

The attestation of analytical laboratory results in archaeology: a pressing need

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This paper presents the results of a preliminary comparison of analyses of metal objects conducted at several laboratories. Differences and similarities are discussed. Results of analyses of the same samples conducted in three laboratories (in Warsaw, Heidelberg and Stockholm) prove the necessity of attestation of laboratories working for archaeology.

KEY-WORDS: archaeological materials science, spectrography, absorption analysis, comparability.

Methods used in contemporary analytical laboratories may be applied to the analyses of chemical composition of archaeological artefacts. Present methods of examining artefacts include: emission spectrometry, atomic absorption spectroscopy, X-ray fluorescence spectrometry, and neutron activation. The use of these techniques is limited however by several basic factors taken together, these include:

1. the size of sample that can be taken from most objects, a limitation due to the nature of the objects examined,
2. the facilities available to the investigating laboratory,
3. the economic factor, the cost of and time taken by the analysis.

Emission spectroscopy has been used on a wide scale in archaeological practice in the Central Laboratory of the Institute of Archaeology and Ethnology, Polish Academy of Sciences (spectrographic analyses conducted from the opening of the Laboratory until the end of 1993 by L. Kozirowska, materials prepared by S. Karwowska, K. Biniewska, B. Marczak and lately T. Jezierska), the laboratory of the Institute of Archaeology of the Russian Academy of Sciences, and the Landesmuseum (WL) in Stuttgart. Atomic absorption spectroscopy is used in the Riksanantikvarieambetet och Statens Historiska Museer Tekniska Institutionen in

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Stockholm (TI RAA). X-ray fluorescence is a basic analytical method employed in the Ceramological Laboratory in Lyon (and an auxiliary method in the Central Laboratory on IAE PAN). Neutron activation and atomic absorption spectroscopy are used in the Max-Planck-Institute (MPI) in Heidelberg, as well as institutions occasionally working in contact with nuclear research establishments (*e.g.*, the Naturhistorisches Museum in Vienna).

One of the tests of the correctness of the analyses conducted by all of these methods is checking against samples of known chemical composition. Such a procedure allows the relatively easy elimination of errors. In order to achieve comparability of results, modern technology and science utilises a series of international standards. In the political divisions existing after 1945 there were two differing standards. In the West the ISO-DIN system was in use, and in eastern Europe the GOST system. National norms were established in relation to these standards. In order to reduce the resultant differences, international commissions were set up to standardise technological materials.

The situation with archaeological material is somewhat different compared with industrial materials science. In the latter a specific composition is sought suitable for the proposed uses of the material and standardised in the process of production (the producer is obliged to respect existing norms so that the elemental composition of the final product is fixed and corresponds to the proposed use). In the study of archaeological material we find a significant differentiation of chemical composition, differing markedly from standards presently in use.

This specific situation in archaeology as well as the important limitation of the permitted size of sample taken, gave rise to the need for determining a standard for the needs of each laboratory. This situation is acceptable when the results of analyses are comparable in the context of one laboratory and any possible errors are repeated in all analyses. The situation looks different when we attempt to compare the results obtained in analyses carried out in different laboratories and also by different methods using different standards. The scale of this problem is apparent from, *e.g.*, the experiments conducted in the 1960s and 1970s by the Corning Museum of Glass (Glaverbel 1973). Due to the importance of this problem for studies on the history of the production and technology of metal artefacts in the mid-1980s the Central Laboratory of IHKM PAN (now IAE PAN) undertook work attempting to examine the scale of this phenomenon in European laboratories. To this aim contacts were established with TI RAA in Stockholm and the Landesmuseum in Stuttgart and the Naturhistorisches Museum in Vienna. TI RAA and WL replied with a positive answer. The basis of the experiment was the laboratories would receive samples of alloys of unknown composition as close as possible to that of ancient artefacts. The laboratories would conduct analyses by

the best method according to their own experience and seeking the elements usually detected. The standards used and size of sample were left to the decision of the laboratories concerned. After the analyses were complete, the results were exchanged. This work is, due to its nature, part of a project which requires many years of co-operation in this field.

I. CHARACTERISTICS OF INVESTIGATIVE METHOD

1. ATOMIC ABSORPTION SPECTROSCOPY (ASA)

A sample intended for ASA analysis is dissolved and the solution obtained is analysed in the spectrometer. The quantity of solution required is dependant on the number of elements analysed. Each element is analysed separately. In the Tekniska Institutionen analysis is carried-out using the Atomic Absorption spectrometer Perkin—Elmer model 460. The sample is first dissolved in nitric acid and subsequently a few drops of hydrochloric acid are added. Two samples were dissolved in nitric acid only (Tekniska Institutionen Report RAA—TA 87—038 dated 22/1/88).

2. SPECTRAL EMISSION ANALYSIS

The investigated material is dissolved in hydrochloric acid in order to eliminate the effect of crystal structure on the results of the analysis. The prepared material is then burnt in an electric arc. The excited atoms emit energy (E) being the difference between the emission of the atom in its resting state (E_k) and the energy of the atom in an energetic state lower than the state of excitation (E_x) of wavelength:

$$\Delta E = h\nu = E_k - E_x; \quad \lambda = \frac{hc}{E_k - E_x}$$

h = Planck's constant 6.6256×10^{-34} Js,

c = speed of light,

ν = frequency of investigated radiation.

Radiation produced in this manner characteristic for particular investigated materials is detected on photographic plates covered with light-sensitive emulsion (spectrographic method) or using a radiation detector (spectrometric method). The constructional features of the spectrograph allow greater or lesser differentiation of the registered wavelengths which determine whether the spectrograph is to be considered as of medium or wide dispersion. The use of spectrographs with wide

dispersion allows the elimination of the merging or overlapping of the lines (coincidence). The number of possible coincidences is very great and is a function of the complication of the chemical composition of the investigated preparation. The registered radiation is next analysed in order to determine the elements present and their proportions in the preparation. One feature of spectrography is the permanent record made of the analysis, allowing us to return to the results of previously-conducted investigations at any time (Koziorowska 1982).

3. CLASSICAL CHEMICAL ANALYSIS

Due to the time-consuming nature, this method has very limited use in the investigation of antiquities. A specific limitation is the size of sample which needs to be taken to analyse for each separate element (0.1–1.0 g) and the low sensitivity of the method. The sample is broken-down chemically and the analysis is carried out by volumetric methods or expressed by weight.

II. DISCUSSION OF THE RESULTS OF THE INVESTIGATIONS

1. EVALUATION OF COMPARATIVE ANALYSES CONDUCTED IN STOCKHOLM AND WARSAW

The analyses were carried-out on 24 samples (Table 1).

Tin

In samples numbered 2–8 and 13–21 there was a relatively good agreement (in samples 3 and 17 complete agreement). A substantial difference was observable in samples 1, 10, 12, 22, 23 and 14 (Fig. 1).

Antimony

The results were in agreement in samples 2–5, 7–12, 15–16 and 21–24. A great difference was seen in samples 14 and 17–20. The preparations contained more than 0.5% Sb and as a general rule we can demonstrate that determinations made in TI RAA are always higher than results obtained in the CL, with the exception of sample 3 (Fig. 2).

Lead

In samples containing less than 1% lead, there is a satisfactory agreement of results in the case of samples 2, 11–12, 15 and 17. In the case of lead content higher than 1%, a similarity of results was found in sample 10, while the greatest difference was seen in sample 24 (Fig. 3).

Table 1. Results of chemical analysis of standard samples (S — results obtained in Stockholm; CL — results obtained in Warsaw).

