



MEDICAL GEOLOGY IN BRAZIL

STATE OF ART

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Geological Survey of Brazil-CPRM

Workshop and Hemispherical Conference on Medical Geology

Gurabo – Puerto Rico November 14 – 18, 2005

Medical Geology Research begin:

In 1996 F in Paraná State: stream sediment, soil and water

In 1996 Pb and Cd in Bahia State: stream sediment and soil

In 1998 Pb in Ribeira Valle – São Paulo and Parana states : stream sediment, soil and water

In 1998 As in Iron Quadrangle Minas Gerais State: stream sediment

In 2002 - 2003



**ENVIRONMENTAL
GEOCHEMISTRY AND MEDICAL
GEOLOGY NETWORK - REGAGEM**
regagem@ige.unicamp.br

**NATIONAL RESEARCH PROGRAM OF
ENVIRONMENTAL GEOCHEMISTRY
AND MEDICAL GEOLOGY - PGAGEM**
www.cprm.gov.br/pgagem



Environmental and Health Effects
of Toxic Elements, Metal Ions, and Minerals

2003 INTERNATIONAL WORKSHOP

October 14 - 16, 2003 Campinas -SP

MEDICAL GEOLOGY

METALS, HEALTH AND THE ENVIRONMENT

110 participants





SYMPOSIUM ON MEDICAL GEOLOGY

32nd IGC – Florence

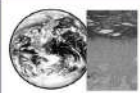
2004

Total: 33 presentations

**Brazilian papers:
04 presentations**



2005 WORKSHOP INTERNACIONAL



Environmental
and health effects
of toxic elements,
metal ions,
and minerals

PÚBLICO-ALVO
O workshop destina-se a geólogos,
geofísicos, meteorólogos, químicos,
biólogos, médicos, toxicólogos,
epidemiologistas, pedólogos,
estatísticos, veterinários, bioestatísticos ou
a outros profissionais interessados em saúde
do meio ambiente e dos participantes
com interesse em geologia médica, em
particular no efeito dos tóxicos dos
metais pesados no meio ambiente e na
saúde humana e animal. O tema
importante do evento é a possibilidade
de aplicar a Biotransformação de metais
de pesados e de outros tóxicos
profissionais que trabalham em
diversos níveis do meio ambiente e
da saúde.

GEOLOGIA MÉDICA

METAIS,
SAÚDE E
AMBIENTE

Uma emergente disciplina que estuda a influência dos fatores
geológicos ambientais sobre a saúde humana e dos animais

02-04 Junho · 2005 · Rio de Janeiro · Brasil

TEMAS

- Saúde Ambiental: Fatores da Exposição e Efeitos
na Saúde dos Elementos Tóxicos, Metais Tóxicos
e Metalóides
- Toxicologia Ambiental, Efeitos Geoquímicos
e Efeitos na Saúde Humana
- Toxicologia Analítica: Exposição dos Elementos
Tóxicos, Métodos Analíticos
- Tópicos Especiais em Pesquisa sobre Geologia
Médica e Saúde Humana
- Palestras Nacionais: Uma Segura de Biotransformação,
Vigilância em Saúde Ambiental,
Epidemiologia/Geoquímica Ambiental e
Geologia Médica, Acúridos: Exposição humana,
Cáncer e Elementos Tóxicos, Fluorose Dentária,
Geoquímica dos Solos, Biofortificação na
Prevenção da Deficiência de Micronutrientes

MINI-CURSO

Dr. Ole Selinus (Serviço Geológico da Suécia)
Dr. Robert Finkelman (Serviço Geológico dos Estados Unidos)
Dr. David Cullen (Instituto de Patologia das Forças Armadas dos Estados Unidos)

PALESTRAS NACIONAIS PARA CONVIDADOS / SESSÃO POSTER ABERTA A INTERESSADOS

CPRM - Serviço Geológico do Brasil

Auditório "Salão Nobre"
Avenida Pasteur, 404, 3º andar - Urca
Rio de Janeiro - RJ - BRASIL

INFORMAÇÕES E INSCRIÇÕES ATÉ 15/5/2005

www.cprm.gov.br/pagagem

Tradução simultânea inglês/português/inglês.
Taxa de inscrição: R\$ 200,00 para profissionais e R\$ 50,00 para estudantes.
Informações: Fátima Maria Nascimento Silva / Fátima Maria Pires Silva
e-mail: fatima@cprm.gov.br - tel: (21) 2209-0704, fax: (21) 2209-5804



210 Participants

55 Brazilian presentations
(11 lectures, 41 posters)



Essentials of **MEDICAL GEOLOGY**

Impacts of the Natural Environment on Public Health

Edited By:
Olle Selinus
Brian Alloway
José A. Centeno
Robert B. Finkelman
Ron Fuge
Ulf Lindh
Pauline Smedley

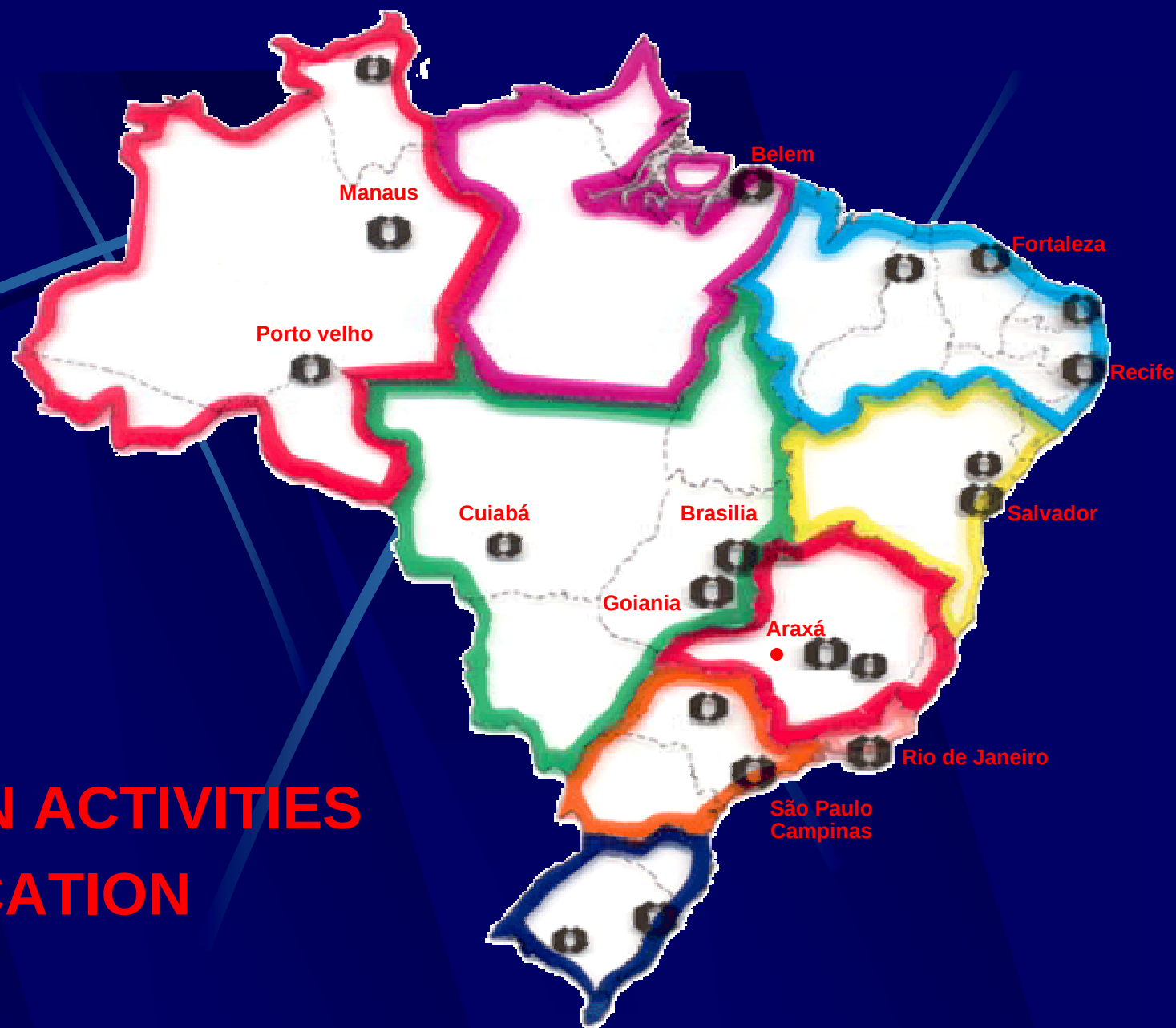
**Acquisition of 36 books
after the workshop**

16 to Geological Survey

20 to other researchers

DISSEMINATION ACTIVITIES – 2003/2005

- Medical Geology Workshop (Jun/03) – SGB/CPRM – RJ
- International Workshop on Medical Geology (Oct/03) – Campinas- SP
- Geology Week (Nov/03) – Rural Federal University of Rio de Janeiro-RJ
- Brazilian Congress of Geochemistry (Nov/03) – Belem - PA
- Amazon Geological Symposium (Dec/03) – Manaus – AM
- Environment and Mining Congress (Mar/04) – Salvador - BA
- Geology Week (Jun/04) – Federal University of Rio de Janeiro
- 32 IGC (Aug/04) – Florence – Italia
- Brazilian Geological Congress (Oct/04) – Araxa – MG
- Distribution of PGAGEM folder
- International Workshop On Medical Geology (Jun/05) – Rio de Janeiro
- Hydric Resources Seminary of Rondonia (Oct/05)
- Short Course Geochemistry Congress (Nov/05) – P.Galinhas - PE



DISSEMINATION ACTIVITIES 2003/2005 - LOCATION

Parintins water supply (NO_3 , Al)

Santana- AP (As)

Amazon east, heavy metal water supply

Ceara State heavy metals water supply

Lucrécia -RN Heavy metals water supply

Lagoa Real - BA (U, Th)

NE Rondônia State, working

São Francisco Valley-MG (F)

Goiás State, working

Itinga-MG, working (Li)

Iron Quadrangle-MG (As)

Paraná State: water, sediment and soil (F, Br, Cl)

Ribeira Valley-SP,PR Pb, As

Lavras do Sul -RS (Hg)

Acid water-SC,RS (coal)

Main areas of research on medical geology



**NATIONAL RESEARCH PROGRAM
ON ENVIRONMENTAL
GEOCHEMISTRY and MEDICAL GEOLOGY
“PGAGEM”- BRAZIL**

NATIONAL PARTNERSHIP:

- **Serviço Geológico do Brasil – CPRM**
- **Universidade de Campinas – UNICAMP**
- **Minerais do Paraná – MINEROPAR**
- **Universidade do Estado de São Paulo – USP**
- **Universidade Federal do Estado do Pará – UFPA**
- **Universidade Estadual de Londrina – UEL**
- **Universidade Federal Fluminense – UFF**
- **Comissão Nacional de Energia Nuclear – CNEN**
- **Instituto Evandro Chagas (Health Institute)**
- **Instituto Adolfo Lutz (Health Institute)**
- **Escola Nacional de Saúde Pública – ENSP (Health School)**
- **Fundação Nacional de Saúde – FUNASA (Ministry of Health)**
- **Empresa Brasileira de Agropecuária – EMBRAPA (Soil)**

INTERNATIONAL PARTNERSHIP:

- *U.S. Geological Survey (USGS)*
- *U.S. Armed Forces Institute of Pathology (AFIP)*
- *Geological Survey of Sweden (SGU)*
- *International Union of Geological Sciences (IUGS)*
- *International Medical Geology Association (IMGA)*

OBJECTIVES

- **Identification of elements: essential and/or toxic compounds;**
- **Public health support;**
- **Mineral exploration;**
- **Identification sources of contamination: industry, agricultural, mining and domestic – rural and urban;**

OBJETIVES

- **Surface and underground water contamination;**
- **Regional assessment of environmental degradation**
- **Environmental impacts;**

