ATLAS

GEOLOGY FOR ENVIRONMENTAL PROTECTION AND TERRITORIAL PLANNING IN THE POLISH-LITHUANIAN CROSS-BORDER AREA

PAŃSTWOWY INSTYTUT GEOLOGICZNY
MENTE ET MALLEO
1919

LIETUVOS GEOLOGIJOS TARNYBA
GEOLOGICAL SURVEY OF LITHUANIA

POLISH GEOLOGICAL INSTITUTE

ATLAS

GEOLOGY FOR ENVIRONMENTAL PROTECTION AND TERRITORIAL PLANNING IN THE POLISH-LITHUANIAN CROSS-BORDER AREA

1:500 000

Co-production:
Polish Geological Institute,
Geological Survey of Lithuania,
Lithuanian Institute of Geology

Warsaw 1997

Sponsored by:

NATIONAL FUND FOR ENVIRONMENTAL PROTECTION AND WATER MANAGEMENT
&
MINISTRY OF ENVIRONMENTAL PROTECTION, NATURAL RESOURCES AND FORESTRY
POLAND

Editor: Barbara SŁOWAŃSKA, M.Sc.

Translated by Grażyna BURCHART, M.Sc.
Cover design: Rimas TUMASONIS (photo Tamara Marszczek-Graniczna)

Accepted for printing by Professor Stanisław SPECZIK
General Director of the Polish Geological Institute, 26.09.1997

This Atlas represents main results both scientific and applied of the joint Lithuanian-Polish regional programme of environmental geological mapping, performed in the period 1994–1996 by the Polish Geological Institute, Geological Survey of Lithuania and Lithuanian Institute of Geology. All data collected under the programme ''Belt of Yotvings – the fragment of Green Lungs of Europe'' are depicted in maps at original scale of 1:200 000 and attributed data bases. All this information is available through the informational services at:

Polish Geological Institute, 4 Rakowiecka 00-975 Warsaw, Poland
Phone: 48-22 49 53 51 Fax: 48-22 495 342
Geological Survey of Lithuania, Konarskio 35, 2600 Vilnius, Lithuania
Phone: 370 2 63 28 89 Fax: 370 67 06 376

WYDAWNICTWO KARTOGRAFICZNE
POLSKIEJ AGENCJI EKOLOGICZNEJ SA

Contents

Introduction

In 1992 the concept was born to create the Green Lungs of Europe covering the most valuable natural areas of Poland, Lithuania, Latvia, Estonia, Belarus and Ukraine. After several meetings of representatives of these countries a preliminary programme for creating the Green Lungs of Europe was set up at the Institute of Sustainable Development in Warsaw, following the recommendations of the 1992 Rio de Janeiro "Environment and Development" Conference to protect European areas of the highest natural values.

The Green Lungs of Europe are to be a model area of international co-operation with uniform research techniques and an integrated approach to the evaluation and management of natural resources.

Based on international agreements, the Chief Geologists of Poland and Lithuania took up the initiative of establishing a joint project in the Polish-Lithuanian border zone aimed at collecting and reviewing existing geological information for the future development of the area, rational utilisation of natural resources and environmental protection.

Successive working meetings in Vilnius (20.08.1992), Warsaw (17.04.1993) and Lazdijai (28.04.1993) resulted in a programme for geological-environmental studies in the "Belt of Yotvings – the fragment of Green Lungs of Europe". The working area agreed is covered by four sheets of the 1:200 000 map: Sejny (whole sheet), Suwałki (eastern part), Grodno (northern part) and Ełk (north-eastern part).

Institutions responsible for the implementation of the project were the Polish Geological Institute and the Geological Survey of Lithuania and the project was divided into the following thematic groups (names of the coordinators given in brackets):

- Quaternary geology (J. Rzechowski/A. Ber, A. Bitinas)
- hydrogeology (J. Mitręga, A. Domaševičius)
- geochemistry (J. Lis, R.Taraškevičius)
- radioecology (R. Strzelecki, J. Mažeika)
- ecology (M. Graniczny/S. Doktór, J. Valiūnas).

M. Graniczny and J. Satkūnas were responsible for the overall supervision.

Approximately one year after the beginning of the geological work conducted by Lithuanian and Polish geologists a seminar was organized in Szelment (19–21.09.1994) to review the work completed and to present the geological results to a large group of potential users. Taking part in the seminar were representatives of the Geological Survey of Lithuania, the Lithuanian Institute of Geology, the Ministry of Building and Urbanization of Lithuania, authorities from the Lithuanian border communities (Lazdijai, Alytus, Marijampolė, Vilkaviškis) as well as from the Polish Geological Institute, Ministry of Environmental Protection, Natural Resources and Forestry, National Fund for Environmental Protection and Water Management, District Inspectorate for Environmental Protection of Suwalki, local administration of Olecko and "Geodan" Poland.

On the 27.06.1995 an Agreement was signed in Warsaw between the Geological Survey of Lithuania and the Ministry of Environmental Protection, Natural Resources and Forestry reviewing the co-operation in geological sciences between the two countries and recommending the continuation of the project "Geological-Environmental Studies of the Belt of Yotvings – the fragment of Green Lungs of Europe".

The final outcome of this project is the present Atlas at 1:500 000 scale which illustrates a synthetic approach to the geological, geochemical, radioecological and hydrogeological questions as well as to mineral resources and environmental protection.

The construction of maps was preceded by accumulation of analytical data in digital form. Lithuanian specialists were responsible for the digitization of the geological maps. Geochemical, radioecological and geoenvironmental maps were generated jointly by Polish and Lithuanian experts. The overall editorial work and computer processing of maps for publication was done in Warsaw.

Geology

WORKING METHODS AND ORGANIZATION

To construct the geological maps (Plates 1–5) at the 1:200 000 working scale teams were set up at the Polish Geological Institute in Warsaw and the Geological Survey of Lithuania in Vilnius including: Andrzej Ber (coordinator, coordinator till 1995 – Jan Rzechowski), Alicja Bałuk, Tomasz Krzywicki, Stanisław Lisicki and, for the last stage, Anna Danielewska (PGI) as well as Albertas Bitinas (coordinator), Rimantė Guobytė and Danguolė Karmazienė (Geological Survey of Lithuania).

During numerous discussions at working meetings of both teams in Warsaw and Vilnius the following questions were agreed:
- kind and number of geological-stratigraphic divisions,
- correlation of Quaternary stratigraphic schemes in Poland and Lithuania,
- methods and unification of lithological and petrographic studies,
- kind and number of geomorphological divisions.

Attached to the map are three geological cross-sections – two submeridionally: A–A' (A. Ber, A. Bitinas) and B–B' (T. Krzywicki, A. Bitinas) and one parallel: C–C' (T. Krzywicki, A. Bitinas). Responsible for the compilation of the map were T. Krzywicki from the Polish Geological Institute and R. Guobytė from the Geological Survey of Lithuania.

To obtain comparable results of the mineral composition of the Quaternary sediments examined so far by different methods and on different fractions in Poland and Lithuania, lithological and petrographic examinations of 304 samples from newly-drilled wells in Lithuania (Norvydai, Aukštakalnis and Lakštučiai) were carried out in Poland by S. Lisicki and B. Gronkowska-Krystek. For chemical analyses carried out in Lithuania (A. Bitinas) 212 samples were collected from wells Odryny and Sejny situated in the Polish territory.

The legend of the geomorphological map was compiled by S. Lisicki, A. Ber and R. Guobytė, the map itself by A. Danielewska and R. Guobytė.

The map of the sub-Quaternary surface relief and the pre-Quaternary geological map were compiled by A. Ber and S. Šliaupa with the latter's contribution to the legend. For these maps 4 micropalaeontological determinations were completed in Poland (E. Gawor-Biedowa) on samples collected from the pre-Quaternary deposits from wells situated in the Lithuanian territory (Aukštakalnis, Norvydai, Lakštučiai, Salaperaugis).

The Quaternary thickness map was compiled by A. Ber and A. Bitinas with collaboration from S. Doktór.

CORRELATION OF THE QUATERNARY STRATIGRAPHIC SCHEMES

Uniform and consistent legends are an essential factor for all kind of mapping in cross-border areas. Therefore, the preparation of a common legend was the most important task for the geological mapping of surficial sediments and for understanding the geological structure of Quaternary sediments.

The stratigraphic (chronostratigraphic) identification of the Quaternary units was based on the correlation of stratigraphic schemes of Lithuania – The stratigraphic scheme of Lithuania assigned for national geological mapping (Satkūnas, 1994; Satkūnas 1995; Satkūnas, Kondratienė 1995; Satkūnas, Bitinas 1995) and Poland – The stratigraphic subdivision of Quaternary for detailed geological mapping on 1:50 000 scale of Poland (1991, with corrections) and on *The stratigraphic subdivision of Quaternary for detailed geological mapping on 1:50 000 scale of Poland* by A. Ber et al. (1996 unpubl.).

The correlation chart (Tab. 1) shows the global and European time division, palaeomagnetic division and marine oxygen isotope stages after Bowen et al. (1986). Obviously, the correlation of schemes of Poland and Lithuania with the global time scale divisions and marine isotope stages here presented should be regarded as very tentative and problematic. It is, nevertheless an attempt to create a working hypothesis for further verification and discussion. On the other hand, this correlation indicates how, with an adequate level of certainty, the local Quaternary stratigraphic units could be linked to global and European time divisions.

The correlation of Lithuanian and Polish stratigraphic schemes was based foremost on correlation of real geological bodies recognized, explored and spatially mapped in the project area. Undoubtedly, such an approach justifies the statement that the stratigraphic units in the project area have been identified and correlated in a proper way.

However, the correlation here presented poses numerous problems to be thoroughly considered and revised in the future. These are chiefly the correlation and reconstruction of stratigraphic events of the last interglacial-glacial cycle where more abundant data is needed to define geochronologically the interstadials in the Early and Middle Weichselian. Likewise, the stratigraphic position of the Snaigupėlė Interglacial, as that separating the tills of the Drenthe and Warthe glacials as well as its correlation with the Lublin Interglacial should be thoroughly reconsidered (Satkūnas, Bitinas 1995). But newly acquired data on the Augustów and Vindžiūnai interglacials imply the necessity of a revision of the Lower Pleistocene stratigraphy.

QUATERNARY GEOLOGICAL MAP

The geological map here presented (Plate 1) shows a generalized geological pattern and origin of the Pleistocene sediments of north-eastern Poland and southern Lithuania. Stratigraphically these sediments belong to two glaciations: Warta (Medininkai) and Vistula (Nemunas). The Vistula (Nemunas) Glaciation sediments, in turn, are divided into two stadials: Świecie and Leszno–Pomorze (Grūda, Baltija). The Świecie sediments are absent from the Lithuanian territory. In the northern part of Lithuania large areas are covered by dammed-lake sediments. Depressions in the

Table 1

Correlation of the stratigraphic schemes of Pleistocene deposits

Correlation of the DIVISIONS	TIME SCALE (years)	MARINE OXYGEN ISOTOPE STAGES[1] (Ages x 10^3 years)			TIME DIVISIONS (EUROPEAN)		POLAND		LITHUANIA	
BRUNHES NORMAL POLARITY CHRON	10 000		1		WEICHSEL, WŪRM, DEVENSIAN	Late	VISTULA, Glacial	LESZNO--POMORZE Stadial	UPPER NEMUNAS, Glacial	BALTIJA, Stadial
		13	2							Interstadial
										GRŪDA, Stadial
	35 000	32	3	35		Middle		GRUDZIĄDZ Interstadial ŚWIECIE Stadial	MIDDLE NEMUNAS Megainterstadial	
	65 000	64	4	65		Early		GNIEW Interstadial	LOWER NEMUNAS Periglacial	
	79 000	75	5 a	79				KASZUBY Stadial		
			5 b							
			5 c							
			5 d	122						
	122 000	128	5 e	132	Eemian		EEMIAN, Interglacial		MERKINĖ, Interglacial	
	132 000	195	6	198	WARTHE	Saale 3 Rugen Saale 2	WARTA, Glacial		MEDININKAI Glacial	
	198 000	251	7	252	Drenthe-Warthe i.g.		LUBLIN, Interglacial		SNAIGUPĖLĖ, Interglacial	
	252 000	297	8	302	SAALE(ss) (Drenthe)		ODRA, Glacial		ŽEMAITIJA, Glacial	
	302 00 0	347	9	338	Holstein	Domnitz (Wacken)	MAZOWSZE, Interglacial		BUTĖNAI, Interglacial	
	338 000	367	10	352		Fuhne (Mehlbeck)				
EMPEROR REVERSED POLARITY SUBCHRON	352 000	440	11	428		Holstein (ss)				
465±50	428 000									
		472	12	480	ELSTER 2		SAN 2, Glacial		DAINAVA, Glacial	
BRUNHES NORMAL POLARITY CHRON	480 000	502	13		Voigstedt ?		FERDYNANDÓW, Interglacial		TURGELIAI, Interglacial	
	512 000	542	14	562	ELSTER 1		SAN 1, Glacial		DZŪKIJA, Glacial	
	562 000 610 000	592	15	630	Cromerian complex	Voigstedt ?	MAŁOPOLSKA, Interglacial			
	630 000	627	16	687		Glacial C	NIDA, Glacial			
	687 000	647	17	718		Interglacial III	AUGUSTÓW, Interglacial		VINDŽIŪNAI, Interglacial	
	718 000	688	18	782		Glacial B				
788	782 000 788 000	700	19	788		Interglacial II				
MATUYAMA REVERSED POLARITY CHRON	790 000	706	20	790		Glacial A (Helme)				
		729	21	812		Interglacial I				
		782	22		„Bavel Complex"					
JARAMILLO POLARITY SUBCHRON 900	900 000		23	900						
			24							
970			25	970						
			26-28		MENAPIAN		NAREW, Glacial		KALVIAI, Glacial	
MATUYAMA REVERSED POLARITY CHRON					WAALIAN		Preglacial		DAUMANTAI, Preglacial	
			30-33		EBURONIAN					
			34	1,510*						
			35	1,560*						
			36	1,580*						
OLDUVAI POLARITY NORMAL SUBCHRON 1,670	1,650.000 1,670.000			1,610* 1,670*	TIGLIAN					
			38							
			39							
1,870	1,870.000		40	1,850* 1,870*						

TIME SCALE, PALAEOMAGNETIC DIVISIONS, MARINE OXYGEN, ISOTOPE STAGES – after BOWEN et al. 1986, Chart 1.

surface of these sediments are filled with lakes where mineral and organic sediments accumulated. In the southern part of the Lithuanian territory and the northern part of NE Poland occur glacial uplands built of tills covered with glacial and fluvioglacial features represented by end moraines, dead ice moraines, kames and eskers. Evident are belts of end moraines marking succesive stages of the Vistula continental ice sheet deglaciation. Surfaces of postglacial uplands of similar structure and origin are known to occur in the north-west and west of the area. The glacial uplands here described originated during the Leszno–Pomorze Stadial. In their foreland occur practically flat outwash plains of Augustów and Druskininkai built of sand and gravel. The surface is diversified by lake kettles representing traces of old subglacial channels. In the southern part of the area occur sediments of the Świecie Stadial and Warta (Medininkai) Glaciation with erratics and detached rafts of Cretaceous and Tertiary rocks.

GEOMORPHOLOGICAL MAP

The area presented in the map (Plate 2) is clearly differentiated: in the north and east occurs the late glacial morainic upland, south of it the Augustów–Druskininkai outwash plain and still further to the south the peat-bearing Biebrza Basin with relics of the Świecie Stadial glacial accumulation and marginal forms of the Warta (Medininkai) Glaciation.

The morainic upland area is topographically the most diversified with absolute altitudes between 130 and 298 m a.s.l. (the highest point is Góra Rowelska – 298 m a.s.l). In the Augustów Plain and the Biebrza Basin absolute altitudes are from 100 to about 170 m a.s.l. (98,6 m a.s.l. where the Wolkuszanka flows into the Czarna Hańcza river).

The morainic upland is diversified by depositional end moraines, push moraines, dead ice moraines, kames and kame terraces as well as fissure forms of the Leszno–Pomorze (Grūda, Baltija) Stadial. The depositional end moraines and push moraines mark the extent and the separate deglaciation stages of the continental ice sheet of this stadial. These moraines were formed during the continental ice sheet transgression. They form a distinctive festoon-like pattern of alternating glaciodepressions and glacioelevations of varying size and disturbed structure.

The dead ice moraines were formed during the final stages of the continental ice sheet vanishing when dead ice blocks melted. With the areal deglaciation processes connected is also the formation of hills, ridges and kame terraces imparting a diversified topography to the bottoms of the meltout depressions and co-occurring with dammed lake sediments.

Fissure forms trains as well as channels and meltout valleys indicate the direction of melt water flow. Melt water valleys follow the lines of earlier channels. Waters from the northern part of the upland flowed through the Suwałki outwash plain (Czarna Hańcza), from the western part through the Rozpuda outwash plain and from the eastern part through an outwash train towards the Augustów Plain. Numerous dunes occur in the southern distal part of the Augustów outwash plain. Erosion and evorsion of glacial waters acting parallel to the edge of the continental ice sheet produced subparallel channels the remains of which are the depressions occupied by lakes such as, for example, Białe, Studzienniczc, Sajno and Mikaszewo.

MAP OF THE QUATERNARY THICKNESS

The Quaternary thickness (Plate 3) is illustrated by 20 m interval isopachytes. The biggest Quaternary thicknesses (up to 281 m) are related to the depressions of the sub-Quaternary surface and occur in the northern part of the project area, while the smallest thicknesses (about 112 m) are known to occur in the south-eastern part of the Augustów Plain. In the central part of the area the thicknesses are about 200 m. The most complete stratigraphic Quaternary sequence occurs in the north-west, whereas the most reduced sequences are reported from the east and south of the project area.

PRE-QUATERNARY GEOLOGICAL MAP

On the Lithuanian territory the sub-Quaternary surface (Plate 4) is built of Triassic, Jurassic, Cretaceous, Paleogene and Neogene sediments. Generally speaking, due to the SW dip, increasingly younger sediments are exposed towards the south-west. In the northern part of the area examined, in deep paleoincisions exposed are Lower Triassic and Jurassic sediments. The thickness of the Triassic sediments icreases nothward from several to more than 150 m. In the north prevail claystones with rare sandstone and oolithic limestone intercalations and in the south sandy sediments are predominant. The Triassic formations are covered by Jurassic, mainly terrigenous, sediments. The subcropping of the 5 m thick Middle and Upper Callovian sediments represented by sandstones and mudstones is, in the north, confined to the deep paleo-valley. The Lower Cretaceous is made up by Albian (45–75 m thick) glauconitic sands and muds. In the lower- and uppermost part of the sequence increased phosphate concentrations were noted. The Upper Cretaceous is represented by Lower Cenomanian sandy, limy glauconitic sediments (6–8 m at the bottom) grading upwards into several meters thick Upper Cenomanian marls. The Turonian–Lower Santonian sediments are exposed mainly in the north and are represented by chalk up to 80 m thick. At the bottom of the Campanian sequence unconformities and depositional gaps are noted. Over most of the area examined the Campanian is underlain by Lower Santonian sediments up to 20 m thick.

Also at the bottom of the Maastrichtian unconformities and depositional gaps are noted. In the south-east the Maastrichtian developed as chalk directly overlies the Campanian, but in the north-east the Maastrichtian rests directly on the Lower Santonian. The biggest Maastrichtian thicknesses occur in the eastern part of the area on Lithuanian territory where 160 m thick Maastrichtian marls and chalk directly overlie the Turonian and Cenomanian.

In the eastern part the Maastrichtian is represented by chalk with a small sand and clay admixture. In the western part predominant are marls with glauconite locally grading upwards into glauconitic sandstones.

The immediate Quaternary substratum is built of Palaeogene sediments exposed in the central part of the project area. Two stratigraphic stages – the Lower Paleocene and the Upper Eocene – have been identified. In the east the Paleocene sequence is represented by glauconitic sands (60 m) with intercalations (0.2–1 m) of strongly cemented sandstones locally replaced by limestones. In the north and west the Palaeocene is represented mainly by 5–10 m thick marls. Upper Eocene sediments are exposed in the central part. The lack of Middle Palaeocene and Lower Eocene sediments is indicative of a long depositional gap followed by Upper Eocene deposition of glauconite sands and marls attaining the thickness of 10–25 m. Neogene sediments are known only from one drilling core and are represented by dark grey muds several m thick.

In the Polish territory in the Quaternary substratum exposed are Upper Cretaceous (Maastrichtian), Lower Palaeocene and Upper Eocene sediments (Ber 1988, 1989a). The Upper Cretaceous is represented by gaizes, marls, and marly limestones. The Lower Palaeocene formations consist chiefly of limy gaizes (Cieśliński, Jaskowiak 1973). In the south-west and south-east of the Polish part of the project area the Quaternary substratum is built of thin, up to 10 m thick, isolated Upper Eocene patches (*Turborotalia cerroazulensis* zone, according to Odrzywolska-Bieniek) of glauconitic sands and glauconitic sandstones. In general, the presence of Maastrichtian and Lower Palaeocene sediments is related to the tectonic structures of the crystalline basement.

MAP OF THE SUB-QUATERNARY SURFACE RELIEF

The map of the sub-Quaternary relief (Plate 5) shows, in the Lithuanian territory, a gently inclined slope extensively cut by deep valleys. Over the major part of the area the predominant altitudes vary from 20 to 30 m a.s.l. Maximum altitutes (up to 40 m a.s.l.) are noted in the east. Distinctive are step-like landforms clearly visible in positive (elevated) forms of similar height. For example, elevations 15 m a.s.l. prevail in the west, forms rising 25–30 m a.s.l. – in the north, whereas those higher than 40 m a.s.l. predominate in the east. These "steps" accentuate well developed edges locally reaching the altitude of 20–30 m with alternating steep and gentle inclinations. Locally, paleo-valleys cut into these edges. Studies of similar edges and slopes in Lithuania and in the Kaliningrad District revealed that they are connected with flexures and faults in the sedimentary cover (A. Šliaupa 1973) and should therefore be regarded as structural-denudational features. Incisions in the Quaternary substratum form a net-like pattern. They are from 1 to 2 km wide and 50 to 100 m deep and most probably represent old erosional valleys. The time of their major development may be from Neogene till Early Pleistocene. Later, during the Pleistocene these forms have been remodelled by continental ice sheets and melt waters. The age of the major elements of the Quaternary substratum in the Lithuanian territory can be related to accumulational and denudational processes active during the Paleogene and Neogene. The magnitude of the neotectonic uplift during the Quaternary reaches 40 m.

But the Quaternary substratum in the Polish territory can be divided into two morphostructural regions:
- the eastern, constituting a plateau of the altitude of 12–20 m a.s.l.
- the western, constituting a depression reaching down to 12–57 m b.s.l. and lower (Ber 1988, 1989a).

Both regions are separated by a clear and very steep subparallel edge attaining the altitude of about 35 m and cut by erosion. Incisions the shape of which resembles the African "wadis" and which form a kind of "network" follow the W–E fault system in the crystalline basement (Kubicki, Ryka 1982). But the edge itself runs parallel to the meridional faults in the crystalline basement. Therefore their origin can be regarded as structural-erosional.

The main features of the sub-Quaternary relief are reflected on the modern surface. A thorough analysis of the Quaternary substratum differentiated into two morphostructural regions implies that its relief is due mainly to tectonics and Neogene erosion as to glacial erosion.

NEOTECTONIC ZONES

Several methods and analytical approaches were used to define the neotectonic zones (see Map of Environmental Hazards – Plate 58):
- analysis of Landsat satellite imagery at 1:250 000–1:500 000 scales,
- photointerpretation of aerial photographs at 1:25 000 scale,
- cartographic methods – III order isobase map at 1:100 000 scale,
- analysis of the semidetailed gravimetric map to detect faults within the crystalline basement and the pre-Quaternary sedimentary cover,
- analysis of structural and thickness maps at 1:200 000 scale.

A system of parallel, meridional and NE–SW lineaments has been identified by analizing satellite imagery. A number of lineaments partly coincides with faults. The regional nature of certain lineaments suggests that they reflect higher order tectonic zones. These photolineaments defined are expressed both in structural and facial elements of the Quaternary substratum and the Quaternary cover.

In the Quaternary substratum the most visible are subparallel and NW–SE tectonic discontinuities. They are most evident in the sub-Quaternary topography marking the directions of the paleo-valleys and structural-erosional escarpments. The most significant subparallel zone in the project area runs between Raczki and Druskininkai and continues westward up to Kętrzyn. It is noticeable that it controls the directions of some elongated lakes (the Wigry lake among others). Similar observations are true for the NW–SE zone interpreted in the Augustów–Raczki area.

As evidenced by the orientation of gravity anomalies, parallel directions are marked in the internal structure of the crystalline basement (S. Šliaupa 1990). In the Lithuanian territory these lineaments have been interpreted as corresponding to the folding directions in the crystalline basement. Between Druskininkai and Marijampolė runs and extensive zone bordered by two NW–SE lineaments. This zone is likely to be related to the Nemunas deep tectonic zone. It is clearly visible on the maps of the Quaternary substratum (see Plates 4 and 5).

Subparallel lineaments occur foremost in the western part of the area discussed (in the Polish territory) between Olecko and Sejny. They are shorter than the linear elements described previously and the longest of them does not exceed 40 km. Parallel lineaments are related to faults within the crystalline basement. NE–SW lineaments seem to be of minor significance.

Our analysis revealed that in the project area two systems – the subparallel and the NW–SE system – may be related to neotectonic and even modern vertical movements of the crust.

CONCLUSIONS

The present studies encourage further joint Polish-Lithuanian geological studies on the Quaternary in the cross-border area with special attention to the problem of the Vistula (Nemunas) deglaciation. To create a complete picture of the Quaternary geology and stratigraphy in this part of Europe it is absolutely necessary to include the Russian and Belarussian areas into the future project.

The successive stage of this project should concentrate on:
- detailed geological mapping of selected areas such as, for example, the Szeszupa (Šešupė) Basin or the Wigry National Park,
- compilation of the structural and geological map of the Quaternary substratum of Belarus, the Mazury region and the Kaliningrad District,
- identification of the separate marginal zones of the Warta (Medininkai) and Vistula (Nemunas) continental ice sheets and their correlation with the marginal zones in Lithuania and Belarus,
- a detailed correlation of the separate Pleistocene stage, particularly the substages of the last glaciation (Vistula, Nemunas),
- compilation of a lithological map on a larger scale suitable for spatial planning.

REFERENCES

Ber A., 1967 – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Jeleniewo. Inst. Geol. Warszawa.

Ber A., 1968 – Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, ark. Jeleniewo. Inst. Geol. Warszawa.

Ber A., 1971 – Mapa geologiczna Polski 1:200 000, ark. Suwałki. Wyd. A i B. Inst. Geol. Warszawa.

Ber A., 1972a – Mapa geologiczna Polski 1:200 000, ark. Sejny. Wyd. A i B. Inst. Geol. Warszawa.

Ber A., 1972b – Mapa geologiczna Polski 1:200 000, ark. Sokółka. Wyd. A i B. Inst. Geol. Warszawa.

Ber A., 1974, 1975 – Mapa geologiczna Polski 1:200 000, ark. Ełk. Wyd. A 1975 i wyd. B 1974. Inst. Geol. Warszawa.

Ber A., 1974 – Czwartorzęd Pojezierza Suwalskiego. *Biul. Inst. Geol.* 269.

Ber A., 1981 – Pojezierze Suwalsko-Augustowskie. Przewodnik geologiczny. Wyd. Geol. Warszawa.

Ber A., 1982 – Marginal zones and deglaciation during the North-Polish Glaciation in the Suwałki–Augustów Lakeland. *Biul. Inst. Geol.* 343.

Ber A., 1987 – Glaciotectonic deformation of glacial landforms and deposits in the Suwałki Lakeland (NE Poland), in: "Tills and Glaciotectonic", Ed. by J.J.M. van der Meer, A.A. Balkema, Rotterdam.

Ber A., 1988 – Quaternary stratigraphy of the Suwalki Lakeland, based on recent data. *Quatern. Stud.* no 8.

Ber A., 1989a – Morfogeneza Pojezierza Suwalskiego i Równiny Augustowskiej. *Stud. Mater. Ocean.* 56, *Geologia Morza* 4.

Ber A., 1989b – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Krasnopol, wraz z Objaśnieniami. Arch. Państw. Inst. Geol. Warszawa.

Ber A., 1990a – Stratigraphy of the Quaternary of the Suwalki Lakeland and its substrate based on recent data. *Kwart. Geol.*, vol. 33, nr 3–4.

Ber A., 1990b – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Suwałki, wraz z Objaśnieniami. Państw. Inst. Geol. Warszawa.

Ber A., Doktór S., Graniczny M., Kowalski Z., Krzywicki T., 1995 – Badania geologiczno-środowiskowe na pograniczu polsko-litewskim – pierwsze rezultaty. *Przegl. Geol.*, vol. 43, nr 6.

Ber A., Gogołek W., Marks L., Rzechowski J., 1996 – Zasadniczy podział stratygraficzny czwartorzędu dla Szczegółowej mapy geologicznej Polski 1:50 000 (unpubl.).

Bowen D.Q., Richmond G.M., Fullerton D.S., Sibrava V., Fulton R.J., Velichko A.A., 1986 – Correlation of Quaternary glaciations in the Northern Hemisphere. Quaternary glaciations of the Northern Hemisphere. Report of the IGCP project 24. Quaternary science reviews, vol. 5.

Bruj M., Woźniak P., 1990 – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Olecko. Państw. Inst. Geol. Warszawa.

Bruj M., Woźniak P., 1991 – Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, ark. Olecko. Państw. Inst. Geol. Warszawa.

Cieśliński S., Jaskowiak M., 1973 – Cretaceous. North-East Poland. In: Geology of Poland. Stratigraphy, vol. 1, part 2, Mesozoic. Polish Geol. Inst. Warsaw.

Guobytė R., 1994 – Kvartero geologinio ir geomorfologinio žemėlapių M 1:50 000 legendos: Valstybinių geologinių tyrimų taisyklės ir metodinės rekomendacijos/Rarengė R. Guobytė – Vilnius, Rankraštis saugomas Lietuvos geologijos tarnybos fonduose.

Instrukcja w sprawie opracowania i wydania Szczegółowej mapy geologicznej Polski w skali 1:50 000, w ujęciu kompleksowym, 1991. Państw. Inst. Geol., Warszawa.

Krzywicki T., 1987 – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Filipów i Żytkiejmy. Państw. Inst. Geol. Warszawa.

Krzywicki T., 1990a – Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, ark. Filipów i Żytkiejmy. Państw. Inst. Geol. Warszawa.

Krzywicki T., 1990b – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Wiżajny i Poszeszupie. Państw. Inst. Geol. Warszawa.

Krzywicki T., 1990c – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Puńsk. Państw. Inst. Geol. Warszawa.

Krzywicki T., 1990d – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Widugiery. Państw. Inst. Geol. Warszawa.

Krzywicki T., 1992 – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Rygol i Rudawka, wraz z Objaśnieniami. Arch. Państw. Inst. Geol. Warszawa.

Krzywicki T., 1993 – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Wiżajny i Poszeszupie. Państw. Inst. Geol. Warszawa.

Krzywicki T., 1995 – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Puńsk i Widugiery. Państw. Inst. Geol. Warszawa.

Kubicki S., Ryka W., 1982 – Geological atlas of crystalline basement in Polish part of the East European Platform. Polish Geol. Inst. Warsaw.

Lisicki S., 1996 – Szczegółowa mapa geologiczna Polski 1:50 000, ark. Sejny i Veisiejai wraz z Objaśnieniami. Arch. Państw. Inst. Geol. Warszawa.

Mojski J.E., 1995 – Pleistocene glacial events in Poland. In: Glacial deposite in North-East Europe, Ed. by: J. Ehlers, S. Kozarski, P. Gibbard, A.A. Balkema, Rotterdam, Brookfield.

Satkūnas J., 1994 – Lietuvos Kvartero stratigrafijos schema Valstybinių geologinių tyrimų taisyklės ir metodinės rekomendacijos/Rarengė J. Satkūnas. Lietuvos geologijos Tarnyba, baltijos stratigrafinės Associacijos Kvartero sekcijos Lietuvos posekcija – Vilnius, Rankraštis saugomas Lietuvos geologijos tarnybos fonduose.

Satkūnas J., 1995 – Kartowanie geologiczne czwartorzędu na Litwie – zadania i problemy. *Przegl. Geol.* vol. 43, nr 3.

Satkūnas J., Bitinas A., 1995 – The lithological composition of Saalian tills in Lithuania as a criterion for lithostratigraphic subdivision. *Acta Geogr. Lodz.*, no 68.

Satkūnas J., Kondratienė O., 1995 – Quaternary stratigraphic scheme of Lithuania for national geological mapping. International Union for Quaternary research: XV International Congress, Berlin, August 3–10; abstracts – Bonn; *Terra Nostra.* no 2.

Шляупа А. [A. Šliaupa], 1970 – Структурно-морфометрические исследования Южной Прибалтики при поисках нефтеносных структур: 04.136: Автореферат дис. канд. геол.-минерал. наук; рук. В. Философов. – Саратов: СГУ.

Шляупа А. [A. Šliaupa], 1973 – Доледниковая поверхность выравнивания Южной Прибалтики. Поверхность выравнивания. Москва.

Шляупа С. [S. Šliaupa], 1990 – Тектоническое строение и открытость недр курортов Бирштонас и Друскининкай. Проблемы экологической геологии в Прибалтике и Белоруссии: Тезисы докладов совещания, Вильнюс, ноябрь 1990 г. Вильнюс.

Geochemical Studies

OBJECTIVE

The present studies were aimed at determining the trace elements of soils and water sediments as well as to assess the degree of their pollution due to anthropogenic impact. It was equally important to compare between geochemical maps compiled with the application of different sampling and analytical techniques. As a rule, the comparison of geochemical maps based on different sampling techniques poses considerable problems as was the case with the geochemical maps of Sweden and Finland (Gustavsson et al. 1994). However, using adequate interpretation methods it is possible to obtain a coherent cartographic picture.

SAMPLING

The geochemical studies included soils from the so called arable level (0.0–0.2 m) and water sediments (alluvial and lacustrine). Sampling density was 1 sample/25 km^2. Soils samples have been collected from sites where land use is typical for the given square (soils from cultivated land, meadows, forests, fallows and barrens). Water sediments samples have been collected from different aqueous environments present in the area examined (streams, lakes, ponds and drainages, ditches and others) in the form of the finest material. Sampling sites have been marked on 1:50 000 topographic maps and information on the type of land use, petrographic nature of the sample, type of aqueous reservoir and the like have been entered on special sampling forms. In the field the soil samples have been subjected to preparatory drying and later sent to the laboratory.

PREPARATION OF SAMPLES

After drying in room temperature, soil and water sediment samples have been sieved on nylon sieves of 1 mm (soils) and 0.2 mm mesh (water sediments). Subsequently, by quartering, two parallel analytical samples have been obtained for the laboratories in Warsaw and Vilnius.

CHEMICAL ANALYSES

Parallel analytical work has been completed in the Central Chemical Laboratory of the Polish Geological Institute in Warsaw (partial content) and in the Analytical Laboratory of the Geological Institute in Vilnius (total content).

Analytical procedures adopted in the PGI Central Chemical Laboratory in Warsaw were identical with those used for the Geochemical Atlas of Poland (Lis, Pasieczna 1995a). 1 g soil and water sediments samples were extracted in 1:4 HCl during 1 hour at temperature of 90°C. The ICP-AES was used to determine the Ba, Ca, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn contents in the fraction extacted by HCl. The Philips spectrometer PV 8060 was used for soils and the Jobin-Yvon JY 70 Plus Geoplasma spectrometer for water sediments.

To determine the pH in the aqueous environment procedures commonly used in pedology were adopted.

In the Analytical Laboratory of the Geological Institute in Vilnius the total contents of Ag, Al, B, Ba, Co, Cr, Cu, Ga, La, Li, Mn, Mo, Nb, Ni, P, Pb, Sn, Ti, V, Y, Yb, Zr and Zn have been determined by the emissiom DFS-13 spectrometer. As, Rb, Sr, Th and U determinations were completed by X-ray fluorescence with the ARF-6 spectrometer (Baltakis 1993; Taraškevičius 1991; Taraškevičius et al. 1995).

STATISTICAL CALCULATIONS

The data bases, separate for each environment and for each analytical method contained the coordinates of sampling points in the "42" topographic system, field data and element contents.

The statistical parameters, both for the whole sets and subsets representing different environments have been computed using STATGRAPHIC software. The arithmetic mean, median and minimum and maximum values have been calculated and are given in Tables 2 and 3.

CONSTRUCTION OF THE GEOCHEMICAL MAPS

A PC 486, 16 MB RAM computer and SURFER 6 software have been used for the generation of the geochemical maps. The construction of the maps was based on sets of sampling points (Plate 6) with known coordinates and attributed element contents. The monoelemental geochemical maps for soils were constructed using the method of inverse distance and isolines presentation while for the water sediments the circular diagram method was applied. The levels of element contents corresponds to percentiles 15, 25, 50, 75, 90, 95, 97, and 99% permitting a correct differentiation of the geochemical background and identification of possible geochemical anomalies.

On the map illustrating soil acidity values have been accepted according to the classification of soils into very acid, acid, slightly acid, neutral and alkaline.

A digitized map on 1:500 000 scale with simplified topography and hydrography served as a base map.

COMPARISON BETWEEN THE TOTAL AND PARTIAL ELEMENT CONTENTS IN SOILS AND WATER SEDIMENTS

In the samples examined the degree of extraction of the individual elements versus their total content is very differentiated and depends foremost on the mode of occurrence of this element in the rock. The average ratios between the partial HCl extractable and the total contents are given in Table 4. The element the most susceptible to HCl extraction (more than 80%) is zinc both from soils and water sediments. The less extractable are such elements

Table 2

Statistical parameters of chemical elements in soils and water sediments
Total contents: DC Arc Emission Spectrometry
(Ag, B, Ba, Co, Cr, Cu, Ga, La, Li, Mn, Mo, Nb, Ni, P, Pb, Sn, Ti, V, Y, Yb, Zr, Zn in ppm), (Al in %), XRF (As, Rb, Sr, Th, U in ppm)
Laboratory of Lithuanian Institute of Geology

Medium	Para-meters	Ag	Al	As	B	Ba	Co	Cr	Cu	Ga	La	Li	Mn	Mo	Nb	Ni	P	Pb	Rb	Sn	Sr	Th	Ti	U	V	Y	Yb	Zr	Zn
Soils of Poland	a	0.013	0.36	1.0	6.2	58	0.6	4.3	1.0	0.5	4	2	52	0.27	2	2.2	236	5	4	0.4	29	1.0	346	1.0	4	3	0.3	48	2
and Lithuania	b	0.241	8.05	6.0	65.2	814	10.0	77.0	34.5	13.1	59	37	3060	2.88	23	33.0	5610	70	149	10.1	176	13.0	4 860	4.1	83	34	8.7	1344	179
n = 385	c	0.063	3.73	3.6	27.0	373	4.4	31.8	8.9	5.6	22	13	477	0.69	12	12.0	801	16	62	2.2	84	9.0	2 429	2.8	34	16	1.9	332	29
	d	0.058	3.67	3.7	26.2	366	4.4	30.2	8.2	5.7	21	13	441	0.66	12	11.0	693	14	59	2.1	83	9.0	2 457	2.8	33	16	1.9	296	23
Cultivated soils	a	0.020	1.56	2.0	12.1	130	1.7	13.6	1.0	2.1	12	7	176	0.30	6	4.7	276	5	38	1.4	54	2.0	1 080	1.5	14	7	0.7	108	7
n = 143	b	0.241	8.05	4.9	65.2	790	10.0	77.0	22.9	13.1	59	37	1242	1.15	23	33.0	2548	39	149	4.3	149	13.0	4 830	4.1	83	33	5.2	1344	109
	c	0.067	4.24	3.6	29.9	438	5.0	37.7	10.1	6.2	24	15	491	0.68	13	14.0	743	14	70	2.2	88	9.2	2 801	2.9	39	18	2.2	371	29
	d	0.062	4.15	3.7	28.8	430	5.0	36.9	9.7	6.3	23	15	476	0.67	14	13.5	654	14	68	2.2	85	10.0	2 799	2.9	38	18	2.2	317	26
Meadow soils	a	0.013	0.51	1.0	11.4	82	1.0	4.9	1.5	0.5	6	2	159	0.40	2	3.0	284	6	4	0.6	52	1.0	507	1.0	4	4	0.4	48	6
n = 132	b	0.210	7.91	5.0	61.1	814	8.8	63.8	34.5	9.9	48	26	3060	2.87	21	26.8	5610	48	138	8.4	176	13.0	4 860	4.0	83	34	4.3	768	178
	c	0.058	3.70	3.5	29.0	365	4.4	31.9	9.6	5.3	22	13	492	0.72	12	12.7	843	14	63	2.1	93	9.2	2 385	2.7	36	16	1.9	304	33
	d	0.056	3.58	3.5	27.8	362	4.3	30.4	9.0	5.4	22	12	425	0.65	11	12.0	688	13	59	2.1	89	9.5	2 409	2.8	33	16	2.0	302	24
Forest soils	a	0.023	0.36	1.0	6.2	58	0.6	4.3	1.4	0.7	4	2	52	0.27	2	2.2	236	6	11	0.4	29	1.0	346	1.0	7	3	0.3	75	2
n = 90	b	0.220	6.12	6.0	45.1	705	5.8	52.9	19.6	9.8	55	20	2142	2.88	17	18.0	1869	58	140	5.7	115	13.0	4 785	4.0	73	26	8.7	775	94
	c	0.066	3.01	3.5	20.2	283	3.2	23.2	5.7	5.2	17	12	431	0.67	12	8.3	841	18	51	2.1	62	8.2	1 932	2.6	27	11	1.5	311	22
	d	0.060	2.87	3.7	19.1	270	3.1	21.6	5.7	5.4	16	13	396	0.62	12	7.8	804	17	48	2.1	60	8.0	1 755	2.7	25	10	1.3	255	15
Fallow soils	a	0.020	1.66	2.2	13.4	130	2.9	14.4	2.9	2.7	13	5	207	0.47	6	5.2	360	10	39	1.4	66	7.0	1 054	2.2	15	8	0.6	115	14
n = 19	b	0.210	5.28	4.9	29.1	776	6.3	46.1	23.3	7.2	43	25	960	1.19	16	20.1	1330	70	79	10.1	162	12.0	4 376	3.9	50	27	3.4	852	179
	c	0.063	3.44	3.9	23.6	359	4.6	27.6	9.0	5.1	21	12	473	0.67	10	10.1	769	22	59	2.9	96	9.5	2 321	3.0	32	17	1.8	344	47
	d	0.050	3.47	3.9	24.8	317	4.5	27.3	7.7	5.2	18	11	460	0.66	10	9.9	812	15	57	2.3	90	10.0	2 408	3.0	31	17	1.9	251	31
Sandy soils	a	0.020	1.47	1.7	12.0	130	1.2	10.5	1.0	1.7	6	5	52	0.30	6	4.4	289	8	20	1.1	29	2.0	697	1.1	10	5	0.3	75	6
n = 180	b	0.220	6.95	4.9	51.6	790	9.0	77.0	34.5	13.1	55	37	1008	2.88	23	33.0	2721	70	98	8.0	164	13.0	4 830	4.0	73	33	8.7	1344	179
	c	0.070	3.27	3.6	23.2	325	3.9	26.6	7.1	5.3	20	13	470	0.68	13	9.5	885	17	53	2.3	72	8.5	2 272	2.7	29	15	1.7	380	27
	d	0.064	3.22	3.7	22.4	325	3.8	24.4	6.7	5.4	19	13	452	0.66	13	8.5	879	16	51	2.2	73	9.0	2 279	2.7	28	15	1.7	377	16
Loamy soils	a	0.020	1.75	1.7	15.2	130	2.0	15.9	5.3	2.4	8	7	171	0.35	7	6.1	284	5	43	1.4	54	3.0	1 080	1.7	20	7	0.7	108	14
n = 166	b	0.241	8.05	5.0	65.2	776	10.0	65.5	23.3	10.4	59	31	2142	1.25	21	28.1	2548	39	149	8.0	162	13.0	4 860	4.1	83	33	5.2	737	148
	c	0.060	4.44	3.6	31.6	439	5.1	39.6	10.9	6.4	24	15	472	0.66	13	15.0	666	14	76	2.2	93	9.7	2 786	2.9	42	18	2.2	314	31
	d	0.057	4.44	3.7	30.0	424	5.0	40.2	10.2	6.3	24	15	444	0.65	13	15.2	588	13	71	2.2	90	10.0	2 798	2.8	41	17	2.2	299	28
Peaty soils	a	0.013	0.36	1.0	6.2	58	0.6	4.3	1.5	0.5	4	2	110	0.27	2	2.2	236	6	4	0.4	52	1.0	346	1.0	4	3	0.4	48	2
n = 36	b	0.120	7.55	6.0	48.7	814	6.9	48.4	22.9	7.1	48	23	3060	2.87	16	26.8	5610	50	140	10.1	176	13.0	3 376	4.0	62	34	3.8	456	103
	c	0.049	2.72	3.3	24.9	312	3.1	22.1	8.8	3.8	18	9	531	0.85	8	10.9	1006	17	48	1.9	103	8.6	1 606	2.6	28	13	1.4	187	31
	d	0.047	2.27	3.5	24.8	327	2.9	20.2	8.5	4.1	16	8	352	0.69	8	10.4	828	14	47	1.5	97	9.0	1 575	2.7	26	12	1.2	181	20
Water sediments	a	0.005	0.32	1.0	5.7	19	0.7	4.0	1.9	0.5	4	1	54	0.28	2	3.0	160	4	12	0.4	11	1.5	400	1.0	7	3	0.2	36	3
of Poland	b	9.950	7.70	5.6	86.1	903	17.8	1249.0	144.0	13.5	329	32	9250	3.23	139	106.0	7429	160	124	59.3	415	30.0	26 760	5.3	149	139	12.9	6428	615
and Lithuania	c	0.117	3.17	3.5	31.0	319	4.6	39.1	10.5	5.9	32	12	760	0.94	13	13.6	881	16	54	2.8	96	8.9	2 927	3.0	36	20	2.6	628	42
n = 394	d	0.061	2.88	3.5	29.1	307	4.2	33.4	9.2	5.7	27	11	511	0.84	12	11.2	761	14	49	2.3	88	9.0	2 784	2.9	32	19	2.5	395	31

a – minimum   b – maximum   c – arithmetic mean   d – median   n – number of samples