Sample	Cu	Sn	Sb	As	Pb	Co	Bi	Ag	Ni	Fe	Mn	Cr	Zn	Al
1 CL	99.66	0.019	0.00160	0.009	0.017	0.00000	0.00120	0.02500	0.01100	0.150	0.00050	0.00900	0.018	0.075
1 S	96.23	2.120	0.11000	0.000	0.270	0.00000	0.07000	0.04000	0.01000	0.210	0.00900	0.00900	0.070	0.020
2 CL	99.45	0.170	0.02200	0.080	0.001	0.00000	0.00530	0.01300	0.02400	0.041	0.00300	0.00450	0.013	0.170
2 S	98.86	0.030	0.03000	0.380	0.010	0.00000	0.01080	0.10000	0.04000	0.160	0.00900	0.00900	0.030	0.040
3 CL	99.46	0.011	0.20000	0.002	0.012	0.00100	0.04800	0.00170	0.19000	0.012	0.01000	0.00900	0.023	0.028
3 S	97.43	0.020	0.19000	0.510	0.030	0.00000	0.03000	0.03000	0.19000	0.030	0.00000	0.00000	0.090	0.000
4 CL	97.48	0.380	0.00000	1.200	0.015	0.00000	0.29000	0.03600	0.01000	0.400	0.01100	0.00900	0.025	0.190
4 S	98.04	0.100	0.04000	1.450	0.040	0.00000	0.41000	0.03000	0.03000	0.100	0.00000	0.00000	0.050	0.030
5 CL	97.31	0.240	0.06800	0.660	0.950	0.00900	0.00000	0.63000	0.00200	0.100	0.00000	0.00001	0.006	0.036
5 S	97.46	0.190	0.08000	0.900	0.770	0.00000	0.04800	0.59000	0.01000	0.160	0.00000	0.00000	0.020	0.000
6 CL	97.50	0.700	0.31000	0.280	0.075	0.00000	0.09800	0.25000	0.02900	0.030	0.08500	0.00900	0.240	0.400
6 S	97.13	0.590	0.51000	0.610	0.110	0.00000	0.08000	0.24000	0.03000	0.050	0.00000	0.00000	0.240	0.130
7 CL	95.02	1.500	0.01100	0.210	1.600	0.00000	0.03200	0.90001	0.24000	0.022	0.80000	0.00600	0.530	0.028
7 S	96.01	1.210	0.09000	0.540	1.140	0.00000	0.02000	0.02000	0.19000	0.050	0.00000	0.00000	0.590	0.000
8 CL	95.16	3.100	0.01100	0.047	0.490	0.00190	0.00130	0.41000	0.38000	0.058	0.02500	0.01400	0.220	0.085
8 S	94.19	3.160	0.08000	0.030	0.550	0.00000	0.07000	0.21000	0.38000	0.040	0.00000	0.00000	0.130	0.090
9 CL	92.30	5.600	0.01600	1.400	0.082	0.00000	0.00140	0.14000	0.00700	0.190	0.00200	0.12500	0.035	0.115
9 S	91.81	6.610	0.08000	1.610	0.080	0.00000	0.04800	0.34000	0.01000	0.050	0.00000	0.00000	0.030	0.020
10 CL	89.97	4.950	0.08000	0.013	3.000	0.00000	0.00140	0.75000	0.04800	0.041	0.00050	0.00000	0.980	0.150
10 S	85.60	7.840	0.17000	0.000	3.070	0.00000	0.08000	0.22000	0.08000	0.050	0.00900	0.00000	0.970	0.000
11 CL	90.85	8.000	0.00900	0.430	0.039	0.00000	0.00130	0.12000	0.01000	0.070	0.05000	0.01700	0.300	0.100
11 S	91.78	8.980	0.08000	0.000	0.050	0.00000	0.08000	0.10000	0.01000	0.270	0.00000	0.00900	0.250	0.000
12 CL	85.43	13.500	0.00930	0.090	0.045	0.00000	0.00200	0.41000	0.00500	0.085	0.00001	0.01200	0.110	0.300
12 S	83.10	16.210	0.08000	0.000	0.050	0.08000	0.01000	0.32000	0.01000	0.140	0.00000	0.00000	0.070	0.000
13 CL	84.16	4.100	0.35000	0.003	6.100	0.00250	0.00170	0.00500	0.00500	0.280	0.00001	0.14000	4.800	0.050
13 S	84.57	4.390	0.51000	0.000	5.490	0.00000	0.05000	0.03000	0.01000	0.090	0.00000	0.00000	4.960	0.000
14 CL	95.18	0.045	0.56000	0.030	0.017	0.00000	0.00000	0.00190	0.27000	0.034	1.55000	0.04300	2.150	0.120
14 S	97.36	0.100	1.85000	0.000	0.070	0.00500	0.05000	0.03000	0.07000	0.180	0.00000	0.00000	2.150	0.000
15 CL	96.56	0.140	0.00000	0.078	0.130	0.00000	0.00000	0.00500	0.08000	1.600	0.38000	0.05200	2.950	0.058
15 S	94.08	0.440	0.04000	0.000	0.130	0.00000	0.01000	0.04000	0.02000	1.500	0.00000	0.00000	3.130	0.000
16 CL	95.80	0.340	0.00000	0.670	0.300	0.00900	0.00000	0.02000	1.75000	0.000	0.00001	0.20000	0.012	0.900
16 S	96.27	0.600	0.01000	0.000	0.360	0.00500	0.02000	0.02000	1.85000	0.070	0.00000	0.05000	0.010	0.000
17 CL	98.98	0.041	0.80000	0.013	0.014	0.00001	0.00100	0.00440	0.00400	0.085	0.00001	0.01200	0.033	0.030
17 S	92.49	0.040	4.36000	0.000	0.020	0.00000	0.01000	0.03000	0.01000	0.110	0.00900	0.00000	0.080	0.000
18 CL	97.54	0.030	1.50000	0.023	0.080	0.00350	0.00500	0.00140	0.10000	0.310	0.00001	0.34000	0.085	0.130
18 S	93.75	0.150	4.02000	0.000	0.100	0.00000	0.05000	0.02000	0.01000	0.050	0.00000	0.00000	0.080	0.000
19 CL	97.41	0.052	1.85000	0.022	0.015	0.00320	0.00000	0.00310	0.00000	0.240	0.00001	0.15000	0.040	0.110
19 S	97.28	0.920	3.36000	0.000	0.040	0.00000	0.01000	0.01000	0.02000	0.100	0.00000	0.05000	0.010	0.000
20 CL	96.96	0.014	2.20000	0.090	0.027	0.00420	0.00000	0.01500	0.11000	0.250	0.00001	0.23000	0.048	0.150
20 S	90.68	0.200	7.82000	0.000	0.050	0.00000	0.01000	0.02000	0.01000	0.050	0.00500	0.00900	0.010	0.000
21 CL	95.72	2.200	0.02200	0.300	1.000	0.00140	0.00000	0.00110	0.01000	0.150	0.00001	0.08200	0.036	0.490
21 S	92.14	2.560	0.04000	0.000	1.160	0.00000	0.02000	0.04000	0.01000	0.070	0.00000	0.00050	0.010	0.000
22 CL	85.13	13.500	0.01400	0.017	1.030	0.00180	0.00001	0.00100	0.00000	0.095	0.00001	0.03600	0.040	0.125
22 S	80.00	18.470	0.02000	0.000	0.500	0.00000	0.00000	0.01000	0.01000	0.040	0.00000	0.00050	0.010	0.000
23 CL	92.40	6.500	0.03200	0.016	0.600	0.00150	0.00001	0.00100	0.00000	0.120	0.00001	0.05000	0.035	0.036
23 S	96.66	11.820	0.12000	0.000	0.640	0.00000	0.08000	0.05000	0.01000	0.080	0.00000	0.00900	0.010	0.000
24 CL	97.32	0.120	0.28000	0.025	2.050	0.00200	0.00001	0.00230	0.01100	0.095	0.00001	0.03500	0.031	0.027
24 S	93.26	1.430	0.39000	0.000	4.040	0.00000	0.01000	0.01000	0.01000	0.140	0.00000	0.05000	0.020	0.000

Table 2. Results of chemical analysis of standard samples (CL — results obtained in Warsaw; MPI — results obtained in Heidelberg; WL — results obtained in Stuttgart).

Sample	Cu	Sn	Sb	As	Pb	Co	Bi	Ag	Ni	Fe	Mn	Cr	Zn	Al
A CL	93.20	0.100	0.4300	1.0400	2.750	0.1160	0.0410	0.990	1.070	0.041	0.00001	0.009	0.017	0.20
A-MPI	90.30	0.088	0.4600	1.1200	2.850	0.0820	0.0660	0.840	0.870	0.170			0.009	
A-WL	93.18	0.100	0.5800	1.0000	2.850	0.1000	0.0400	0.950	1.010	0.040			0.000	
B2-CL	92.01	0.540	1.2600	3.3000	0.150	0.5000	0.0080	0.120	0.860	0.290	0.00001	0.009	0.740	0.21
B2-MPI	92.80	0.480	1.2300	3.0700	0.190	0.4300	0.0120	0.086	0.530	0.300			0.580	
B2-WL	92.30	0.590	1.4700	3.3500	0.130	0.5100	0.0080	0.110	0.600	0.300			0.630	
C-CL	93.38	0.980	2.6500	0.5200	0.630	0.0005	0.0005	0.290	0.340	0.009	0.00001	0.006	1.050	0.14
C-MPI	95.80	0.740	2.9500	0.4600	0.000	0.0007	0.0000	0.260	0.230	0.400			0.830	
C-WL	93.20	1.040	3.5800	0.4900	0.480	0.0000	0.0000	0.300	0.290	0.009			0.960	
D-CL	93.04	2.650	0.0100	0.0510	1.080	0.2600	0.0080	0.059	2.590	0.021	0.00001	0.007	0.022	0.18
D-MPI	93.50	2.900	0.0115	0.0400	0.950	0.1760	0.0077	0.047	2.370	0.120			0.010	
D-WL	93.30	2.970	0.0200	0.0400	1.020	0.2600	0.0100	0.050	2.480	0.000				
E-CL	92.94	5.830	0.0550	0.0110	0.044	0.1100	0.0001	0.480	0.100	0.100	0.00001	0.006	0.009	0.30
E-MPI	90.50	5.560	0.0465	0.0093	0.058	0.0900	0.0030	0.440	0.087	0.077			0.006	
E-WL	93.00	6.140	0.0700	0.0090	0.080	0.1100	0.0000	0.500	0.100	0.020			0.000	
F-CL	88.22	11.020	0.1230	0.0980	0.005	0.0004	0.1100	0.011	0.050	0.041	0.00001	0.009	0.140	0.17
F-MPI	88.00	11.300	0.1000	0.0970	0.000	0.0004	0.0000	0.010	0.047	0.050			0.089	
F-WL	87.50	11.400	0.1500	0.0800	0.080	0.0000	0.1080	0.010	0.050	0.002			0.100	
G-CL	93.72	0.980	0.4600	0.8000	0.140	0.1100	0.0200	0.270	2.380	0.350	0.00001	0.003	0.580	0.23
G-MPI	95.10	0.870	0.4500	1.0700	0.115	0.0620	0.0180	0.270	2.310	0.400			0.470	
G-WL	95.10	0.980	0.6400	1.1300	0.080	0.0700	0.0150	0.310	2.500	0.270	0.00000		0.480	

