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Geochemical Atlas of Slovak Republic Part Soils

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Abstract. Soil samples were collected from 5000 soils profiles throughout the country with density of 1 sample per 10 km^2. Samples were tested for 36 chemical elements concentrations. For each element computerised monoelemental map was constructed.

The preliminary results on geochemical mapping of Slovakian soils presented in this paper deal with basic problems of soil pollution in Slovakia documented with few examples of geochemical maps and with background values for the some of the risk elements (As, Ba, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Zn), in major soil units.

Based on geochemical mapping a first understanding of the distribution of chemical elements in Slovakian soils is outlined. Soils are more highly contaminated around the sites with ore mining, smelting and reworking operations. From the sites with an old mining history the pollution has spread to the alluvial river plains. Some of the highest mountainous parts and some border mountains ranges intercept aerosols and may point to the transboundary air pollution, by trace elements.

***Key words*:** soil- geochemical mapping, soil pollution, soil background values, chemical elements distribution, geochemical atlas

Introduction

Soil has great significance to all life; vegetation is rooted in it and water infiltrates through it. Geochemical mapping of soils, showing surface distribution of chemical elements and risk substances can contribute to a general awareness on soil deterioration and its possible adverse effects to other environmental constituents.

Subproject "Soils" is guided by Soil Fertility Research Institute (Bratislava). About 5000 soil profile were described, composite samples were collected and analysed from upper (A-) and deep (C-) soil horizons throughout the country. The total content of 36 of major and trace chemical elements has been ascertained. By this way a first understanding of chemical element distribution is established in relative to geology and soil types.

At present, the analytical programme is not finished. Therefore the presented information is preliminary. The present chemical analyses represents extensive data collection (set of 4491 samples from A and 4531 from C horizons). The data set is statistically representative and no statistically significant changes are expected in the final stage. Small corrections in the graphic presentations can, however, occur.

The aim of this paper is to gain an overall picture on the background values for some risk elements in soils and finally approach a first draft of maps of the spatial distribution of some chemical elements in soils. From the above statement is evident that some areas with the elements excesses and deficiencies that could prejudice some environmental problems can be later detected.

Very promising results can be also expected in the following stage by the synthesis of the results obtained from the geochemical mapping of stream sediments, rocks, water and biota which will provide an overall picture on environmental pollution in Slovakia.

Methodology

The primary reference network is based on 10 km^2 grid cells distributed over all country. In these cells the soil samples were taken at random. The samples were taken from A, B and C horizons. From the financial reason only samples from A and C horizons were analysed for the assemblage of 36 elements: Al (AES-ICP, det.lim.:1ppm), As(HG-AS, 0.5ppm), B (AES-ICP, 1ppm), Be (AES-ICP, 0.2ppm), Ca (AES-ICP, 1ppm), Cs (FAAS, 1ppm), Cu (AES-ICP, 0.1ppm), F (ISE, 300ppm), Fe (FAAS, 1ppm), Ga (AES-ICP, 2ppm), Hg (AAS-ETA, 0.01ppm), K (AES-ICP, 20ppm), La (AES-ICP, 1ppm), Li (AES-ICP, 1ppm), Mg (AES-ICP, 10ppm), Mn (AES-ICP, 0.1ppm), Mo (AES-ICP, 0.2ppm), Na (AES-ICP, 1ppm), Ni (AES-ICP, 1ppm), P (AES-ICP, 50ppm), Pb (AES-ICP, 0.5ppm), Rb (FAAS, 1ppm), Sb (HG-AAS, 0.1ppm), Se (HG-AAS, 0.1ppm), Sn (AES-ICP, 1ppm), V (AES-ICP, 3ppm), W (AES-ICP, 1pmm), Y (AES-ICP, 1ppm), and Zn (AES-ICP, 0.2ppm). At each site 3-5 subsamples were collected and one composite sample was prepared for each horizon. The samples were prepared by dry sieving. The fraction < 0.125 mm was then used for the chemical analysis and the fraction < 2 mm was used for the soil analysis (Čurlík and Šefčík 1994).

The analytical requirements are compatible with the international standards and accuracy of the results have been tested. Above mentioned analytical methods were employed in the EL spol. s r.o. Spišská Nová Ves. No changes in the methodology of sample preparation and analytical procedures proceeded during this project.

All data (soil morphology, chemical analyses) are stored in a database. Stored duplicate samples are kept in contaminant free containers for the future use. Basically the principles for the geochemical mapping published in Darnley et al. (1995) have been followed.

Soil analysis (pH, carbonate status, texture) were carried out in Soil Fertility Research Institute (Bratislava) using routine soil analytical methods.

Soils in Slovakia

In regional sense, with respect to the: geological history this territory belongs to the young Alpine - formed mountain ranges of the northern branch of the Alpine - Himalayan belt. This was formed in a complicated nappe - forming process which has reflected in a considerable shortening of the depositional areas, accumulation of rock complexes as well as reduction of tectonic units. This resulted in complicated geology (lithology) and relief.

Due to this development (during late Neogene and Quaternary) the relief of Slovakia is characterised by two marked geological - geomorphological formations: by the (West) Carphatian arc (mountains) and adjacent lowlands.

The main soil units occurring in Slovakia are related to the soil parent material and to the relief (altitudes). The great orographical manifoldness and complicated lithology has influenced soil cover diversity in both formations. The extension of soil units in agriculture and forest lands present the Tables 1 and 2.

Subcarpathian lowlands

Mantle rocks of the lowlands differ from one region to another:

In *Záhorská nížina lowland* (West Slovakia - part of Vienna basin) the main part is covered by Quaternary aeolian sands. Relative low fertile soils as Protic, Haplic and Cambic Arenosols, up to locally Arenic Podzols are present under the forest vegetation. On places with shallow groundwater tables, with present or former hydromorphism so called "black sands" (Histi-Mollic Gleysols and Arenic Gleysols) occur (humus accumulation). In northern of this lowland (Chvojnická pahorkatina hillyland) Luvisols prevail. But on loess some Chernozems are present. Locally also small spots with Haplic Vertisols on heavy clays occur.

Podunajská nížina lowland (Danubian lowland) comprises of alluvial sediments and loess. On young (Holocene) alluvial sediments of the lowland Calcaric Fluvisols and Fluvic Gleysols are evolved. On older alluvial sediments not inundated at present Mollic Gleysols and Mollic Fluvisols (all of them Calcaric) and even Calcaric Haplic Chernozems are developed. In southern part of Danubian lowland with shallow groundwater tables and with highly mineralized water salt affected soils locally occur (Solonchaks and Solonetz). In the depressions, especially in old oxbow lakes, Haplic Histosols are present.

In *Východoslovenská nížina lowland* (East Slovakian lowland) which is covered prevailingly by non-calcareous, heavy textured alluvial sediments, various units of Fluvisols and Gleysols occur, prevailingly Eutric Fluvisols, Vertic Fluvisols and Fluvic Gleysols. Very locally Arenosols are developed on sand dunes. Also salic and sodic soils occur here rarely. On hilly part of this lowland Stagnosols, Stagni-Haplic Luvisols and Stagnic Glossisols predominate. On loess cover Luvi-Haplic Chernozems and Stagni-Haplic Chernozems occur.

