Alina Wiercińska

A RESEARCH ON THE CONTENT OF TRACE ELEMENTS IN HUMAN BONES. THE STATISTICAL ANALYSIS

Research on content of trace elements in soil and in human and animal bones has been developing quickly over the last five years. Comparative analysis has enabled archaeologists and anthropologists a new insight into people's diet and into soil and hydro-climatic conditions. All that could form a basis for new theories concerning examined cultures.

It is widely known that increased amount of lead in human body is associated with many different ailments and illnesses.

One of more interesting studies, which prompted me to begin my own research was a work concerning strontium contents by T.D. Price, and Melissa Connor of Dept. of Anthropology of University of Wisconsin and by John D. Parsen of Soil and Plant Analysis Laboratory of the same university.

The expedition from the named university excavated a late-archaic site in the south-western US. They found that the diet of an archaic community which dwelled there consisted of 60 percent meat products and 40 percent vegetable foods. The people there consumed a lot of fresh-water fish with very small amount of strontium what might distort the percentage proportion in favour of vegetable food. The American scientists also noted that there are differences between sexes: pregnant and feeding women usually have lower strontium level than men. One possible explanation is that women preferred vegetables over meat.

After I had acquainted with bibliography on the above mentioned subject I decided to begin similar kind of research. I took the opportunity of using the equipment and knowledge kindly provided to me by Longina

Koziorowska M.Sc. from the Spectrographic Lab of the Monuments' Surveys and Registration Dept. of the State Archeological Museum, Warsaw.

The data on content of ten trace elements in human bones found at prehistoric burial grounds in: Żerniki Górne, Nemrik, and Cecele were the subject of the study. Surveyed were samples from *substantia spongiosa* and *substantia compacta* of long bones.

Spectroscopic analysis was carried out by L. Koziorowska from the Spectrography Lab. She marked content of each element listed below in the form of spectral intensity. The elements taken into consideration were: aluminium (Al), barium (Ba), calcium (Ca), iron (Fe), magnesium (Mg), phosphorus (P), lead (Pb), silicon (Si), titanium (Ti). Also, I have asked P. Jaskólski to make statistical calculations.

Mean values and standard deviations of each of six samples for each of ten elements were calculated. Significance of differences (*t*-Student test) between samples of:

a) *substantia spongiosa* and *substantia compacta* in each sample,
b) *substantia spongiosa* between all samples,
c) *substantia compacta* between all samples was estimated.

The significance of differences were compared with three levels of α error significance: 0.05, 0.01, 0.001 (small differences, big differences and very big differences). Contents of each element in the analysed series were compared.

It is worth emphasizing that the mean value of content of barium was approximately at the same level in all samples ranging from 45 to 59.8 (units of analytical line intensity).

As for other elements: we found 30 very big differences, 12 big and 9 small (in all, 51 significant differences among 90 possible ones).

It means that as far as spectral line intensities are concerned (indicating content of each element) the differences in contents of all the surveyed elements are quite significant.

A. **A comparison of content of trace elements in samples of *substantia spongiosa* and *substantia compacta* taken from the same burial ground.**

– Żerniki Górne: differences refer to four elements;
very big differences: Al, Fe, Si,
big differences: Mg, P, Ti, small differences: Mn, Pb.
– Nemrik: differences refer to eight elements;
very big differences: Al, Fe, Si,

big differences: Mg, P, Ti, small differences: Mn, Pb.
- Cecele: differences refer to five elements;
very big: Fe, Si, Ti.
big: Al, Ca.

Only for three elements: Al, Si, Ti, big and very big differences occurred repeatedly. The lack of soil samples makes impossible any estimation of influence of chemical composition of the respective soils.

It could be essential because those elements seem to be linked with inorganic undersoil.

Among other elements, only iron content differs significantly from sample to sample which seems to be connected with important role it plays in vital functions of human organism.

B. **A comparison of concent of trace elements in samples of *substantia spongiosa* taken in different burial grounds.**

- Żerniki Górne-Nemrik. Contents of the elements differ in seven cases; very big differences refer to: Al, Mg, P, Si,
big differences refer to: Ti,
small to: Ca and Pb.
- Żerniki Górne-Cecele. There are differences in four cases: very big differences in the cases of Si, Ti and big differences in the case of P.
- Nemrik-Cecele. Differences appears in five cases: very big in the case of Al, Mg, Mn and P. There are also small differences between Pb content.

Noteworthy, the Polish series differ more from the Nemrik series than they do between themselves (not so in the case of aluminium of which content always changes significantly in each soil).

These differences concern the elements which, possibly, are significantly connected with biochemical functions.