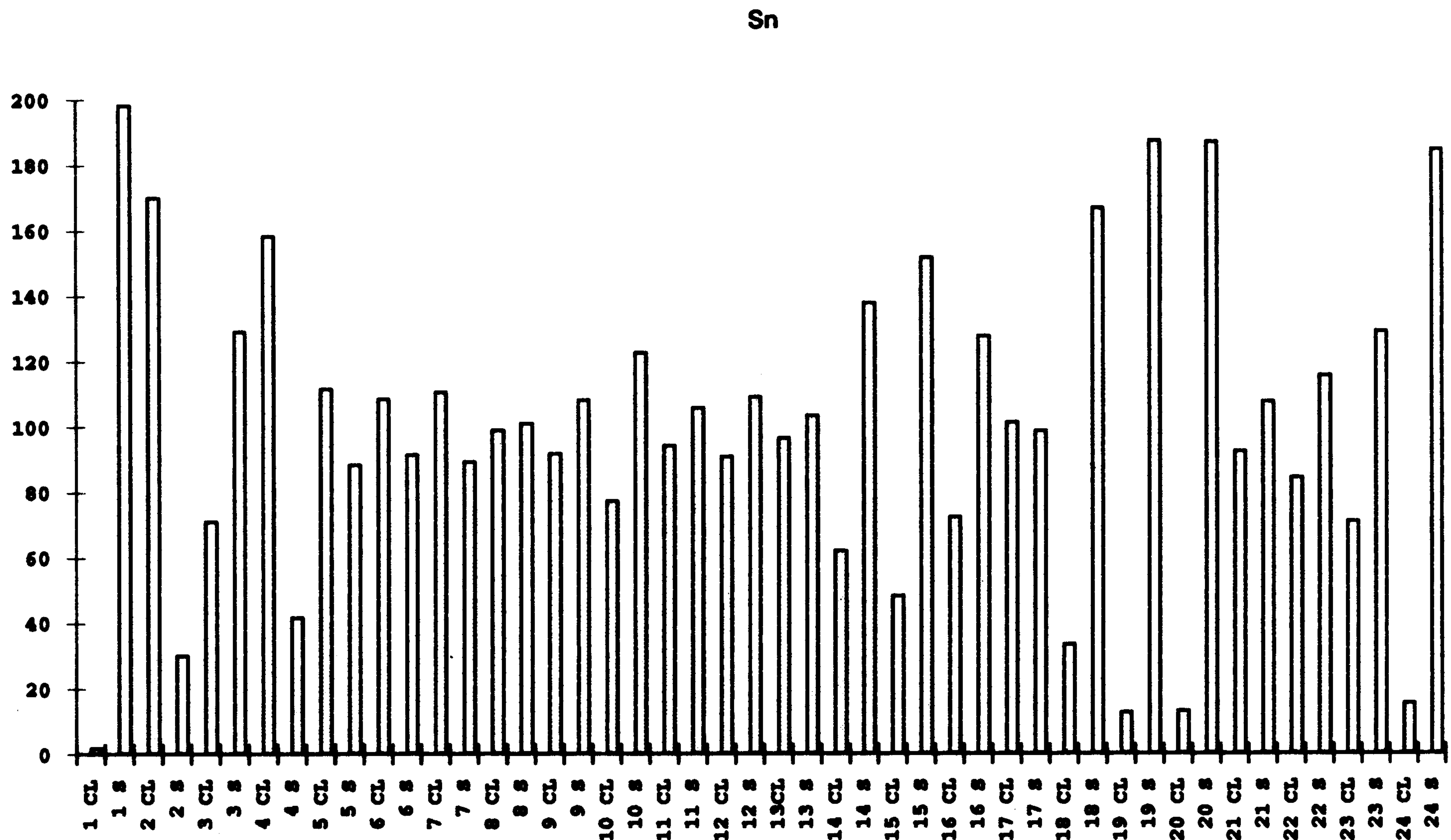


Fig. 1. Tin content (in percent) in comparison to mean value.

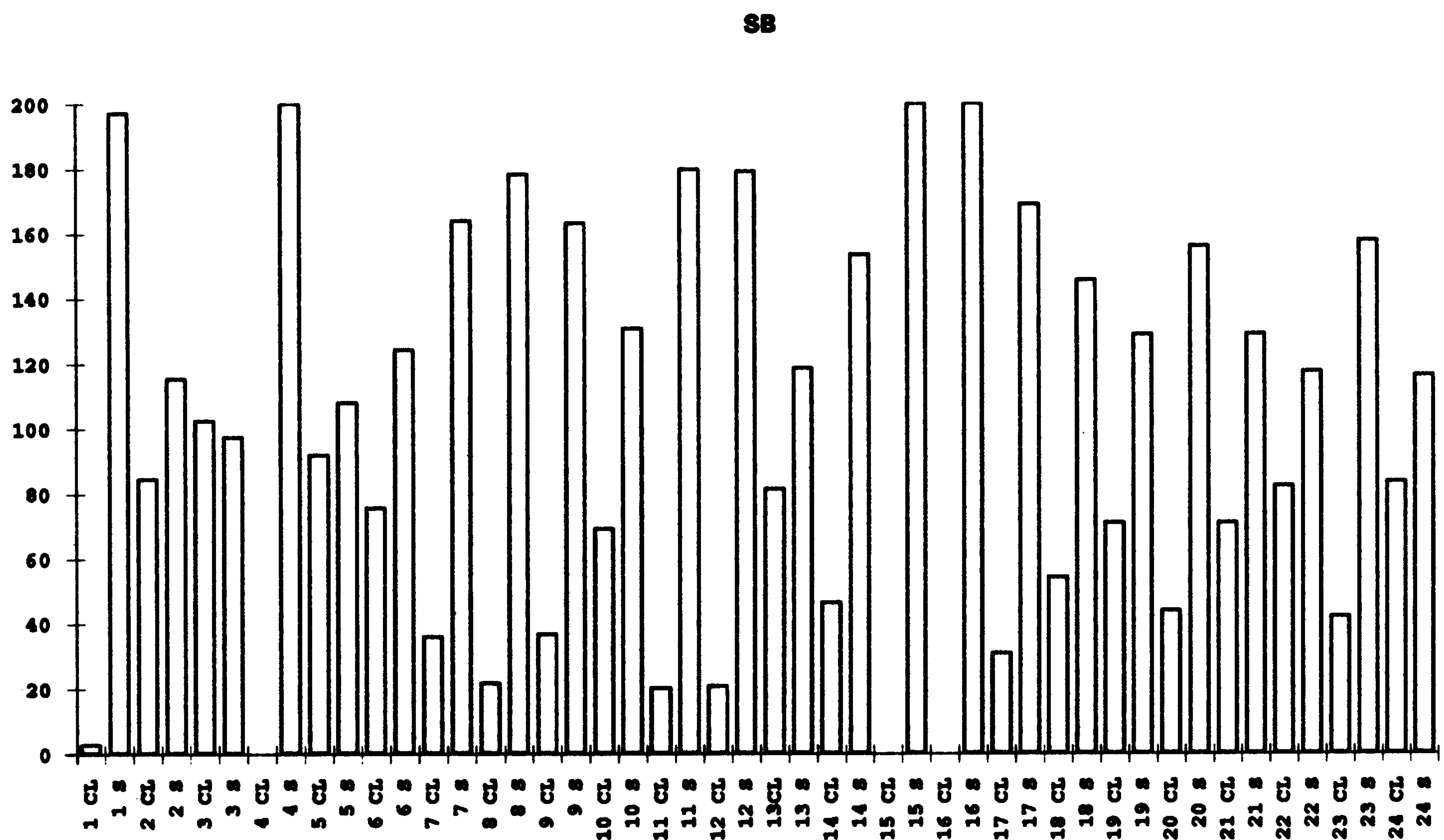


Fig. 2. Antimony content (in percent) in comparison to mean value.

Nickel

In most of the examined samples there was a general agreement of results, the exception is sample number 14 (TI RAA Ni = 0.07%, while the CL analysis was Ni = 0.27%) (Fig. 4).

Silver

Most of the determinations made in both laboratories are in agreement, while sample 10 again differs (CL 0.75% Ag, while TI RAA 0.22%) (Fig. 5).

Arsenic

There was a good correspondence of results in samples containing less than 0.05% As. Together with the increase in As content however we observe an increase in the differences between the results, e.g. sample 11 TI RAA found no arsenic, while CL found 0.43%. In most cases TI RAA detected more As than CL (Fig. 6).

Bismuth

Only in a few cases do the results obtained in both laboratories agree (samples 2 and 22) or are close (samples 6 and 7). The results most differing from each other are the results for sample 4. Generally TI RAA detected a higher bismuth content than CL (Fig. 7).

Iron

For samples containing less than 0.1% iron, the agreement of results is quite good. Especially great differences were seen in sample 4 (TI RAA 0.1%, CL 0.4%) (Fig. 8).

Aluminium

Complete agreement was seen in one sample (no. 8). Especially great differences occur in sample 6. The CL analyses contain in most cases a greater Al content (Fig. 9).

2. EVALUATION OF RESULTS OBTAINED IN STUTTGART, HEIDELBERG AND WARSAW (Table 2).

Silver

In the range from 0 to 1% there was good agreement of results. Only in the case of sample A, the result obtained in Heidelberg is 20% lower than the result obtained in Warsaw and Stuttgart (Fig. 10).

Arsenic

In all investigated samples the results are very close. In the case of sample G, the results obtained in CL are lower than the others (Fig. 11).

Bismuth

In the case of samples B₂, C, D, D E and G the results obtained in all laboratories are very close. In two cases (samples A and F) the results obtained in Heidelberg differed from those obtained in the other laboratories (Fig. 12).

Cobalt

With the exception of one sample (D) all results are very close (Fig. 13).

Copper

All results fall within a 10% margin of error. With reference to the character of this element, this should be regarded as a very good agreement (Fig. 14).

Iron

The results for iron were very differentiated. Only in one case were the results obtained in the three laboratories comparable (sample B₂). The greatest difference was observed in sample C (Heidelberg 0.4%, Stuttgart 0.006% and Warsaw 0.009%) (Fig. 15).

Nickel

In most cases the results agreed or were very close. Only in sample B₂ was there a difference in results (the CL results are 50% higher than results obtained in the German laboratories) (Fig. 16).

Lead

In most cases there was a marked agreement of results, with the exception of the result obtained for sample C at Heidelberg (Fig. 17).

Antimony

In most analyses there was a good agreement of results, the greatest difference was observed in sample C (CL 2.65%, Stuttgart 3.59%, Heidelberg 2.95%) (Fig. 18).

Tin

All analyses are characterised by an exceptional agreement of results (Fig. 19).

Zinc

All results are very close and fall within a 10% margin of error (Fig. 20).