Intramountainous basins

Mostly tectonic- erosional basins can be divided in three groups:

Lower basins, Middle basins and Higher basins

Lower basins (up to about 300 m above sea level) are covered partly by loess, loess-like sediments and alluvial sediments. To this type belong Košická kotlina, Lučenecká kotlina basins and middle part of Váh river basin. Luvisols and Luvic Stagnosols with sporadic occurrence of Luvi- and Stagni-Haplic Chernozems and Cambisols are present in Košická kotlina basin. Cambisols can be found also on clayey - gravely Neogene sediments of the Lučenecká kotlina basin and on similar alluvial sediments of river Váh basin.

Middle basins (about 300 to 500 m above sea level) - compresses mostly of colluvial and alluvial sediments (Žilinská, Hornonitrianska, Zvolenská, Žiarska, Pliešovská, Rožňavská and Hornádska kotlina basins). In Stagnosols and Albic Luvisols with Stagnic properties and Eutric Cambisols with Stagni-Eutric Cambisols on stony colluvial sediments are predominant. In Stagnosols and Albic Luvisols with Stagnic properties and Eutric Cambisols with

Stagni-Eutric Cambisols on stony colluvial sediments are predominant. On the calcaric rocks in the Hornádska kotlina basin Rendzic Leptosols are developed.

Higher basins (over 500 m above sea level) like those of Turčianska, Liptovská, Popradská and Oravská kotlina basins as well as the Horehronské podolie basin are typical of higher precipitation and cooler climate. Here Dystric Planosols, Luvic- and Gleyic Stagnosols and Stagni-Dystrc Cambisols predominate. These units are accompanied with other Cambisols, Glossisols, Rendzinic Leptosols and Fluvisols and as inclusions Fibric Histosols. In Turčianská kotlina basin even Calcari-Mollic Fluvisols occur on carbonatic sandy materials.

Soils of Mountains

Geological units of West Carpathian Arc- or better to say- units of internal part of the orogenic zone consist of Mesozoic complexes of the Alpine geosyncline (mostly limestones and dolomites) of the Late and Early Paleozoic, and of crystalline complexes in the core mountains (mostly granitic rocks and crystalline schists). This complexes belong to the internides. Externides are formed by Alpine flysch sequences with nappe structure. Paleogene flysch zone consists of sandstones and claystones. In this zone clayey and loamy-sandy Dystric Cambisols and Stagni-Eutric Cambisols are predominant, but Eutric Cambisols, Stagnic Glossisols and varied Stagnosols are frequent too. In Klippen zone, Rendzic Leptosols and Rendzi-Lithic Leptosols occur.

Tab. 1: Soil units in agricultural land

Soil Units (WRB, 1994)	ha	%
Histosols	4 895	0.2
Anthrosols	129 702	5.3
Rendzic Leptosols	85 652	3.5
other Leptosols	12 236	0.5
Mollic Fluvisols and Mollic Gleysols	178 645	7.3
other Fluvisols	386 658	15.8
other Gleysols	19 578	0.8
Solonchaks and Solonetz	4 894	0.2
Andosols	2 450	0.1
Podzols	2 447	0.1
Planosols	134 596	5.5
Chernozems	291 217	11.9
Phaeozems	4 894	0.2
Haplic Luvisols	286 322	11.7
Albic Luvisols and Glossisols	105 230	4.3
Stagnosols	141 937	5.8
Eutric Cambisols	391 552	16.0
Dystric Cambisols and Umbrisols	239 826	9.8
Arenosols	24 472	1.0
Agricultural Soils of Slovakia	*2 447 203*	*100.0*

On the Crystalline rocks of the West Carpathians changing with altitudes a row of various soils, from Eutric Cambisols over Dystric Cambisols, Cambic Umbrisols, Cambic (Umbric) Podzols up to Haplic Podzols and Leptosols are developed.

On the Mesozoic rocks (mostly limestones and dolomites) Rendzic Leptosols and Rendzi-Lithic Leptosols prevail. On the karst plateaus with preserved Terrae Calcis material Chromic Luvisols and Stagni-Chromic Luvisols are sporadically developed.

On the intermediary to basic volcanic rocks Eutric Cambisols are developed, except of greater heights where Dystric cambisols both with inclusions of Andosols are present.

Tab. 2: Soil units in forest land

Soil Units (WRB, 1994)	ha	%
Lithic Leptosols	7 962	0.4
Rendzic Leptosols	288 611	14.5
other Leptosols	49 760	2.5
chromic soils (Leptosols, Luvisols)	39 809	2.0
Fluvisols	5 971	0.3
Gleysols	39 809	2.0
Andosols	29 856	1.5
Podzols	69 664	3.5
Chernozems	1 990	0.1
Haplic Luvisols	5 971	0.3
Albic Luvisols and Glossisols	238 851	12.0
Planosols and Stagnosols	39 809	2.0
Calcaric Cambisols	19 904	1.0
other Cambisols and Umbrisols	1 144 494	57.5
other soils (salic, sodic, histic, anthropic, etc.)	7 962	0.4
Forest Soils of Slovakia	*1 990 424*	*100.0*

Background values for the main soil units

The soil quality and environmental risk assessment for soil has became one of the important environmental issues. The public concern for soil pollution has recently lead to the approval of a soil legislation also in Slovakia (Soil protection law No. 307/1994) within which Dutch ABC list for risk substances has been adopted (Tab. 3).

This reference list for the large number of pollutants (inorganic and organic) is known from the literature. Meanwhile this list was modified and attention is paid to put it on a scientific basis (ecotoxicological risk concept, no observable adverse effect concentration - NOAEC concept, etc.). But the idea of background values for soils is still the main principle for the target values definition in relation to the metals.

In order to understand the real distribution of risk elements in soils since they are usually natural soil com-

Tab. 3 Reference list for inorganic contaminants in soils used in Slovakia (mg.l)

	A	A1	B	C	Background value A-horizon	Background value C-horizon
As	29	5	30	50	7,10	6,40
Ba	500		1000	2000		
Be	3		20	30		
Cd	0,8	0,3	5	20	0,30	0,10
Co	20		50	300	9,00	10,00
Cr	130	10	250	800	85,00	86,00
Cu	36	20	100	500	17,00	17,00
Hg	0,3		2	10	0,08	0,04
Mo	1		40	200		
Ni	35	10	100	500	24,00	28,00
Pb	85	30	150	600	20,00	13,00
Se	0,8		5	20	0,10	0,05
Sn	20		50	300		
V	120		200	500		
Zn	140	40	500	3000	61,00	54,00

ponents, the pollutant concentration need to be checked against the background values for unpolluted soils (Baize, 1995; Vanmechelen et al., 1995). It is clear that when more such descriptive soil investigation are carried out for the complicated soil and geological conditions (and Slovakia is one of the examples), a good basis for the comparison could be obtained. Geochemical mapping of Slovakian soils gave us an opportunity to determine the background values for risk elements in ten major soil units.

