Coordinating and integ**R**ating state-of-the-art Earth Observation **A**ctivities in the regions of North Africa, Middle East and Balkans and **D**eveloping **L**inks with G**E**O related initiatives toward GEOSS

GEO-CRADLE pre-Kick-Off Meeting
Friday, 18th of February, 2016

EuroGeoSurveys Geochemistry Expert Group

(http://www.eurogeosurveys.org/topics/Geochemistry/)

Compiled and presented on behalf of the Group by
***EurGeol* Alexandros (Alecos) Demetriades**

EUROGEOSURVEYS European Geoscience for Society
The Geological Surveys of Europe

IONIC Centre, 11 Lysiou Street
Athens, Greece

HORIZON 2020

(1) FOREGS Geochemical Atlas of Europe, and

(2) GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

DEVELOPMENT OF UNIFORM AND HOMOGENEOUS PAN-EUROPEAN GEOCHEMICAL DATABASES demands that sampling, sample preparation and chemical analysis be performed by exactly the same methodologies, and quality control procedures.

In order to ensure data homogeneity and comparability, and to avoid any bias between laboratories or analytical methods, each laboratory has undertaken to analyse complete randomised sample suites by exactly the same analytical technique or techniques, with strict external quality control procedures.

FOREGS Geochemical Atlas of Europe

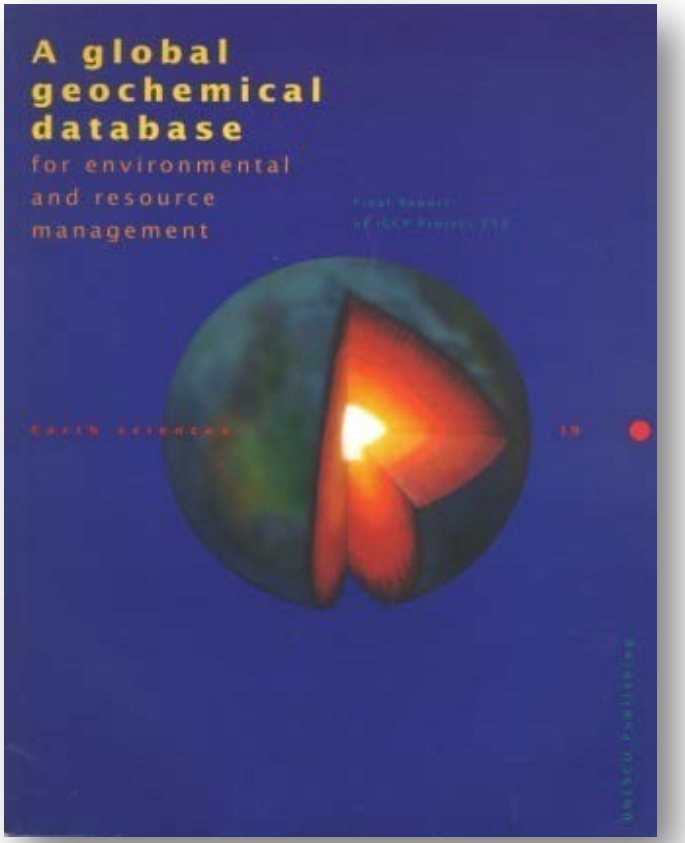
The Geological Surveys of Europe

Objective:

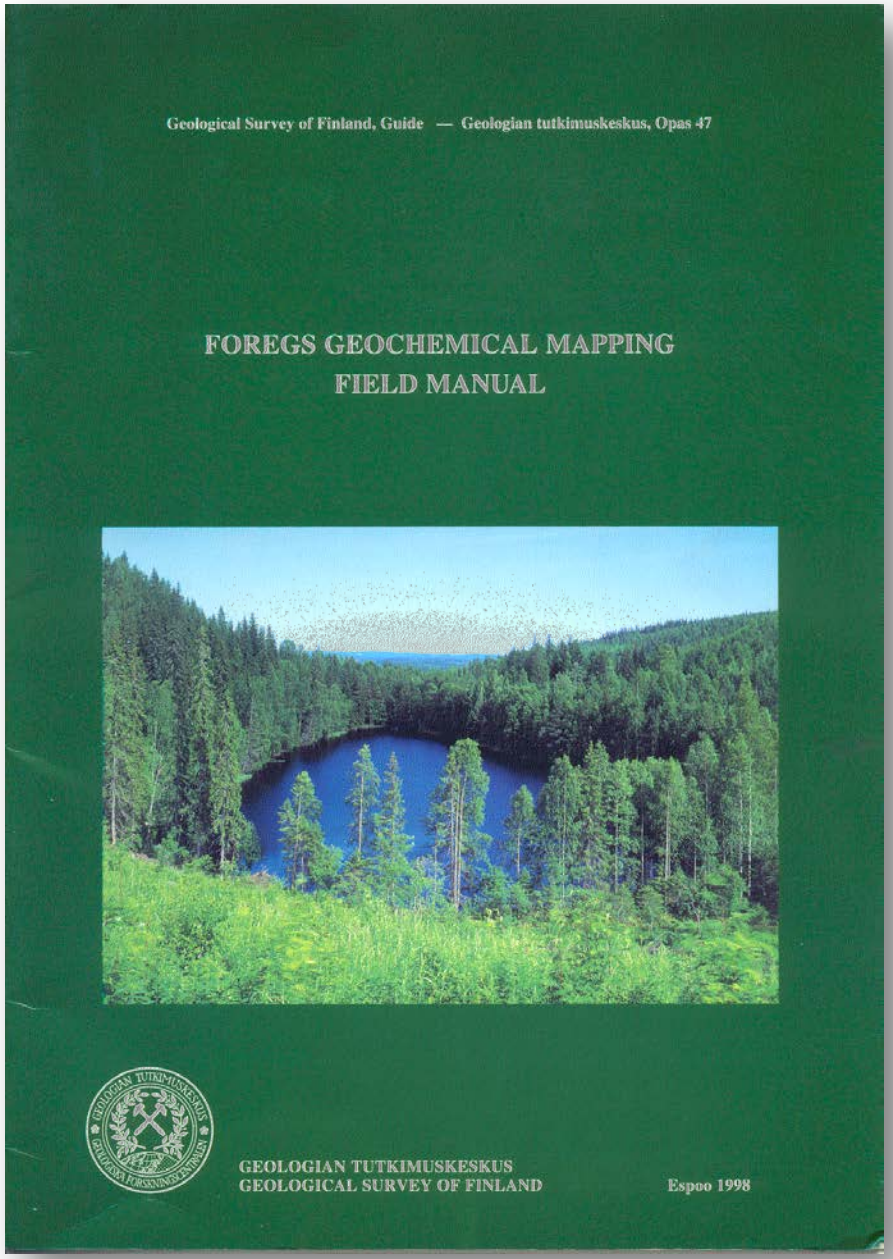
To provide high quality geochemical baseline data for Europe for multi-purpose use by using standardised sampling, sample preparation and analytical methodologies.

Planning

IGCP 259 final report by Darnley *et al*. (1995) "*A global geochemical database for environmental and resource management*", known as the BLUE BOOK, provides all the necessary information for the planning of harmonised continental-scale Geochemical Mapping Surveys



Source: http://www.globalgeochemicalbaselines.eu/wp-content/uploads/2012/07/Blue_Book_GGD_IGCP259.pdf



SAMPLING

Field Manual

was published in 1998

Salminen, Tarvainen *et al*., 1998. *FOREGS Geochemical Mapping, Field Manual*. Geological Survey of Finland. Guide Number 47.

Field sampling manual was compiled by experienced applied geochemists in sampling in different morpho-climatic environments, and then tested in the field before finalisation

URL: http://tupa.gtk.fi/julkaisu/opas/op_047.pdf

FOREGS Geochemical Atlas of Europe, http://weppi.gtk.fi/publ/foregsatlas/

***26 countries participated in the FOREGS project of Geochemical Mapping of Europe**: Austria, **Albania**, Belgium, **Croatia**, Czechia, Denmark, Estonia, Finland, France, Germany, **Greece**, Hungary, Ireland, Italy, Latvia, Lithuania, The Netherlands, Norway, Poland, Portugal, Slovakia, **Slovenia**, Spain, Sweden, Switzerland and United Kingdom*

- **Area covered: 4,250,000 km²**
- **Overall 925 sample sites**
- **1 sample site/4,600 km²**

Geochemical Atlas of Europe 6 sample types collected

➢ (1) **Stream water** (unfiltered and filtered)

➢(2) **Stream sediment** (minerogenic)

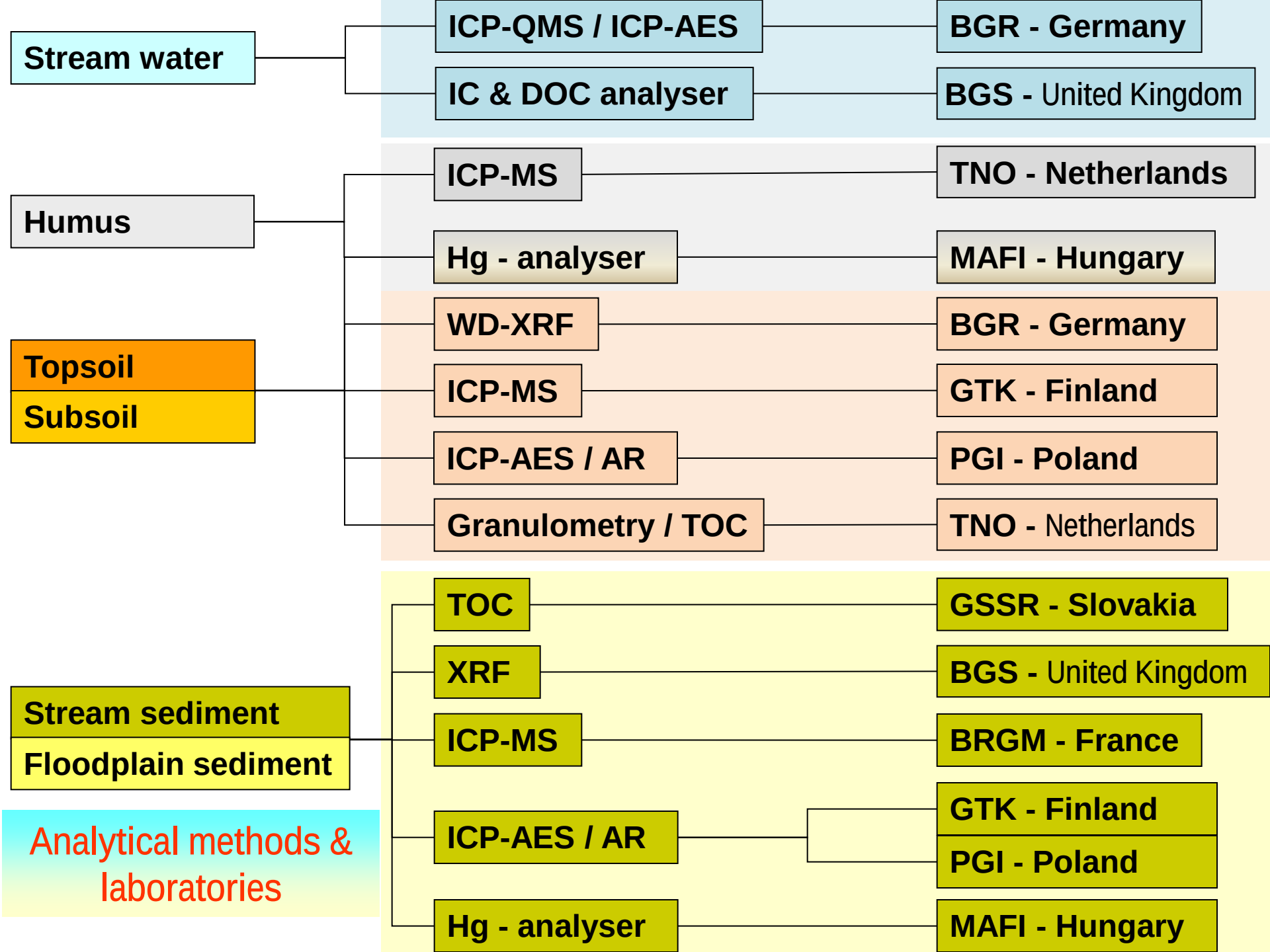
➢ (3 & 4) **Residual soil**, top & bottom

➢ (5) **Humus** *(only from 20* countries**)

➢ (6) **Floodplain sediment**

Fieldwork was carried out from 1998 to 2002 as national projects

*(**Humus samples:* Austria, Czechia, Denmark, Estonia, Finland, Germany, Norway, Poland, Slovenia, Sweden and Switzerland; northern Italy, and parts of Lithuania, France, Ireland and United Kingdom, and one sample from Slovakia)


Stream water
ICP-QMS / ICP-AES
BGR - Germany
IC & DOC analyser
BGS - United Kingdom
Humus
ICP-MS
TNO - Netherlands
Hg - analyser
MAFI - Hungary
Topsoil
Subsoil
WD-XRF
BGR - Germany
ICP-MS
GTK - Finland
ICP-AES / AR
PGI - Poland
Granulometry / TOC
TNO - Netherlands
Stream sediment
Floodplain sediment
TOC
GSSR - Slovakia
XRF
BGS - United Kingdom
ICP-MS
BRGM - France
ICP-AES / AR
GTK - Finland
PGI - Poland
Hg - analyser
MAFI - Hungary
Analytical methods & laboratories

Determinands analysed:

Stream water (n=808)

66 determinands: Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Ge, Hf, Ho, I, In, K, La, Li, Lu, Mg, Mn, Mo, Na, Nb, Nd, Ni, Pb, Pr, Rb, Sb, Se, SiO_2, Sm, Sr, Ta, Tb, Te, Th, Ti, Tl, Tm, U, V, W, Y, Yb, Zn, Zr, pH, EC, HCO_3^-, Br^-, Cl^-, F^-, NO_3^-, SO_4^{2-}, DOC

Humus (n=377)

12 determinands (total extraction): Ba, Cd, Co, Cu, Ga, Hg, La, Ni, Pb, Rb, Sr, Zn

Residual topsoil (n=845)

Residual subsoil (n=790)

12 determinands (aqua regia extractable): As, Ba, Co, Cr, Cu, Fe, Mn, Ni, Pb, S, V, Zn

64 determinands (total extraction): Ag, Al_2O_3, As, Ba, Be, Bi, CaO, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe_2O_3, Ga, Gd, Hf, Hg, Ho, I, In, K_2O, La, Lu, MgO, MnO, Mo, Na_2O, Nb, Nd, Ni, P_2O_5, Pb, Pr, Rb, Sb, Sc, SiO_2, Sm, Sn, Sr, Ta, Tb, Te, Th, TiO_2, Tl, Tm, U, V, W, Y, Yb, Zn, Zr, TOC, pH, 4 grain-sizes

Stream sediment (n=852)

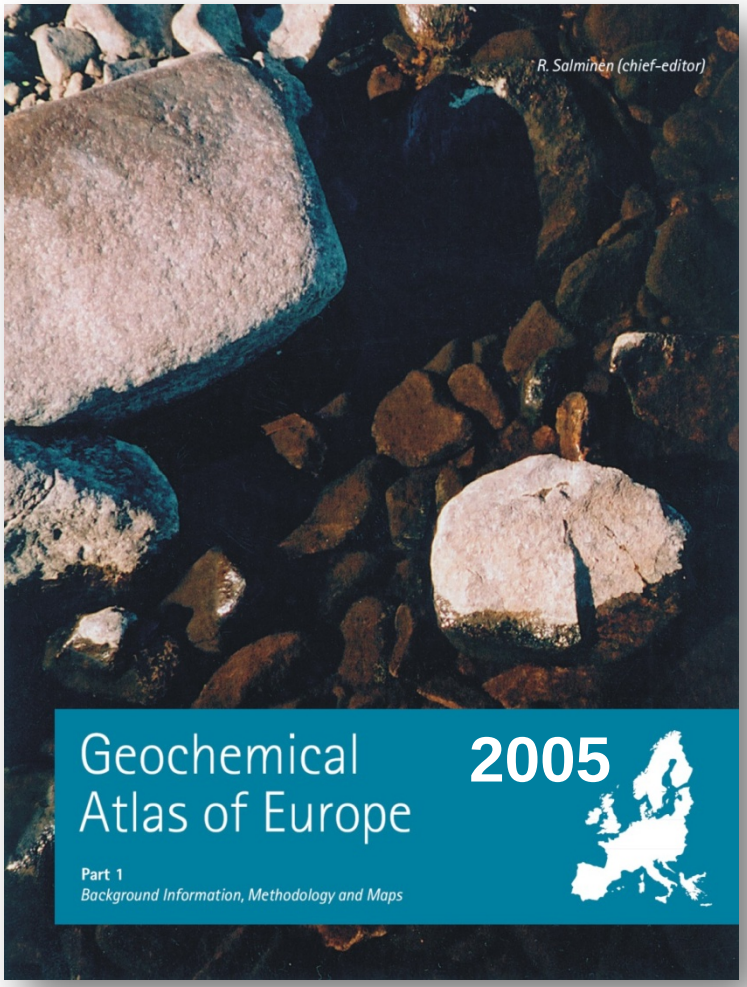
Floodplain sediment (n=749)

