AN INTRODUCTION TO THE ENVIRONMENTAL AND HEALTH RISKS OF THE LAVREOTIKI-LAVRION AREA

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Athéna

Lavreotiki

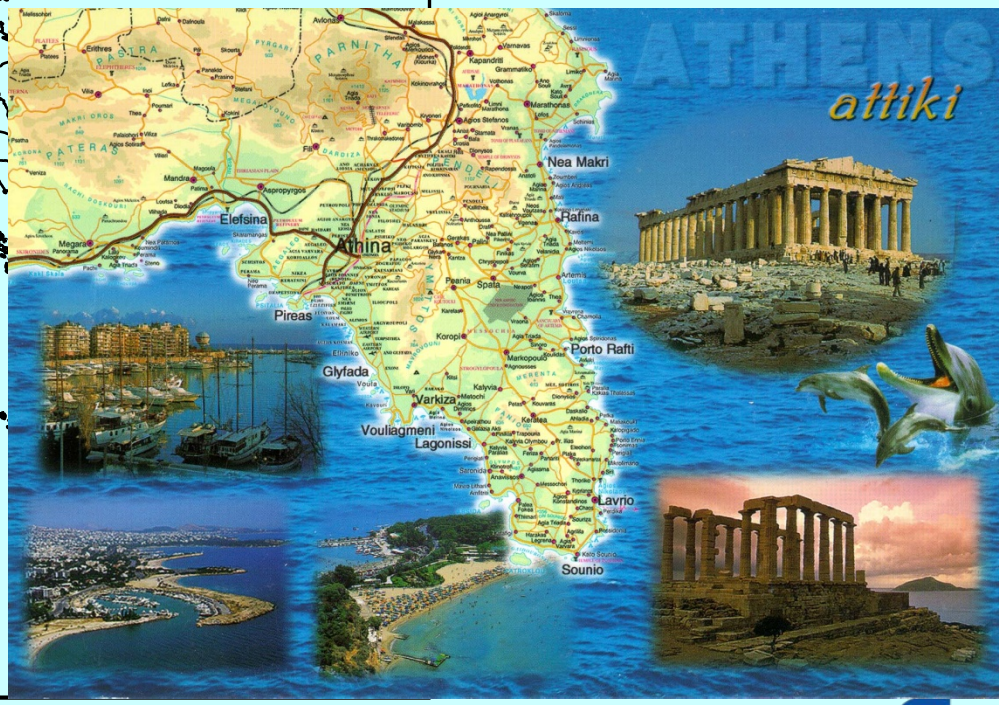
N

100 km

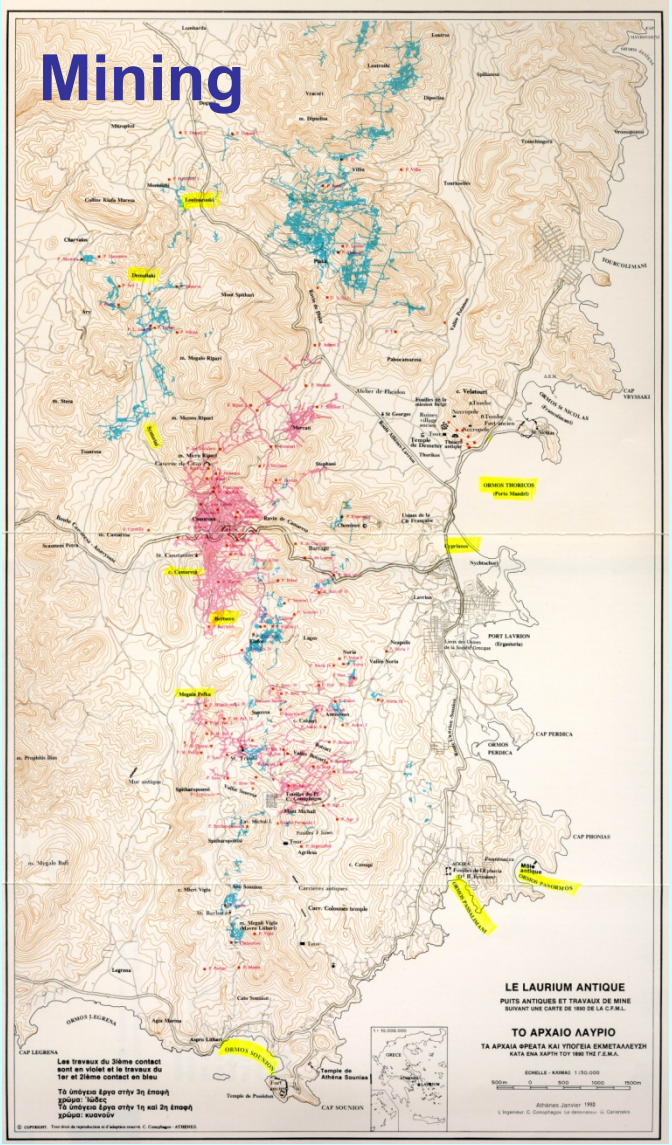
Lavreotiki peninsula

Lavrion urban area

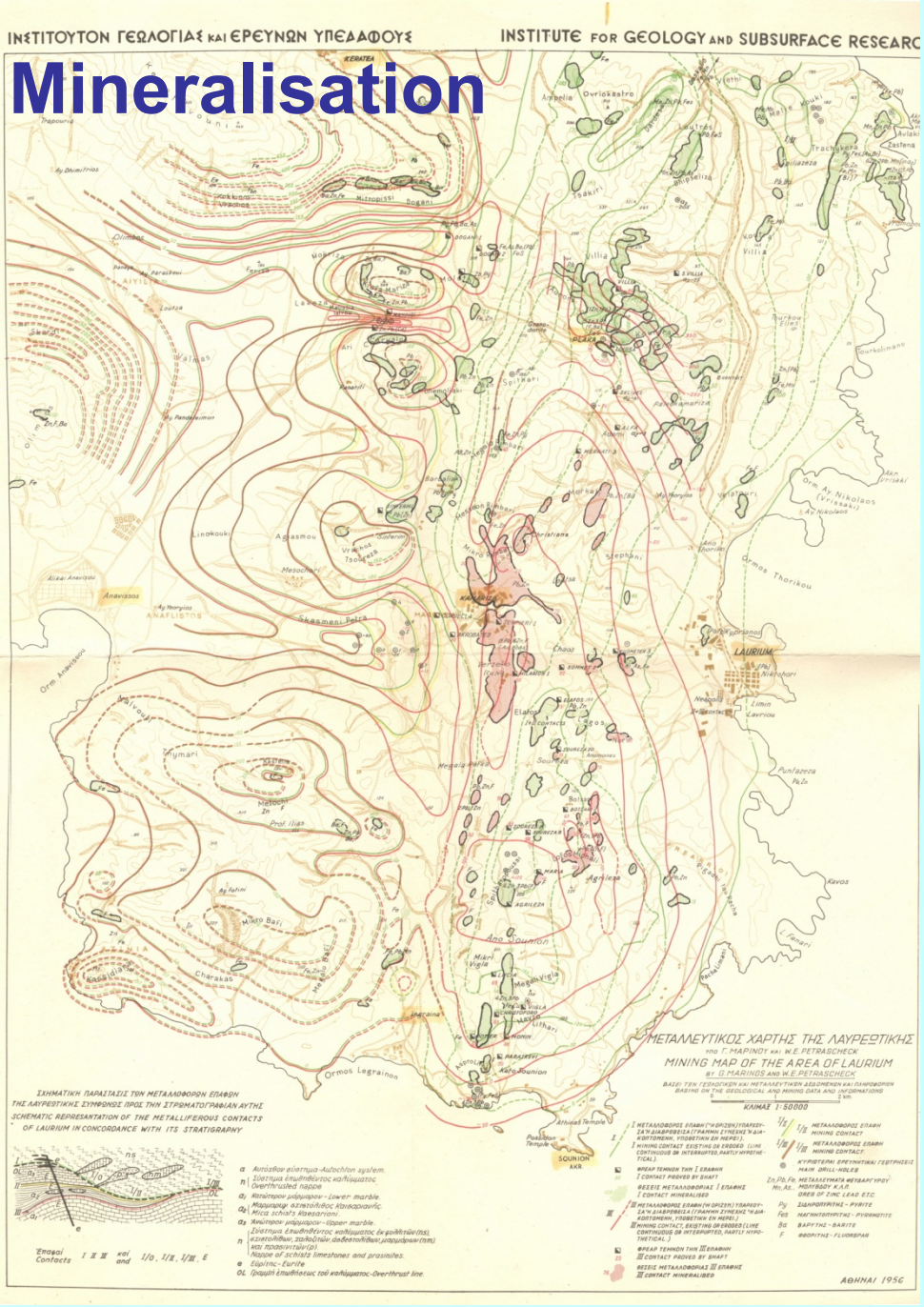
Cape Sounion



Mining



Mineralisation



Calcite

[$CaCO_3$]

Galena

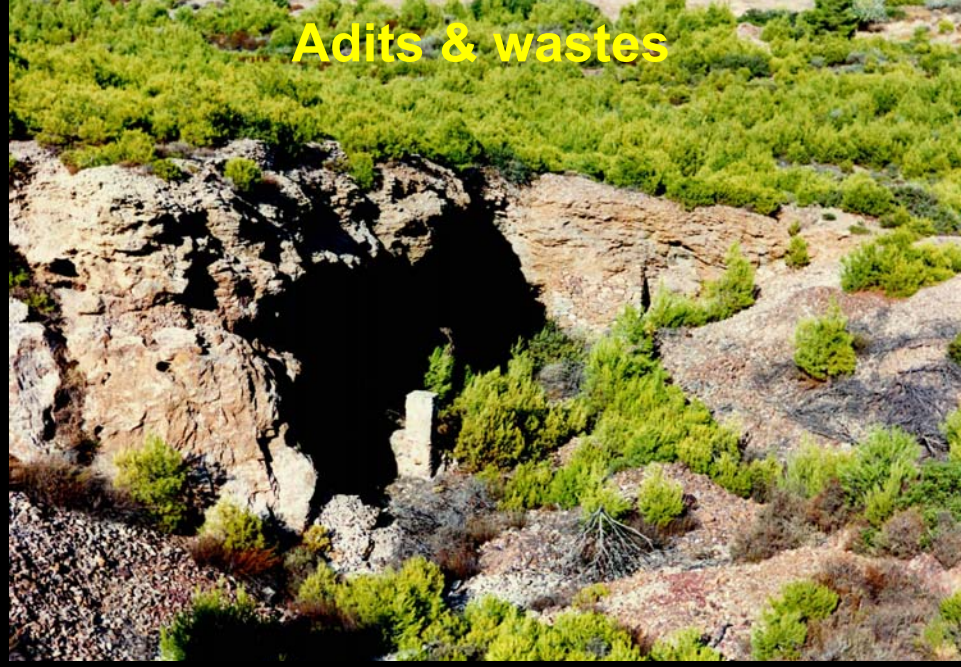
[PbS]