Informations obtained by sampling of unpolluted soils should be characterised as "current background values" or "present background values for not abnormally polluted soils" because diffuse contamination caused by atmospheric deposition is accounted for, together with the pollution caused by the fertilisers and chemicals which are normally used in the practise (Vanmechelen et al., 1995).

In the table 4 the background values for the A- and C-horizons of major soil units are presented as results obtained from geochemical mapping. They include the assemblage of following chemical elements: As, Ba, Cd. Co, Cr, Cu, Hg, Ni, Pb, Sb, Se, Zn, which are considered as risk elements.

Closer look to the values and to the individual chemical elements point to several conclusions:

Tab. 4: Background values of the risk chemical elements in the main soil units (mg.kg^{-1})

Soil units (FAO)	Horizons	Count	As	Ba	Cd	Co	Cr	Cu	Hg	Ni	Pb	Sb	Se	Zn
Chernozems	A	344	7,4	395	0,20	9,0	82	20	0,01	28,0	15	0,5	0,10	56
	C	360	6,8	343	0,15	8,0	72	16	0,02	26,0	10	0,4	0,07	45
Orthic Luvisols	A	346	6,7	393	0,20	9,0	89	17	0,10	26,0	16	0,6	0,05	54
	C	352	7,6	395	0,10	10,7	88	17	0,03	29,7	14	0,6	0,06	53
Albic Luvisols	A	224	5,7	360	0,20	7,0	79	12	0,10	19,0	22	0,7	0,10	50
	C	226	7,7	422	0,14	11,0	91	20	0,06	27,0	14	0,8	0,13	55
Dystric Planosol	A	219	5,2	387	0,10	8,0	88	12	0,10	19,0	15	0,4	0,05	44
(Pseudogleys)	C	216	7,3	418	0,10	12,0	98	18	0,05	28,0	14	0,5	0,09	52
Phaeozem	A	204	7,0	390	0,30	9,0	85	25	0,10	32,0	18	0,4	0,10	84
	C	205	7,6	379	0,16	9,5	78	19	0,03	32,0	11	0,5	0,09	52
Rendzinas	A	204	12,5	240	0,85	9,0	69	18	0,30	25,5	42	17,0	0,10	84
	C	206	10,2	225	0,66	9,0	67	19	0,19	32,6	20	0,9	0,10	58
Cambisols	A	1584	6,9	383	0,30	9,0	85	16	0,10	22,0	23	0,8	0,10	65
	C	1607	6,1	398	0,10	11,0	81	18	0,10	29,0	14	0,5	0,05	60
Podzols	A	65	10,0	383	0,40	3,0	44	10	0,30	7,0	61	2,6	0,10	44
	C	64	7,2	444	0,15	6,0	60	10	0,10	16,0	18	0,8	0,10	53
Fluvisols	A	356	7,3	373	0,30	10,0	93	22	0,10	32,0	13	0,6	0,10	70
	C	345	6,9	390	0,20	10,0	92	19	0,01	31,0	14	0,4	0,01	58
Gleysols	A	47	6,4	414	0,30	11,0	109	24	0,10	44,0	23	0,5	0,10	79
	C	49	5,9	464	0,10	10,0	120	28	0,10	44,0	16	0,4	0,05	66

- Some elements as As, Cd and Hg show highest values in such genetically different soils as Rendzinas and Podzols. Both soil are present in the high mountainous positions. This may be an evidence for the airborne origin of these elements brought to the soils by dust deposition no prove is presented.
- The highest values are for the Ba in Podzols which is due to higher content of Ba in feldspars (Podzols are developed mostly on granitic rocks) and partly due to Ba accumulation in sesquioxides (Mn-oxides). Similar reason may be accounted for the higher content of Ba in Gleys (higher content of Fe-Mn oxides in upper part of gley horizons).
- Higher values for Cr and Cu may be due to deposition on reducing geochemical barriers (Gleys and Fluvisols) and due to affinity of these chemical elements to organic matter.
- Cobalt which is leached from the soil profiles is rather uniformly distributed in the main soil units but its content is low.
- Nickel shows some increased values in soils with higher humus (organic matter) content. Grand mean (in sense of the authors Kabata-Pendias and Pendias, 1992 - means "mean" for various soil types) calculated for the world soils 22 mg.kg^{1} is not very much higher in Slovakian soils.

Lead opposite to Ni may be bound to the feldspars which are most abundant in the granitic rocks. The highest values in Podzols may be due to feldspars content but some particulate matter deposition could also contribute to this increase.

- Antimony - background values are higher in Podzols because Sb-mineralisation is found in crystalline rocks of Nízke Tatry Mts. Malé Karpaty Mts. and Spišsko-gemerské rudohorie Mts. The background values in other soil units are similar to the world soils (Kabata-Pendias and Pendias, 1992).
- Selenium content in Slovakian soils is generally low. This values range Slovakian soils to the selenium poor.
- Zinc which is concentrated in clay fraction of the soils does not correlate with the soil units.
- Generally there are some relations to the soil litological units (Pb, Ba content in feldspars) to the airborne pollution (Cd, As, Hg, Pb?) and finally to the supergenne processes in soils.

From the statistical point of view, medians were taken as background values, because there are broad ranges of concentration for the individual chemical elements. When comparing to the Dutch ABC list which is related to the theoretical soils with (with 25% of clay and 10% of humus) some real soils in Slovakia have higher concentration of some chemical elements than reference (A-) value. In this relation the target concentration should be revised.

The spatial distribution of the risk chemical elements

The statistical results on risk elements distribution in the topsoils (in the A-horizons) and in subsoils (in the C-horizons) are presented in the following tables (Tab. 5-6) and graphically in the histograms (Fig. 1-2)

Arsenic in most soils ranges from 1-95 mg.kg^{-1} with mean values about 9 mg.kg^{-1} (Kabata-Pendias and Pendias, 1992). In rocks the content of arsenic is lower and ranged from 0.5-3.0 mg.kg^{-1}. In studied soils arsenic content is higher and median is 7.1 in A and 6.4 in C horizons. When comparing A horizons of forest soils with those in agricultural ones the trend of enrichment in topsoil of the forest soils (medians 7.9/5.7 mg.kg^{-1}) is more evident. This enrichment which is mentioned for the topsoils (Fergusson, 1990) is caused by external sources of arsenic (pollutions). Very high concentrations which reach up to several thousand mg.kg^{-1} (maximum 2438 mg.kg^{-1}) were found in the surrounding of old mining sites. Some above the limit concentrations (above 29 mg.kg^{-1}) were also found in the vicinity of smelters and coal burning facilities (Fig. 3).