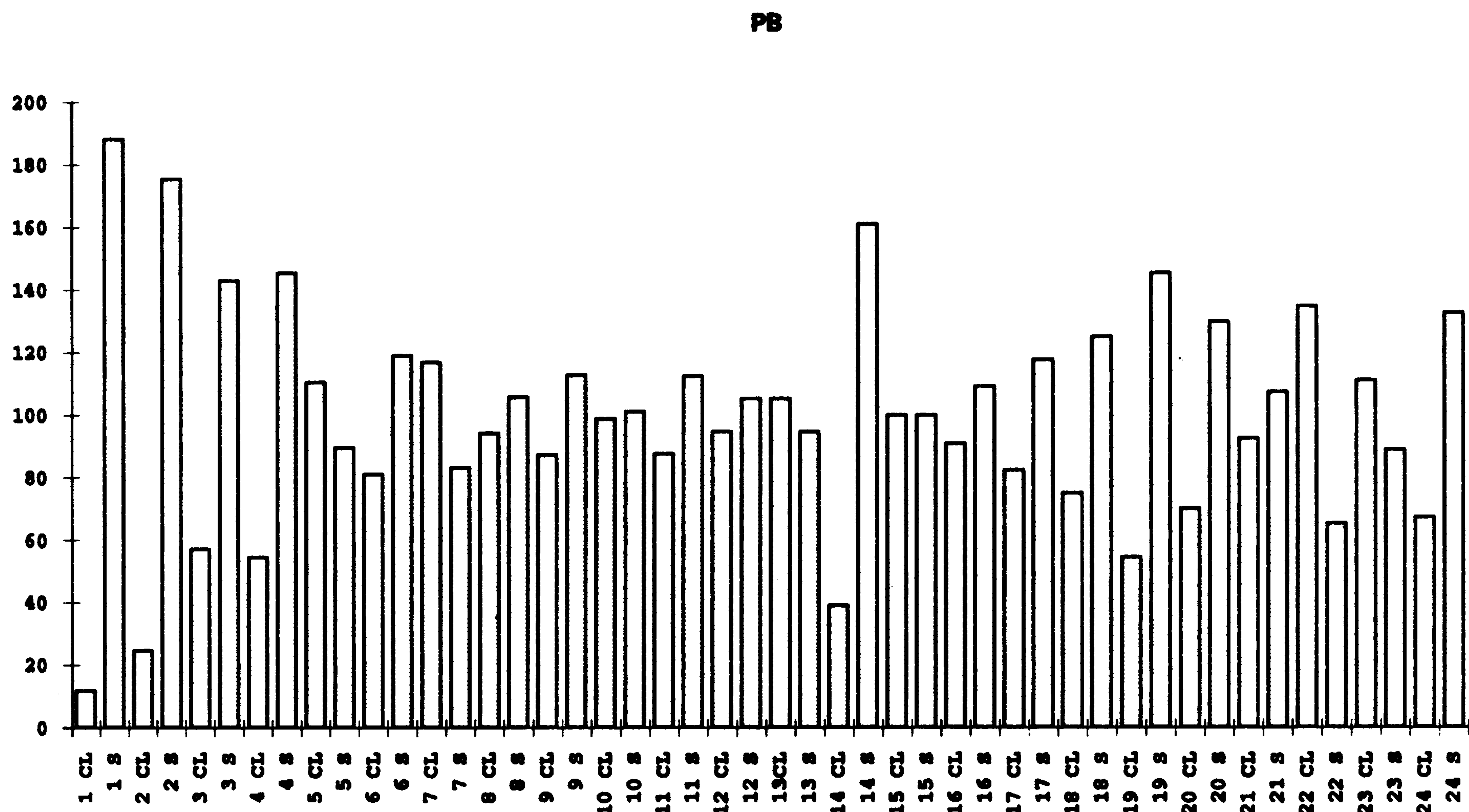


Fig. 3. Lead content (in percent) in comparison to mean value.

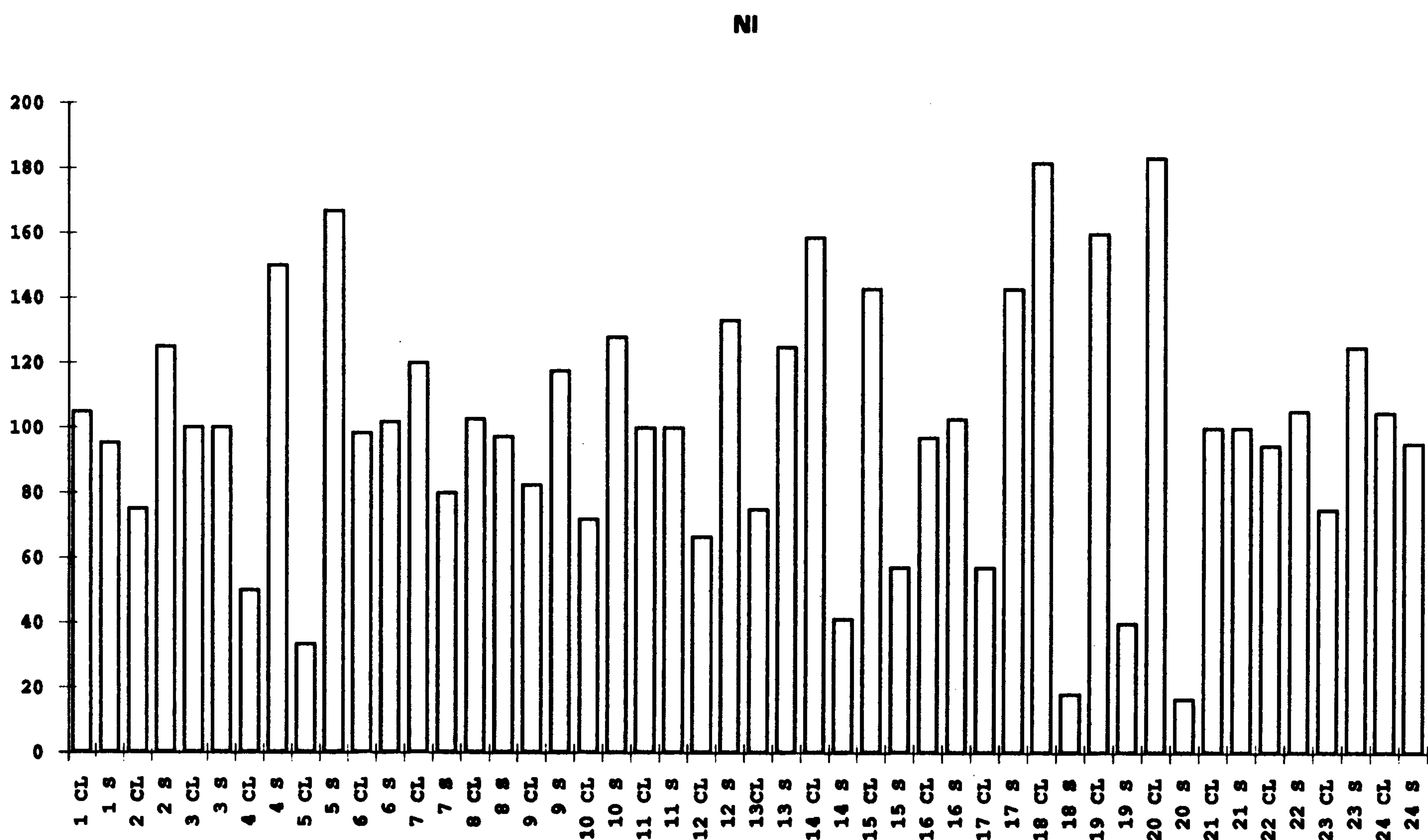


Fig. 4. Nickel content (in percent) in comparison to mean value.

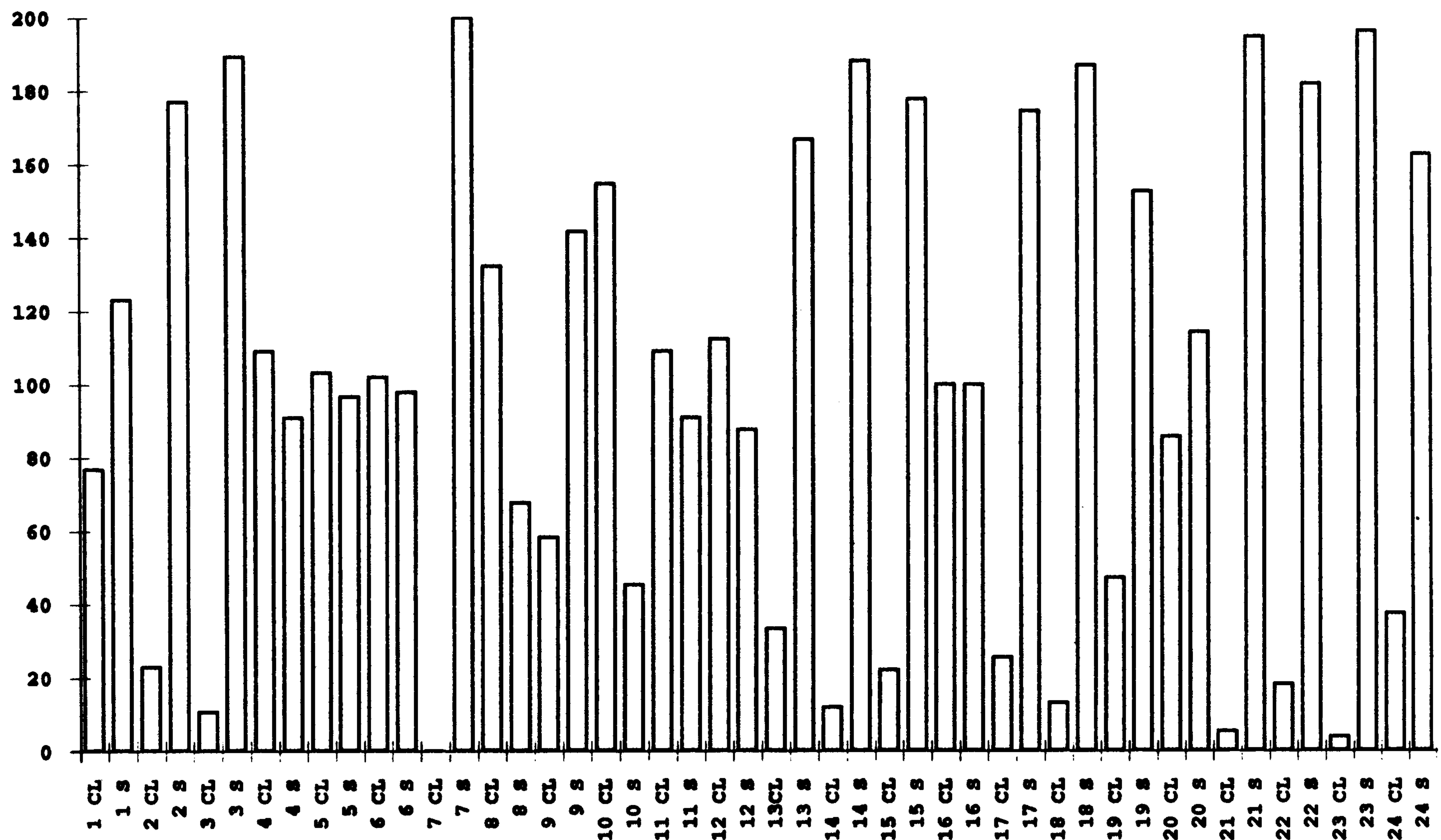


Fig. 5. Silver content (in percent) in comparison to mean value.