C. **A comparison of content of trace elements in samples of *substantia compacta* taken in different burial grounds**

- Żerniki Górne-Nemrik. There are differences in eight cases:
very big differences in the cases of: Al, Ca, Pb,
big differences in the cases of: Mg, Si, Ti.
- Żerniki Górne-Cecele. Those series differs in the content of three elements: Al, Ca and P,
- Nemrik-Cecele. Differences concern seven elements:

very big: Al, Fe, Mn, Si, Ti,
big: Mg and Pb.

Similarily as for the Polish series above, we found slight differences. The significant differences (excluding aluminium) concern calcium and phosphorus (both very important as main components of bones). However, both Polish series differ from the Nemrik series in up to six cases.

It is possible that the differences are not only the result of different base soil layers but of different diets as well.

D. A detailed comparison of trace elements

Al – the average content ranges from 79.6 to 158. All the series differs one between the other so it can mean (as was mentioned above) that the amount of that element is connected with differences in basement soil.

Ba – lack of differences which may result from high variability (variability coefficient up to 73.6% – Nemrik, *substantia compacta*).

Ca – the differences appear twice – one of these is big, the another is small. The calcium content varies (as the essential element for bones, calcium is subject to very precise control).

Therefore the differences which appeared four times are worthy of paying attention. In the two instances where the differences are very big and they refer to the differences of content of trace elements in *s. compacta* between the bones from Żerniki on the one side and those from Nemrik and Cecele on the other. The bones from Żerniki are more calcified. It can be explained in two ways: one interpretation is that the difference in calcium is a consequence of different diet (we can draw a conclusion concerning the health conditions); second interpretation is that the soil rich in calcium determined the average content of Ca (this is more probable).

Fe – there are three instances of differences in iron level. In each case these differences are very important. These are differences *between s. spongiosa* and *s. compacta* in Nemrik and Cecele and differences between the samples of *s. compacta* only taken in two places – Nemrik and Cecele.

Mg – the significant differences appear five times, twice they are very big, twice big and once small. In any case those differencesoccur in Nemrik samples. The content of magnesium is higher there in both *s. spongiosa* and *s. compacta* as well. It is most probably connected with geochemical diferences.

Mn – the differences appeared four times, similarly to that of magnesium, probably there are also common conditions which cause both of them.

P – six differences. Three are very big. They are connected with much higher contect of phosphorus in *s. compacta* than in *s. spongiosa* in the Nemrik site.

Pb – the content of lead is evidently different in six instances but only in one case there is very big dissimilarity and big in the another.

Si, Ti – the differences in content of those two elements are almost identical. In two cases the differences regarding titanium are smaller. The accordance in the differences between these elements may point out at a convergence in the processes of regulation of their content of in human body. However, similar soil composition could play a role here.

General Conclusion

1) The Polish series differs from each other in 66.7% but from Nemrik series in 90%.
2) The differences in content of Al and Ba in the first case are always significant and in the second case insignificant – it means that they could be left out of account.
3) The differences of content of trace elements between *s. spongiosa* and *s. compacta* may imply that the soil is responsible for that phenomenon.
4) The differences of content of calcium and phosphorus in the Polish series may show that diet and generaly the way of life may play some role in it.
5) The number of significant differences between Polish series and the Nemrik ones may suggest dissimilarity of soil, way of life, climate etc.
6) According to a visible regularity of significant differences of content of the particular elements we can set up three groups:

The first one: Al, Si, Ti, Pb related to mineral subsoil.

The second group: Ca, P – the structural elements of bones.

The third group: Fe, Mg, Mn trace elements taking part in metabolic processes in bones.

Summary

It seems to be most advisable to intensify research concerning trace elements in bones which could include collecting more samples from comparable sites, not only of human bones but also animal ones (both herbivorous and carnivorous) and samples of soil attached to human and animal samples.

Such an extensive analysis could led to more justifiable interpretations o differentiations of environmental conditions, mode of life, diet of human populations. In this context cultural differences inside surveyed populations and between them could be discovered.