Table 3

Statistical parameters of chemical elements in soils and water sediments

Partial contents: HCl – extractable, ICP-AES

(Ba, Co, Cr, Cu, Mn, Ni, Pb, Sr, Ti, V, Zn in ppm), (Ca, Fe, Mg, P, S in %)

Central Chemical Laboratory of Polish Geological Institute

Medium	Para-meters	Ba	Ca	Co	Cr	Cu	Fe	Mg	Mn	Ni	P	Pb	S	Sr	Ti	V	Zn	pH
Soils of Poland	a	6	0.01	<1	<1	<1	0.09	0.01	5	<1	0.008	<3	<0.005	1	3	1	6	1.9
and Lithuania	b	188	8.86	13	26	33	7.17	1.05	1760	25	0.337	36	0.155	104	167	53	167	8.0
n = 385	c	35	0.97	3	6	6	0.72	0.21	238	6	0.039	8	0.016	15	53	9	27	6.5
	d	29	0.43	2	5	5	0.60	0.16	213	5	0.033	7	0.010	10	50	8	24	6.8
Cultivated soils	a	8	0.04	<1	<1	1	0.14	0.01	50	1	0.011	<3	<0.005	1	10	1	9	4.8
n = 143	b	102	8.69	13	26	22	2.72	0.84	784	25	0.148	29	0.070	72	144	37	99	8.0
	c	37	0.94	3	7	6	0.75	0.25	265	7	0.039	8	0.012	15	60	10	29	6.9
	d	32	0.47	3	6	6	0.68	0.21	247	6	0.035	7	0.010	11	58	9	25	7.0
Meadow soils	a	11	0.06	<1	1	1	0.17	0.02	55	1	0.010	<3	<0.005	2	3	1	8	1.9
n = 132	b	188	8.86	11	24	25	5.46	1.05	1760	25	0.337	21	0.155	104	167	33	160	7.9
	c	41	1.39	3	7	6	0.85	0.26	250	7	0.046	8	0.034	22	55	10	29	6.8
	d	32	0.92	3	5	5	0.67	0.21	209	6	0.039	7	0.013	17	53	9	25	7.0
Forest soils	a	6	0.01	<1	<1	<1	0.09	0.01	5	<1	0.008	<3	<0.005	1	7	1	6	3.4
n = 90	b	172	3.74	7	18	10	7.17	0.65	1097	14	0.089	23	0.118	60	108	53	62	7.5
	c	23	0.28	1	3	3	0.52	0.07	175	3	0.028	8	0.011	6	35	5	17	5.1
	d	16	0.05	1	2	2	0.30	0.03	129	2	0.025	7	0.007	3	29	4	14	4.9
Fallow soils	a	11	0.13	<1	2	3	0.28	0.06	117	2	0.016	4	<0.005	4	22	3	18	5.5
n = 19	b	104	4.61	5	11	33	1.38	0.49	760	8	0.105	36	0.031	73	167	18	167	7.7
	c	34	1.51	2	5	8	0.60	0.24	250	5	0.038	14	0.013	20	71	8	45	6.9
	d	28	0.94	2	5	6	0.59	0.22	222	5	0.035	10	0.011	13	68	8	30	7.0
Sandy soils	a	6	0.01	<1	<1	<1	0.09	0.01	5	<1	0.008	<3	<0.005	1	8	1	6	1.9
n = 180	b	1	10	8	12	25	7.17	0.71	760	12	0.112	36	0.030	49	167	53	167	7.7
	c	24	0.50	2	4	4	0.48	0.12	204	3	0.032	8	0.009	8	44	6	24	6.0
	d	22	0.17	1	3	3	0.40	0.07	204	3	0.030	7	0.008	5	39	5	18	6.3
Loamy soils	a	8	0.08	1	2	2	0.24	0.03	50	1	0.010	<3	<0.005	2	26	3	8	4.5
n = 166	b	172	8.69	13	26	33	2.72	1.05	1097	25	0.148	29	0.074	73	167	37	128	8.0
	c	41	1.17	4	9	7	0.88	0.31	266	8	0.039	8	0.014	19	67	12	30	7.0
	d	34	0.75	3	8	6	0.79	0.26	133	7	0.035	7	0.011	16	64	11	26	7.1
Peaty soils	a	17	0.21	<1	1	2	0.29	0.04	55	1	0.016	4	0.007	6	3	1	11	4.0
n = 36	b	188	8.86	7	19	22	5.46	0.80	1760	16	0.337	23	0.155	104	113	28	61	7.9
	c	65	2.41	2	5	7	1.20	0.24	281	6	0.069	11	0.061	39	37	9	27	6.7
	d	48	2.11	2	4	5	0.96	0.19	195	4	0.053	10	0.056	36	34	8	24	7.0
Soils of Poland[1)]	a	<1	<0.01	<1	<1	<1	<0.01	<0.01	<1	<1	<0.005	<3	<0.005	<1	<1	<1	<1	2.1
n = 10840	b	1777	25.45	46	1873	6401	9.57	4.90	24270	146	1.613	16972	3.263	1298	1542	266	91110	9.7
	c	48	0.47	3	6	10	0.67	0.10	267	6	0.042	35	0.017	17	34	8	88	6.0
	d	32	0.18	2	4	5	0.51	0.06	217	4	0.034	13	0.012	8	26	7	35	6.1
Cultivated soils	a	<1	<0.01	<1	<1	<1	0.03	<0.01	<1	<1	<0.005	<3	<0.005	<1	<1	<1	<1	2.8
of Poland[1)]	b	1404	14.96	29	1873	2190	5.99	1.75	24270	146	0.476	2113	1.860	1179	968	58	2140	9.3
n = 4899	c	41	0.43	3	6	8	0.64	0.10	286	6	0.043	20	0.013	15	34	8	53	6.3
	d	32	0.19	2	5	5	0.53	0.07	246	4	0.038	12	0.011	9	29	7	34	6.4
Soils of urban	a	5	0.03	<1	<1	<1	0.09	<0.01	6	<1	0.005	5	<0.005	1	8	1	15	3.3
and industrial areas	b	1777	12.40	17	95	805	3.21	3.81	2229	89	0.254	16972	0.516	708	318	60	11899	8.6
of Upper Silesia[2)]	c	144	0.96	4	9	30	0.98	0.21	440	10	0.044	320	0.026	43	63	12	719	7.3
n = 228	d	116	0.59	3	7	16	0.87	0.13	338	8	0.035	102	0.019	27	49	11	317	7.6
Water sediments	a	4	<0.01	<1	<1	1	0.05	0.02	8	<1	0.006	<3	<0.005	1	4	<1	7	
of Poland	b	247	25.50	12	20	42	6.07	1.35	3020	23	0.492	150	0.518	204	209	32	301	
and Lithuania	c	41	2.36	2	5	6	0.74	0.37	286	5	0.051	7	0.045	23	48	7	33	
n = 350	d	31	1.76	2	4	5	0.58	0.29	187	4	0.037	6	0.023	19	43	6	26	

a – minimum b – maximum c – arithmetic mean d – median n – number of samples

[1)] J. Lis, A. Pasieczna 1995b; [2)] J. Lis, A. Pasieczna 1995a;

as Ba, Cr, Sr, Ti and V. The remaining elements here examined have average extraction abilities varying from 30–60%. Similar aqua regia extration values ranging from 1 to 100% of the individual elements from tills have been found in Scandinavia during ultra low density geochemical sampling (Eden, Bjørklund 1995). Noteworthy is that both in Scandinavia and in our project area the same elements show low extraction susceptibility values (in descending order from 29% to 8% for Cr, V, Ti, Ba, Sr).

To a considerable extent the extraction susceptibilty depends on the granulometry of the soil. The less extractable are elements from sandy soils, much more from clayey and peaty soils. In sandy soils with a low sorption capacity a significant amount of elements is contained in the crystal lattice of rock-forming and accessory minerals. Elements released from these minerals during weathering processes are not retained in soils but, due to a fairly acid environment, are transported to ground and surface waters.

Table 4

Comparison of some element contents in soils and water sediments using different analytical methods

(partial contents – ICP, HCl – extractable, total contents – DC Arc Emission Spectrometry and XRF)

Central Chemical Laboratory of Polish Geological Institute

Element	Average ratio of partial contents to total contents in %					R partial contents to total contents	
	soils n = 385	sandy soils n = 180	loamy soils n = 166	peaty soils n = 36	water sedi-ments n = 350	soils	water sedi-ments
Ba	9.3	8.2	9.0	21.4	11.6	0.40	0.42
Co	49.6	36.6	68.3	60.5	48.9	0.72	0.78
Cr	15.9	11.9	20.1	22.1	11.3	0.80	0.48
Cu	54.8	48.8	59.0	69.3	49.8	0.76	0.72
Mn	44.8	36.6	53.0	55.4	32.9	0.79	0.86
Ni	38.6	29.0	49.5	51.0	33.2	0.78	0.86
P	45.6	35.6	55.2	66.2	50.6	0.63	0.71
Pb	50.2	42.7	56.6	64.6	36.3	0.44	0.79
Sr	12.0	7.3	16.5	32.6	19.2	0.81	0.86
Ti	2.0	1.8	2.4	1.9	1.5	0.53	0.22
V	22.5	17.3	27.6	32.1	16.1	0.81	0.80
Zn	84.9	81.9	88.3	83.7	80.8	0.75	0.52

Usually, sandy soils are distinctive by low concentrations of most elements. In clayey soils containing fair amounts of clay minerals and in organic (peaty) soils a considerable amount of elements released during weathering of the basement rocks or derived from anthropogenic contamination is retained in sorption forms easily extractable by inorganic acids.

The calculated coefficients of the linear correlation between the total element content and the extractable content revealed significant, usualy fairly strong correlations between these values (Tab. 4). In soils the highest correlation coefficients (> 0.70) have been found for Co, Cr, Cu, Mn, Ni, Sr, V, Zn. For water sediments R > 0.70 has been obtained for Co, Cu, Mn, Ni, P, Pb, Sr and V. Low correlation coefficient between the total and the extractable contents for such elements as Ba and Ti indicate that these minerals occur in rock-forming minerals (Ba probably in feldspars) or in heavy minerals (Ti in sphene or in ilmenite). This might be also inferred from a very low susceptibilty to HCl extraction from soils and water sediments (respectively, for Ba 9.3% and 11.6% and for Ti 2.0% and 1.5%). The relationship between the total and the extractable content is also illustrated by the scatter diagrams (Figs. 1 and 2).

Data from the correlational analysis revealed the possibility of combining geochemical maps compiled from data obtained by different analytical techniques into a coherent cartographic picture. A confirmation of this conclusion are the geochemical maps completed for the majority of the elements examined.

GEOCHEMICAL MAPS

The monoelemental geochemical maps (Plates 7–50) and the map showing soil acidity (Plate 51) illustrate the spatial distribution of elements in soils and water sediments. The main factor responsible for the differentiation of the elements is the geological structure. The anthropogenic factor has no bearing on the element accumulation in soils. Only a minor enrichment in silver, chromium, copper, lead, tin and zinc noted in water sediments in the vicinity of Augustów in Poland and of Marijampolė in Lithuania could perhaps be regarded as anthropogenic. Concentrations of these elements are hardly significant. The arable soils have not been found to exceed the first class of purity (Kabata-Pendias et al. 1995). But a clear differentiation of both total and extractable contents is found to depend on the kind of land use and the type of soil. Most often the kind of land use results from the type of soil and the latter – to a considerable degree – from lithology of the geological substratum. The less abundant in most chemical elements are sandy forest soils developed on fluvioglacial sand and gravel, for example of the Augustów Forest in Poland. As a rule, richer in elements are clayey soils developed on tills and clayey limnoglacial sediments, chiefly in the northern part of the map sheet in the Lithuanian territory.

In the cartographic picture of soils and water sediments a subparallel belt of clearly elevated concentrations of most elements can be distinguished in the northern part of the region. In the east this belt is built of Vistula (Nemunas) limnoglacial formations with a considerable amount of Holocene peats and lacustrine muds, in the east predominant are tills.

In the south of the project area a vast zone of low concentrations of most elements has been noted between Augustów in Poland and Leipalingis in Lithuania. Low concentrations in soils and water sediments of this area are connected with the presence of fluvioglacial and eolian sands. This area is also distinctive by acid and occassionally very acid soils.

Despite differences between the total and extractable content of elements in the environments examined, the cartographic pictures are most often almost identical. Particularly consistent pictures have been obtained for Co, Cr, Cu, Ni, P, Sr, Ti, V, Zn that is for practically all elements examined parallel by different analytical methods.

REFERENCES

Baltakis V., 1993 – Foniniai mikroelementų pasiskirstymai ir jų tarpusavio ryšiai Lietuvos dirvožemiuose. *Geologija* 15.

Eden P., Bjørklund A., 1995 – Geochemistry of till in Fenoscandia from ultra-low density sampling. *J. Geoch. Explor.* 52.

Gustavsson N., Lampio E., Nilsson B., Norblad G., Ros F., Salminen R., 1994 – Geochemical maps of Finland and Sweden. *J. Geoch. Explor.* 51.

Kabata-Pendias A., Piotrowska M., Motowicka-Terelak T., Maliszewska-Kordybach B., Filipiak K., Krakowiak A., Pietruch Cz., 1995 – Podstawy oceny chemicznego zanieczyszczenia gleb. Bibl. Monitoringu Środowiska. Warszawa.

Lis J., Pasieczna A., 1995a – Geochemical Atlas of Poland 1:2 500 000. Polish Geol. Inst. Warsaw.

Lis J., Pasieczna A., 1995b – Atlas geochemiczny Górnego Śląska 1:200 000. Państw. Inst. Geol. Warszawa.

Taraškevičius R., 1991 – Important features of heavy metals geochemical behavior in the Nemunas Basin rivers/USA–USSR project 02.07.31 "Comprehensive Analysis of Environment" subproject "Prediction of Ecological Impacts of Environment Pollutants". Vilnius.

Taraškevičius R., Radzevičius A., Zinkutė R., 1995 – Miestų teritorijų dirvožemio ir gruntinio vandens užterštumo ekologinis – geocheminis įvertinimas/Geologijos mokslo pasiekimai – gamtosaugai: str. rink. Vilnius.

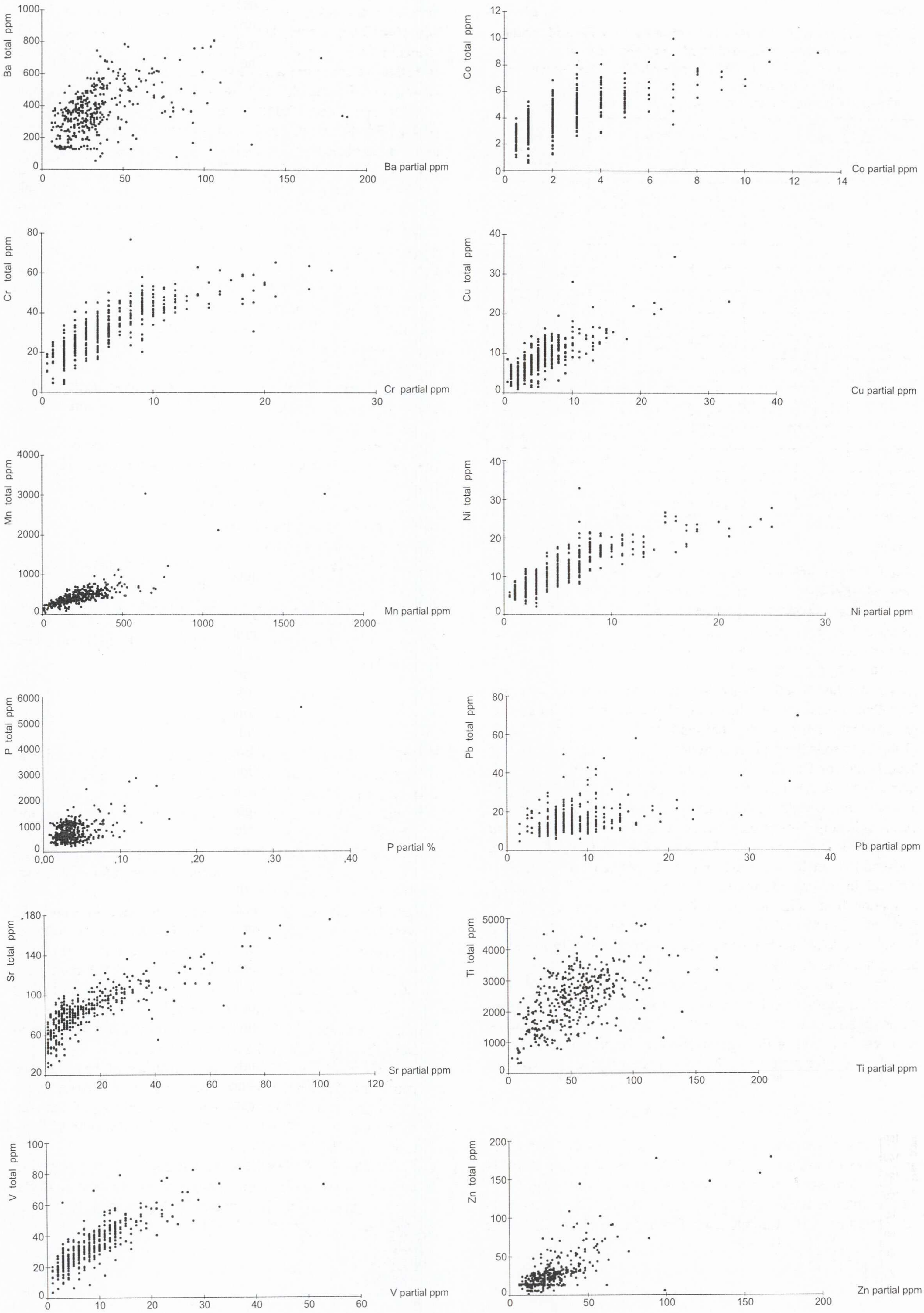


Fig.1. Scatter diagrams of elements contents in soils, total content versus partial content

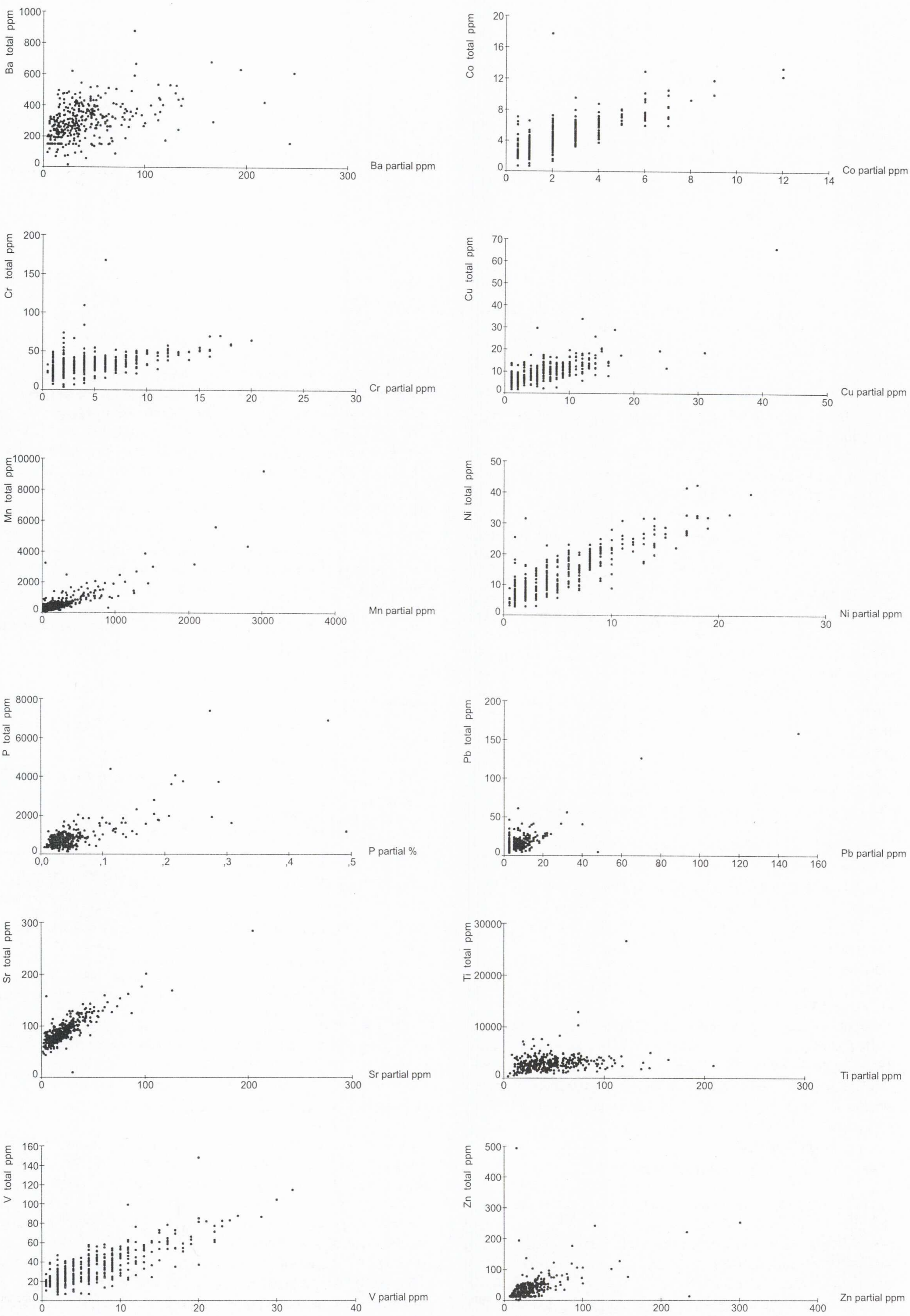


Fig.2. Scatter diagrams of elements contents in water sediments, total content versus partial content

Radioecology

OBJECTIVE

The failure of the Chernobyl nuclear plant and the consequent emission of artificial radionuclides into the atmosphere entailed a growing interest in the effect of radiation on a human being. During the first days after the disaster north-eastern Poland and Lithuania found themselves in the zone of direct influence of the emission (Butkus et al. 1994; Mažeika et al. 1996; Strzelecki et al. 1994b). To define the condition of the natural environment in The Green Lungs area radiometric measurements have been completed and the occurrence of natural and artificial radionuclides (particularly of the post-Chernobyl long-lived cesium isotopes) and their effect on the dose rate received by a human being has been evaluated. Radon is responsible for the major part of ionizing radiation. It is estimated that, depending on the geological conditions, it makes up from 50 to 80% of a dose received by a human. The magnitude of radon emanation into the natural environment is directly controled by the geology of the basement, that is its lithology, directions of tectonic lines, porosity and permeability of soils and radon concentration in ground waters. As radon originates from uranium disintegration, the preliminary identification of areas prone to elevated radon concentrations is illustrated by the map of uranium concentration (Plate 53).

WORKING METHODS

For several decades measurements of the natural gamma radiation background have been used in exploration for uranium ore and since the seventies a spectrometric version of these measurements consists in selective *in situ* determination of concentrations of natural isotopes – emitters of gamma radiation i.e. potassium ^{40}K, bismuth ^{214}Bi equivalent of uranium – eU) and thalium ^{208}Tl (equivalent of thorium – eTh). The failure of the Chernobyl reactor significantly, though to a varying degree, spatially disturbed the gamma radiation field over considerable areas (Strzelecki et al. 1993, 1994a). As eight years have elapsed between the Chernobyl disaster and the present measurements, it is now practically the cesium isotopes (^{137}Cs and considerably less ^{134}Cs) that remain in the environment.

Gamma-Spectrometric Measurements

The method of cesium radioisotope determination consists in defining the dose rate of radiation connected with these radionuclides as a difference between the total radiation dose found by measurements and the total radiation dose from natural gamma radiation emitters. Concentrations of the latter are defined by measurements including energetic lines 1.46 MeV, 1.76 MeV and 2.62 MeV for potassium, uranium and thorium respectively as well as lines above 0.56 MeV for the TC channel (total radiation). The presence of cesium isotopes does not affect the energetic spectra of natural radionuclides. Measurement coefficients permitting the determination of natural isotopes concentrations are defined experimentally from routine calibration procedures. The equipment used in the present work is calibrated on a natural spatial standard located in Bratkovice near Przybram (Czech Republic) which are subjected to international intercalibration. Measurements of the cosmic background have been completed on the Zegrzyń artificial lake near Warsaw more than 100 m from the nearest shore.

As it is not possible to create adequate spatial standards for cesium, an approximate calibration method was used devised in the Central Laboratory of Radiological Protection (CLOR) in Warsaw, based on point sources.

Natural isotope concentrations have been defined according to the following formula:

$$Qi = aip \times Npi$$

where:

Qi – concentration of i isotope (in % for K, in g/t from U and Th),
aip – calibration coefficient,
Npi – frequency of counts in spectrometric channels.

The cesium isotope concentration has been defined from the formula:

$$QCs = KCcs \times d\,(NT - NNAT)$$

where:

KCs – calibration coefficient defining the relationship between the frequency of spectrometer counts of Cs – related radiation and the expositional dose rate of this radiation,
d – calibration coefficient defining the relationship between the dose rate of ^{137}Cs radiation and concentration of this element in soil. The value of this coefficient depends on the depth distribution of the radionuclide concentration in the soil. An average value characteristic for the given type of soil is assumed for the interpretation.
NT, NNAT – the measured (NT) frequency of counts in the TC channel and calculated (NNAT) from concentrations of the natural radionuclides.

Radon Concentration Measurements

Radon concentrations in soil air have been measured by the emanometer constructed by "Ing. Jiri Plch SMM" Luk-3R (Czechia). Signal detection was in the Lucas scintillation chambers.

The sample of soil air from the depth of 80 cm is placed in a 20 ml "injector". The hole is made by a small-diameter driven probe o cut off the inflow of atmospheric air. Subsequently, the air from the "injector" is introduced to the measuring chamber. The measuring programme RADON recommended by the producer was used. Its total counting time is 10 min. The outcome of the measurement if the read-out of thorium and radon concentration in soil air expressed in Bq/m^3 and the radon determination error in %.

Radon ^{222}Rn concentrations in water have been determined by the same equipment and a 510 ml flask. In this case the measuring procedure was as follows:

- placing a 300 ml water sample in the flask,
- after 15 min. temperature measurement,
- shaking the flask with water for 1 min.,
- after 1 min. collecting the air sample and introducing it to the measuring chamber,
- measurement with 200 sec. counting time,
- conversion of the amount of counts into Bq/l.

Field Work

Gamma-spectrometric measurements were completed (June–July 1994) along N–S profiles following the meridians at 7.5' intervals. The distance between measuring points was 1 km. The results were recorded twice: in the spectrometer memory and in the field book. Additionally, data on the type of vegetation, granulation of soil and its colour were entered.

Measurements were completed by a portable scintillation gamma-spectroscope, model GS-256 produced by "Geofizyka" Brno. This is a modern spectrometer designed for radioactive measurements for geological purposes. It has a fully automatic spectrum stabilization and an internal memory permitting to record 380 measurements. The detector is a sodium iodide crystal, 3"×3" in size, activated by thallium. The ^{137}Cs standard serving for spectrum stabilization has been replaced by a barium standard (^{133}Ba, SZBa-4 code) with 47.0 kBq activity of the basic radionuclide. This standard has been placed on the casing of the measuring probe with the distance from the crystal selected in such a way that, at a sufficiently strong signal permitting the stabilization of the measuring spectrum, the effect of the standard on the TC channel could be avoided.

The counting time adopted was 2 min. The detector was placed at 1.5 m above the ground level to prevent the effect of small topograhic differences on the geometry of the measurement. Measuring sites have been selected in such a way that a 20 m zone of uncultivated ground (forests, meadows, fallow) surrounds the site.

The total of 650 measurements have been completed out of which 160 in the area examined but under a different project for radiometric mapping of Poland (1992). The remaining points used for constructing the map surround the Polish-Lithuanian project area from the Polish side. The total of 1167 points have been used.

Radon concentrations measurements have been completed in the Lithuanian territory (83 determinations on 55 measuring sites).

RADIOECOLOGICAL MAPS

Map of Gamma Radiation Dose

The map presenting the gamma radiation dose (Plate 52) is a composite picture of gamma radiation derived from natural radionuclides of uranium ^{238}U, thorium ^{232}Th and potassium ^{40}K and for cesium isotopes $^{137+134}Cs$ artificially introduced and contaminating the environment.

The average rate of the gamma radiation dose in the project area is 44.2 nGy/h but it is regionally fairly differentiated. For the entire Polish territory it is 34.2 nGy/h (Strzelecki et al. 1993).

In the area examined the highest values exceeding 70 nGy/h, with maximum values more than 96 nGy/h, occur north-east of the village of Simnas and are related to limnoglacial sediments of the Vistula (Nemunas) Glaciation developed as sand, mud and clay. West of this zone extends an area with nGy/h values ranging from 50 to 70 built of limnoglacial formations and Holocene peats. Slightly lower values (40–60 nGy/h) have been noted in the western part of the area up to the Augustów–Sejny–Seirijai line. This area is built of Leszno–Pomorze (Grūda, Baltija) tills. Similar gamma radiation values have been reported from the vicinity of Lipsk from the Warta (Medininkai) Glacial tills.

The lowest known gamma radiation values are related to sands of the outwash plains occurring from Augustów to Veisiejai and Druskininkai as well as to eolian sands south of the outwash plains. Within these formation gamma radiation ranges from 20 to 30 nGy/h.

Map of Uranium Concentration

In the area examined the uranium content (Plate 53) varies from 0 to 4.5 g/t, the average content being 1.4 g/t. This average value is identical to that for the entire Polish territory. The highest uranium contents have been found north-east of Simnas and are connected with limnoglacial sediments of the Leszno–Pomorze (Grūda, Baltija) Stadial. A belt of elevated uranium concentrations runs further west but its values are lower (1.5–3 g/t). Similar uranium contents occur along the state border between Wiżajny and Sejny, along the border between Lithuania and the Kalinigrad District and in a small area between Suwałki and Augustów. They are connected with the Leszno–Pomorze (Grūda, Baltija) Stadial tills predominating in this part of the project area.Very low uranium contents, rarely exceeding 1 g/t have been reported from outwash plains and eolian sands between Augustów and Veisiejai and also south of Suwałki and Sejny. Uranium concentrations ranging from 1 to 2 g/t occur on the mosaique-like surface (fluvioglacial sands, tills and limnoglacial sediments), among others between Lazdijai and Kalvarija as well as north of Wiżajny.

Map of Thorium Content

In the area discussed thorium concentrations (Plate 54) range from 0 to 10.3 g/t, averaging 4.3 g/t. This value is evidently higher than the average for the entire Polish territory (3.29 g/t). Two highest values exceeding 7 g/t have been found north-east of Simnas and a belt of concentrations above 5 g/t extends over the whole area from Simnas and Balbieriškis in the east through Kalvarija and Marijampolė up to Wiżajny. This area is made up of limnic sediments in the east and of the Leszno–Pomorze (Grūda, Baltija) Stadial tills in the west. Similar thorium concentrations occur in the Polish territory west of the Augustów–Suwałki–Sejny line and are connected with tills and boulder fields fairly abundant in this area. Thorium contents exceeding 4 g/t occur also south and east of Lipsk and are related to the Warta (Medininkai) Glaciation.

A belt of low thorium contents (less than 4 g/t) extending from Augustów and Lipsk up to Veisiejai and Seirijai corresponds to a sandy zone (fluvial and eolian sands). Similar thorium concentrations are known from the area between Kalvarija and Lazdijai built of fluvioglacial sediments of the Leszno–Pomorze (Grūda, Baltija) Stadial and of Holocene lacustrine deposits.

Map of Potassium Content

In the area examined (Plate 55) the average potassium content is 1.2%, the extreme values being 0.1 and 2.5%. The average for the entire Polish territory is much lower (0.74%).

The highest potassium contents exceeding 1.8% occur north--east of Simnas. Slightly lower ones are known from the Polish-Lithuanian border north of Suwałki. Relatively high potassium contents exceeding 0.9% occur throughout the area, west and north of the Augustów–Veisiejai line. This area is built of tills and limnoglacial deposits of the Leszno–Pomorze (Grūda, Baltija) Stadial. Similar potassium values are distincive for the Warta (Medininkai) Glaciation tills in the vicinity of Lipsk.

The lowermost potassium contents (0.3–0.9 g/t) have been found south-east of the Augustów–Veisiejai line and are related to fluvioglacial and eolian sands. Relatively low values occur also in the area from Kalvarija to Lazdijai.

Map of Cesium Concentration

The Polish-Lithuanian cross-border zone was very seriously threatened by the Chernobyl radioisotope emission. However, favourable atmospheric conditions prevented the deposition of particles migrating in the atmosphere. Therefore, the area examined should be regarded as very clean. The cesium radioisotope concentration varies from 0 to 11.6 kBq/m^2, the average concentration being 3.8 kBq/m^2 and the standard deviation 1.6 kBq/m^2. The average concentration for the whole Polish territory is even higher and reaches 4.67 kBq/m^2 with maximum concentrations exceeding 100 kBq/m^2.

In the area examined (Plate 56) the highest cesium radioisotope concentrations (4–8 kBq/m^2) are noted in the vicinity of Augustów and concentrations exceeding 8 kBq/m^2 have a very limited extent. Values higher than 4 kBq/m^2 are known from small areas close to Sejny, Simnas and west of Suwałki. Over the remaining area 2–4 kBq/m^2 concentrations prevail. The results obtained revealed that nowadays the area examined is not threatened by the presence of artificial radioisotopes.

STUDIES OF RADON CONCENTRATION

Radon concentrations in soil air have been measured on 55 sites (83 measurements) located basically in two areas: west of the Kalvarija–Vilkaviškis line and between Veisiejai and Prienai. But the small number of measurements available permits only a general assessment of the results obtained.

Radon concentrations varying from traces to 55 kBq/m^3 have been recognized. As the volume of emanation depends strictly on the lithology of the substratum and on porosity and permeability of the medium, these values are very differentiated. The highest radon concentrations have been found in the western part of the region, north-east of Vištytis in the area of low uranium contents and a low radiation dose and built of sandy porous deposits underlain by shallow-occurring tills. The latter are the source of radon acummulated in the sandy deposits.

In the east, between Druskininkai and Prienai radon concentrations range from several to a dozen or so kBq/m^3. Noteworthy is that in the area NE of Simnas distinctive by the highest uranium contents and the highest gamma radiation doses, radon concentrations are very low and do not exceed 1 kBq/m^3. The surface in this area is built of clay sediments characterized by low radon emanations.

A considerable differentiation of radon concentrations and the fairly high values in sandy deposits indicate that further studies are needed to provide a statistically significant amount of measurements on each lithological type known from the area examined.

CONCLUSIONS

The radioecological studies revealed that the highest concentration of radioisotopes examined and, consequently, the highest total gamma radiation doses occur in the north-eastern part of the project area and are related to lacustrine clayey-silty deposits of the Leszno–Pomorze (Grūda, Baltija) Stadial. Slightly lower values are characteristic of the entire north-west part of the area examined. Very low concentations of radioactive elements and low total radiation doses are typical for outwash plains and eolian sands occurring south-east of the Augustów–Veisiejai line.

The Chernobyl disaster did not contaminate the area examined with artificial cesium radioisotopes. The contents here identified are very low and create no radiological hazard.

Radon concentration found in soil air imply that in the project area sites exist threatened by elevated radon emanation and its concentration in dwelings. However, further studies, supplemented by grain size distribution analysis for soils, are necessary to irrefutably confirm this opinion.

REFERENCES

Butkus D., Morkūnas G., Krenevičius R., Kandrotas G., Pocius Z., 1994 – Investigation of ^{137}Cs distribution in the territory of Lithuania. *Atmospheric Physics* 16.

Mažeika J., Jasiulionis R., Savickaitė I., Gudelis A., 1996 – Radiogeochemical investigations of soil and groundwater in the Eastern Region of Lithuania. *Geologija* 19.

Strzelecki R., Wołkowicz S., Szewczyk J., Lewandowski P., 1993 – Radioecological maps of Poland 1:750 000. Part 1. Państw. Inst. Geol., Warszawa.

Strzelecki R., Wołkowicz S., Szewczyk J., Lewandowski P., 1994a – Radioecological maps of Poland 1:750 000. Part 2. Państw. Inst. Geol., Warszawa.

Strzelecki R., Wołkowicz S., Lewandowski P., 1994b – Koncentracje cezu w Polsce. *Przegl. Geol.*, nr 1.

Groundwaters as Component of the Geopotential

OBJECTIVE

Two main goals were defined for the hydrogeological studies:
- analysis of hydrogeological information directed at recognition of the geopotential and stability in the project area,
- preparation and conducting groundwater monitoring in the Polish-Lithuanian cross-border zone.

In the initial stage groundwater monitoring was expected to permit a diagnosis of the present groundwater contamination and a reference level for future changes of the groundwater quality. The attached maps contain, in a synthetic form, the latest and most important hydrogeological information.

GROUNDWATER POTENTIAL

Fresh groundwaters occur in Quaternary formations but also in the Palaeogene and Upper Cretaceous treated jointly as pre-Quaternary systems.

Excluding some fragments of the area excamined connected with the Nemunas river valley, the Quaternary aquifers are, as a rule, productive. Several water-bearing horizons may be present in the Quaternary sequence but show no preferences as to any portion of the sequence. Not uncommon is also a complete lack of aquifers down the bottom of the Quaternary both in the Polish and Lithuanian territory. In this area the Quaternary has an extremely diversified lithology reflected in an extremely diversified permeability of the lithological units. The percolation values for poorly permeable sediments range from 0.001–0.0001 m/d. The aquifers are characterized by 0.5–150 m/d permeability coefficients and are very close to the values for permeable surficial formations.

This "scattered" occurrence of aquifers creates substantial difficulties in their spatial correlation and is responsible for the lack of an aquifer of regional extent. The hydrogeological conditions of the Quaternary water-bearing system in the Polish part of the project area permitted to define its hydrostructure as "compartment-like" (Mitręga, Pachla 1984; Mitręga 1988; Mitręga, Pachla 1990). As a consequence, direct hydraulic communication favouring renewability and flow between aquifers become more significant than percolation and the surface drainage network becomes more incompetent versus aquifers.

The type of hydrogeodynamic conditions in the project area controls the possibilities, intensity and depth of percolation from the ground surface. To a considerable extent the groundwater recharge and circulation conditions are fairly uniform. The majority of Quaternary aquifers particularly those occuring on a depth less than 120 m are distinctive by conditions favouring fluxes from the surface.

The Quaternary substratum is built of Cretaceous and Tertiary rocks. The presence of groundwater and hydrogeological conditions in sub-Quaternary formations are poorly known. The Tertiary and Cretaceous rocks occur at depth of 200–300 m in the Polish part and at a smaller depth, sometimes from several tens to 100 m, in the Lithuanian part. They are represented by gaizes, marls and sandstones and in Lithuania also by chalk. In general, they are distinctive by low permeability (about 0.02–0.002 m/d) and higher permeability is, to a certain extent, due to a better hydraulic contact with waters present in the Quaternary structures.

Favourable hydraulic properties have been found only in Cretaceous aquifers occuring in the southern part of the area, i.e. below the Bargłów–Augustów–Lithuanian/Belarussian border line, in Belarus and in the northern part of the Lithuanian territory (Plate 57). The utilization of waters in this area is practically limited to only several sites. In the Polish territory they are captured individually by single supply wells in Bargłów and Augustów while in Lithuania they are extracted jointly with the overlying horizon e.g. Palaeogene or Quaternary.

The Palaeogene aquifer, connected with sandstones and locally with gaizes, overlies the Cretaceous aquifer within the groundwater system. It is common in Lithuania, but its productivity is only local. In the Polish territory this aquifer is absent.

A practical approach has been adapted to the understanding of the geopotential with regard to groundwaters. It has been accepted that the geopotential is represented only by aquifers with wells yields not lower than 10 m^3/h. This criterion served to define the extent of productive water-bearing horizons usually including groundwaters in the Quaternary but also in elder systems such as Palaeogene and Upper Cretaceous. The classification of productivity is based on the potential yield of the wells according to the following scheme: less than 30 m^3/h, from 30 to 120 m^3/h and more than 120 m^3/h (low, medium and high, respectively).

Quaternary groundwaters are commonly utilized by single dug wells over the whole area. The existing data do not permit a reliable evaluation of total groundwater extraction, although the total groundwater consumption may be significant. The development of groundwater in Lithuania (Juodkazis, Klimas 1993; Domaševičius et al. 1994) and in Poland is comparable.

The picture of geopotential with regard to fresh groundwaters is complemented by regional hydroisohypses (see Plate 57).

GROUNDWATER MONITORING

In the Polish-Lithuanian cross-border area the groundwater monitoring network was set up in several stages, different in both countries. In the Lithuanian part of the area discussed the monitoring network is composed of three base stations in the form of multi-piezometer points monitoring the main aquifers and 13 drilled wells. In the Polish territory the cross-border monitoring system has been based on existing drilled wells, both single and occurring in well fields: 26 hydrogeological wells and 4 springs selected according to the requirements of the National Environmental Protection Inspectorate (Plate 58).

In the monitoring schedule sampling was planned twice a year: April/May and October/November. Such a sampling procedure results from studies of the hydraulic cycle, recharge and renewability of groundwaters in the Suwałki Landscape Park. The scope of determinations depended on analytical possibilities and included: specific electric conductivity, pH, oxygen demand, alkalinity and hardness, contents of silica, sodium, potassium, calcium, magnesium, total and bivalent iron, manganese, strontium, aluminum, copper, lead, nickel, zinc, hydrocarbonates, chlorides, sulphates, nitrogen compounds (nitrates, nitrites, ammonia), chromium, vanadium and cadmium.

As a result of the three measurement series (May 1995, November 1994 and 1995) over 120 water samples were collected: 54 from Lithuania, 71 from Poland. The Polish samples consisted of 55 groundwaters, 12 samples from springs, 4 samples coupled with flow velocity measurements in rivers. Additionally Polish archival data derived from the HYDRO data bank, National Fresh Water Monitoring Network of the National Environmental Protection Inspectorate and data on renewability of Quaternary groundwaters in the Suwałki Landscape Park were taken into consideration. The Lithuanian partner supplemented the results with archival data from the European Groundwater Monitoring. Ultimately a set of more than 700 analytical data was obtained corresponding to the time span between the mid-fifties till the present day.

Both in the Lithuanian and Polish territory elevated values of some elements, as companed with the hydrochemical background, have been noted on certain sampling sites. These elements are: amonium ion, redox, sulphates and magnesum, chlorides, sodium and potassium (Groundwater Monitoring in Lithuania 1994, 1995). Elevated amonium ion concentrations are known to occur over areas with intense agricultural activity, while changes of the redox potential are connected with urban areas. Both factors reflect the human impact on the natural environment (Juodkazis, Klimas 1993).

Other elevated values are due to natural geological conditions – sulphates and magnesium on morainic uplands whereas chlorides, potassium and sodium in areas controled by faults in the Quaternary substratum (Juodkazis, Klimas 1993). In the Polish territory the reason for classifying some waters as low quality is that single elements exceed the formally required standard concentrations. This applies to heavy metals naturally occurring in groundwaters (Plate 58).

According to the methods recommended by the National Environmental Protection Inspectorate for defining the quality class of groundwaters the majority (more than 70%) belongs to the high-quality class, more than 20% to the highest class.

Thus, results from water samples collected during monitoring of the project area provide a favourable picture of groundwater quality.

REFERENCES

Juodkazis V., Klimas A., 1993 – Groundwater extraction and its quality changes in Lithuania. Groundwater quality and water supply: Reports of the International Workshop, Lithuania, Vilnius–Druskininkai, 13–16 September 1993. Vilnius.

Lietuvos požeminės hidrosferos monitoringas, 1993 – Groun-water Monitoring in Lithuania 1993: Bulletin; Comp. **J. Giedraitienė**; Ed in chief. **A. Klimas**; Vilnius State Hydrogeological Company "ARTVA". Vilnius, 1994 (Sum. Engl.).

Lietuvos požeminės hidrosferos monitoringas, 1994 – Groundwater Monitoring in Lithuania 1994: Bulletin; **A. Domaševičius, K. Kadūnas, B. Paukštys, V. Mičiudienė**; Geological Survey of Lithuania. Vilnius: LGT, 1995 (Sum. Engl.).

Lietuvos požeminės hidrosferos monitoringas, 1995 – Groundwater Monitoring in Lithuania 1995: Bulletin; **A. Domaševičius, J. Giedraitienė, J. Arustienė**; Geological Survey of Lithuania. Vilnius: LGT, 1996 (Sum. Engl.).

Mitręga J., 1988 – Zagadnienia hydrogeologiczne okolic Jeleniewa. CPBP 04.10 Ochrona i kształtowanie środowiska przyrodniczego. Ochrona środowiska przyrodniczego przed wpływami przemysłu wydobywczego na przykładzie Suwalszczyzny. Mat. Konf. Naukowej Wigry 88. Szczecin–Suwałki.

Mitręga J., Pachla J.P., 1984 – Hydrochemical budgeting in studies of groundwater renewability in areas of glacial formation systems. Proc. of Intern. Symp. "Hydrochemical balances of freshwater systems", IAHS Publ. No. 150, Uppsala.

Mitręga J., Pachla J.P., 1990 – Odnawialność czwartorzędowych wód podziemnych i warunki geologiczno-inżynierskie masywu suwalskiego w rejonie złóż rud żelaza, cz. 1, CPBP nr 18, cel 26, punkt kontrolny nr 2; Arch. ZHiGI Państw. Inst. Geol., Warszawa.

Ecogeology

MAP OF THE GEOPOTENTIAL

The map of the geopotential (Plate 57), i.e. of the natural potential, presents the whole of resources (objects, conditions, phenomena and processes) that can be involved in human activity, depending on economic and/or technical factors, without degrading the natural environment. Economic-technical possibilities change with time and so does this part of the natural environment that can be utilized by man.

The part of resources which can be used for economic-technical and cultural development of the society is called positive geopotential. The remaining resources which impede and negatively affect man's living conditions are defined as a negative geopotential. It can be either natural (e.g. peat-bog fires, karstification, erosion, landslides, earth-quakes) or caused by human activity (e.g. groundwater pollution, exhaustion of resources, induced earth-quakes).