Calcite

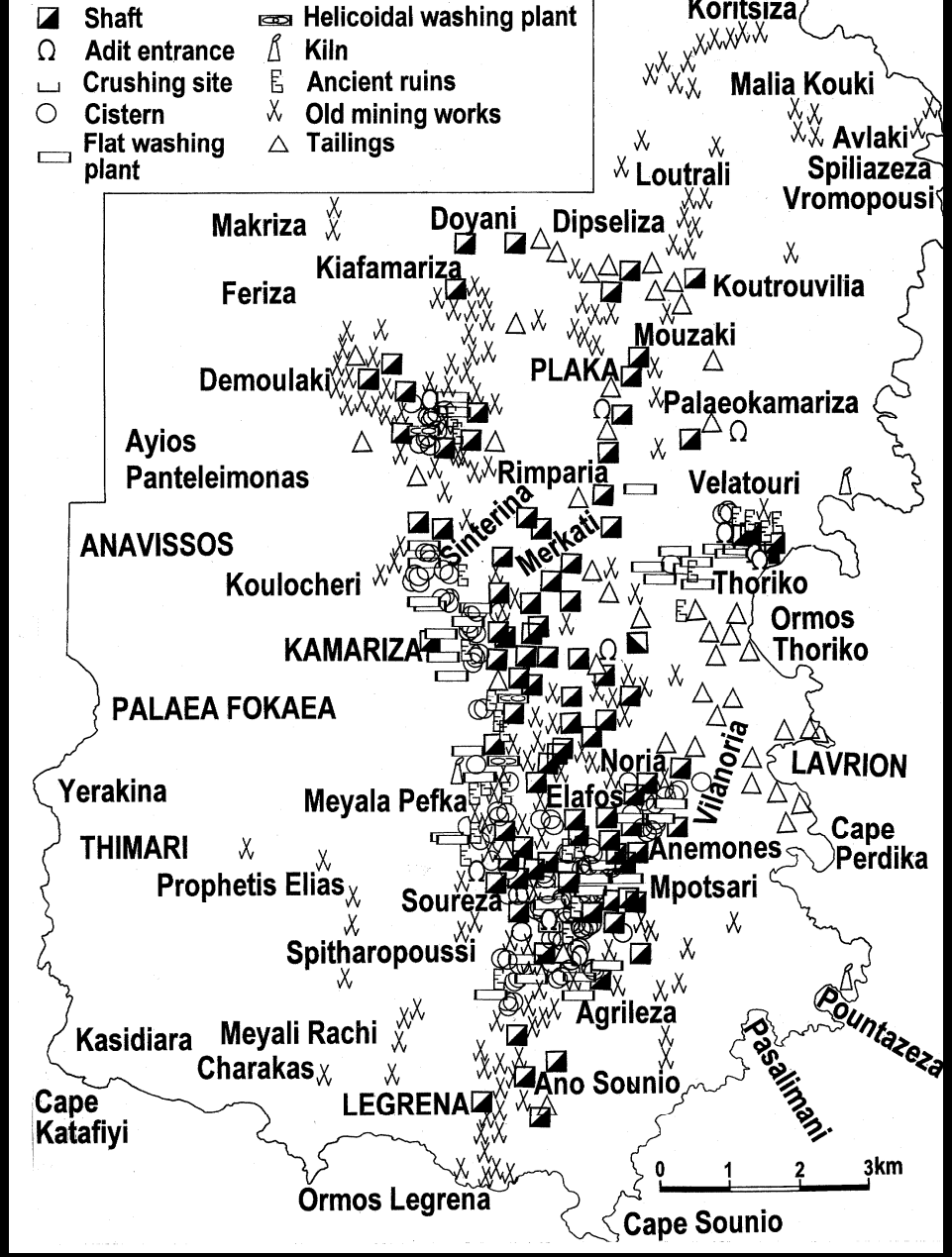
[$CaCO_3$]

Ancient adits & wastes

Ancient washing plants for the beneficiation of ore



Recent exploitation & wastes



Ancient and recent mining & metallurgical operations and wastes

[from Conophagos (1990) & I.G.M.E. studies]

The result of the intensive mining and metallurgical activities from 3500 B.C. to almost the end of the 20th century is the

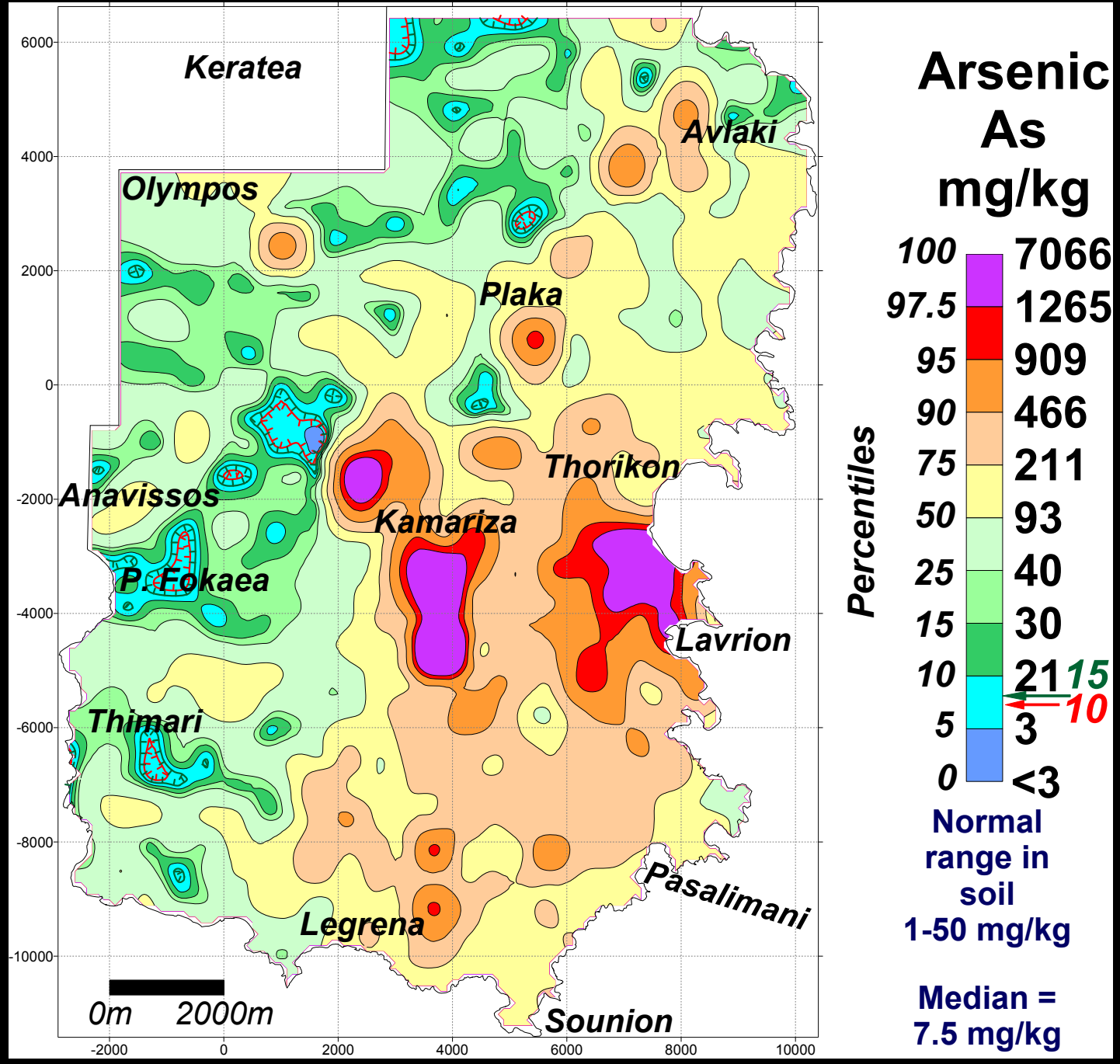
contamination of soil

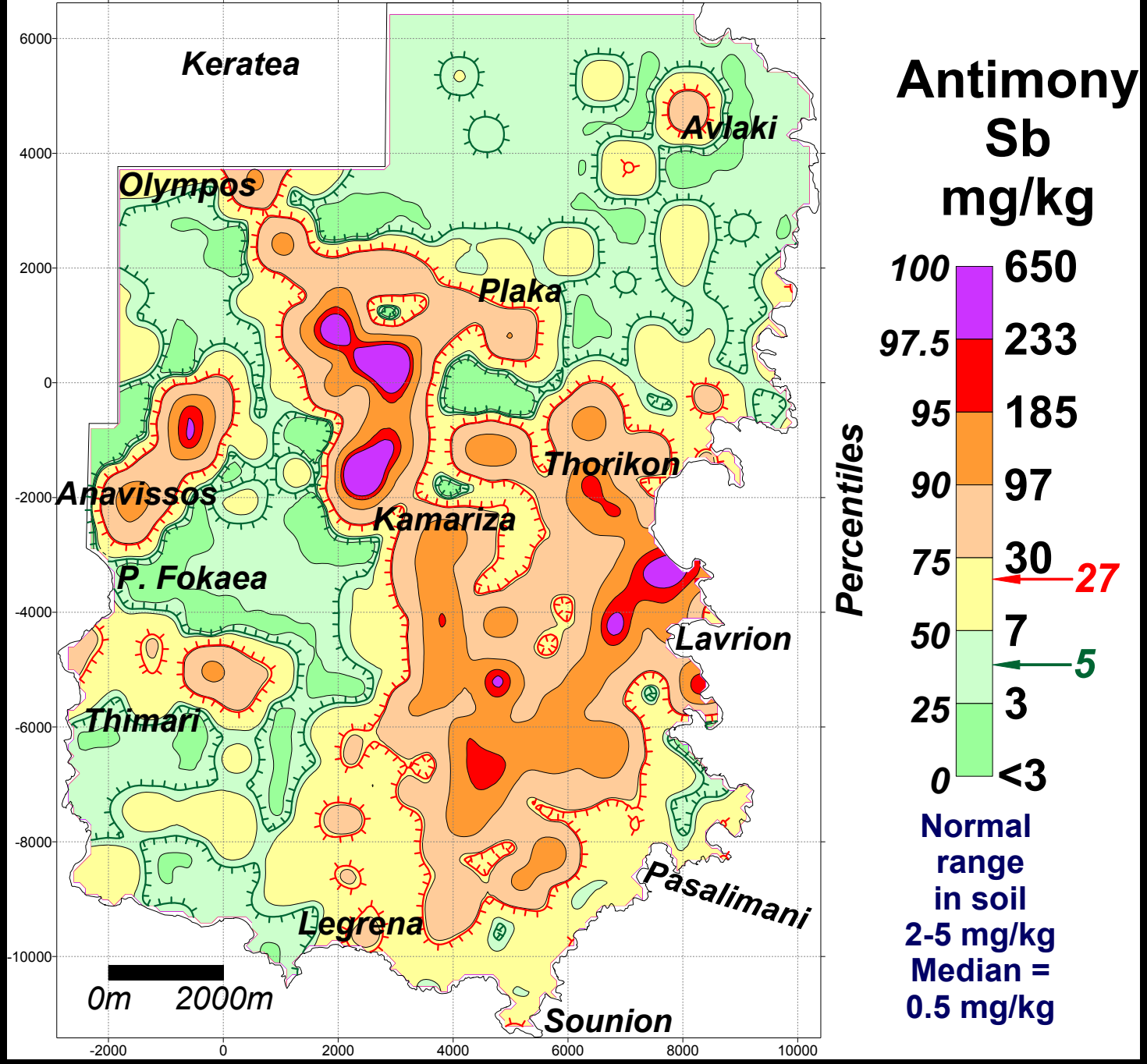
over the whole Lavreotiki peninsula, and especially the Lavrion urban and suburban area