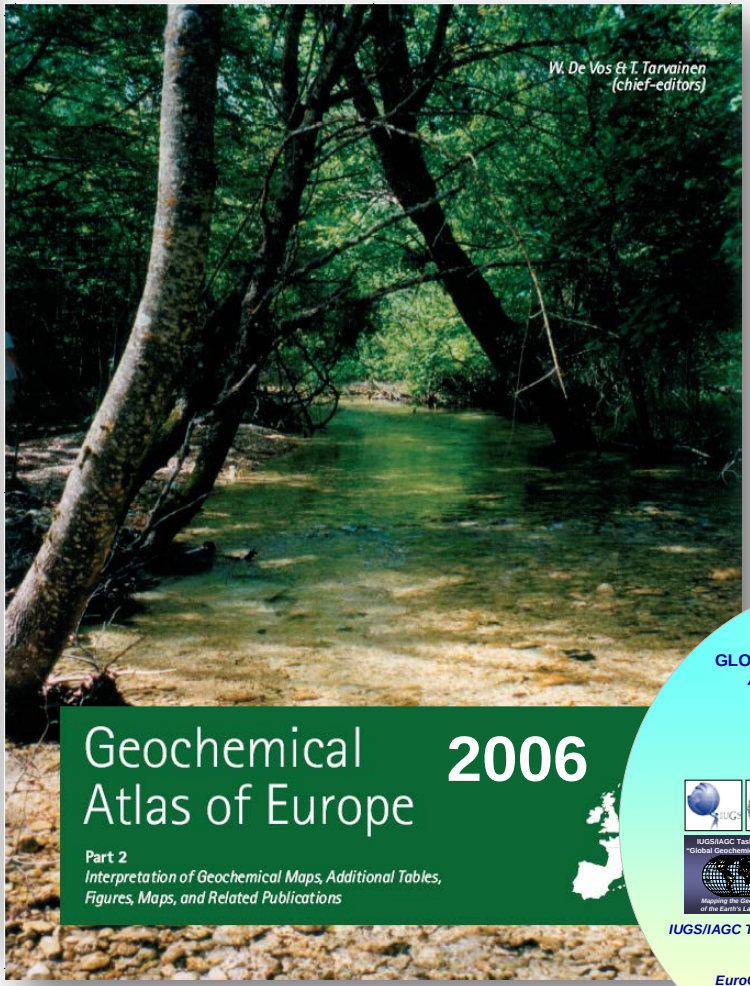
12 determinands (aqua regia extractable): As, Ba, Co, Cr, Cu, Fe, Mn, Ni, Pb, S, V, Zn

54 determinands (total extraction): Al_2O_3, As, Ba, Be, CaO, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe_2O_3, Ga, Gd, Hf, Hg, Ho, K_2O, La, Li, Lu, MgO, MnO, Mo, Na_2O, Nb, Nd, Ni, P_2O_5, Pb, Pr, Rb, Sb, SiO_2, Sm, Sn, Sr, Ta, Tb, Th, TiO_2, Tl, Tm, U, V, W, Y, Yb, Zn, Zr, TOC

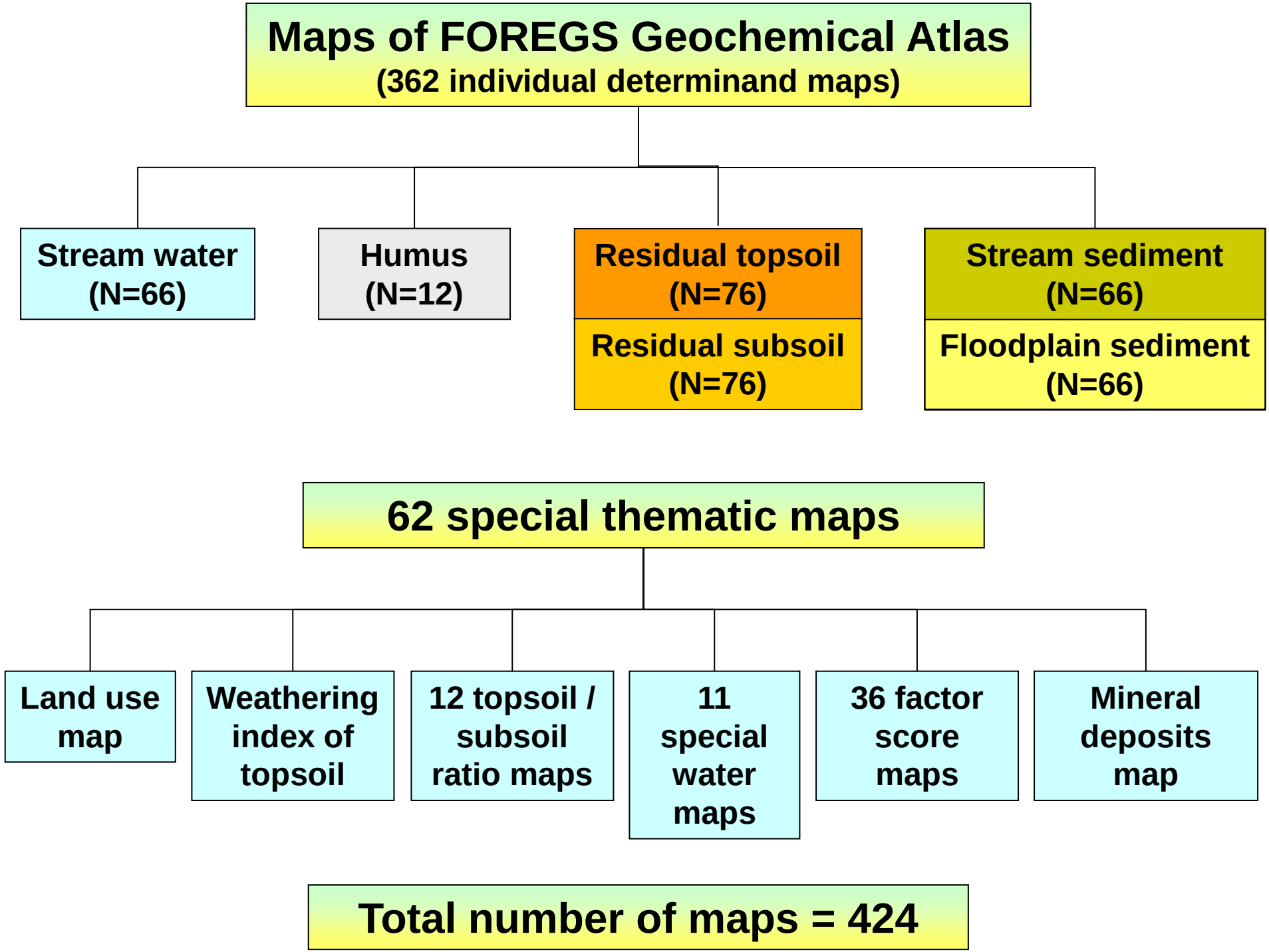
FOREGS Geochemical Atlas of Europe

Printed Publications

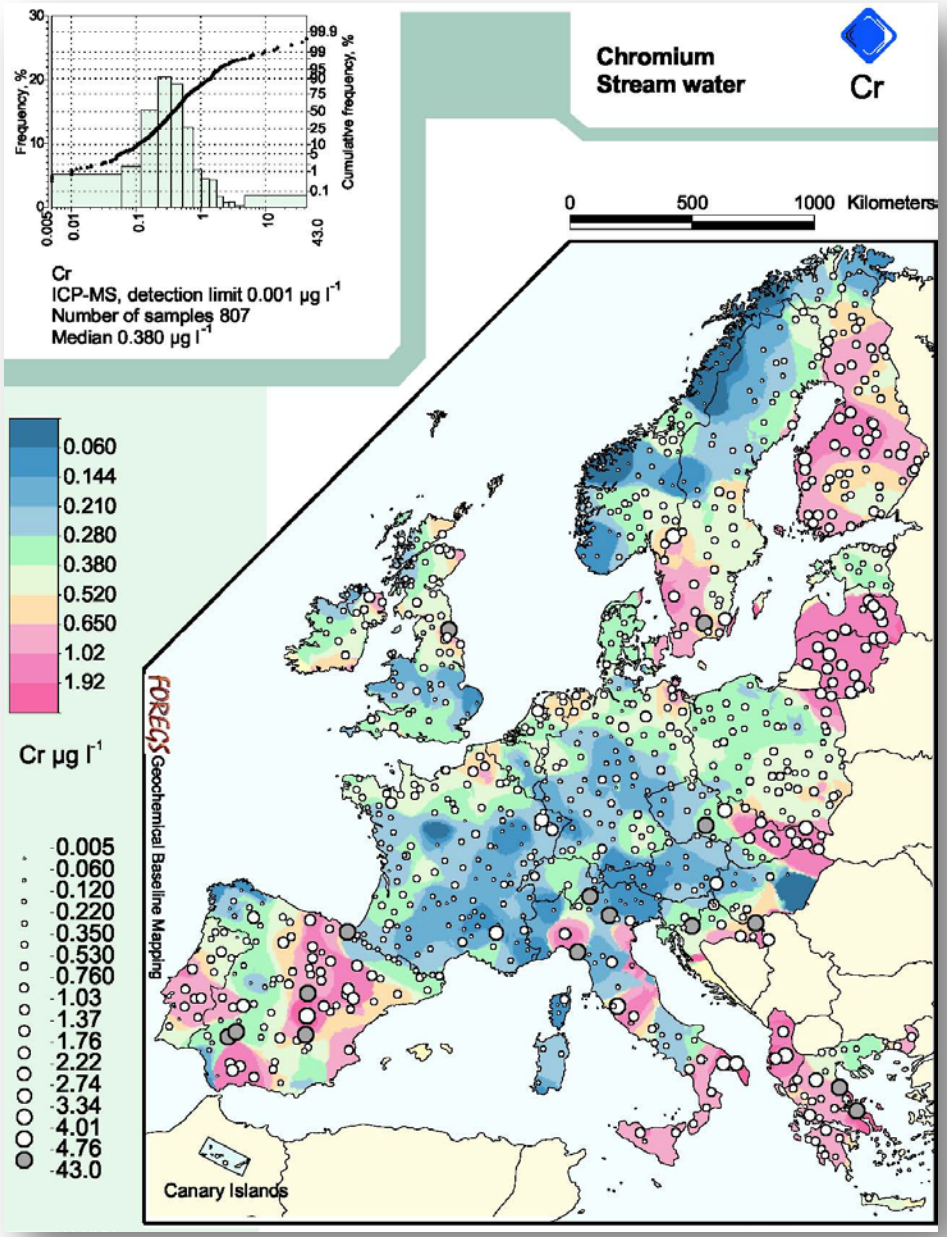




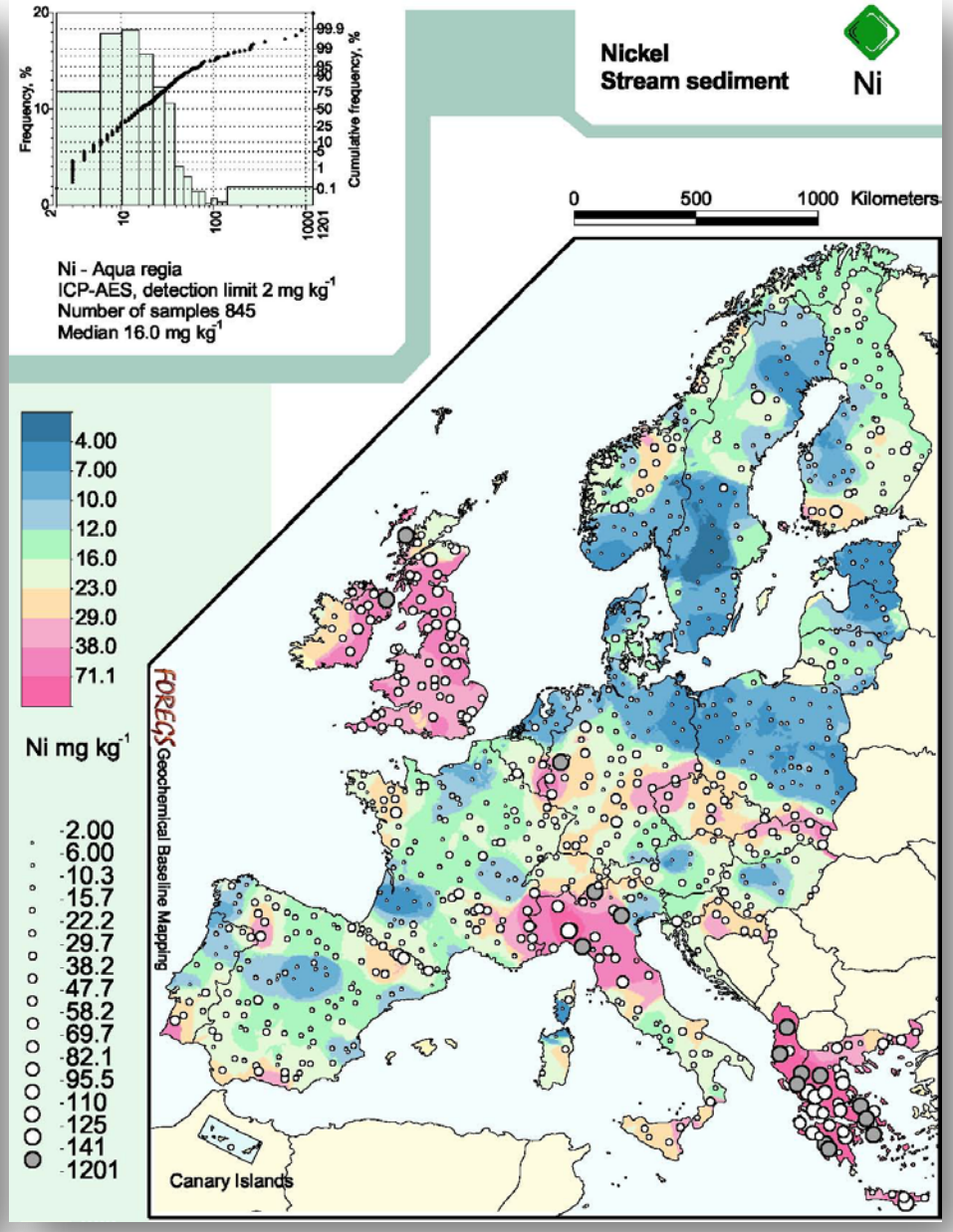
http://weppi.gtk.fi/publ/foregsatlas/


Maps of FOREGS Geochemical Atlas
(362 individual determinand maps)
Stream water (N=66)
Humus (N=12)
Residual topsoil (N=76)
Residual subsoil (N=76)
Stream sediment (N=66)
Floodplain sediment (N=66)
62 special thematic maps
Land use map
Weathering index of topsoil
12 topsoil / subsoil ratio maps
11 special water maps
36 factor score maps
Mineral deposits map
Total number of maps = 424

FOREGS Geochemical Atlas of Europe

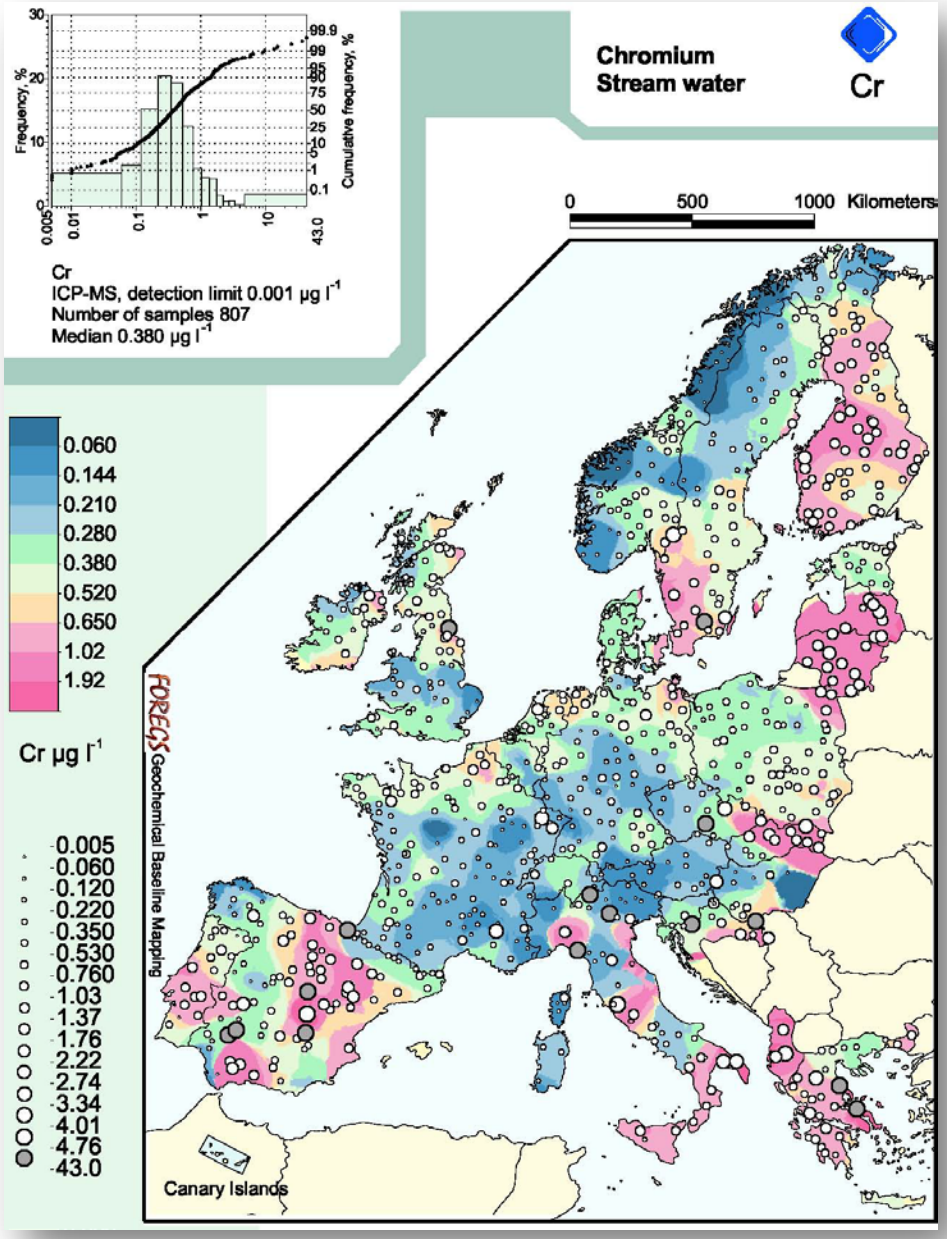


Source: Salminen *et al.*, 2005, p.191,
http://weppi.gtk.fi/publ/foregsatlas/maps/Water/w_icpms_cr_edit.pdf