Cadmium content in most magmatic and sedimentary rocks does not exceed 1 mg.kg^{-1}, except the clay shales in which can be higher due to affinity to Zn which is also concentrated in the clay. In this respect the median value in A horizon of agricultural soils is 0.2 and forest soils 0.4 which is higher, similar to that reported to the soils of the different countries (Kabata-Pendias and Pendias, 1992). Some enrichment of the topsoils may be due to contamination (fertilizers, smelters). High concentrations of cadmium (up to 18 mg.kg^{-1}) were found near the old mining districts (Fig. 4).

Cobalt content in the rocks is low except the ultramafic rocks. Due to weathering cobalt is leached from the profile. As a result the content of Co in soils is low but principally is inherited from the rocks. The content of cobalt ranges between 0.1-120 mg.kg^{-1}. The medians values in Slovakian soils are 9 mg.kg^{-1} in A and 10 mg.kg^{-1} in C-horizons. Higher concentrations (up to 120 mg.kg^{-1}) are bound with soils on basic and mineralized rocks.

Cromium similarly to Co is bound to ultramafic rocks. In other rocks it ranges from 5 - 120 mg.kg^{-1} (Kabata-Pendias and Pendias, 1992). Mean values range for the different soils of the world from 10 to 200 mg.kg^{-1}. Grand mean for the soils is calculated to be 54 mg.kg^{-1} (Kabata-Pendias and Pendias, 1992). The median values for A horizons are 85 mg.kg^{-1} and 86 mg.kg^{-1} for C horizons, in Slovakian soils. Very high concentration in were found around the smelters and mining works (up to 6000 mg.kg^{-1}) (Fig. 5) . In these soils Cr is mostly fixed to secondary Fe and Mn oxides. Organic matter plays an important role in immobilising the cromium. No significant trends are found in the soils.

Copper similarly to the Co, Cr, Ni and Zn, has the tendency to be concentrated in basic and intermediate

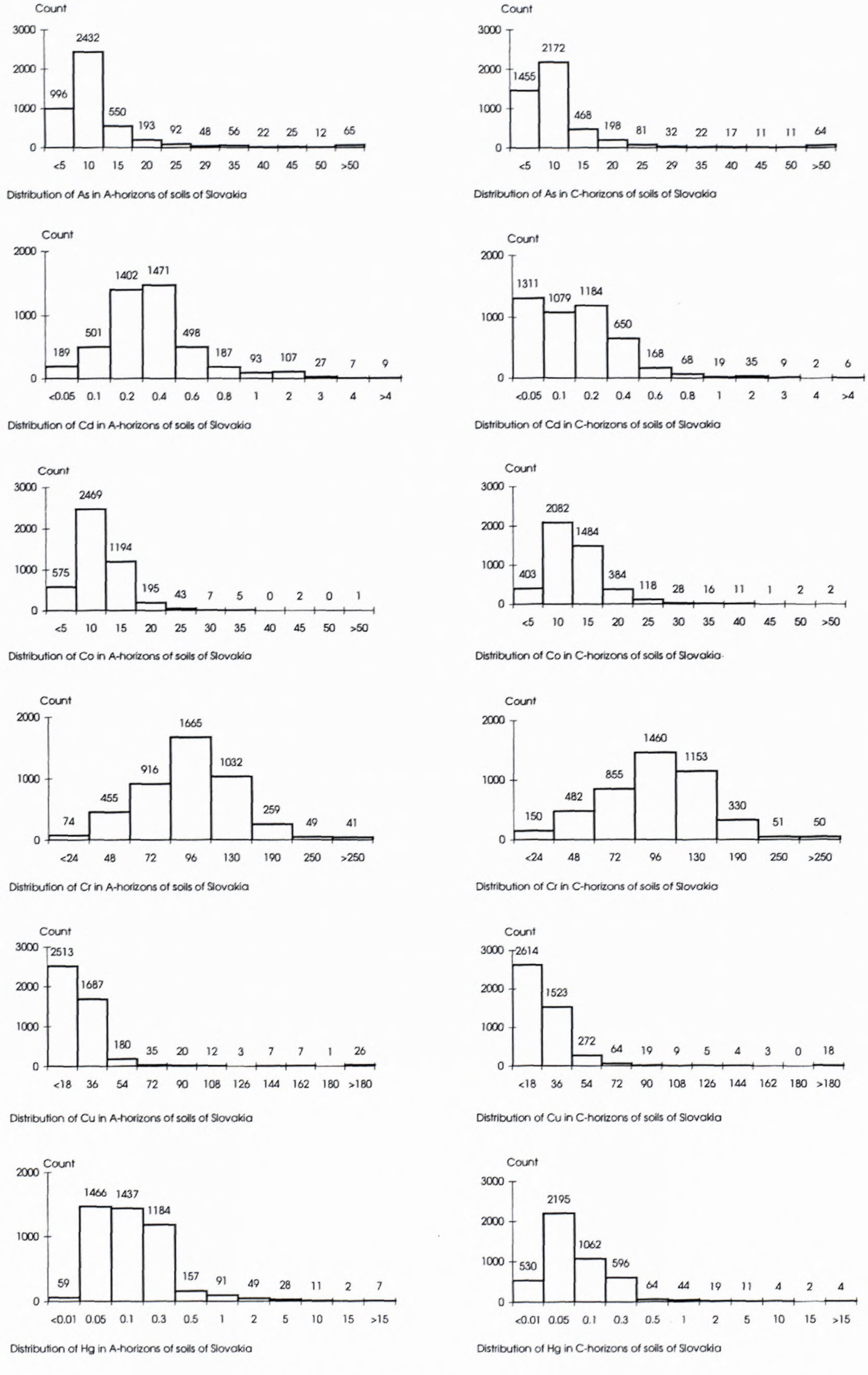


Fig. 1 Frequency distribution of the trace chemical elements (mg.kg^{-1}) in Slovakian soils (As, Cd, Co, Cr, Cu, Hg)