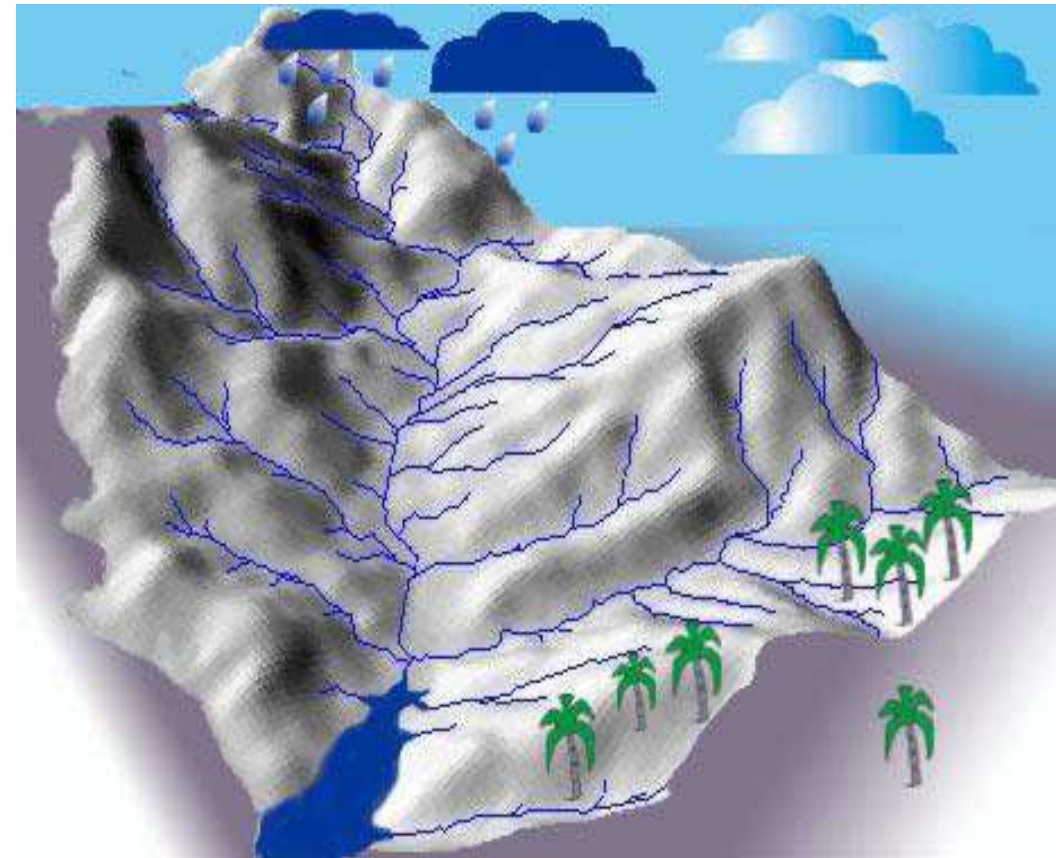
OBJETIVES

Give support to:

- **National Agency of Water, Hydrographic Basin Committee,**
- **Federal, state and county environmental institutions,**
- **EEZ, GEO Brazil/IBAMA/PNUMA.**

METHODOLOGY

- **Environmental geochemistry survey in the whole country**
- **Establishment of partnerships**
- **Water samples, soil and rivers and lakes bottom sediments**
- **On line data base**



Hydrographic basin and sampling of sediment

STREAM SEDIMENT AND WATER

Brazil was divided in two areas,
according to the access:

AREA I: 1 sample/2.000 Km² basin – the remaining territory, areas with remote access (eg. Amazon)

AREA II: density of 1 sample/100 Km² basin – larger and most developed country areas, with good access

STREAM SEDIMENT AND WATER

North
3.800.000 km²
8.250 samples

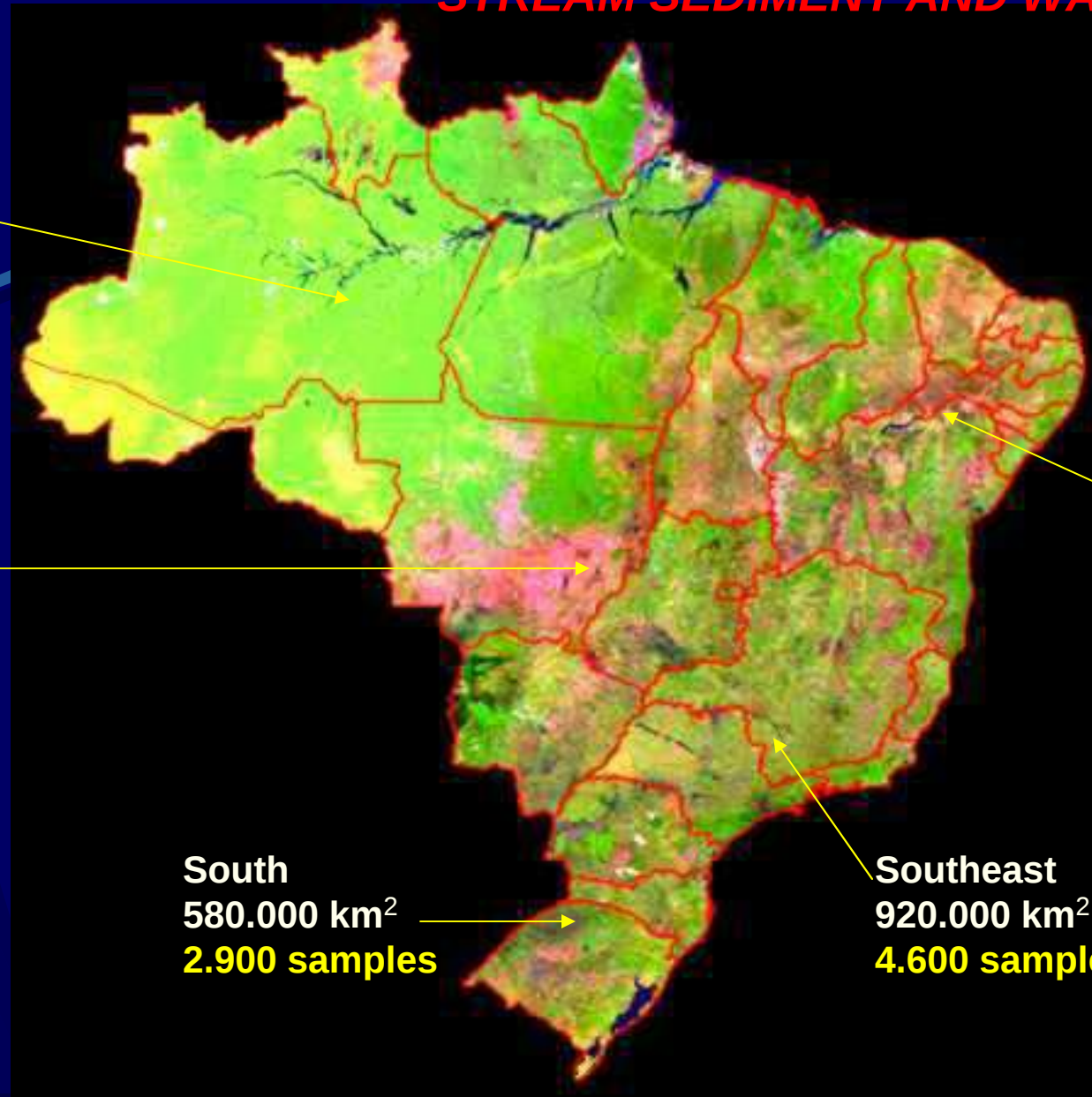
West Center
1.614.000 km²
6.200 samples

Northeast
1.600.00 km²
7.750 samples

South
580.000 km²
2.900 samples

Southeast
920.000 km²
4.600 samples

Total
8.514.000 km²
29.700 samples



- **Water supply:**

In counties where there is no treated water
– 1 water sample will be collected.

- **Soil:**

In counties where the main agricultural products or subsistence farming (soy, bean, cotton, rice, coffee, corn) cultivated areas – 3 soil samples will be collected.

H																	He
Li	Be											B	C	N	O	F	Kr
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

ICP - MS

Sediment and soil analysis

H																	He
Li	Be											B	C	N	O	F	Kr
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	Fr	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

ICP - AES



ÂNIONS



WATER QUALITY PHYSICAL PARAMETERS (IN FIELD): Ph, Eh, Conductivity, Dissolved Oxygen, Temperature.