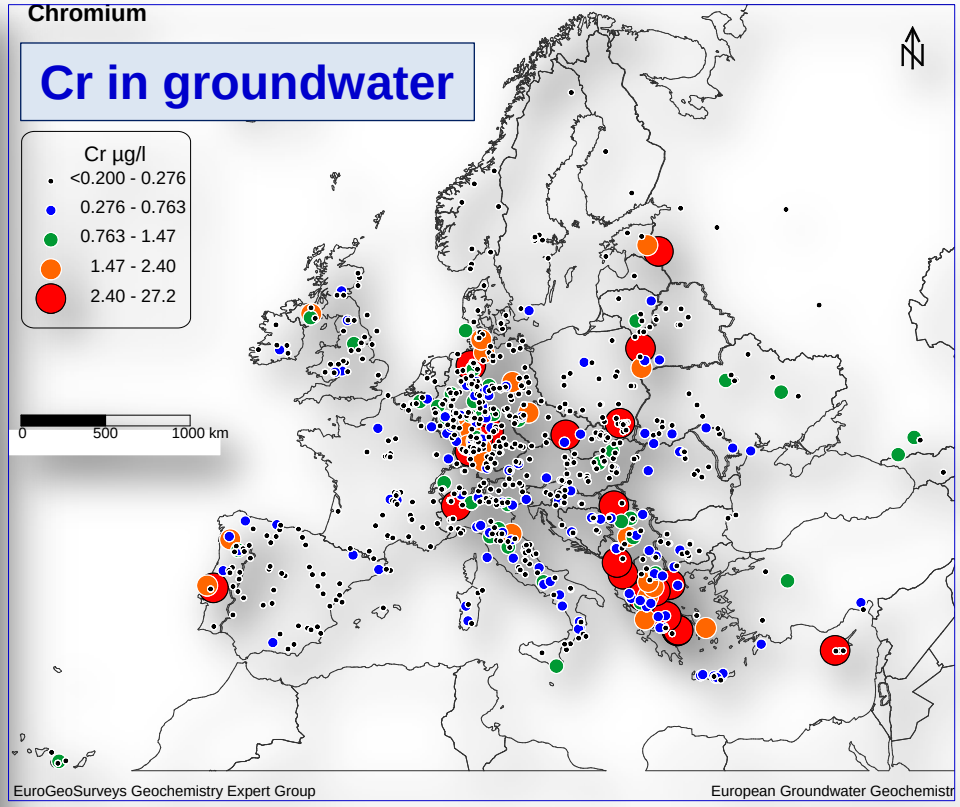


Source: De Vos, Tarvainen *et al.*, 2006, p.663,
http://weppi.gtk.fi/publ/foregsatlas/maps/StreamSed/s_aricpaes_cr_edit.pdf

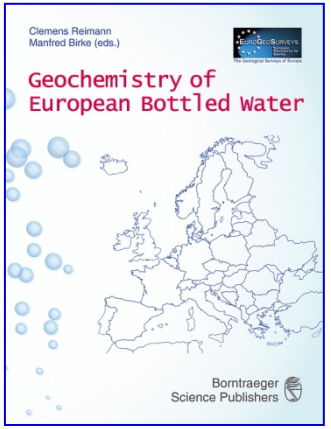
FOREGS & EGG Geochemical Atlas of Europe



Source: Salminen *et al.*, 2005, p.191,
http://weppi.gtk.fi/publ/foregsatlas/maps/Water/w_icpms_cr_edit.pdf

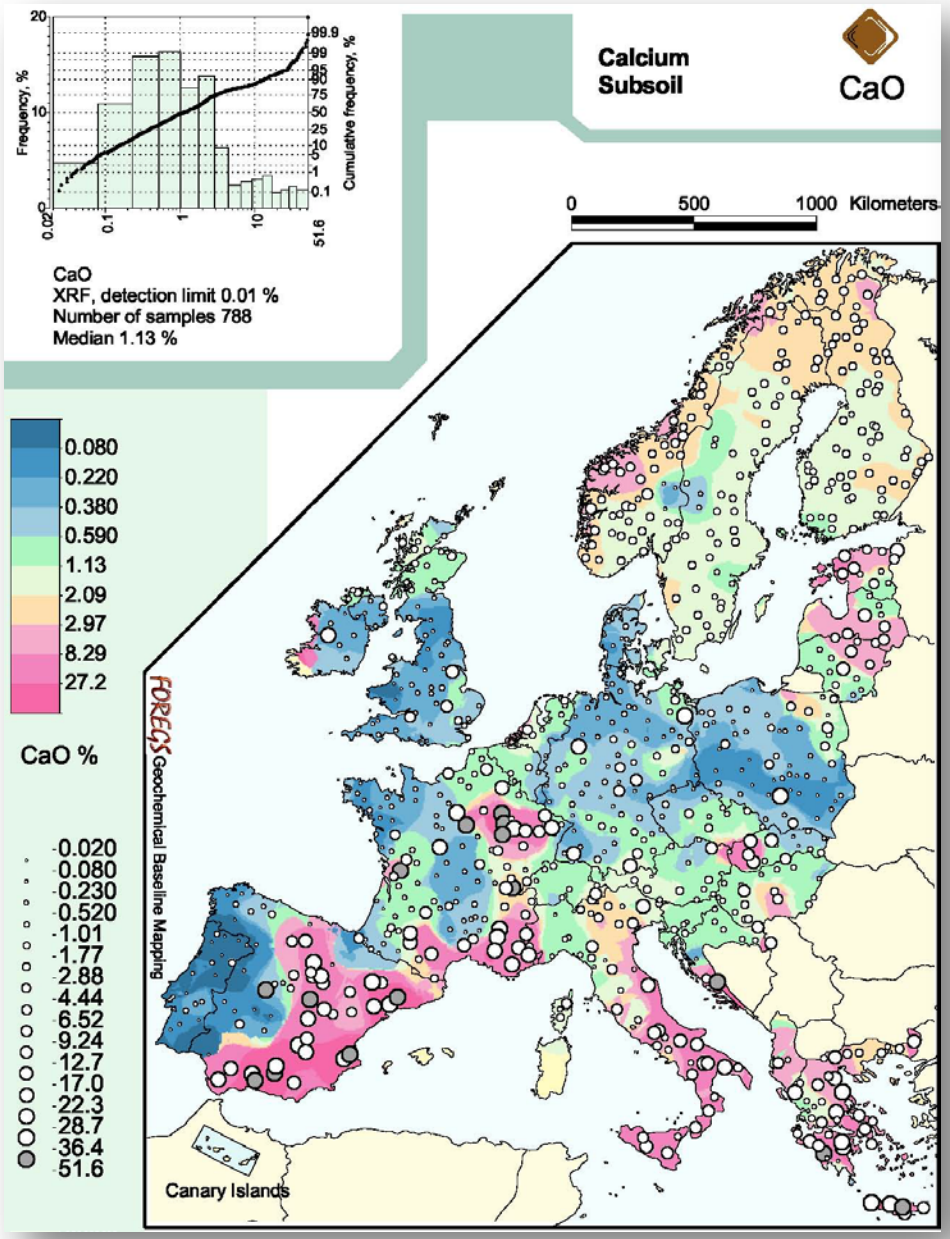


Source: Demetriades *et al.*, 2015, Fig. 3, p.26,
http://eurogeologists.eu/wp-content/uploads/2015/11/EGJ40_final_LR.pdf

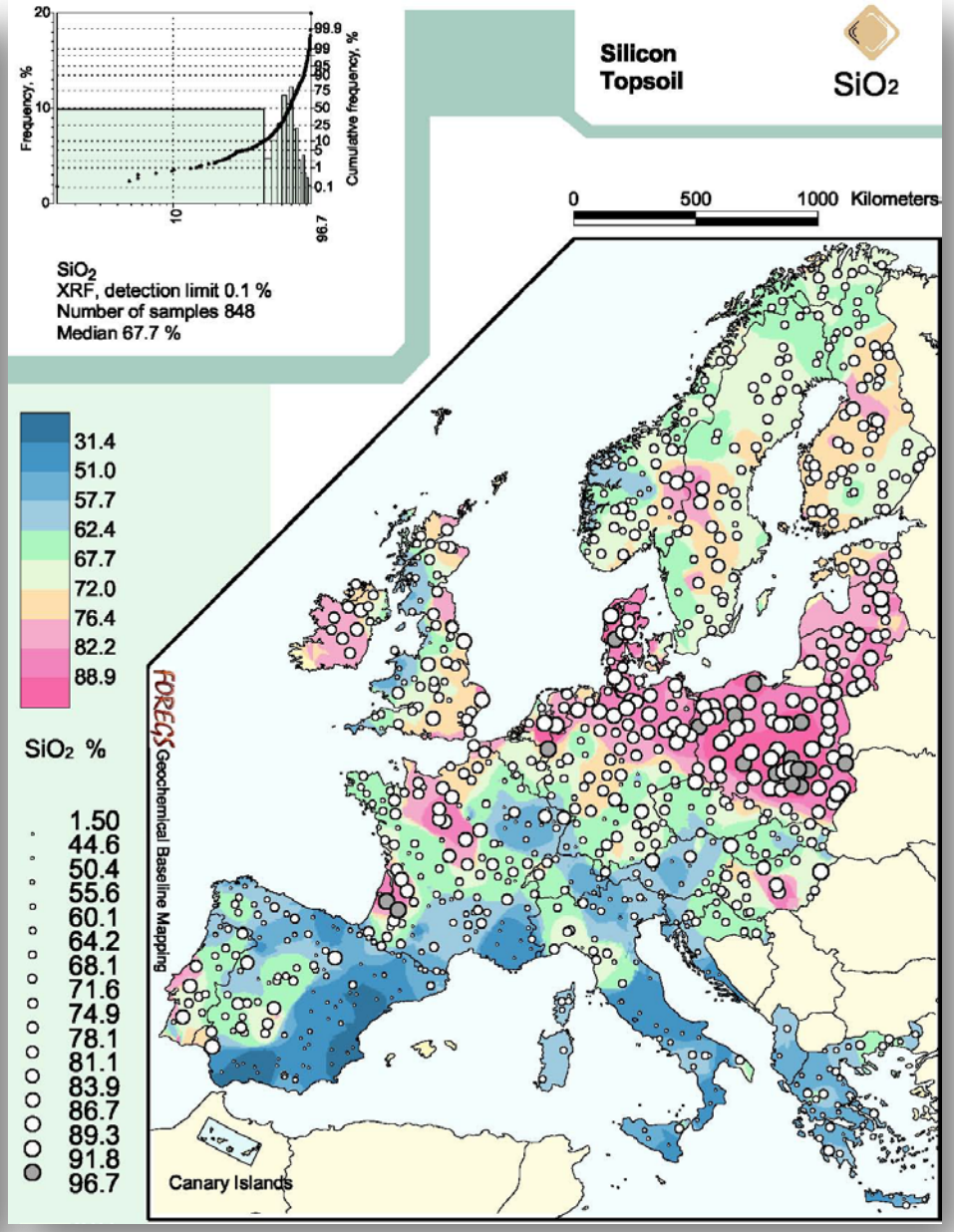


http://www.schweizerbart.de/publications/detail/artno/001201002#

FOREGS Geochemical Atlas of Europe

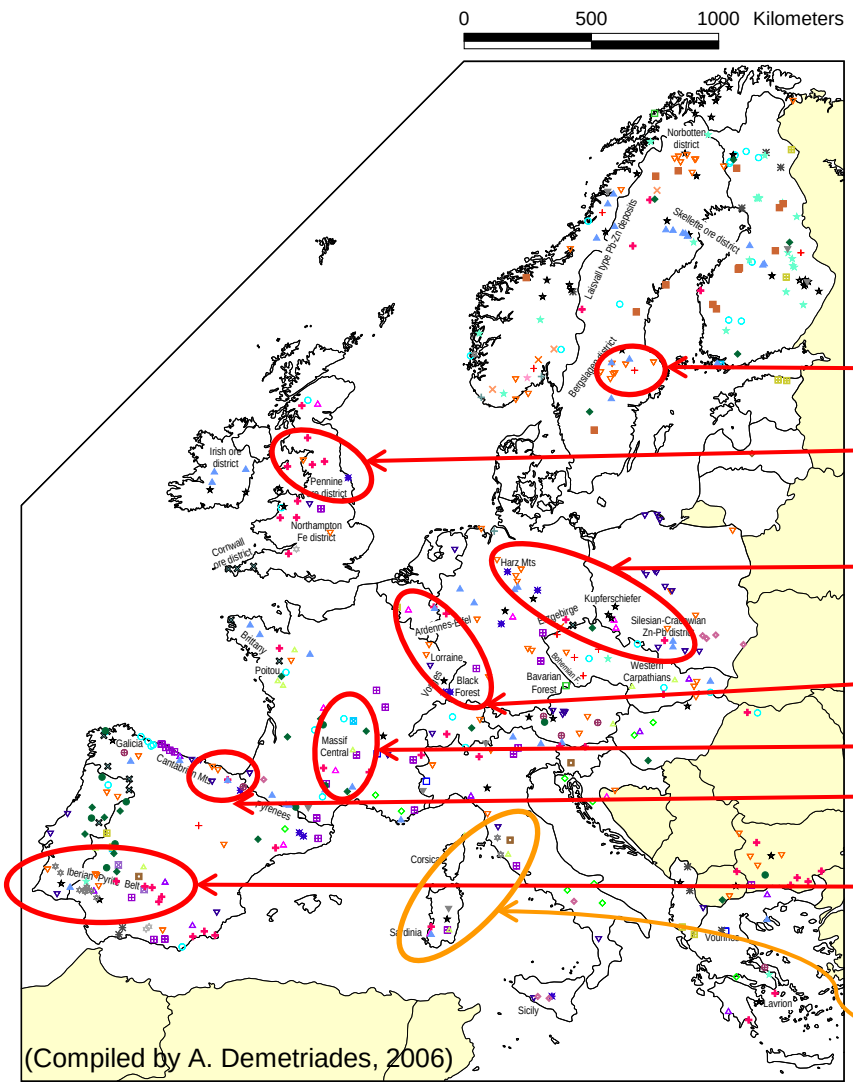


Source: Salminen *et al.*, 2005, p.157,
http://weppi.gtk.fi/publ/foregsatlas/maps/Subsoil/c_xrf_cao_edit.pdf



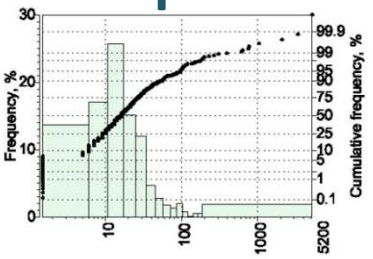
Source: Salminen *et al.*, 2005, p.417,
http://weppi.gtk.fi/publ/foregsatlas/maps/Floodplain/f_xrf_sio2_edit.pdf

FOREGS Geochemical Atlas of Europe



(Compiled by A. Demetriades, 2006)

Source: De Vos, Tarvainen *et al*., 2006, p.430, http://weppi.gtk.fi/publ/foregsatlas/articles/Discussion.pdf



Pb - Aqua regia
ICP-AES, detection limit 3 mg kg^{-1}
Number of samples 747
Median 16.0 mg kg^{-1}

Lead
Floodplain

Pb

0 500 1000 Kilometers

Pb mg kg^{-1}

3.00
7.00
9.00
11.0
16.0
21.0
27.0
38.0
96.0

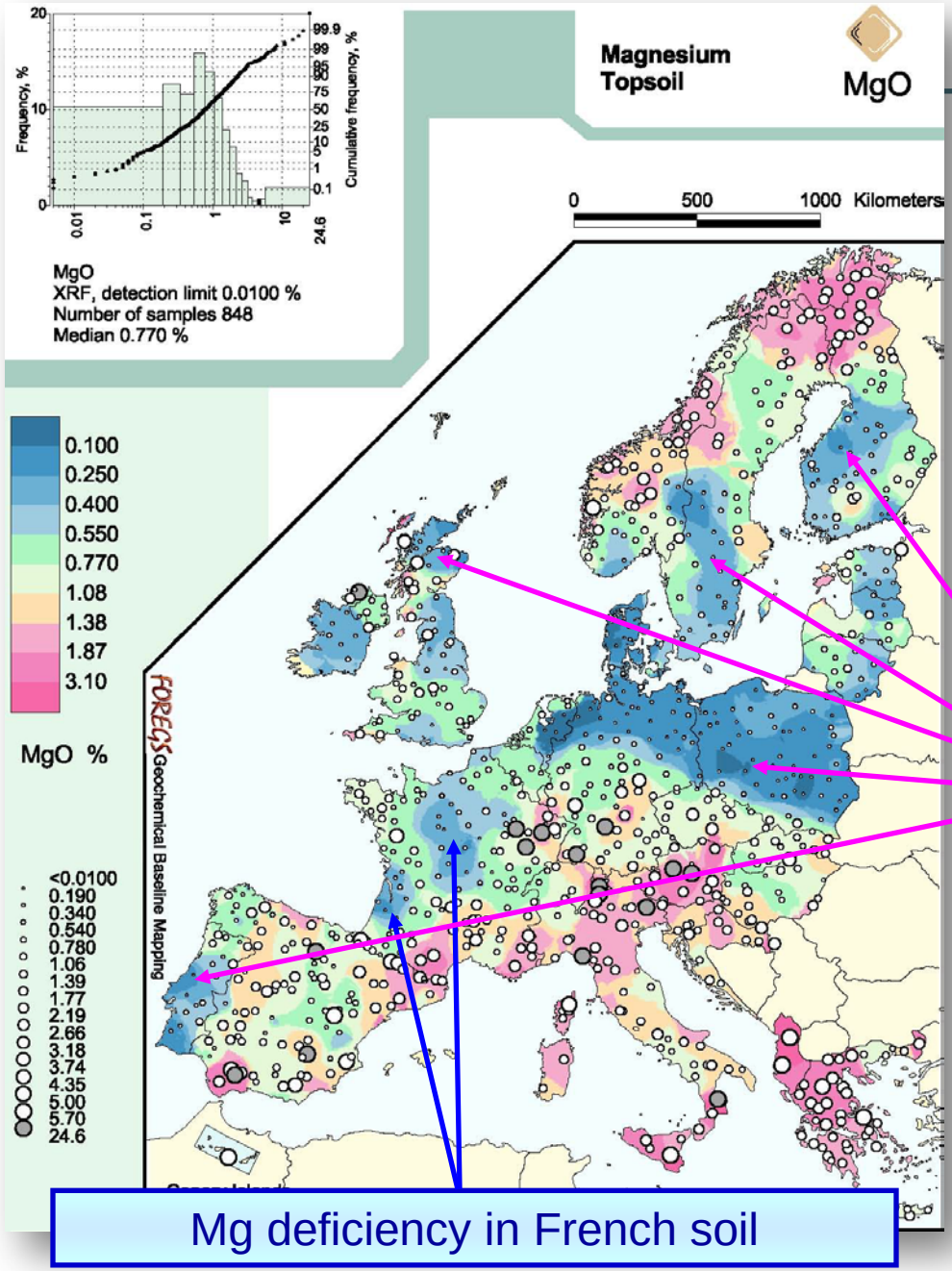
<3.00
6.00
10.8
17.1
24.9
34.2
45.0
57.4
71.2
86.6
100
120
140
160
180
5200