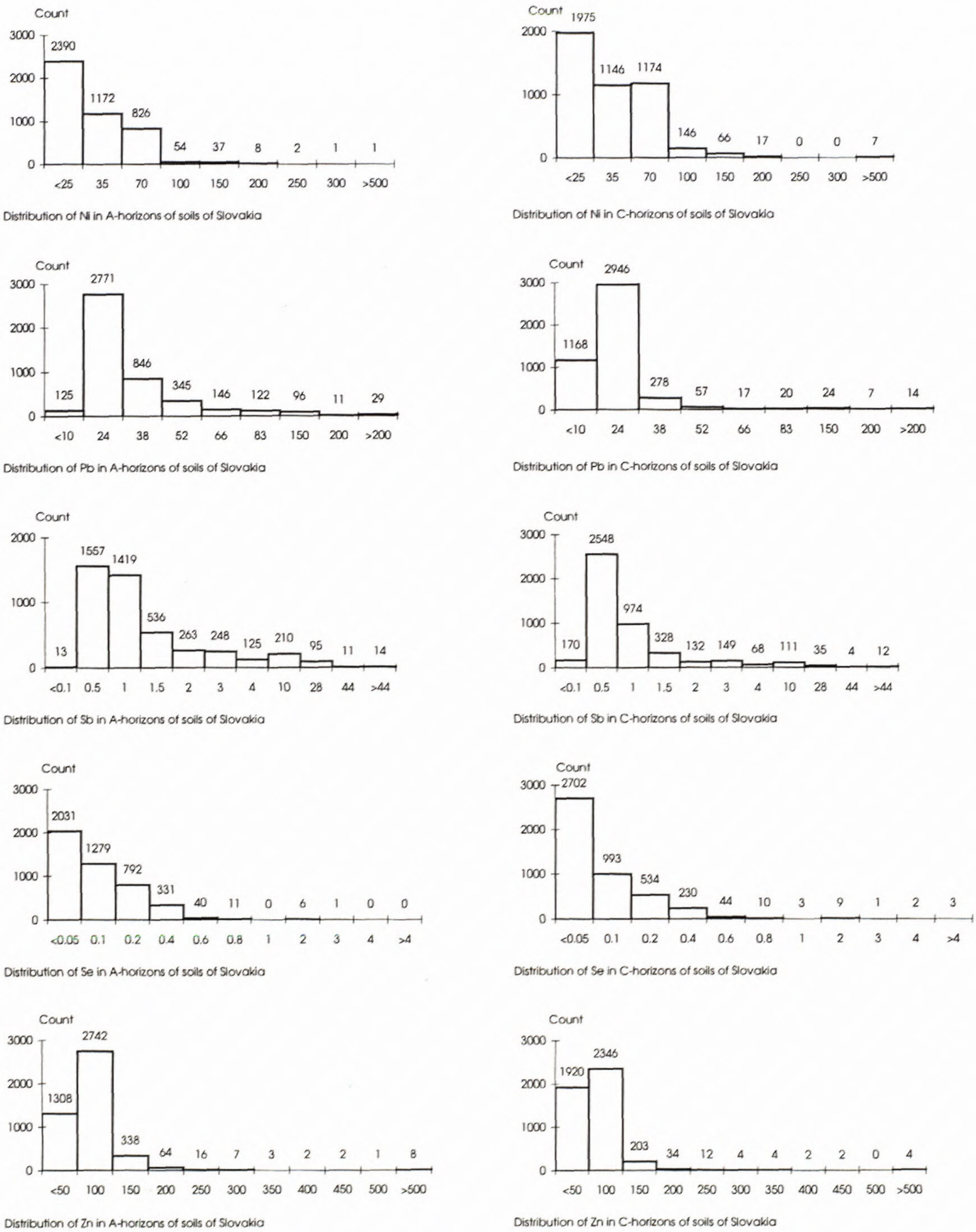


Fig. 2 Frequency distribution of the trace chemical elements ($mg.kg^{-1}$) in