AS

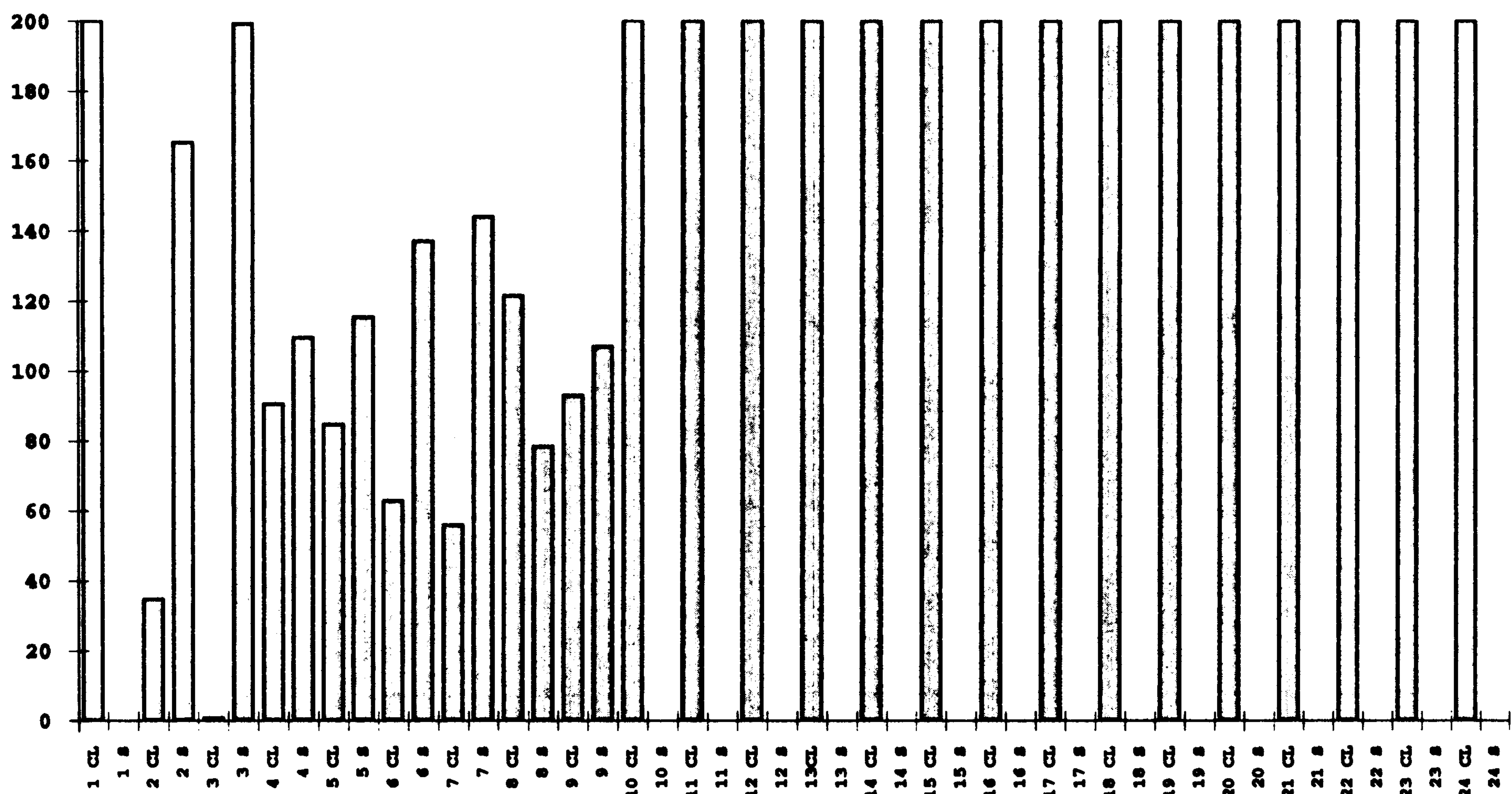


Fig. 6. Arsenic content (in percent) in comparison to mean value.

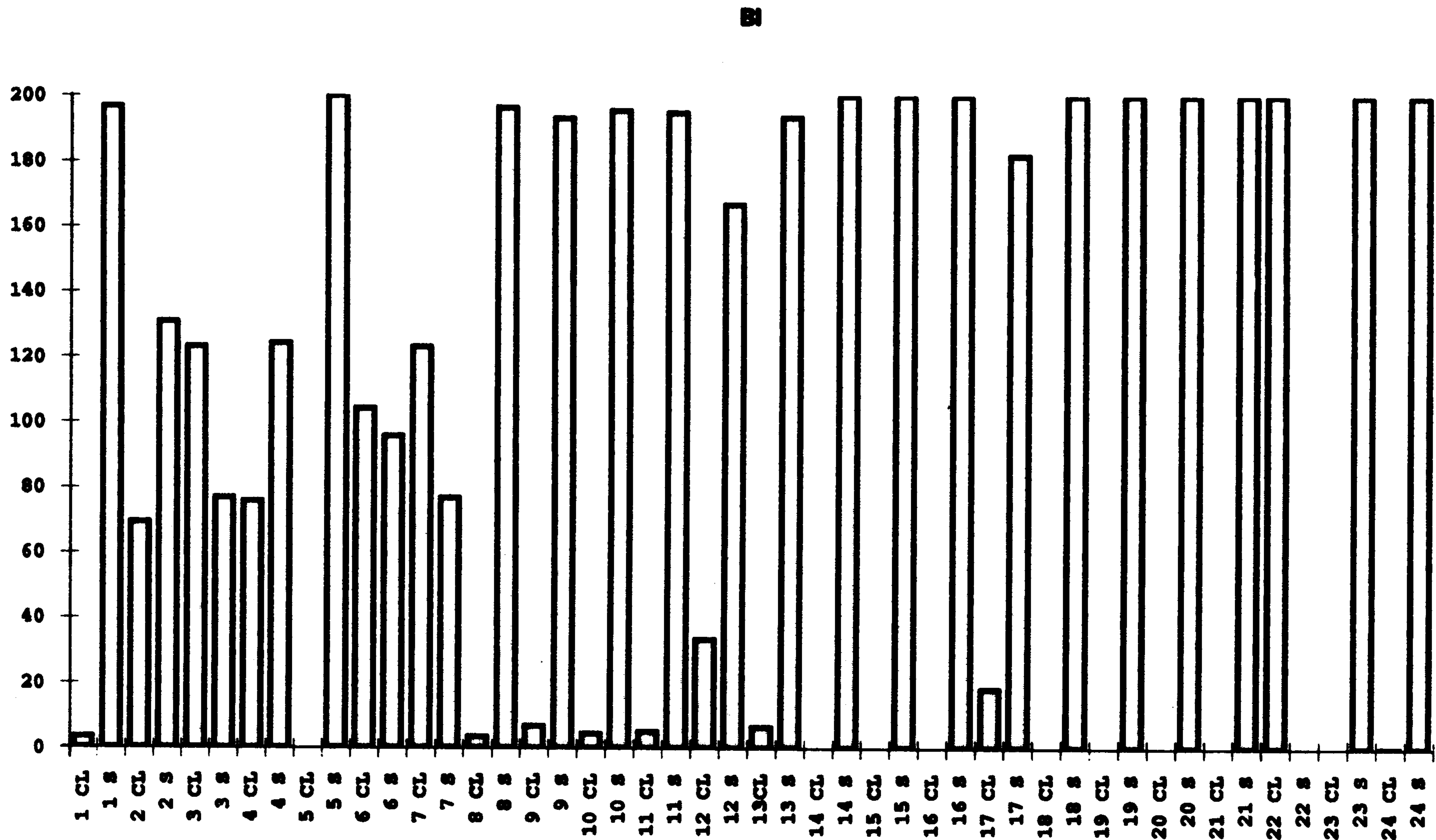


Fig. 7. Bismuth content (in percent) in comparison to mean value.