Water (cations and anions) analysis

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ARSENIC OCCURRENCE IN BRAZIL AND HUMAN EXPOSURE

Bernardino R. Figueiredo,
Ricardo P. Borba & Rômulo S. Angélica

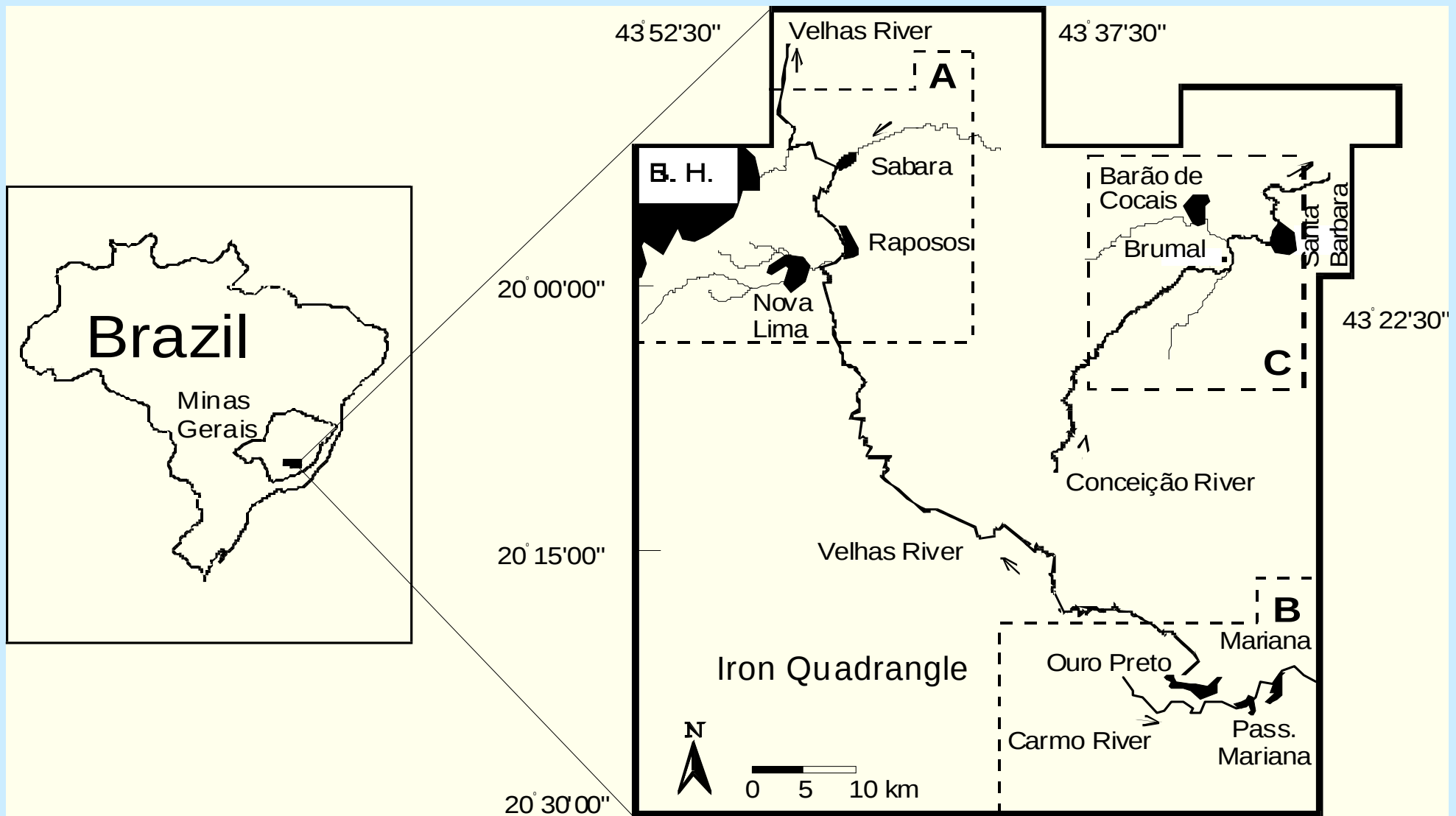
Latin America



**Santana
Amapá**

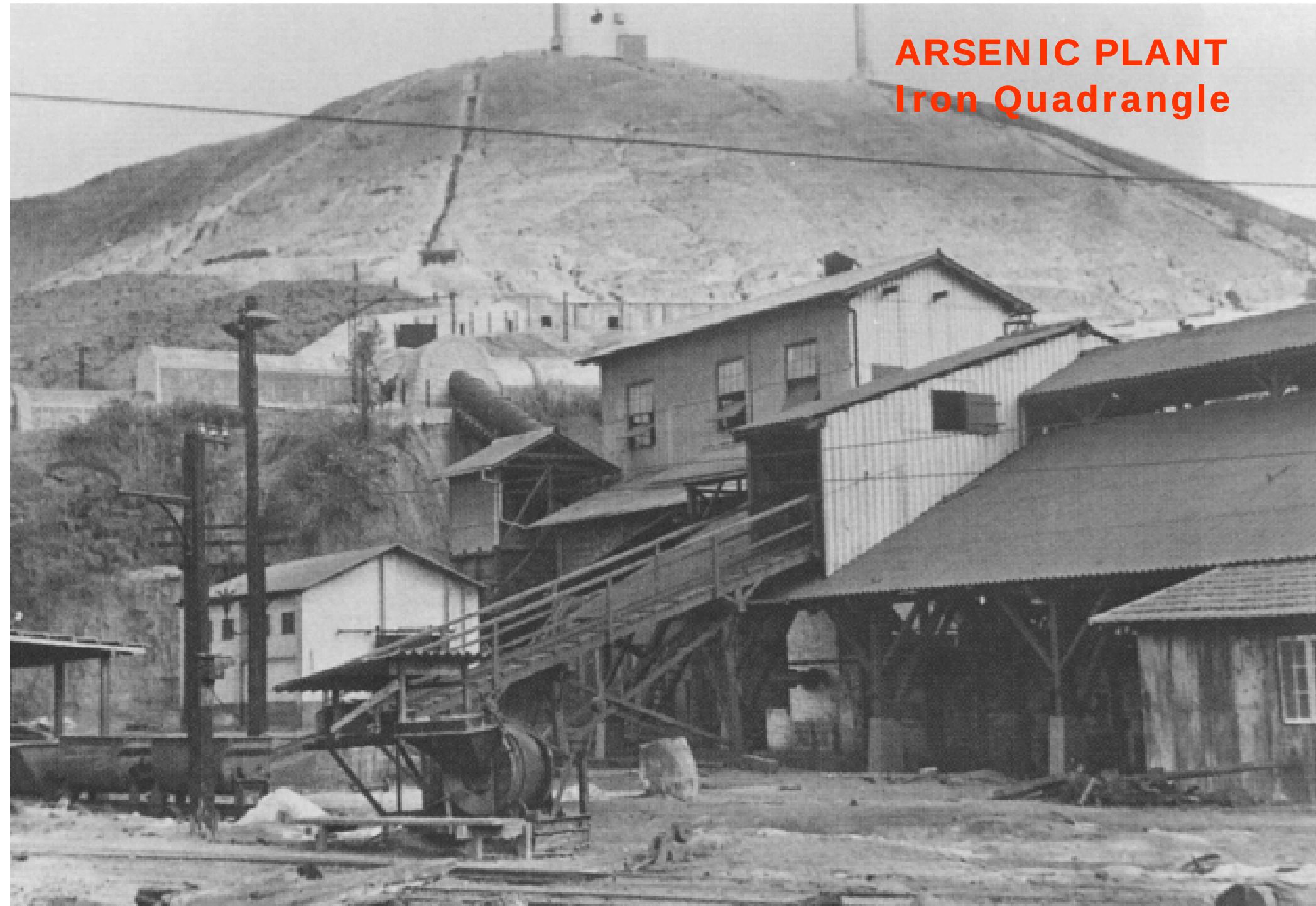
**The Iron
Quadrangle**

**Ribeira
Valley**



The Iron Quadrangle, Minas Gerais State

ARSENIC PLANT
Iron Quadrangle



ARSENIC DISTRIBUTION IN THE IRON QUADRANGLE

Sediments

<4,000 mg/Kg As

Surface waters

<350 $\mu\text{g/L}$ As

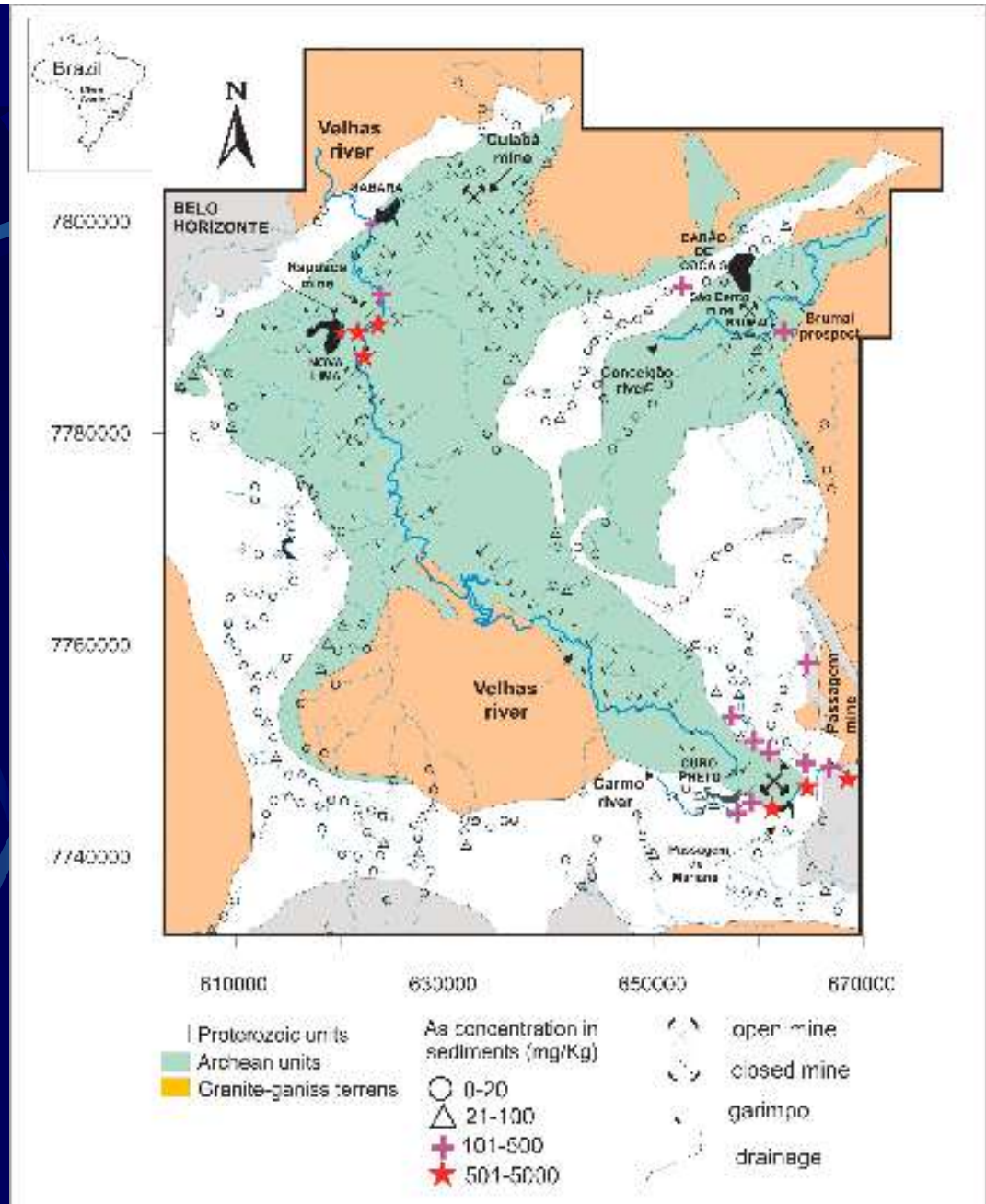
Groundwater

<10 $\mu\text{g/L}$ As

Mine waters

<2980 $\mu\text{g/L}$ As_{total}

<86 $\mu\text{g/L}$ As³⁺



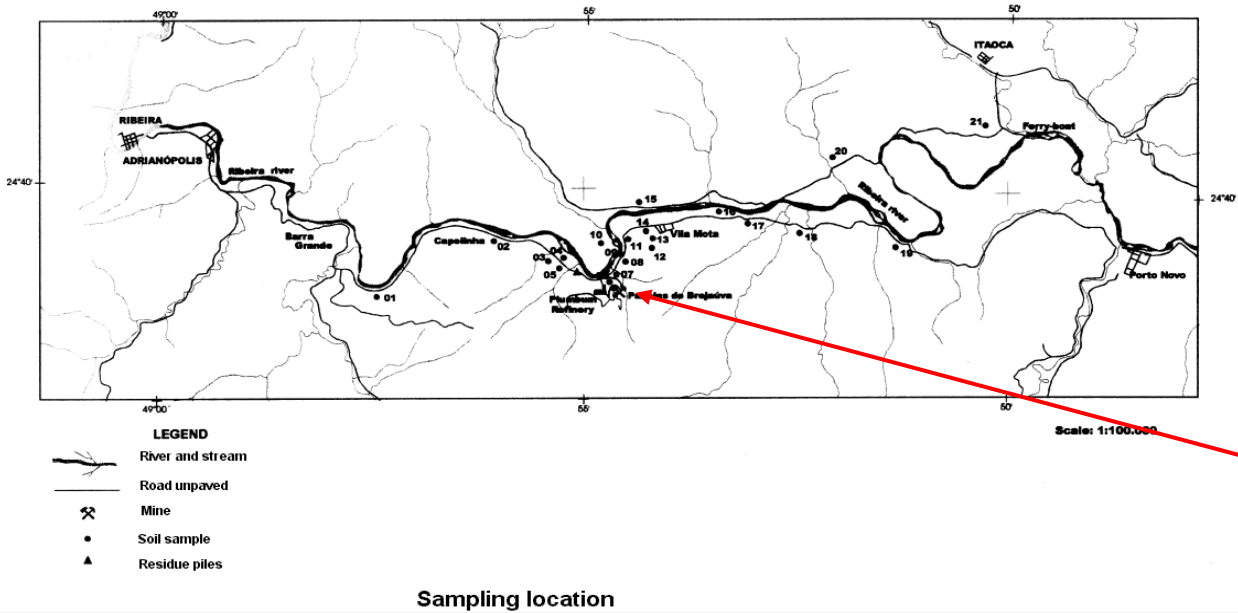
ARSENIC IN URINE – IRON QUADRANGLE 1998 ($\mu\text{g/L As}$)

Locality	n	mean	boys	girls
Galo		30.2	31.3	29.3
Mingu		18.5	21.4	13.5
Brumal		25.3	27.0	23.8
TOTAL	126	25.7	27.1	24.3

19 % of children $> 40 \mu\text{g/L As}$
(5 % - 2003)



Ribeira Valley, Southeastern Brazil



Plumbum Smelter Ribeira Valley

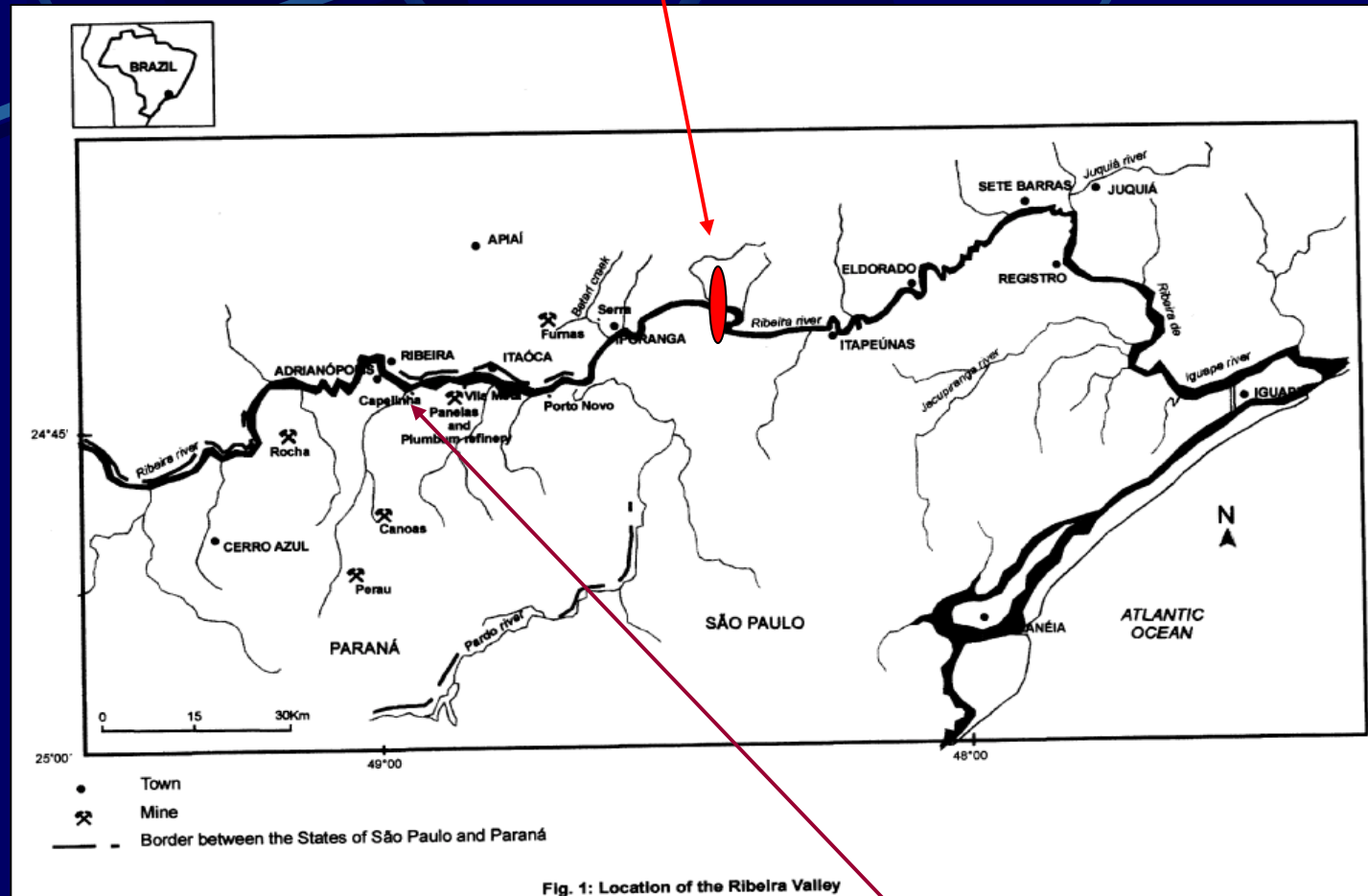
Middle Ribeira Valley – Natural arsenic anomaly