MAPPING OF CONTAMINATION

The Institute of Geology and Mineral Exploration (I.G.M.E.) mapped the contamination over the Lavreotiki peninsula with funds from the Regional Structural Funds Programme 202.088.00 of the Attiki Region.

698 surface soil samples down to a depth of 10 cm were collected over 170 km^2 of the Lavereotiki peninsula using a grid of 500 x 500 metres.


Keratea
Avlaki
Olympos
Plaka
Thorikon
Anavissos
Kamariza
P. Fokaea
Lavrion
Thimari
Pasalimani
Legrena
Sounion
0m
2000m
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-2000
0
2000
4000
6000
8000
10000
Arsenic
As
mg/kg
Percentiles
100
97.5
95
90
75
50
25
15
10
5
0
7066
1265
909
466
211
93
40
30
21
15
10
3
<3
Normal range in soil 1-50 mg/kg
Median = 7.5 mg/kg



Antimony Sb mg/kg

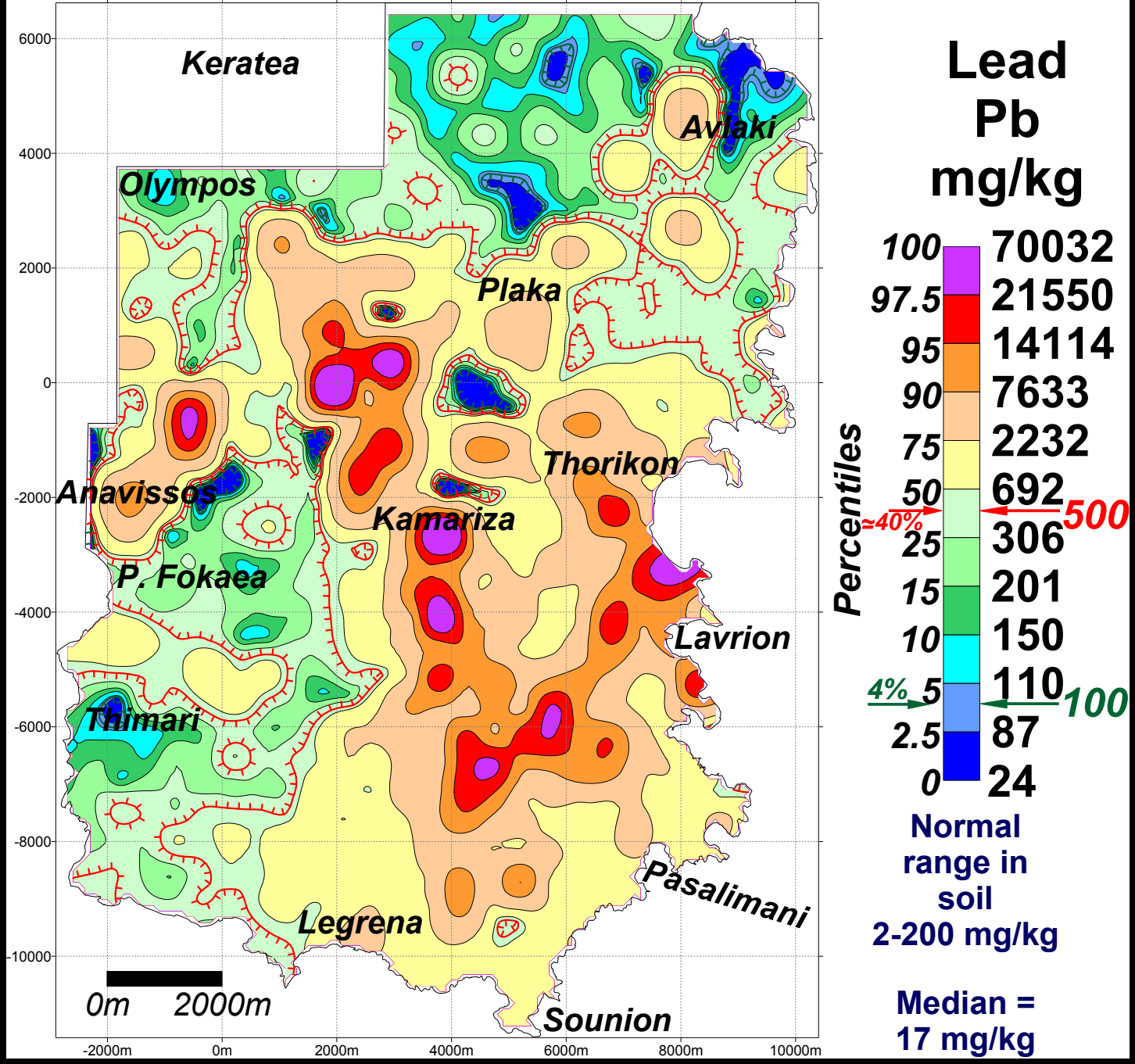
Percentiles

Percentiles	mg/kg
100	650
97.5	233
95	185
90	97
75	30
50	7
25	3
0	<3

27

5

Normal range in soil 2-5 mg/kg
Median = 0.5 mg/kg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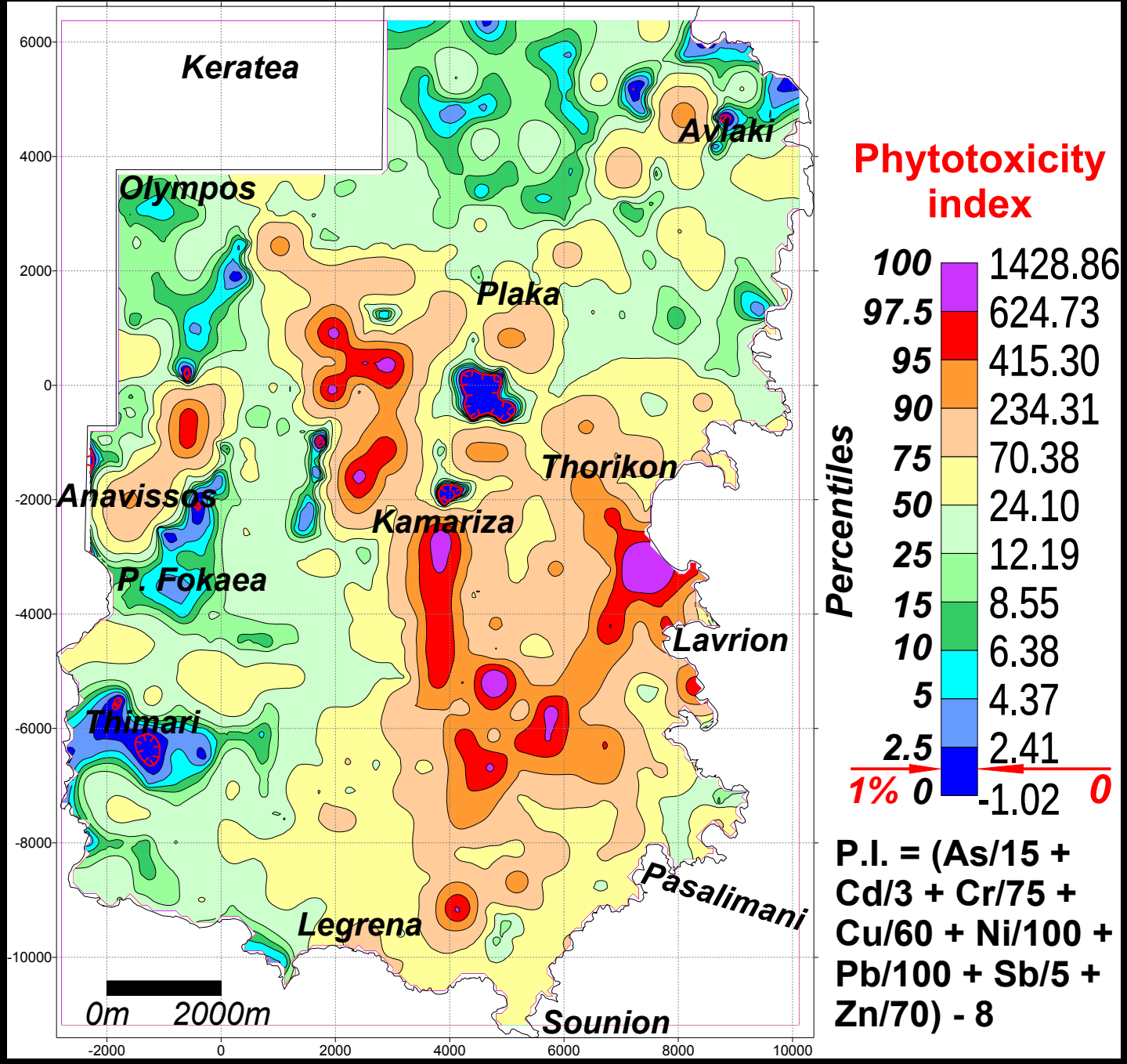
0m 2000m
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-2000m
0m
2000m
4000m
6000m
8000m
10000m
Lead
Pb
mg/kg
Percentiles
100 70032
97.5 21550
95 14114
90 7633
75 2232
50 692
≈40% 500
25 306
15 201
10 150
4% 5 110
100
2.5 87
0 24
Normal range in soil 2-200 mg/kg
Median = 17 mg/kg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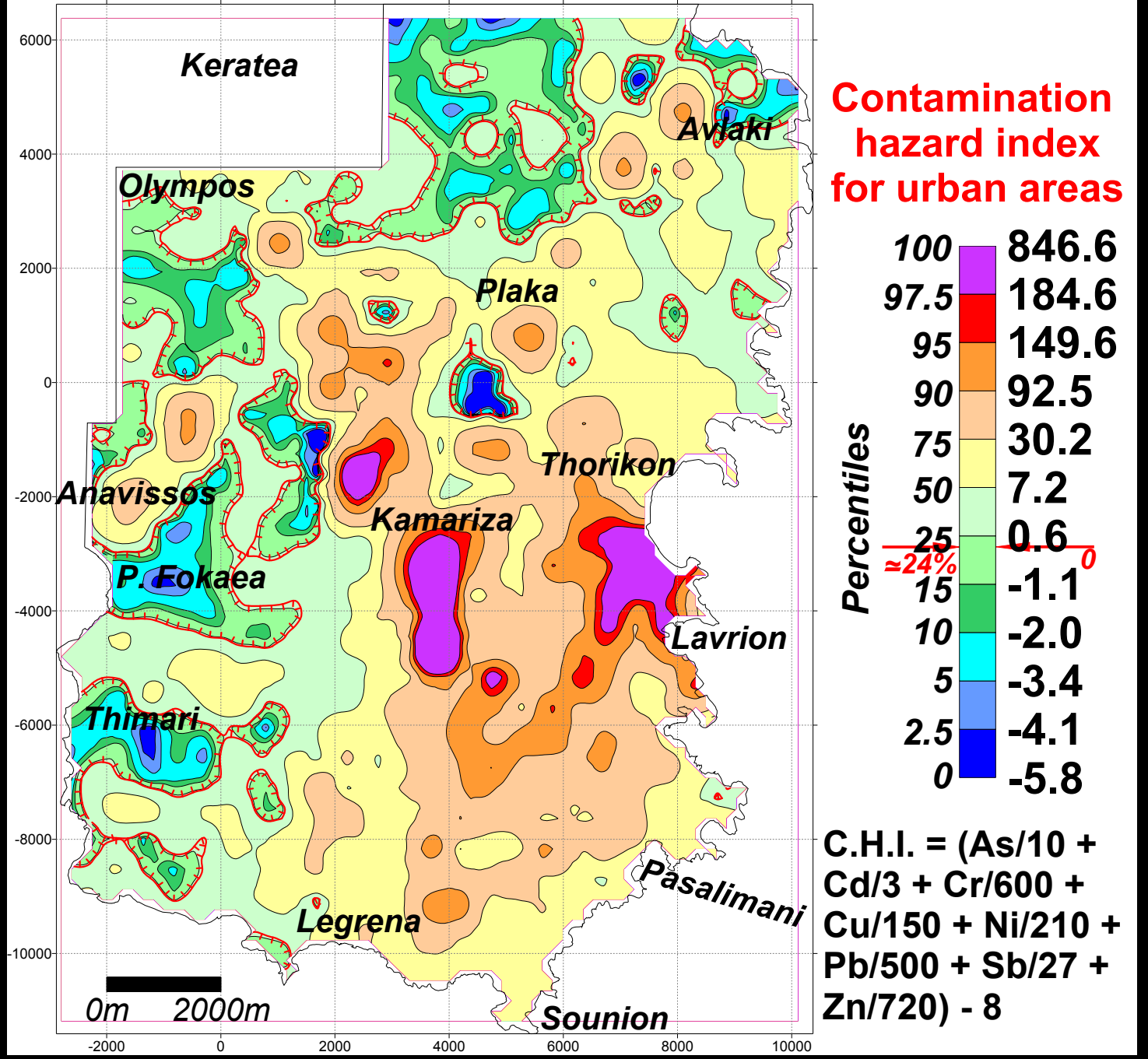
Pasalimani
Legrena
Sounion
0m 2000m
6000
4000
2000
0
-2000
-4000
-6000
-8000
-10000