Table 1. Intervals of trace elements concentration in the examined bone material with a list of elements not found in the samples (by L. Koziorowska)

SEMI-QUANTITATIVE ANALYSIS	
Trace element	Per cent concentration intervals
Al - aluminium	0.001-0.01
Ba - barium	0.01-0.1
Ca - calcium	0.1-1.0
Fe - iron	0.001-0.01
Mg - magnesium	0.1-1.0
Mn - manganium	0.01-0.1
P - phosphorus	0.01-0.1
Pb - lead	0.01-0.1
Si - silicon	0.01-0.1
Ti - titanium	0.001-0.01
QUALITATIVE ANALYSIS	
Ag - silver	Approximate concentration
As - arsenic	z.i. - minimal content (less than 0.0001%)
Be - berylium	x - very small content, approx. 0.0001%
Cu - copper	xx - small content, approx. 0.001%
Ni - nickel	xxx - considerable content, approx. 0.01%
Sn - tin	
Zn - zinc	
TRACE ELEMENTS NOT DETECTED	
Au - gold, b - boron, Bi - bismuth, Cd - cadmium, Co - cobalt, Cr - chronium, Ge - germanium i Sb - antimony	

Table 2. The arithmetical means of spectral line intensities of the listed elements form: Cecele, Nemrik, Żerniki Górne

Table 2. The arithmetical means of spectral line intensities of the listed elements form: Cecele, Nemrik, Żerniki Górne

The site	The type of bone tissue	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti	Atomic number
Cecele (Wielbark) culture)	*substantia compacta*	114,2 (63-144)	62,8 (29-91)	124,3 (99-140)	119,3 (77-144)	32,5 (19-73)	51,1 (8-88)	123,9 (110-145)	29,1 (6-112)	129,0 (52-183)	51,4 (4-102)	N = 23
	substantia spongiosa	128,6 (107-143)	53,8 (38-75)	133,8 (121-154)	133,8 (11-149)	39,7 (24-62)	41,8 (15-73)	123,5 (95-142)	41,8 (12-116)	161,2 (131-188)	80,1 (35-106)	N = 24
Nemrik (Neolithic Age, Iraq)	*substantia compacta*	79,6 (65-98	45,0 (8,83)	81,4 (52-107)	81,4 (52-107)	43,6 (34-51)	7,8 (0-19)	121,8 (115-141)	8,4 (3-19)	68,2 (44-101	16,4 (4-35)	N = 5
	substantia spongiosa	116,6 (110-122)	59,8 (47-66)	134,2 (109-132)	134,2 (127-140)	66,2 (58-80)	21,6 (8-34)	90,8 (68-108)	23,6 (8-38)	149,6 (137-160)	71,6 (50-98)	N = 5
Żerniki Górne (Neolithic Age)	*substantia compacta*	129,0 (120-138)	55,0 (44-78)	153,6 (142-159)	103,4 (73-178)	35,8 (34-40)	45,2 (27-74)	146,4 (143-152)	26,8 (24-30)	105,0 (88-137)	37,0 (26-56)	N = 5
	substantia spongiosa	158,0 (152-169)	46,0 (31,65)	143,6 (133-158)	132,0 (124-141)	38,6 (28-43)	34,4 (6-57)	137,8 (128-151)	55,0 (29-83)	184,2 (174-195)	122,8 (96-141)	N = 5

Table 3. Significance of differences between the mean values

Żerniki Górne, s.s.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Żerniki Górne, s.c.	<0.001							<0.05	<0.001	<0.001

Nemrik, s.s.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Nemrik, s.c.	<0.005			<0.001	<0.01	<0.05	<0.01	<0.05	<0.001	<0.01

Cecele, s.s.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Cecele, s.c.	<0.01		<0.001	<0.001					<0.001	<0.001

Żerniki Górne, s.s.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Nemrik, s.c.	<0.001		<0.05	<0.001	<0.001		<0.001	<0.05	<0.001	<0.01

Żerniki Górne, s.s.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Cecele, s.c.	<0.001								<0.001	<0.001

Nemrik, s.s.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Cecele, s.c.	<0.001				<0.001	<0.001	<0.001	<0.05		

Żerniki Górne, s.c.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Nemrik, s.c.	<0.001		<0.001		<0.05	<0.01	<0.01	<0.01	<0.05	<0.05