This short description indicates that two questions are of essential significance for a coordinated utlization of natural resources. The first is the proper and correct assessment of the natural resources with indications of the time and feasibility of their utilization permiting to avoid chaotic exploitation. The second is the necessity to define the kind of land use.

The map of the geopotential contains information on mineral resources, groundwater (see page 20), and areas protected by law.

Mineral Resources

A significant amount of mineral resources connected with Quaternary sediments occurs in the Polish and Lithuanian area. Their origin and mode of occurrence favours easy exploitation. However, their extraction leads to significant devastation of the natural environment and destruction of the landscape due to open--pit mining. The degree of knowledge of the mineral reserves is variable. But deposits with well defined reserves are included in the national balance of mineral resources of both countries.

Poland

Sand and gravel. 86 deposits of natural broken stone are known from the area examined. However, only 17 of them have reserves exceeding 1000 thou t. Out of them only 5 deposits (Łęgowo, Potasznia I, Sobolewo–Krzywe, Sobolewo A and Suwałki–Krzywólka) are included in the "Mineral Resources of Poland" as those for which geological reports exist and production is currently updated. For several deposits with measured reserves (Sedranki II, Starosty, Olecko Małe, Potasznia, Potasznia II, Potasznia III) production data are missing. Unusual are deposits, included in the "Mineral Resources of Poland", for which no data on measured reserves exist but production is quite considerable (e.g. Zaboryszki).

Clay. In the area discussed clay deposits play a minor part. They are decisively less numerous (8) with reserves far below these of the natural broken stone. With the exception of the Gordejki deposit near Olecko (3831 thou t) the reserves of none of the remaining deposits reach more than 400 thou t. This clay is used for building ceramics.

Other mineral resources. A commodity of national importance is iron ore (Krzemianka, Udryń deposits) very well recognized in C2 category. However, the development of these deposits is not envisaged in the nearest future. Lacustrine chalk and peat known from this area are of no economic significance. Minor amounts of medicinal mud occur in the Kolnica deposit near Augustów.

Lithuania

Sand and gravel. 14 sand and 46 gravel deposits occur in the area discussed, out of which 32 are included in the Lithuanian balance of mineral resources and 24 are currently under exploitation.

These gravel deposits controled by geological structure are unevenly distributed. They are less abundant in the northern part where limnoglacial and glacial sediments are predominant. Over the remaining area they are related to fluvioglacial sediments. The biggest ones are Juodeliai, Tabarai, Trakėnai and Šlavantai. Moreover, prospects exist to extract natural broken stone in the southern and south-western part of the area.

Sand is used for different purposes: for road building (Juodeliai, Pavištidčiai, Montrimai), in brick industry (Dirimiškes), for concrete production (Mangarotas, Meškapievė, Škenovys) and in housing industry (Egliabaliai).

Clay. 11 clay deposits occur in the area examined out of which three are included in the national balance of mineral resources and two are under exploitation. Clay deposit known from the north and east are connected with limnoglacial sediments. Due to a high carbonate content their quality is usually poor. The biggest deposits are: Dženčialauka, Adrija, Orija. Clay is used mainly for brick production.

Peat. Peat-bogs are abundant in the area examined. However, out of 576 deposits included in the national balance of mineral resources, only 2 (Palios and Susia) are under exploitation. Peat is used chiefly as fertilizer. The deposits are usually small and 66% of them have reserves not exceeding 50 thou t. Only in 7.3% of the deposits the reserves are larger than 200 thou t. The biggest deposits – Žuvintas and Amalva – lie, like many smaller ones, in areas protected by law. Considering the significance of swamps for the natural environment, these deposits are unlikely to be exploited.

Lacustrine chalk. 45 deposits are known from this area but only 14 have reserves larger than 100 thou m^3. The largest one (Padovinys) contains 1363 thou m^3 of the commodity. An essential factor impeding extraction is the relationship to surface waters (lakes, rivers).

Areas Protected by Law

A considerable number of areas protected by law distinctive by their extraordinary landscape and unique natural values are:

National Parks (3)
- Wigry National Park,
- Biebrza National Park,
- Dzūkijos National Park.

Landscape Parks (5)
- Suwałki Landscape Park,
- Vištyčio Landscape Park,
- Nemuno kilpu Landscape Park,
- Vejsieju Landscape Park,
- Metelio Landscape Park.

Natural Reserves (30, out of which 29 are in the Polish territory).

All the above areas protected by law as well as all the natural monument sites are entered on the map of the geopotential (Plate 57).

MAP OF ENVIRONMENTAL HAZARDS

This map (Plate 58) contains information on the potential natural and human factors affecting the natural environment. The principal factors entered on the map are geodynamic processes, ground- and surface water pollution and sites of particular hazards.

The assessment on geoecological hazards is based on existing and potential geodynamic phenomena such as, deflation, fluvial erosion, surface mass movements and others.The most intensive negative eolian processes are noted over limnoglacial and eolian areas built of fine-grained sand or, locally where the groundwater level is below 5–10 m, of fluvioglacial fine-grained sand. The chief factor favourable to deflation is the distruction of the humus layer due to impoverishment of soil. The potential threat from deflation depends on hydroclimatic factors (total rain fall, wind velocity and frequency) and the quality od soil resulting from the origin and lithology of surface sediments. Consequently, areas threatened by erosion are distinguished on the map with additional information on such factors as hydroclimate, land use and the like. Basically, zones threatened by wind erosion occur throughout the project area, although the biggest ones are located in the southern part. Forests covering the entire area prevent deflation. However, in case of destruction of forest vegetation and/or inadequate land cultivation deflation processes may become active.

The most threatened by denudation are areas with differentiated topography, particularly steep slopes, erosional edges and the like. In areas with little differentiated topography the main factor is slope inclination and, in the case of higher elevations, the length of the slope.

Ravine and lateral erosion can be observed mostly in deep river and lake valleys. Most likely, this erosion is now of no major significance. However, by thoughtless land use such as devastation of the natural vegetation cover these processes can be easily revived. Areas threatened by erosion should be excluded from agricultural use and assigned to recreaction, afforestration and other purposes.

From the hydrogeological standpoint this area, as a regional grounwater recharge zone, is particularly sensitive to pollution (see page 20). Therefore, the map of environmental hazards shows the unconfined aquifer zone, the extent of natural pollution and groundwater monitoring stations.

Industrial hazards (with few exceptions) are practically negligible. Due to the particular sensitivity of the area, on the map entered are potential pollution sources such as: big industrial objects, processing plants and sewage release sites, waste (garbage) dumps as well as the up to 15 km wide buffer zone along roads of envisaged heavier traffic. The assumed extent of the buffer zone follows the regulations for evaluating the effect of highways on the natural environment. For some towns the dust and gas emission is given in tons of SO_2/year.

MAP OF ENVISAGED ENVIRONMENTAL CONFLICTS

Information assembled in layers and presented on the maps of geopotential and environmental hazards also served to construct this map (Plate 59). The following data sets have been used:
- prospect areas for mineral resources,
- areas protected by law, including those to be protected in the future,
- planed highways and heavy traffic roads.

The map of envisaged environmental conflicts has been compiled using GIS, that is information layers stored in a data base set up for the purpose of this project. Conflict zones have been identified by overlaying information layers for prospect areas of mineral resources and areas protected by law to avoid negative human impact. Particular attention has been given to the possible negative impact from the Via Baltica highway now under construction and the road between Grodno and Kaliningrad. In areas of unconfined aquifers buffer zones are particularly threatened by possible road accidents of vehicles carrying dangerous loads.

As heavy traffic roads are known to have an unfavourable effect on the natural environment, areas where the area of the future road overlaps present or future protected areas, should be regarded as those of envisaged environmental conflicts.

LAND USE

To define the land use and trace its changes in the Polish-Lithuanian cross-border area, two satellite imageries have been aquired: Landsat MSS 202/22 of 1979 and of 1992, later processed by the PCI (EASI/PACE) programme on the HP 715 work station. As the area examined is located on a fragment of satellite imagery scene, a section with the following geographic coordinates of its corners has been used for processing:

1 – 22°14'E, 53°40'N
2 – 22°14'E, 54°40'N
3 – 24°00'E, 54°40'N
4 – 24°00'E, 53°40'N.

Land use has been analyzed by non-controlled and controlled classification method. According to non-controlled classification 5 land use classes have been distinguished:
- coniferous forests,
- mixed forests,
- cultivated lands,
- wetlands and pastures,
- lakes.

The two analyzed satellite imageries have been taken in the month of September, that of 1979 in the first and that of 1992 in the second decade (Plate 60) and this timeshift may influence the correctness of conclusions (e.g. potatoe harvest at the end of September). Because of the considerable differences between the Polish and the Lithuanian areas, statistical calculations have been completed separately for each territory. In addition, to follow the changes in the protected areas, land use in the Wigry National Park (Tab. 5) has been analyzed.

The analysis of land use revealed, that 52%, 45% and 60% of the Polish, Lithuanian and the Wigry National Park area respectively have remained unchanged.Thus, considerably more changes are noted in the Lithuanian territory. Noteworthy is, that cultivated lands change into wetlands, most probably due to climatic factors. In September 1992 rain fall was more than twice the average value for September 1951–1990. Another factor re-

Table 5

Changes in land use according to interpreted satellite imageries (in %)

Class	Polish part		Lithuanian part		Wigry National Park	
	1979	1992	1979	1992	1979	1992
Coniferous forests	15.9	17.9	12.6	12.6	43.2	46.6
Mixed forests	17.0	15.1	9.6	12.8	23.3	16.7
Cultivated lands	28.8	31.3	48.5	28.5	9.2	9.3
Wetlands and pastures	26.3	26.4	14.1	35.9	2.4	4.7
Lakes	3.2	3.2	2.7	2.7	16.9	16.9
Nonclassified	8.8	6.1	12.5	7.5	5.0	5.8
Total	100.0	100.0	100.0	100.0	100.0	100.0

sponsible for the shrinking of cultivated land surface is the economic breakdown of former state and collective farms. Nowadays, a major part of this land forms the so called black fallow or is ovegrown with grass. Another phenomenon worth of note in the Lithuanian territory is the drying of peat-bogs and their successive replacement by pine forests.

In the Polish territory the surface of deciduous forest stands is shrinking, while coniferous forests are expanding. This is particularly true in the southern fragment of the Augustów Forest. In the Romnice Forest, distinctive by its rich habitats, spruce is being gradually replaced by pine.

CONCLUSIONS

Due to its geological structure the project area is particularly rich in mineral resources. However, its unique natural value and still unpolluted environment require that due consideration be given before final decisions are made with regard to its further development and possible extraction of mineral resources. Only deposits located outside protected areas could be taken into account for future exploitation, but then all environmental requirements should be met. The occurrence of unconfined acquifers, very sensitive to pollution, over most of the area entails a rigorous limitation of economic activity to avoid even a potential risk.

Possible hazards related to geodynamic processes are related largely to deflation and fluvial erosion. These processes are the most significant in limnoglacial and eolian areas or, in some instances, in fine-grained fluvioglacial sands with groundwater occurring below 5–10 m. Fluvial erosion is the most significant in areas with marked topographic differences and therefore such areas should be carefully monitored to prevent geodynamic processes.

From the ecological point of view this area is to be recommended for tourism, recreation and eco-farming. As for industry, transportation and cross-border infrastructure, all the ecological restrictions must be taken into account.

Summation

MAJOR ACHIEVEMENTS

Geology. New data have been obtained on the geological contents, spatial arrangement and stratigraphy of the area. Five fully cored wells have been drilled piercing the Quaternary cover (150–250 m thick) and providing samples for laboratory tests. A comprehensive analysis of all the acquired data permitted to construct all the geological maps and three geological cross-sections described previously. The geological data entered on the maps and contained in the explanatory text create a basis for further evaluation of potential pollution of groundwaters, mining impacts, exo- and endodynamic processes, geochemical conditions and the like.

Geochemistry. 385 samples have been collected for geochemical examinations from the surficial soil layer, 13 profiles (to the maximum depth of 1.25 m) along with 394 samples of water sediments (rivers, lakes). In the Laboratory of the Geological Survey of Lithuania, these samples have been examined for the total content of:

– Ag, Al, B, Ba, Co, Cr, Cu, Ga, La, Li, Mn, Mo, Nb, Ni, P, Pb, Sn, Ti, V, Y, Yb, Zr, Zn (Dc Arc emission spectroscope),
– As, Rb, Sr, Th, U (XRF method).

The same samples have been examined in the laboratory of the Polish Geological Institute by ICP-AES methods for the extractable content of:

– Ba, Ca, Co, Cr, Cu, Fe, Mg, Mn, Ni, P, Pb, S, Sr, Ti, V and Zn.

Comprehensive geochemical results (obtained from different methods) have been assembled in the form of geochemical maps which revealed the project area to be "geochemically clean". Therefore, these geochemical maps are the best advertisement of the Belt of Yotvings – a wonderland for tourism, recreation and the nowadays so fashionable eco-farming.

Radioecology. Radioecological examinations have been conducted on 1167 sites to define ^{137}Cs, ^{40}K, ^{238}U and ^{232}Th concentrations and total gamma radiation. In addition radon ^{222}R concentration in soil has been measured on 55 sites.

The above mentioned data served to compile radiological maps. According to the radiological picture shown on the map, the impact of the Chernobyl nuclear plant failure on the project area is insignificant. Values of other radionuclides do not exceed background values. Some elevated radiation anomalies in the north (Lithuanian territory) are of natural origin and create no hazard.

On several sites radon ^{222}R concentrations seem to exceed the "high risk level" (more than 50 Bq/m^3). But further studies are needed to either confirm or refute this finding.

Hydrogeology. The area examined is particularly sensitive to pollution as it constitutes the regional groundwater recharge zone for southern Lithuanian and northern Poland. The groundwater flow is towards the Nemunas and Biebrza rivers. To define quality and hydrodynamic parameters, a groundwater monitoring system was set up under this project and monitoring methods were coordinated by both partners. Five new monitoring stations were created in the Lithuanian territory. So far no anthropogenic contamination has been found in the main acquifers. However, the hydrogeological and environmental data here collected should serve as a basis for future studies.

Ecogeology. The ecogeological maps contain information essential for reasonable land use, spatial planning and environmental protection.

The map of geopotential contains data on mineral and groundwater resources and areas protected by law. Also changes in land use have been interpreted. The map of environmental hazards illustrates natural threats, threats due to human activity, selected geodynamic effects, surface and groundwater pollution and gives the location of objects hazardous to the environment. The map of envisaged environmental conflicts indicates measures to reduce negative human impact.

A comprehensive analysis of all the data assembled under this project implies that, due to its exceptional natural values, attractive landscape and negligible effects of anthropogenic impact, this area should be used for tourism, recreation and agriculture (with special recommendation of eco-farming). The development of infrastructure and particularly the future highways and expressways should be planned with utmost care and due consideration to the exceptional beauty of the Belt of Yotvings.

SUGGESTIONS FOR USE OF THE COLLECTED DATA

Data obtained under this project should be used for:

– devising spatial management plans,
– reasonable use and protection of groundwaters,
– improvement of agricultural activity (particularly in the Lithuanian territory),
– reasonable management of mineral resources,
– reasonable planning of cross-border infrastructure and communication lines,
– health protection (avoiding radon hazards),
– development of infrastructure for tourism and recreation, promotion of ecological tourism,
– establishing new areas protected by law.

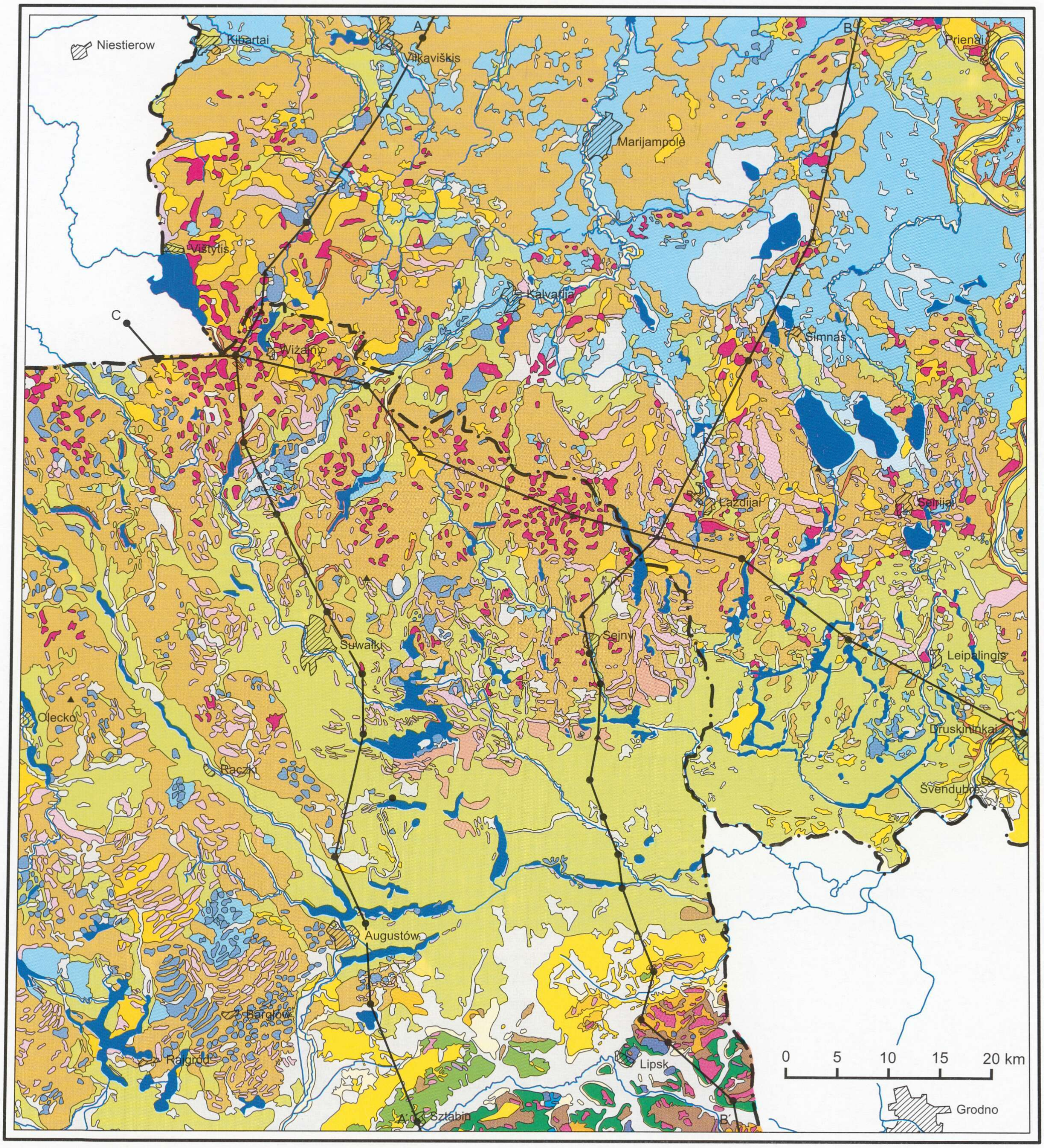
*
* *

The present atlas is a comprehensive presentation of data obtained due to a cooperative effort of the geological surveys of Poland and Lithuania. A cooperation between two surveys on such a large scale is a good example and encouragement to other European organizations to resume similar efforts. The published material permits to integrate data from different geological domains and compare working methods based on the latest technologies available such as satellite imagery, laboratory equipment, GIS and others. This comprehensive presentation of the collected material confirms the low grade of pollution in the Polish-Lithuanian cross-border zone with respect to surface, groundwaters, soil (heavy metals) and radiological contamination. Therefore, regional spatial development plans must be devised with utmost care and thorough consideration to preserve this area ecologically intact for future generations. Bearing in mind the educational value of all the collected material and the need to approach the "simple" inhabitant of the Polish-Lithuanian cross-border zone, a possibly most intelligible way of presentation has been attempted.

Plates 1–5, 57–59

Area of research

QUATERNARY GEOLOGICAL MAP (with the geological cross-sections)



HOLOCENE

- peat and boggy mud
- lacustrine clay, silt and sand, gyttja and sapropel
- alluvial sand and gravel

HOLOCENE - PLEISTOCENE

- deluvial sand and loam
- eolian sand

VISTULA, NEMUNAS GLACIATION

LESZNO-POMORZE, GRŪDA-BALTIJA STADIAL

- alluvial sand and gravel
- kame and kame terrace sand, gravel, silt and clay
- glaciolacustrine sand, silt and clay
- glaciofluvial sand and gravel
- dead ice moraine: sand, gravel and till
- esker and crevice deposits: sand, gravel, boulders and till
- end moraine sand, gravel, boulders and till
- glacigenous sand, gravel and boulders
- water-morainic sand, gravel and till
- till

ŚWIECIE STADIAL

- glaciofluvial sand and gravel
- esker sand, gravel, boulders and till
- end moraine sand, gravel and boulders
- glacigenous sand, gravel, boulders and till
- till

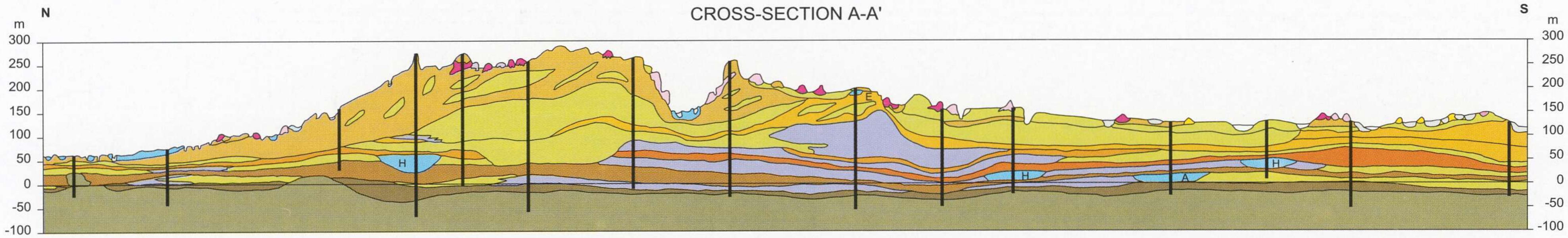
WARTA , MEDININKAI GLACIATION

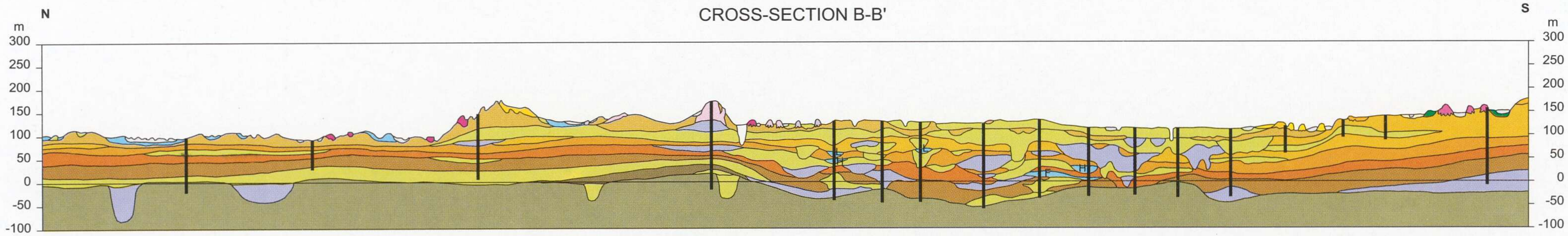
- glaciolacustrine sand, silt and clay
- kame and kame terrace sand, gravel, silt and clay
- glaciofluvial sand and gravel
- esker sand, gravel, boulders and till
- end moraine sand, gravel, boulders and till
- glacigenous sand, gravel and boulders
- till
- megablocks (rafts) of dislocated bedrocks

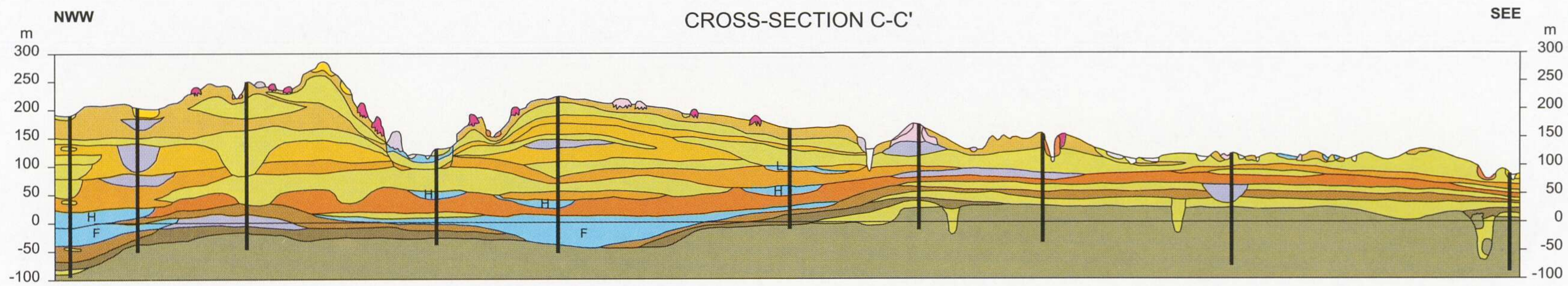
A —— A′ geological cross-section line

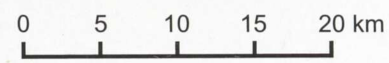
● boreholes

▲ boreholes with lito-petrographical investigations









ON THE CROSS - SECTIONS ONLY

EEMIAN, MERKINĖ INTERGLACIAL

E — lacustrine clay, silt, sand and gyttja

WARTA, MEDININKAI GLACIATION

till

LUBLIN, SNAIGUPĖLĖ INTERGLACIAL

L — lacustrine clay, silt, sand and gyttja

ODRA, ŽEMAITIJA GLACIATION

till

MAZOWSZE, BUTĖNAI INTERGLACIAL

H — lacustrine clay, silt, sand and gyttja

SAN 2, DAINAVA GLACIATION

till

FERDYNANDÓW, TURGELIAI INTERGLACIAL

F — lacustrine clay, silt, sand and gyttja

SAN 1 and NIDA, DZŪKIJA GLACIATION

till

AUGUSTÓW, VINDŽIŪNAI INTERGLACIAL

A — lacustrine clay, silt, sand and gyttja

NAREW, KALVIAI GLACIATION

till

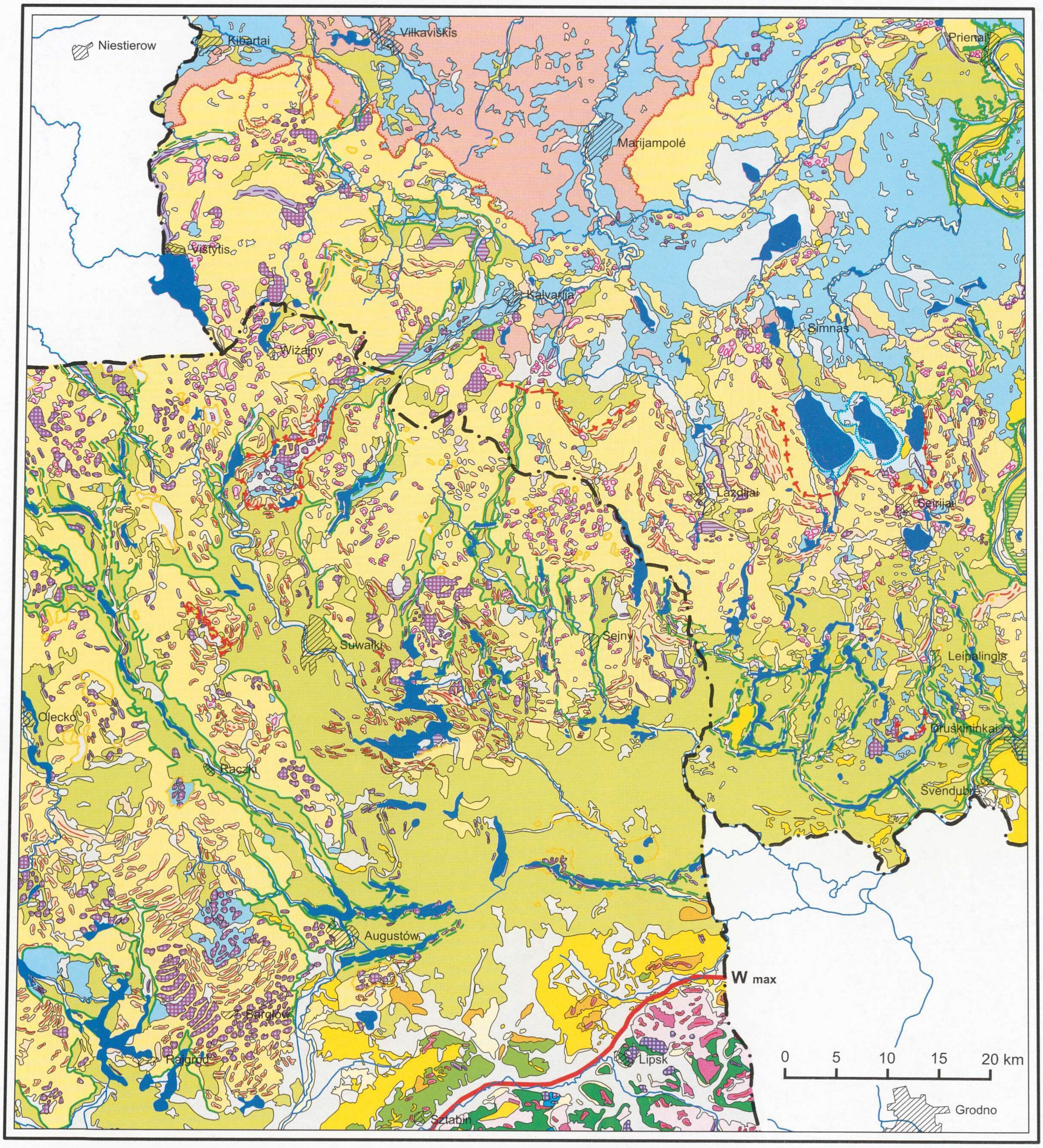
UNSTRATIFICATED DEPOSITS

glaciolacustrine sand, silt and clay

glaciofluvial sand and gravel

pre-Quaternary rocks

GEOMORFOLOGICAL MAP



HOLOCENE AND LATE GLACIAL RELIEF

- peat plains
- lacustrine plains
- lacustrine terraces slopes and steps
- flood plain valleys
- fluvial terraces slopes and steps
- kettle holes
- slopes
- eolian relief

PLEISTOCENE RELIEF

VISTULA, NEMUNAS GLACIATION

LESZNO-POMORZE, GRŪDA-BALTIJA STADIAL

- glaciofluvial valleys
- river valley slopes
- glaciolacustrine plains
- slopes and steps abrasion terraces
- outwash plain
- glaciofluvial terraces
- channels of subglacial streams
- drainage channels of melt water streams
- kame terraces
- kames
- eskers and crevice forms
- dead ice moraines
- end moraine zones
- end moraine ridges
- push moraine ridges
- morainic upland slopes and steps
- glaciodepressions
- hilly morainic relief
- till plain

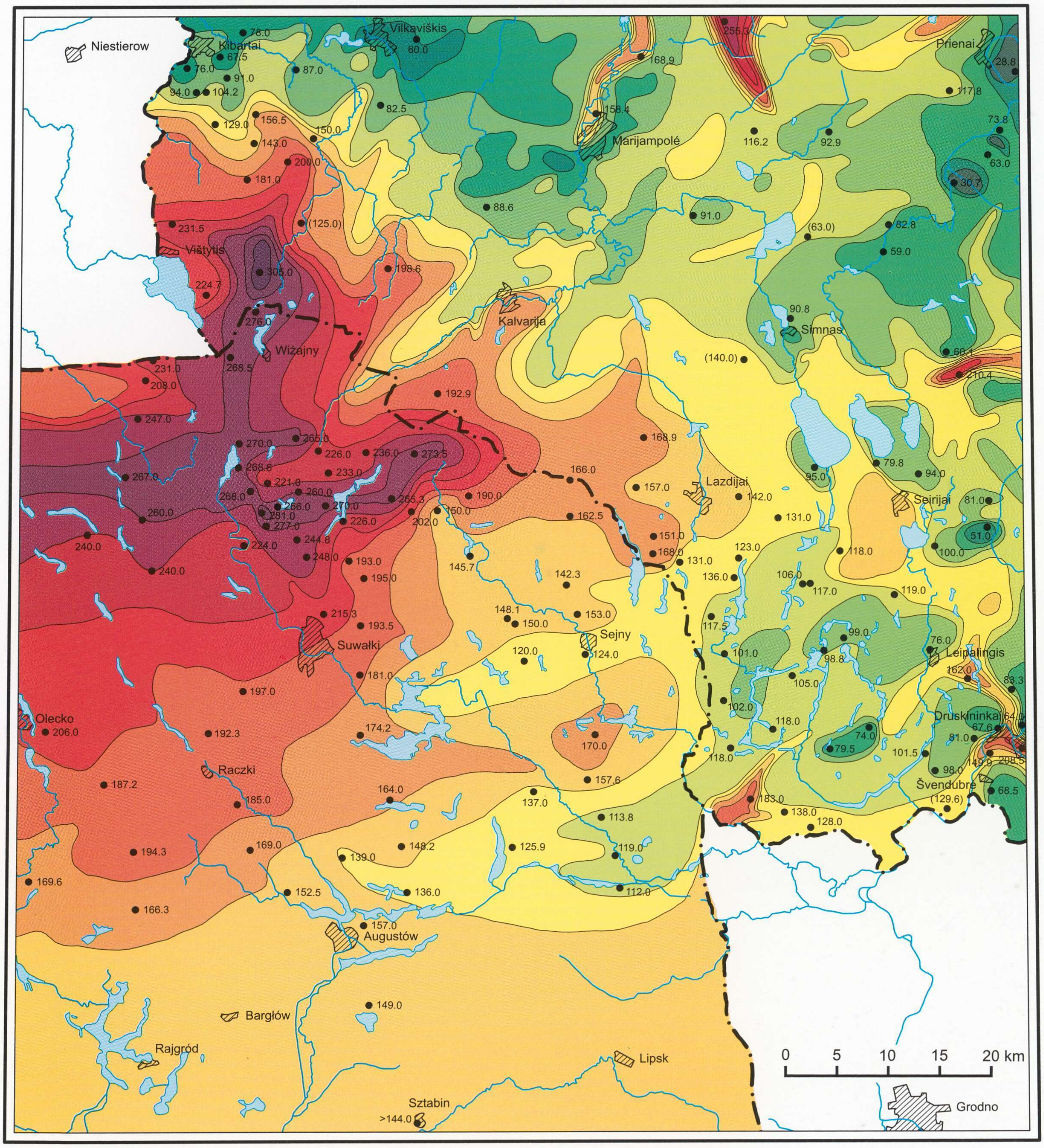
ŚWIECIE STADIAL

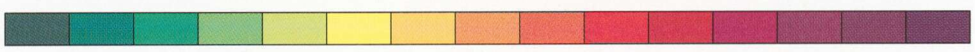
- outwash plain
- eskers and crevice forms
- end moraine ridges
- hilly morainic relief

WARTA, MEDININKAI GLACIATION

- glaciolacustrine plains
- glaciofluvial plains
- kames
- eskers and crevice forms
- end moraine zones
- end moraine ridges
- hilly morainic relief
- megablocks (rafts) of dislocated bedrocks
- Wmax Extent of the last glaciation

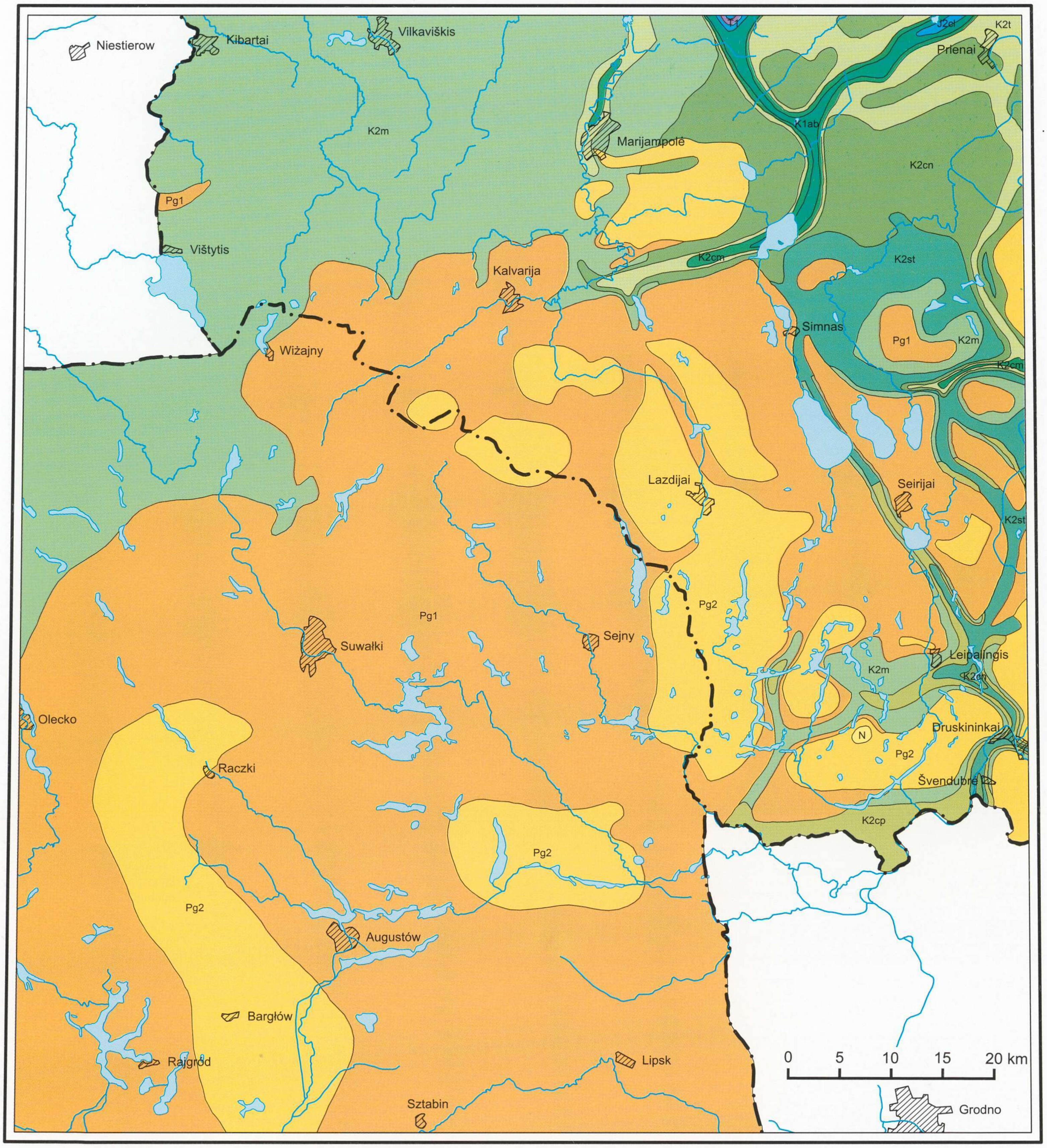
MAP OF THE QUATERNARY THICKNESS





● 226.0 borehole and thickness of Quaternary deposits (the number in brackets indicates the thickness in borehole which not reached the pre-Quaternary rocks)

PRE-QUATERNARY GEOLOGICAL MAP



NEOGENE

N — Sand

PALEOGENE

Pg2 — *Middle-Upper Eocene.* Glauconic sand, silt

Pg1 — *Lower Paleocene.* Glauconic sand, sandstone, silt, marl

CRETACEOUS

UPPER CRETACEOUS

K2m — *Maastrichtian.* Gaize, marl

K2cn — *Conniacian.* Gaize

K2cp — *Campanian.* Gaize

K2t — *Turonian.* Gaize

K2st — *Santonian.* Gaize

K2cm — *Cenomanian.* Marl, gaize, glauconic sandstone, sand, phosphorite

LOWER CRETACEOUS

K1ab — *Albian.* Glauconic sand, silt, rare sandstone, clay

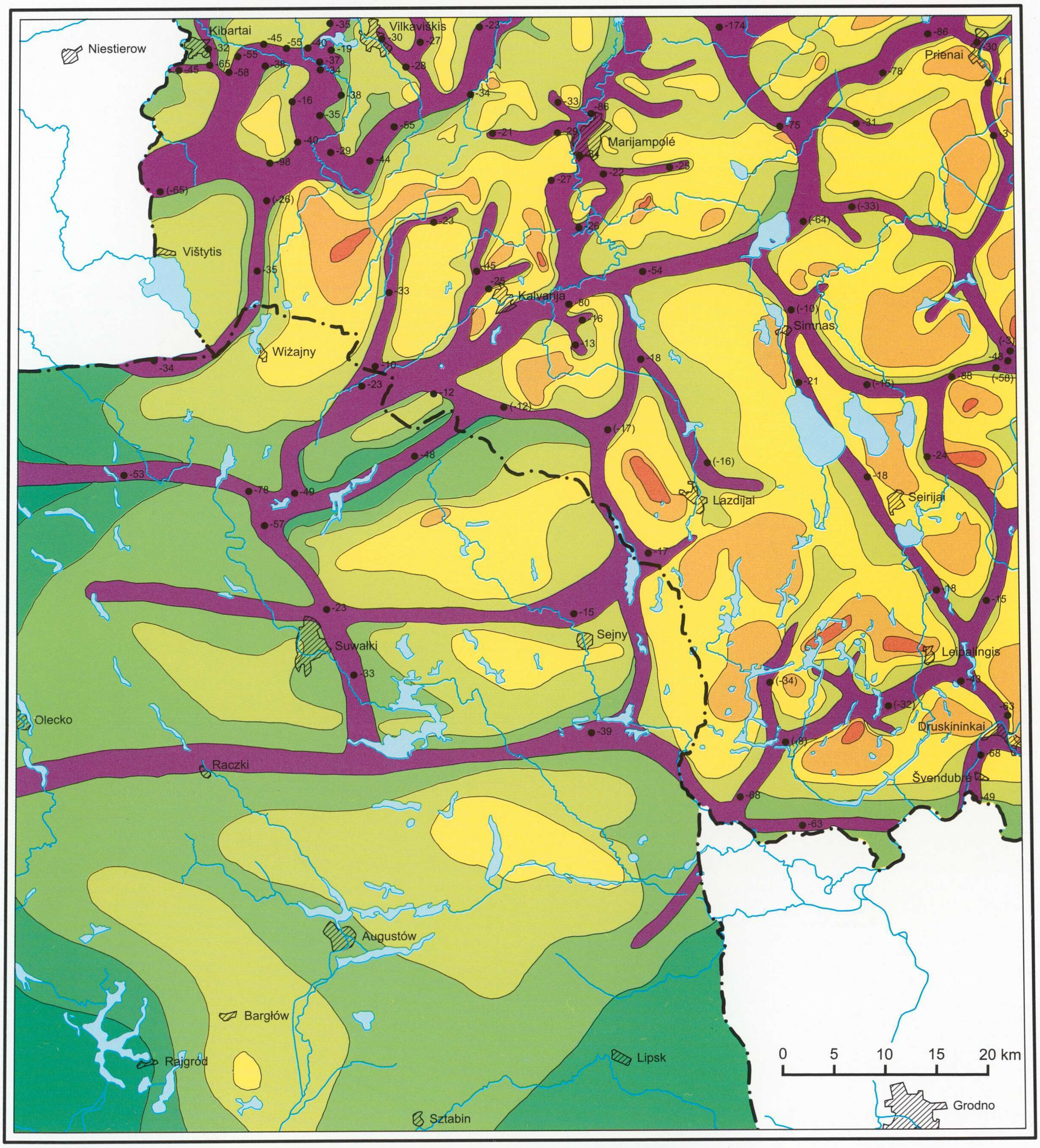
MIDDLE JURASSIC

J2cl — *Callovian.* Sand, sandstone, clay, limestone

LOWER TRIASSIC

T1 — Claystone, sandstone, siltstone, limestone

MAP OF THE SUB-QUATERNARY SURFACE RELIEF



-80 -60 -40 -20 0 20 40 60

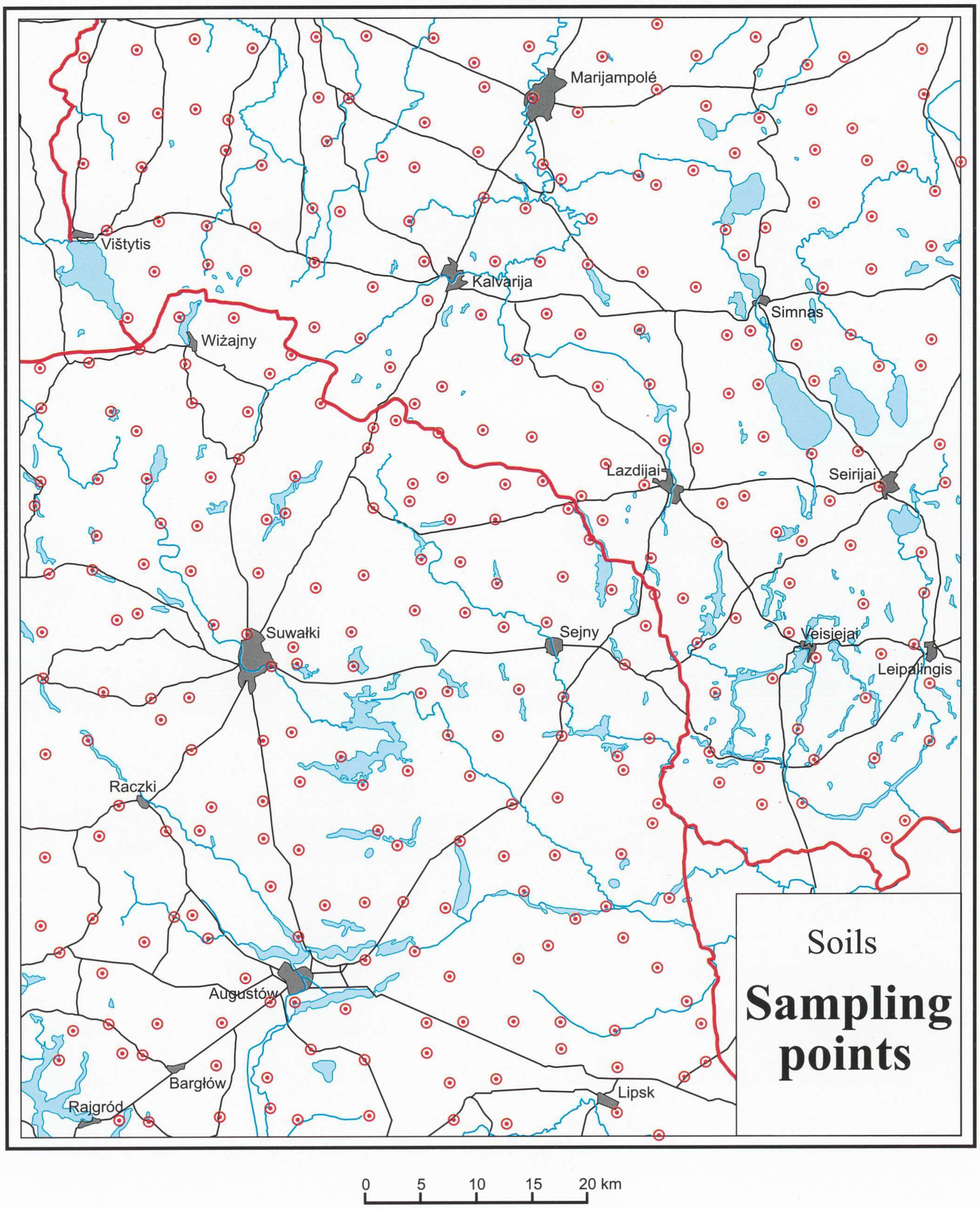
● -10 altitude of the sub-Quaternary surface within palaeoincision (m) (the number in brackets indicates the altitude of borehole bottom which did not reach the pre-Quaternary rocks)

fossil valleys

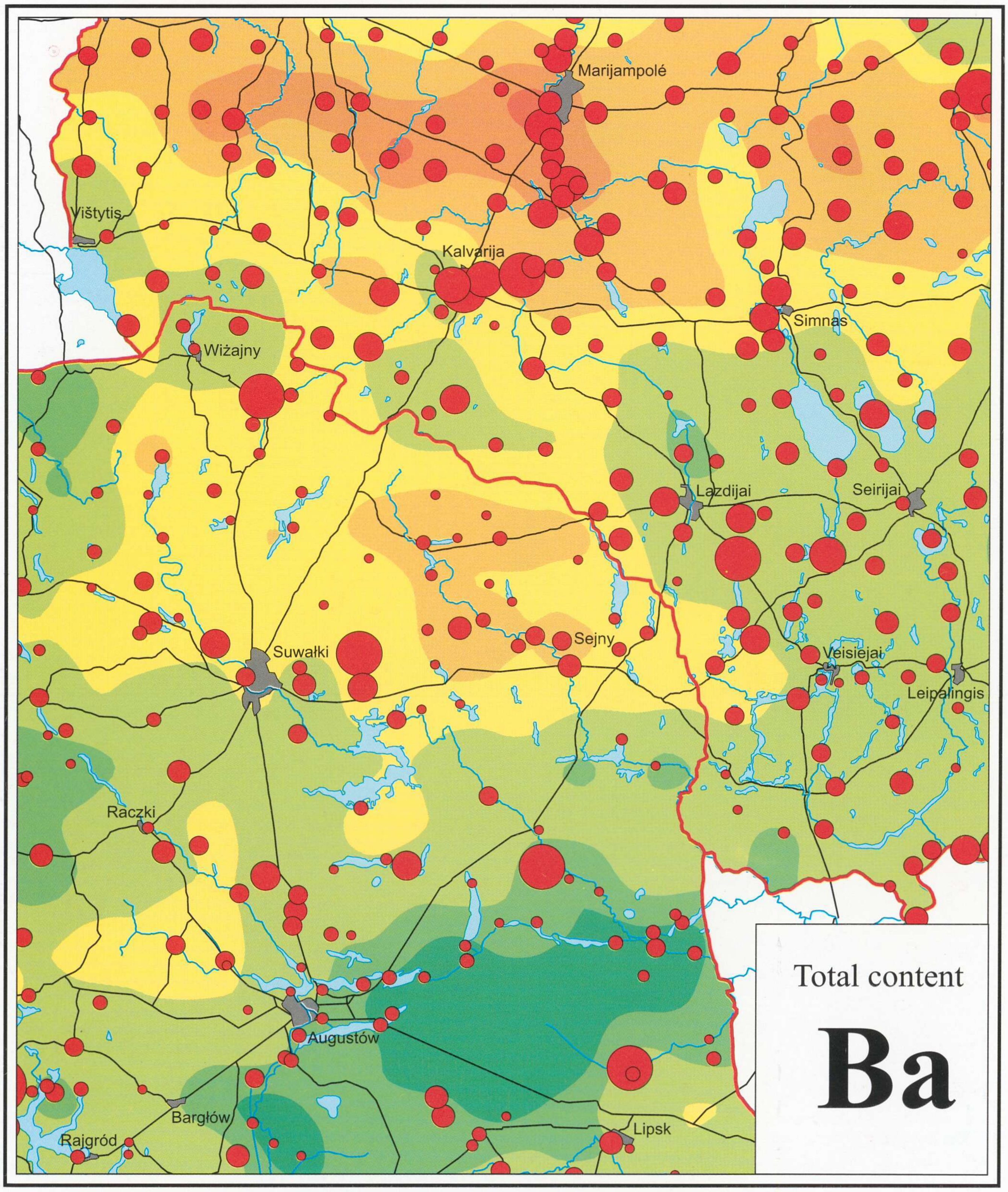
GEOCHEMICAL AND RADIOECOLOGICAL MAPS (Plates 6–56)