Slovakian soils (Ni, Pb, Sb, Se, Zn)

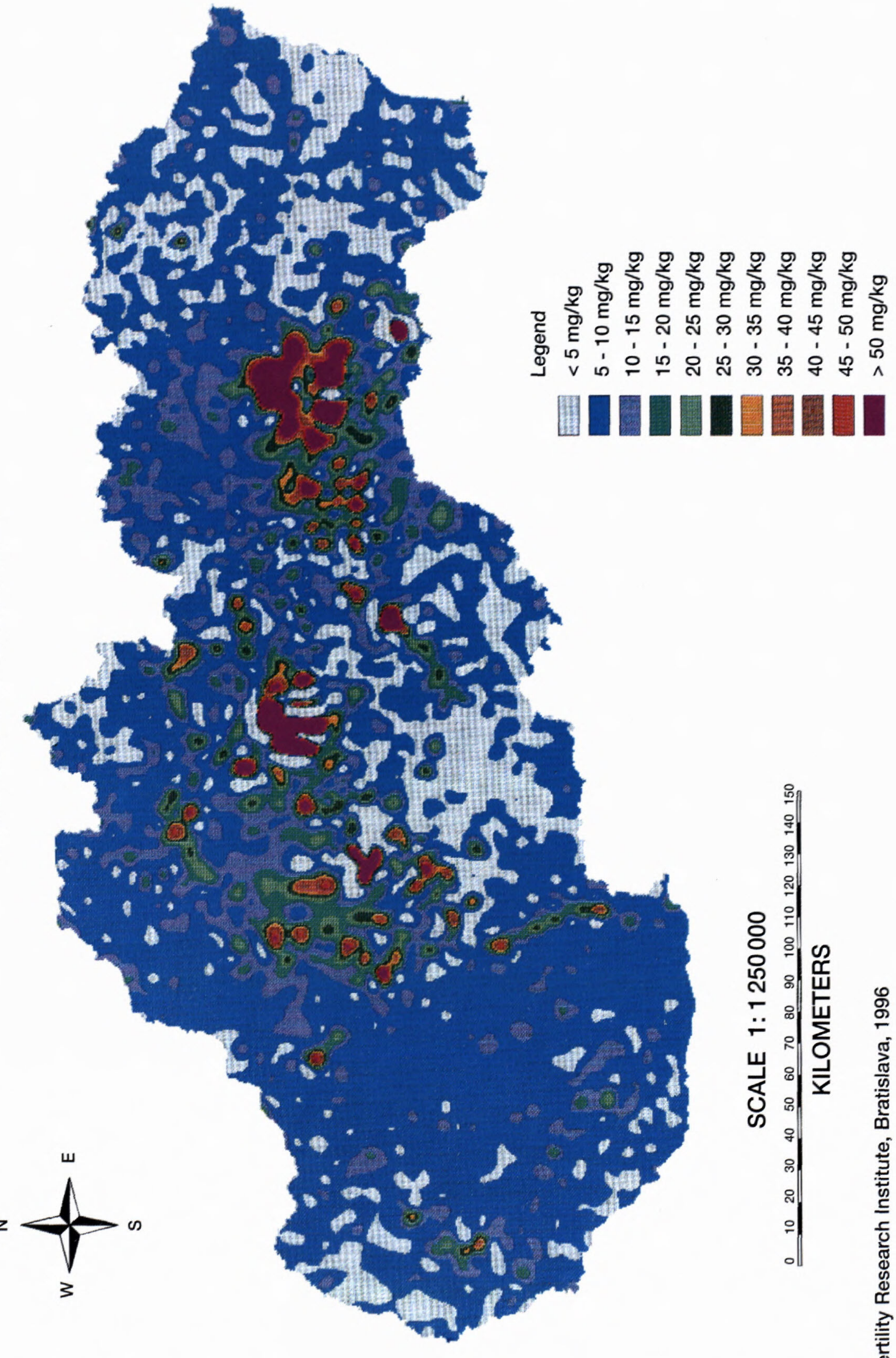
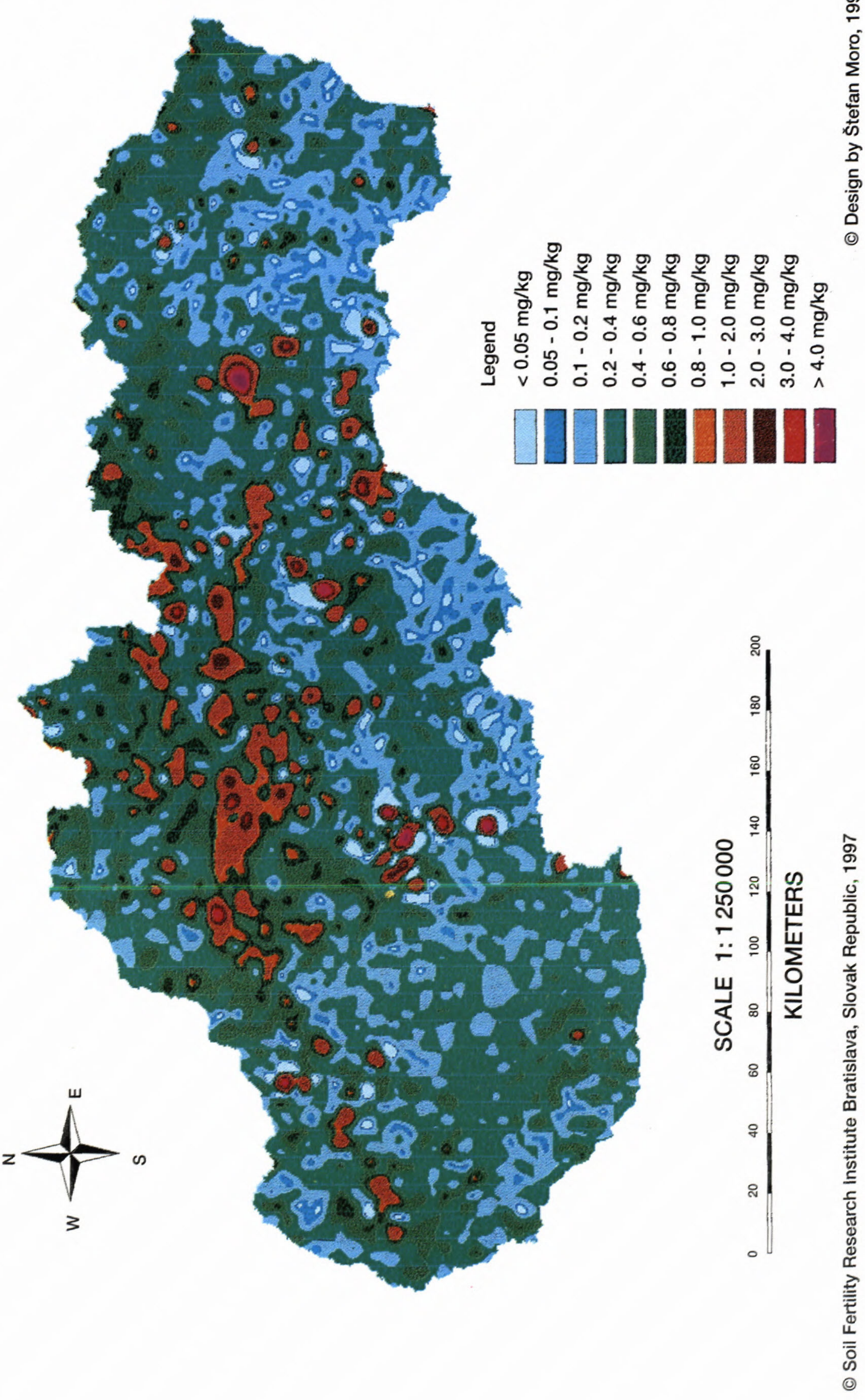