As contents

Sediments
<355 mg/Kg

Surface water
<9 µg/L

Soils (0-30 cm)
<2,000 mg/Kg



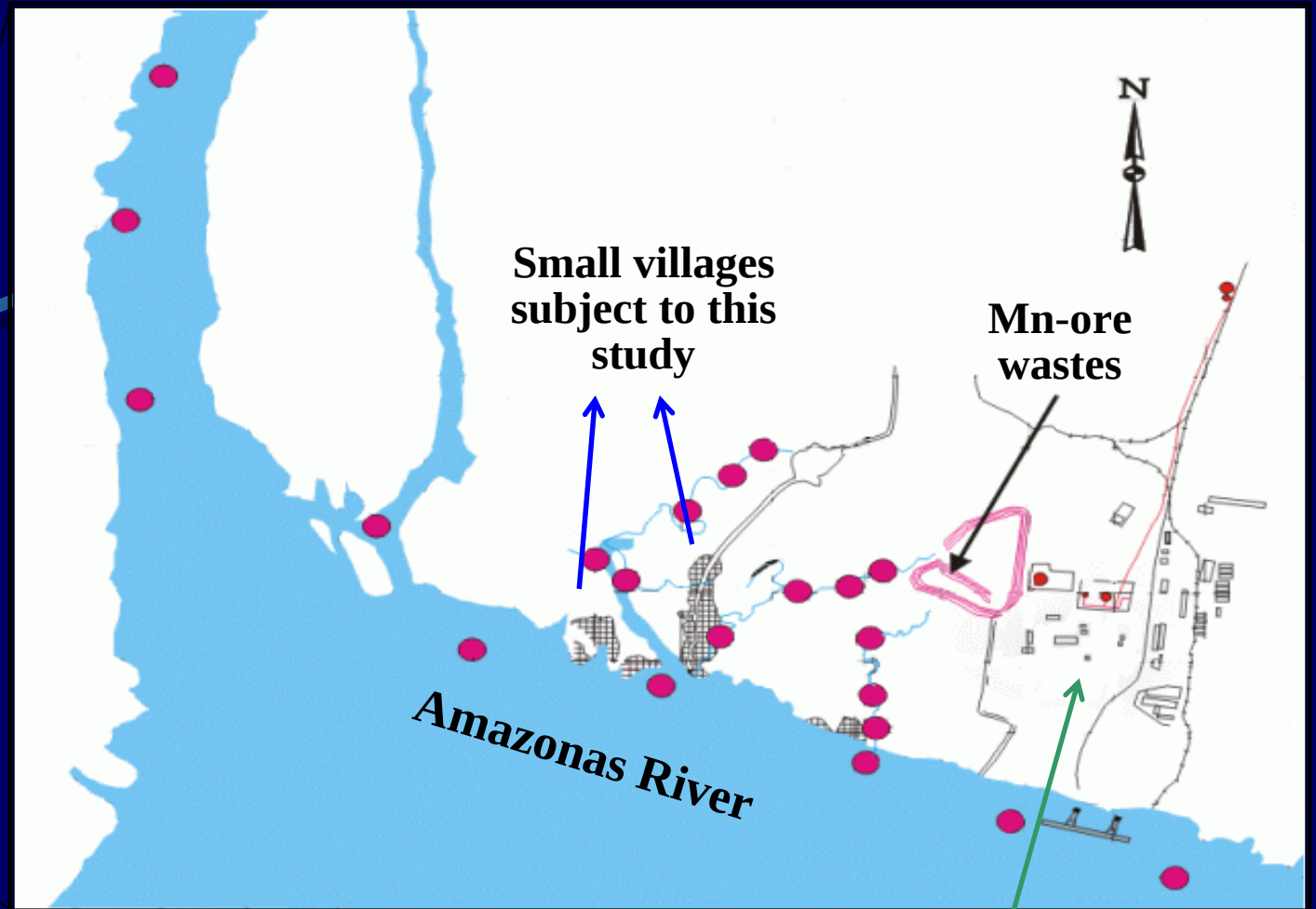
Upper Ribeira Valley – Pb-Zn mining and refinery

ARSENIC IN URINE – RIBEIRA VALLEY – 2002-2003 ($\mu\text{g/L As}$)

Locality	n	Mean	Min	Max
Cerro Azul	156	3.86	1	34.12
Serra	175	8.90	1	62.54
Iporanga	108	8.35	1	33.49
Pilões	49	4.63	1	68.92
Castelhanos	54	9.48	1	60.32
São Pedro	51	11.35	1	76.19
Maria Rosa	26	2.24	1	24.34
Nhungara	22	6.98	1	36.55
TOTAL	641			

Source: Sakuma et al. (2003, 2005)

SANTANA- AMAPÁ AREA



● Surface water and sediment samples

Beneficiation plant

ARSENIC IN HAIR – SANTANA 2001-2002 ($\mu\text{g/g}$)

Population	n	Mean	Min	Max
MEN	182	0.200	0.074	1.936
WOMEN	330	0.200	0.063	1.855
TOTAL	512	0.200	0.063	1.936

Source: Santos et al. (2003)

CONCLUDING REMARKS

Only point pollution sources known so far

- **High As concentrations in river sediments and soils**
- **Deep chemical weathering favors As retention in soils and sediments**
- **Very low As concentrations in surface waters (dilution phenomena)**
- **Low levels of human exposure for As**
- **Population less dependent on groundwater supply (except in NE region)**

FINAL REMARK

Non-point pollution sources still unknown

- **studies on As-bearing geological formations and major aquifers in Brazil where As-anomalies have been indicated are still to be done**

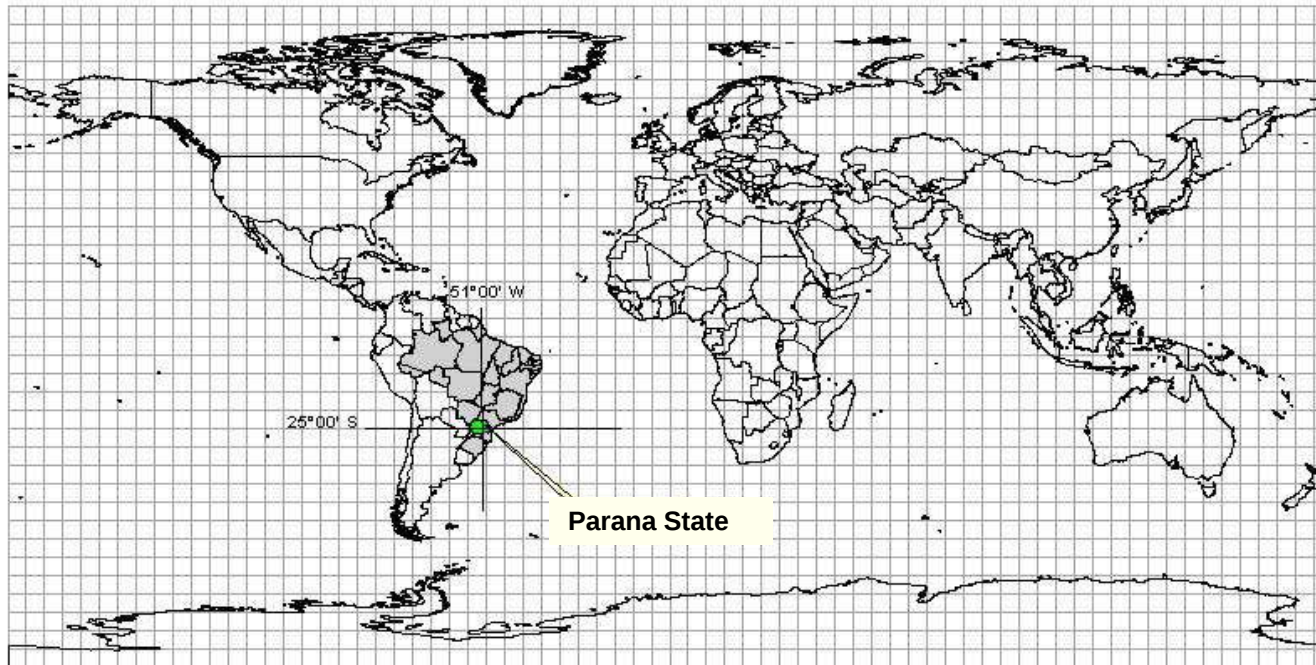
berna@ige.unicamp.br



MULTIELEMENT GEOCHEMICAL OF SURFACE TO DELIMIT ENVIRONMENTAL RISKS AND IMPACTS, PARANÁ STATE, BRAZIL

LICHT, O.A.B., Otavio@pr.gov.br

Minerais do Paraná S.A. - MINEROPAR



Low Density Sampling

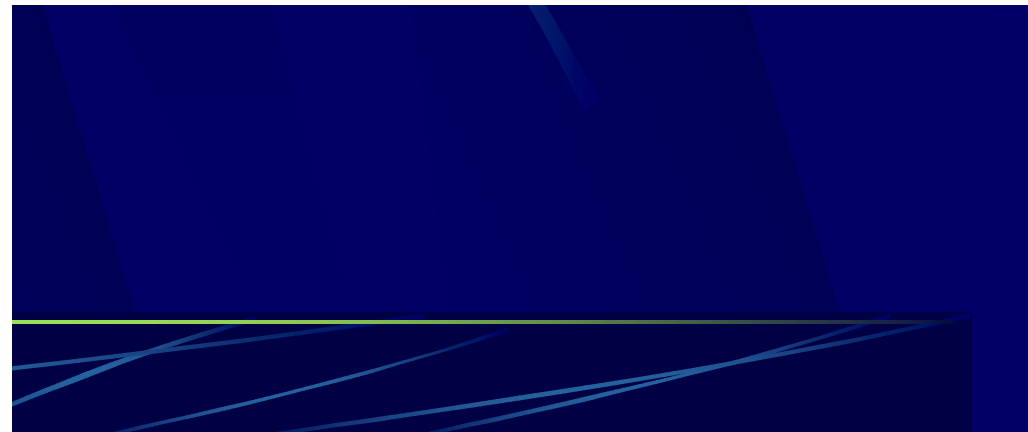
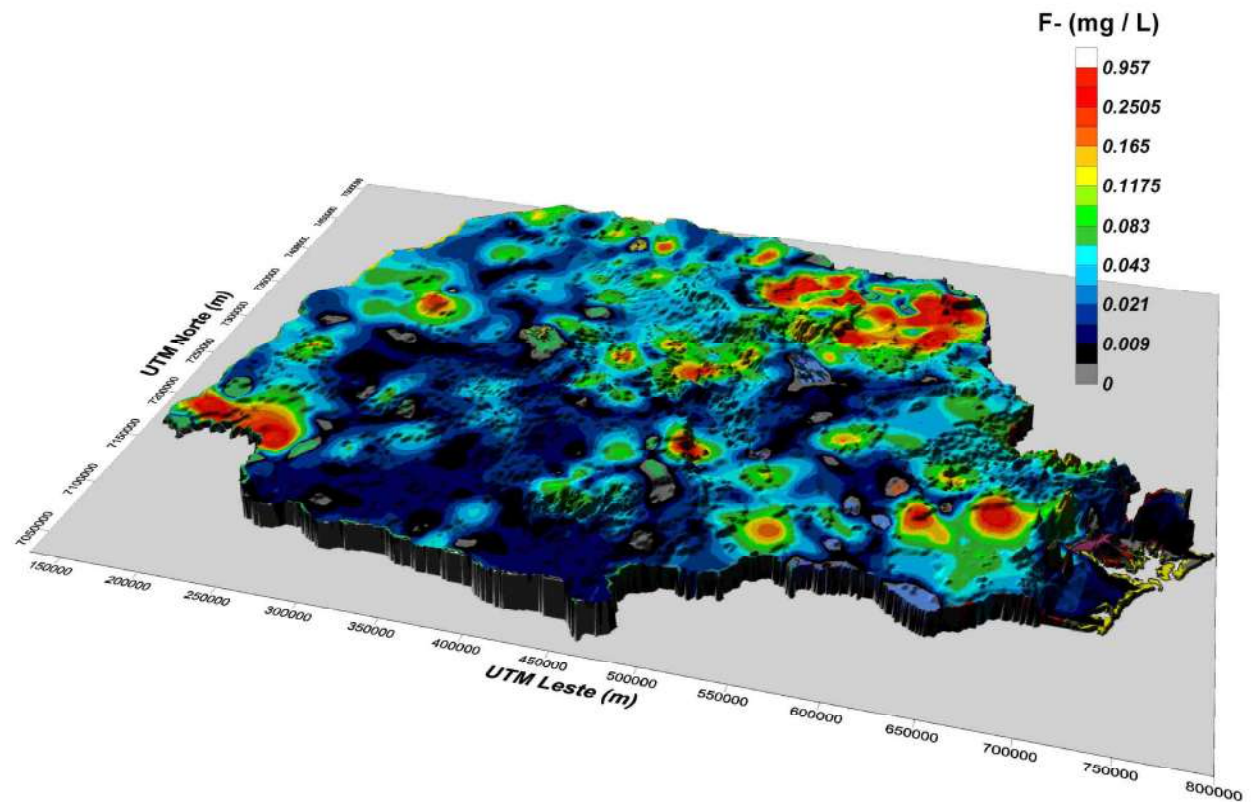
Area: 200.000 Km²