-2000 0 2000 4000 6000 8000 10000
Phytotoxicity index
Percentiles
100 1428.86
97.5 624.73
95 415.30
90 234.31
75 70.38
50 24.10
25 12.19
15 8.55
10 6.38
5 4.37
2.5 2.41
1% 0 -1.02 0
P.I. = (As/15 + Cd/3 + Cr/75 + Cu/60 + Ni/100 + Pb/100 + Sb/5 + Zn/70) - 8



Contamination hazard index for urban areas

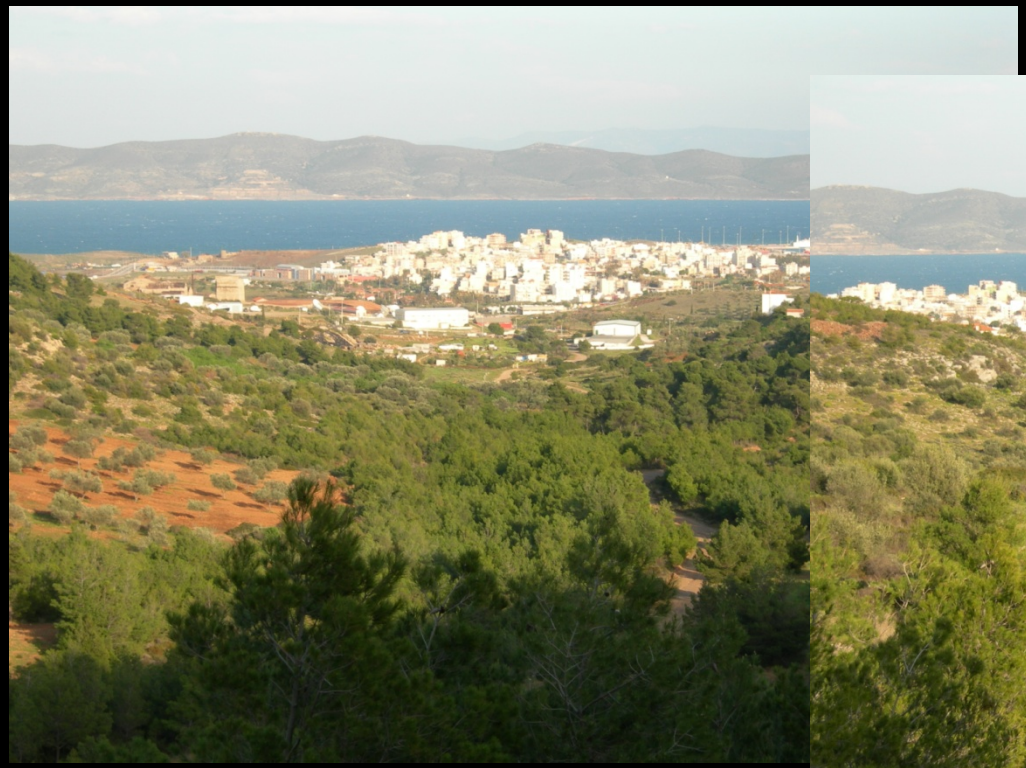
Percentiles	
100	846.6
97.5	184.6
95	149.6
90	92.5
75	30.2
50	7.2
25	0.6
≈24%	0
15	-1.1
10	-2.0
5	-3.4
2.5	-4.1
0	-5.8

C.H.I. = (As/10 + Cd/3 + Cr/600 + Cu/150 + Ni/210 + Pb/500 + Sb/27 + Zn/720) - 8

Lavrion urban & suburban area

LIFE Contract No. 93/GR/A14/GR/4576

Soil Rehabilitation in the Municipality of Lavrion



MAIN OBJECTIVES

- Risk assessment
- Risk communication
- Environmental management plan for the rehabilitation of soil

MAPPING

- Lithology (collection of representative rock samples to produce lithogeochemical maps)
- Soil contamination
- House dust contamination
- Contamination sources (collection of representative samples from all types of metallurgical processing wastes and their geochemical characterisation)
- Land use
- Property ownership

SAMPLING & LABORATORY METHODS

- Sampling and chemical analysis of rock, soil, house dust, metallurgical processing wastes;
- Particle size analysis of soil and metallurgical processing wastes and chemical analysis of different fractions;
- Five step selective leaching of soil and house dust samples, and
- Particle characterisation of representative soil and house dust samples.