Fig. 3 Geochemical atlas of Slovakian soils
Distribution of As in A-horizons

Fig. 4 Geochemical atlas of Slovakian soils
Distribution of Cd in A-horizons



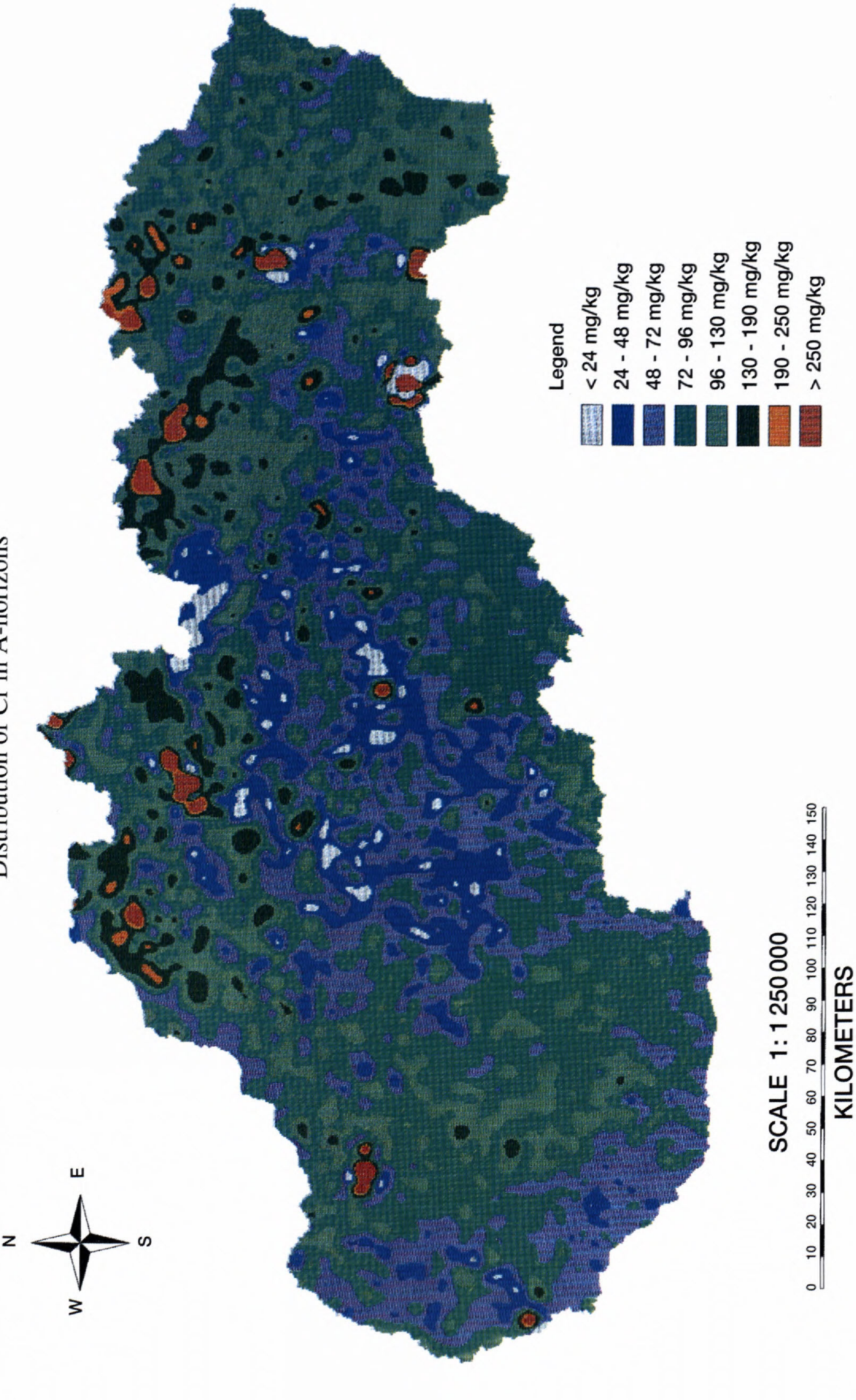
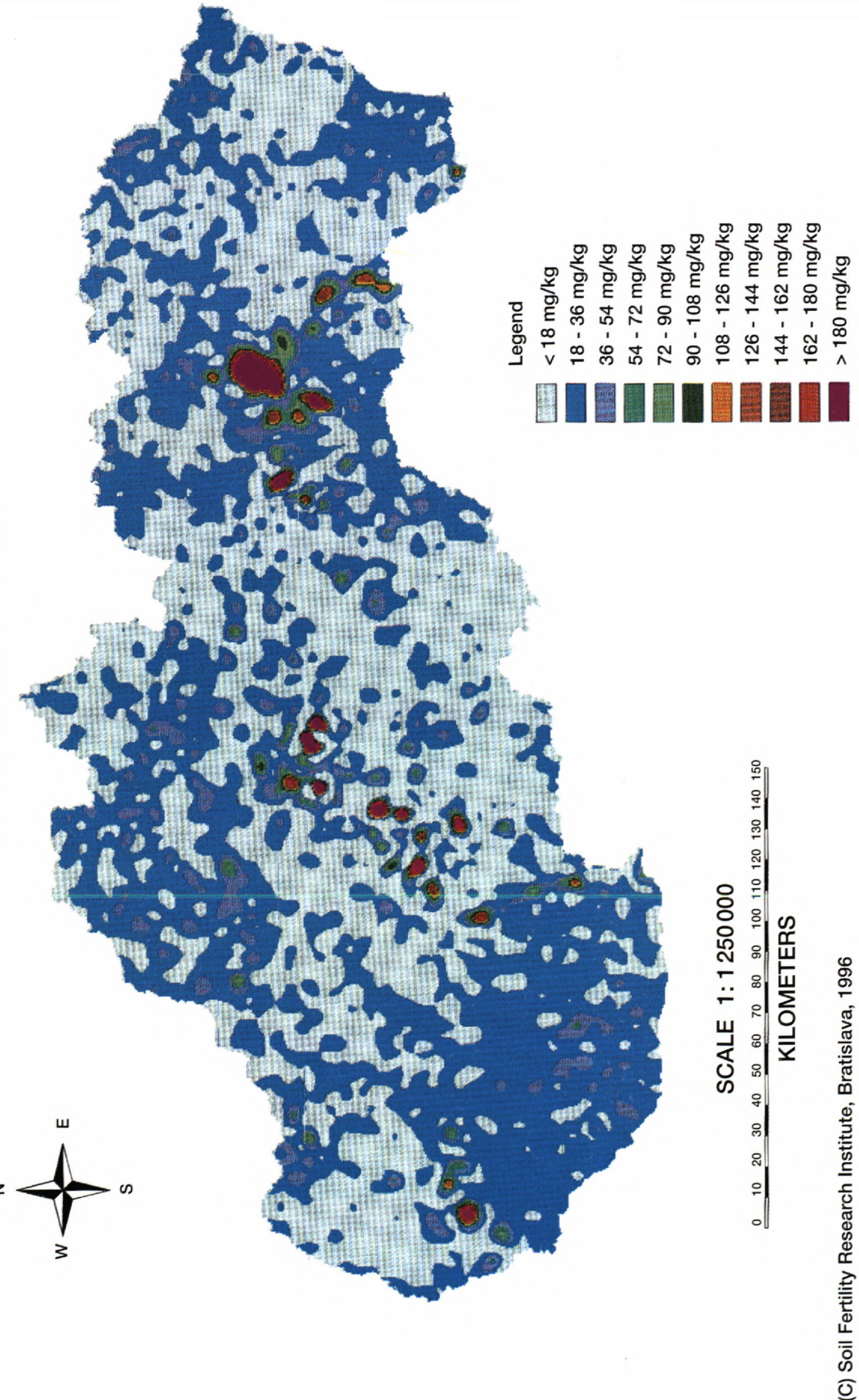