FOREGS Geochemical Baseline Mapping

Canary Islands

Source: Salminen *et al*., 2005, p.381, http://weppi.gtk.fi/publ/foregsatlas/maps/Floodplain/f_aricpaes_pb_edit.pdf

FOREGS Geochemical Atlas of Europe



Mg deficiency in French soil

France

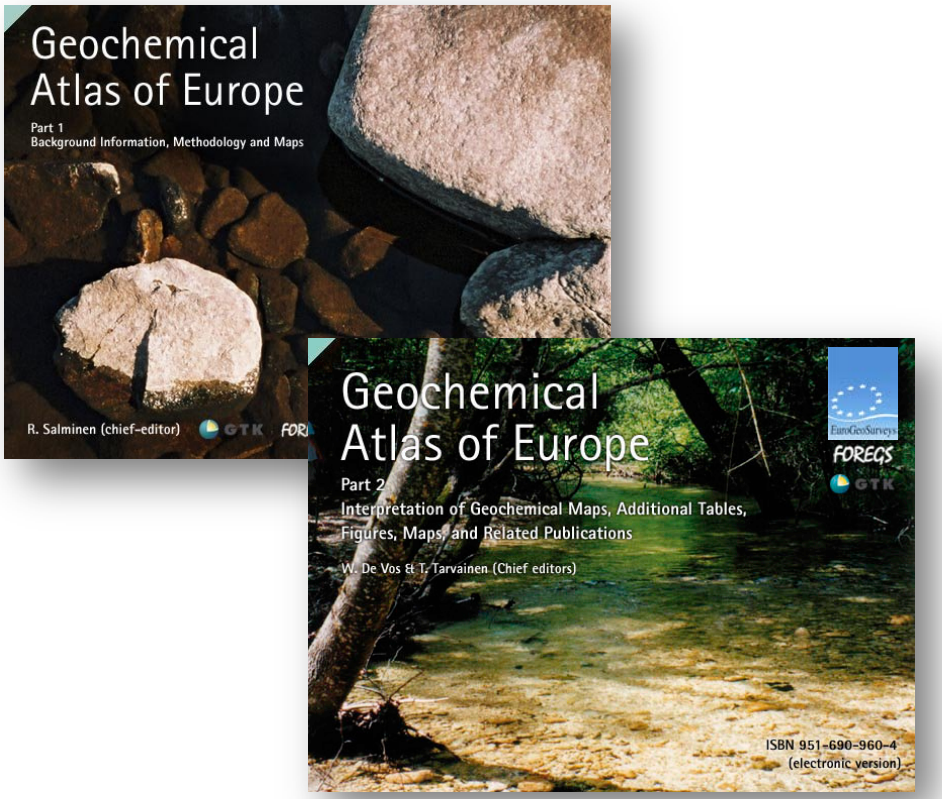
Magnesium deficiency in certain types of soil has been associated with specific kinds of cancer.

High risk areas with magnesium deficiency in soil should be investigated

Source: Salminen *et al.*, 2005, p.318

FOREGS Geochemical Atlas of Europe

The Geochemical Atlas of Europe can be used for effective land use planning, *i.e.*, to decide if the particular land is fit for:



- **Mineral exploration,**
- **Agriculture,**
- **Forestry,**
- **Animal husbandry,**
- **Land use policy,**
- **Health related research,**
- **Environmental policy,**
- **Construction of new towns, *etc*.**

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe, http://gemas.geolba.ac.at/

Land-use related geochemical data needed at the European scale for the REACH regulation *(**R**egistration, **E**valuation, **A**uthorisation and restriction of **CH**emical substances)* by the companies of the European Association of Metals (Eurometaux, http://www.eurometaux.org/).


Grazing land soil, 0-10 cm


Agricultural soil (A_p-horizon), 0-20 cm

2 sample materials collected at 1 site / 2500 km²

<2 mm fraction analysed by aqua regia extraction

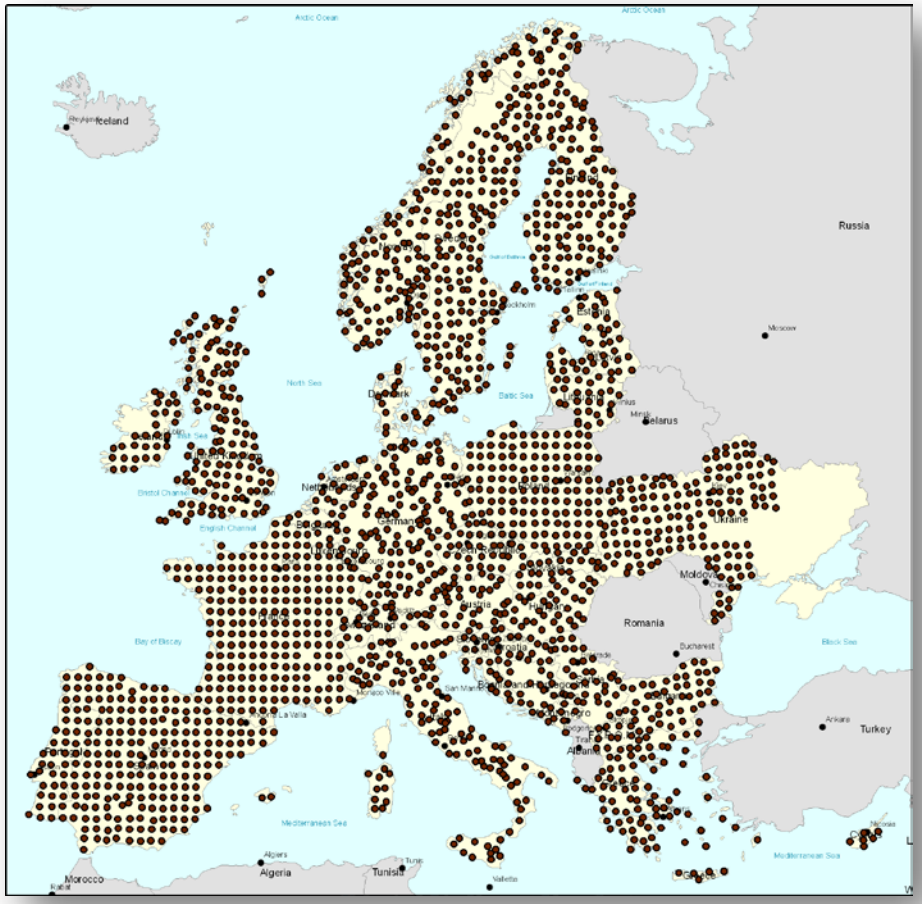
The GEMAS Field Manual is available from:

http://www.ngu.no/en-gb/hm/Publications/Reports/2008/2008-038/

Fieldwork was carried out from May 2008 to March 2009 as national projects

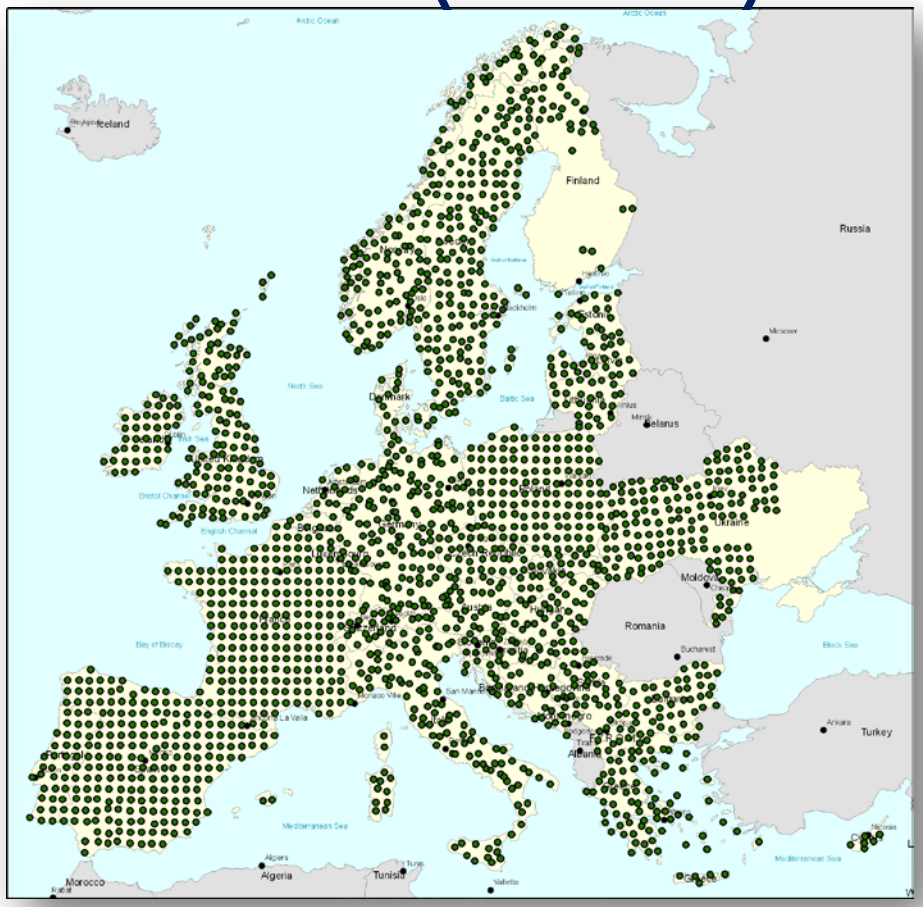
GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

Agricultural soil (A_p) 0-20 cm (N = 2108)



Source: Reimann *et al*., 2009, Fig. 1, p.9

Grazing land soil (Gr) 0-10 cm (N = 2024)



Source: Reimann *et al*., 2009, Fig. 2, p.9

33 countries - 5.6 million km² - 4132 soil samples in total

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

33 countries:

Austria, Belgium, ***Bosnia and Herzegovina****,* ***Bulgaria****,* ***Croatia****,* ***Cyprus****, Czechia, Denmark, Estonia, Finland, France,* ***F.Y.R.O.M.****, Germany,* ***Greece****, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg,* ***Montenegro****, The Netherlands, Norway, Poland, Portugal,* ***Serbia****, Slovakia,* ***Slovenia****, Spain, Sweden, Switzerland, Ukraine, United Kingdom*

Source: Birke *et al.*, 2014, Fig. 10.1, p.94

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

GEMAS – Analytical Programme

H																He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															
			Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	
			Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

- **ACME commercial laboratory: Aqua regia extraction on 15 g aliquot of soil (53 elements) and determination by ICP-MS/AES**: Ag, Al, As, Au, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Fe, Ga, Ge, Hf, Hg, In, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Pd, Pt, Rb, Re, S, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Ti, Tl, U, V, W, Y, Zn and Zr.

- **BGR, Germany, Total element concentrations by X-Ray Fluoresence (41 determinands):** SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, SO_3, LOI, Cl, F, As, Ba, Bi, Ce, Co, Cr, Cs, Cu, Ga, Hf, La, Mo, Nb, Ni, Pb, Rb, Sb, Sc, Sn, Sr, Ta, Th, U, V, W, Y, Zn and Zr.

- **SGS (Canada) – analysis of the agricultural soil samples only:** Extraction by Mobile Metal Ion (MMI®) solution and determination of 53 elements by ICP-MS: Au, Ba, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Dy, Er, Eu, Fe, Ga, Gd, Hg, In, K, La, Li, Mg, Mn, Mo, Nb, Nd, Ni, P, Pb, Pd, Pr, Pt, Rb, S, Sb, Sc, Se, Sm, Sn, Sr, Ta, Tb, Te, Th, Ti, Tl, U, V, W, Y, Yb, Zn and Zr.

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

- **Geological Survey of Norway:** pH-$CaCl_2$
- **Geological Survey of Slovakia:** Cation Exchange Capacity (CEC).
- **FUGRO (now KIWA):** Total Organic Carbon (TOC) and grain size.
- **Geological Survey of Norway – *determinations on the agricultural soils samples only*:** Total Carbon and Sulphur, Pb isotopes ($^{206}Pb/^{207}Pb$, $^{206}Pb/^{208}Pb$, $^{207}Pb/^{208}Pb$), Magnetic susceptibility, and soil colour on dry and wet samples.
- **Copenhagen & Canberra Universities:** Sr isotopes (*agricultural soil only*).
- **TU Bergakademie Freiberg**: Total C, N, S (*agricultural soil only*) – on-going.

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

- **Kazan Federal University, Tartastan, Russia:** Magnetic measurements (*agricultural soil only*) – on-going.

- **CSIRO Land and Water, Adelaide, Australia**: Determination of Partitioning coefficients (K_d) for Ag, B, Co, Cu, Mo, Mn, Ni, Pb, Sb, Se, Sn, Te, V, and Zn by Mid-Infrared Diffuse Reflectance Spectroscopy (MIR).

  Note: In addition, with this method it is possible to estimate different chemical and physical properties on soil samples, *e.g.*, clay, organic matter, moisture, cation exchange, pH, electrical conductivity, mineralogy, *etc*.

GEMAS Quality control report on the aqua regia extraction analysis results

http://www.ngu.no/upload/Publikasjoner/Rapporter/2009/2009_049.pdf

GEMAS Quality control report on the results of

- **total C and S (NGU)**
- **XRF major & trace elements (BGR)**
- **TOC (FUGRO)**
- **CEC (Slovak Republic)**
- **pH in $CaCl_2$-extraction (NGU)**
- **PSD - particle size distribution (FUGRO)**

Particle Size Distribution results are the only GEMAS-results that could not be accepted due to poor quality.

PSD was predicted using CSIRO's MIR-spectra based on a model developed for European soils (cooperation between BGR, CSIRO & ARCHE).

http://www.ngu.no/upload/Publikasjoner/Rapporter/2011/2011_043.pdf

GEMAS Quality control report on the results of

- **Particle size analysis (clay, sand, silt – estimated by MIR)***
- **Lead isotopes**
- **Extraction by Mobile Metal Ions method (SGS)**
- **Quality control of project standards Ap & Gr**

*** Collaboration between BGR, CSIRO & ARCHE for the development of European MIR model**

http://www.ngu.no/upload/Publikasjoner/Rapporter/2012/2012_051.pdf

GEMAS Geochemical Maps of Europe

(186 individual determinand maps)

Aqua Regia	Total (XRF)	MMI®	
Agricultural soil (N=52)	Agricultural soil (N=31)	Agricultural soil (N=17)	Agricultural soil Pb isotopes (N=3)
Grazing land soil (N=52)	Grazing land soil (N=31)		

115 special maps

Thematic 49	Cluster 10	EDA 11	Factor analysis 8	Physico-chemical 10	Ratios 2	Mineral deposits 10	Risk Ass. 12

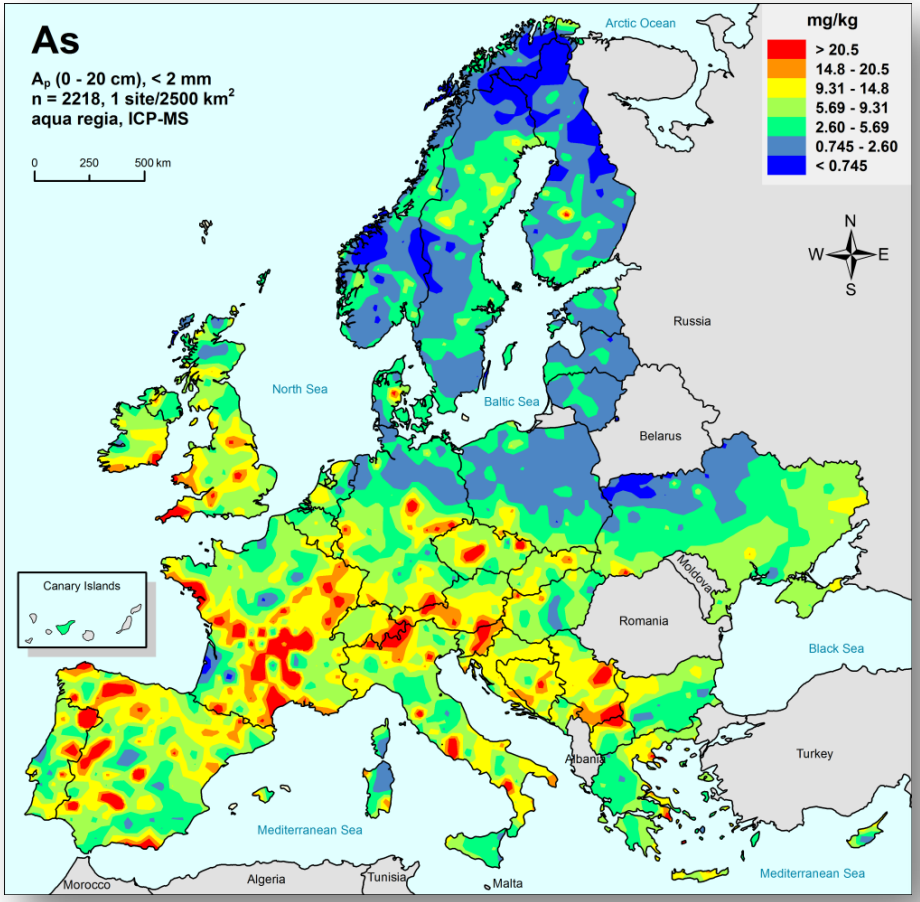
Inferred lithology + Mobility Index + Macronutrient Index