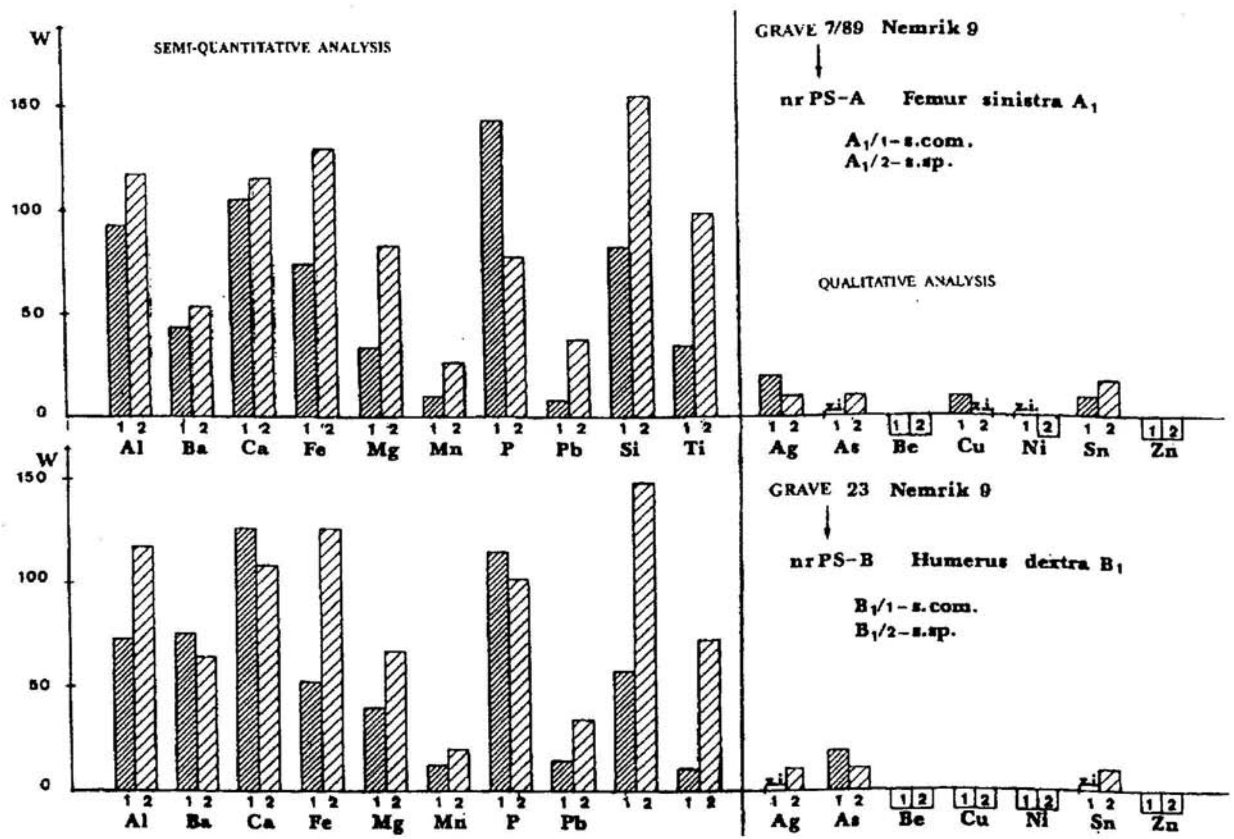
Żerniki Górne, s.c.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Cecele, s.c.	<0.01		<0.001				<0.001			

Żerniki Górne, s.c.	Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Cecele, s.c.	<0.001			<0.001	<0.01	<0.001		<0.01	<0.001	<0.001