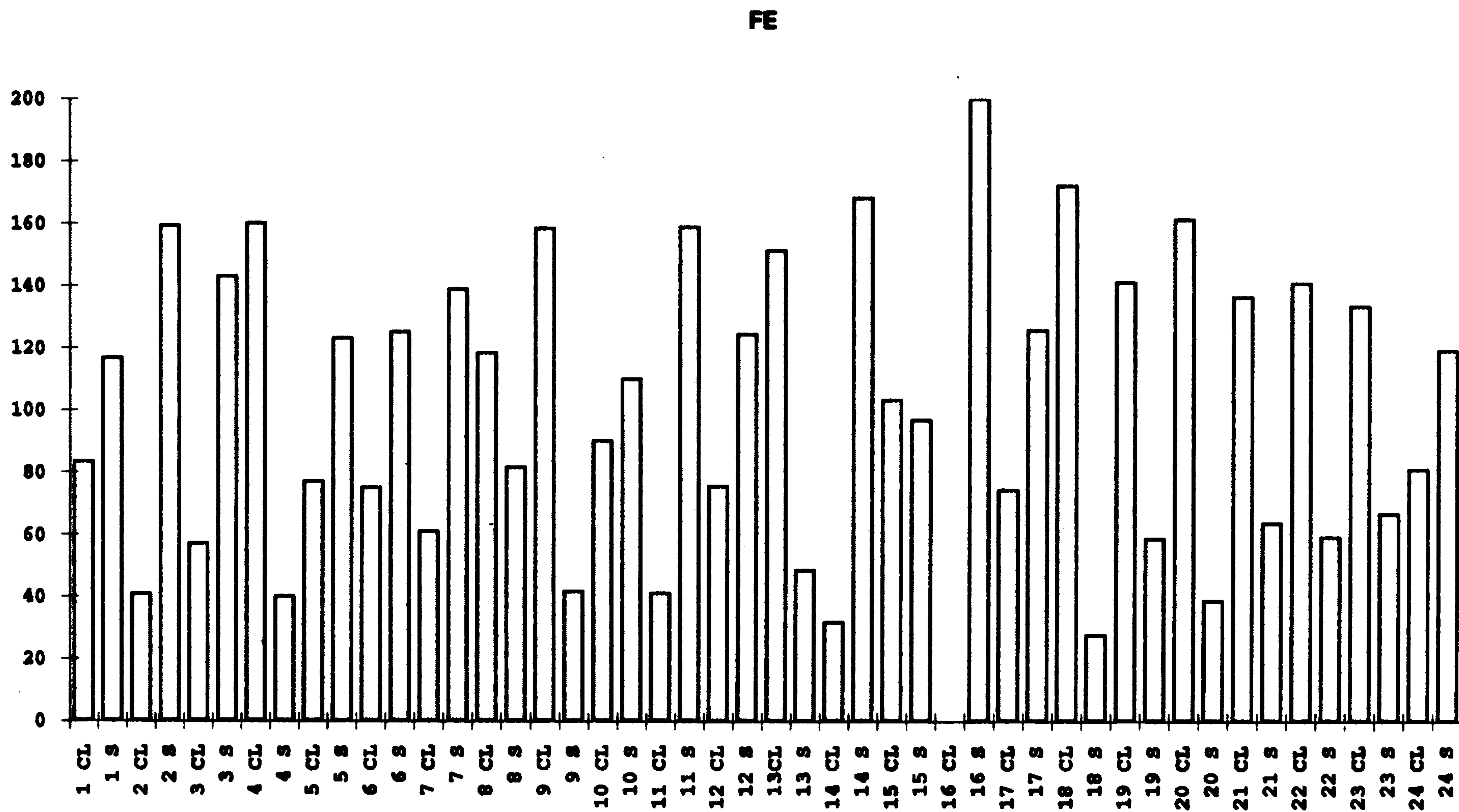


Fig. 8. Iron content (in percent) in comparison to mean value.

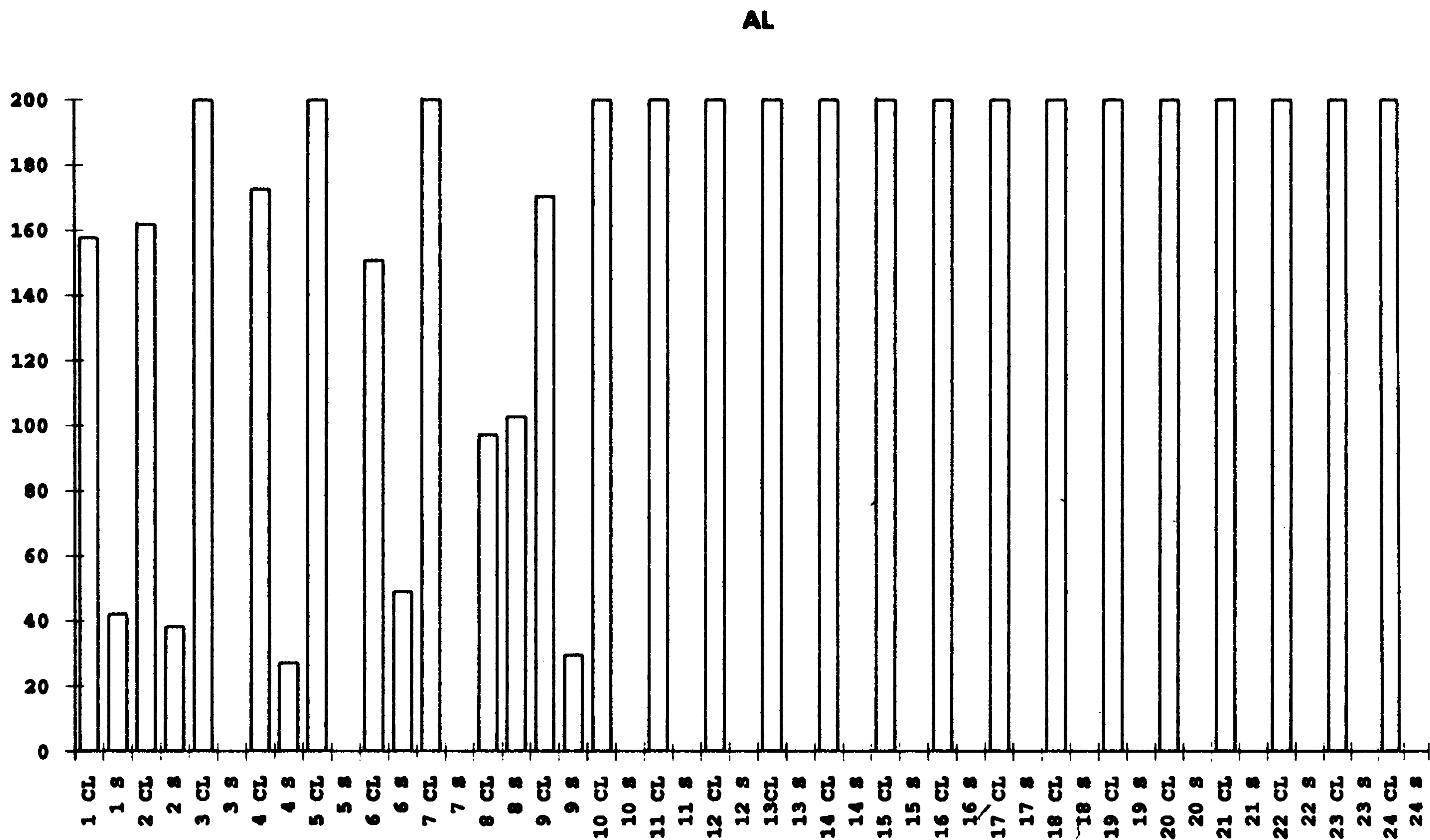


Fig. 9. Aluminium content (in percent) in comparison to mean value.

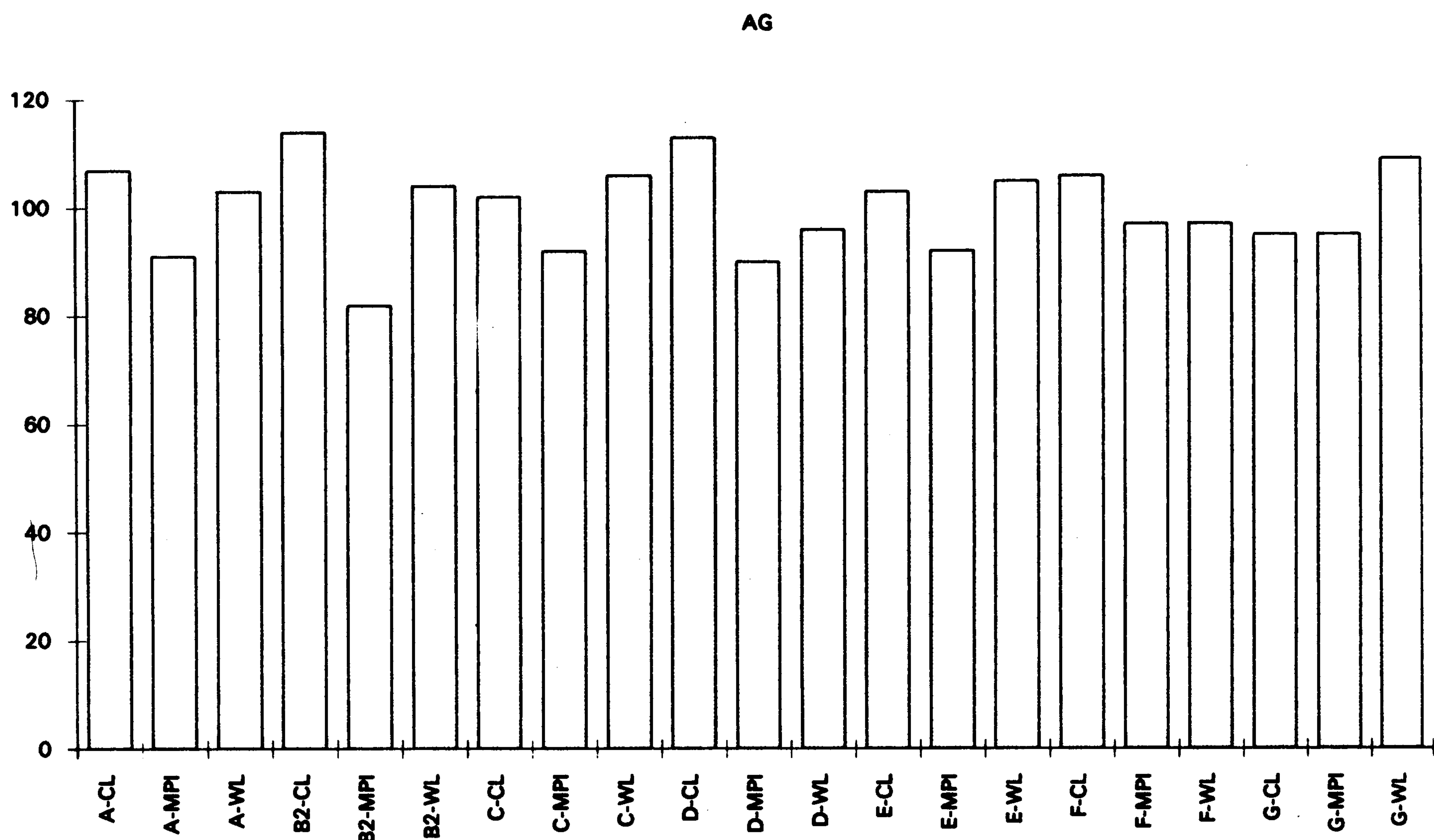


Fig. 10. Silver content (in percent) in comparison to mean value.