Total number of maps ≈ 340 in two volumes

Total Maps on DVD ≈ 2234

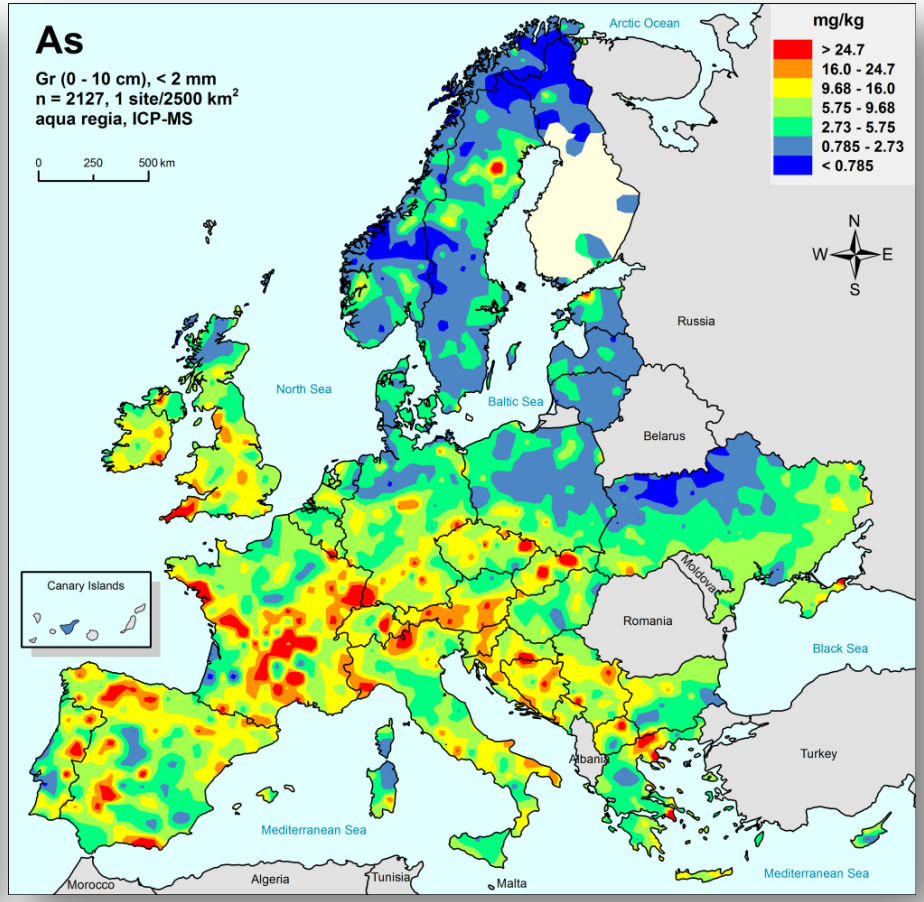
GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

Agricultural soil, 0-20 cm



Source: Reimann *et al*., 2014c, Fig. 11.9.5, p.155

Grazing land soil, 0-10 cm



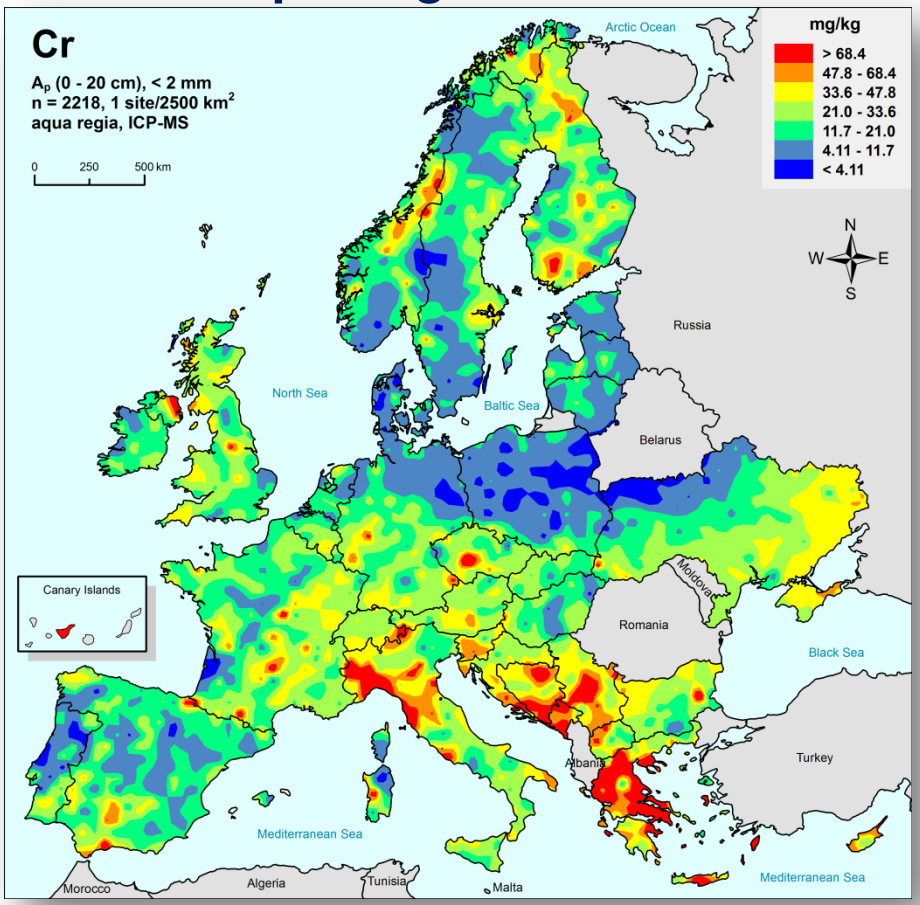
Source: Reimann *et al*., 2014c, Fig. 11.9.5, p.155

Two different sample types/site, each *ca*. 2100 samples – the maps are robust

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

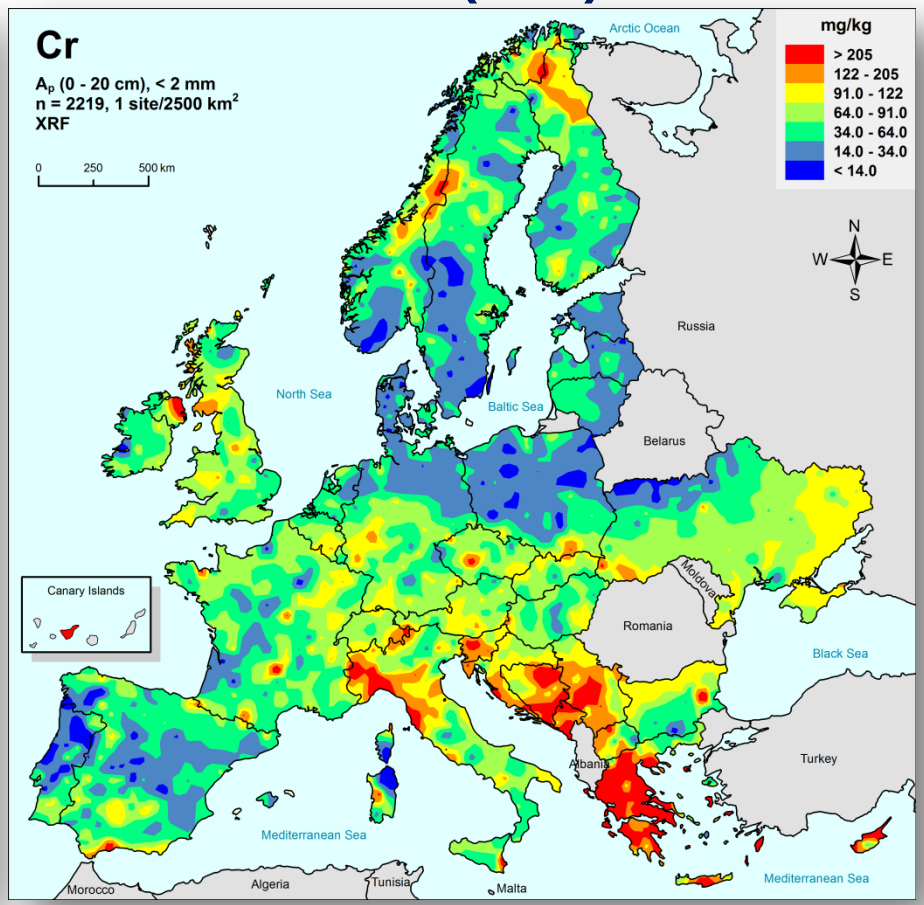
Agricultural soil, 0-20 cm

Aqua regia extraction



Source: Reimann *et al.*, 2014c, Fig. 11.21.5, p.225

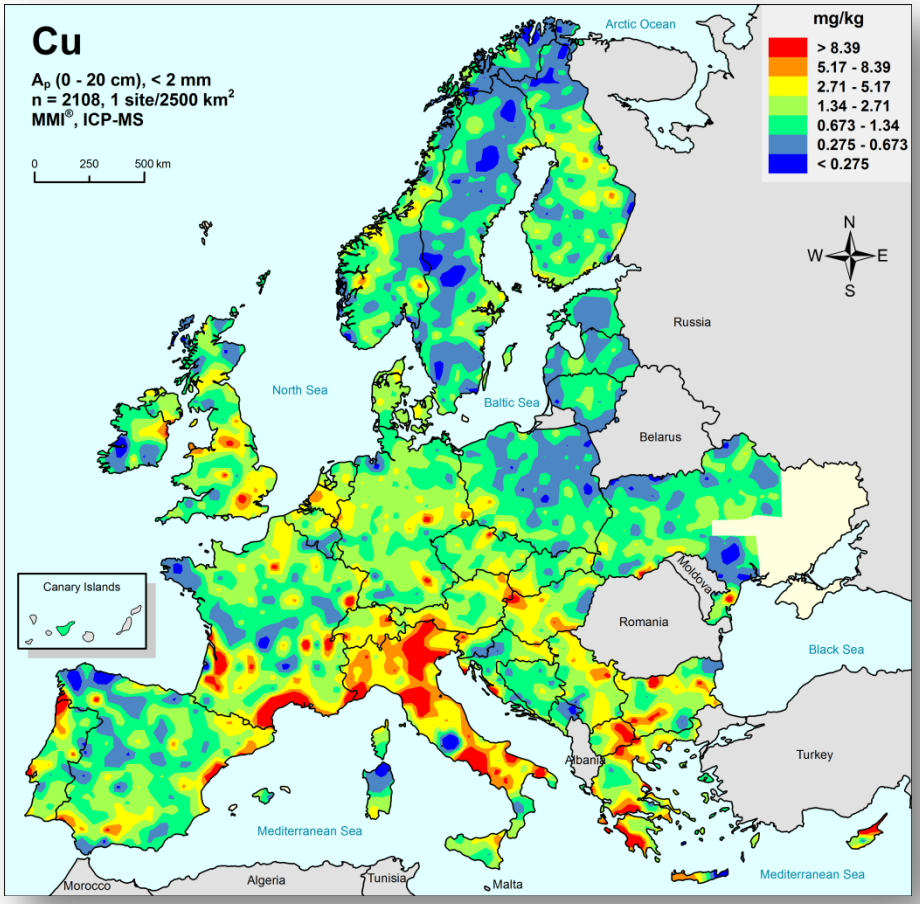
Total (XRF)



Source: Reimann *et al.*, 2014c, Fig. 11.21.5, p.226

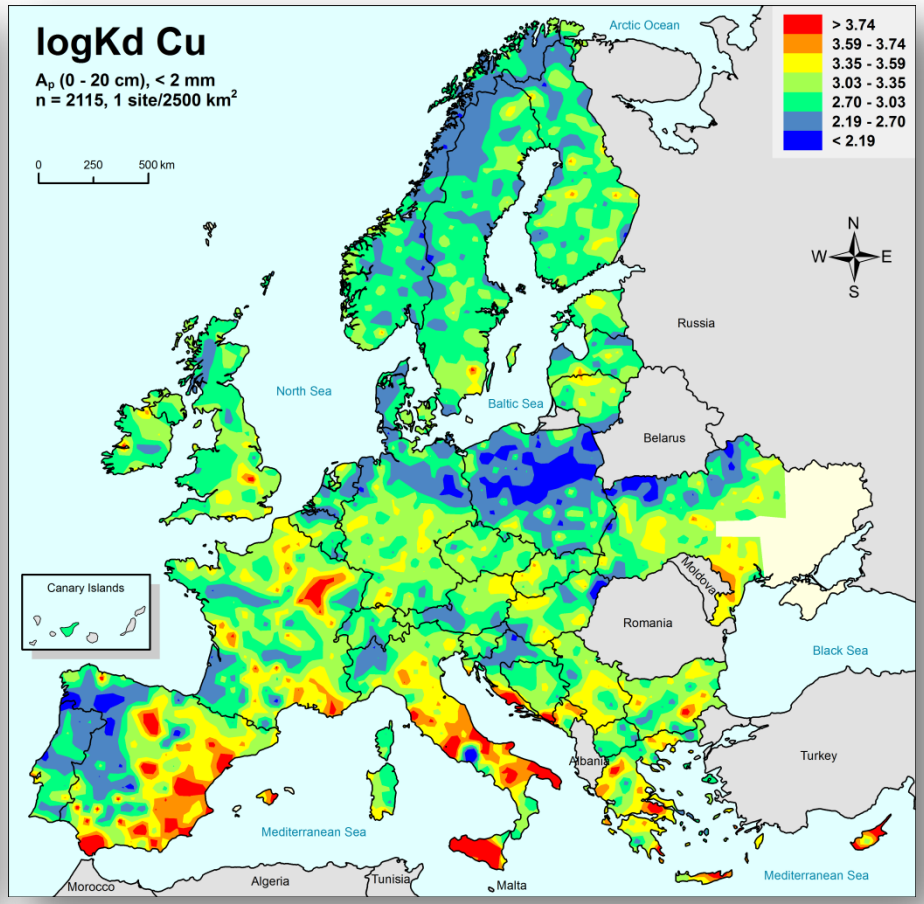
Agricultural soil, 0-20 cm

MMI® extraction



Source: Mann *et al*., 2014, Fig. 13.14, p.217

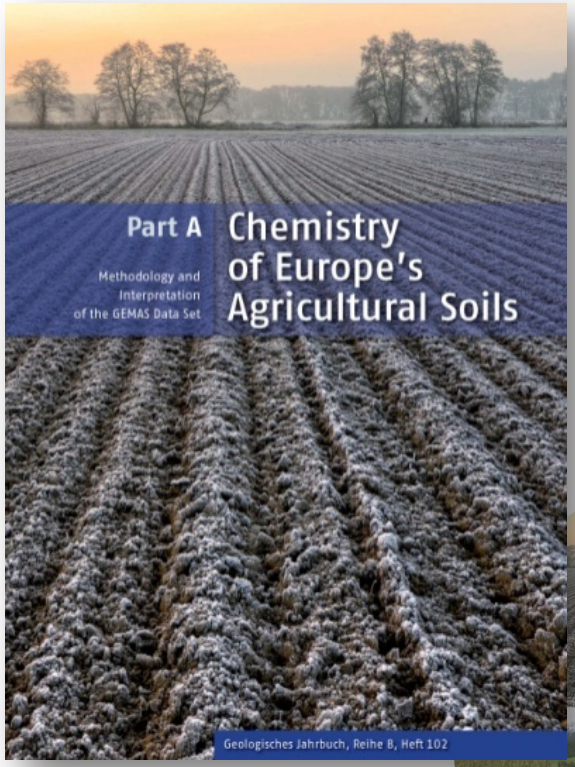
Log solid-solution partition coefficient, Kd