Table 4. Mean contents of trace elements in samples

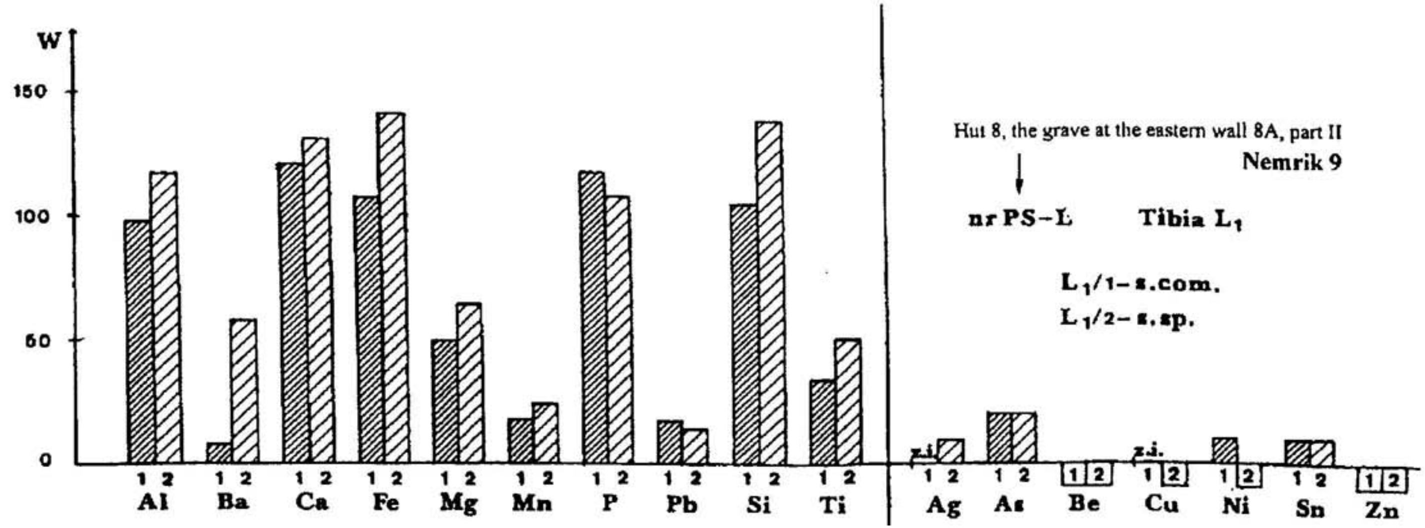
	n		Al	Ba	Ca	Fe	Mg	Mn	P	Pb	Si	Ti
Żerniki Górne	5	avg	158	46	143.6	132	28.6	34.4	137.8	55	184.2	122.8
s.s.		sds	6.75	12.9	11.22	6.89	6.02	21.56	8.79	22.08	10.03	16.65
Żerniki Górne	5	avg	129	55	153.6	103.4	35.8	45.2	146.2	26.8	105	37
s.c.		sds	7.38	13.45	7.02	23.95	2.49	19.99	4.28	2.39	19.1	12.43
Nemrik	5	avg	116.6	59.8	122.2	134.2	66.2	21.6	90.8	23.6	149.6	72.6
s.s.		sds	4.34	8.26	9.65	5.63	9.5	9.76	16.66	12.38	8.68	21.4
Nemrik	5	avg	79.6	455	122.2	81	43.6	7.8	121.8	8.4	68.23	16.4
ss.c.		sds	14.47	33.14	10.47	19.53	6.73	8.01	10.89	6.23	22.66	15.66
Cecele	24	avg	128.6	53.8	133.8	133.8	39.7	41.8	123.5	41.5	161.2	80.1
s.s.		sds	10.71	9.35	10.18	8.79	10.9	15.47	14.56	21.44	18.26	20.46
Cecele	24	avg	114.2	62.8	124.3	119.3	32.5	51.1	123.9	29.1	129	51.7
s.c.		sds	16.67	15.82	9.97	16.65	10.93	22.36	10.1	25.59	32.77	26.84

Annex. 1[1]. Graphs of the results of the spectrographic analysis. Nemrik



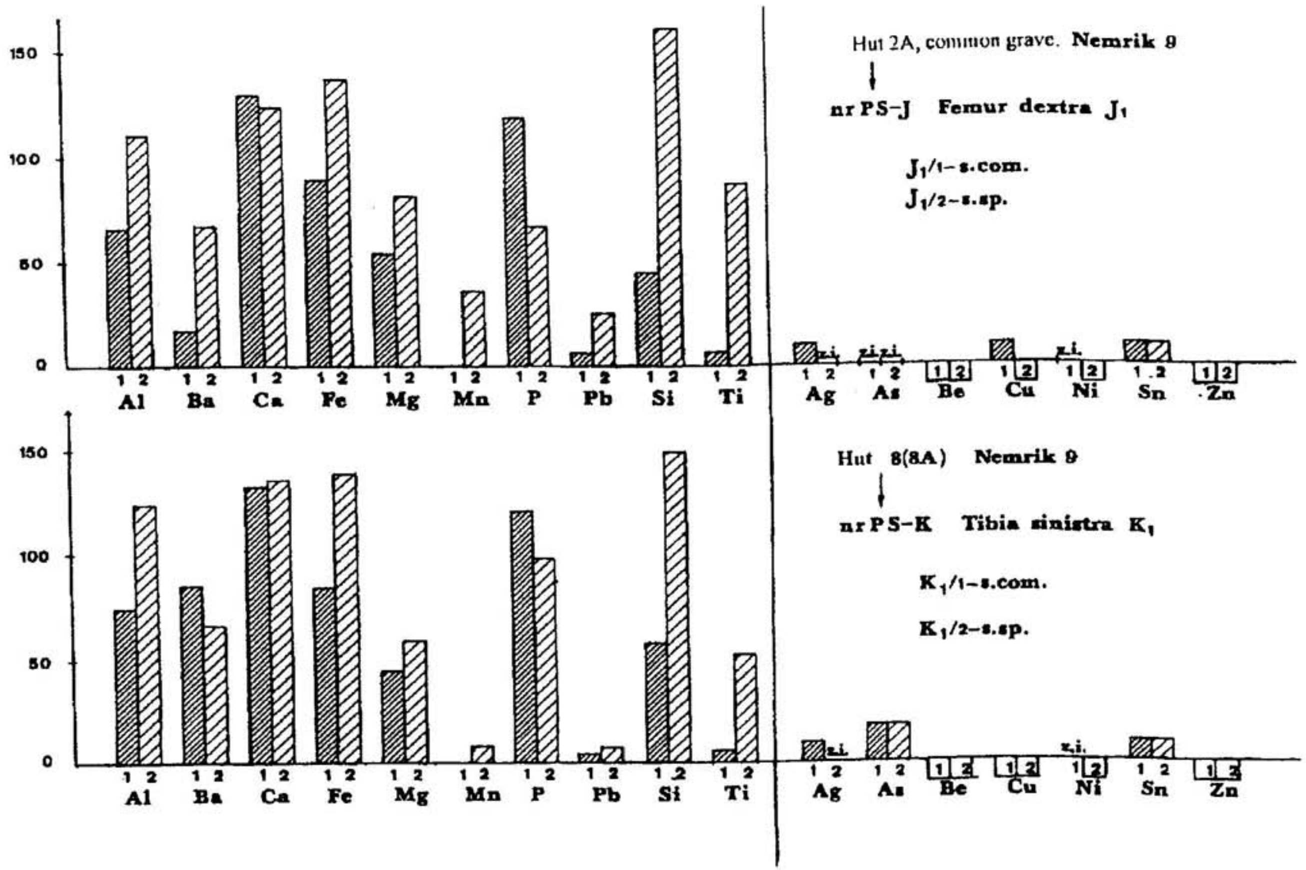
1. Letters are codes used in the Spectrographic tab.

