are Cu
and Ni, the main
metals emitted?



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Comparison of element concentrations in different sample materials



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An unpolluted site (Ni 2 mg/kg in moss) in N-Norway – what happened with the ground vegetation?



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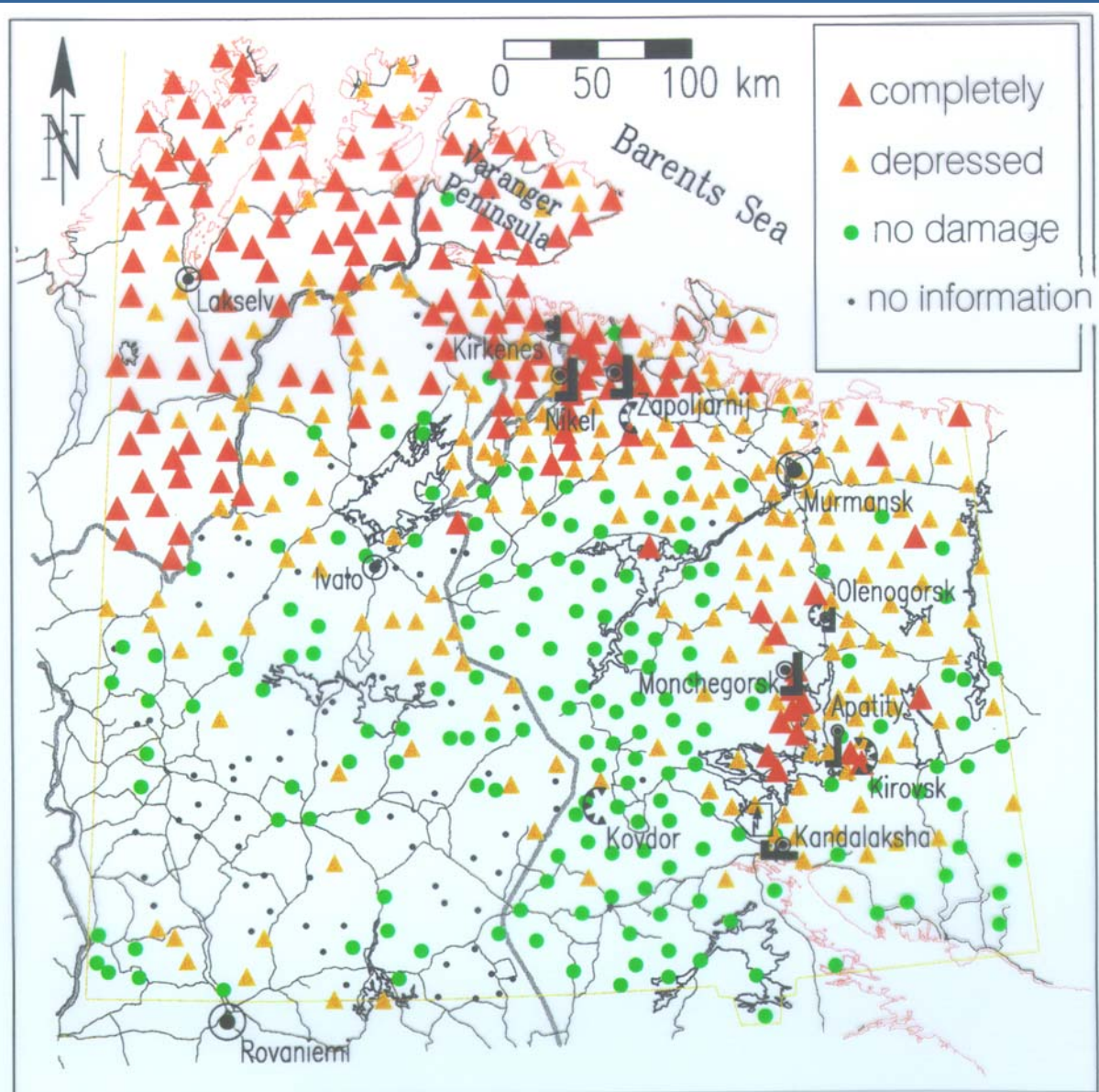


A highly polluted site (Ni in moss 45 mg/kg) in Russia – no visible damage to the ground vegetation.