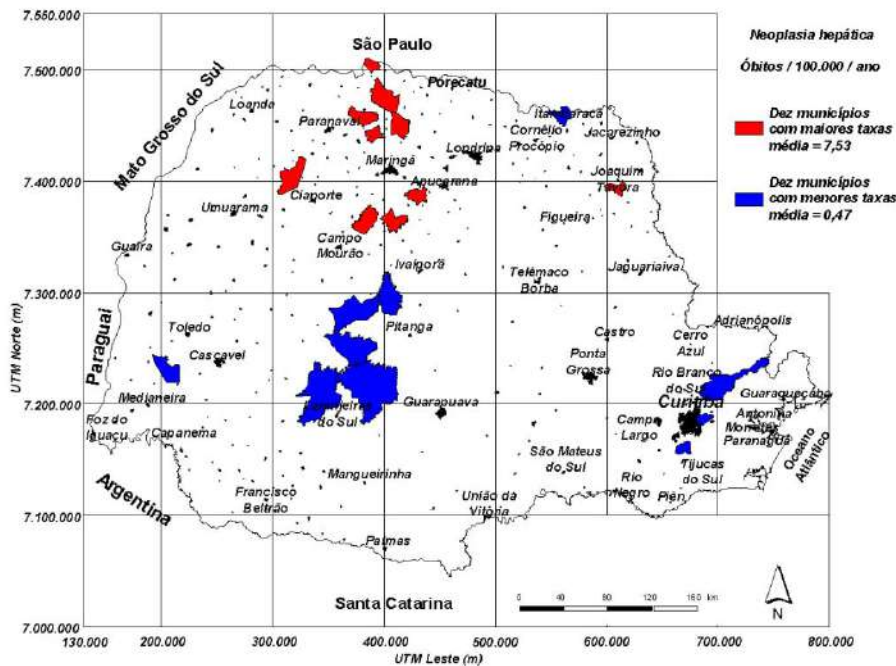
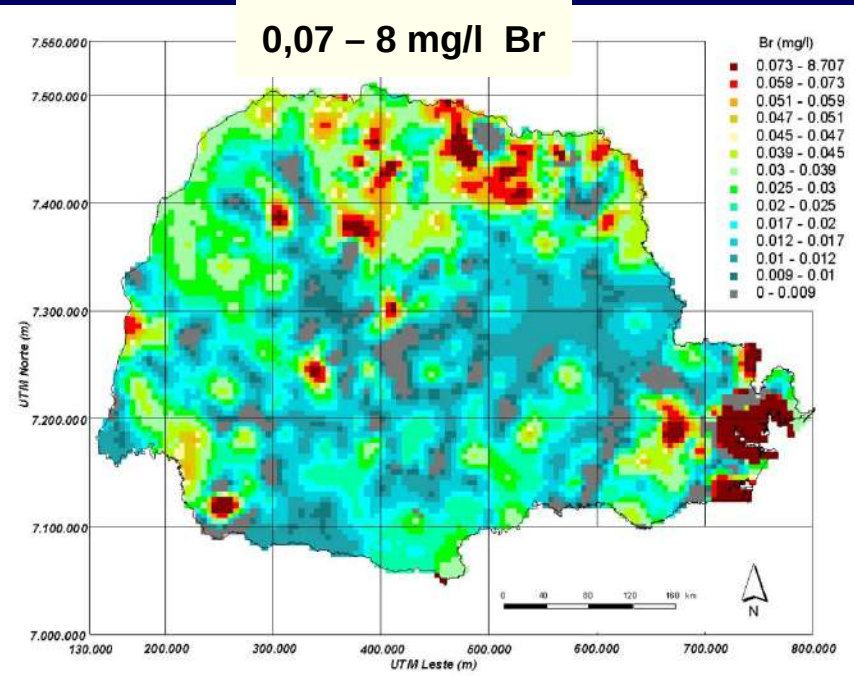
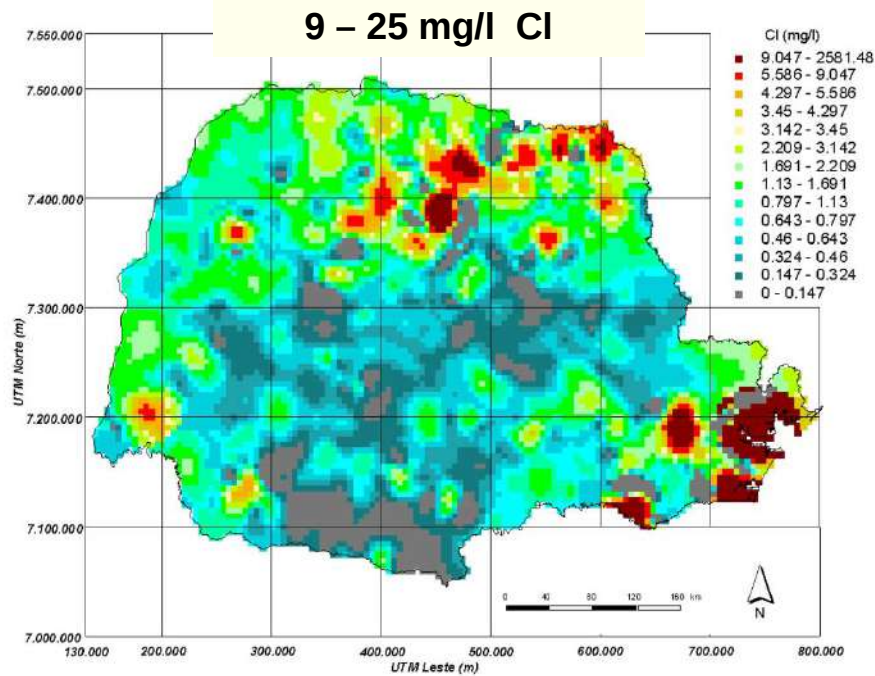
water sample: 696

sediment sample: 696

soil sample: 307

2,2 mg/l F
Groundwater





Death: 10 municipality > rate 7.5/100.000 inhabitants cancer of liver

10 municipality < rate 0.47/100.000 inhabitants

FLUORIDE GROUNDWATER AND FLUOROSIS IN SÃO FRANCISCO MUNICIPALITY – MINAS GERAIS/BRAZIL

Research Group

Geology Department – UFMG

Leila Nunes Menegasse Velásquez

Lúcia Maria Fantinel

Alexandre Uhlein

Walter Duarte Costa

Paulo Roberto Antunes Aranha

Odontology Department – UFMG

Efigênia Ferreira e Ferreira

Lia Silva de Castilho

Andréia Maria Duarte Vargas



Location: São Francisco river basin

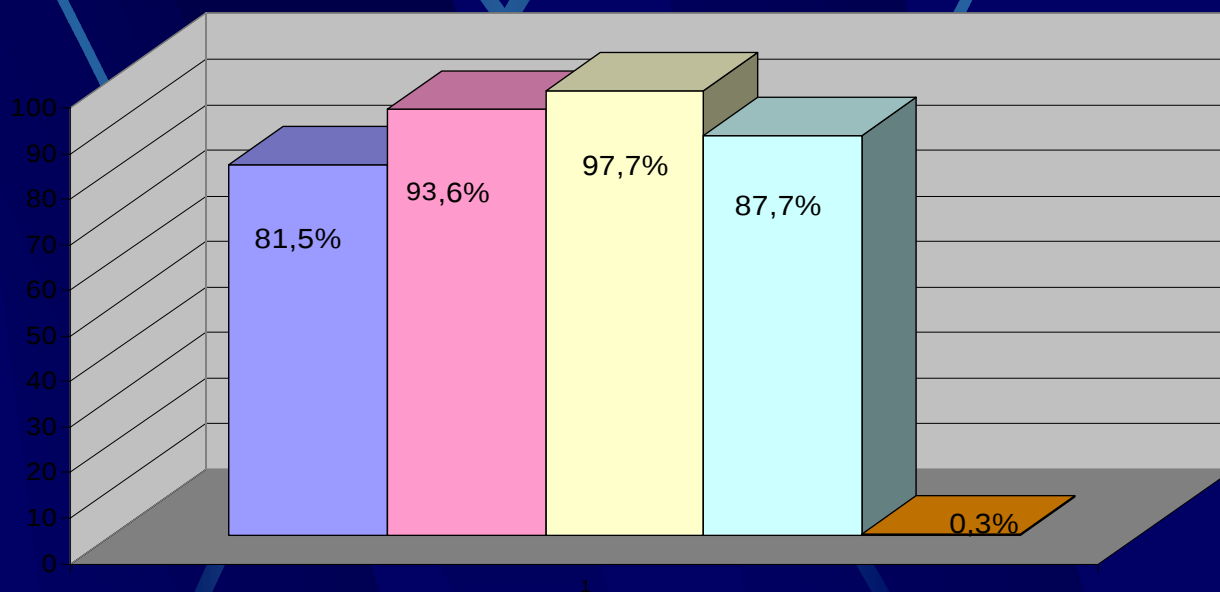


Epidemiological Research



Fluorosis - Mocambo

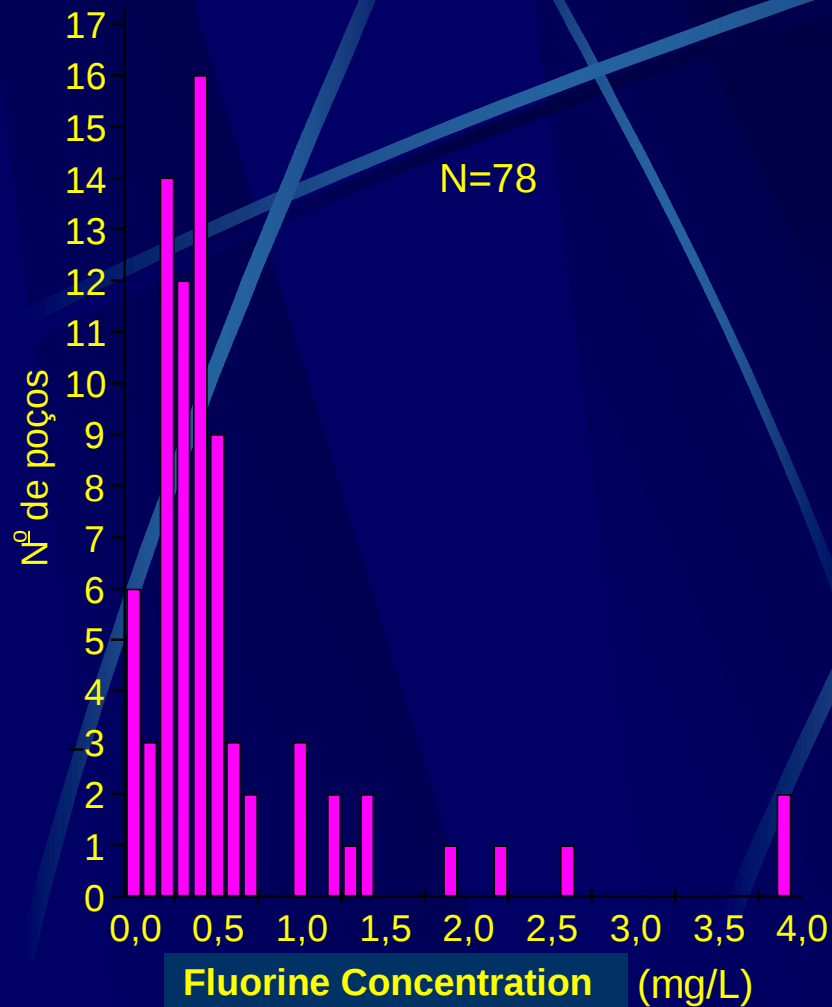
People with fluorosis



Mocambo - 1,18 mg/L	Vaqueta - 1,92 mg/L
N. Horizonte - 3,9 mg/L	Alto S. João - 3,93 mg/L
Retiro - 0,20 mg/L	