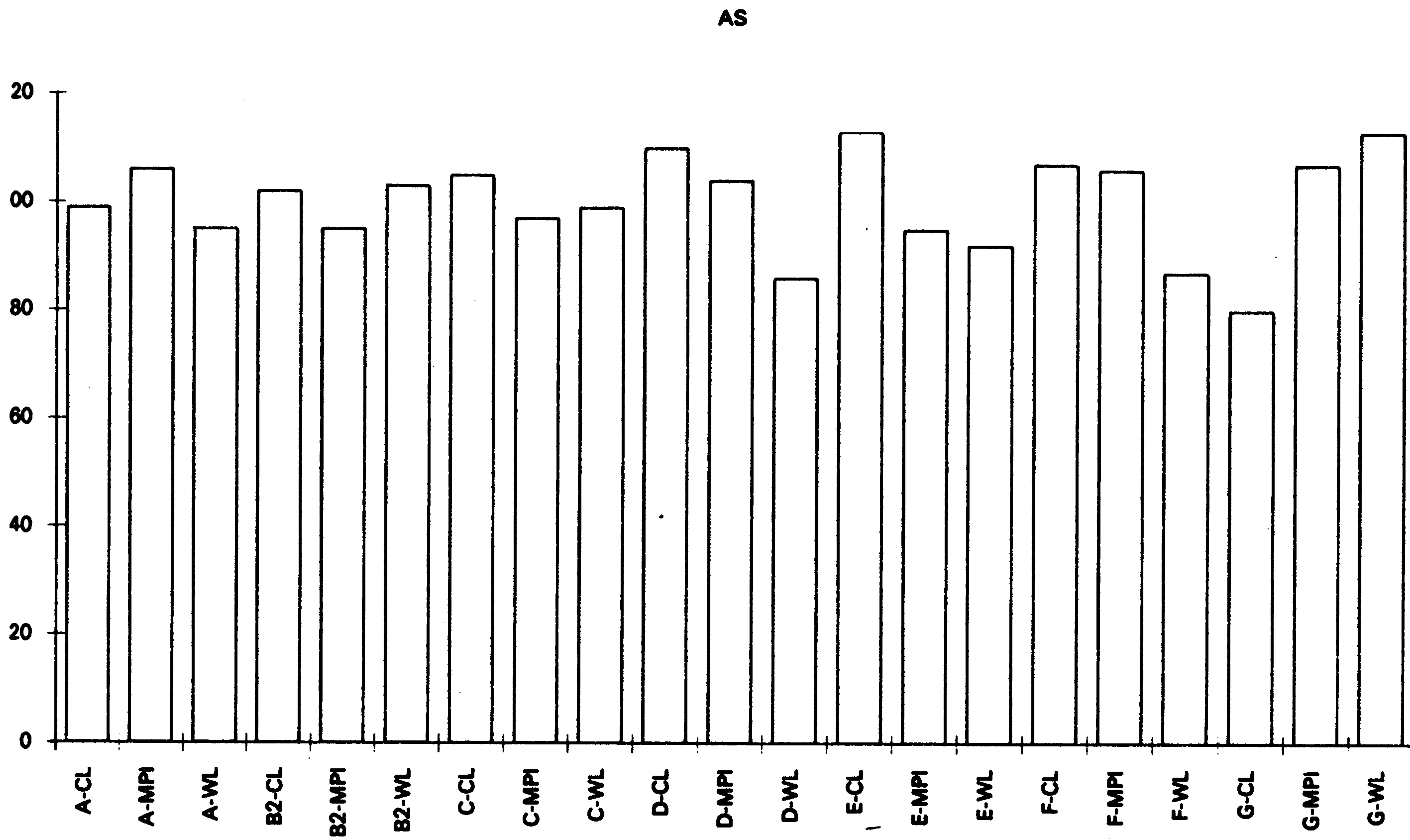


Fig. 11. Arsenic content (in percent) in comparison to mean value.

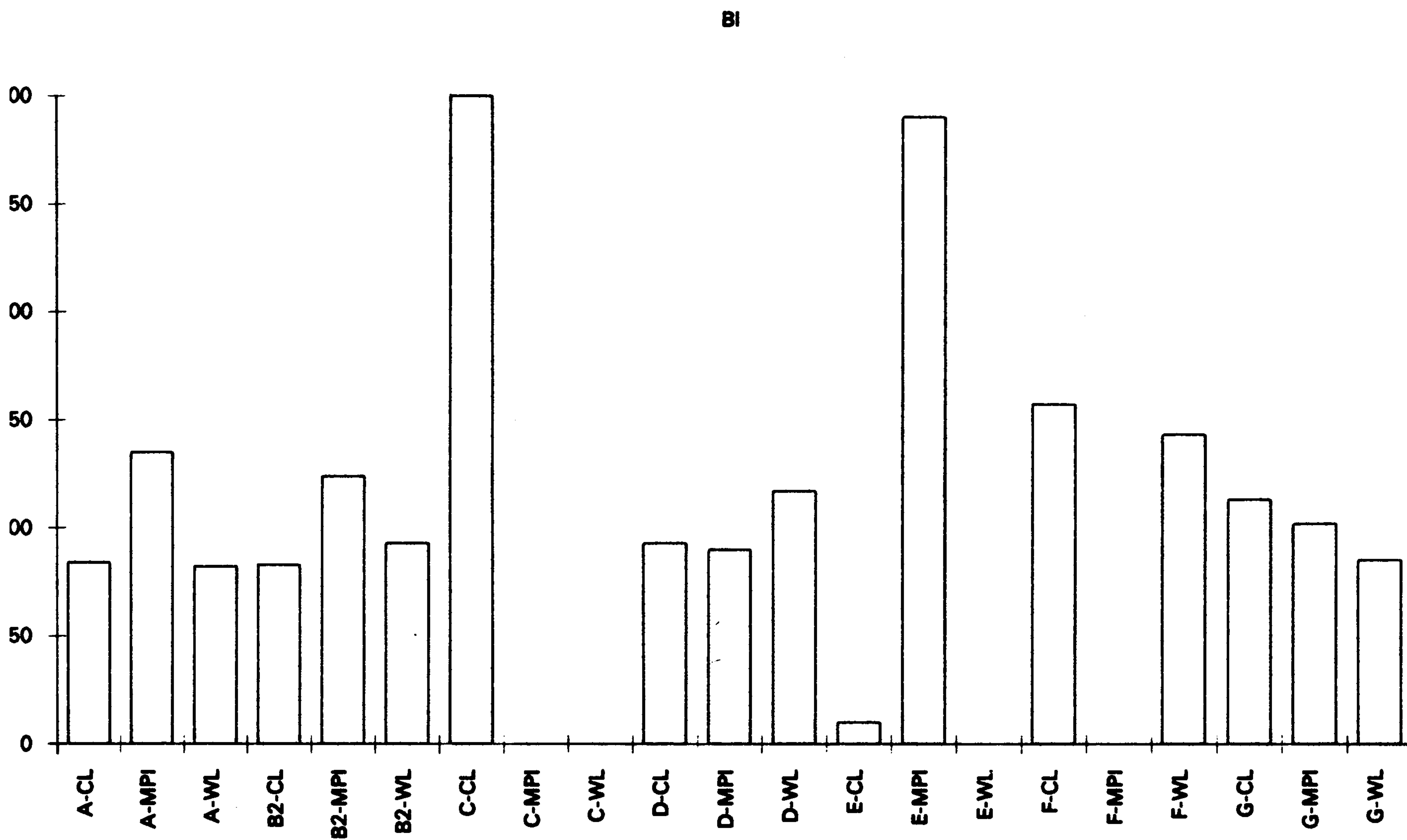


Fig. 12. Bismuth content (in percent) in comparison to mean value.