Slag
Pyrite


Pyrite

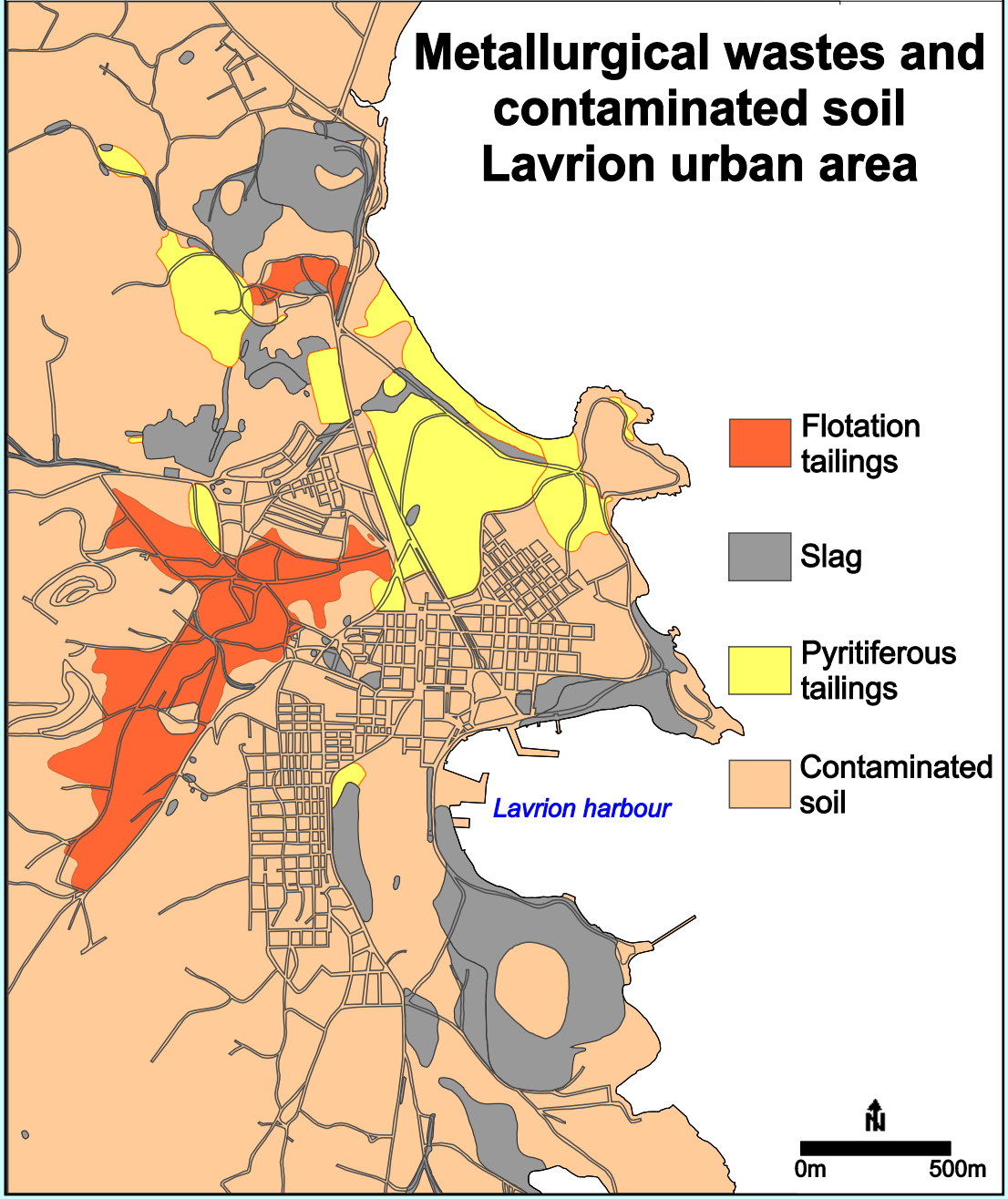

Slag


Pyrite

A LARGE PART OF THE TOWN IS BUILT ON THE SANDY WASTES FROM THE BENEFICIATION OF ORE

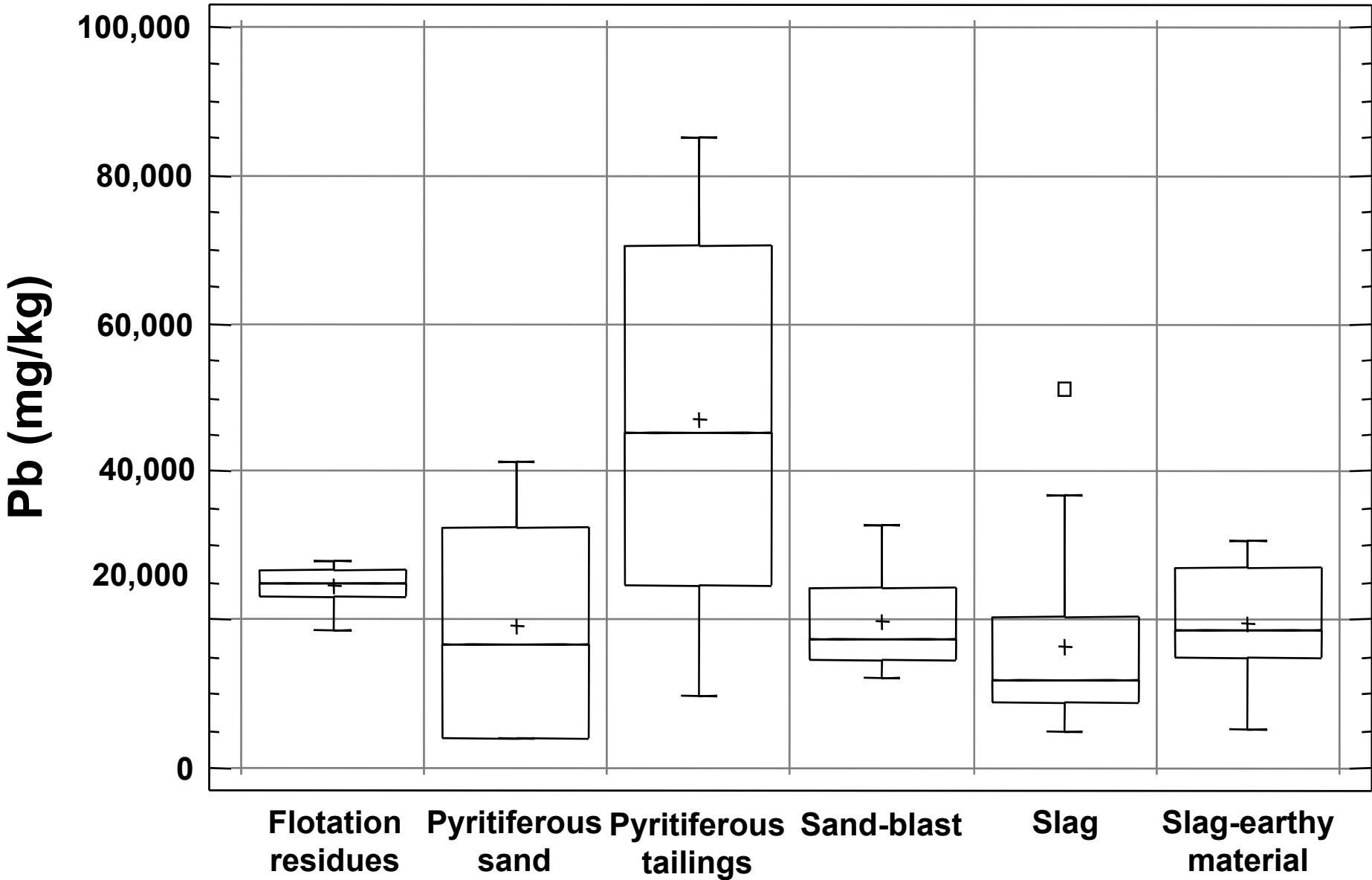
SLAG AS HARDCORE

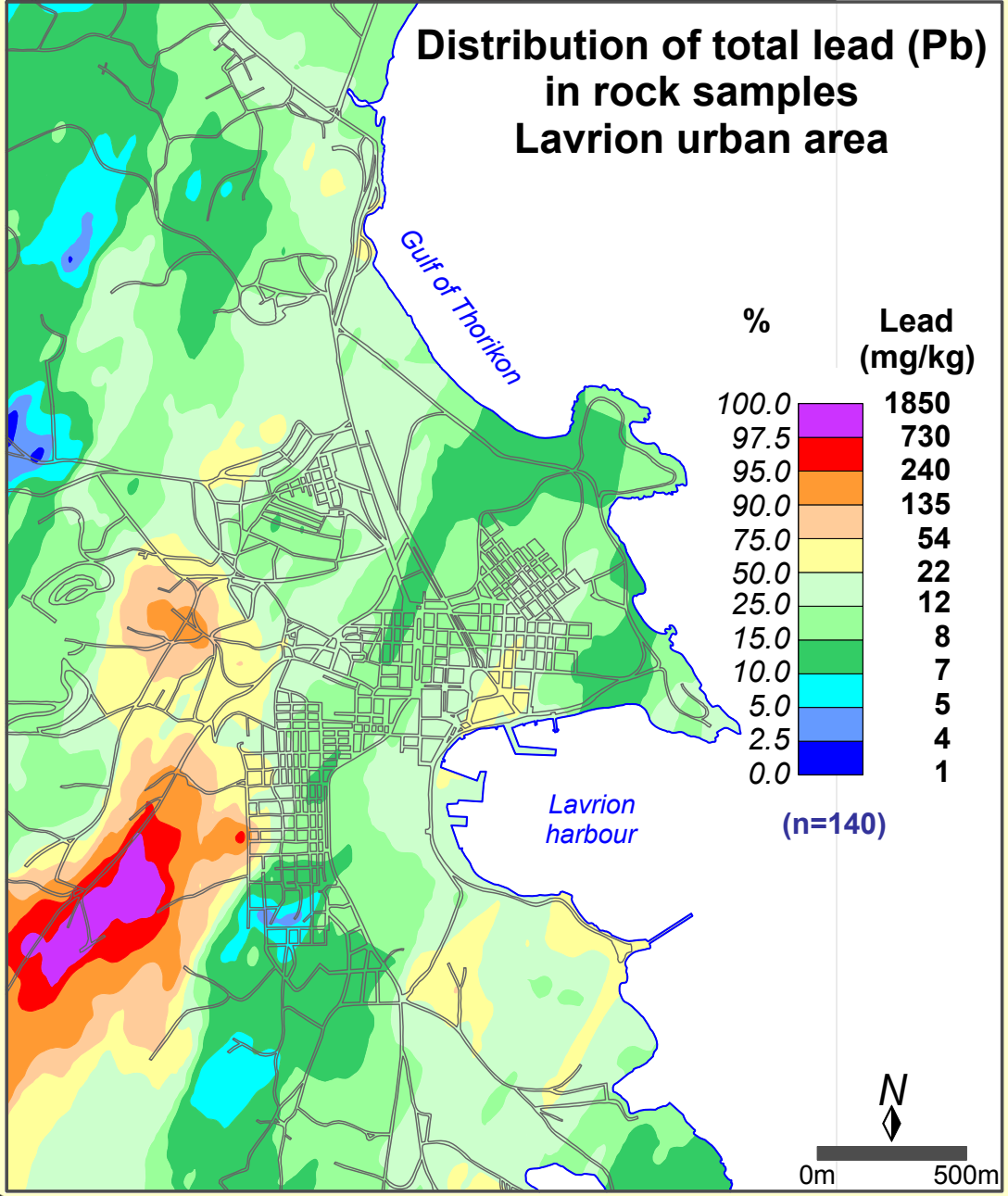
Slag and earthy material



The different types of metallurgical processing wastes were mapped at a scale of 1:5000, and representative samples collected and analysed.