Area of research

MAP OF SAMPLING POINTS OF SOILS



MAP OF TOTAL CONTENT OF BARIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

SOILS

15 25 50 75 90 95 97 percentile

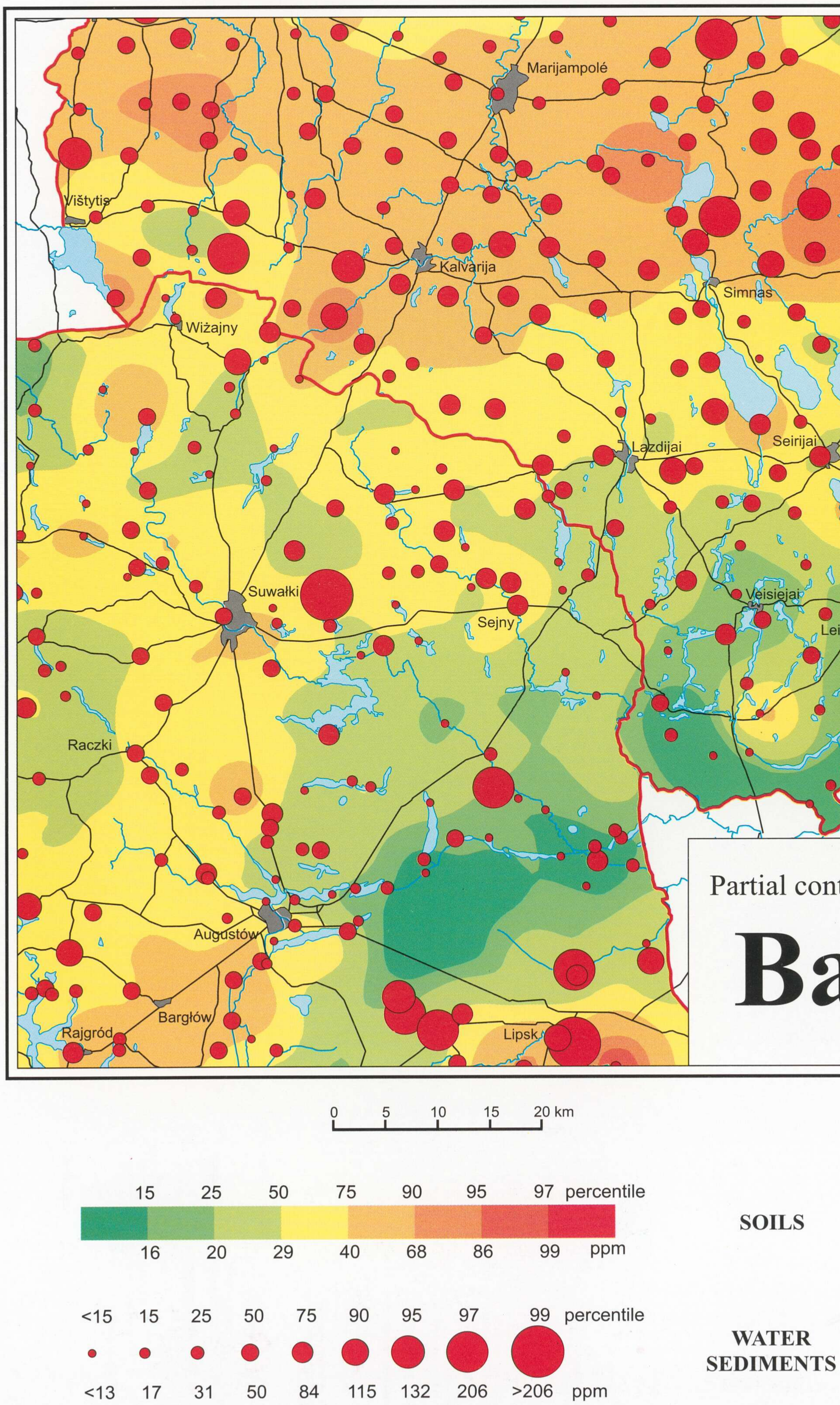
200 270 370 470 570 630 690 ppm

WATER SEDIMENTS

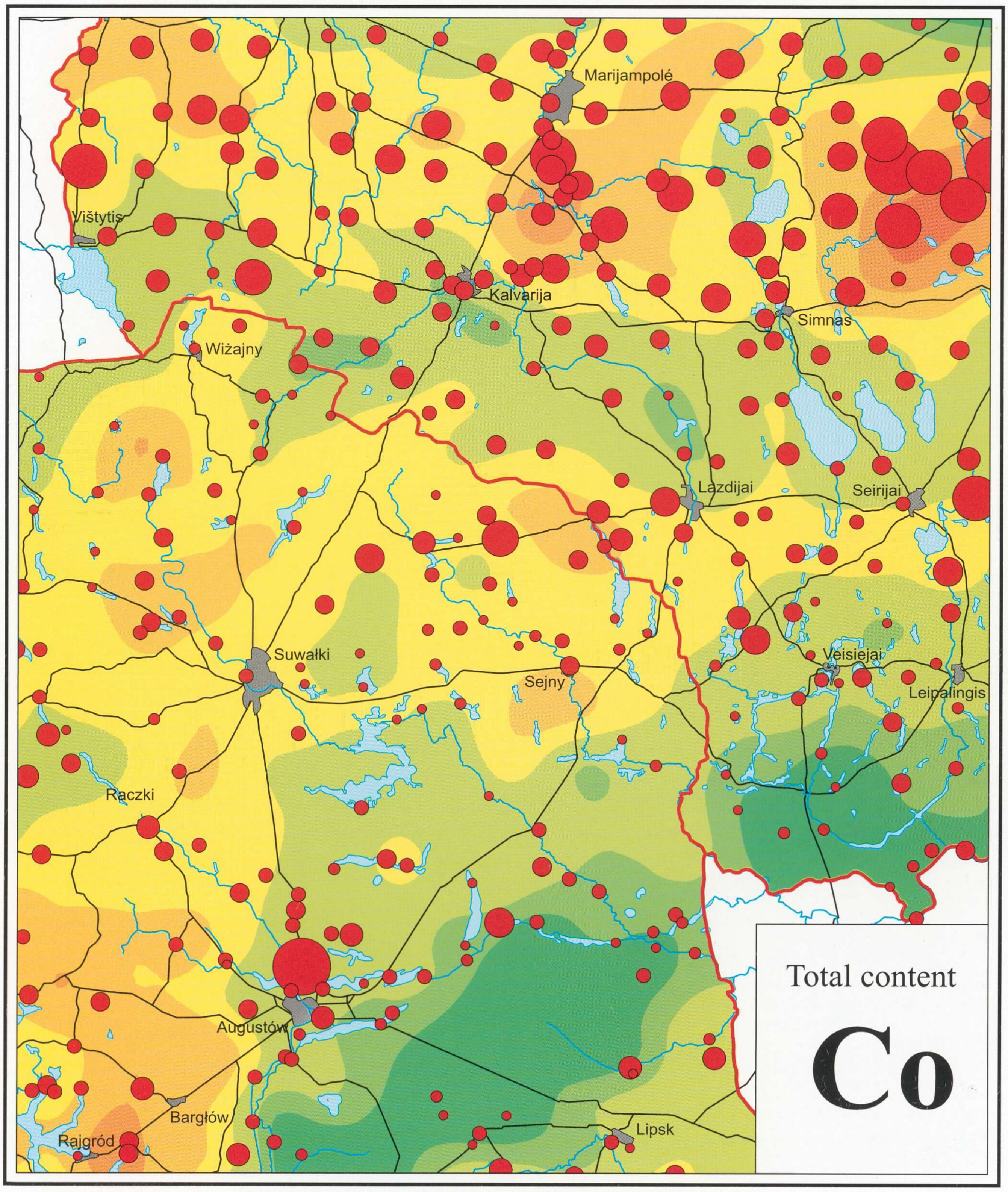
<15 15 25 50 75 90 95 97 99 percentile

<190 233 307 396 479 539 597 698 >698 ppm

MAP OF PARTIAL CONTENT OF BARIUM IN SOILS AND WATER SEDIMENTS



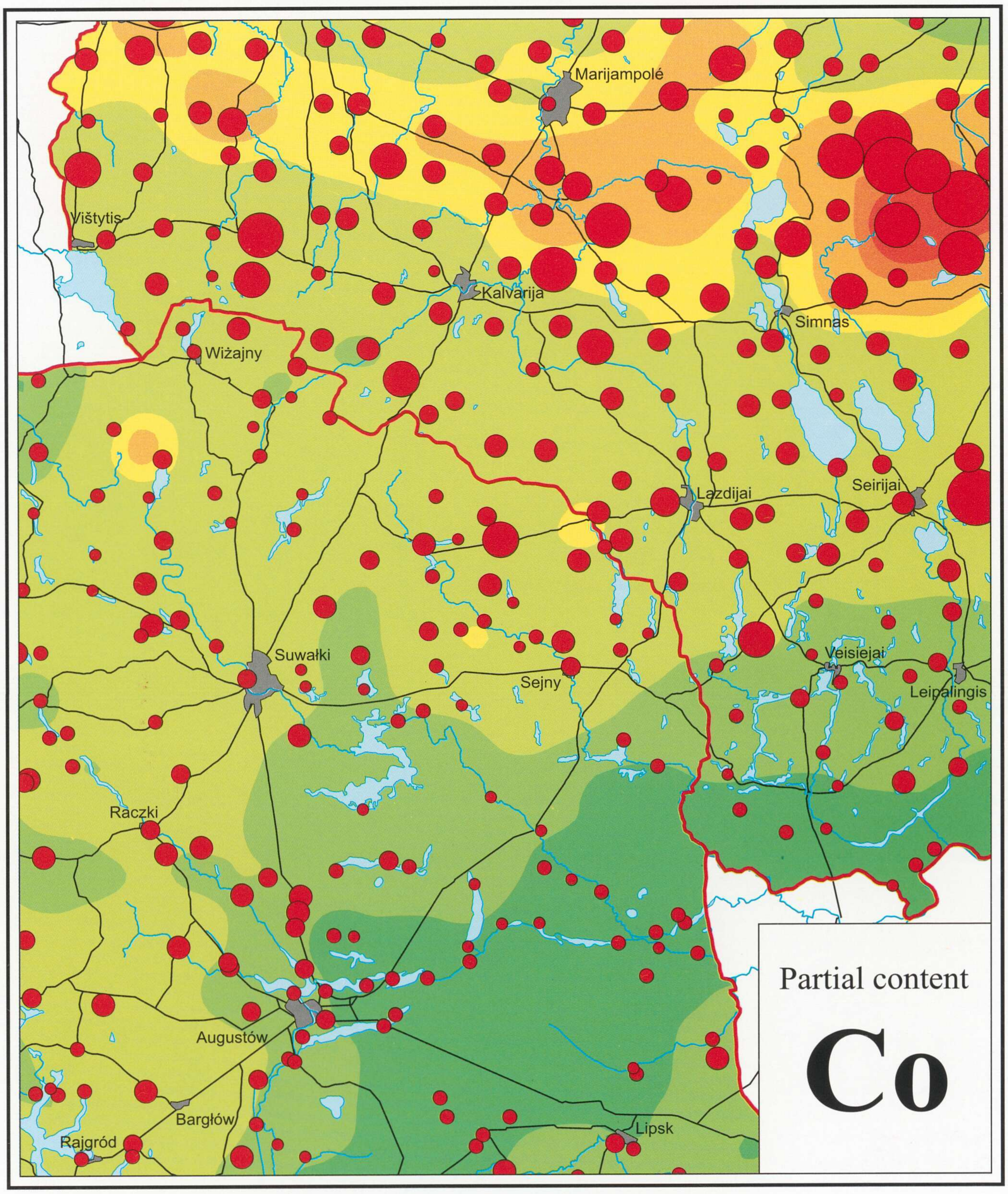
MAP OF TOTAL CONTENT OF COBALT IN SOILS AND WATER SEDIMENTS



	15	25	50	75	90	95	97 percentile
SOILS	2.7	3.2	4.4	5.3	6.3	7.1	7.6 ppm

	<15	15	25	50	75	90	95	97	99 percentile
WATER SEDIMENTS	<2.4	2.9	4.2	5.8	7.1	8.6	9.6	12.4	>12.4 ppm

MAP OF PARTIAL CONTENT OF COBALT IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

25 50 75 90 95 97 percentile

1 2 4 5 7 8 ppm

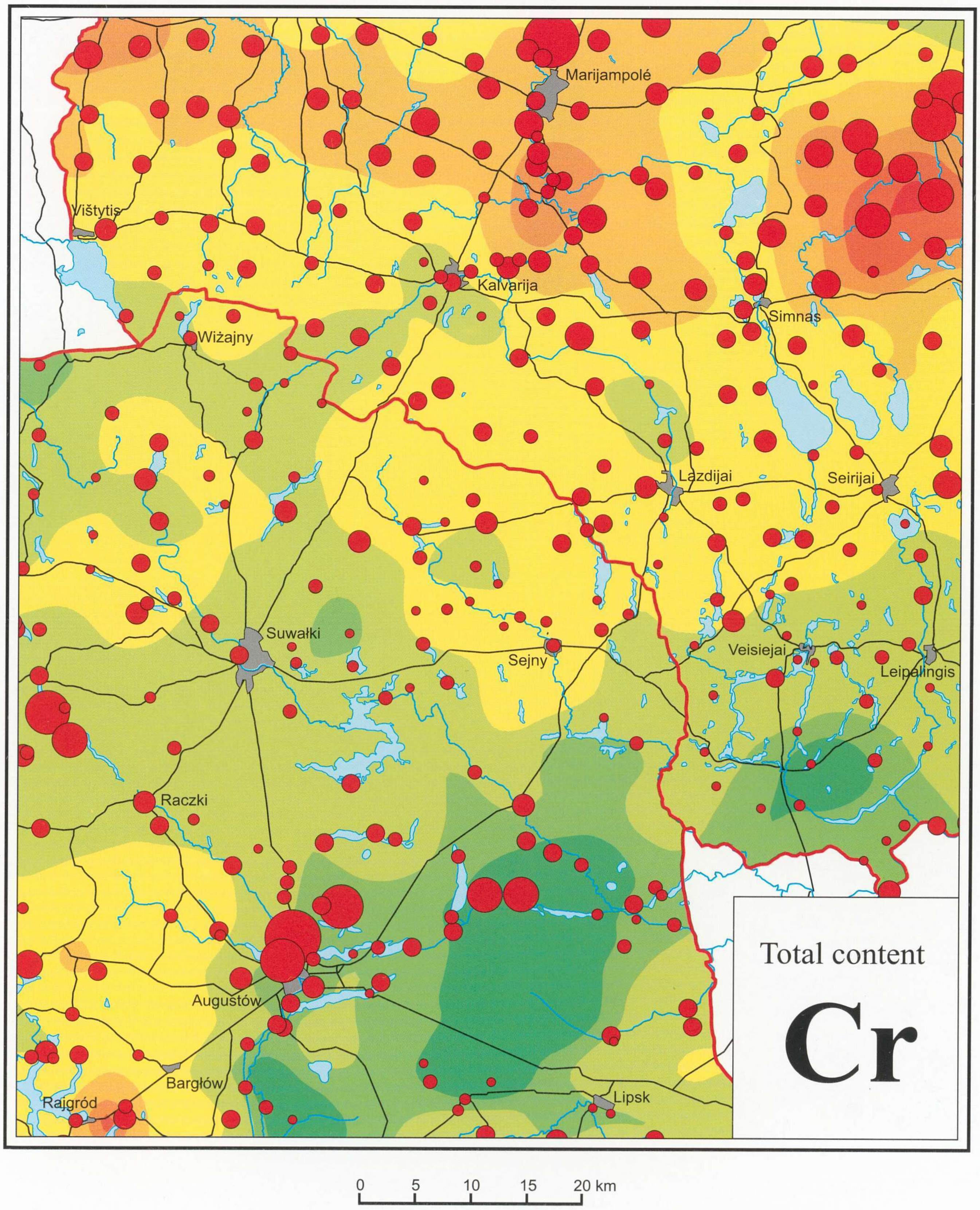
SOILS

<25 25 50 75 90 95 97 99 percentile

<1 2 3 5 6 7 9 >9 ppm

WATER SEDIMENTS

MAP OF TOTAL CONTENT OF CHROMIUM IN SOILS AND WATER SEDIMENTS



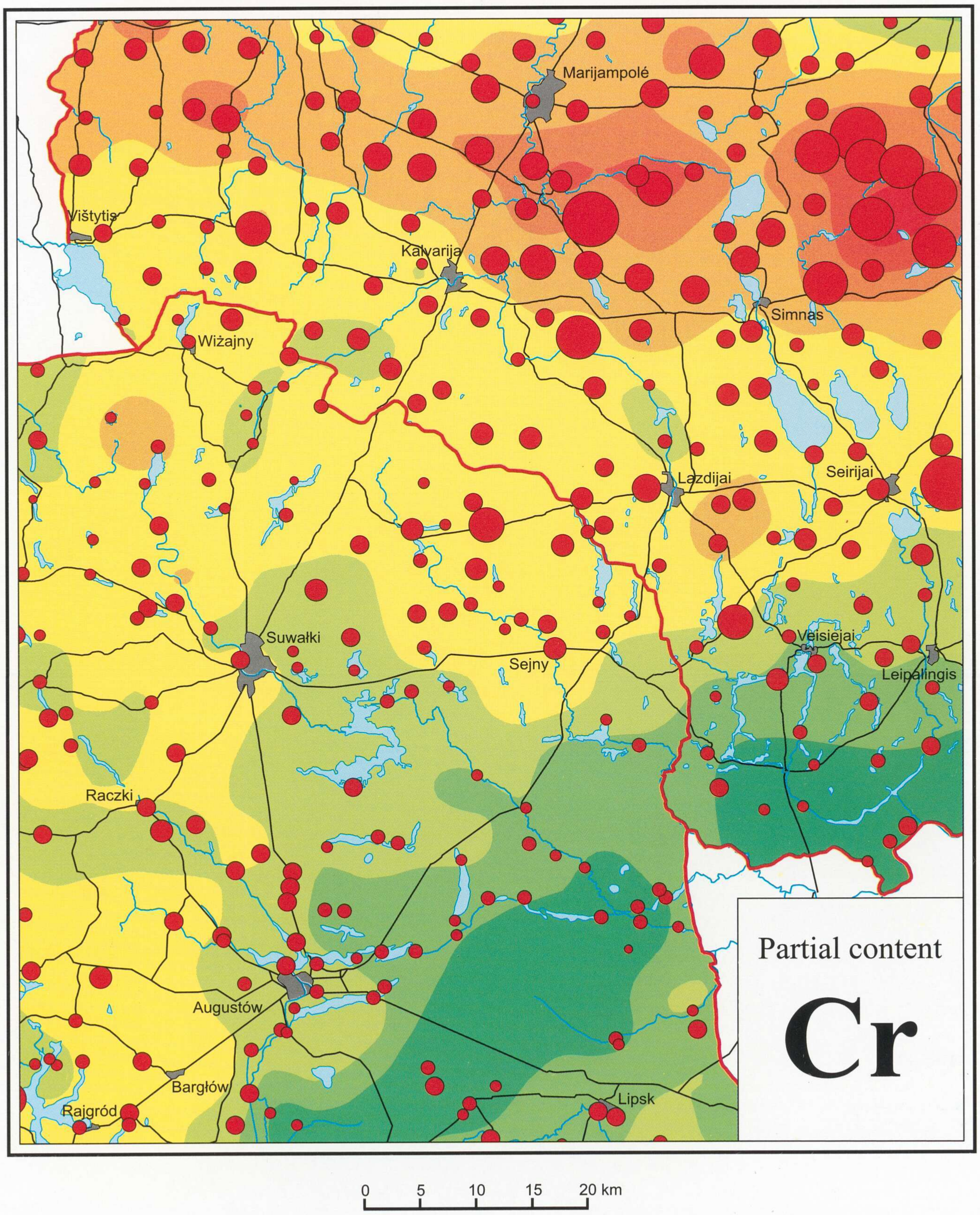
SOILS

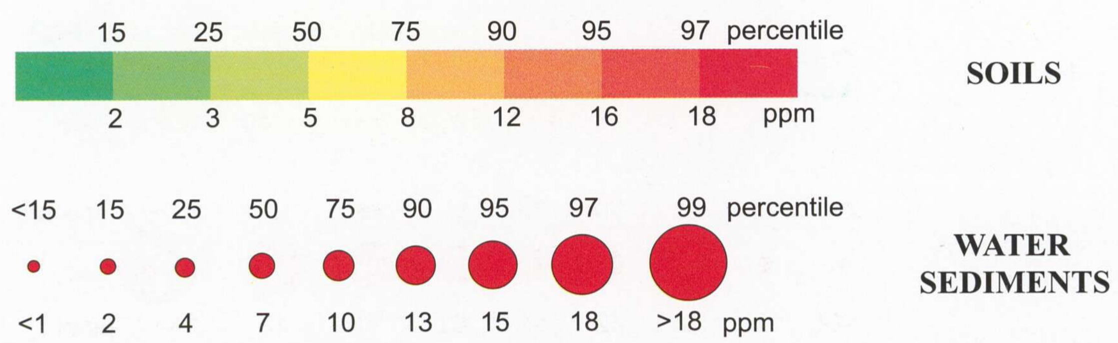
percentile	15	25	50	75	90	95	97
ppm	19	22	30	41	49	52	56

WATER SEDIMENTS

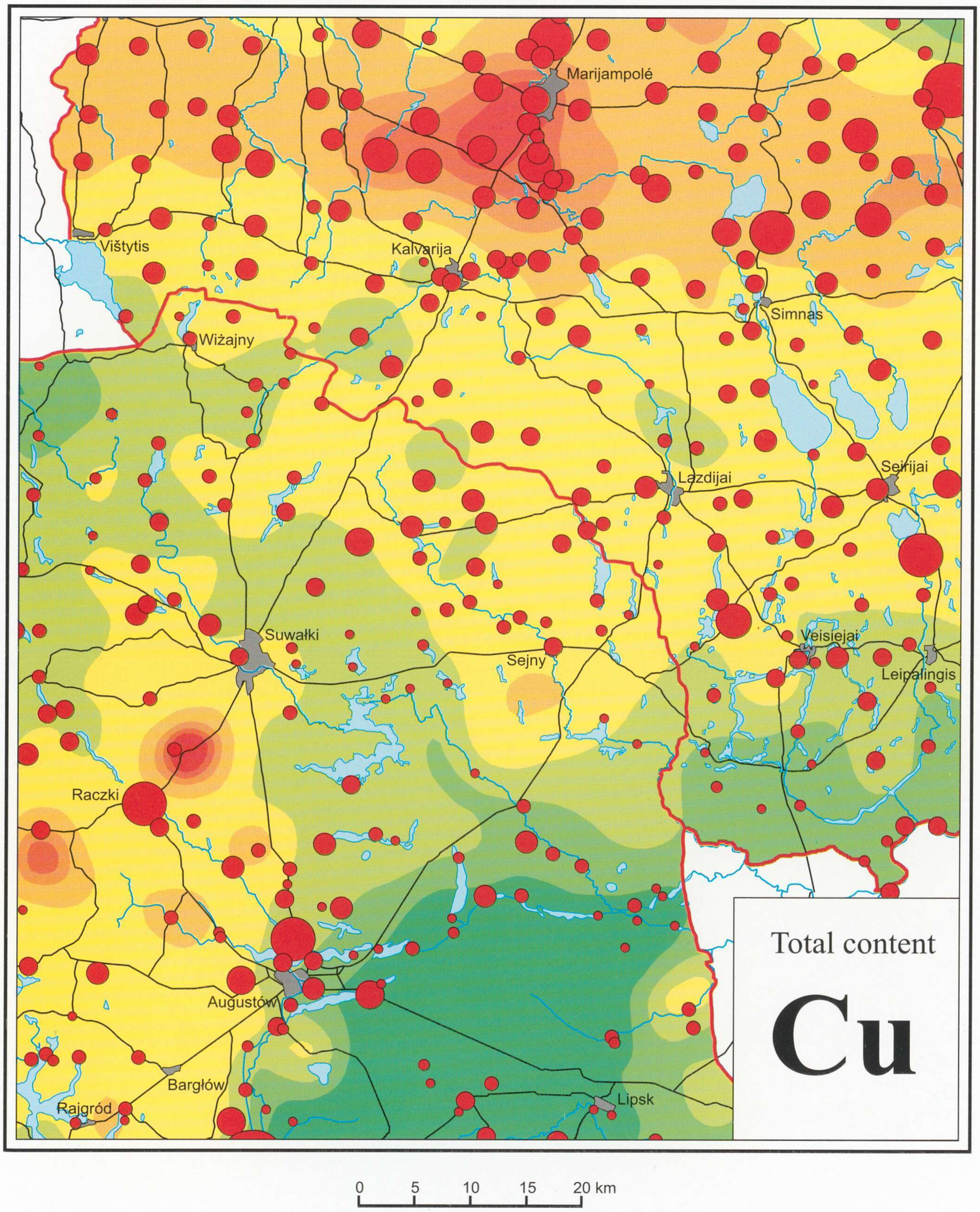
percentile	<15	15	25	50	75	90	95	97	99
ppm	<22	26	33	42	51	61	71	142	>142

MAP OF PARTIAL CONTENT OF CHROMIUM IN SOILS AND WATER SEDIMENTS





MAP OF TOTAL CONTENT OF COPPER IN SOILS AND WATER SEDIMENTS



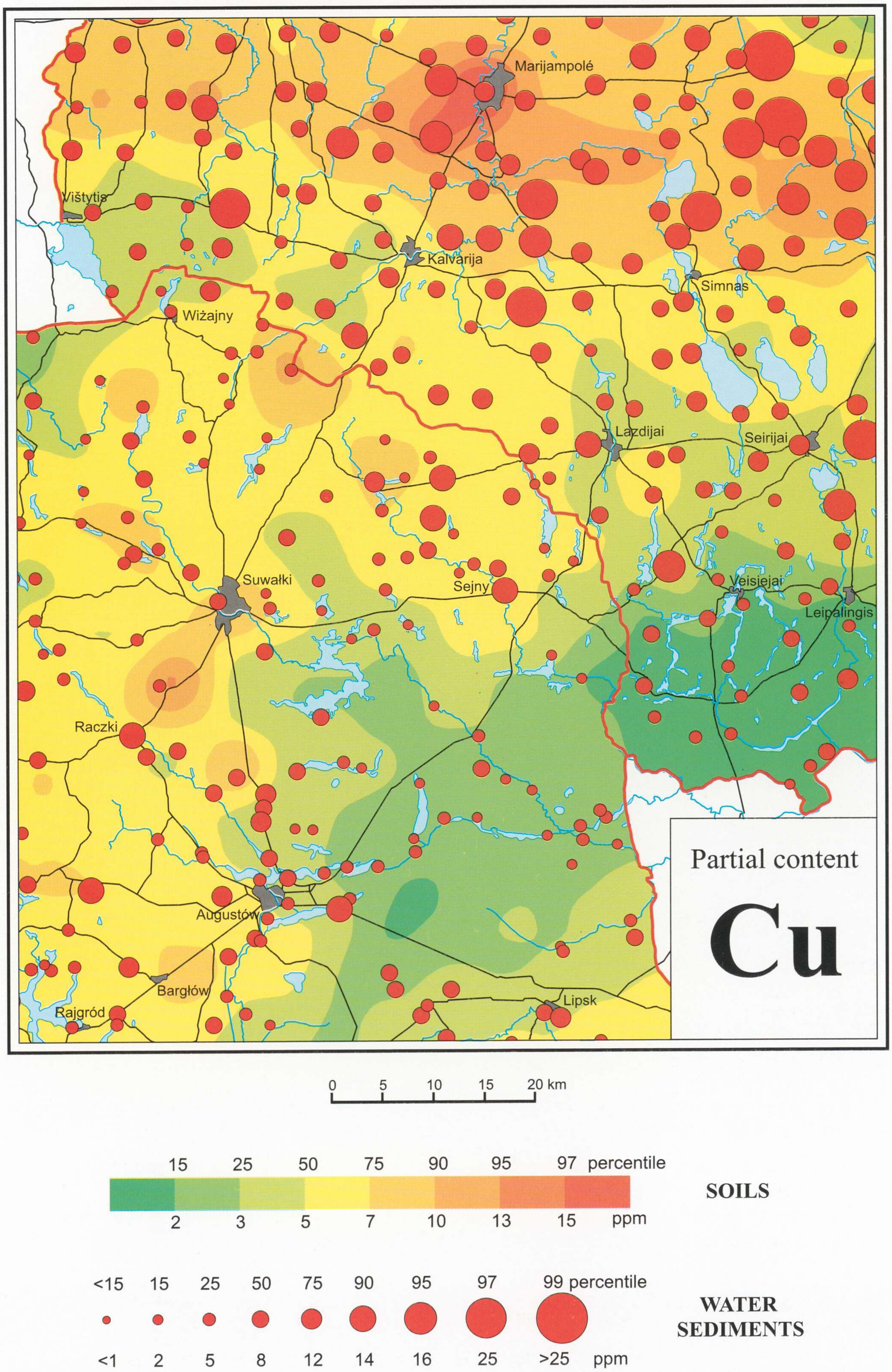
SOILS

percentile	15	25	50	75	90	95	97
ppm	5	6	8	11	14	16	17

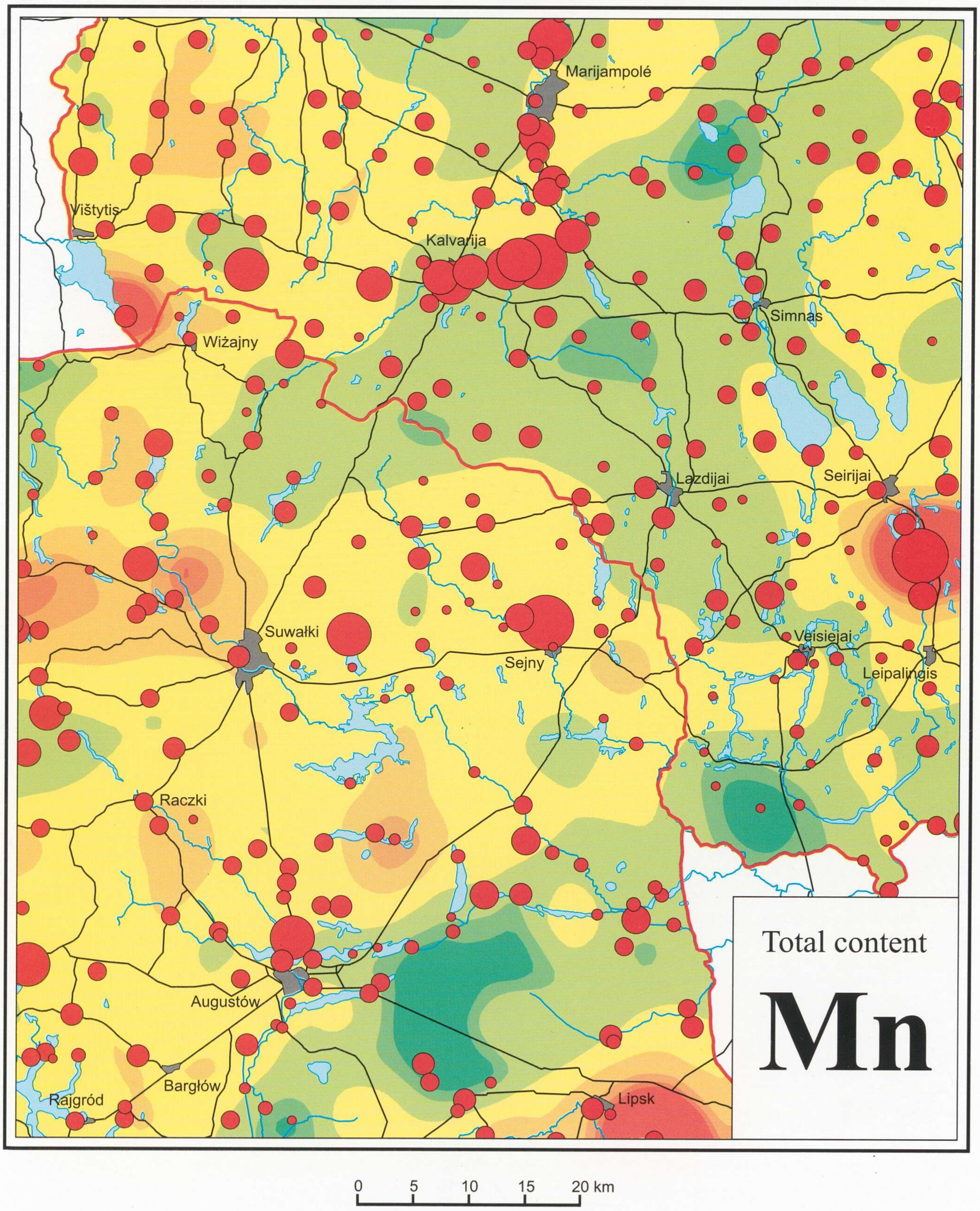
WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<6	7	9	12	16	18	24	40	>40

MAP OF PARTIAL CONTENT OF COPPER IN SOILS AND WATER SEDIMENTS



MAP OF TOTAL CONTENT OF MANGANESE IN SOILS AND WATER SEDIMENTS



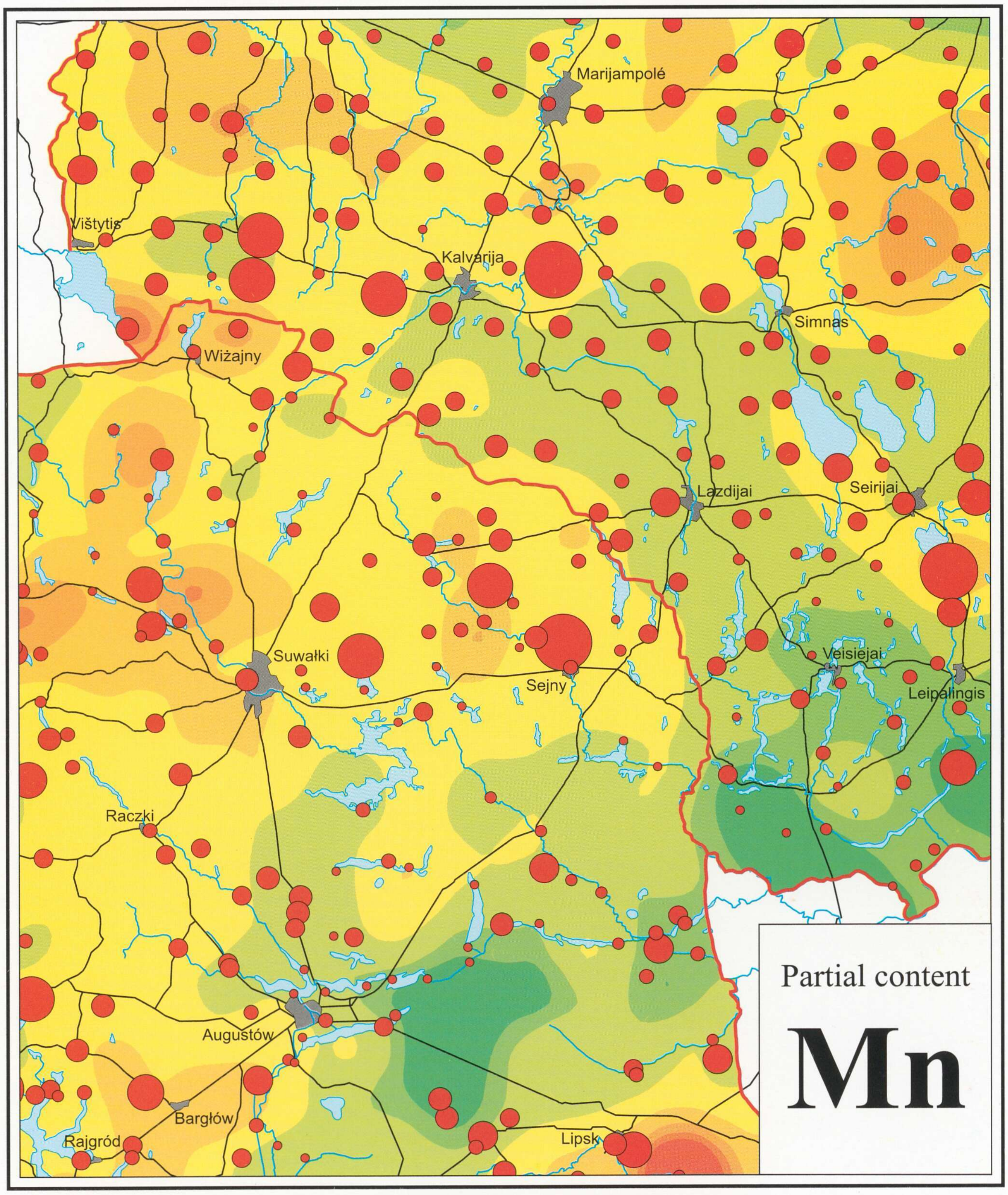
SOILS

percentile	15	25	50	75	90	95	97
ppm	310	350	440	560	680	760	820

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<318	374	511	824	1502	2123	2822	3924	>3924

MAP OF PARTIAL CONTENT OF MANGANESE IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

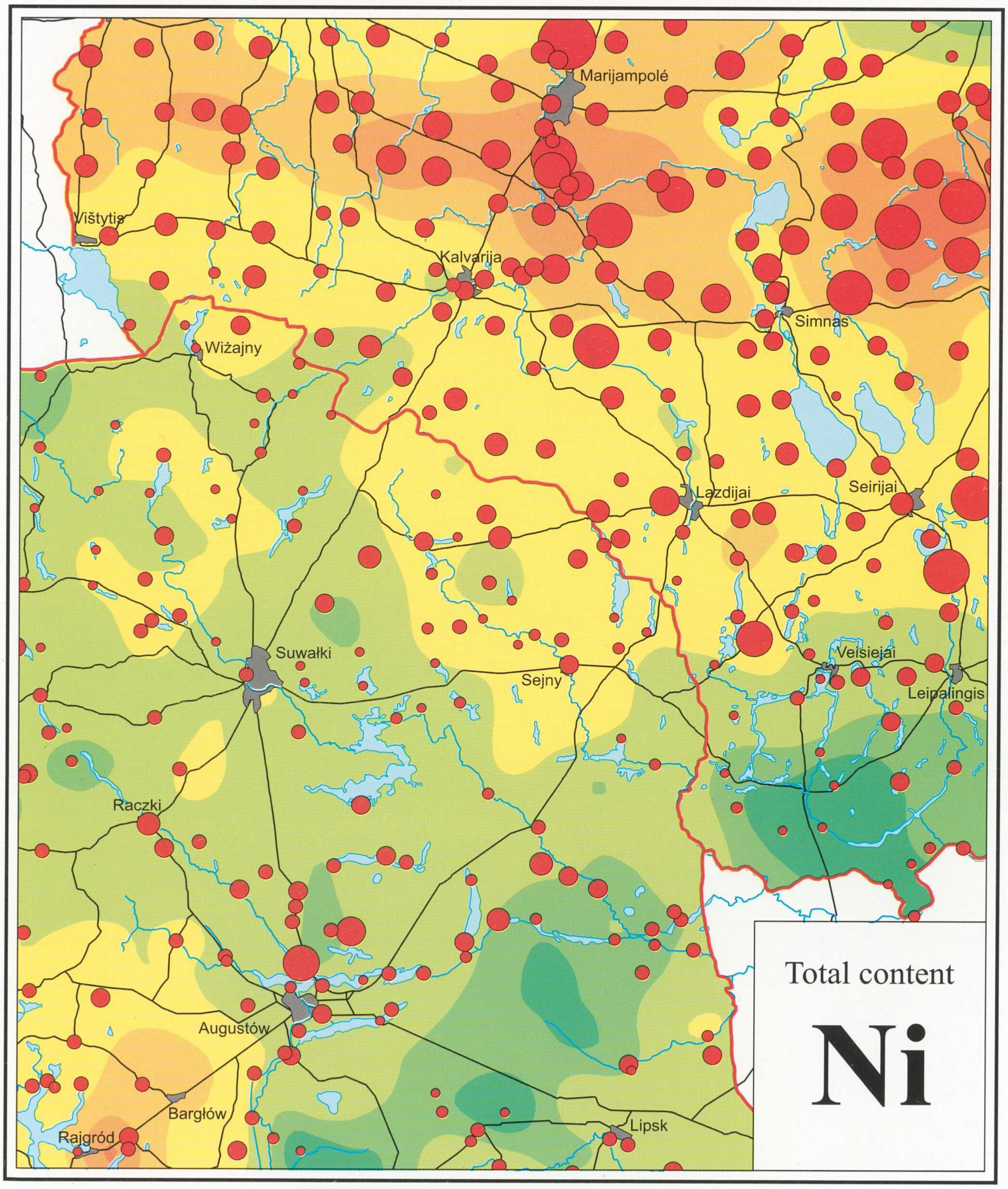
SOILS

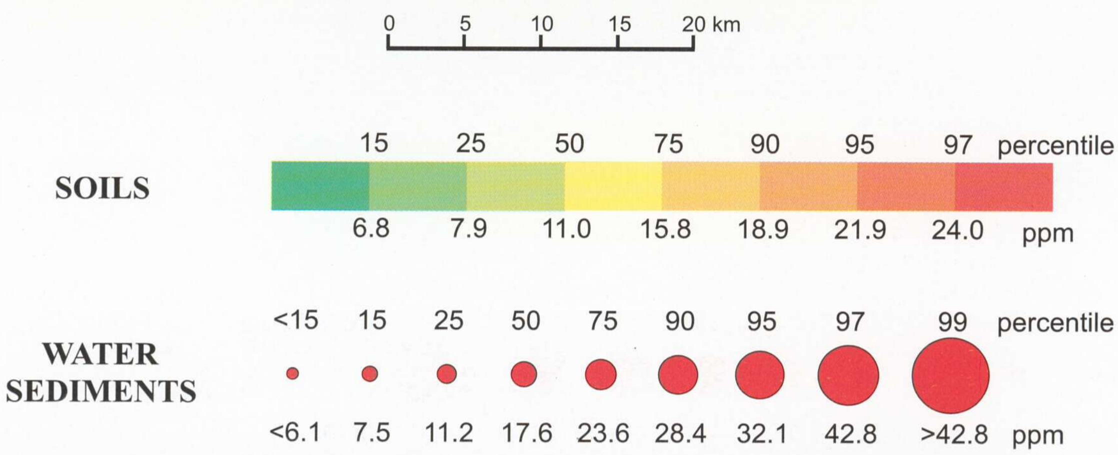
percentile	15	25	50	75	90	95	97
ppm	110	145	213	302	399	481	557