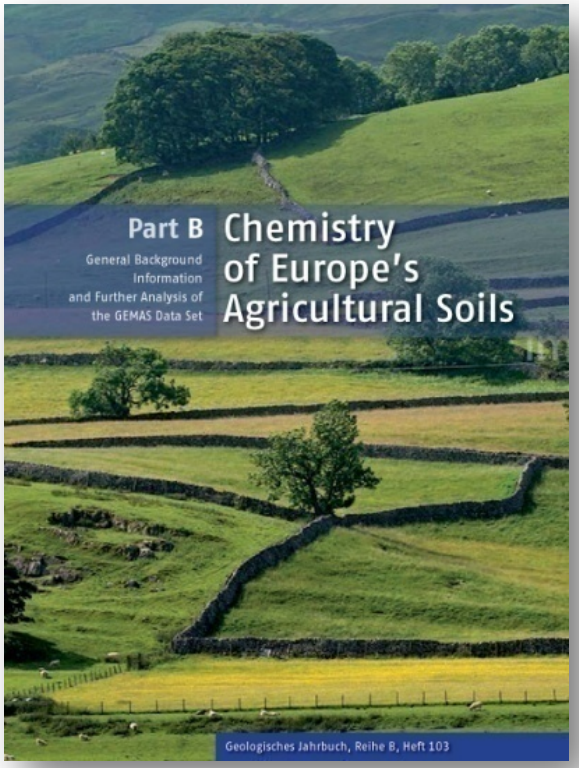


Source: Reimann *et al*., 2014a, on accompanying DVD

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

Printed Publications





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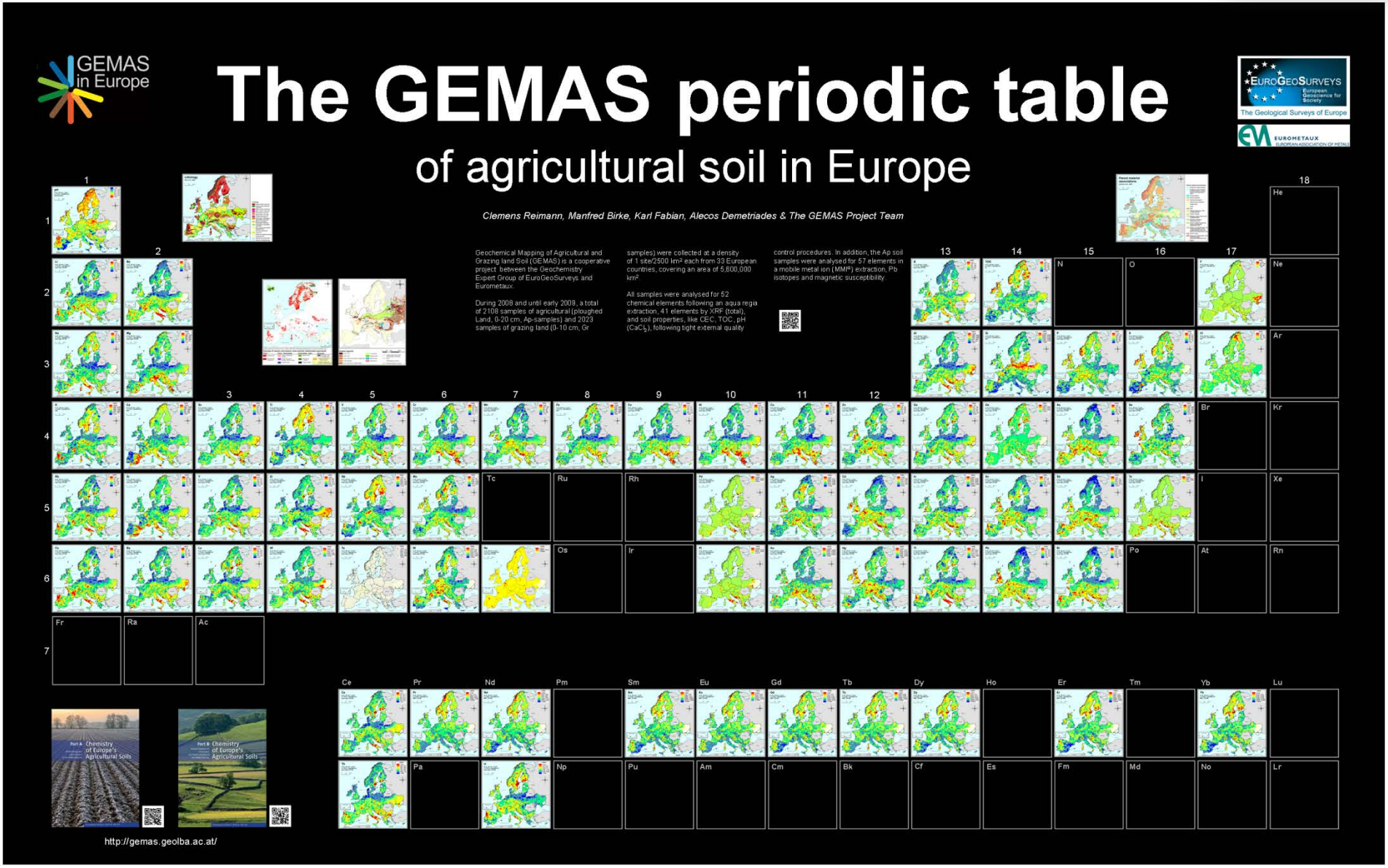
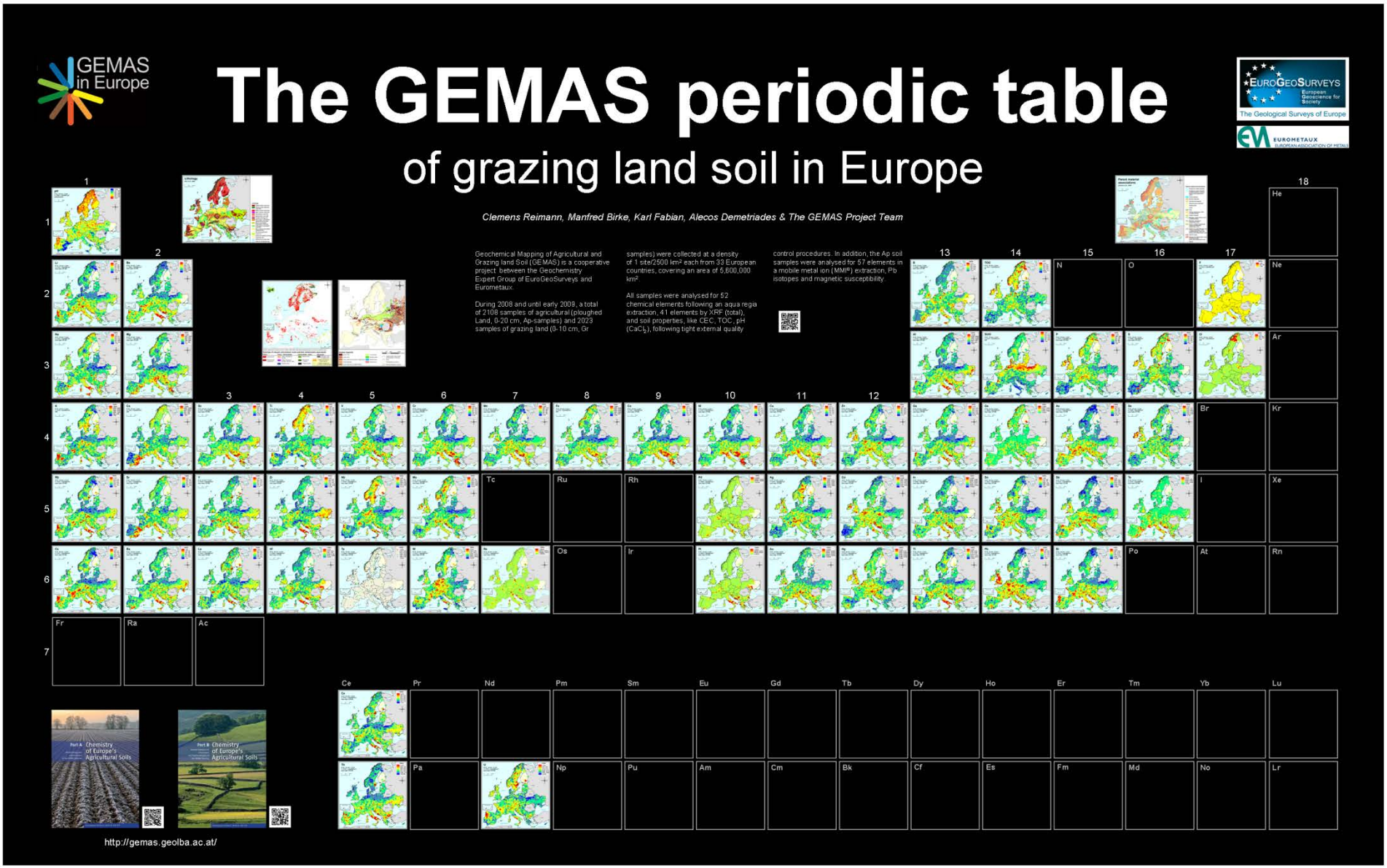
GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

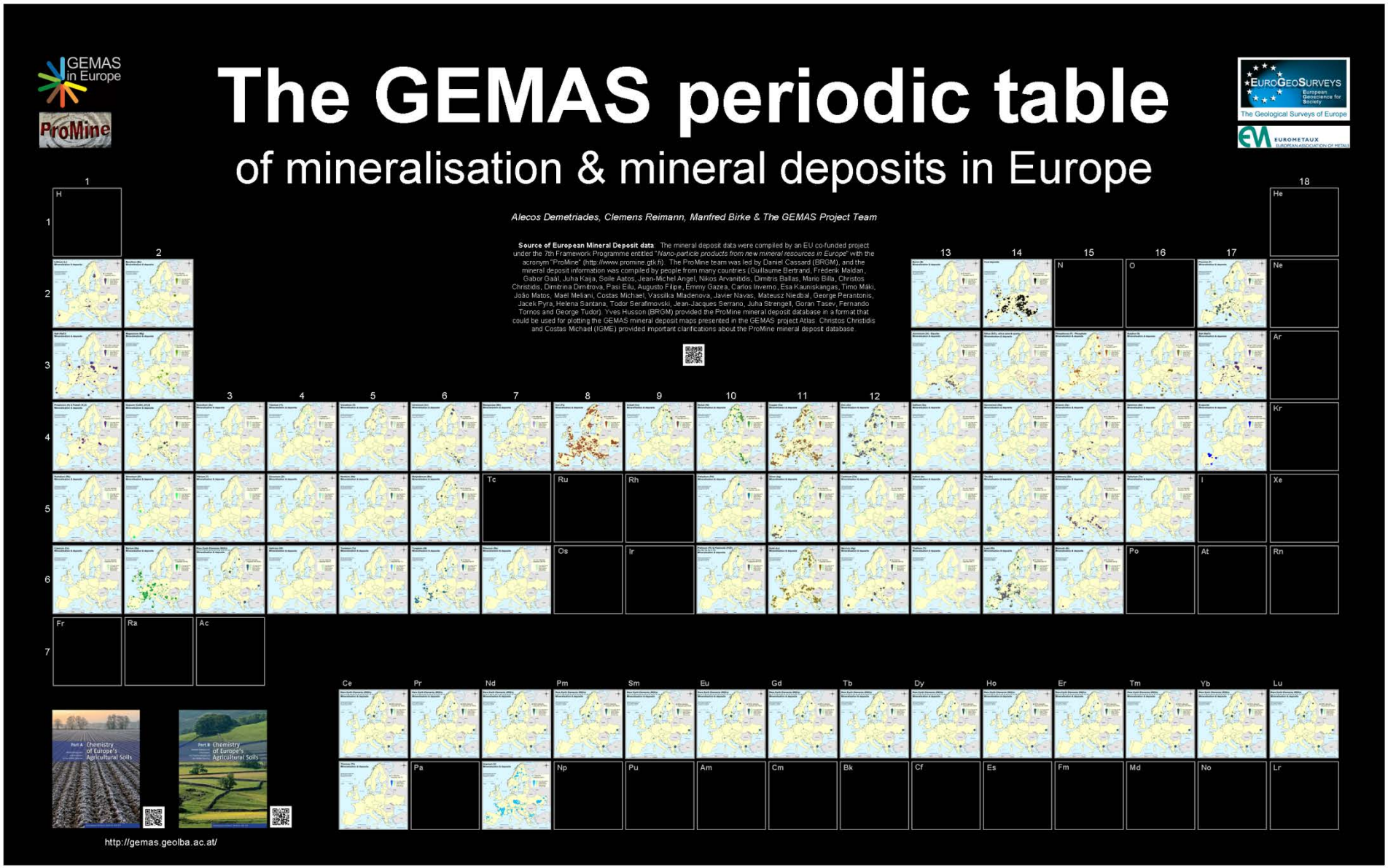


http://gemas.geolba.ac.at/Download/GEMAS_Periodic_Table_of_Elements_High_resolution.pdf

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe



GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe



http://gemas.geolba.ac.at/Download/GEMAS_Mineralisation_Periodic_Table_Poster_high.pdf

GEMAS – GEochemical Mapping of Agricultural and grazing land Soil of Europe

The GEMAS atlas results can be used for effective land use planning:

- **Agriculture,**
- **Grazing land,**
- **Mineral exploration,**
- **Land use policy,**
- **Health related research,**
- **Environmental policy,**
- **Construction of new towns, *etc*.**

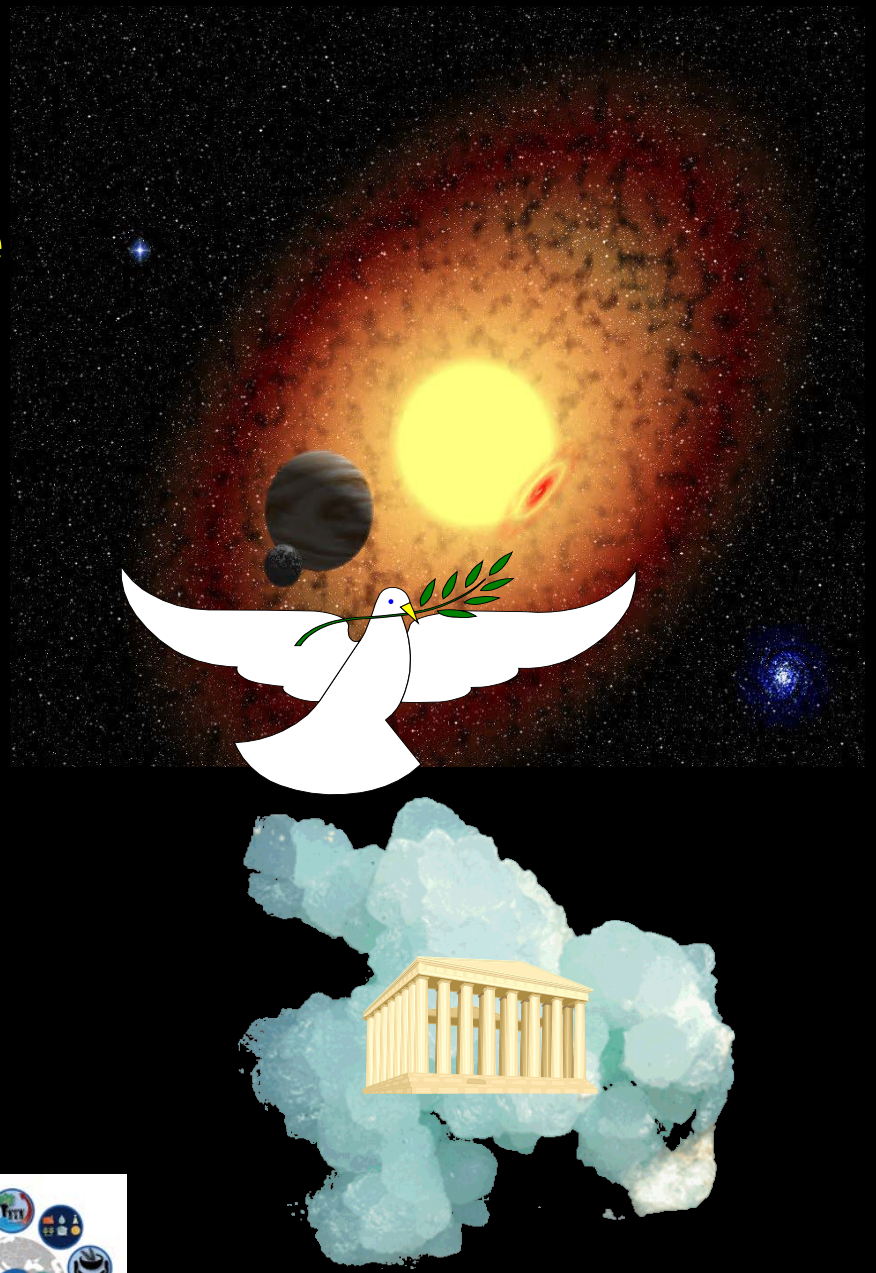
FOREGS & GEMAS Geochemical Atlases

Data Gaps:

- **Mineralogy of solid sample media** (stream & floodplain sediment, soil), and
- **Organic compounds.**

Geological Surveys consider it their obligation to provide to the present and future generations of humankind high quality geochemical databases for environmental and resource management, and for improving the living conditions on our home planet Earth

Thank you for your attention



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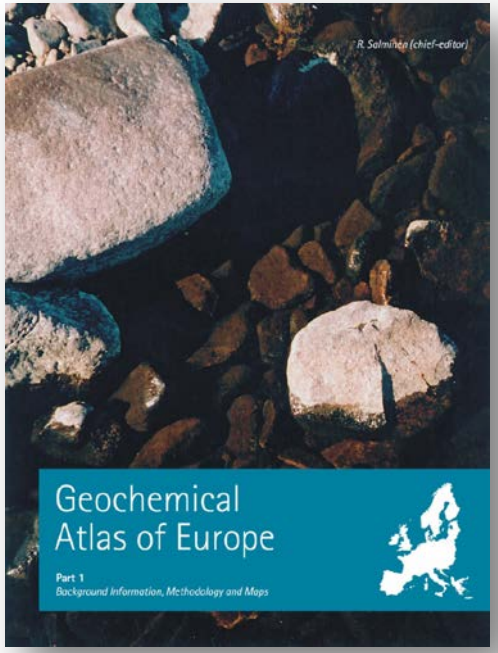
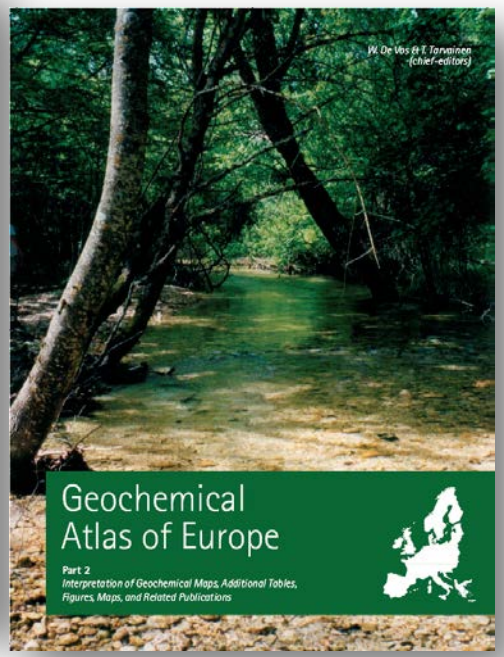
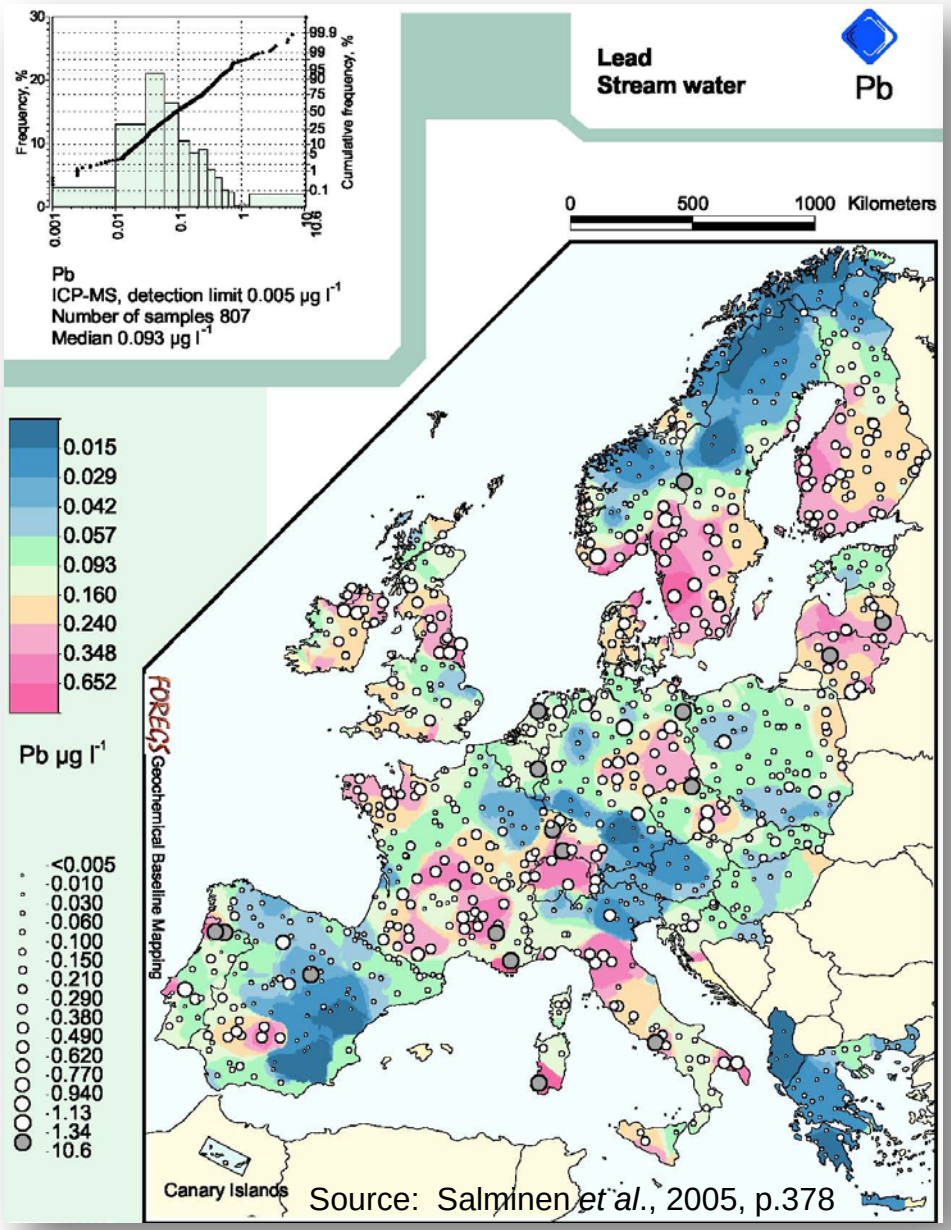
Additional maps to show the variety of data and geochemical maps that are available for a single element in different sample media