cont.

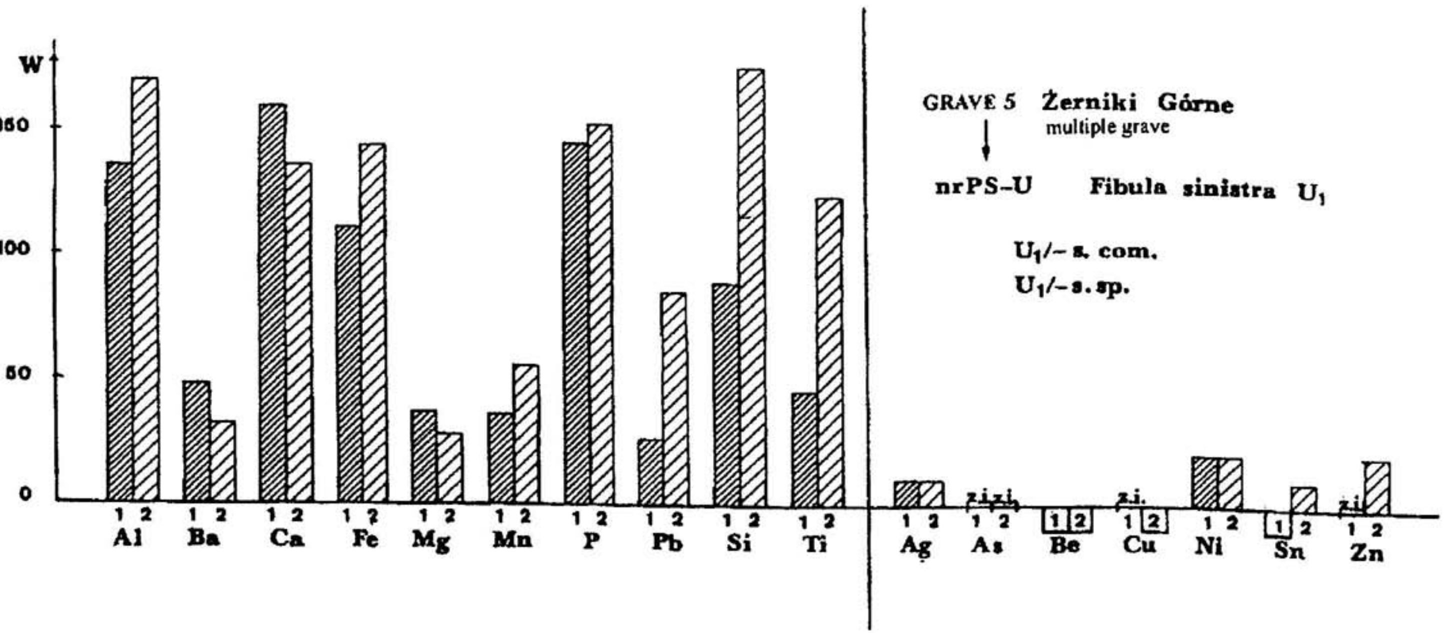


W
150
100
50
0
1 2
Al
Ba
Ca
Fe
Mg
Mn
P
Pb
Si
Ti
Ag
As
Be
Cu
Ni
Sn
Zn
z.i.
Hut 8, the grave at the eastern wall 8A, part II
Nemrik 9
nr PS-L
Tibia L1
L1/1-s.com.
L1/2-s.sp.