65,4% high level

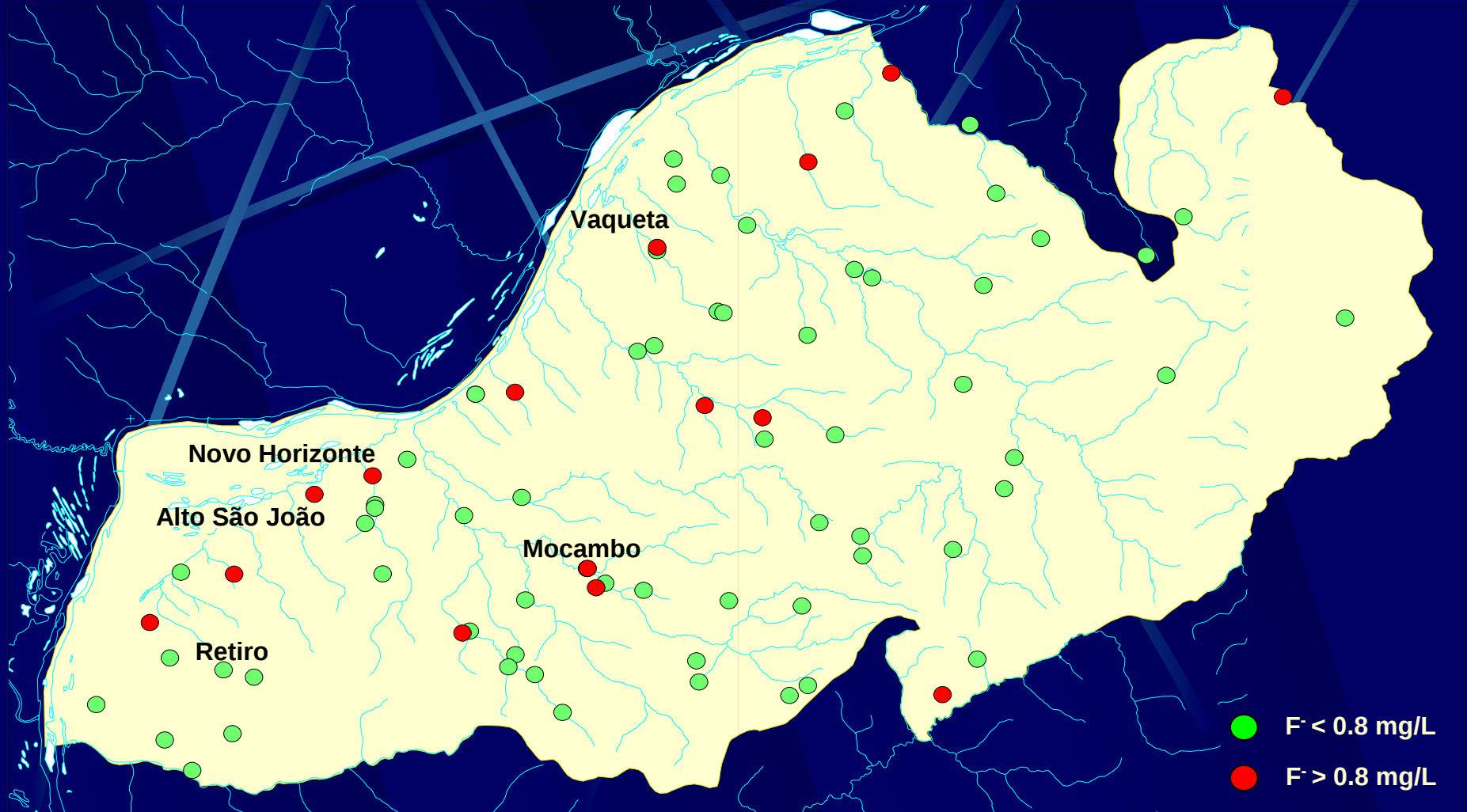
Fluorine concentration in groundwater



- ♦ Background: 0,45mg/L
- ♦ 27 samples above BG (34.6%)
- ♦ 13 samples above MVP (16.7%)

MVP =	T °C	Good (mg/L)	Max (mg/L)	
	26.4 – 32.5	0.7	0.8	Source: MS/1976

Fluorine distribution in groundwater



Conclusions

- High endemic tooth fluorosis in São Francisco municipality;
- The cause of the tooth fluorosis is the long consumption of groundwaters rich in F^- (> 0.8 ppm) ;
- Fluoride disseminated in calcitic veins, in limestone, is the main source of contamination;
- The anomalous of F^- has hard association with fractures and with the stratigraphy;
- It is necessary to expand the research to other areas, north and east of Bambuí Supergroup (limestone).

The biofortification as a tool to prevent micronutrients deficiency

Marilia Regini Nutti

Embrapa Agroindustry of Aliments

Research network

- 1 - Embrapa Acre
- 2 - Embrapa Agrobiology
- 3 - Embrapa Food Technology**
- 4 - Embrapa Tropical Agroindustry
- 5 - Embrapa Agriculture West
- 6 - Embrapa Cotton
- 7 - Embrapa Amapá
- 8 - Embrapa Western Amazon
- 9 - Embrapa Eastern Amazon
- 10 - **Embrapa Rice and Beans**
- 11 - Embrapa Goats
- 12 - Embrapa Cerrados
- 13 - Embrapa Temperate Climate
- 14 - Embrapa Forests
- 15 - Embrapa Beef Cattle
- 16 - Embrapa Dairy Cattle
- 17 - **Embrapa Vegetables**
- 18 - Embrapa Agricultural Information
- 19 - Embrapa Agricultural Instrumentation
- 20 - **Embrapa Cassava & Fruits**
- 21 - Embrapa Environment
- 22 - Embrapa Mid-North
- 23- **Embrapa Maize & Sorghum**
- 28- **Embrapa Genetic Resources & Biotechnology**



Agricultural Ministry



Situation in Brazil - Micronutrients

✓ Epidemiologic Data :

Iron Deficiency

Vitamin A Deficiency

Iodine Deficiency (fortification with kitchen salt)

✓ Isolated studies show:

Problem related to Zn and Se

Ca (low swallow)

Other ??

CONCLUSIONS

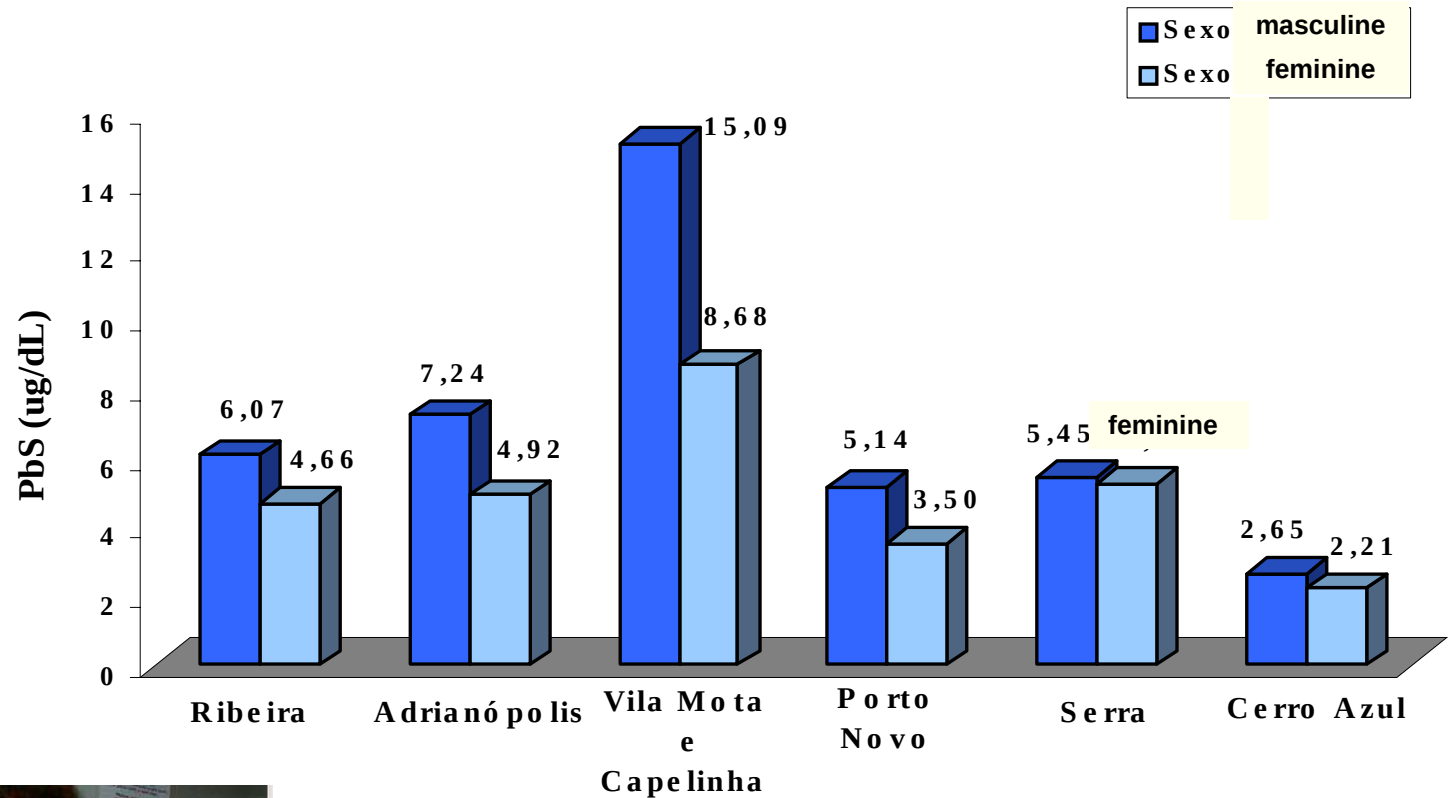
- ✓ 1) The swallow of some minerals (Fe, Ca, Zn , Se) is lower than recommended or is faintly bio-available in diet.
- ✓ 2) Biochemical parameters lower than reference values: population risk groups, confirm the necessity of intervention
- ✓ 3) Solution to the problem depends on integrated efforts of scientific community, industries and government, searching for best alternatives

Pb HUMAN AND ENVIRONMENTAL CONTAMINATION IN ADRIANÓPOLIS, PARANÁ STATE, BRAZIL

Fernanda Gonçalves da Cunha¹, Bernardino Ribeiro de Figueiredo², Mônica Maria Bastos Paoliello³, Eduardo Mello De Capitani⁴, Alice Sakuma⁵

¹Serviço Geológico do Brasil, ²Instituto de Geociências/UNICAMP, ³Departamento de Patologia Aplicada, Legislação e Deontologia/Universidade estadual de Londrina, ⁴Faculdade de Ciências Médicas/UNICAMP, ⁵Instituto Adolfo Lutz,





Middle concentrations of Pb in children's blood (335), per sex



Conclusion

**Area 4 Km² surroundings of the metallurgy
(soil with 21-916 µg/g)**

**20 children of Capelinha and Mota Village with more
than 10 µg/dL (60% of the analysed children)**

**Contaminated mainly by dust and food (local
vegetable)**

Garimpos Areas



Extensive areas contaminated
with Hg in Au “garimpos”

Pluma de sedimentos
Floresta Nativa
Água limpa
Garimpo Ativo
Área degradada
Sedimento em suspensão = SS

5 km



Rio Tapajós

Adição de mais sedimento

SS = 30mg/l água
Hg no S = 6,6mg/l água

Pluma de sedimentos abrangendo metade da água do rio

Pluma poluidora

SS = 540mg/l água
Hg no SS = 42mg/l água
Hg transportado = 4ton/ano

Rio Crepori

Bacia do Rio Tapajós
Amazônia - Brasil

Fonte: Projeto de Cooperação para o
Desenvolvimento Sustentável no
Setor Mineral - GSC/CPRM/CIDA
LANDSAT = TM3,G = TM4,B = TM5
Kevin Telmer, Maycira Costa, 1998

Hg garimpeiro's hair on Amazon Brazil 1996

Poconé, MT, out garimpo	0,3 a 3 ppb
Poconé, in garimpo area : (34 ppb after amálgama burn by 16 years)	1,3 a 34 ppb
Cumarú, PA, max	14 ppb
Rio Madeira, RO, max	97 ppb
Rainha, Rio Tapajós, max	34 ppb
São Luiz do Tapajós, max	48 ppb
Barreiras, Rio Tapajós, max	71 ppb
Paraná Mirim, Rio Tapajós, max	15 ppb