WATER SEDIMENTS

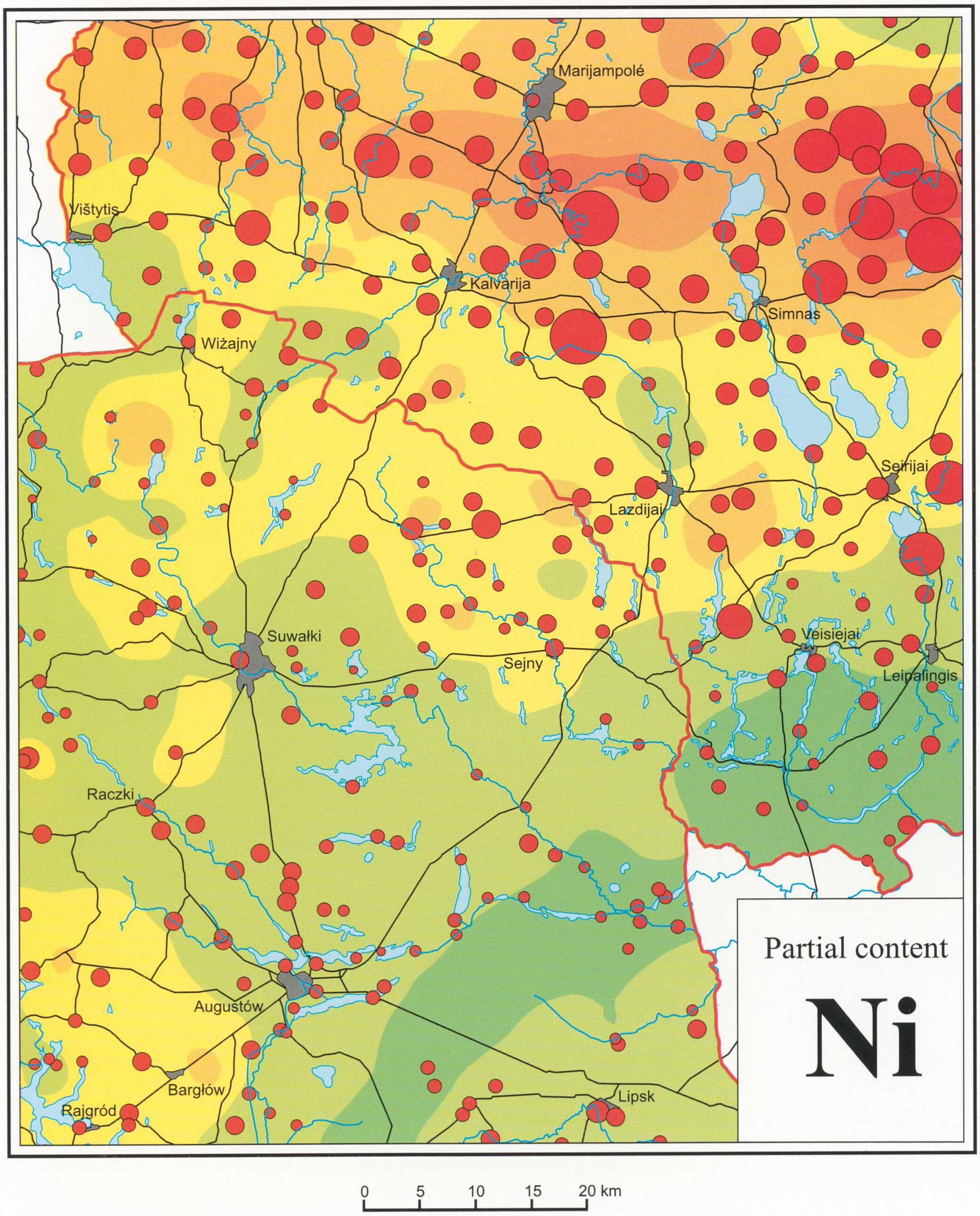
percentile	<15	15	25	50	75	90	95	97	99
ppm	<56	100	187	328	633	877	1189	2218	>2218

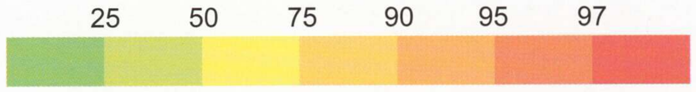
MAP OF TOTAL CONTENT OF NICKEL IN SOILS AND WATER SEDIMENTS



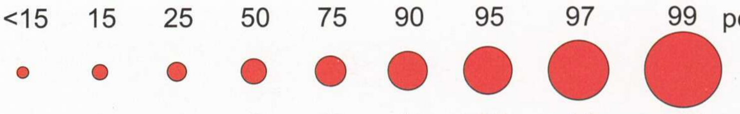


MAP OF PARTIAL CONTENT OF NICKEL IN SOILS AND WATER SEDIMENTS



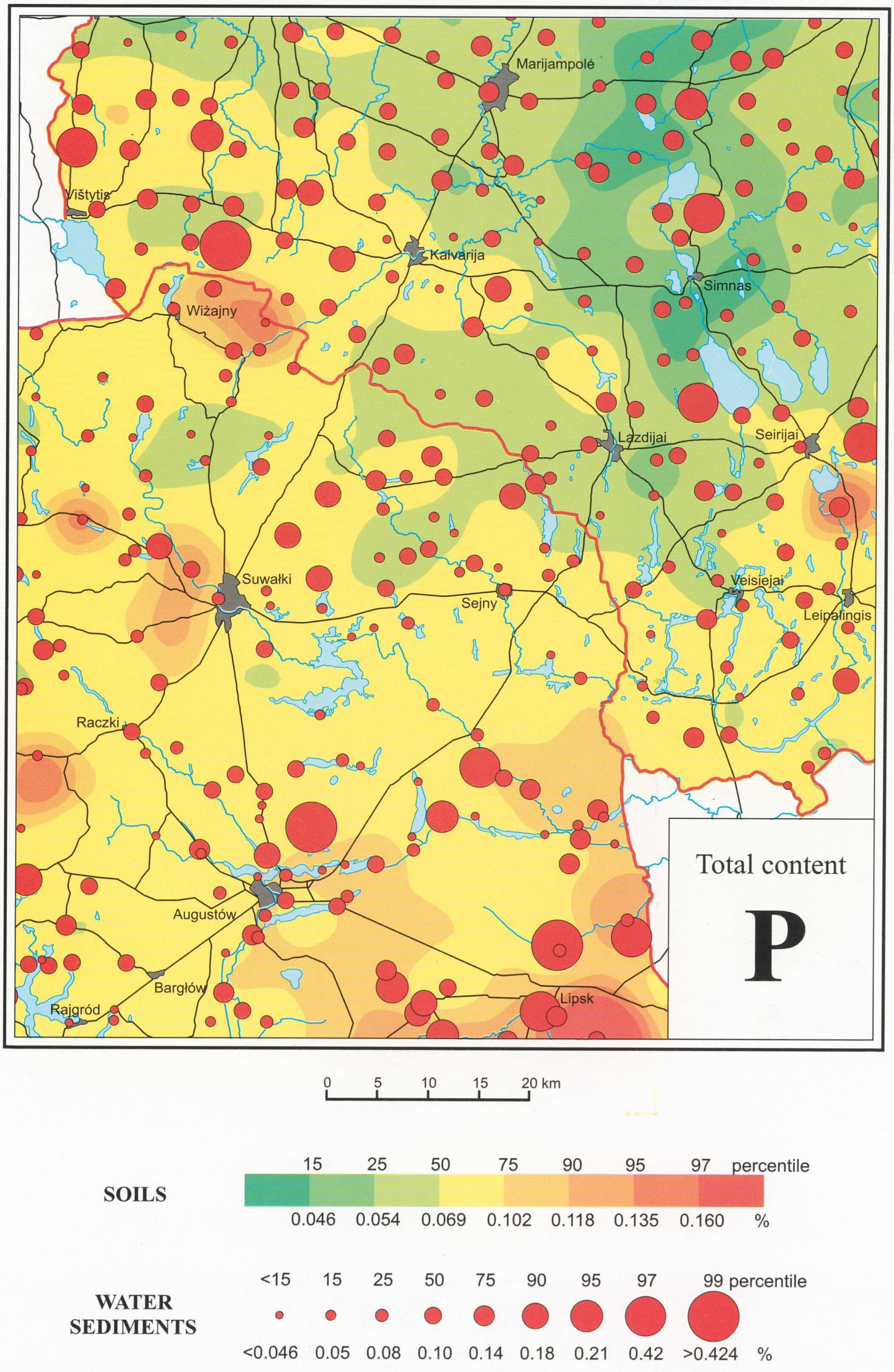


SOILS

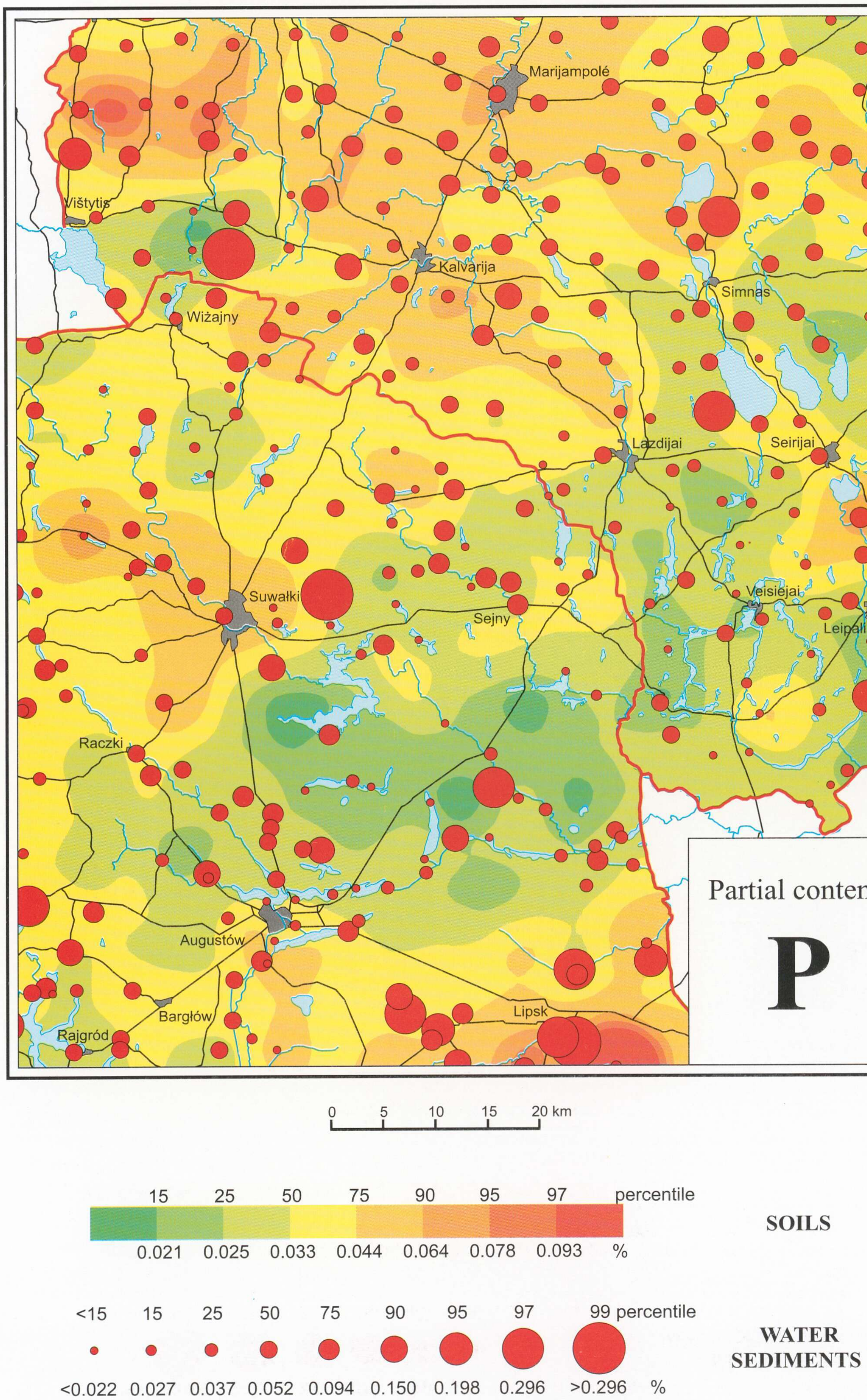


WATER SEDIMENTS

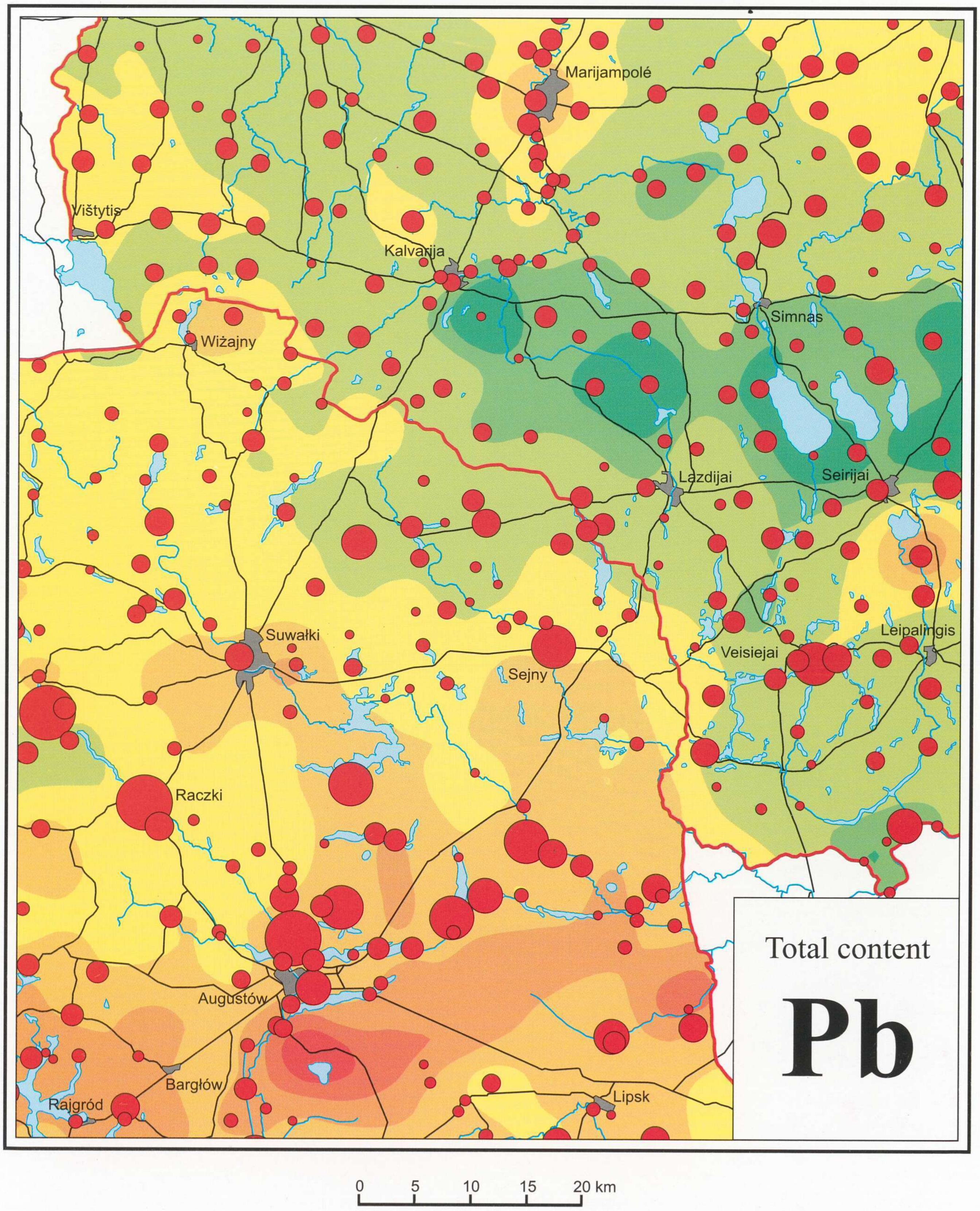
MAP OF TOTAL CONTENT OF PHOSPHORUS IN SOILS AND WATER SEDIMENTS

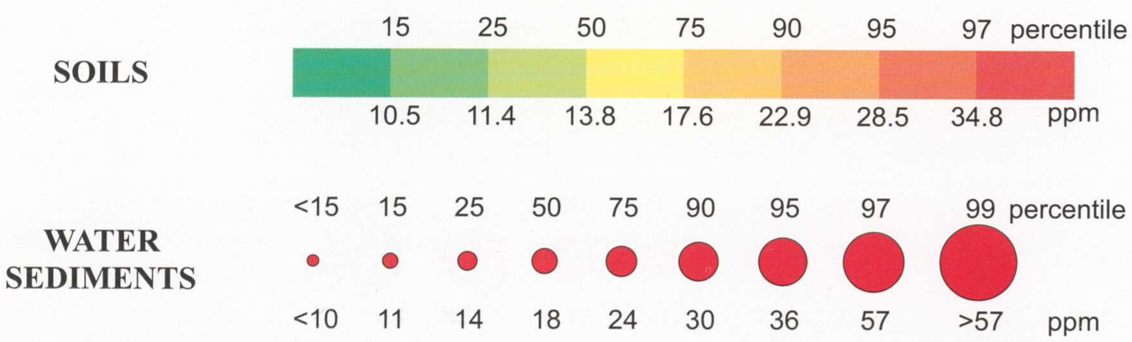


MAP OF PARTIAL CONTENT OF PHOSPHORUS IN SOILS AND WATER SEDIMENTS

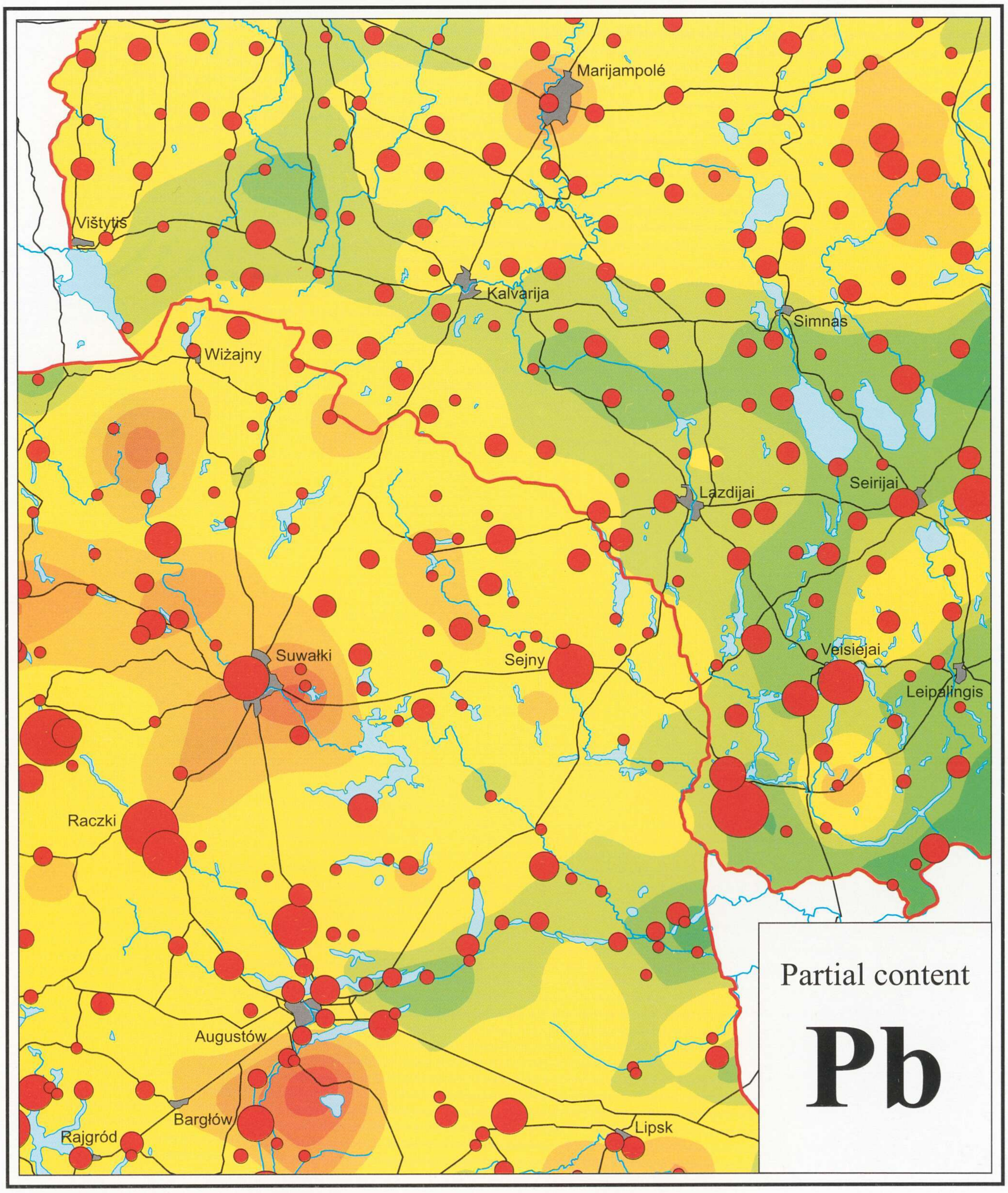


MAP OF TOTAL CONTENT OF LEAD IN SOILS AND WATER SEDIMENTS





MAP OF PARTIAL CONTENT OF LEAD IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

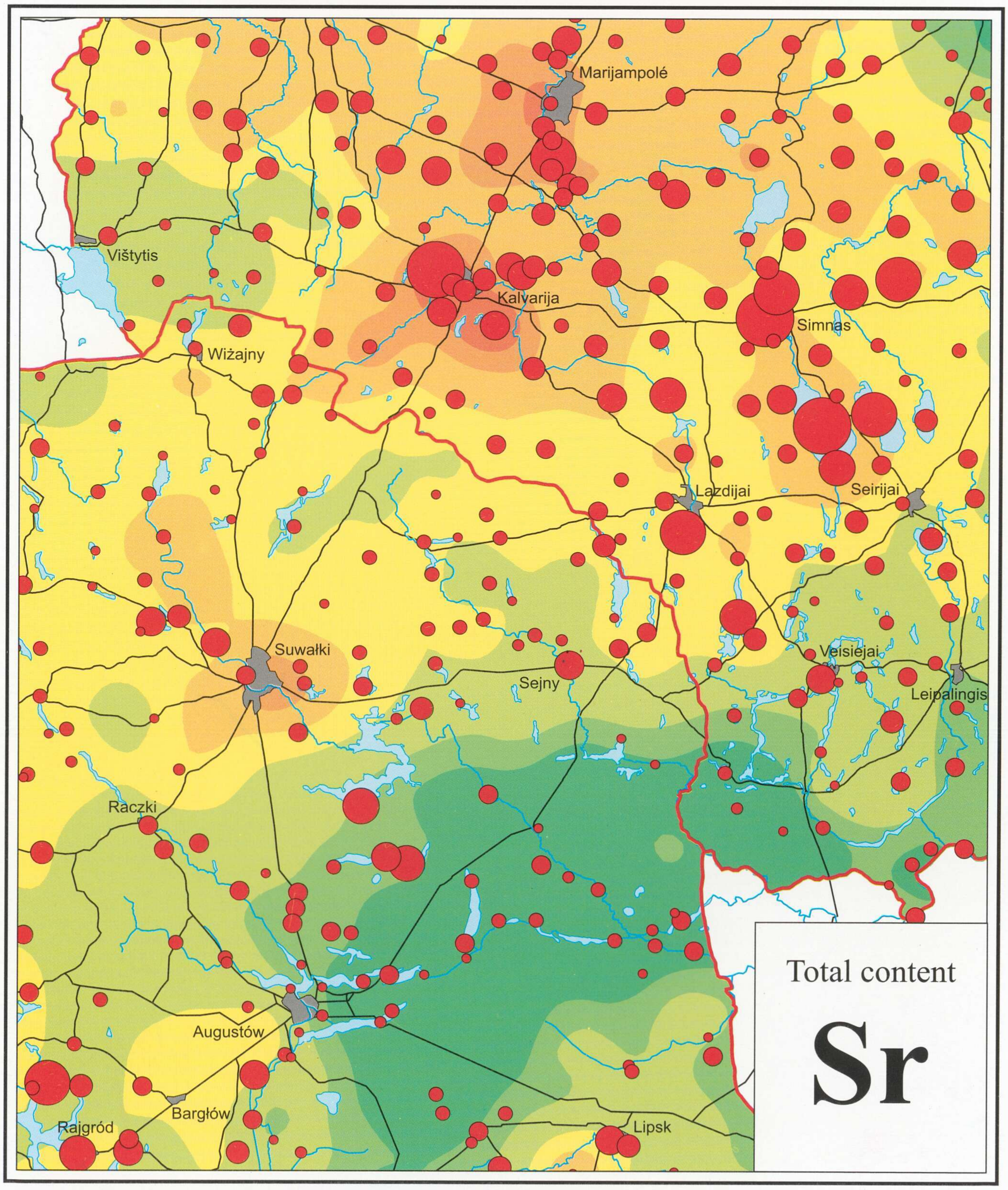
SOILS

15	25	50	75	90	95	97 percentile
5	6	7	10	12	15	18 ppm

WATER SEDIMENTS

<25	25	50	75	90	95	97	99 percentile
3	6	9	13	17	21	44	>44 ppm

MAP OF TOTAL CONTENT OF STRONTIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

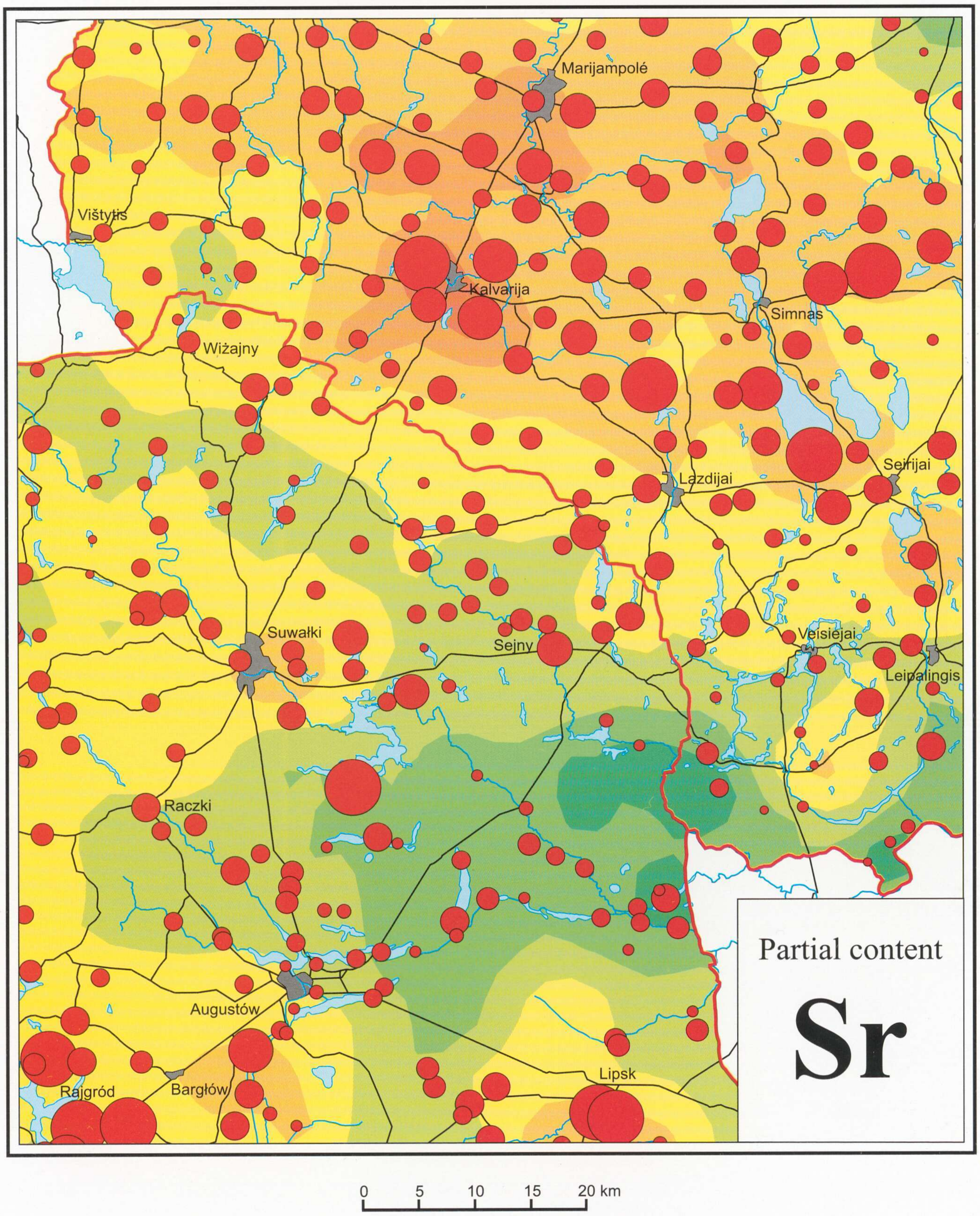
SOILS

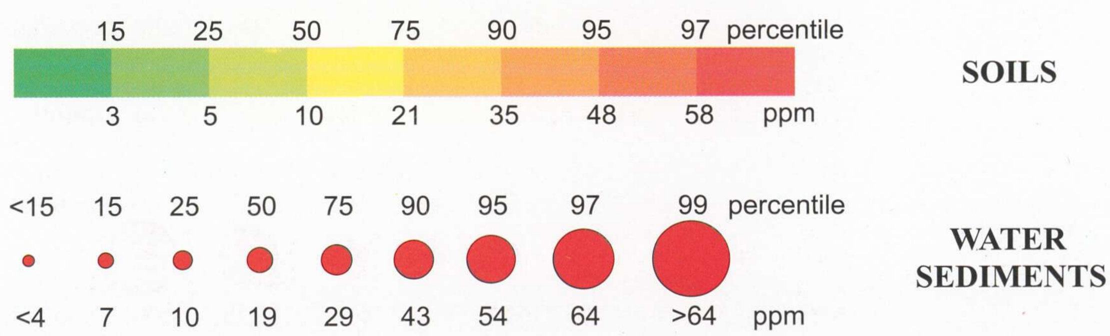
percentile	15	25	50	75	90	95	97
ppm	61	69	83	96	111	123	135

WATER SEDIMENTS

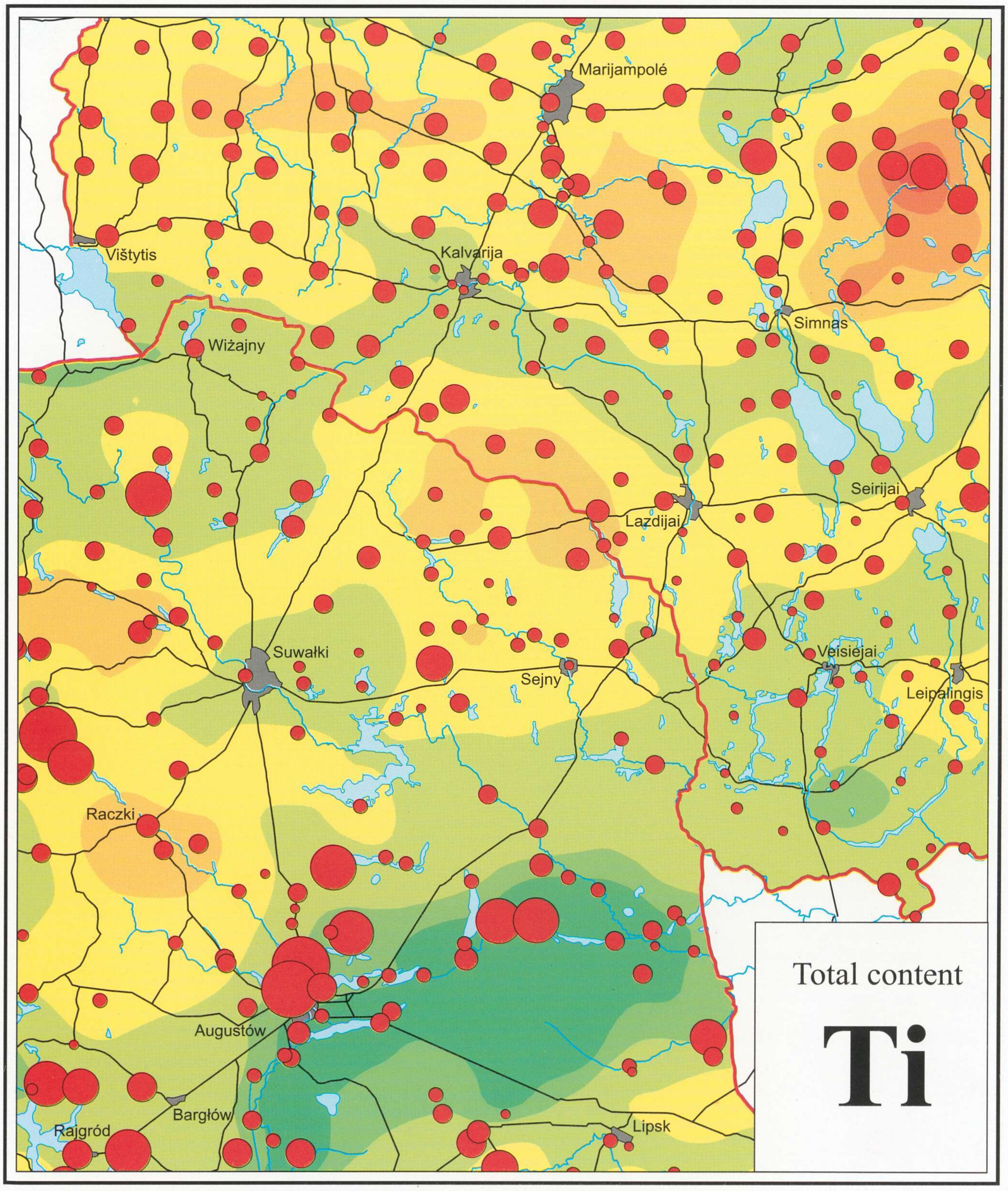
percentile	<15	15	25	50	75	90	95	97	99
ppm	<71	76	88	107	128	148	176	271	>271

MAP OF PARTIAL CONTENT OF STRONTIUM IN SOILS AND WATER SEDIMENTS





MAP OF TOTAL CONTENT OF TITANIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

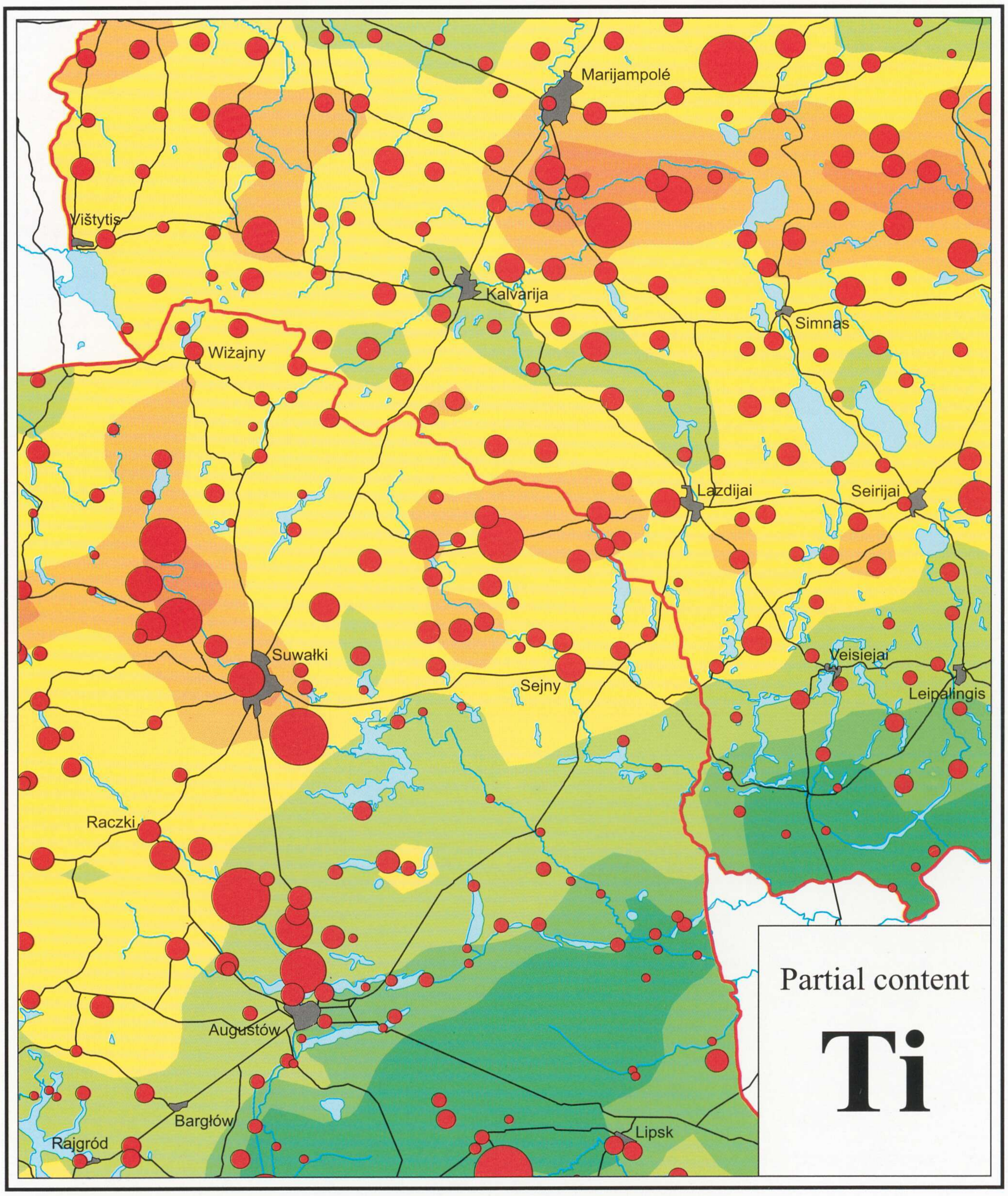
SOILS

percentile	15	25	50	75	90	95	97	
ppm	1454	1747	2457	3034	3495	3795	4027	

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<1610	1917	2784	3562	4319	4875	5466	8459	>8459

MAP OF PARTIAL CONTENT OF TITANIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

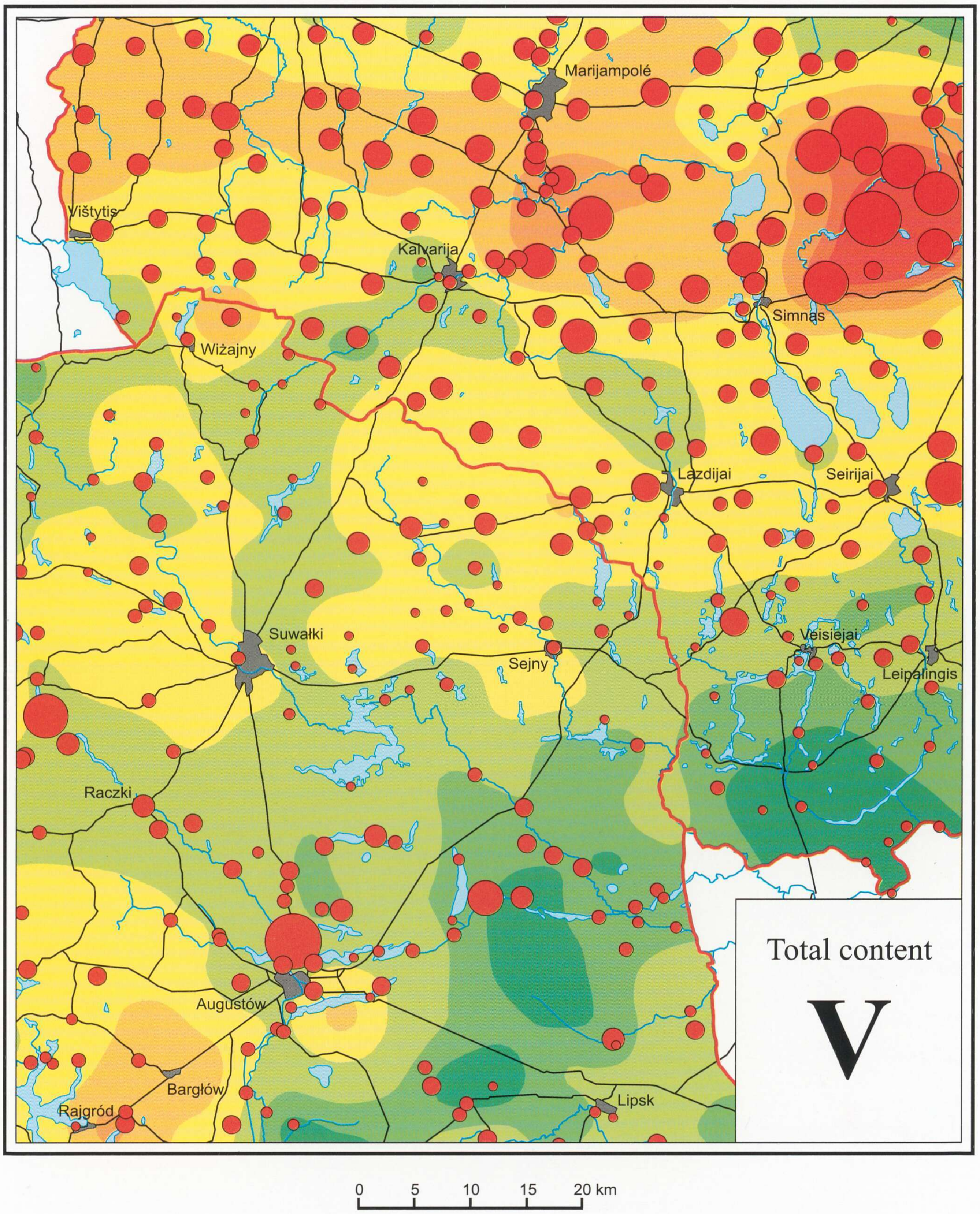
SOILS

percentile	15	25	50	75	90	95	97
ppm	25	33	50	70	86	105	110

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<22	26	43	62	82	100	111	146	>146