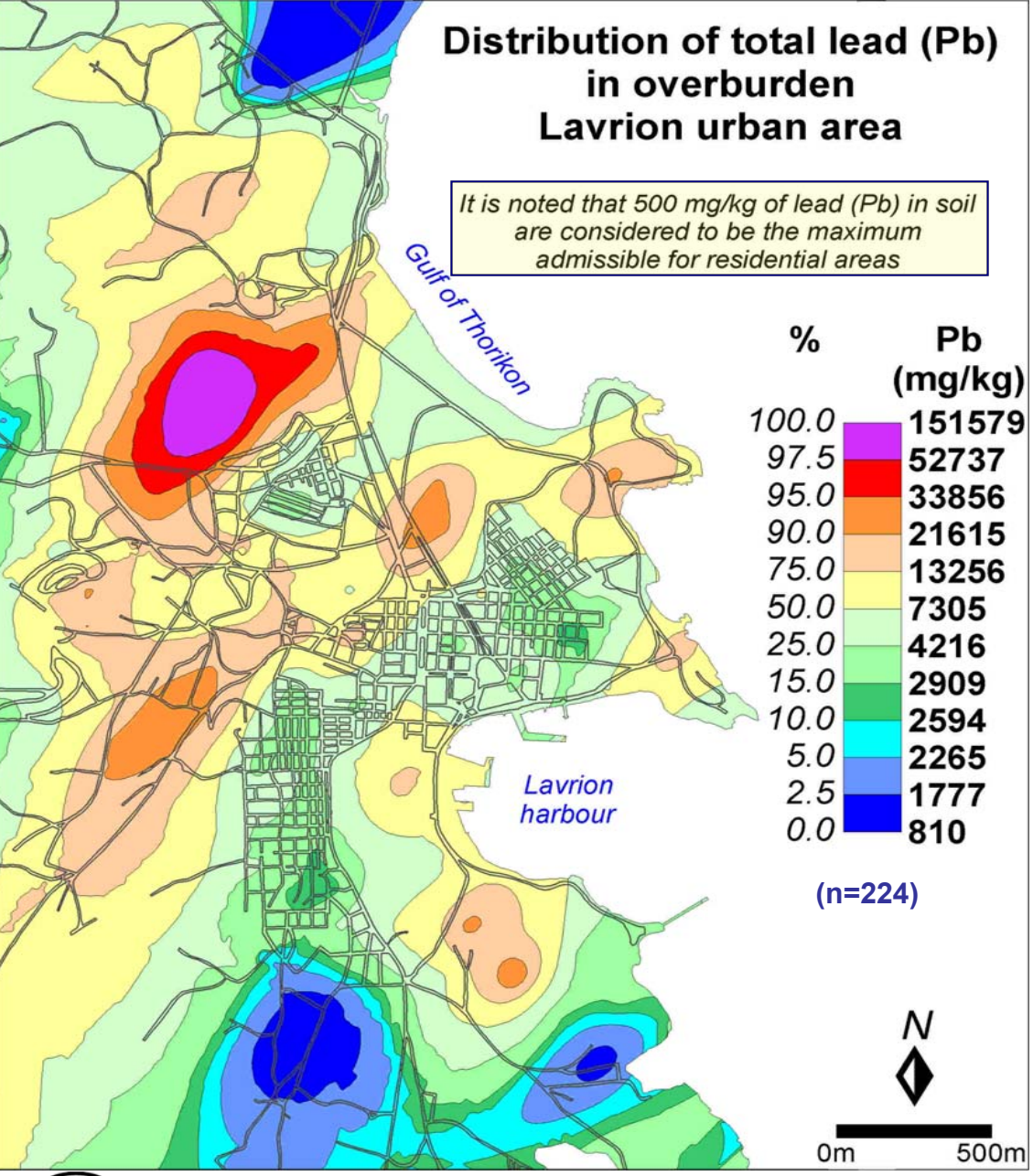
Pb distribution in metallurgical processing wastes





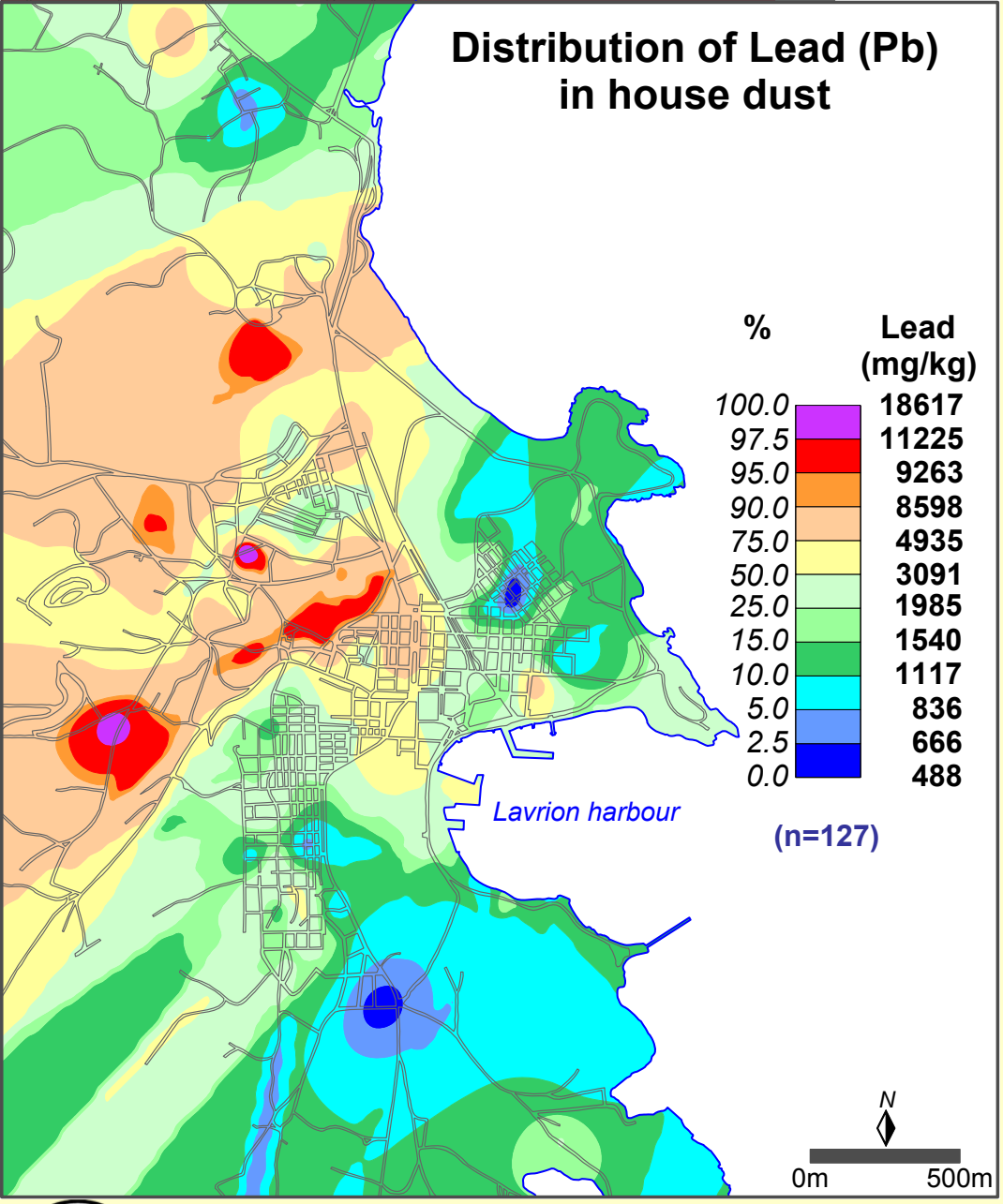
Since surface soil is highly contaminated it is impossible to determine its natural geochemical background variation.

An indirect method of learning something about the primary natural "C" horizon soil geochemical conditions is rock geochemistry.



Soil contamination down to a depth of 5 cm is quite evident from the Pb concentrations, which vary from 810 to 151,579 mg/kg (~15%).

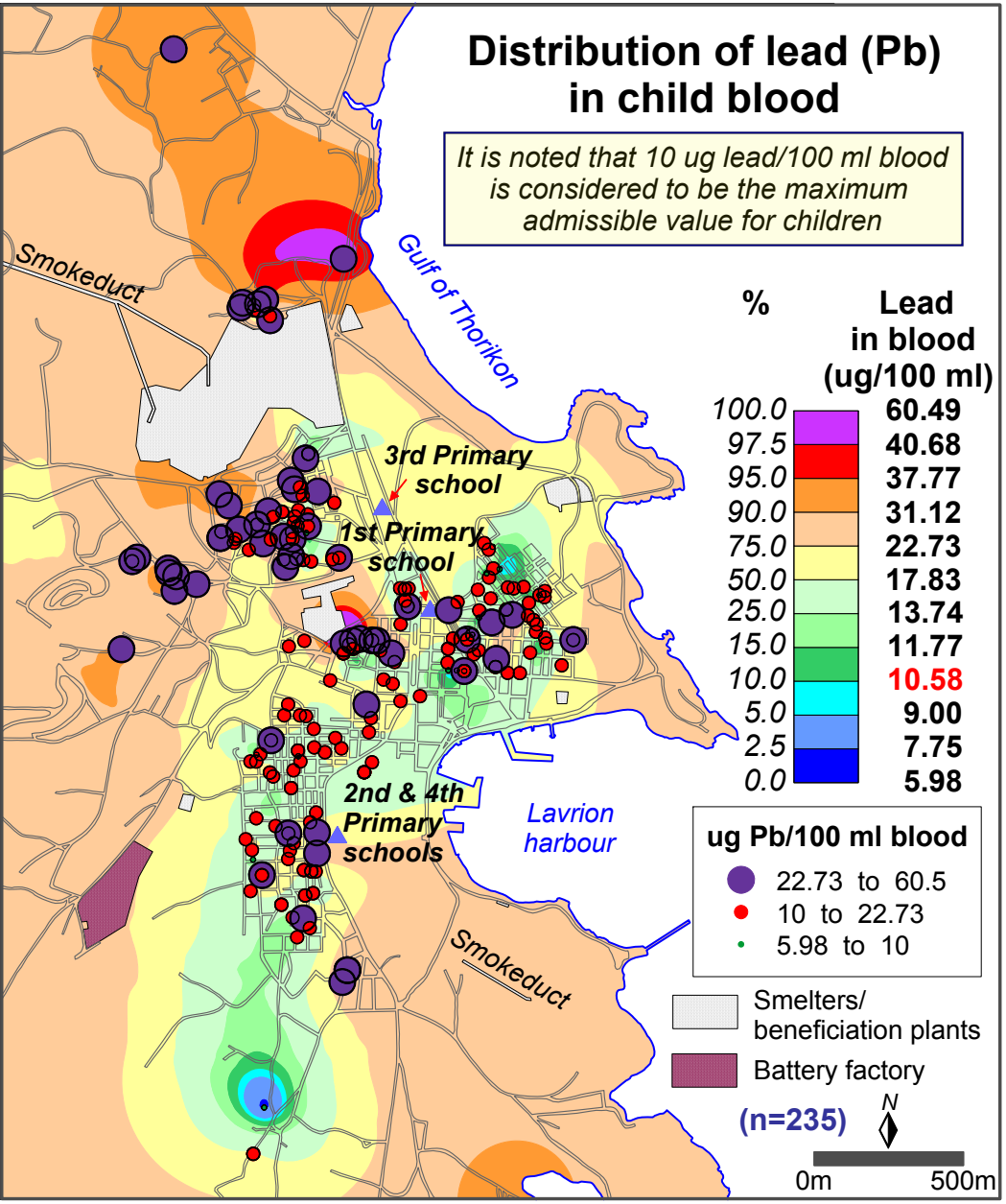
Where as in parent rocks, Pb values vary from 1 to 1,850 mg/kg.