• Reference hair, WHO, 1 – 2 ppb

GEOCHEMISTRY IN PUBLIC SUPPLY WATER, EAST AMAZON

Edesio M. Buenano Macambira , emacambira@be.cprm.gov.br

Eduardo Paim Viglio, eviglio@be.ccprm.gov.br

II – CPRM, Belém – PA

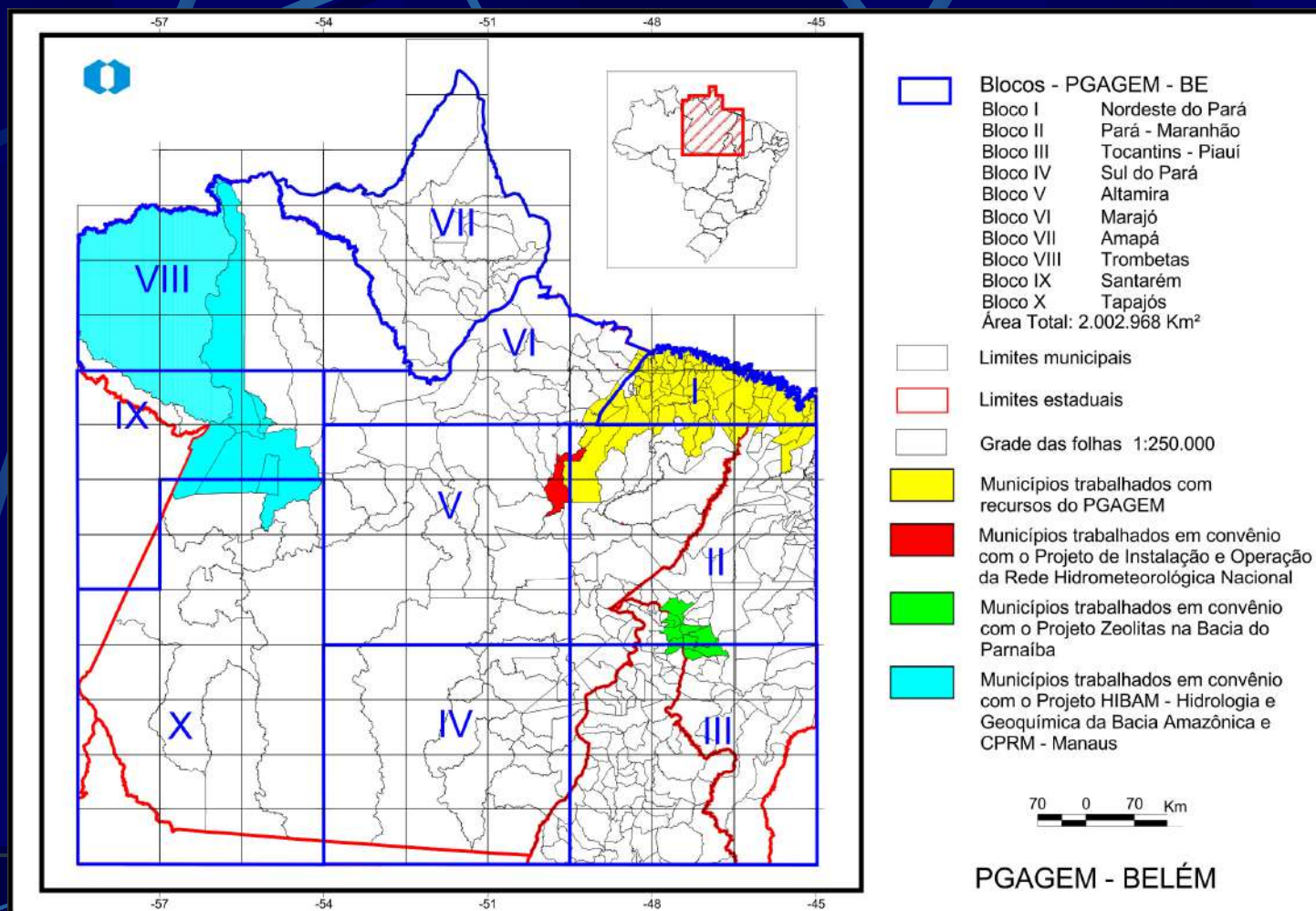
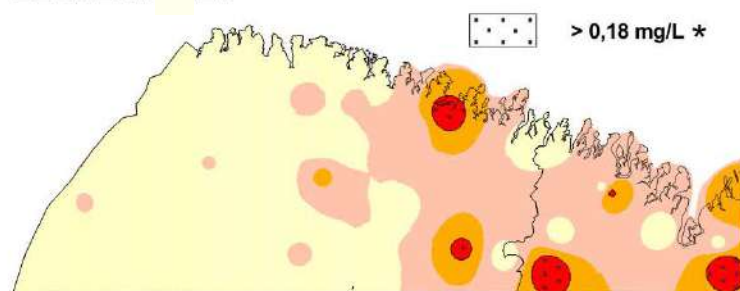
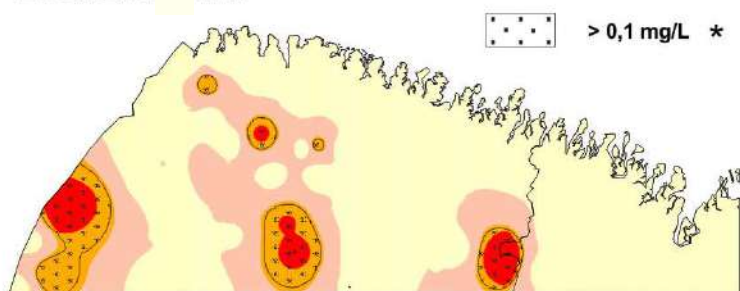


Fig 1: Mapa de localização dos trabalhos executados pelo PGAGEM-Belém na coleta de água de abastecimento público

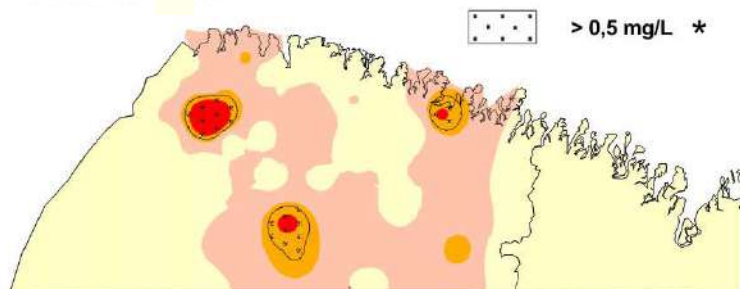
ELEMENT Zn



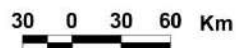
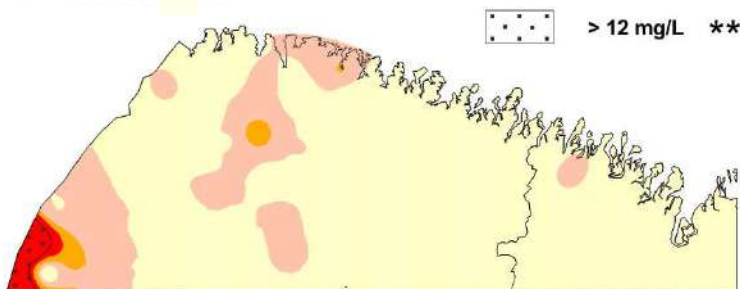
ELEMENT Mn



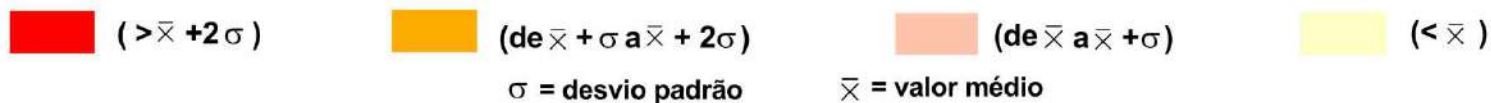
ELEMENT B



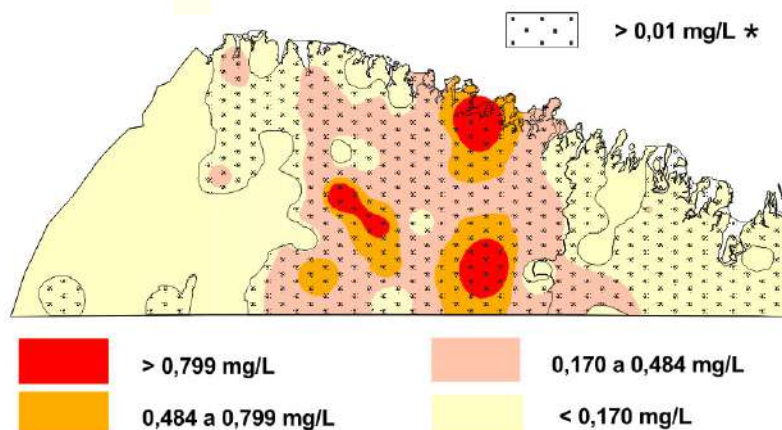
ELEMENT K



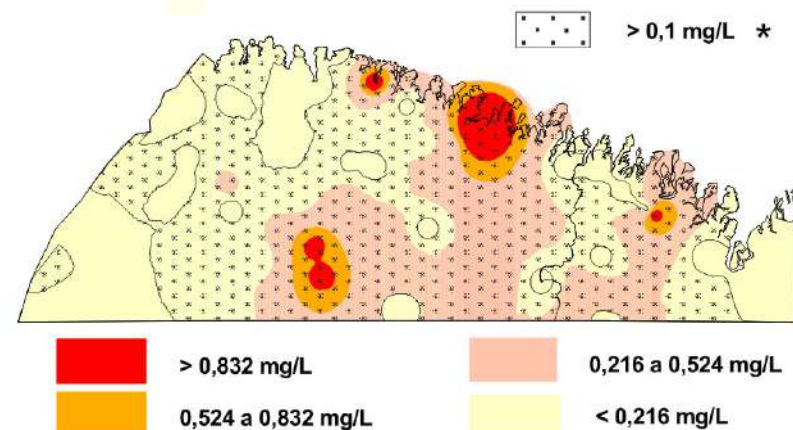
 : Valor maximum, reference – * CONAMA/BRAZIL - ** WHO



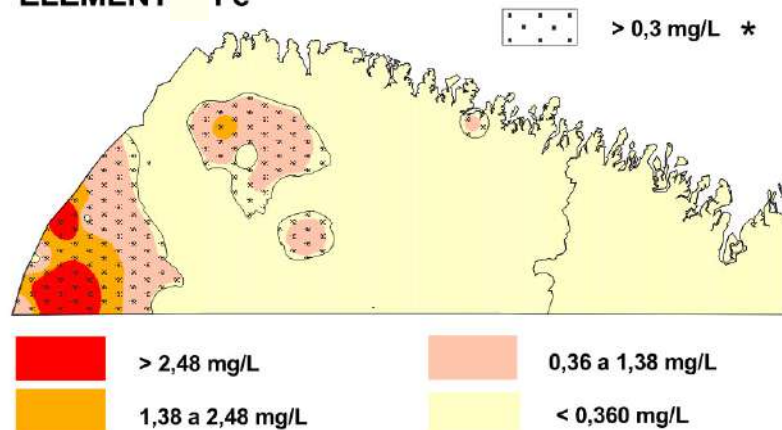
ELEMENT Pb



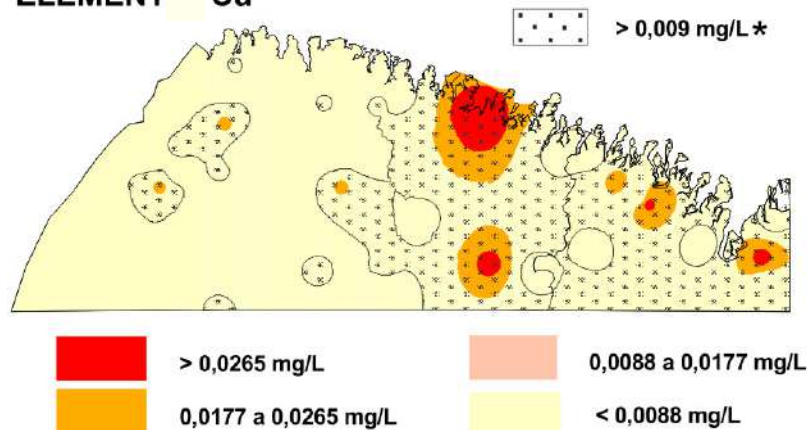
ELEMENT Al



ELEMENT Fe



ELEMENT Cu



maximum value, reference

* CONAMA/BRAZIL

** WHO

Water Supply Northeast Para State: East Amazon

Pb (145 x); Al (18 x); Fe (8 x); Cu (3 x): above WHO - natural source

pH 4-6 in 90% area - organic source

High disease rates by water (worm, hepatitis, diarrhea, etc)