Kola Ecogeochemistry

Regional map of
moss cover
damage as
identified from
field photos

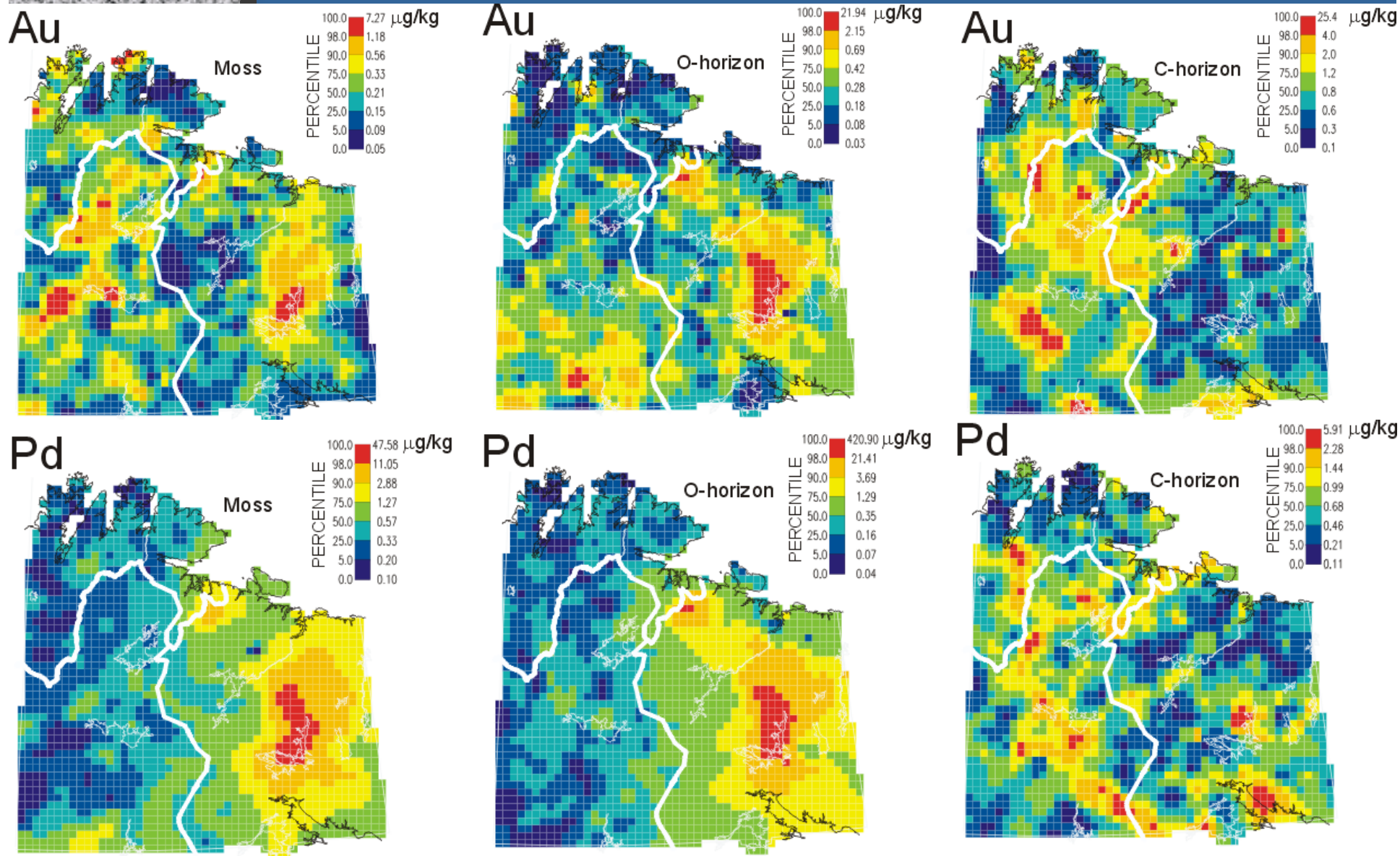


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An industry that looks rather nice and is thus not perceived as an environmental threat.

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CONCLUSION

Multi-medium, multi-element regional geochemistry is a powerful tool to understand sources, levels, cycling and fate of chemical elements in the environment.

The relative importance of natural processes is currently often underestimated.

Both are needed: detailed process studies and large scale regional surveys. (Take a step back to get the full picture.)



Kola Ecogeochemistry

Acknowledgements

The Kola Ecogeochemistry Project Team, especially:

Viktor Chekushin, Igor Bogatyrev, Vladimir Pavlov

Matti Äyräs, Heikki Niskavaara, Marja-Liisa
Räisänen

Rognvald Boyd, Patrice de Caritat, Jo H.
Halleraker, Galina Kashulina, Tore Volden



**The Royal Norwegian Ministry of the
Environment, NGU, GTK and CKE.**