House dust is also highly contaminated as is shown by Pb concentrations, which vary from 488 to 18,617 mg/kg.

Surface soil: 810 to 151,579 mg/kg Pb

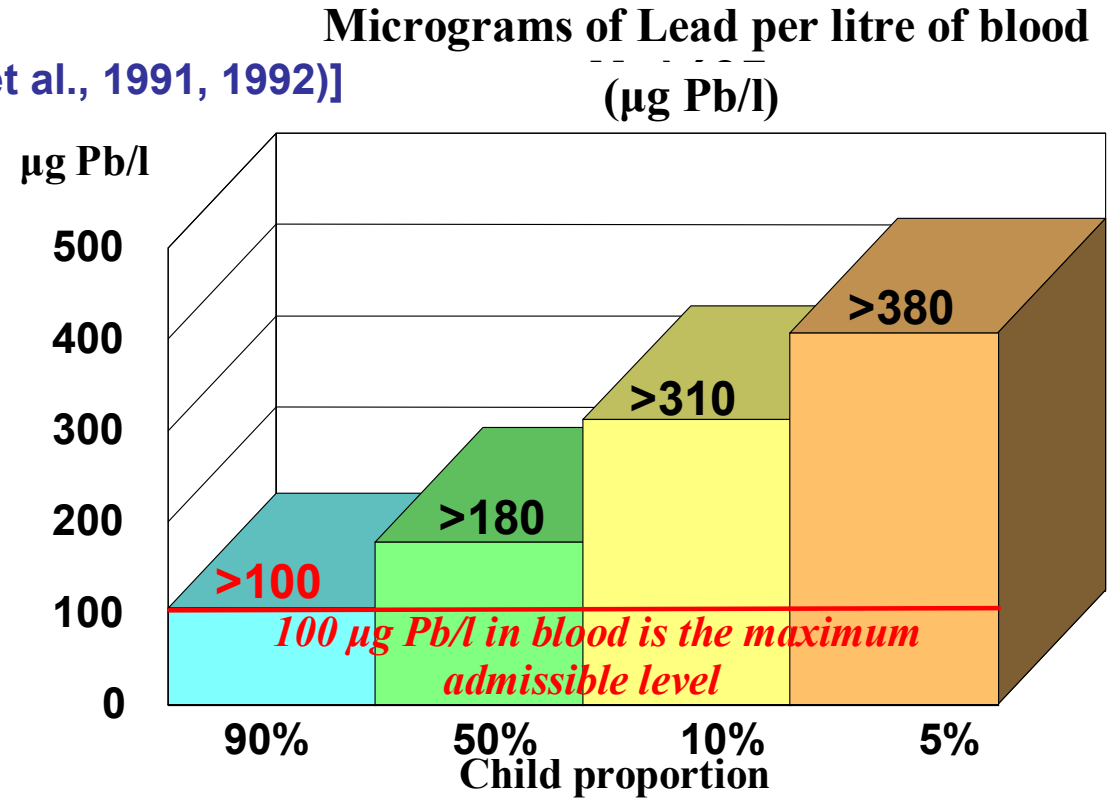
Parent rocks: 1 έως 1,850 mg/kg Pb



The effects of soil contamination are quite evident from the results of blood-Pb levels in children.

More than 90% of the 235 children involved in this study have blood-Pb levels>10 μg/100 ml

[1988 study Makropoulos et al., 1991, 1992)]



- 90% of the children (n=235) that participated in the cross-sectional epidemiological study had more than 100 micrograms of lead per litre of blood,

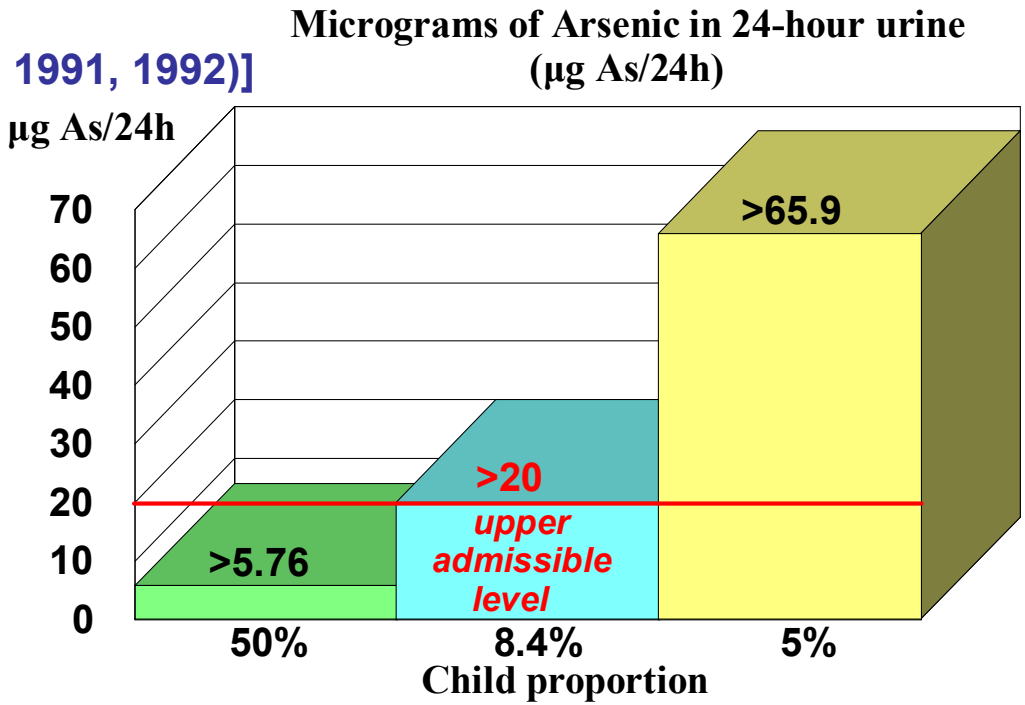
- 50% had more than 180 micrograms of lead per litre of blood,

10% had more than 310 micrograms of lead per litre of blood, and

5% had more than 380 micrograms of lead per litre of blood.

It is noted that 100 μg Pb/litre of blood is the W.H.O. upper acceptable limit for children (i.e., 10 μg Pb/100 ml or 10 μg Pb/decilitre).

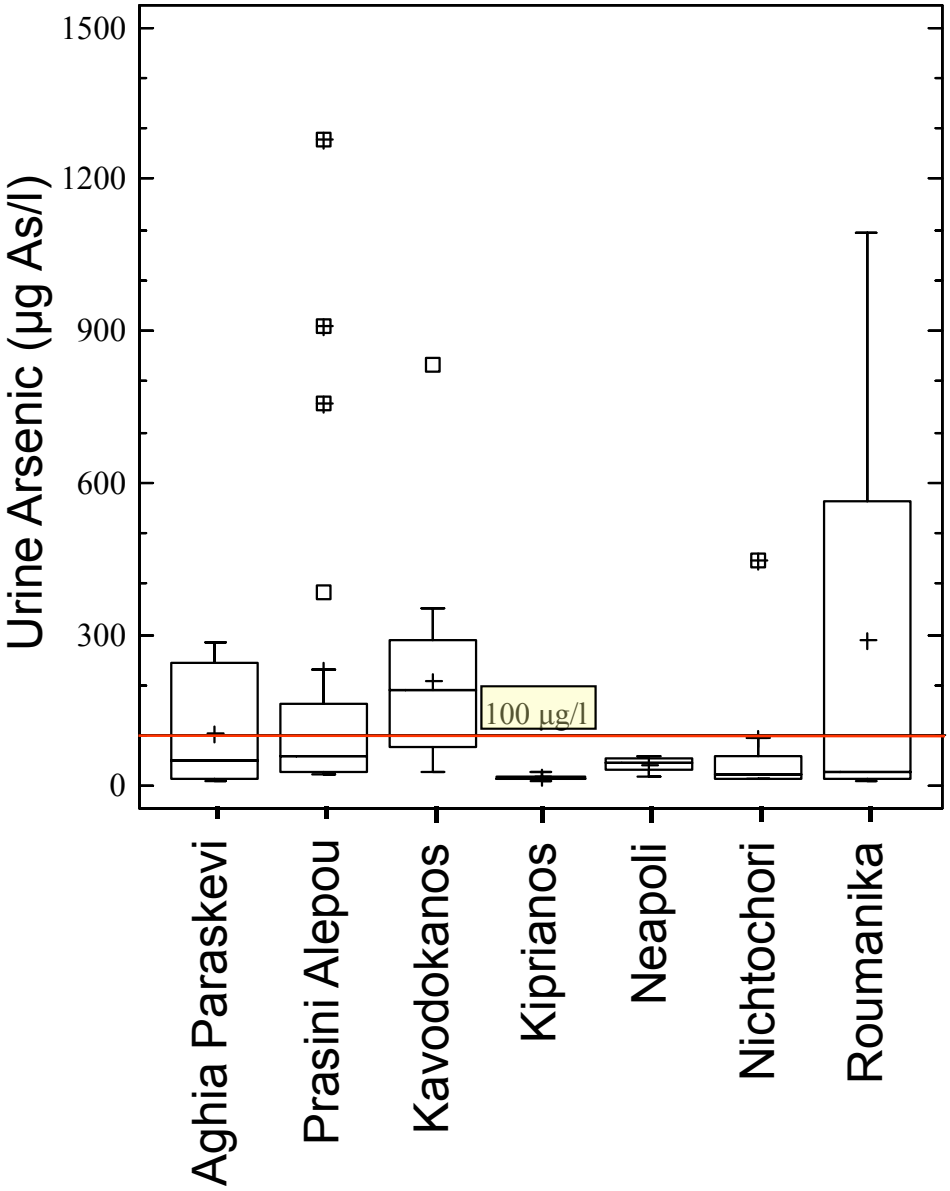
[1988 study
Makropoulos et al., 1991, 1992)]



- 8.4% of the children (n=235) that participated in the cross-sectional epidemiological study had more than 20 micrograms of arsenic in 24-hour urine, and

- 5.0% had more than 65.9 micrograms of arsenic in 24-hour urine.