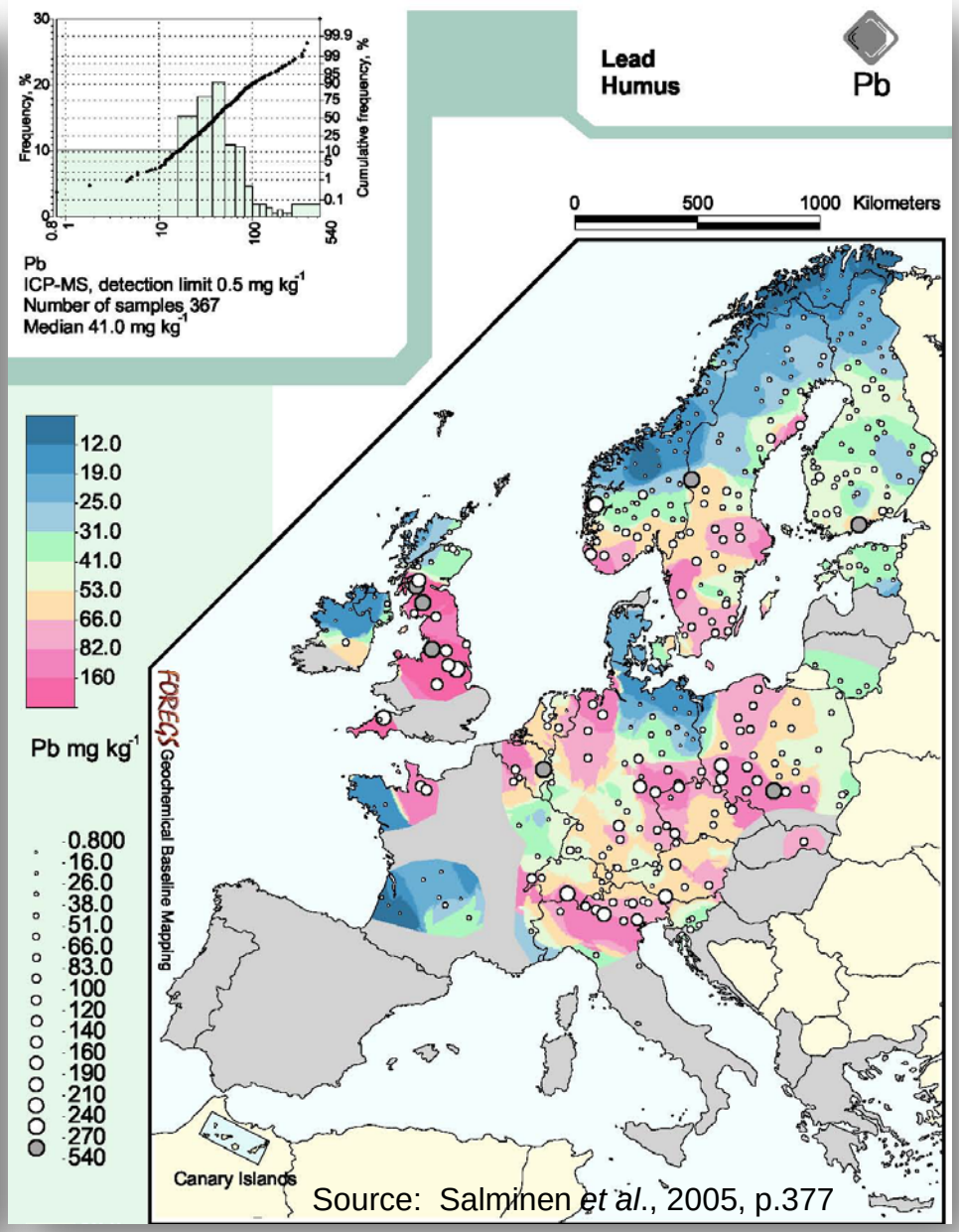




FOREGS Geochemical Atlas of Europe: Maps of lead (Pb) in samples of Stream Water and Humus

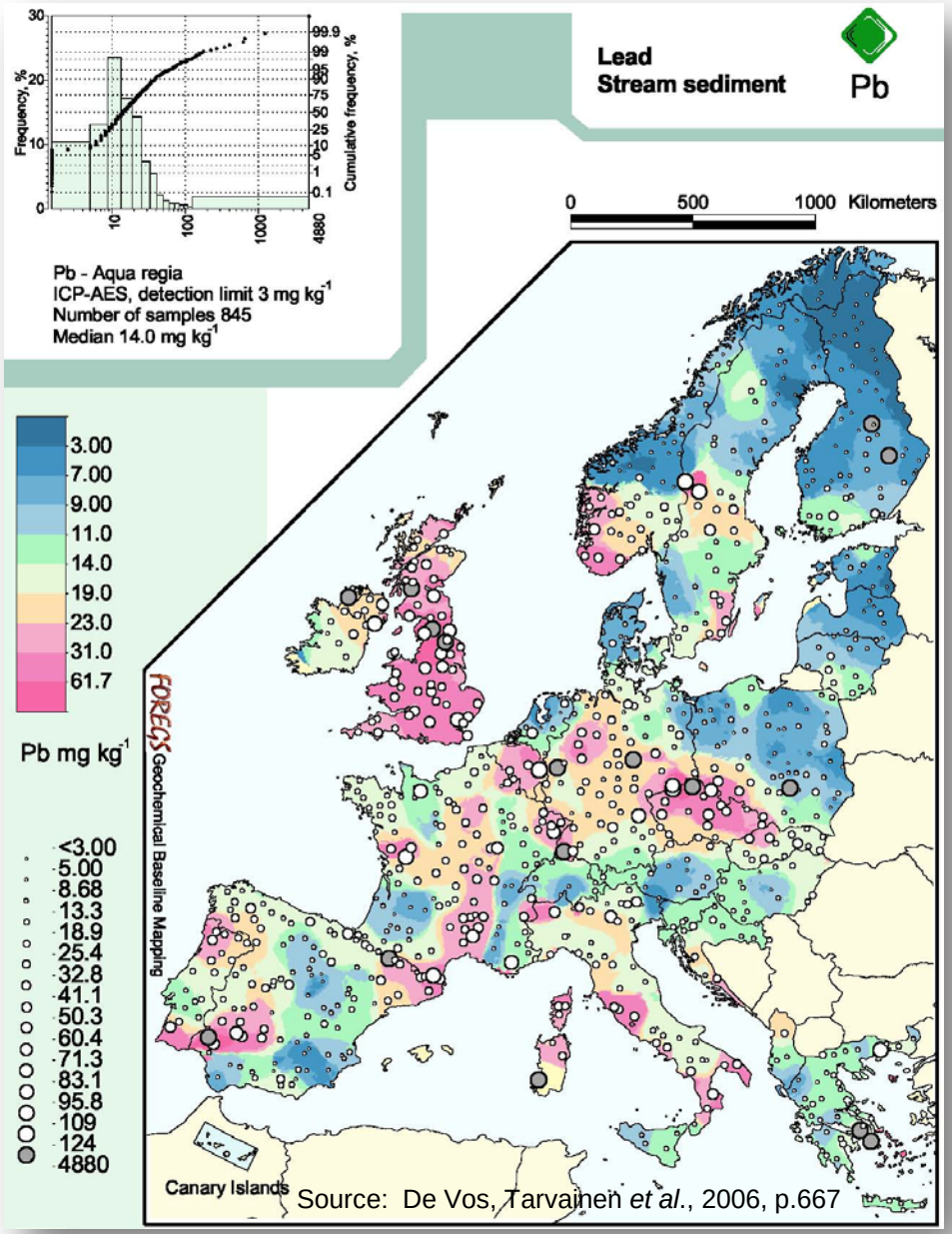


Source: Salminen *et al.*, 2005, p.378

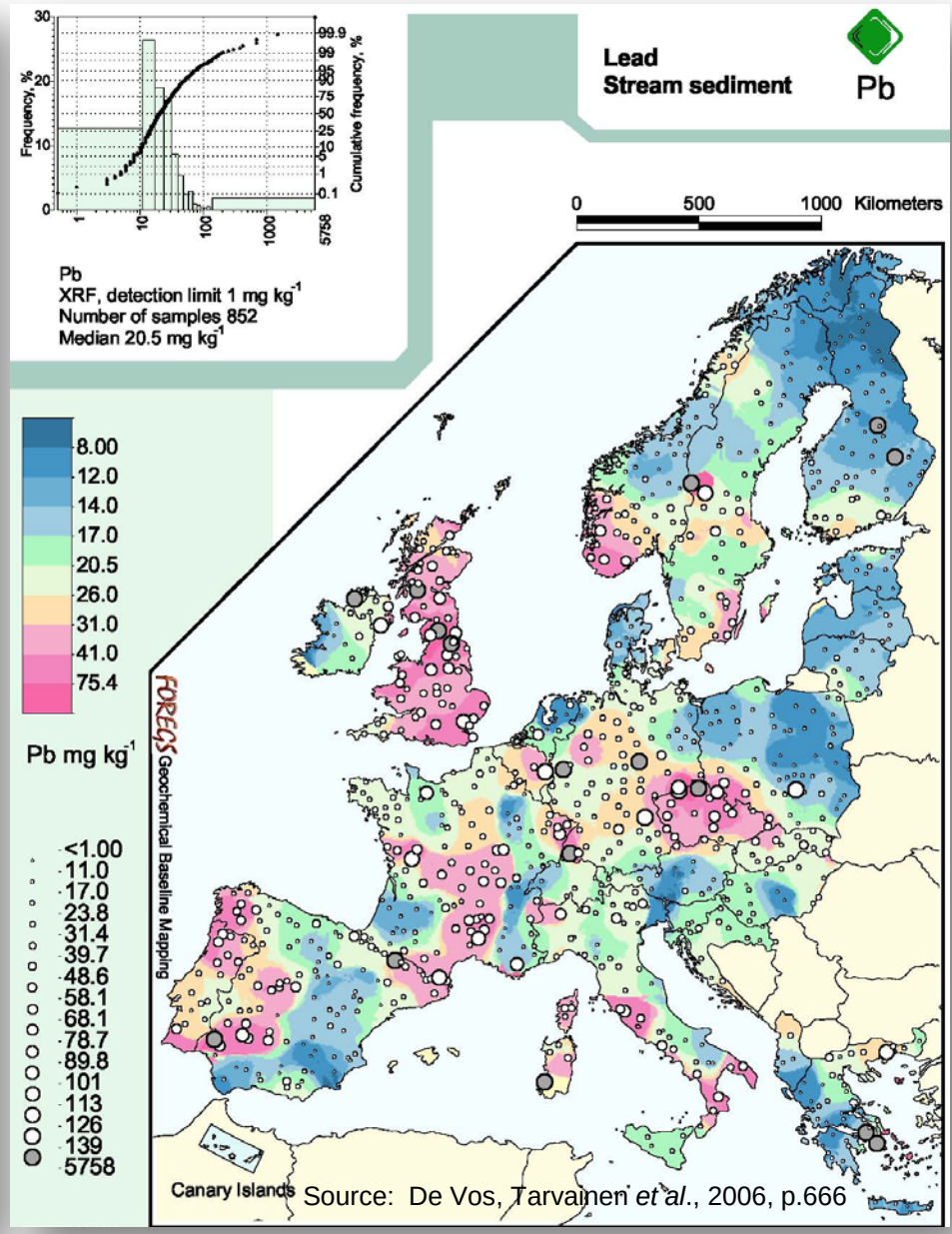


Source: Salminen *et al.*, 2005, p.377

FOREGS Geochemical Atlas of Europe: Maps of lead (Pb) in samples of Stream Sediment – Aqua regia & Total extractions

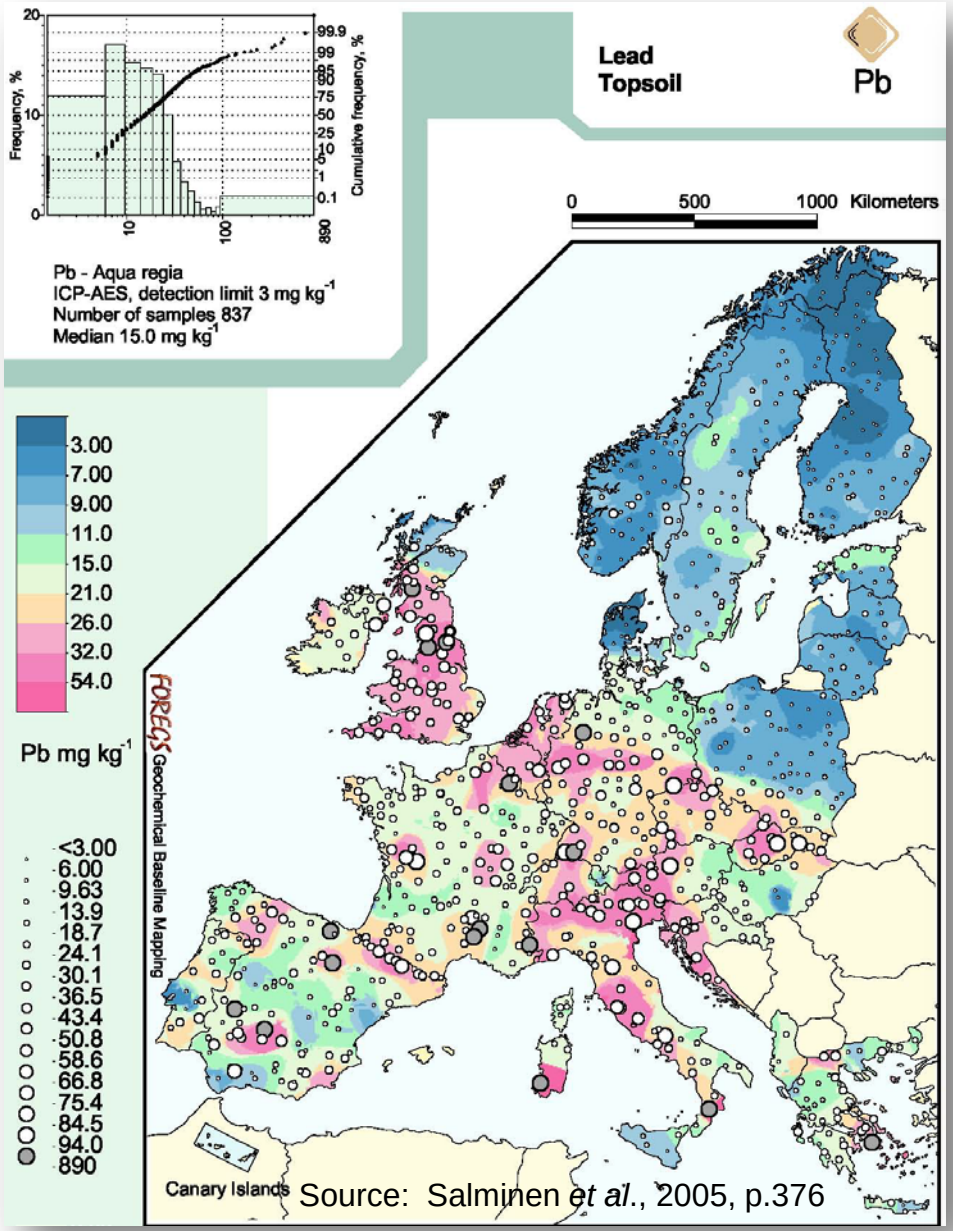


Source: De Vos, Tarvainen *et al.*, 2006, p.667



Source: De Vos, Tarvainen *et al.*, 2006, p.666

FOREGS Geochemical Atlas of Europe: Maps of lead (Pb) in samples of Topsoil – Aqua regia and Total extractions