Fig. 5 Geochemical atlas of Slovakian soils
Distribution of Cr in A-horizons

(C) Soil Fertility Research Institute, Bratislava, 1996

Fig. 6 Geochemical atlas of Slovakian soils
Distribution of Cu in A-horizons



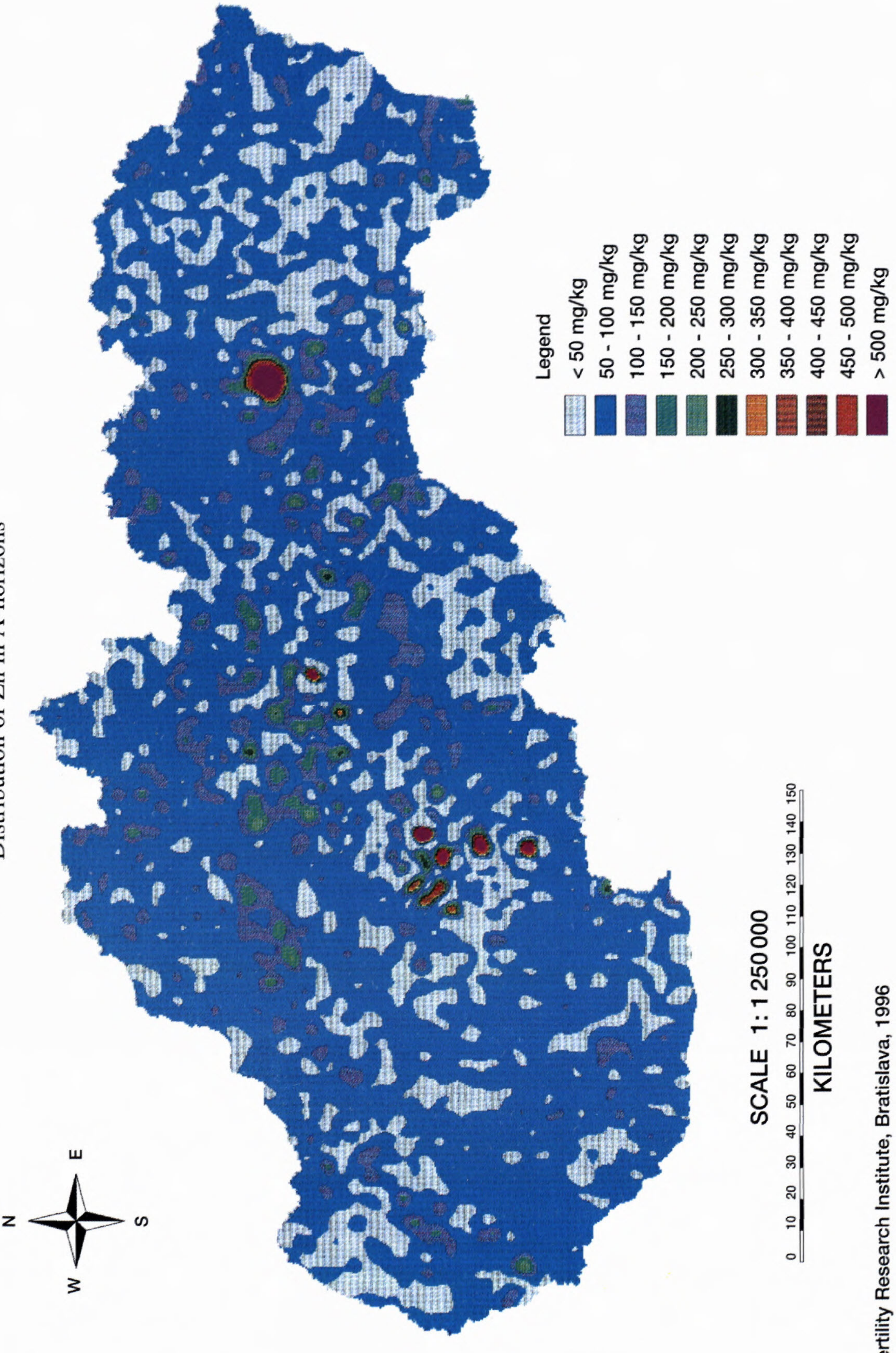


Fig. 7 Geochemical atlas of Slovakian soils
Distribution of Zn in A-horizons

rocks, and excluded from acid and carbonate rocks. The mean values in the soils vary from 13 - 24 $mg.kg^{-1}$ (Kabata-Pendias and Pendias, 1992). The similar picture is obtained for the Slovakian soils in which median for A and C horizons is 17 $mg.kg^{-1}$ (Fig. 6). Some tendencies of enrichment in A horizons of agricultural land is due to pollution and due to use of chemicals (especially in vineyards). Very high concentrations of Cu are found around the mineralized rocks, mines, smelters and above limit concentrations in the topsoils of the vineyards (Cu-pest).

Mercury content in the soil is generally low and has a tendency to be fixed to the organic complexes. This has been proved for the forest topsoils in which the highest median value 0.13 $mg.kg^{-1}$ was found. When we compare the median of forest soils in A and C horizons (0.04 $mg.kg^{-1}$), high decrease of Hg content can be also ascribed to some pollution to topsoils. Very high concentrations are accounted to the pollution sources. Especially high concentrations were found around the smelters in which tetraedrite ores with high Hg concentrations have been reworked.

Nickel as it is mentioned above has similar geochemical history as Co, Cu, Cr, Zn, being fixed to ultrabasic and basic rocks. It is easily mobilised during weathering and pedogenesis. But mostly increased content of Ni in soils is bound with increased content in humus and secondary Mn oxides. The mean values for the soils range in rather broad limit but grand mean calculated for the world soils (Kabata-Pendias and Pendias, 1992) is 22 $mg.kg^{-1}$. The mean values are not much higher in Slovakian soils. But very high local concentrations are bound with mineralized rocks and mining works.

Lead content in the soil can be affected in many ways. It is very common pollutant from the roadside dust, metal processing, mining, battery manufactories and others. Natural content in the soils is included from the parent rocks. The highest content of Pb is in acidic rocks (tens of $mg.kg^{-1}$). The common trend of enrichment in Pb content in the topsoils due to divergent sources of pollution are proved also for the Slovakian soils. The median for the topsoil is 20 and subsoils 13 $mg.kg^{-1}$. Very high concentrations (above 0.3%) are connected with old mining activities.

Antimony content in the rocks and thus in the soils is low. It is supposed that antimony can migrate in the water and can be leached from the weathering profile. Not very much data is available in the literature on the antimony (Kabata-Pendias and Pendias, 1992; Fergusson, 1990). Kabata-Pendias and Pendias (1992) gives the grand mean for the soils 0.9 $mg.kg^{-1}$. The topsoils in Slovakia have median 0.6 and subsoils 0.5 $mg.kg^{-1}$. Highest median value 1.1 $mg.kg^{-1}$ have been calculated for the forest soils. Higher values are found in mineralized rocks with antimony and around the dumping fields. This gives an opportunity to study the processes of migrations (chemical, mechanical), availability for the plants and possible adverse effects.

Zinc content in soils depends mostly on the parent rocks. Higher concentration in the argillaceous sediments cause the higher content in the soils. The total content in the surface soils according to Kabata-Pendias and Pendias (1992) range from 17-125 $mg.kg^{-1}$ and grand mean was calculated 64 $mg.kg^{-1}$. The median in the A horizons is 51 $mg.kg^{-1}$ and 54 $mg.kg^{-1}$ in the C horizons which is rather close to this values. The highest concentrations of zinc are found around the mining areas (polymetalic ores) and reach 2160 $mg.kg^{-1}$. In some vineyards regions (zinc stay wires) above limits concentrations of Zn were found (Fig. 7).

Till now almost no data on *selenium* content in Slovakian soils are available. This is the first picture which is obtained from rather representative samples collections. Selenium is an essential element for human (animal) health in the low range of concentrations. On the other hand can be toxic in elevated concentrations. That is why Se content in soils has received much attention. Surface soils in a world - wide scale contain an average 0.33 $mg.kg^{-1}$ of Se. If we compare the Slovakian soils median value for A horizons and C horizons is rather low and is 0.1 $mg.kg^{-1}$ (0.05 $mg.kg^{-1}$ respectively). Non significant increase in Se content in forests can be with question mark ascribed to some airborne sources of pollution. These values range the Slovakian soils to the selenium poor.

Conclusions

The ranges of natural content of the chosen chemical elements in soils are wide. High values for the most elements are in connection with some point sources of contamination in old mining (reworking) areas. Higher concentration of some risk elements in border parts of high mountains (Malá Fatra Mts., Vysoké Tatry Mts., Nízke Tatry Mts.) may point to the transboundary air pollution. Depending on the wind direction some marginal mountain ranges may play a dominant role in the particular matter deposition.

The natural levels of chemical elements will provide information on their dispersion within the soil profiles. The obtained data will be used to define the threshold limits for some of the risk elements in the soils. They will yield background values to compare with the total content of the chemical elements in European soils.

Soil pollution in Slovakia is connected to mining, smelting and industrial activities. Some of the geochemical anomalies are the secondary halos around mineralized ore bodies.

The great number of the lower "outliers" are connected mostly with analytical limits for which in statistical sense a half of lower detection limits were taken.

Great number of upper "outliers" belong to polluted or mineralized sites.

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