It is noted that 20 μg of Arsenic (As) in 24 hour urine is the W.H.O. upper acceptable limit for children (20 μg As/24 hr)



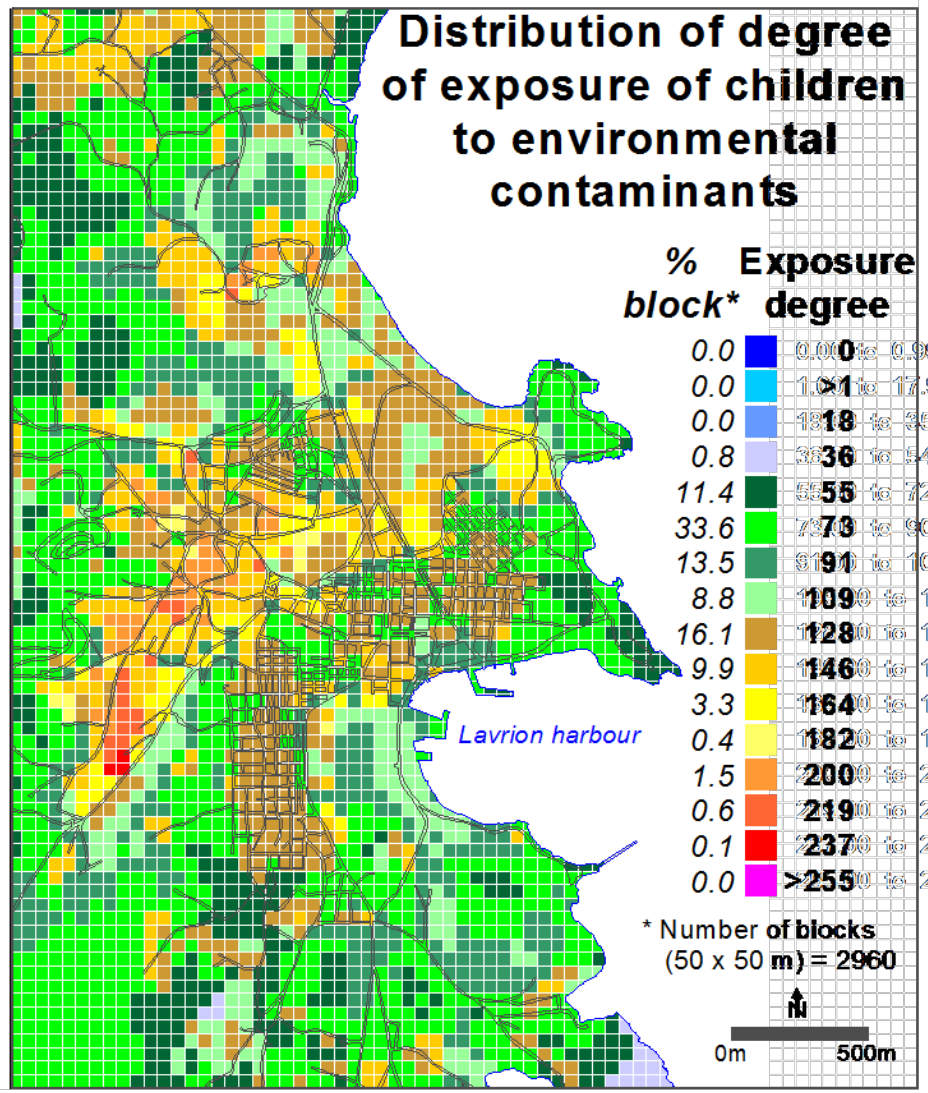
New Urine samples

Samples of urine were collected on the 19th November 1988 from 65 Lavrion inhabitants.

Based on the non-occupational limit of 100 µg As/l urine (Caroli et al., 1994), 37% of the inhabitants had urine As levels above this limit.

It is inferred that As is still available for absorption 9 years after the closure of the metallurgical complex. Therefore, the source is still active, and this is considered to be the metallurgical processing wastes and the contaminated soil.

Degree of exposure



Eight factors and two constraints were considered in a multicriteria exposure assessment, including Pb concentrations in overburden/soil:

(A) Factors:

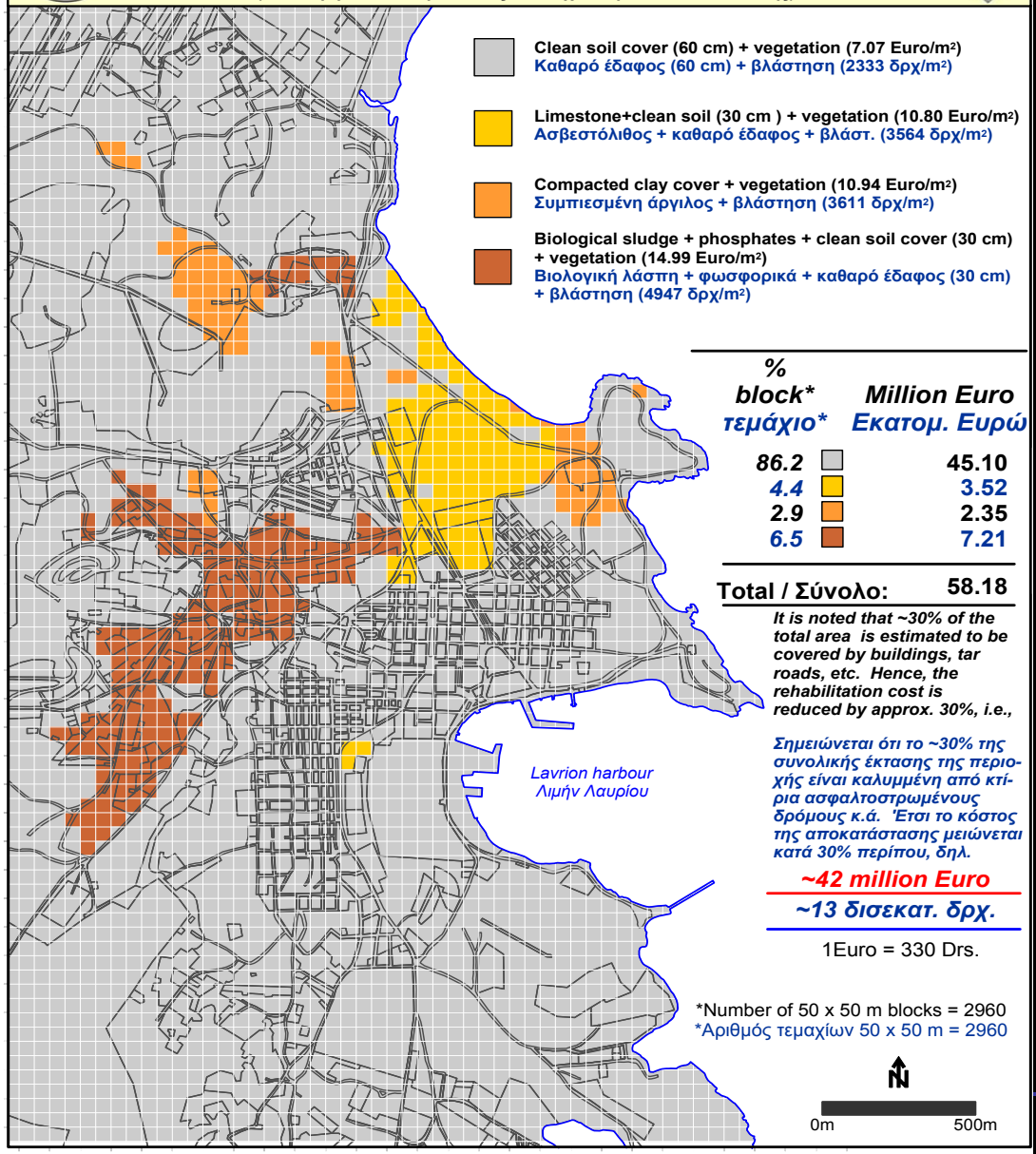
1. Lead (Pb) concentration in overburden/soil;
2. Degree of dustiness of the metallurgical waste;
3. Proximity to metallurgical wastes;
4. Proximity to current or previous stacks;
5. Proximity to roads;
6. Proximity to rivers;
7. Proximity to Pb-industry;
8. Degree of exposure.

(B) Constraints:

9. Area with metal-related industry, and
10. Area over Quaternary deposits.

Fig. 13
Least cost technologies for the rehabilitation of metallurgical wastes and contaminated soil in the Lavrion urban area
(distribution of Cost Index of the rehabilitation methods)

Σχ. 13
Τεχνολογίες χαμηλότερου κόστους για την αποκατάσταση των μεταλλουργικών απορριμμάτων και του ρυπασμένου εδάφους της αστικής περιοχής του Λαυρίου
(κατανομή του Δείκτη Κόστους των τεχνολογιών αποκατάστασης)



% block* τεμάχιο*	Million Euro Εκατομ. Ευρώ
86.2	45.10
4.4	3.52
2.9	2.35
6.5	7.21
Total / Σύνολο:	**58.18**

It is noted that ~30% of the total area is estimated to be covered by buildings, tar roads, etc. Hence, the rehabilitation cost is reduced by approx. 30%, i.e.,

Σημειώνεται ότι το ~30% της συνολικής έκτασης της περιοχής είναι καλυμμένη από κτίρια ασφαλτοστρωμένους δρόμους κ.ά. Έτσι το κόστος της αποκατάστασης μειώνεται κατά 30% περίπου, δηλ.

~42 million Euro
~13 δισεκατ. δρχ.

1Euro = 330 Drs.

*Number of 50 x 50 m blocks = 2960
*Αριθμός τεμαχίων 50 x 50 m = 2960

Plant type	*Lead in crop (mg/kg)*	*Lead in leaves (mg/kg)*
Olive tree	**5.6 (olive)**	**386**
Vine	**8.7 (grape)**	**175**
Limits of European Union Directives	**0.1**	**0.3**

The Lavrion inhabitants must be informed in order to change certain habits and activities (*Short term aim*)

All agricultural and animal rearing activities must stop (*Short term aim*)

Children must not play with the materials on the beaches and with soil (Short term aim)

QUALITY OF LIFE

An obvious question is posed:

Can the inhabitants of Lavrion have quality of life in an environment with such an extreme contamination?

ALL TYPES OF RISK TACKLED

- Risk assessment
- Risk communication
- Risk perception
- Risk management

Result?

Thank you for your attention