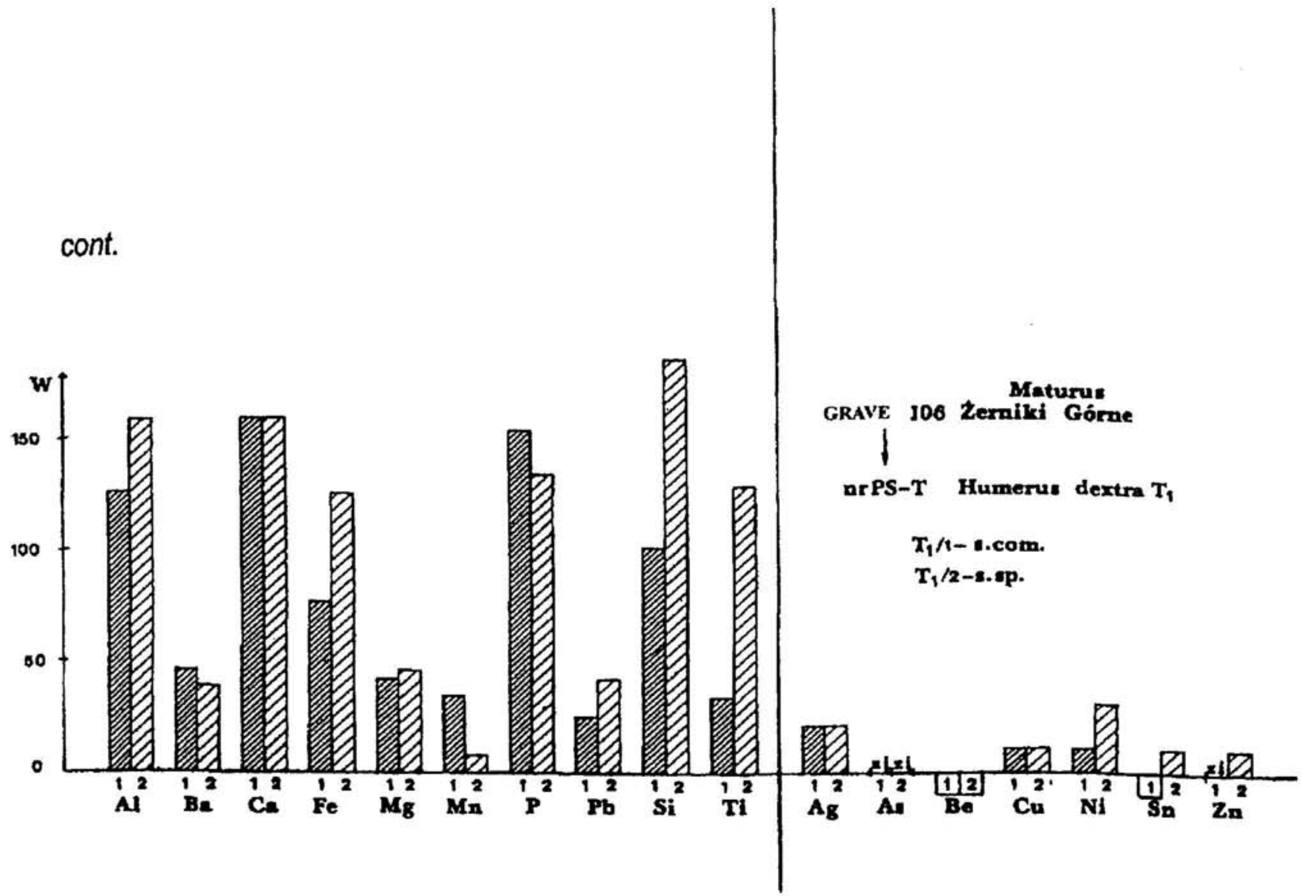
cont.


150
100
50
0
Al
Ba
Ca
Fe
Mg
Mn
P
Pb
Si
Ti
Ag
As
Be
Cu
Ni
Sn
Zn
z.i.
Hut 2A, common grave. Nemrik 9
nr PS-J Femur dextra J1
J1/1-s.com.
J1/2-s.sp.
Hut 8(8A) Nemrik 9
nr PS-K Tibia sinistra K1
K1/1-s.com.
K1/2-s.sp.