Pará State / highest rate stomach cancer in Brazil

There isn't any study relating the diseases with these results



HEAVY METAL IN PUBLIC SUPPLY WATER, CEARA STATE, NORTHEAST-BRAZIL

Sergio Frizzo, frizzo@fo.cprm.gov.br
Geological Survey of Brazil – CPRMFO

CEARÁ (146.000 Km² - 7.430.000 inhabitants)

Urban population 5.300.000 inhabitants (71%)

760 district in 184 municipalities

470 (62%) Districts with regular supply; 154 of them
without water treatment

290 (38%) Districts with other types of supply
(fountain, private well, cask truck)

SAMPLING WATER STATION

**234
SAMPLES**



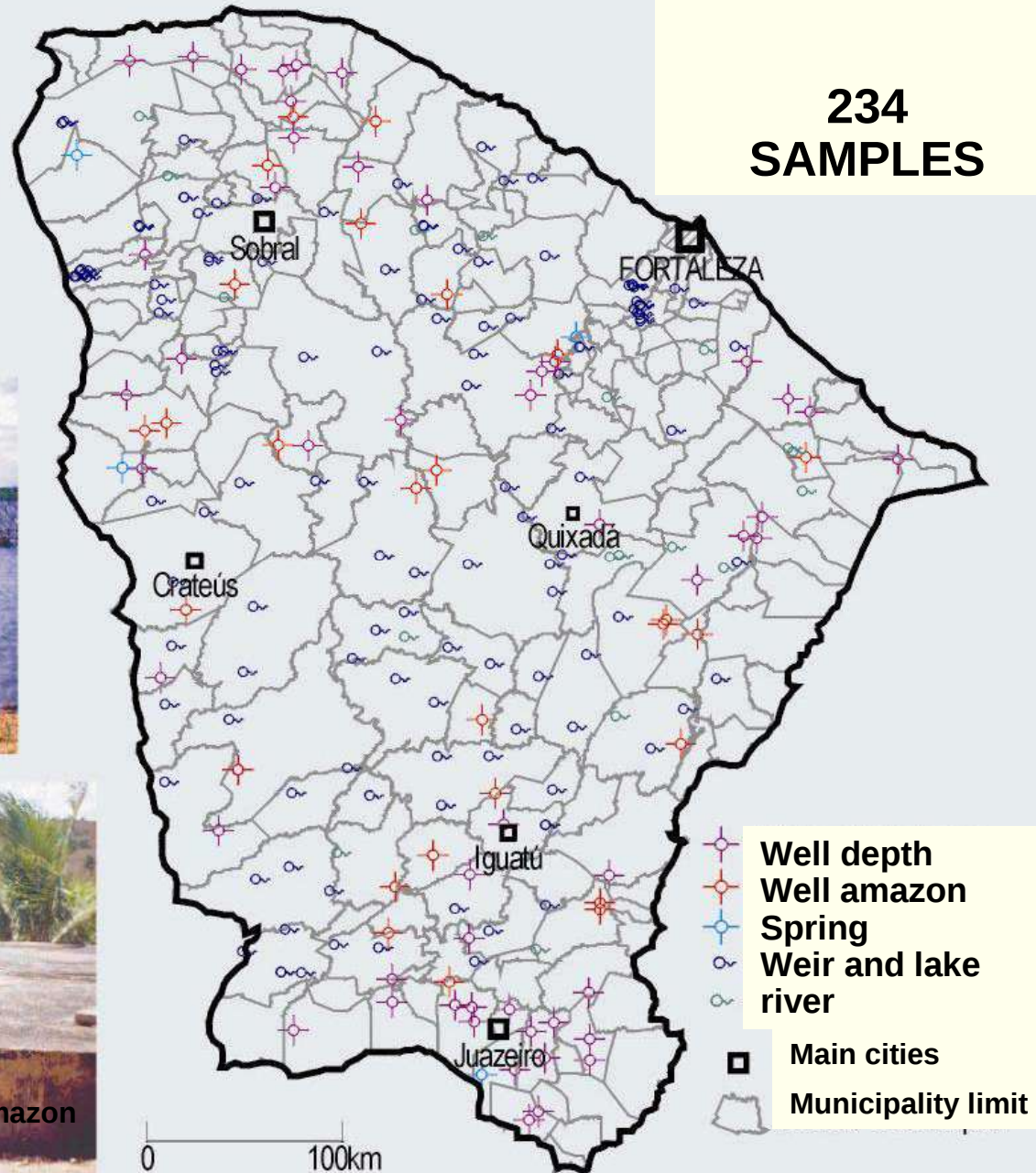
Well depth



Weir



Well amazon



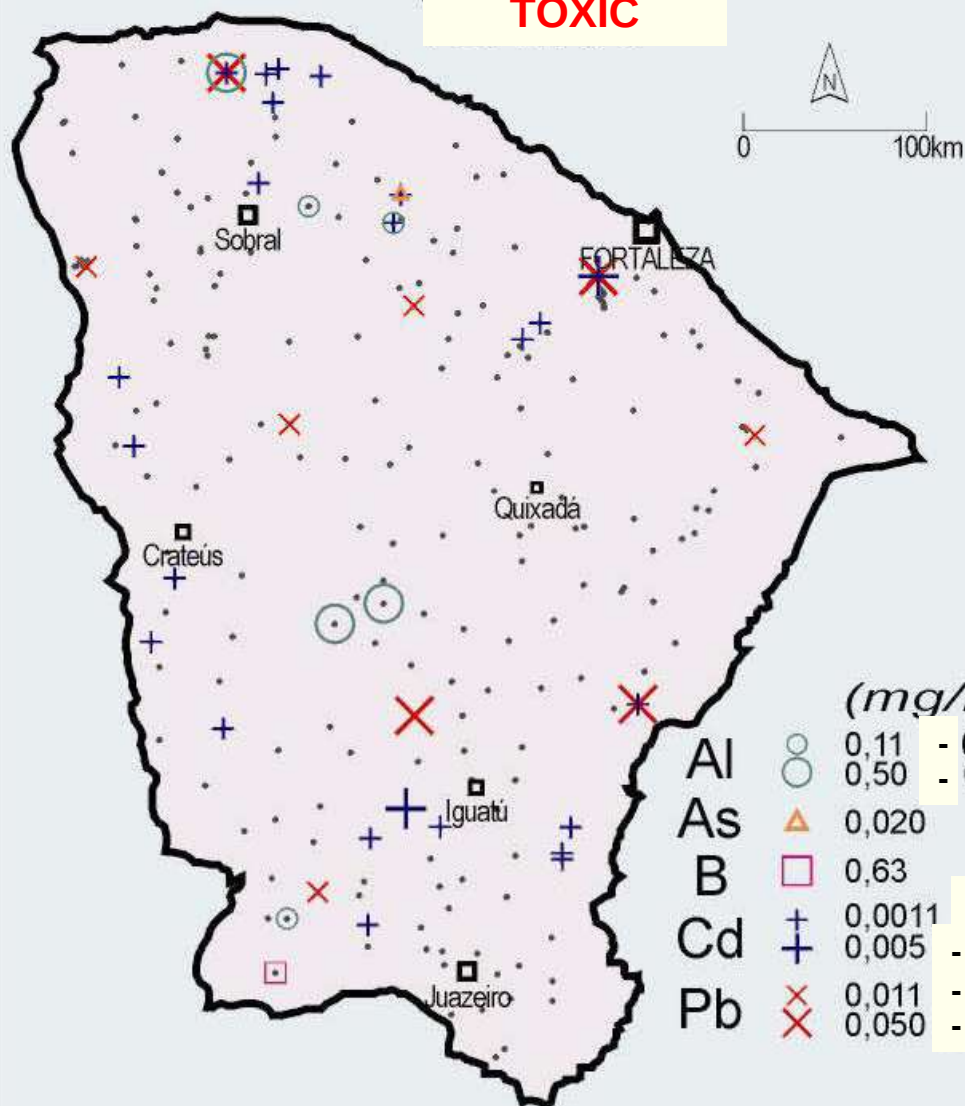
METAL CONCENTRATION ABOVE CONAMA/BRAZIL REFERENCE

(○ until 5 X the reference value

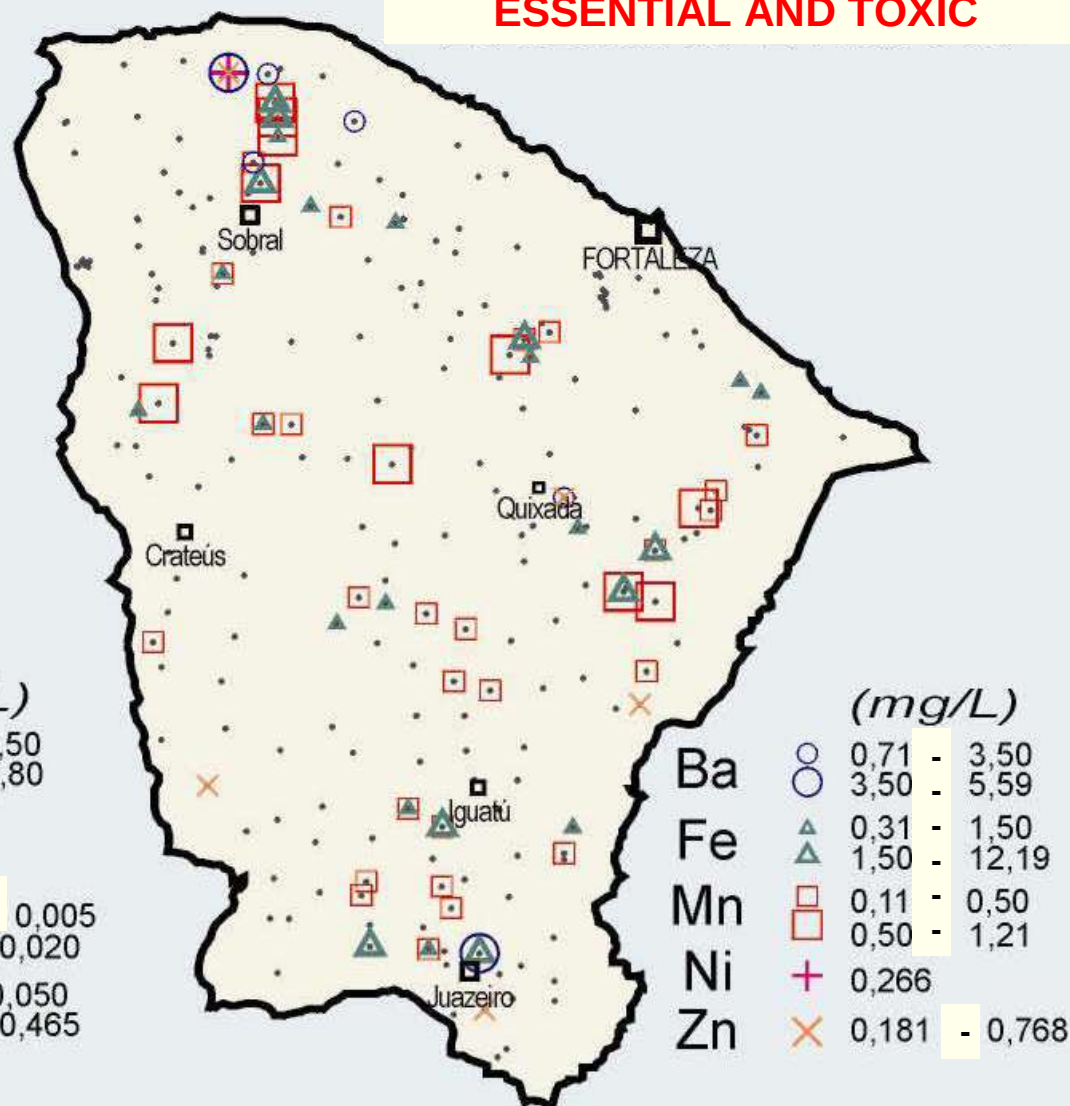
○ from 5 X until the highest result

TOXIC

ESSENTIAL AND TOXIC



	(mg/L)
Al	○ 0,11 - 0,50 ○ 0,50 - 0,80
As	△ 0,020
B	□ 0,63
Cd	+ 0,0011 - 0,005 + 0,005 - 0,020
Pb	× 0,011 - 0,050 × 0,050 - 0,465



	(mg/L)
Ba	○ 0,71 - 3,50 ○ 3,50 - 5,59
Fe	△ 0,31 - 1,50 △ 1,50 - 12,19
Mn	□ 0,11 - 0,50 □ 0,50 - 1,21
Ni	+ 0,266
Zn	× 0,181 - 0,768

100 samples (43%) with excess in one or more metals

CONCLUSION

- ⇒ Medical Geology has grown very fast in Brazil in the last 3 years
- ⇒ International short courses held in Brazil have helped this growth
- ⇒ Today there are more than 300 researchers on medical geology in the network
- ⇒ It's estimated that there are about 80 researchers working on medical geology
- ⇒ Important work contribution to people's well-being and environmental policy
- ⇒ *The need for introducing Medical Geology to Medicine and Geology courses*



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