MAP OF TOTAL CONTENT OF VANADIUM IN SOILS AND WATER SEDIMENTS



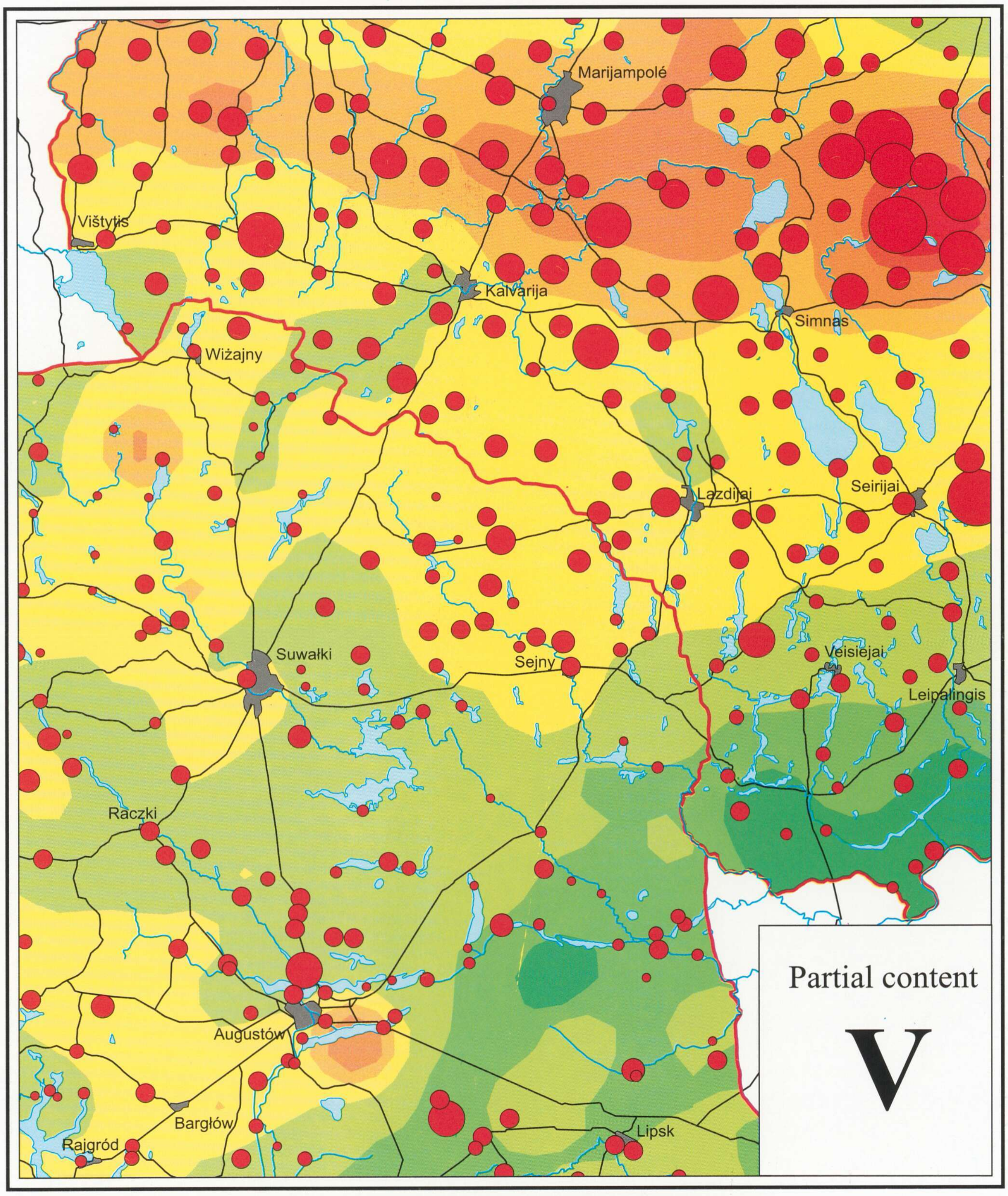
SOILS

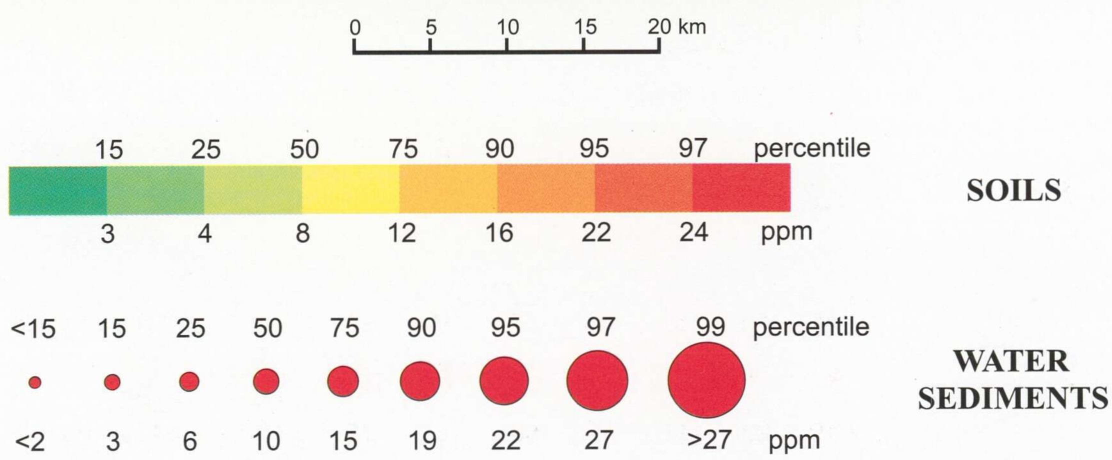
percentile	15	25	50	75	90	95	97	
ppm	22	25	33	43	51	58	63	

WATER SEDIMENTS

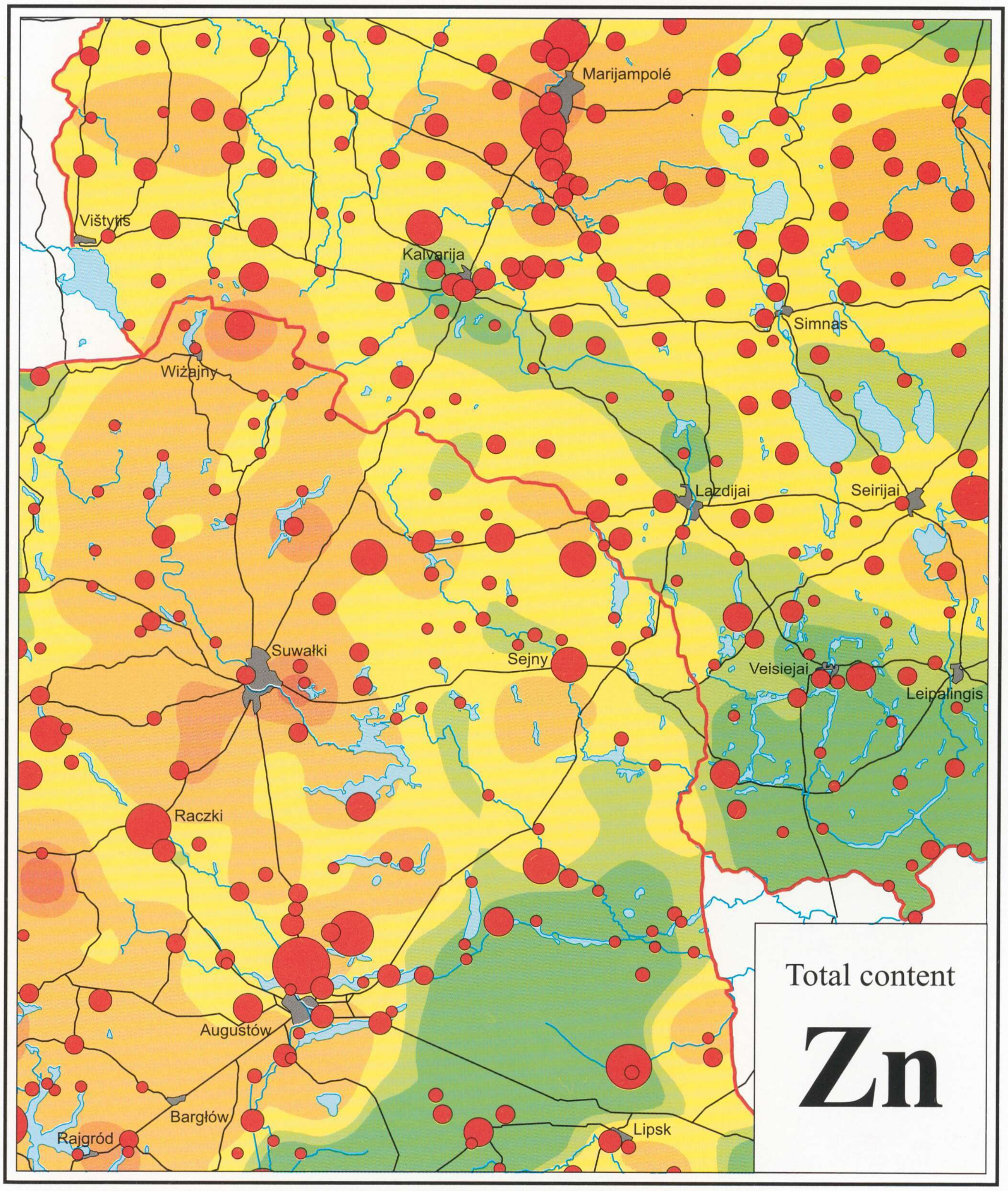
percentile	<15	15	25	50	75	90	95	97	99
ppm	<19	23	32	44	59	70	79	100	>100

MAP OF PARTIAL CONTENT OF VANADIUM IN SOILS AND WATER SEDIMENTS





MAP OF TOTAL CONTENT OF ZINC IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

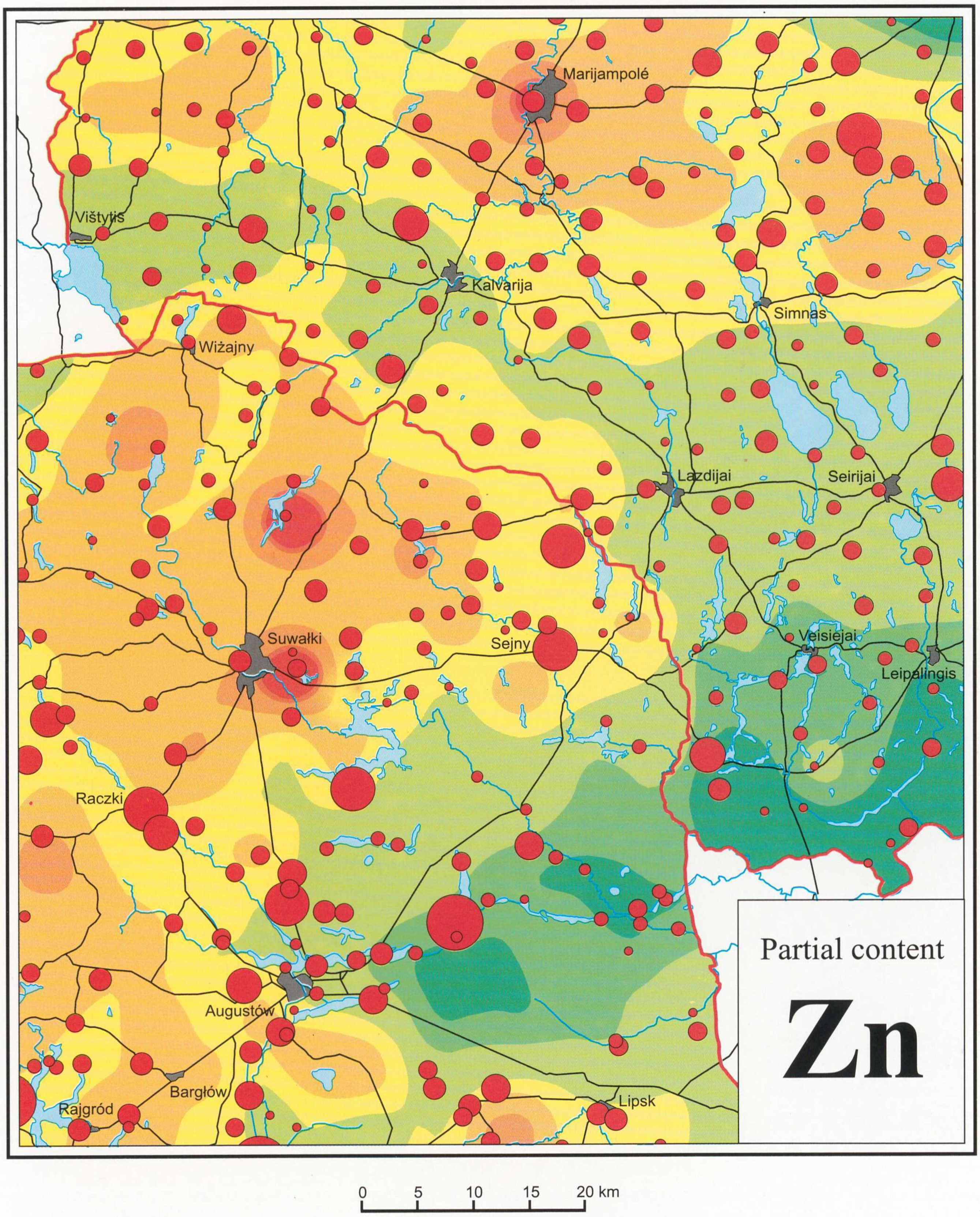
SOILS

percentile	15	25	50	75	90	95	97
ppm	10	20	23	32	55	74	91

WATER SEDIMENTS

percentile	15	25	50	75	90	95	97	99
ppm	<20,0	30,7	50	74	99	127	289	>289

MAP OF PARTIAL CONTENT OF ZINC IN SOILS AND WATER SEDIMENTS



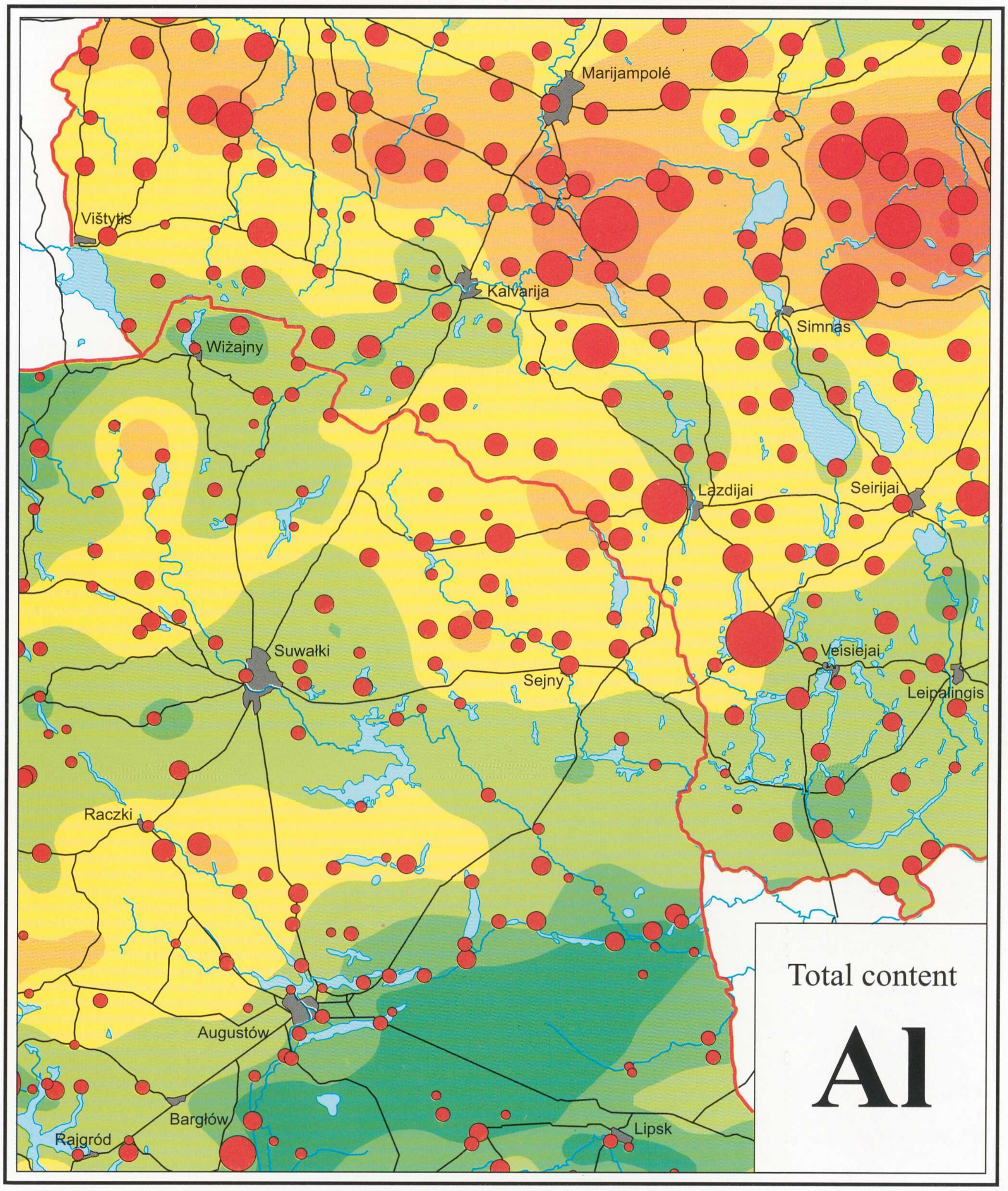
SOILS

percentile	15	25	50	75	90	95	97
ppm	13	16	24	32	45	58	62

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<14	18	26	37	52	75	96	195	>195

MAP OF TOTAL CONTENT OF ALUMINIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

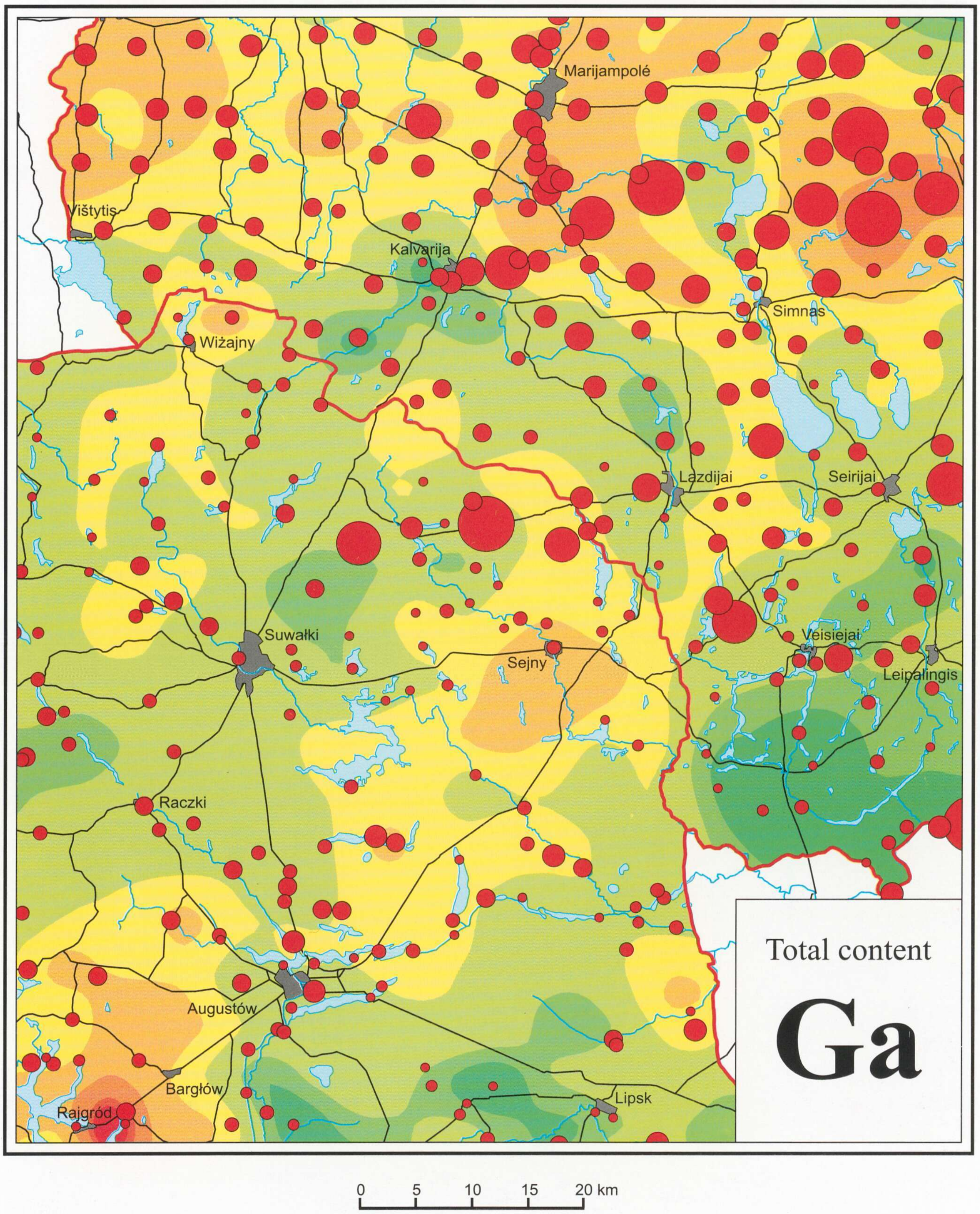
SOILS

percentile	15	25	50	75	90	95	97
%	2.25	2.83	3.67	4.55	5.40	6.00	6.85

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
%	<2.01	2.24	2.88	3.96	4.98	5.79	6.22	6.93	>6.93

MAP OF TOTAL CONTENT OF GALLIUM IN SOILS AND WATER SEDIMENTS



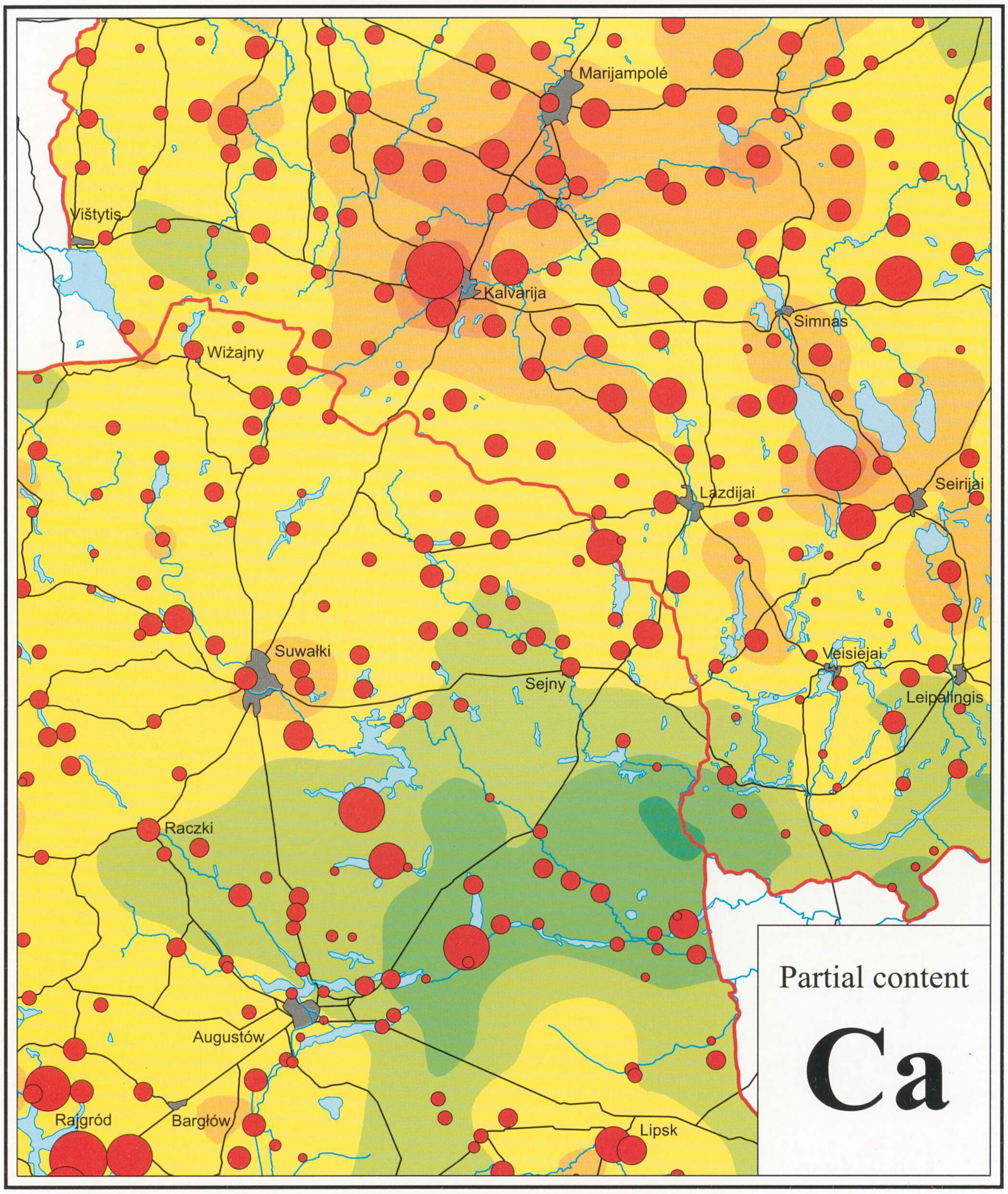
SOILS

percentile	15	25	50	75	90	95	97
ppm	3.8	4.5	5.7	6.7	7.9	8.7	9.0

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<2.9	3.7	5.7	8.2	9.7	10.7	11.2	12.6	>12.6

MAP OF PARTIAL CONTENT OF CALCIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

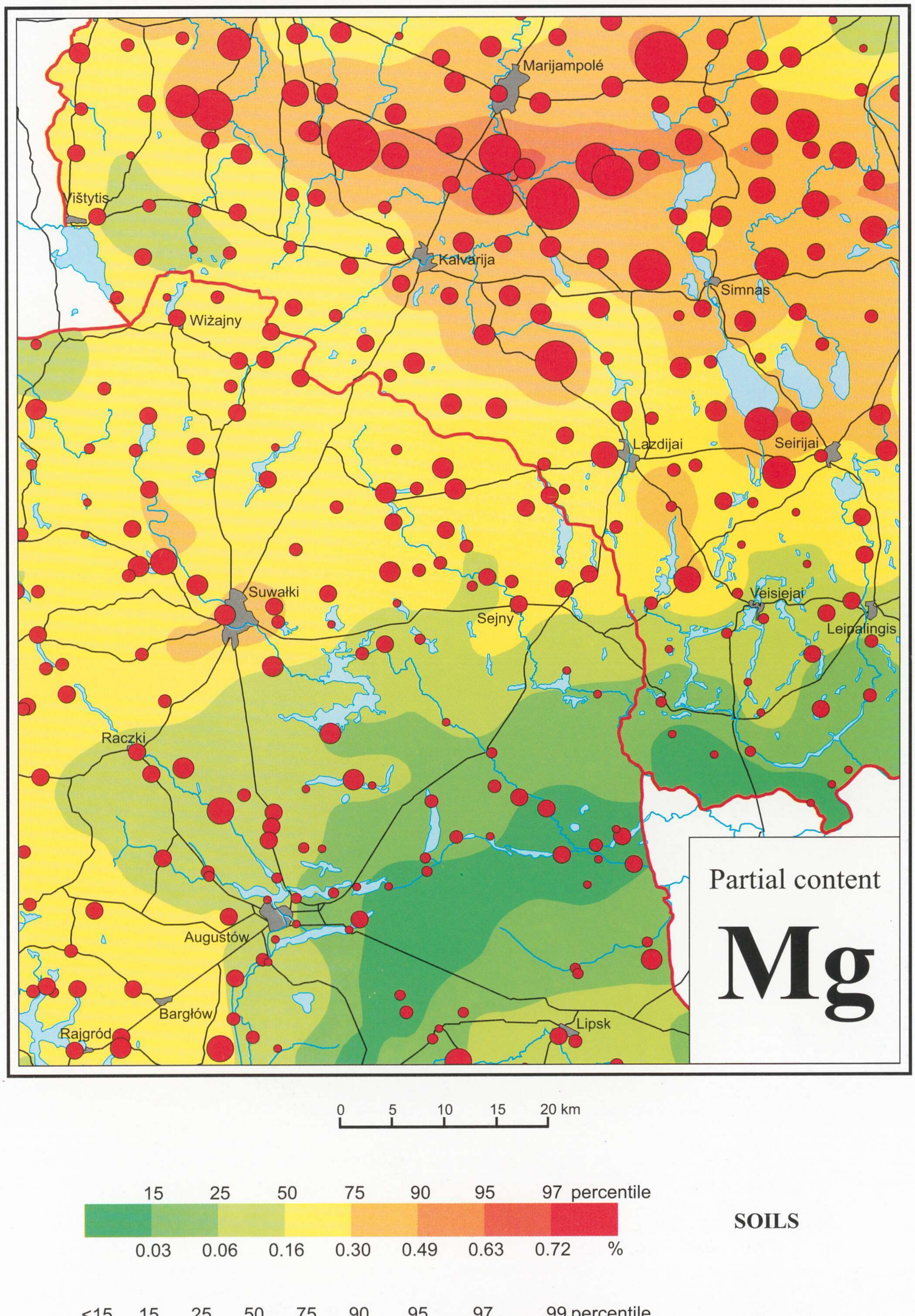
SOILS

	15	25	50	75	90	95	97 percentile
	0.06	0.15	0.43	1.47	2.64	3.44	3.86 %

WATER SEDIMENTS

<15	15	25	50	75	90	95	97	99 percentile
<2.01	2.24	2.88	3.96	4.98	5.79	6.22	6.93	>6.93 %

MAP OF PARTIAL CONTENT OF MAGNESIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

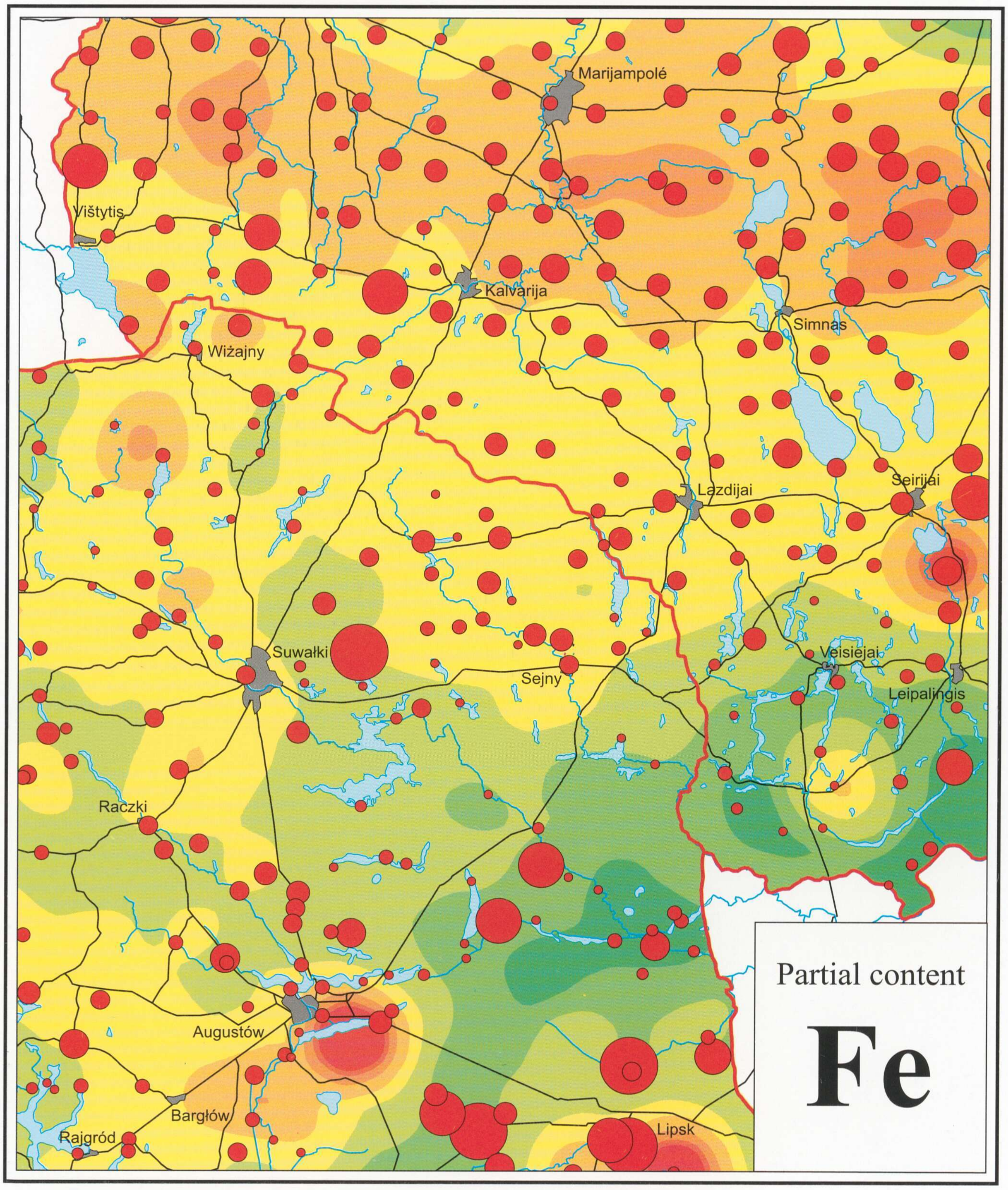
SOILS

percentile	15	25	50	75	90	95	97
%	0.03	0.06	0.16	0.30	0.49	0.63	0.72

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
%	<0.10	0.15	0.28	0.49	0.80	1.04	1.08	1.31	>1.31

MAP OF PARTIAL CONTENT OF IRON IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

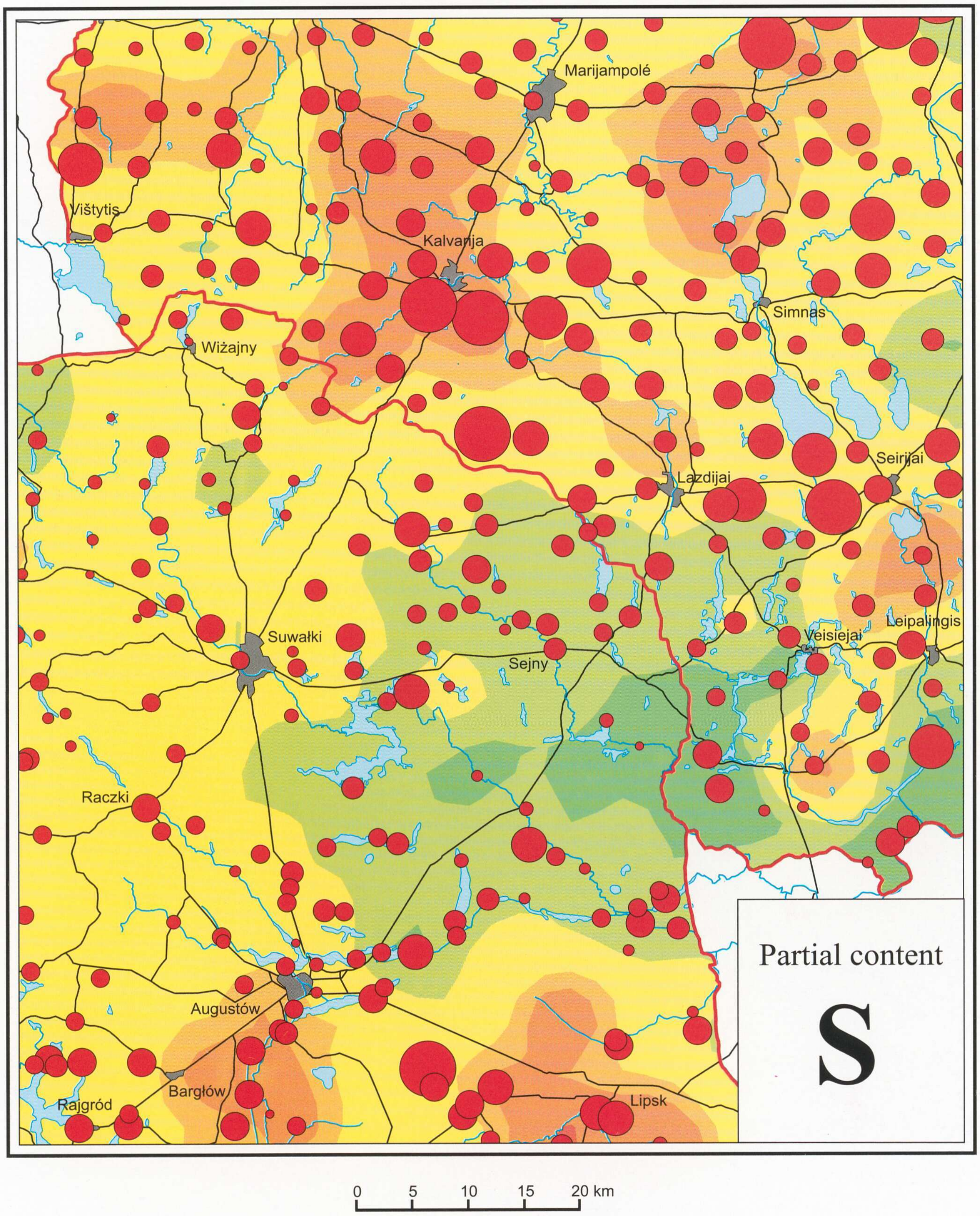
SOILS

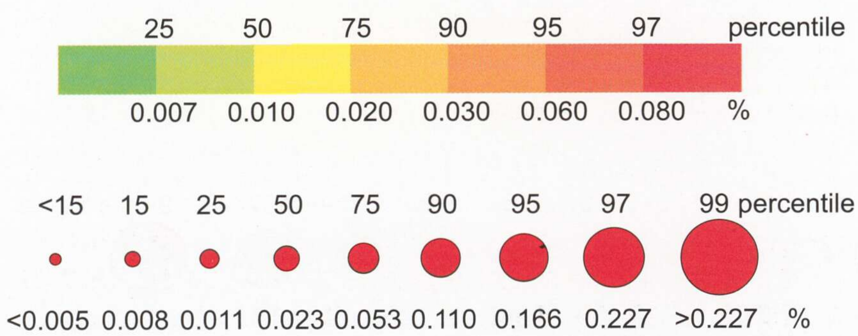
15	25	50	75	90	95	97 percentile
0.29	0.39	0.60	0.87	1.27	1.64	1.87 %

WATER SEDIMENTS

<15	15	25	50	75	90	95	97	99 percentile
<0.17	0.27	0.57	0.91	1.46	2.16	2.55	4.48	>4.48 %

MAP OF PARTIAL CONTENT OF SULPHUR IN SOILS AND WATER SEDIMENTS

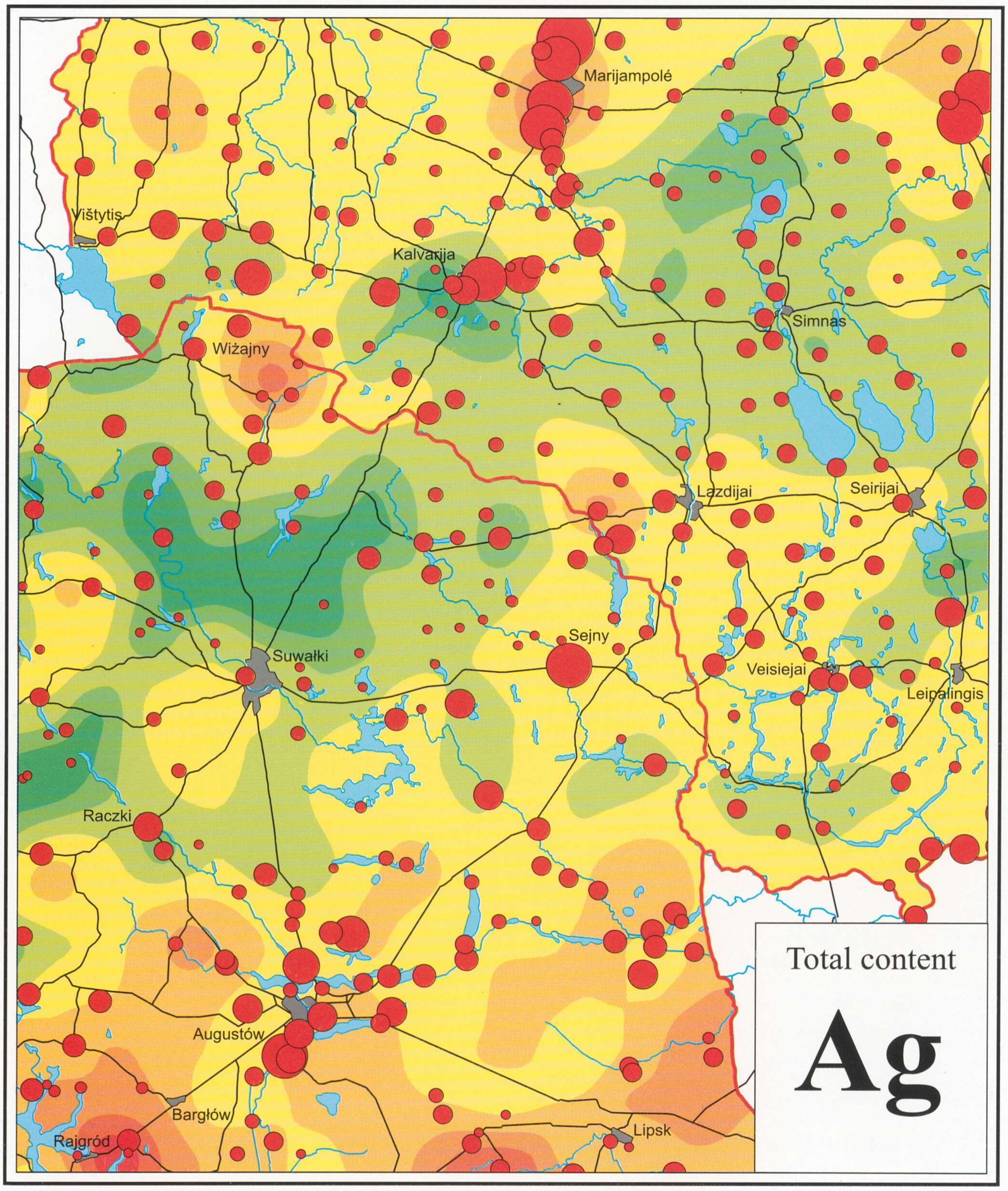




SOILS

WATER SEDIMENTS

MAP OF TOTAL CONTENT OF SILVER IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

SOILS

15 25 50 75 90 95 97 percentile

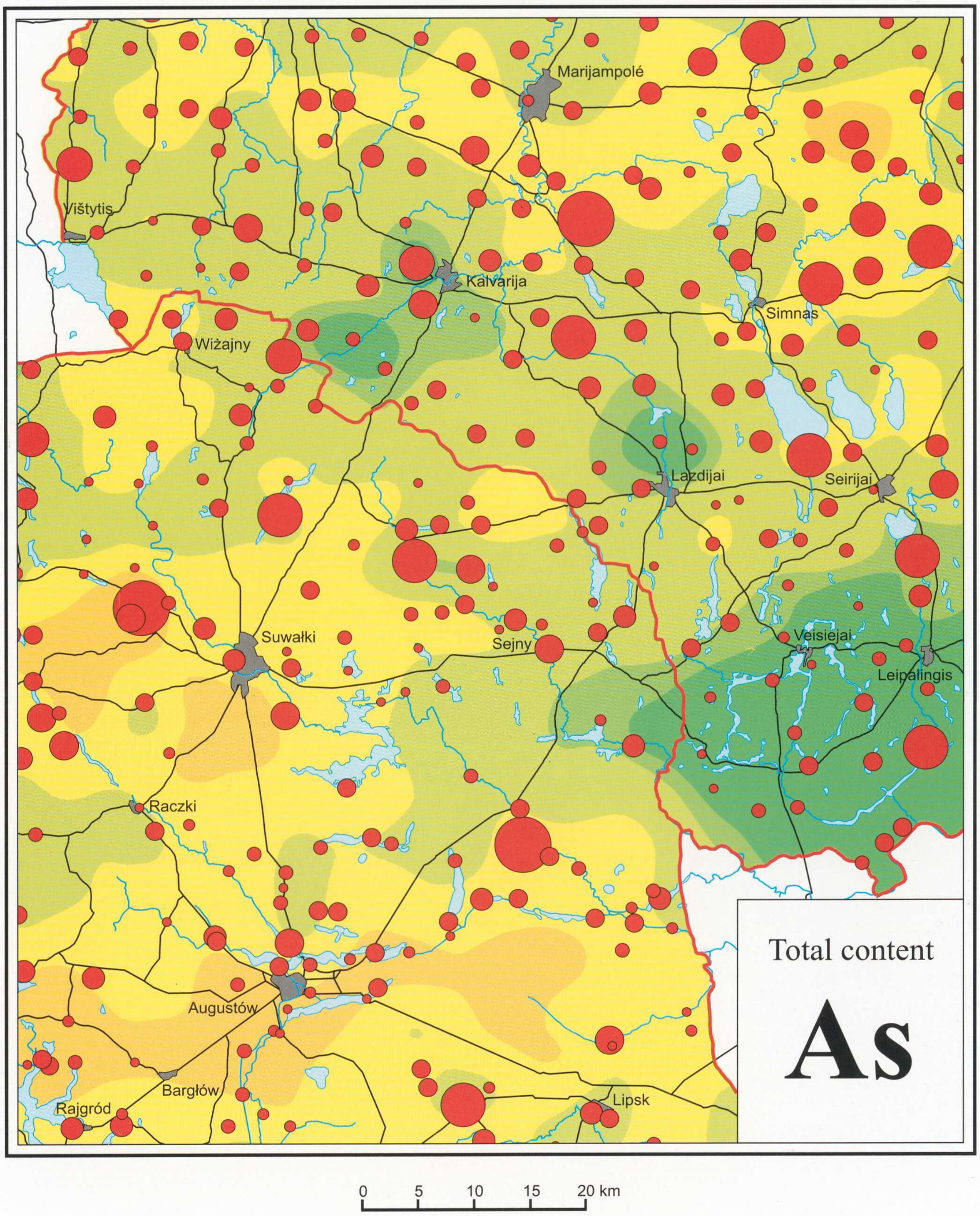
0.04 0.05 0.06 0.07 0.09 0.11 0.13 ppm

WATER SEDIMENTS

<15 15 25 50 75 90 95 97 99 percentile

<0.04 0.05 0.06 0.09 0.12 0.16 0.21 0.77 >0.77 ppm

MAP OF TOTAL CONTENT OF ARSENIC IN SOILS AND WATER SEDIMENTS



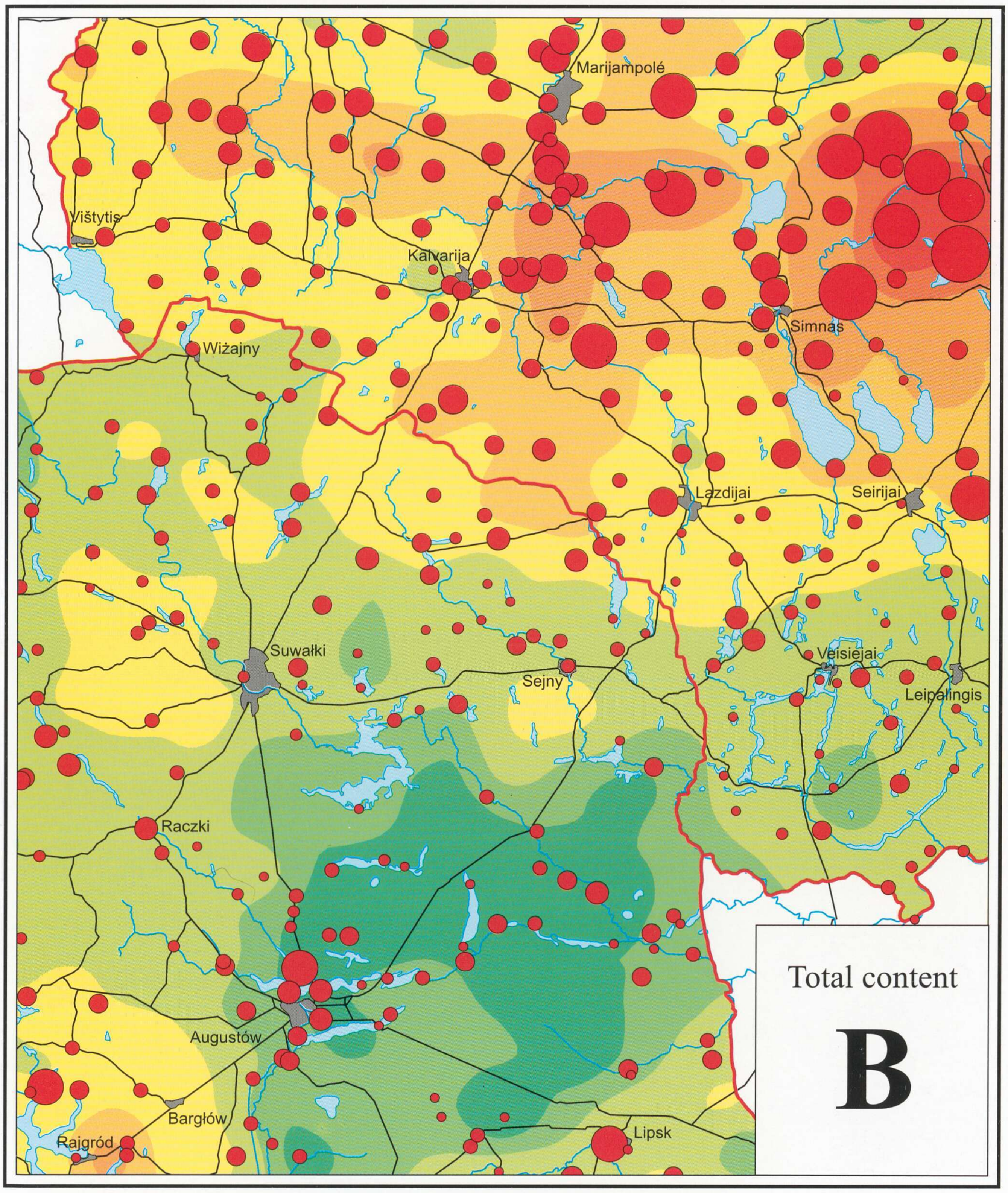
SOILS

	15	25	50	75	90	95	97 percentile
	2.7	3.0	3.7	4.2	4.6	4.8	4.9 ppm

WATER SEDIMENTS

<15	15	25	50	75	90	95	97	99 percentile
<2.5	2.9	3.5	4.1	4.8	5.0	5.1	5.4	>5.4 ppm

MAP OF TOTAL CONTENT OF BORON IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