Annex 2. Graphs of the results of the spectrographic analysis Żerniki Górne

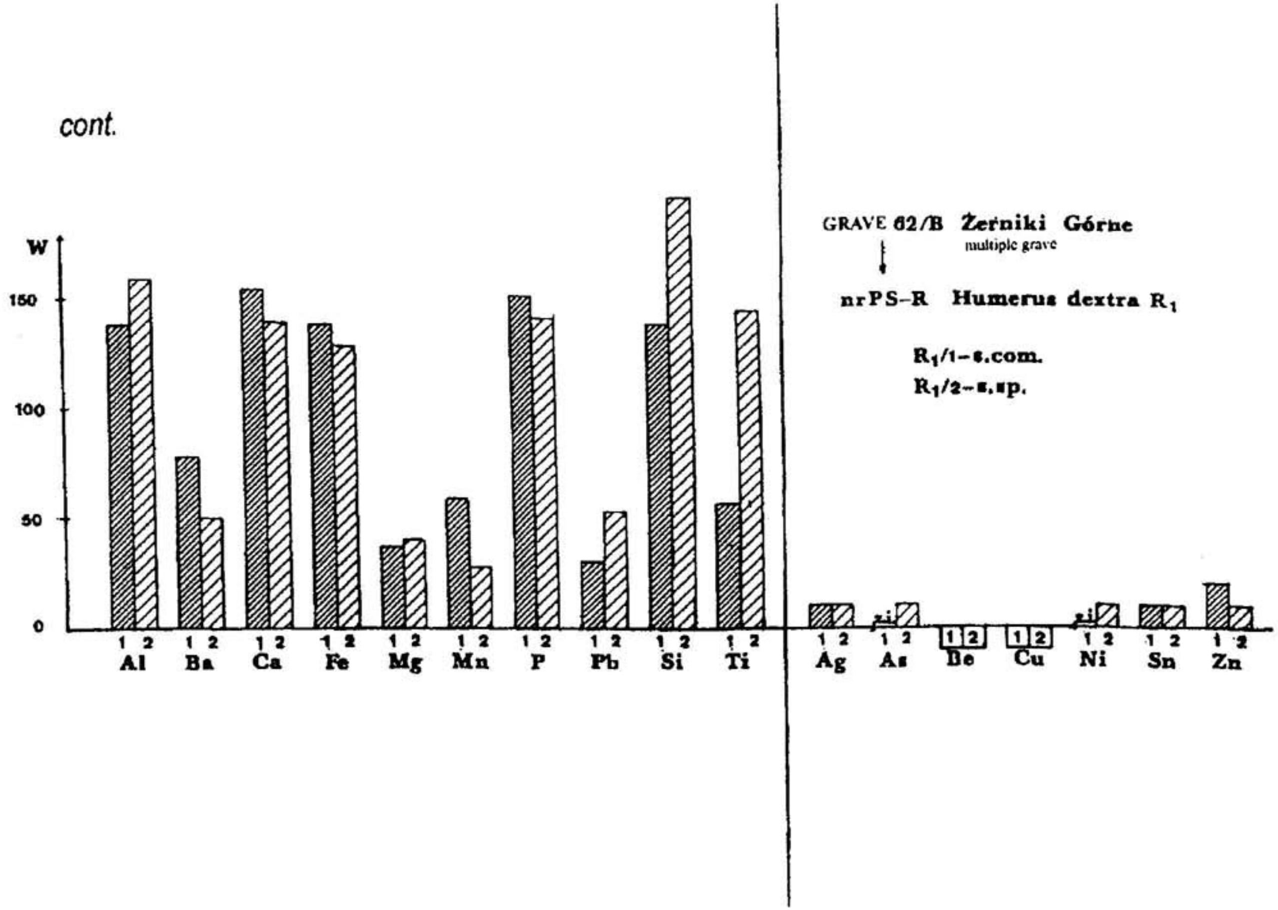


cont.



W
150
100
50
0
Al
Ba
Ca
Fe
Mg
Mn
P
Pb
Si
Ti
Ag
As
Be
Cu
Ni
Sn
Zn
Maturus
GRAVE 106 Żerniki Górne
nrPS-T Humerus dextra T1
T1/1 – s.com.
T1/2 – s.sp.

cont.



W
150
100
50
0
Al
Ba
Ca
Fe
Mg
Mn
P
Pb
Si
Ti
Ag
As
Be
Cu
Ni
Sn
Zn
GRAVE 62/B Żerniki Górne
multiple grave
nrPS-R Humerus dextra R1
R1/1-s.com.
R1/2-s.sp.