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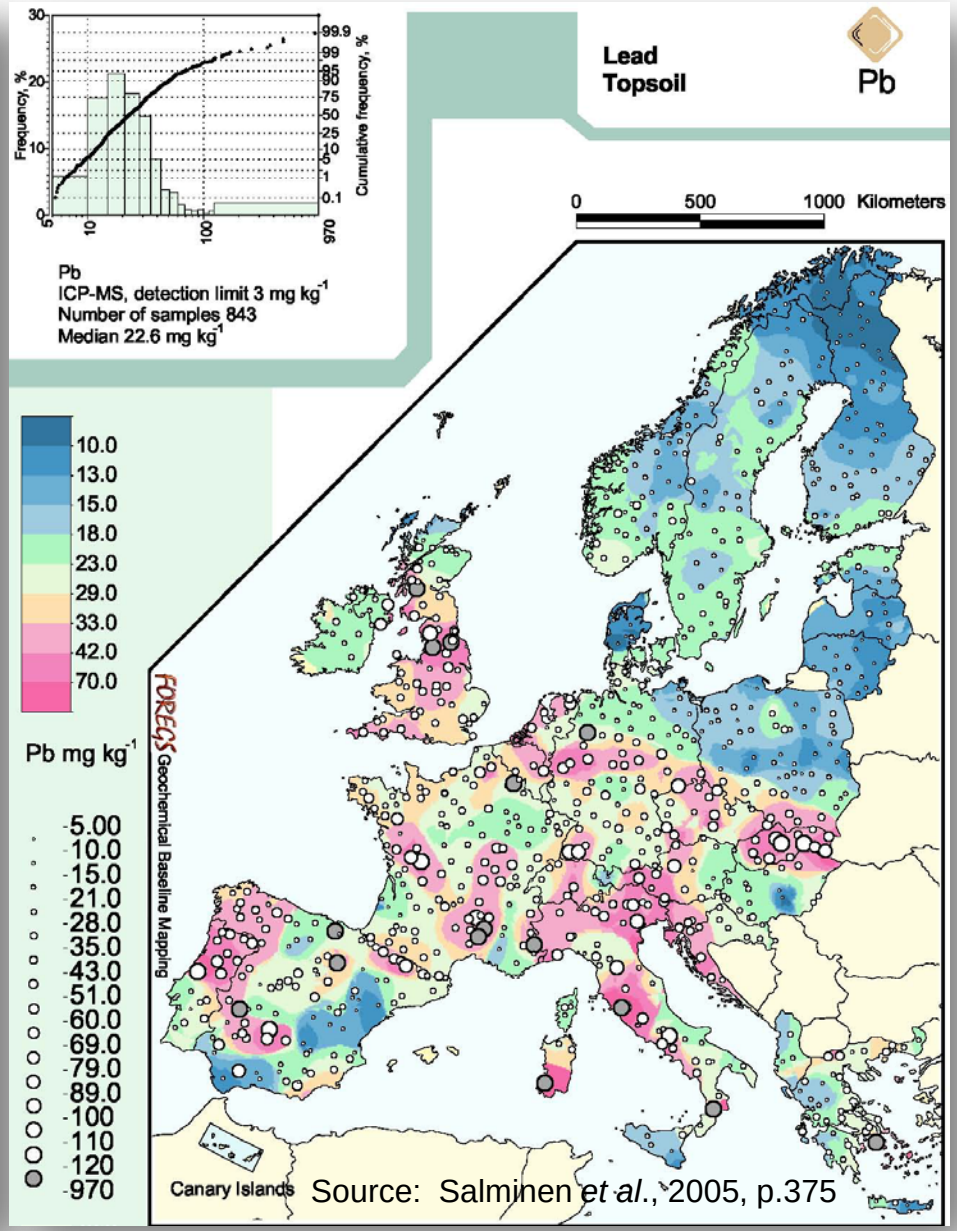

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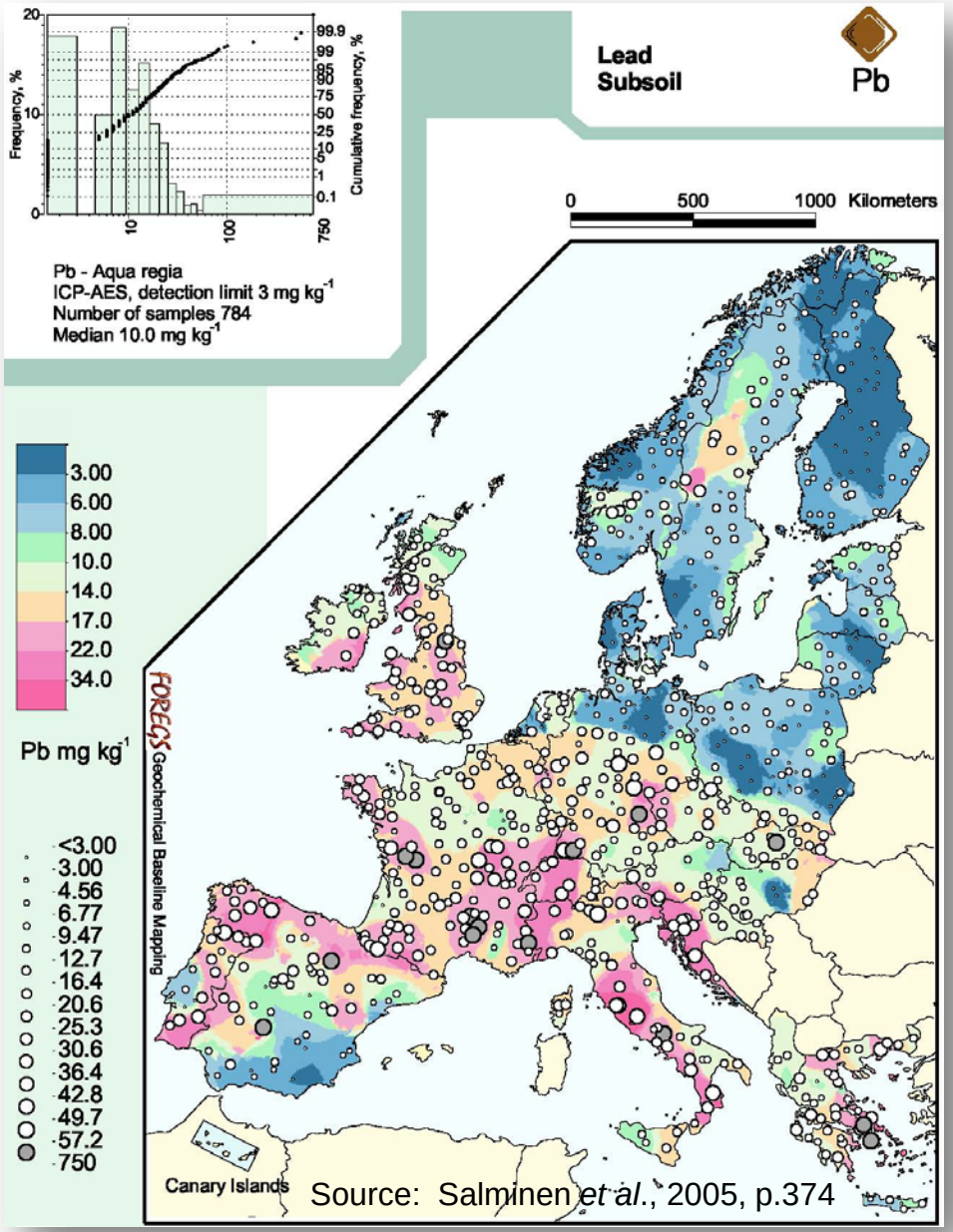

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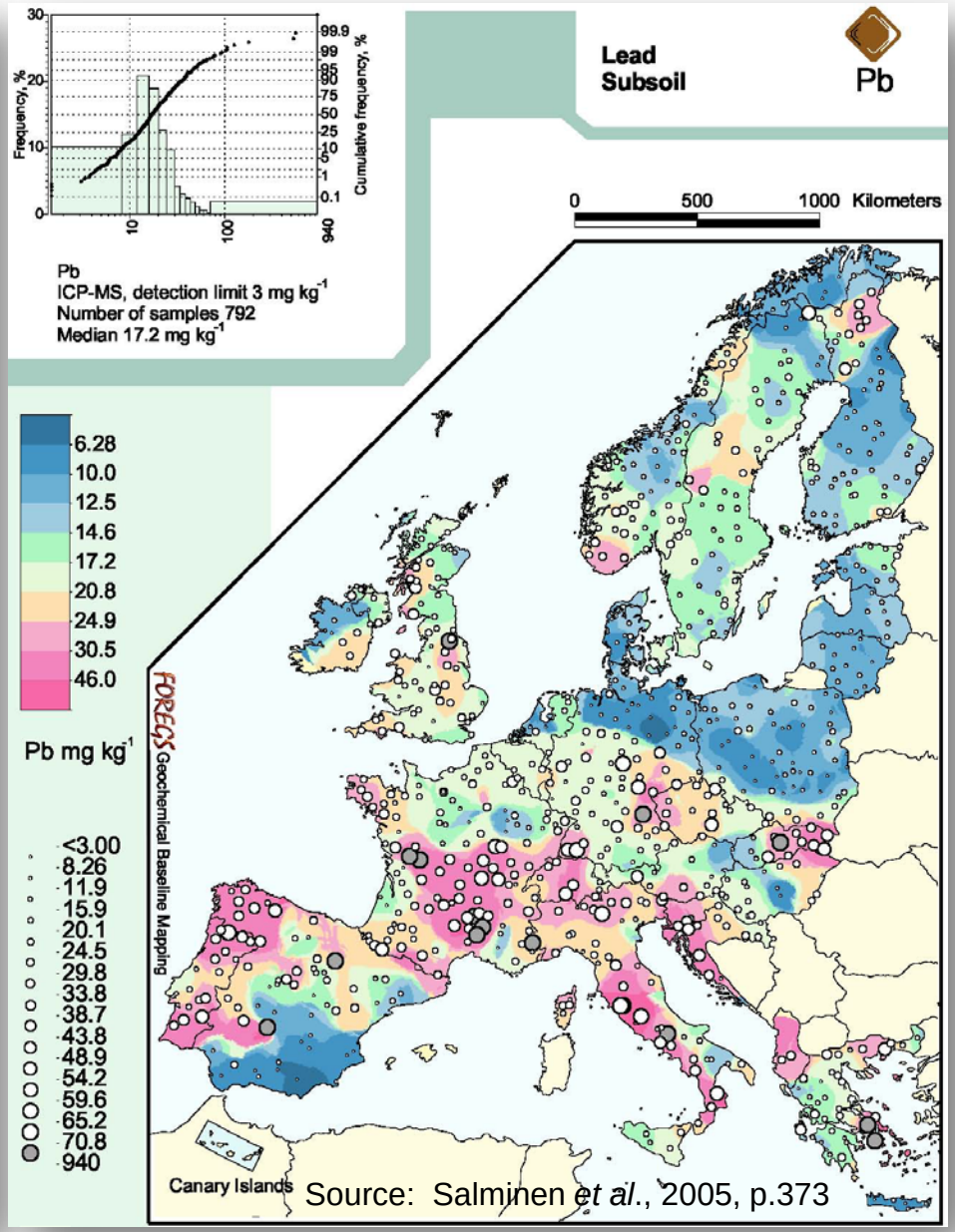
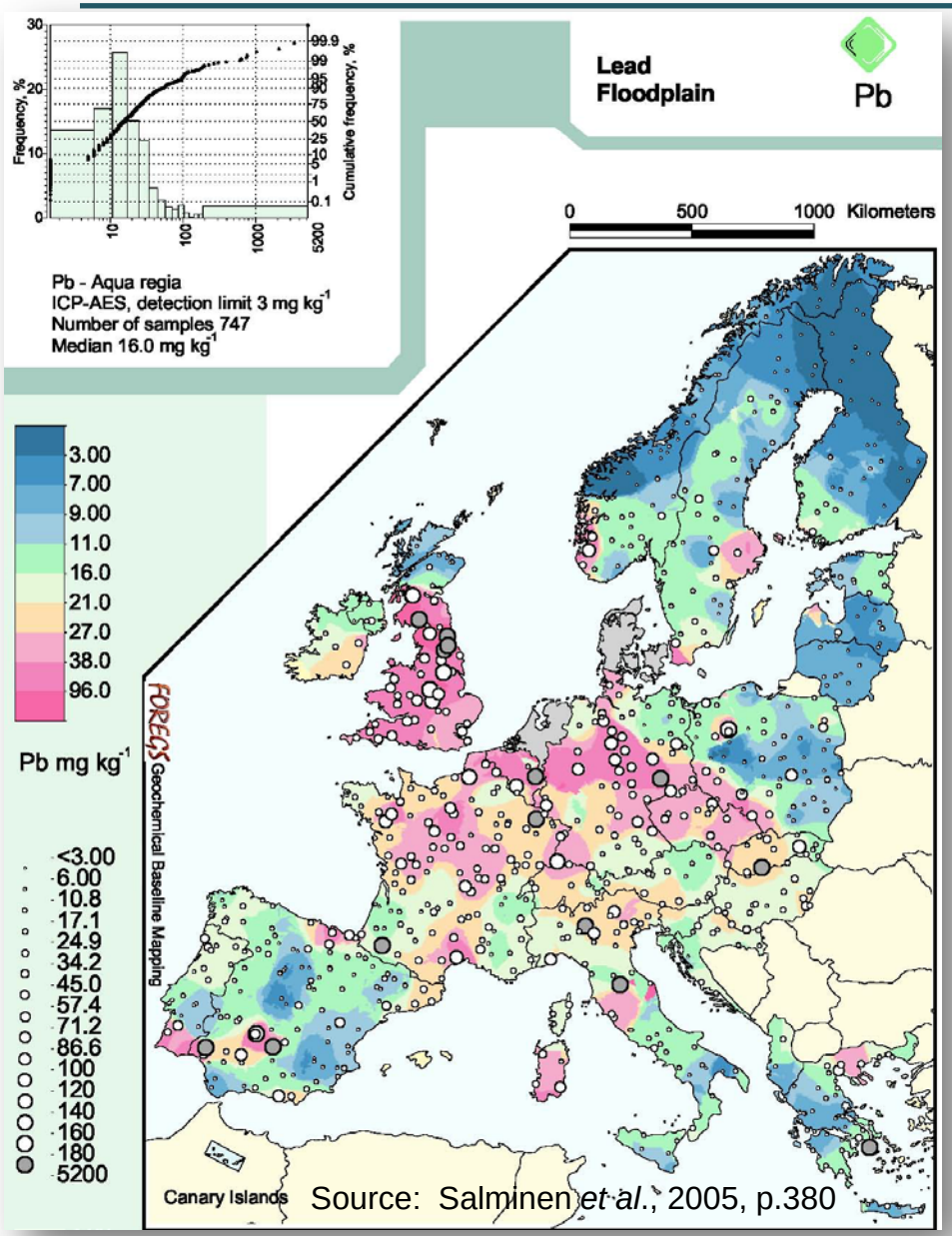


Source: Salminen *et al.*, 2005, p.373

FOREGS Geochemical Atlas of Europe: Maps of lead (Pb) in samples of Floodplain sediment – Aqua regia & Total extractions



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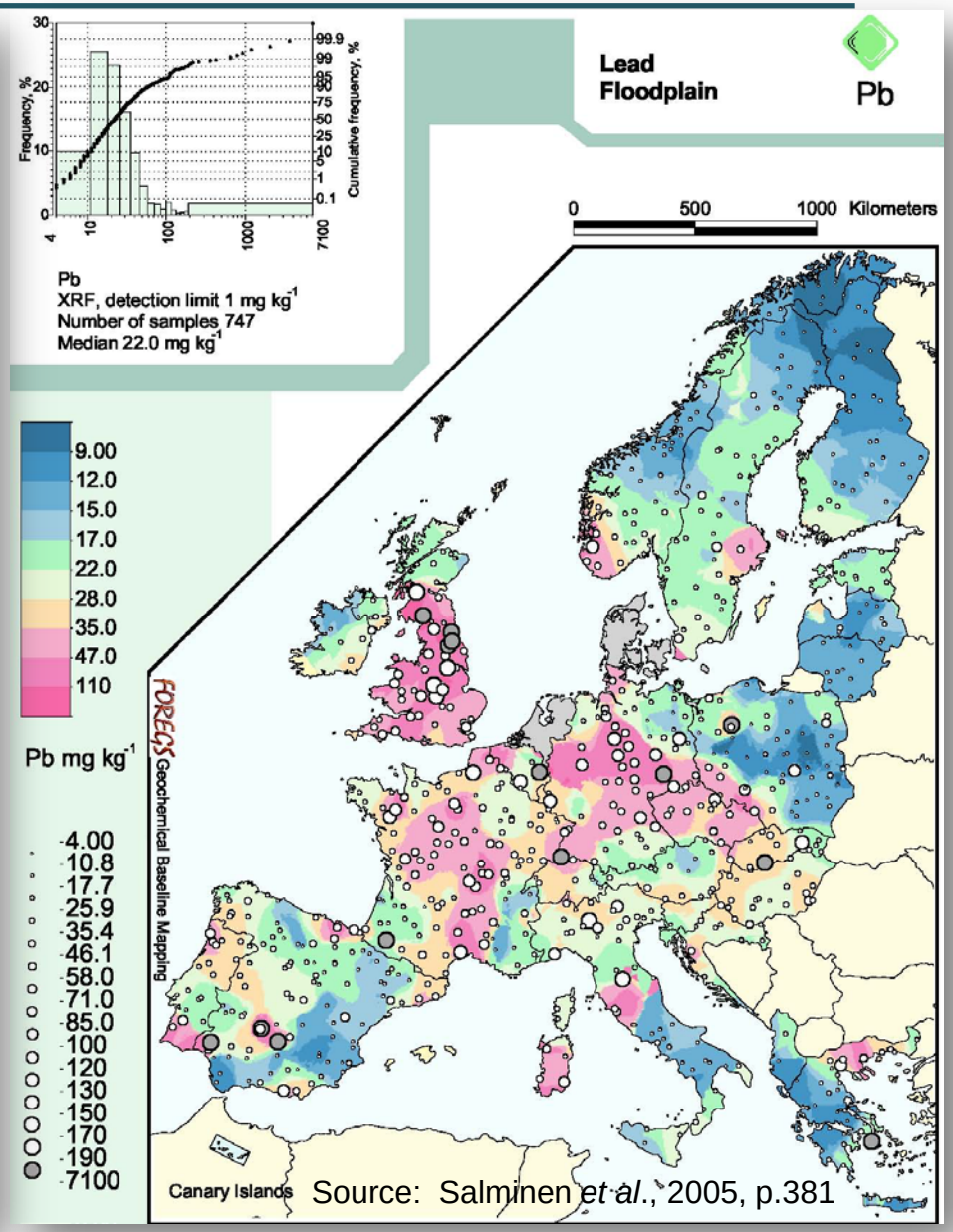

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