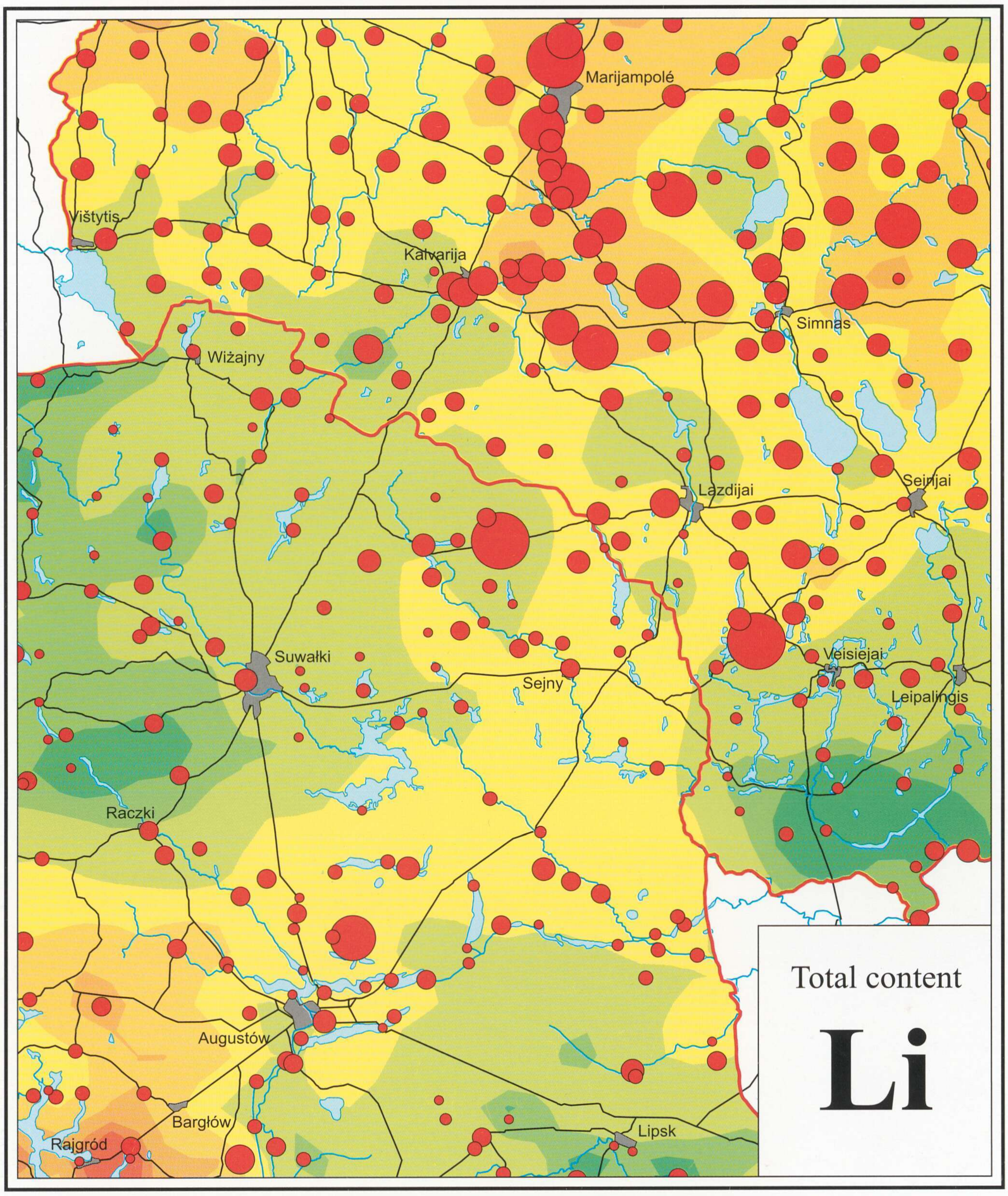
SOILS

percentile	15	25	50	75	90	95	97
ppm	18.6	21.6	26.2	31.4	36.3	43.6	48.2

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<23.4	25.1	29.1	35.3	43.1	49.5	53.6	68.3	>68.3

MAP OF TOTAL CONTENT OF LITHIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

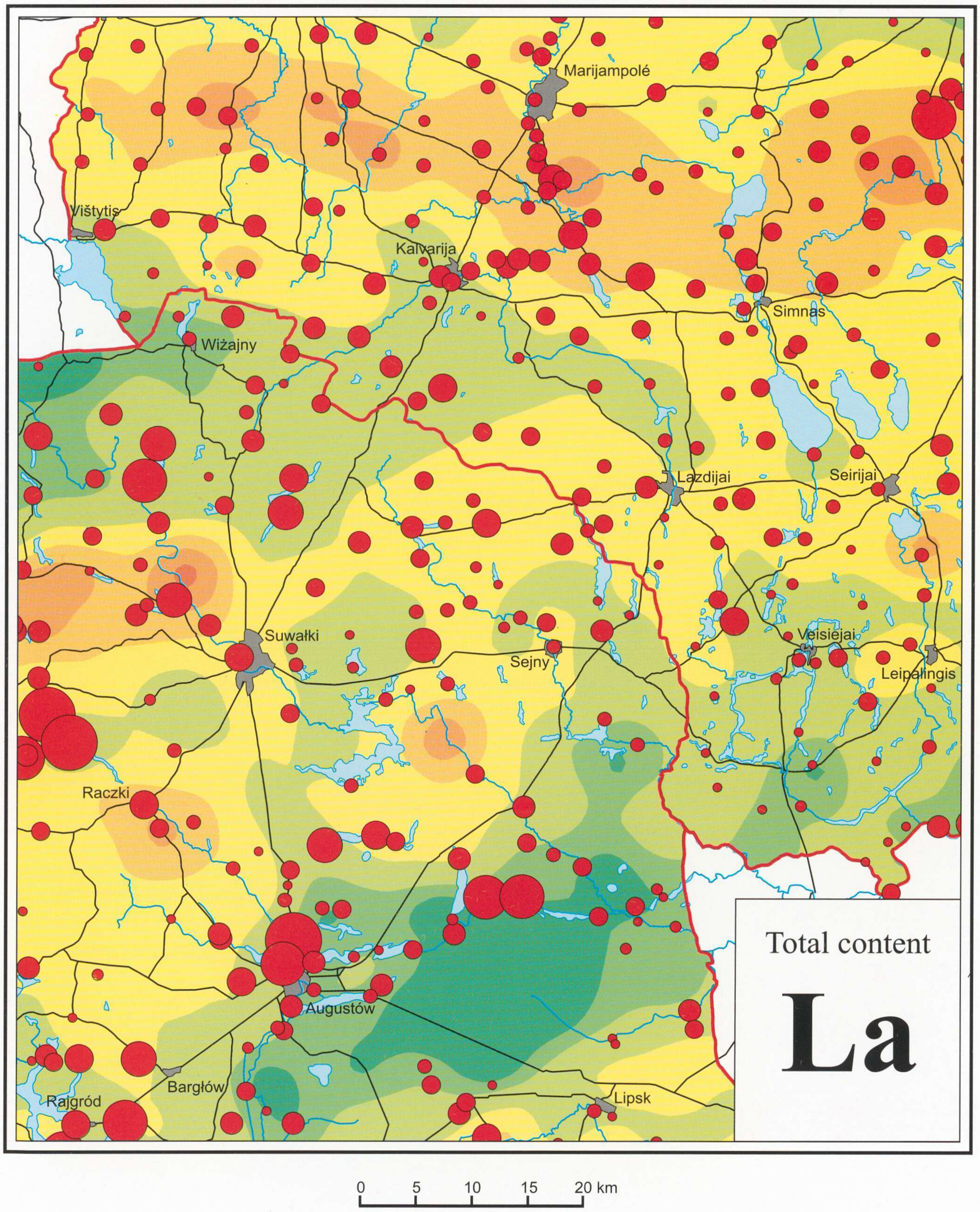
SOILS

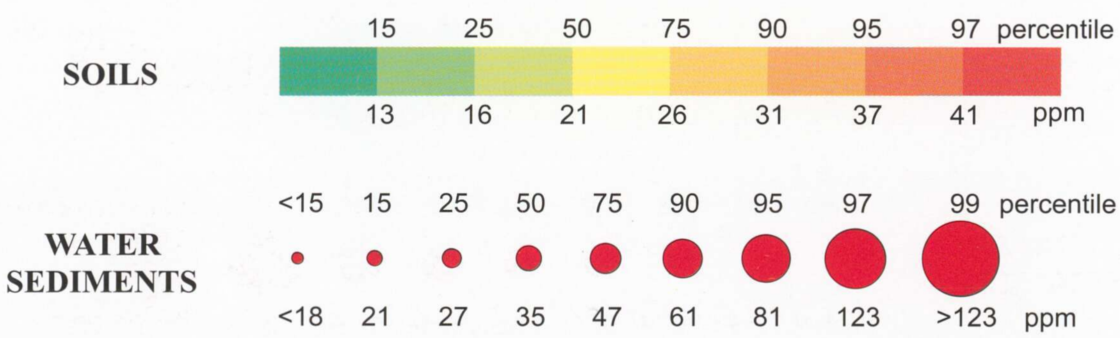
percentile	15	25	50	75	90	95	97
ppm	8.8	10.0	13.2	16.5	19.3	21.5	22.8

WATER SEDIMENTS

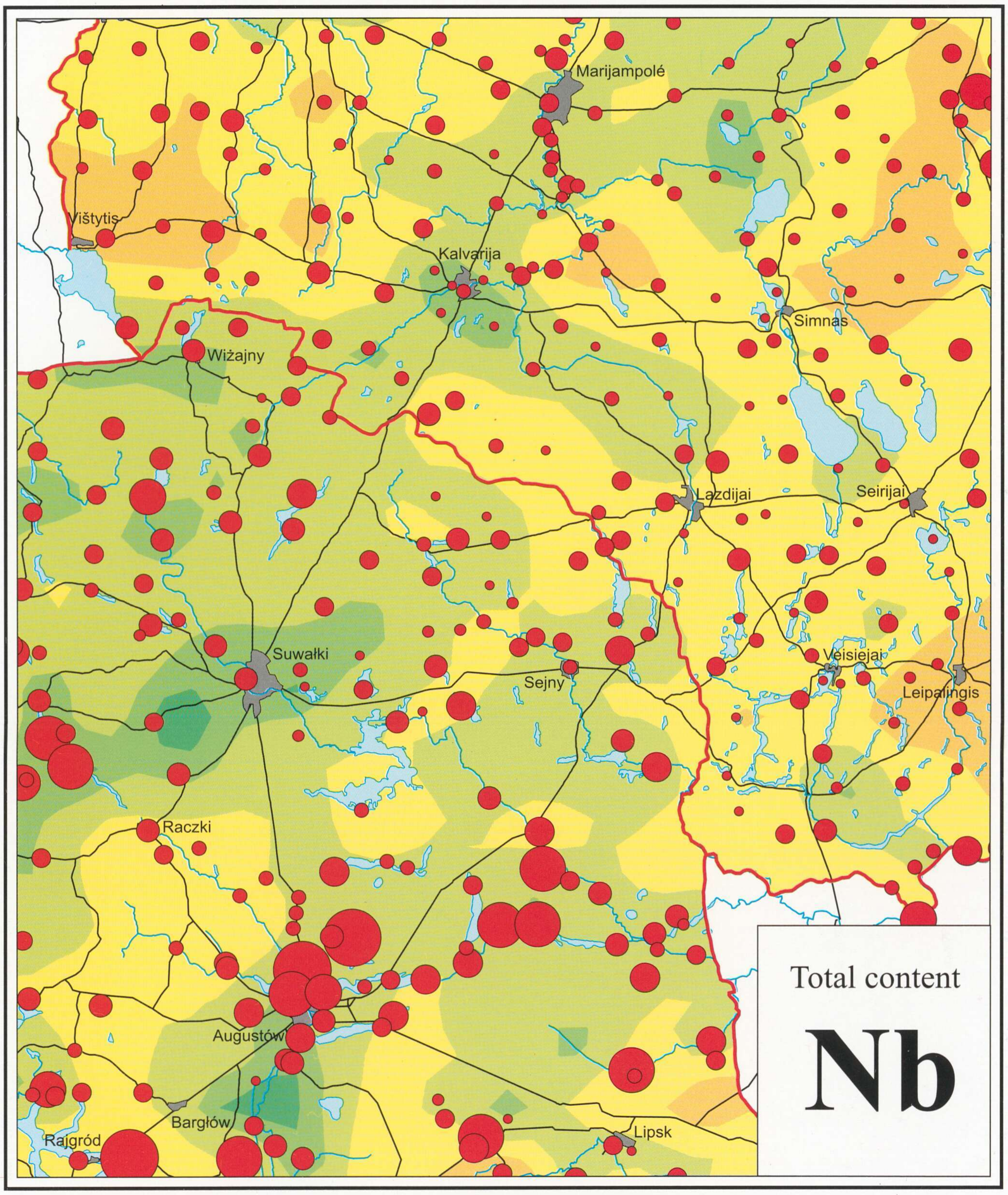
percentile	<15	15	25	50	75	90	95	97	99
ppm	<6.7	7.8	10.7	14.6	19.5	22.6	23.9	27.6	>27.6

MAP OF TOTAL CONTENT OF LANTHANUM IN SOILS AND WATER SEDIMENDS





MAP OF TOTAL CONTENT OF NIOBIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

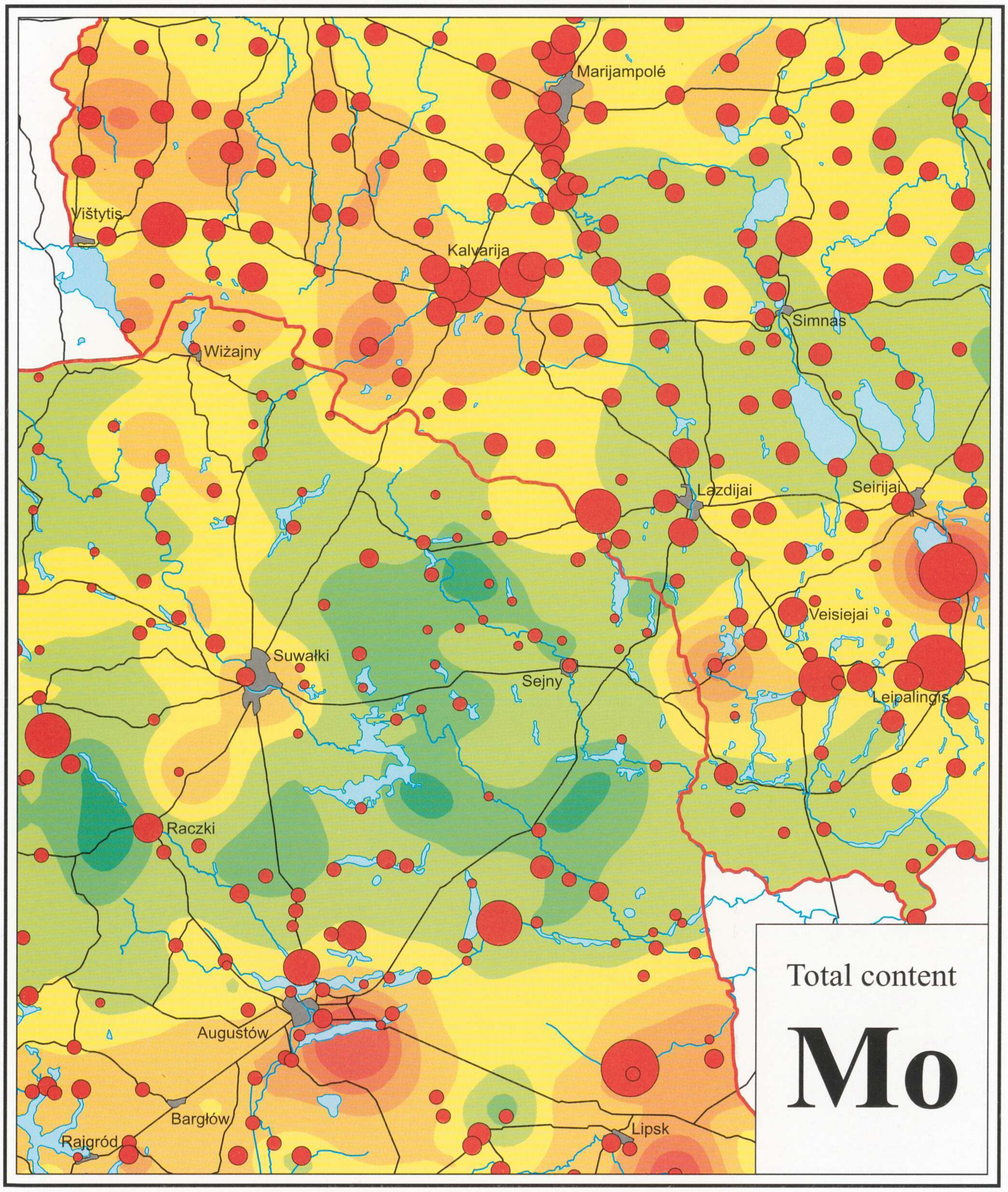
SOILS

percentile	15	25	50	75	90	95	97
ppm	8.6	9.8	12.3	14.7	16.7	17.7	18.1

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<8.0	9.2	12.0	15.7	19.5	22.9	27.2	46.4	>46.4

MAP OF TOTAL CONTENT OF MOLYBDENUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

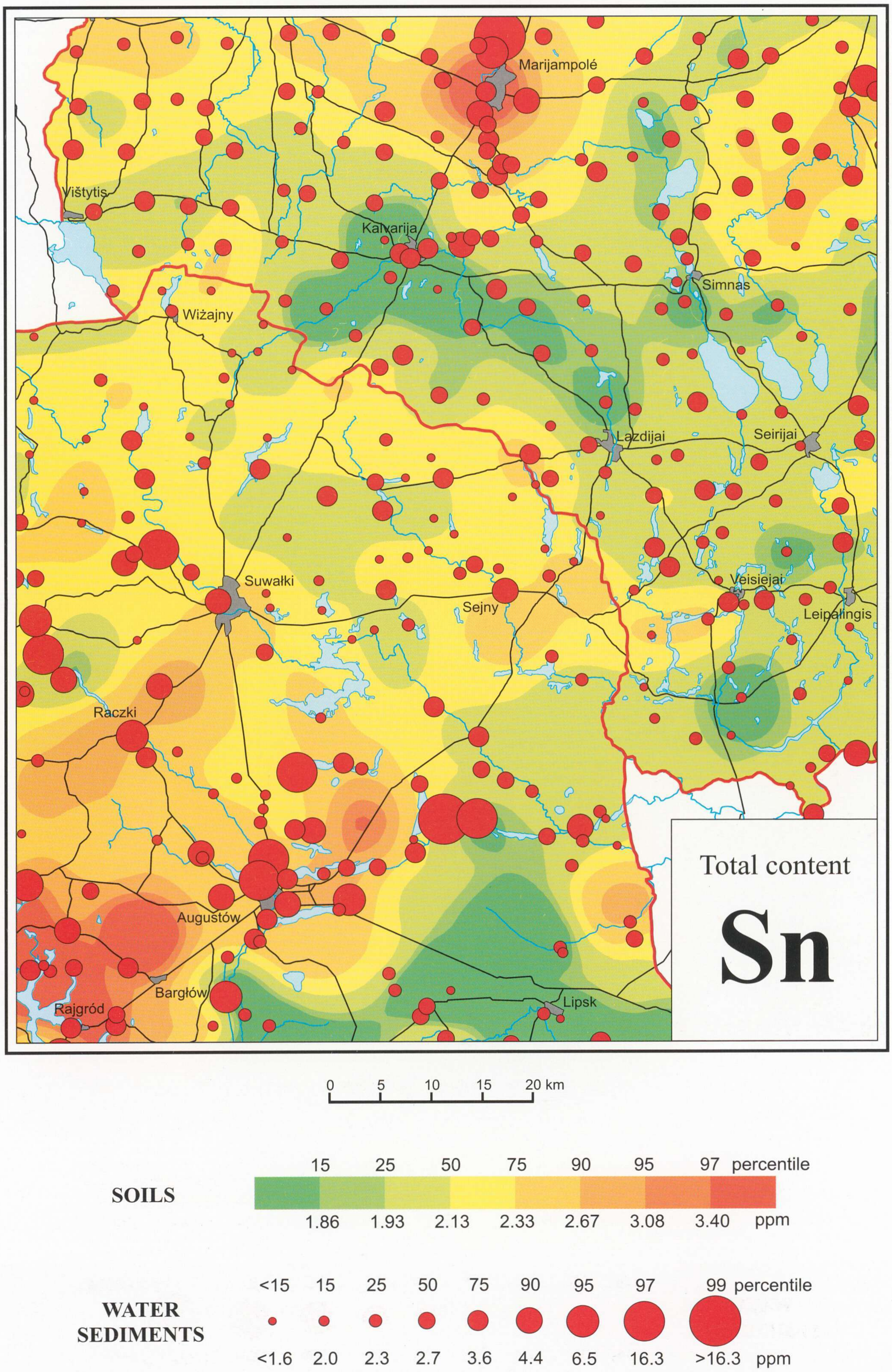
SOILS

15	25	50	75	90	95	97	percentile
0.53	0.58	0.65	0.73	0.86	1.00	1.16	ppm

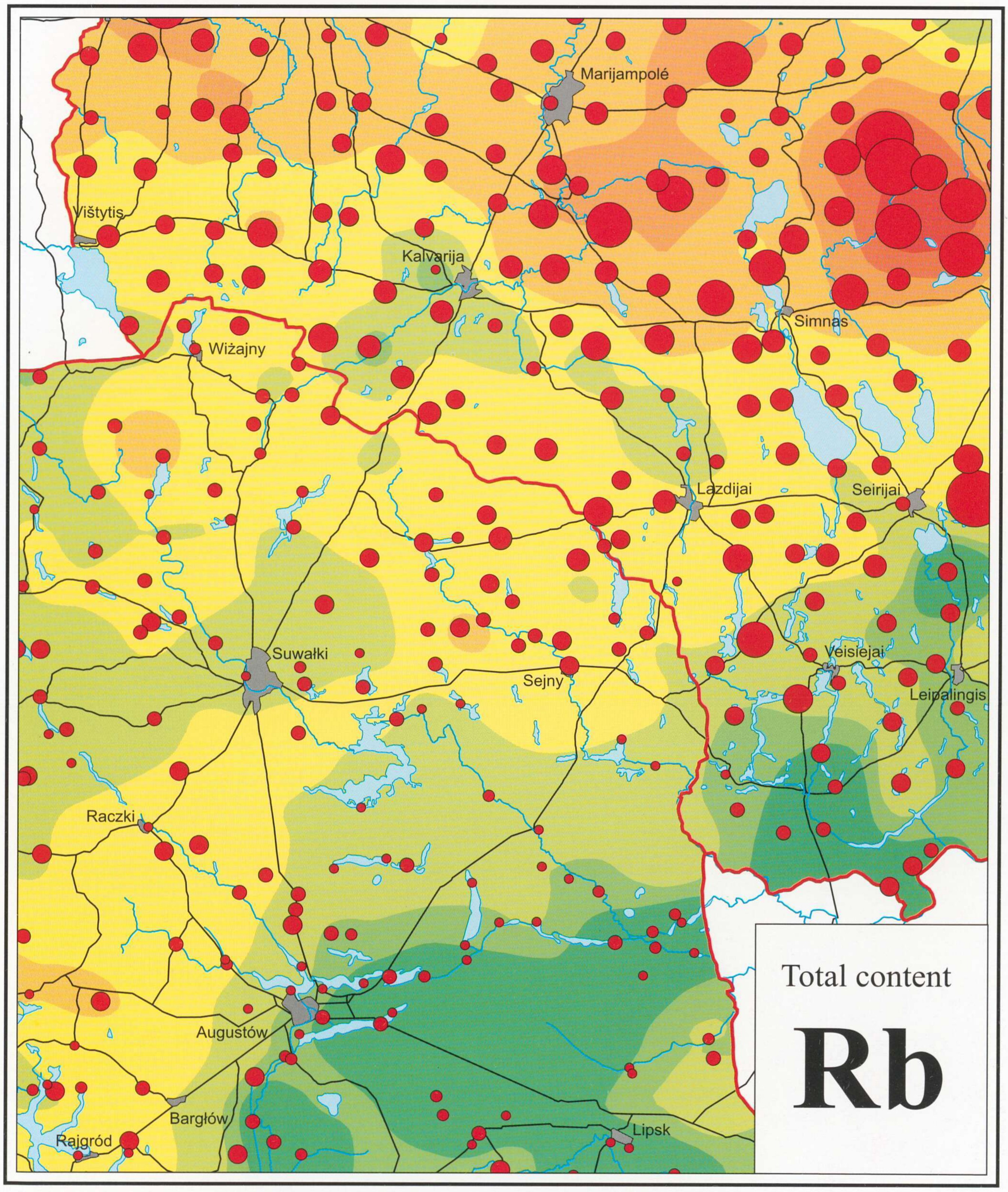
WATER SEDIMENTS

<15	15	25	50	75	90	95	97	99	percentile
<0.5	0.6	0.8	1.2	1.5	1.9	2.2	2.6	>2.6	ppm

MAP OF TOTAL CONTENT OF TIN IN SOILS AND WATER SEDIMENTS



MAP OF TOTAL CONTENT OF RUBIDIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

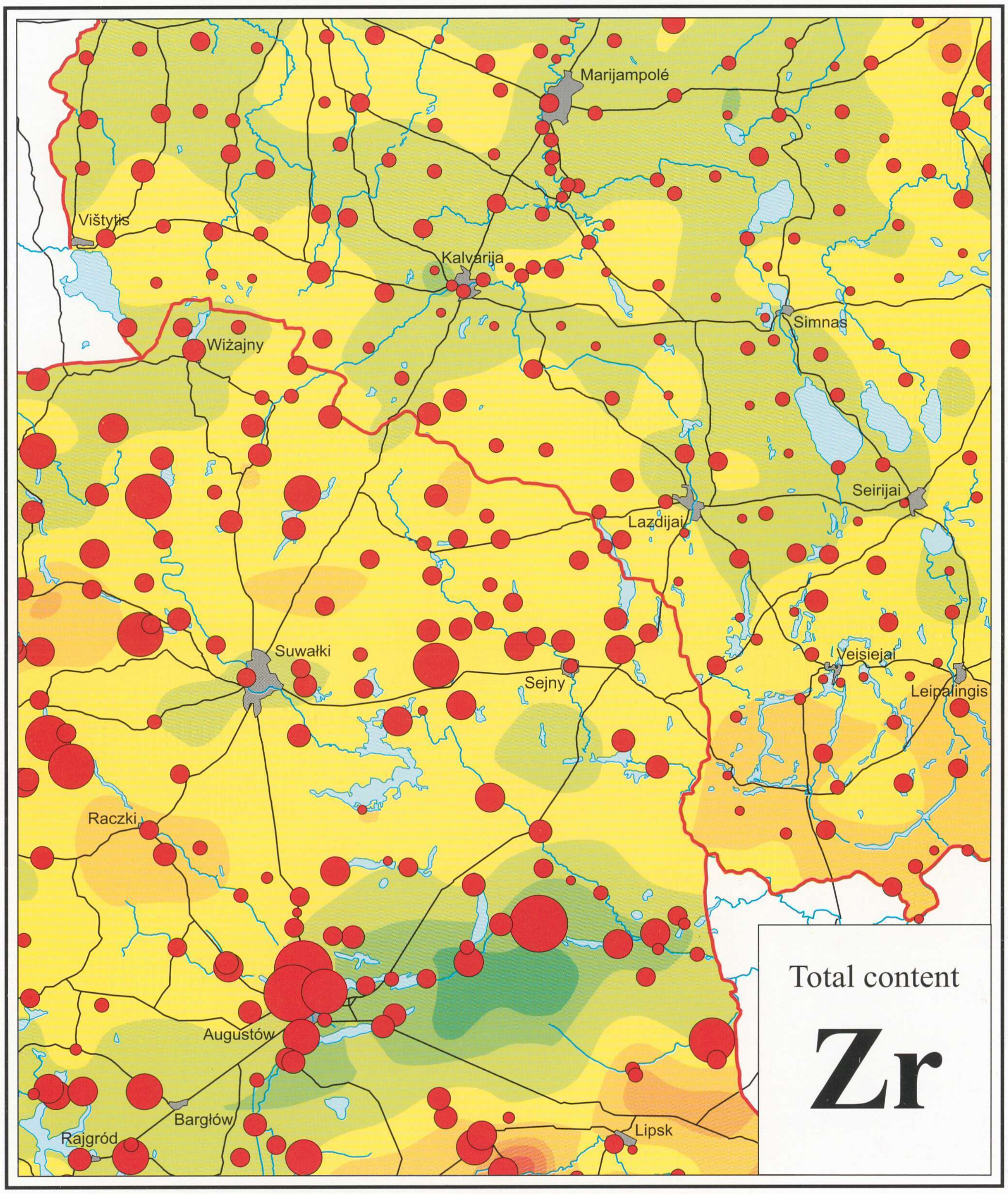
SOILS

Percentile	15	25	50	75	90	95	97
ppm	43	48	59	72	90	104	116

WATER SEDIMENTS

Percentile	<15	15	25	50	75	90	95	97	99
ppm	<34	38	49	68	85	98	105	121	>121

MAP OF TOTAL CONTENT OF ZIRCONIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

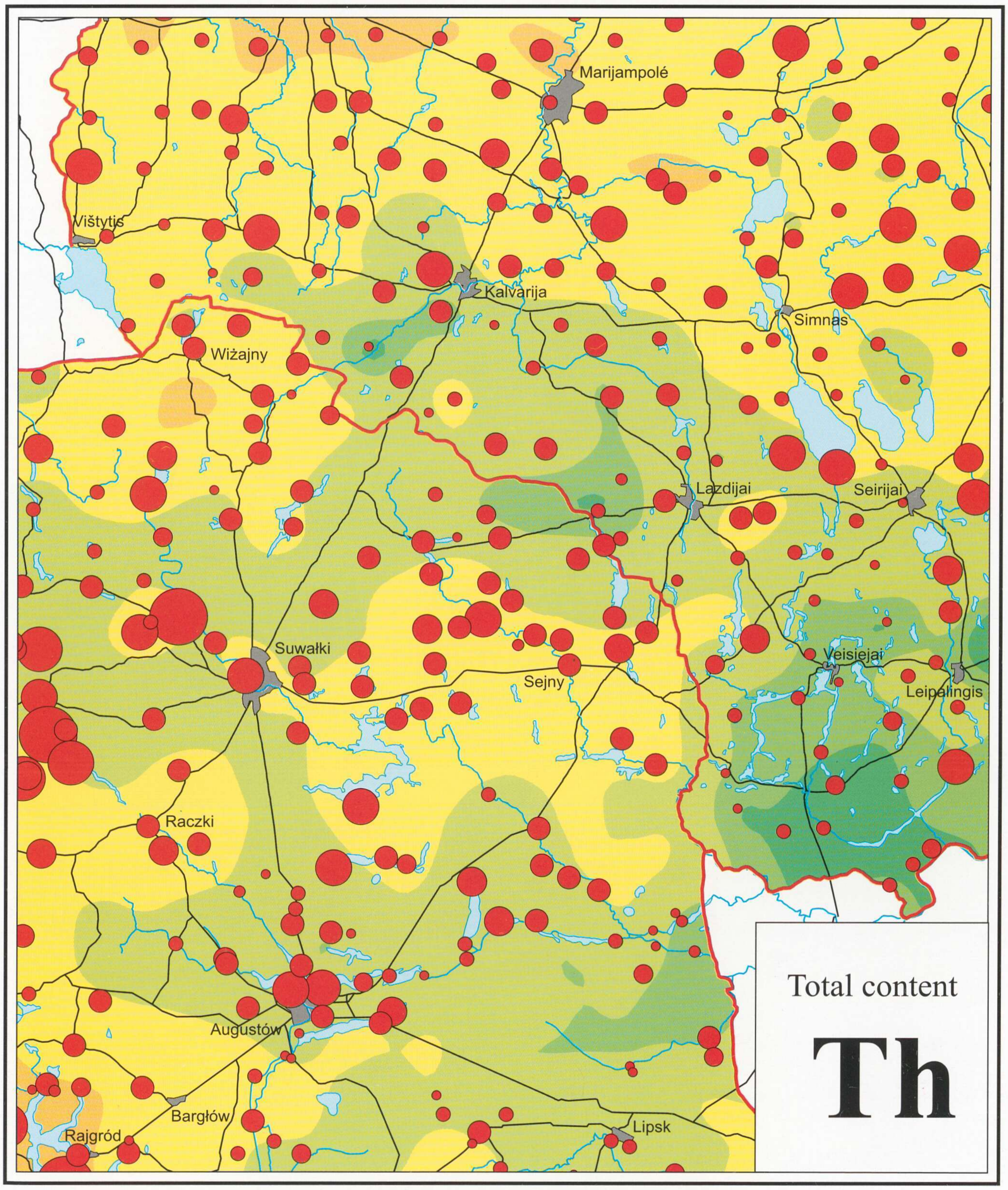
SOILS

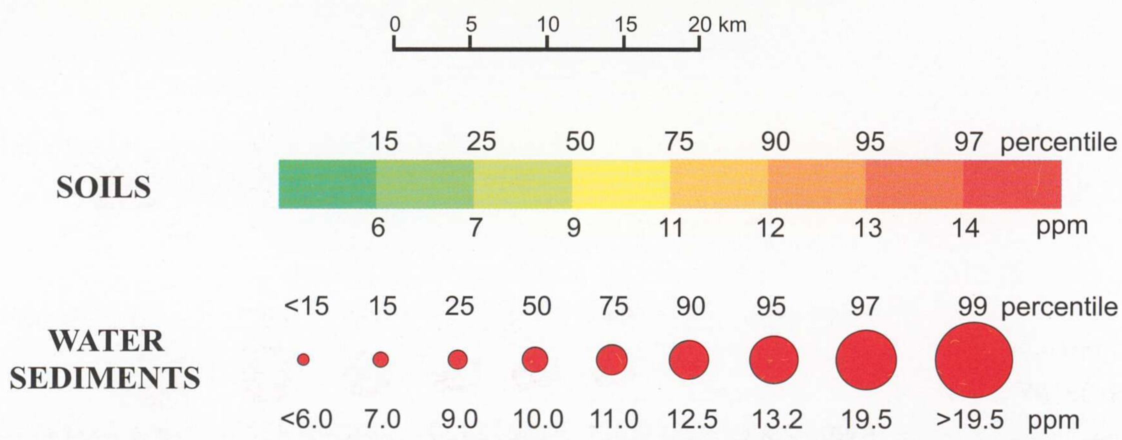
percentile	15	25	50	75	90	95	97
ppm	164	196	296	437	567	644	733

WATER SEDIMENTS

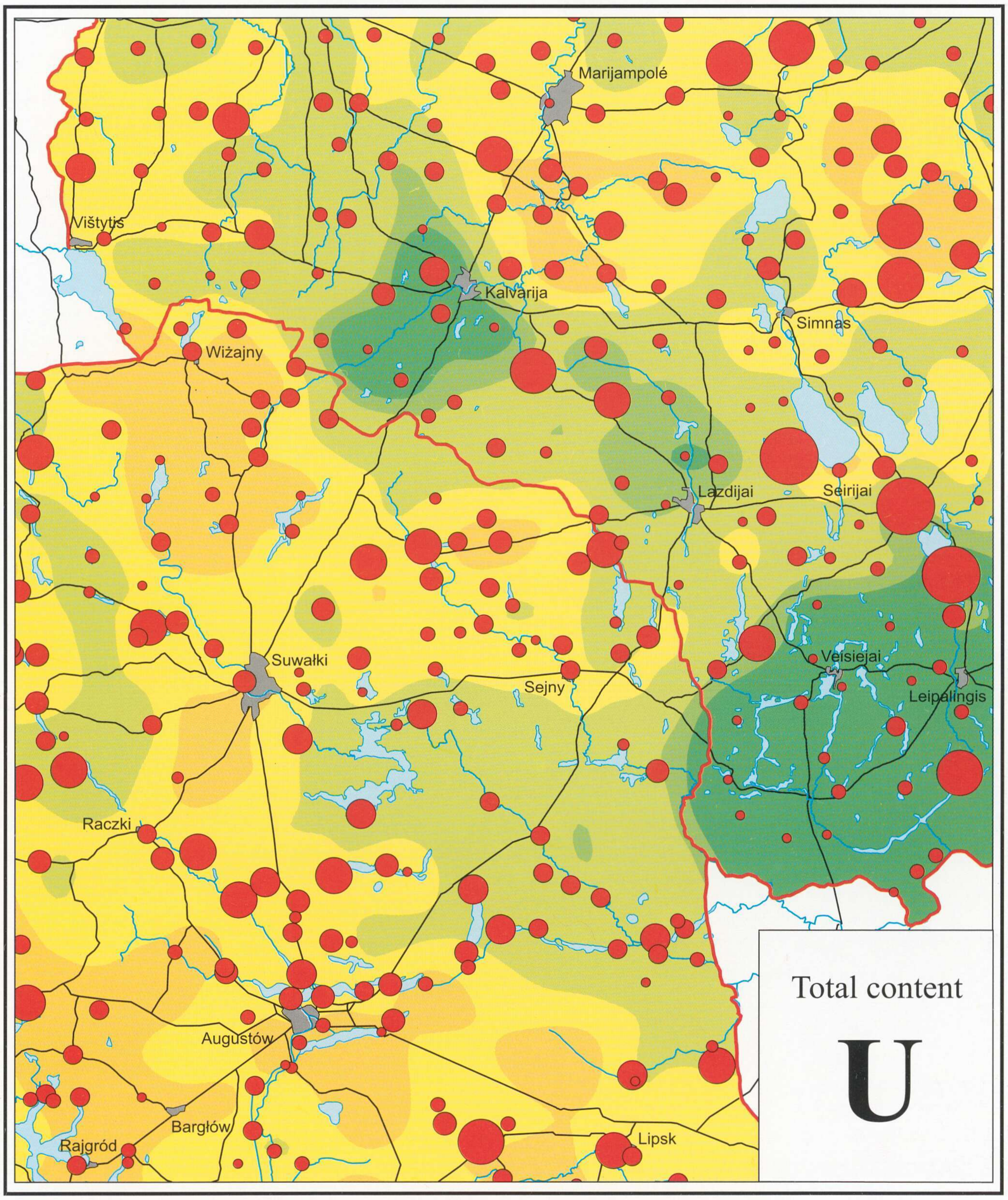
percentile	<15	15	25	50	75	90	95	97	99
ppm	<190	252	395	733	1276	2230	2681	4273	>4273

MAP OF TOTAL CONTENT OF THORIUM IN SOILS AND WATER SEDIMENTS





MAP OF TOTAL CONTENT OF URANIUM IN SOILS AND WATER SEDIMENTS



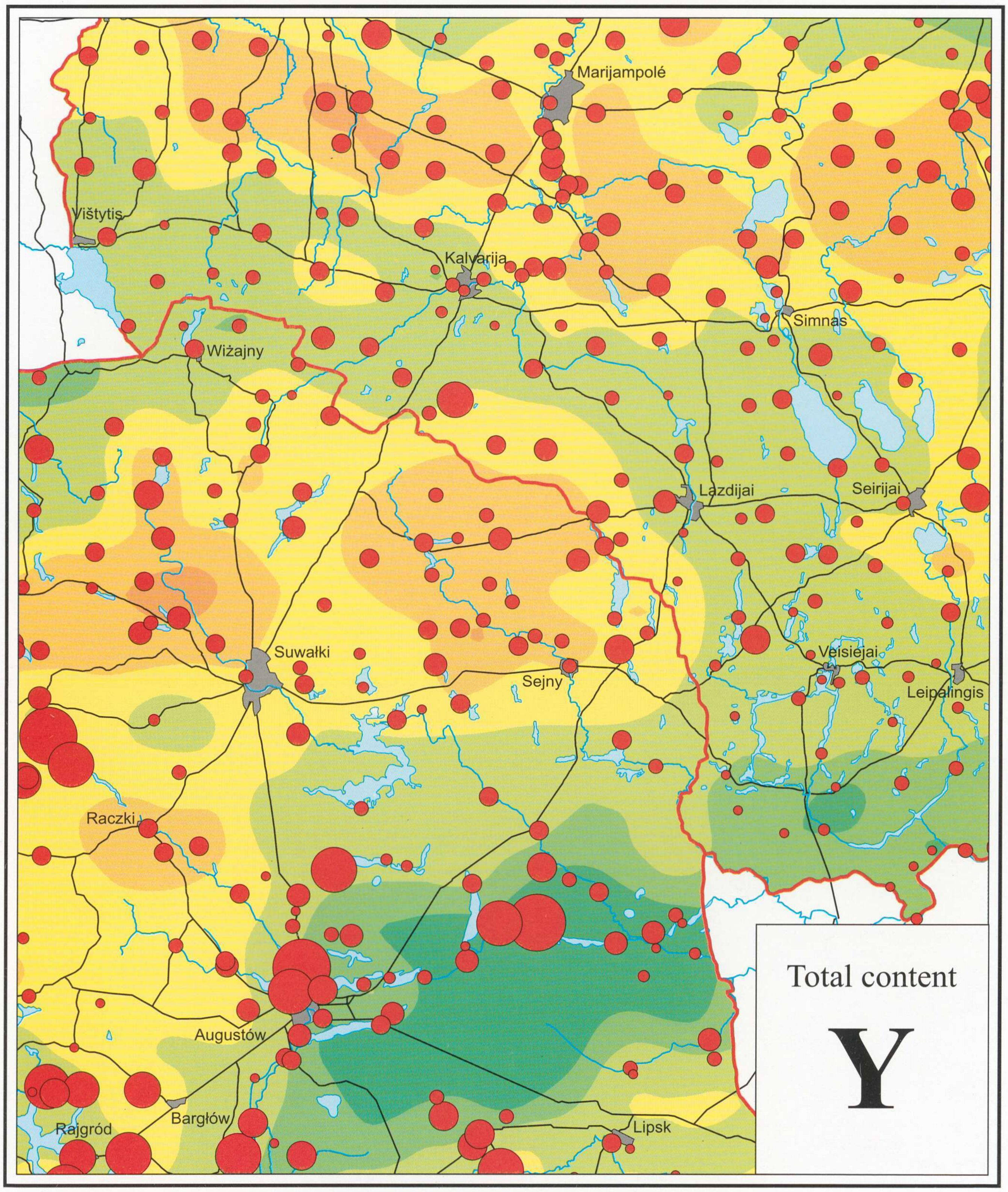
SOILS

percentile	15	25	50	75	90	95	97
ppm	2.2	2.4	2.8	3.1	3.5	3.8	3.9

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<2.2	2.4	2.9	3.7	4.0	4.1	4.3	4.6	>4.6

MAP OF TOTAL CONTENT OF YTTRIUM IN SOILS AND WATER SEDIMENTS



0 5 10 15 20 km

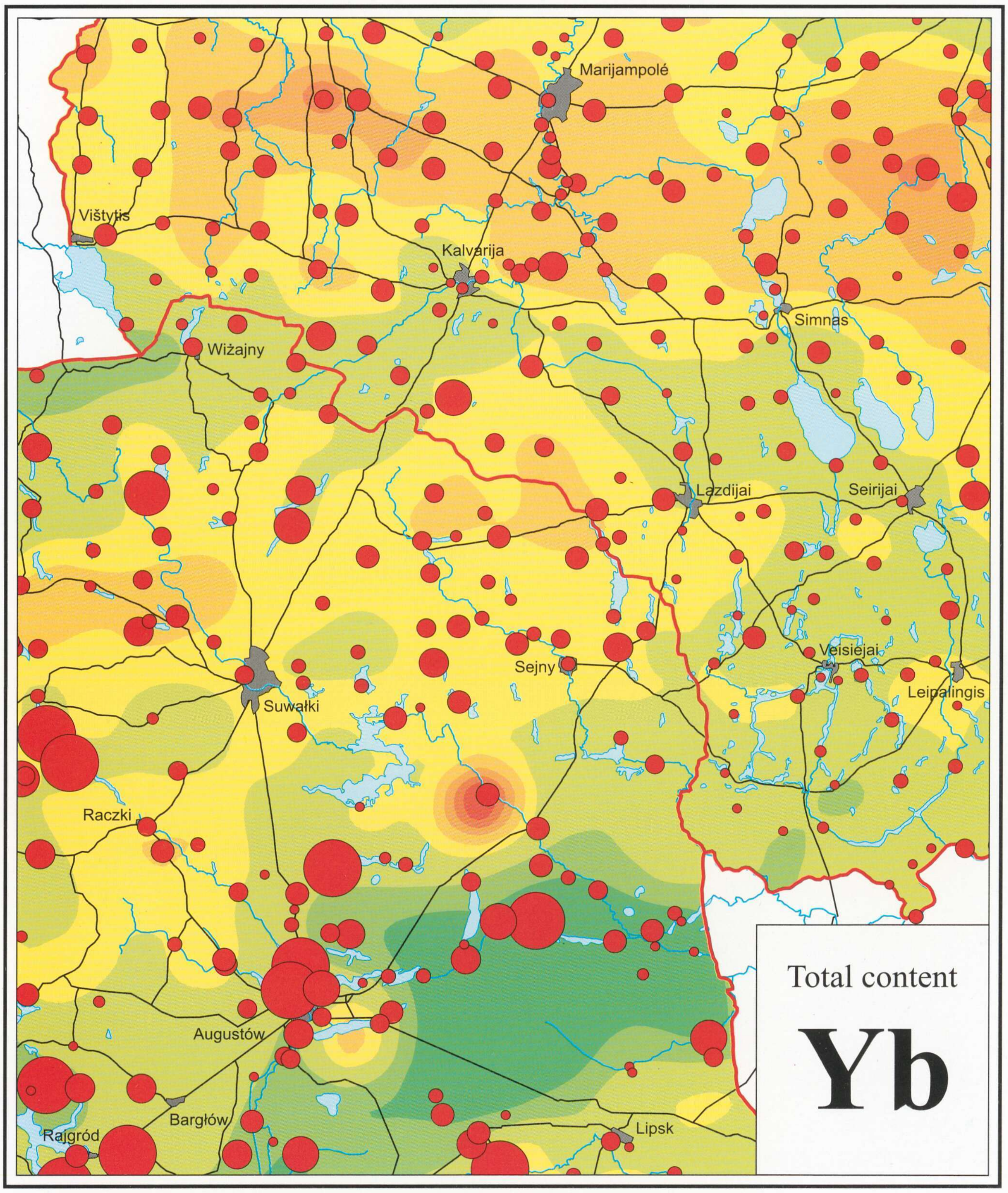
SOILS

percentile	15	25	50	75	90	95	97
ppm	9.2	11.7	16.2	19.6	23.8	26.4	27.5

WATER SEDIMENTS

percentile	<15	15	25	50	75	90	95	97	99
ppm	<11.6	14.0	19.1	23.4	29.4	34.8	44.1	71.6	>71.6

MAP OF TOTAL CONTENT OF YTTERBIUM IN SOILS AND WATER SEDIMENTS



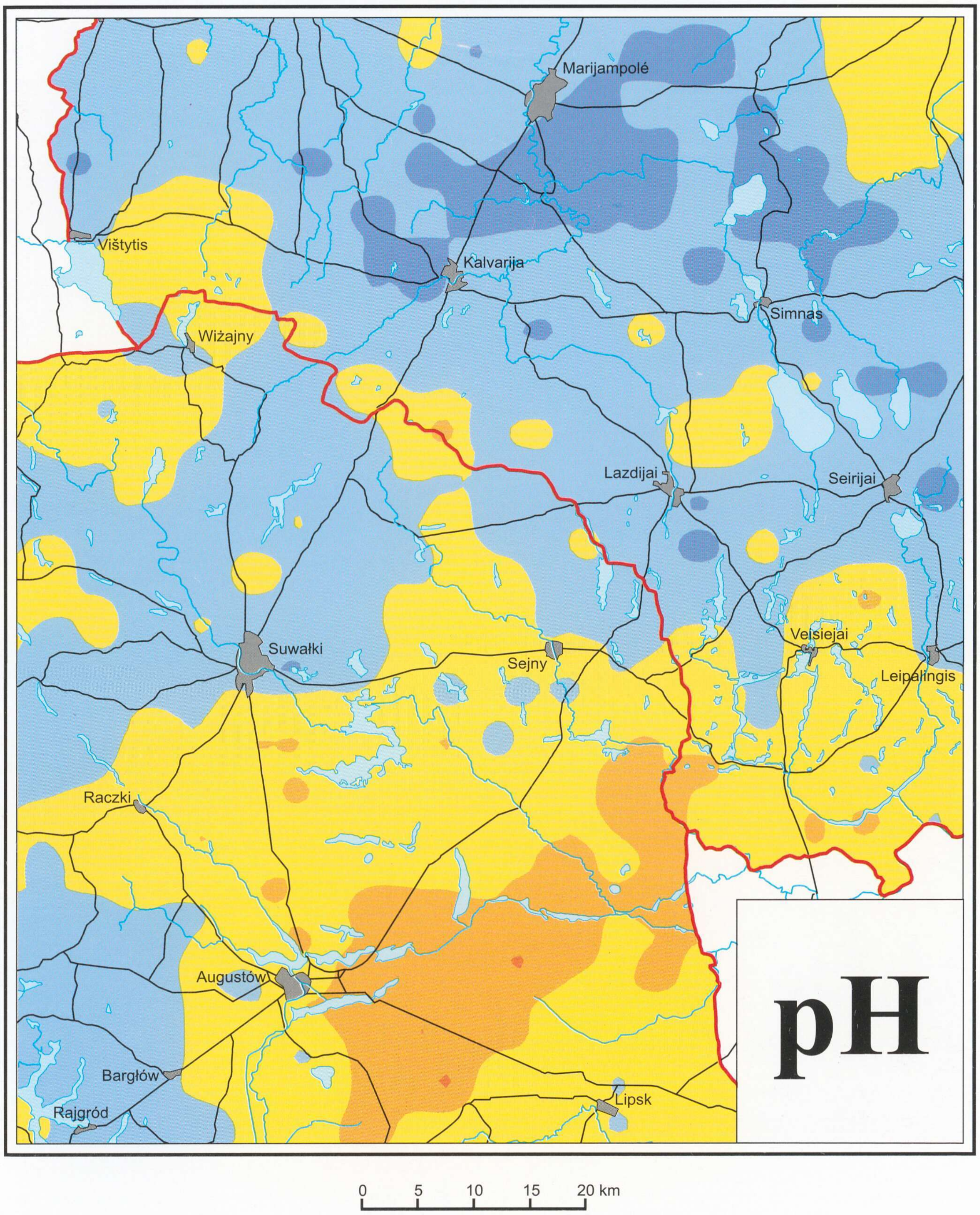
SOILS

	15	25	50	75	90	95	97	percentile
	1.0	1.3	1.9	2.4	2.9	3.3	3.8	ppm

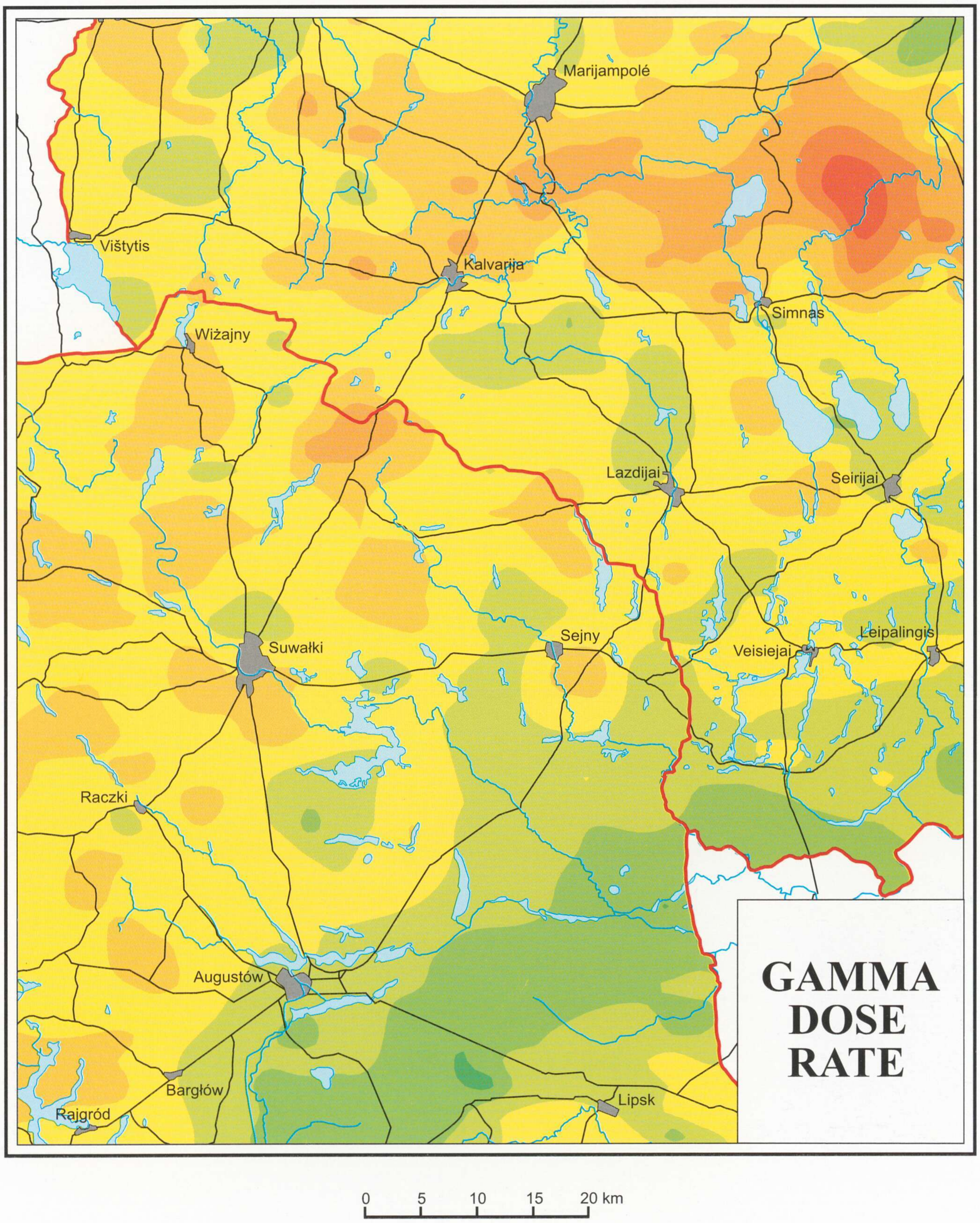
WATER SEDIMENTS

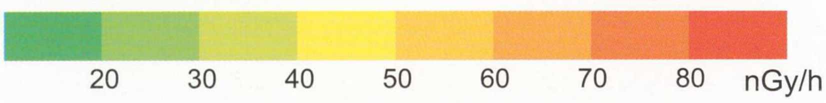
<15	15	25	50	75	90	95	97	99	percentile
<1.5	1.9	2.5	3.1	3.7	4.2	5.4	7.5	>7.5	ppm

MAP OF ACIDITY OF SOILS

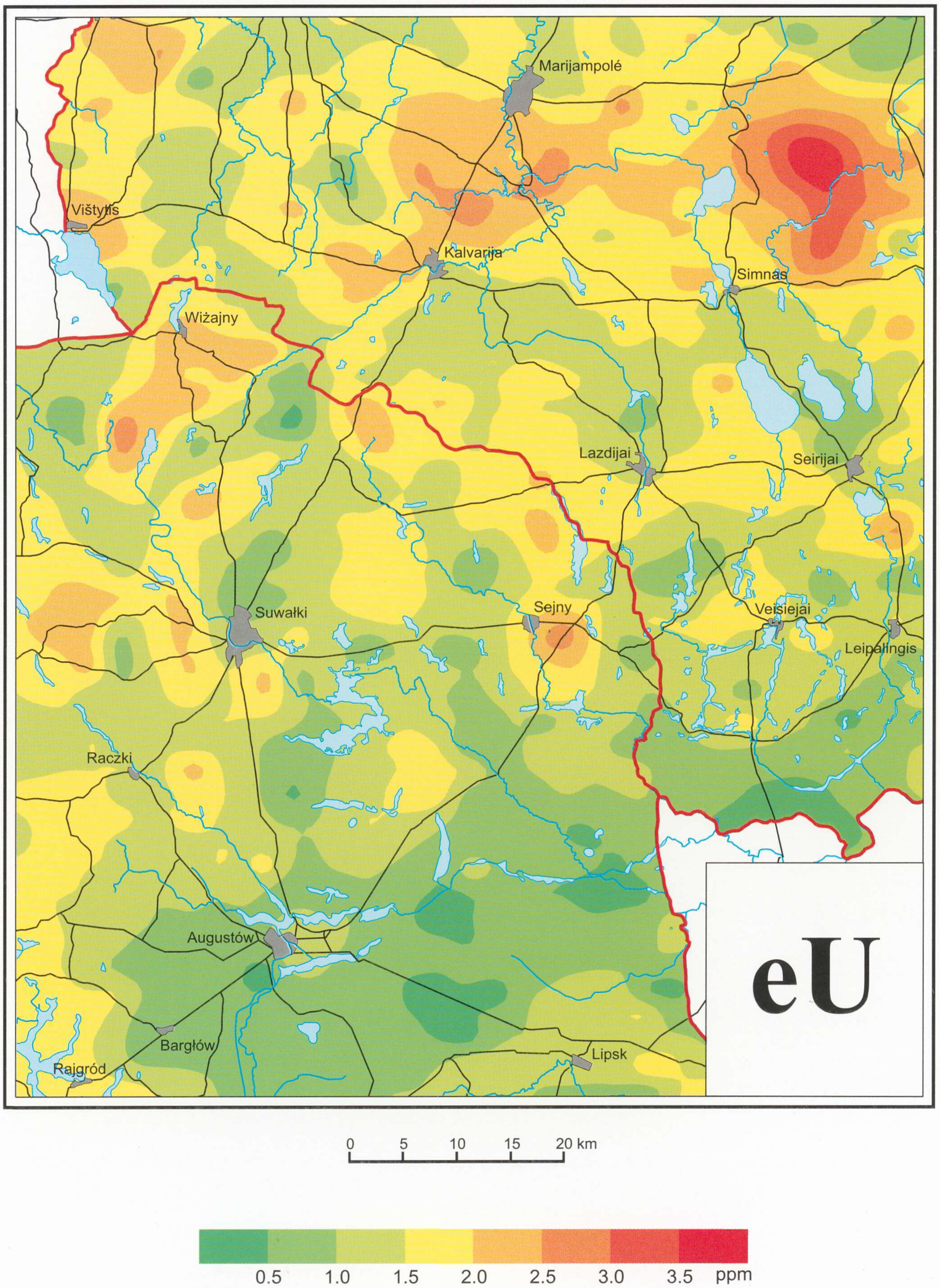


MAP OF GAMMA RADIATION DOSE

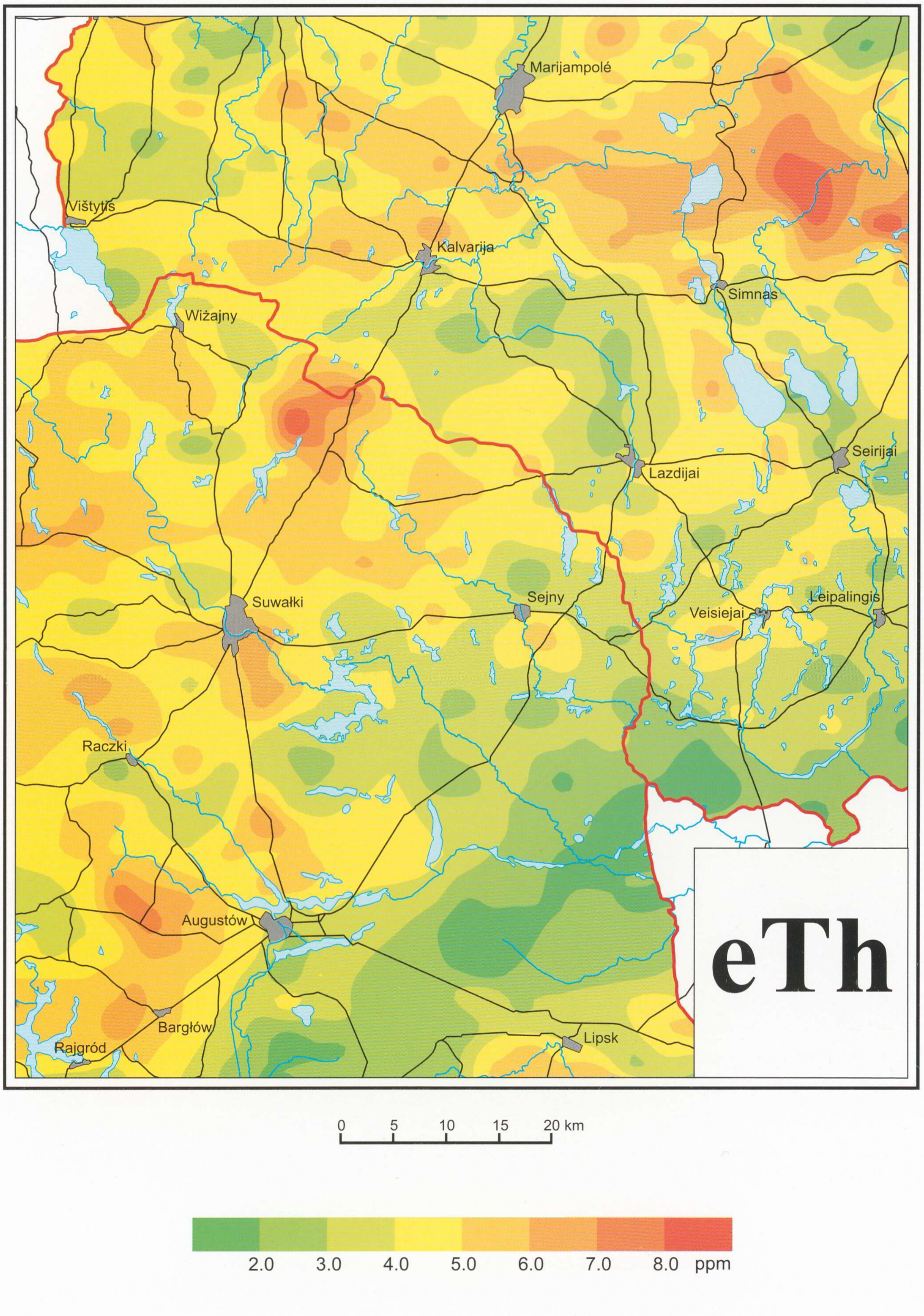




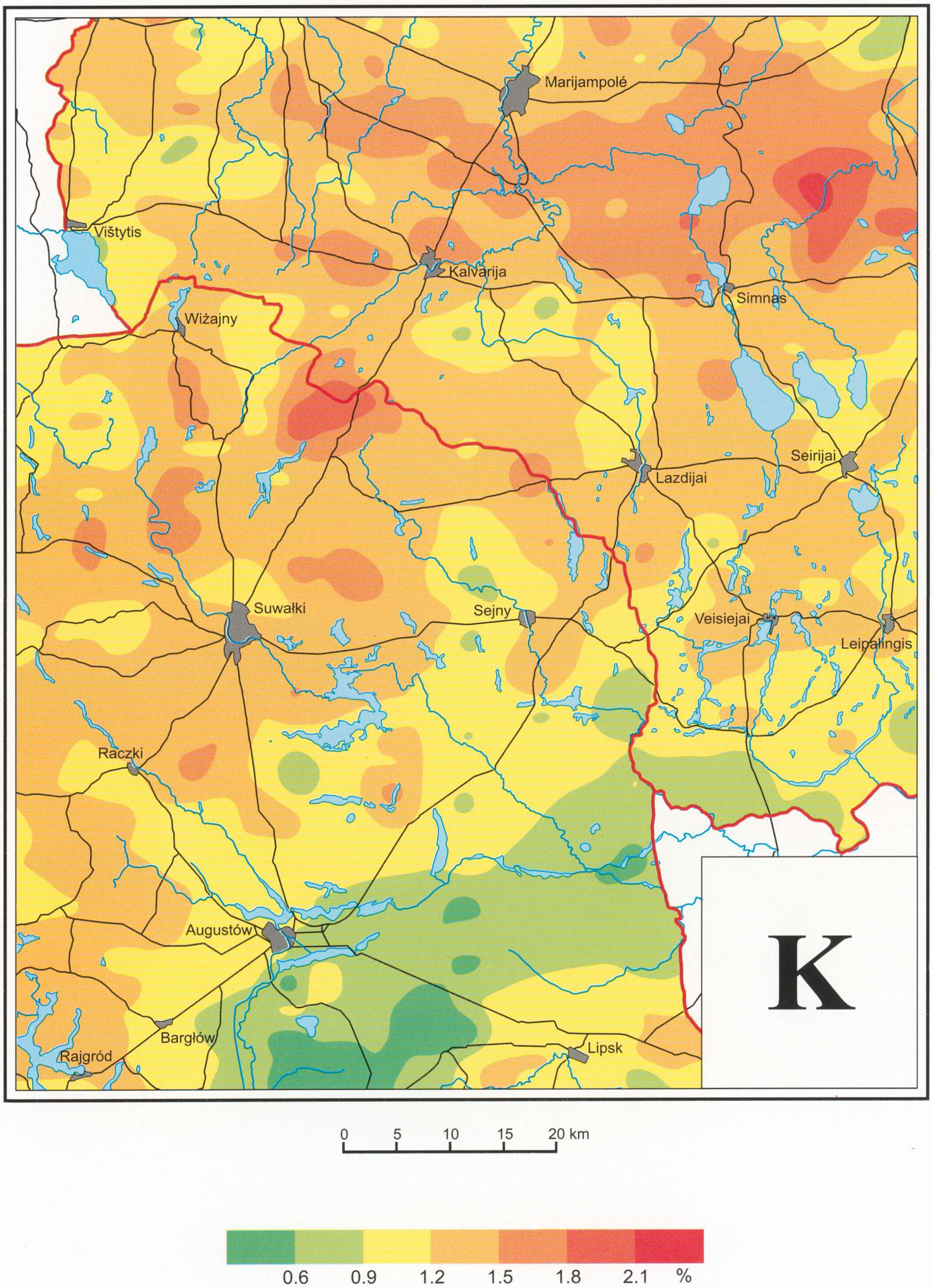
MAP OF URANIUM CONCENTRATION



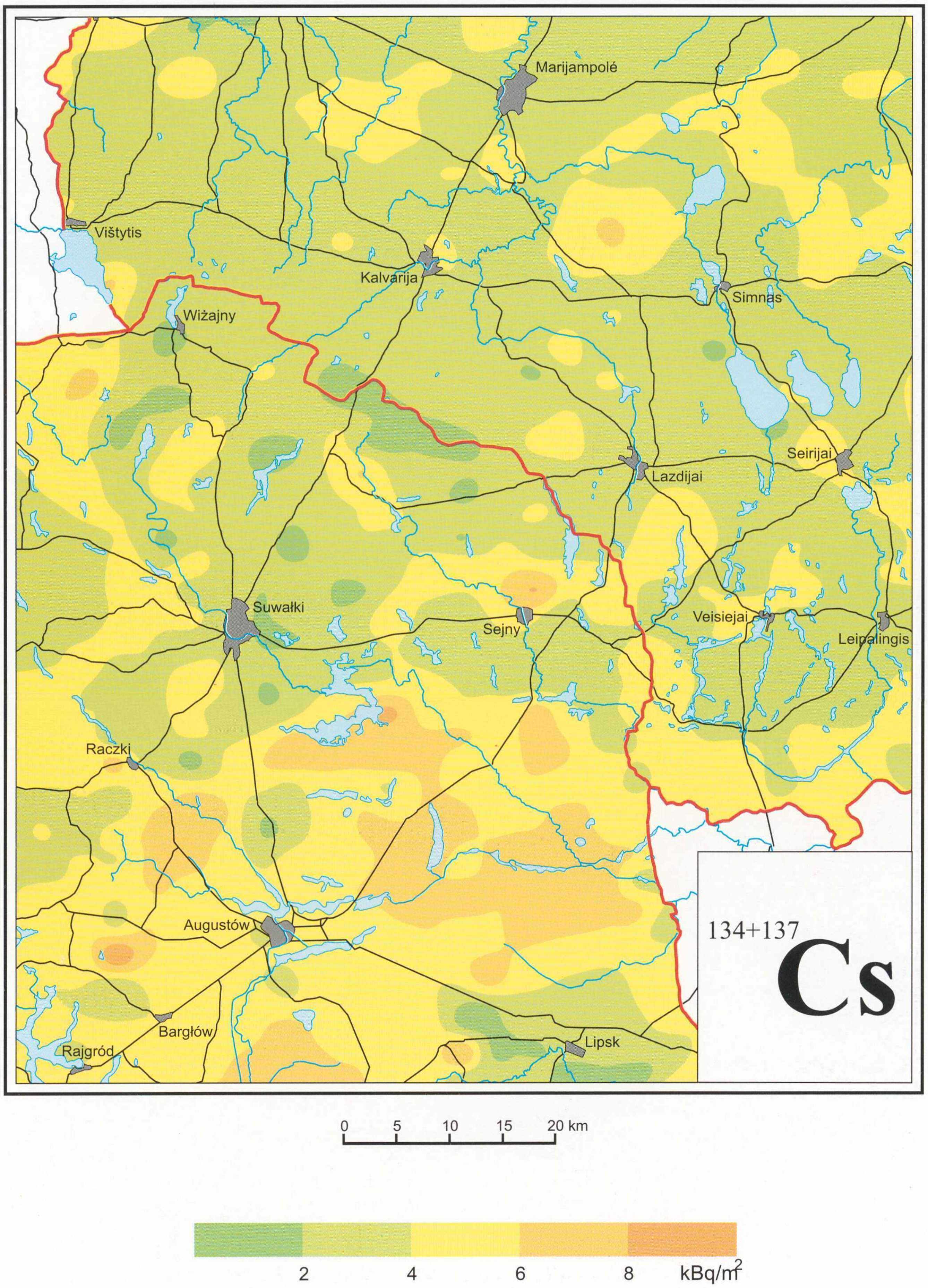
MAP OF THORIUM CONTENT



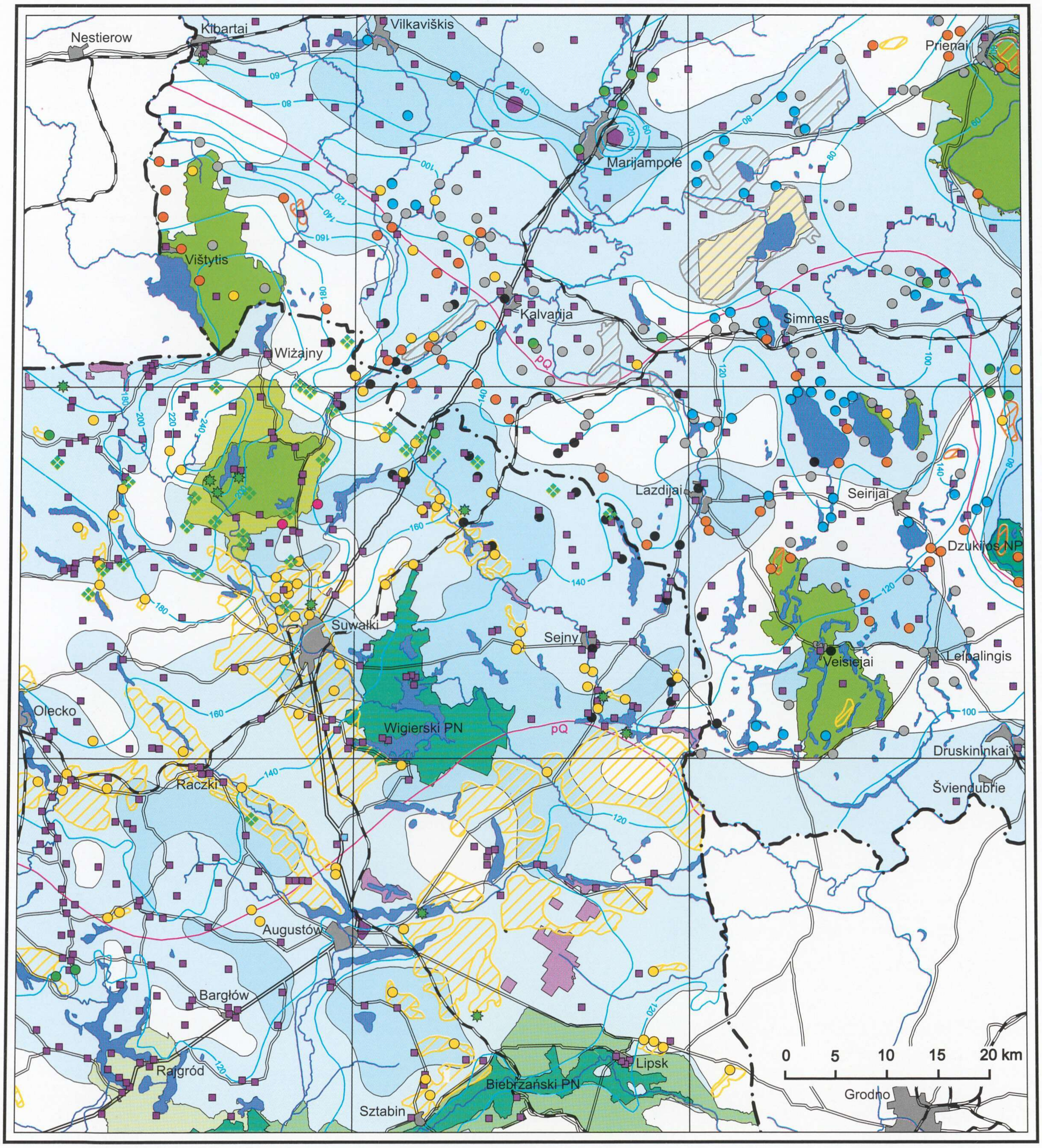
MAP OF POTASSIUM CONTENT



MAP OF CESIUM CONCENTRATION



MAP OF THE GEOPOTENTIAL



MINERAL RESOURCES

- clay
- lacustrine chalk
- sand
- iron ore
- peat
- gravel

PROSPECT AREAS

- sand
- peat
- gravel

HYDROGEOLOGY

AQUIFER YIELD

- high
- medium
- low

WATER SUPPLY WELLS

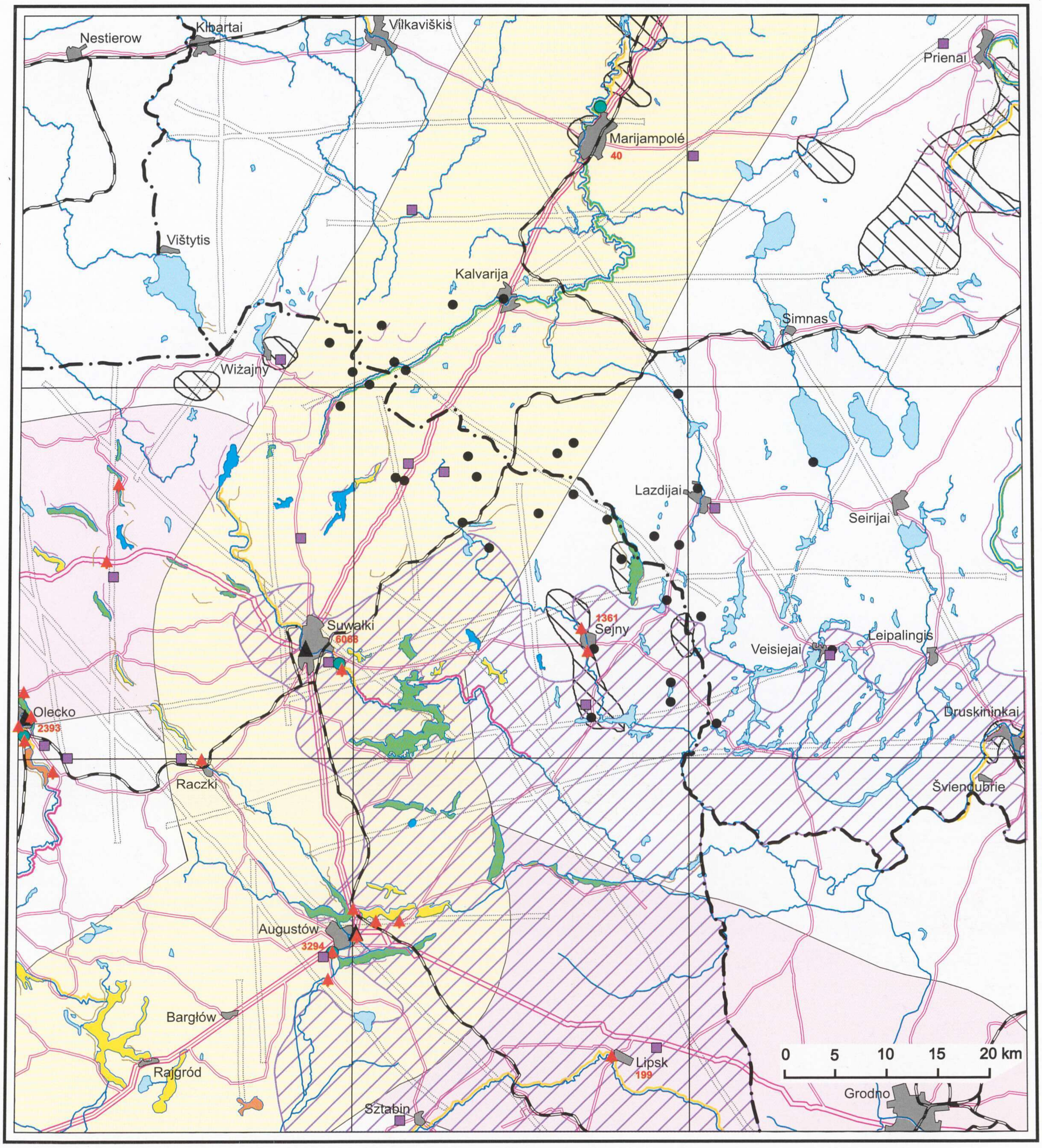
- well field
- with artificial recharge
- low to medium
- groundwater monitoring

- hydroisohypses (m)
- sub-Quaternary aquifers extent (pQ)

AREAS PROTECTED BY LAW

- national parks
- envelopments of national parks
- landscape or regional parks
- envelopments of landscape or regional parks
- areas of protected landscape
- nature reserves
- nature curiosities
- inanimate nature monuments

MAP OF ENVIRONMENTAL HAZARDS



main rivers (without quality determination)

lakes (without quality determination)

199 main cities (emission of dust SO_2 t / year)

railways

main roads

Via Baltica

expected heavy traffic road

GROUNDWATERS

upmost unconfined aquifer

natural groundwater contamination

groundwater monitoring

SURFACE WATERS

RIVERS QUALITY

II – low contamination

III – medium contamination

IV – high contamination

LAKES QUALITY

I – clean

II – low contamination

III – medium contamination

IV – high contamination

OTHERS

large industrial objects

water treatment plants

sewage discharges

waste disposals

lineaments indicating neotectonic movements

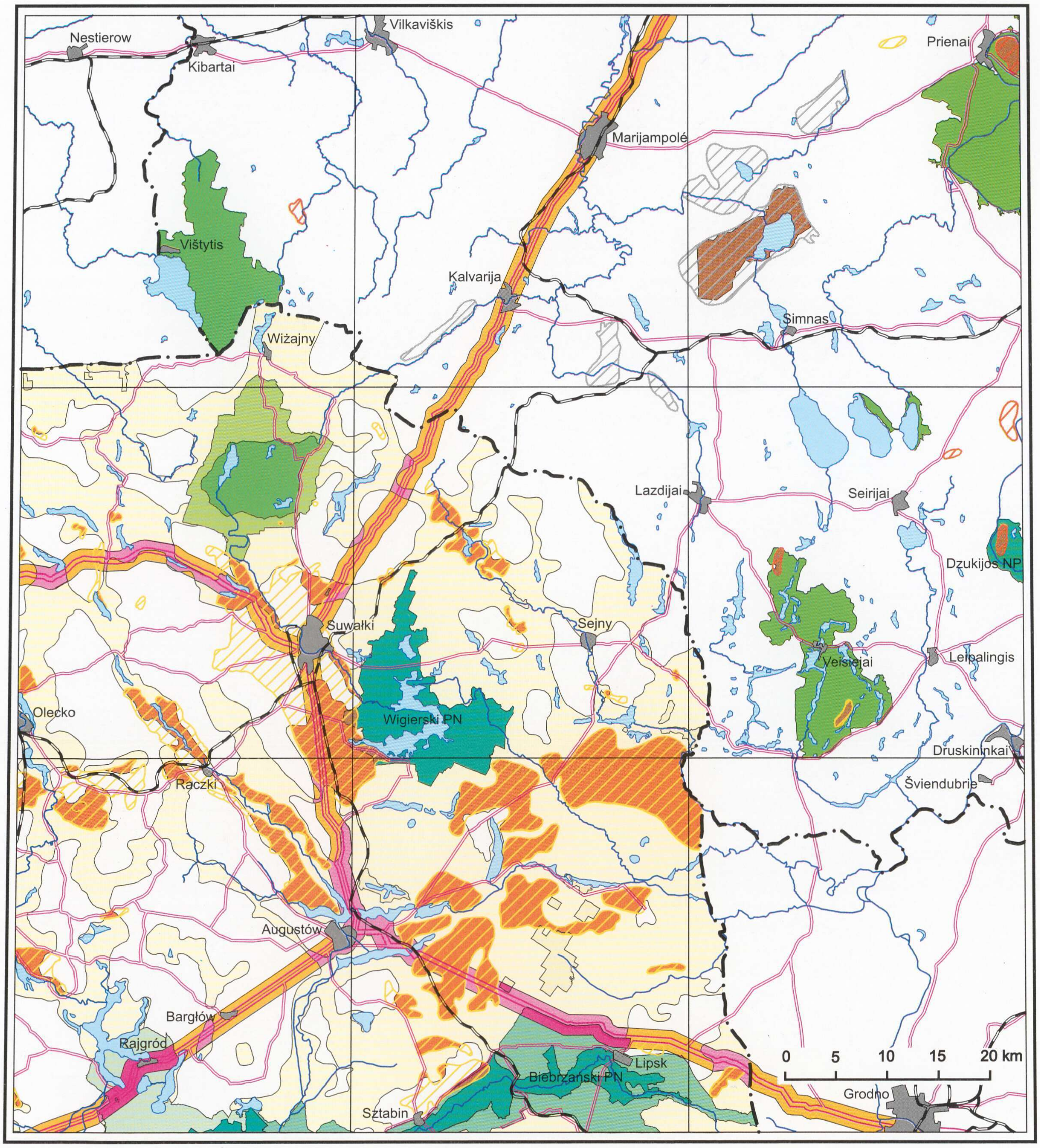
landslides, riverbank erosion

ravine erosion

buffer zone of highway Via Baltica (radius 15 km)

buffer zone of expected heavy traffic road (radius 15 km)

MAP OF ENVISAGED ENVIRONMENTAL CONFLICTS



Via Baltica

expected heavy traffic road

buffer zone of highway and expected heavy traffic road (radius 1 km)

MINERAL RESOURCES, PROSPECT AREAS

sand

peat

gravel

AREAS PROTECTED BY LOW

national parks

envelopments of national parks

landscape or regional parks

envelopments of landscape or regional parks

areas of protected landscape

nature reserves

planned protected areas

CONFLICTS :

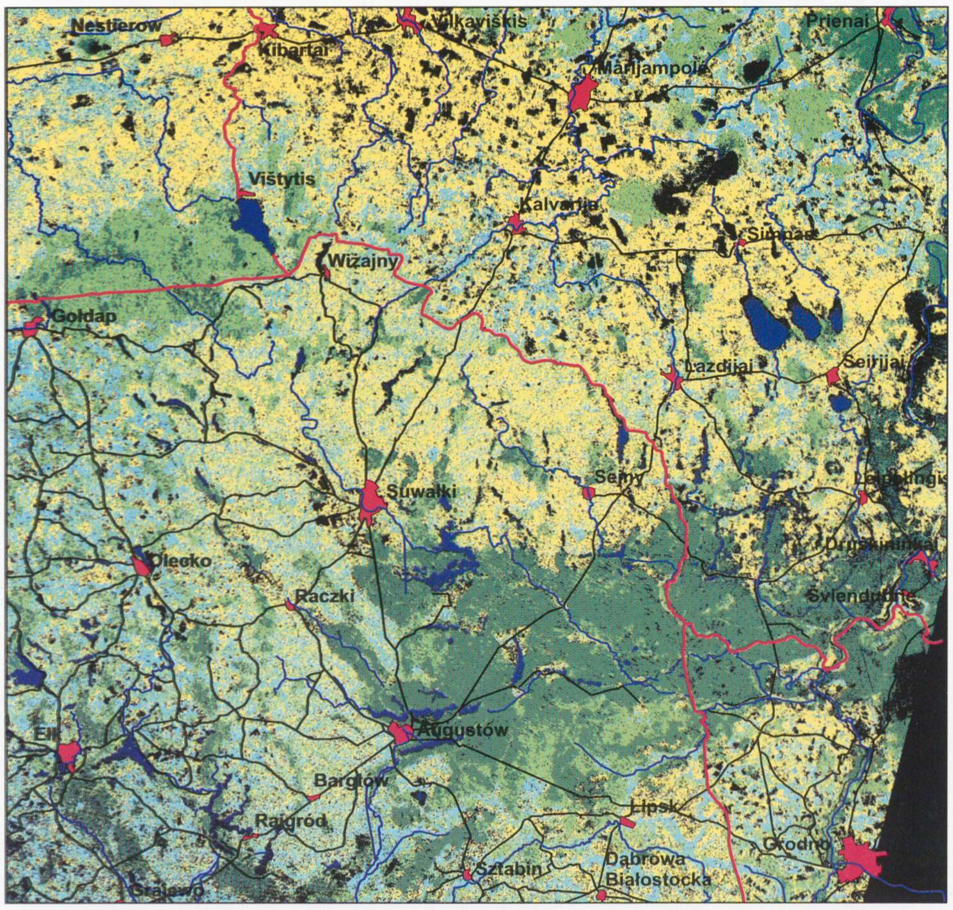
between the prospect areas and existing protected areas

between the prospect areas and planned protected areas

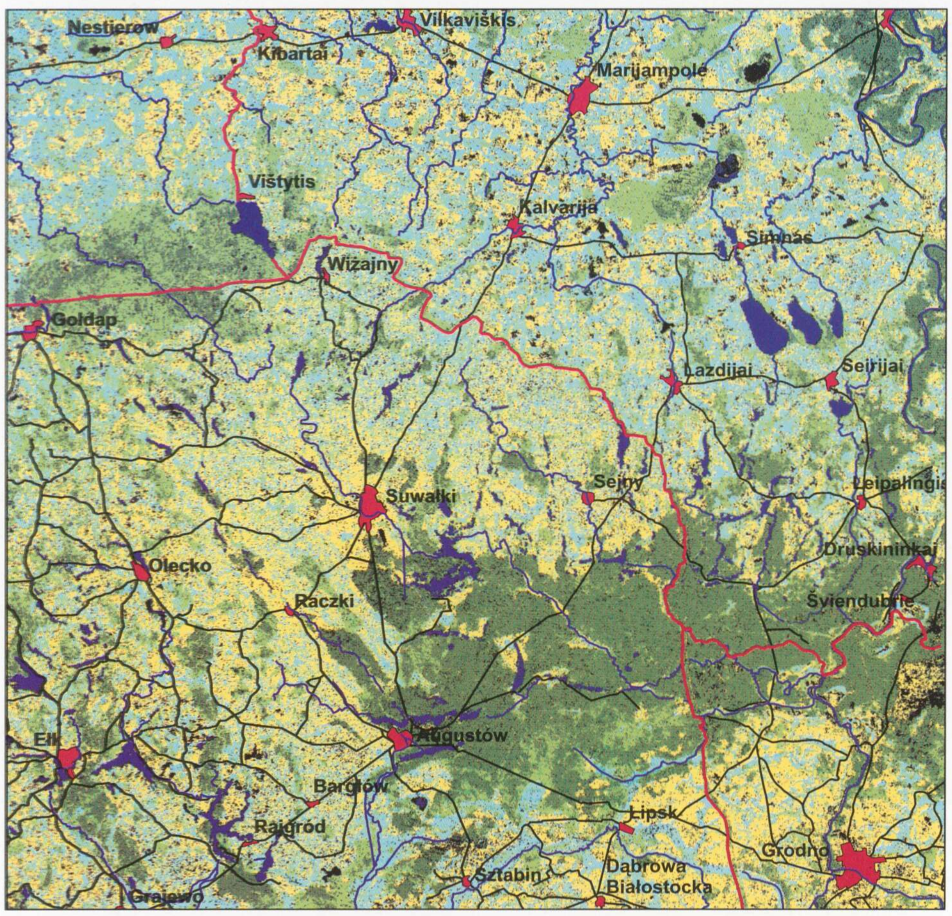
between the buffer zone of highway, expected heavy traffic road and existing protected areas

between the buffer zone of highway, expected heavy traffic road and planned protected areas

PROCESSED SATELLITE IMAGERIES



Classifield Landsat MSS Image (03.09.1979)



Classifield Landsat MSS Image (23.09.1992)

- rivers
- towns
- lakes
- coniferous forest
- mix forest
- agriculture land
- wetlands and pasture

ATLAS

THE BELT OF YOTVINGS – A FRAGMENT OF GREEN LUNGS OF EUROPE