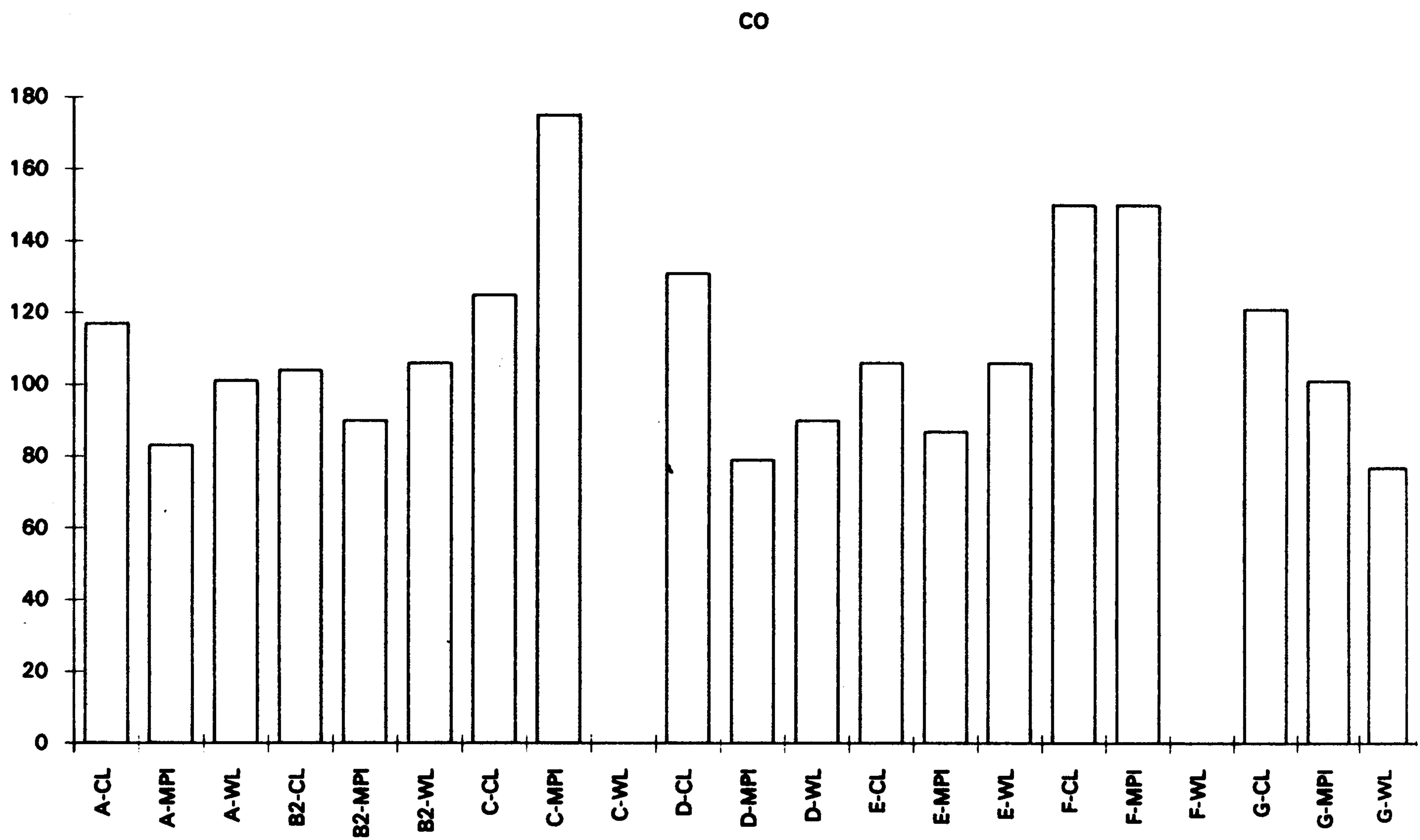


Fig. 13. Cobalt content (in percent) in comparison to mean value.

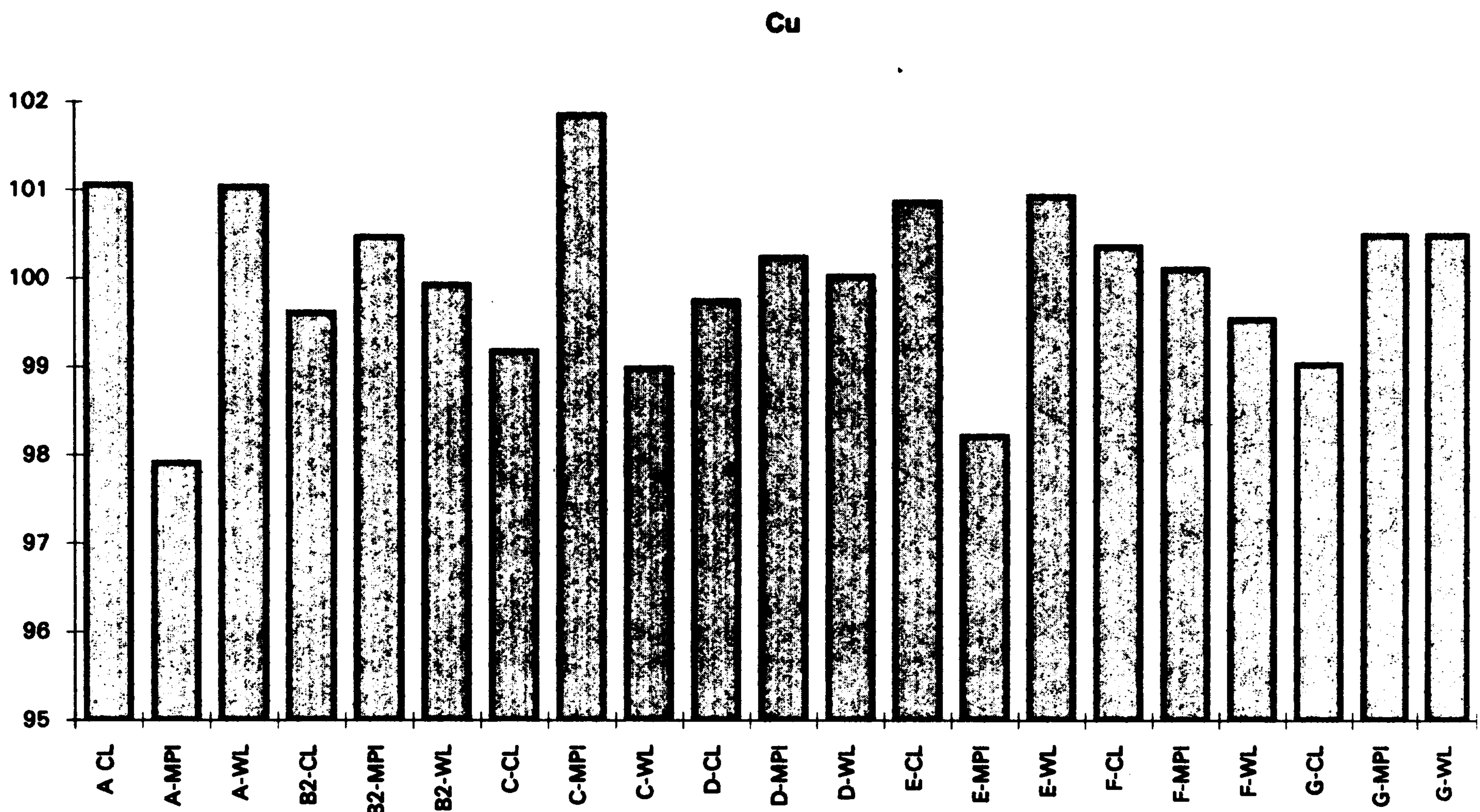


Fig. 14. Copper content (in percent) in comparison to mean value.

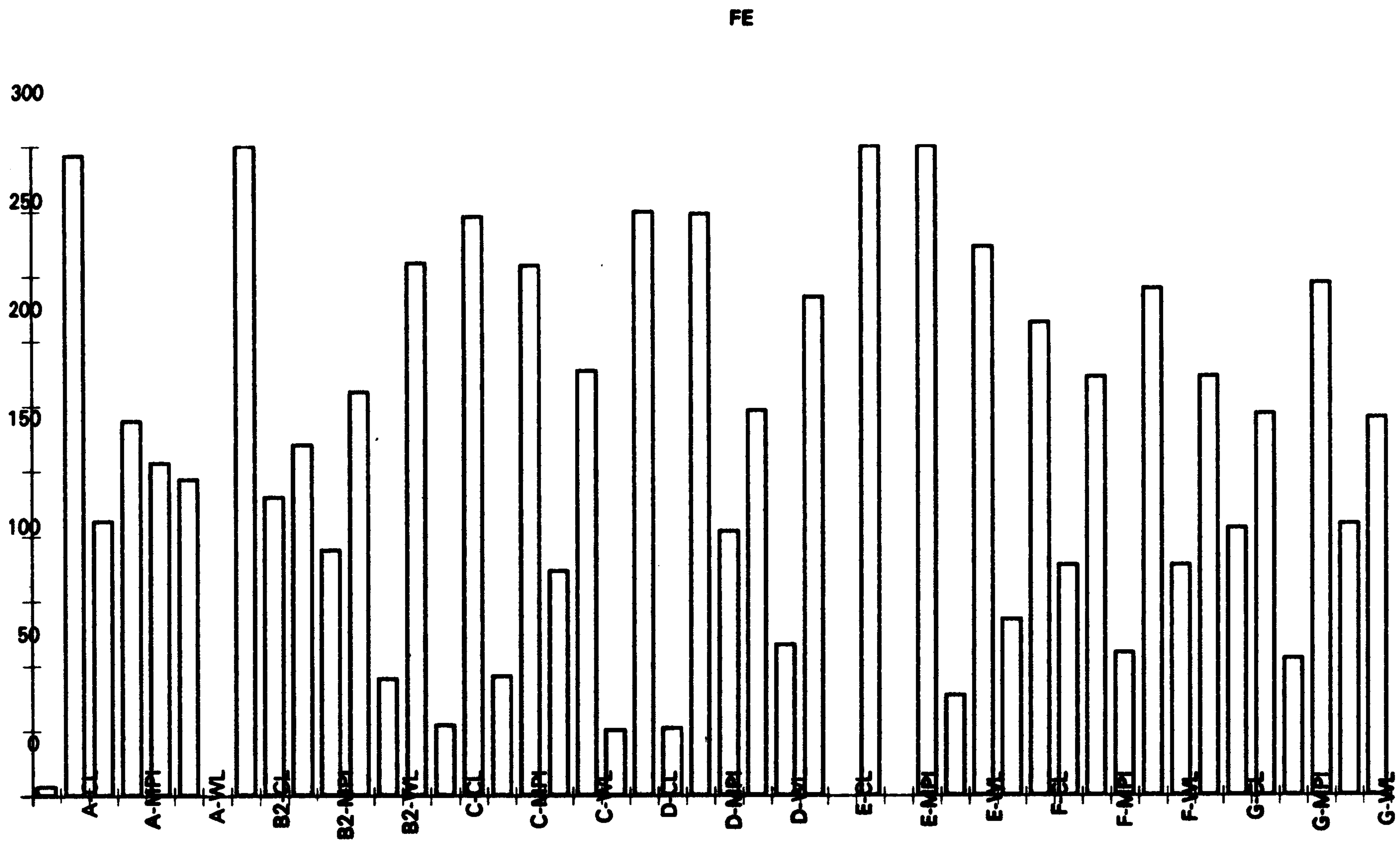


Fig. 15. Iron content (in percent) in comparison to mean value.

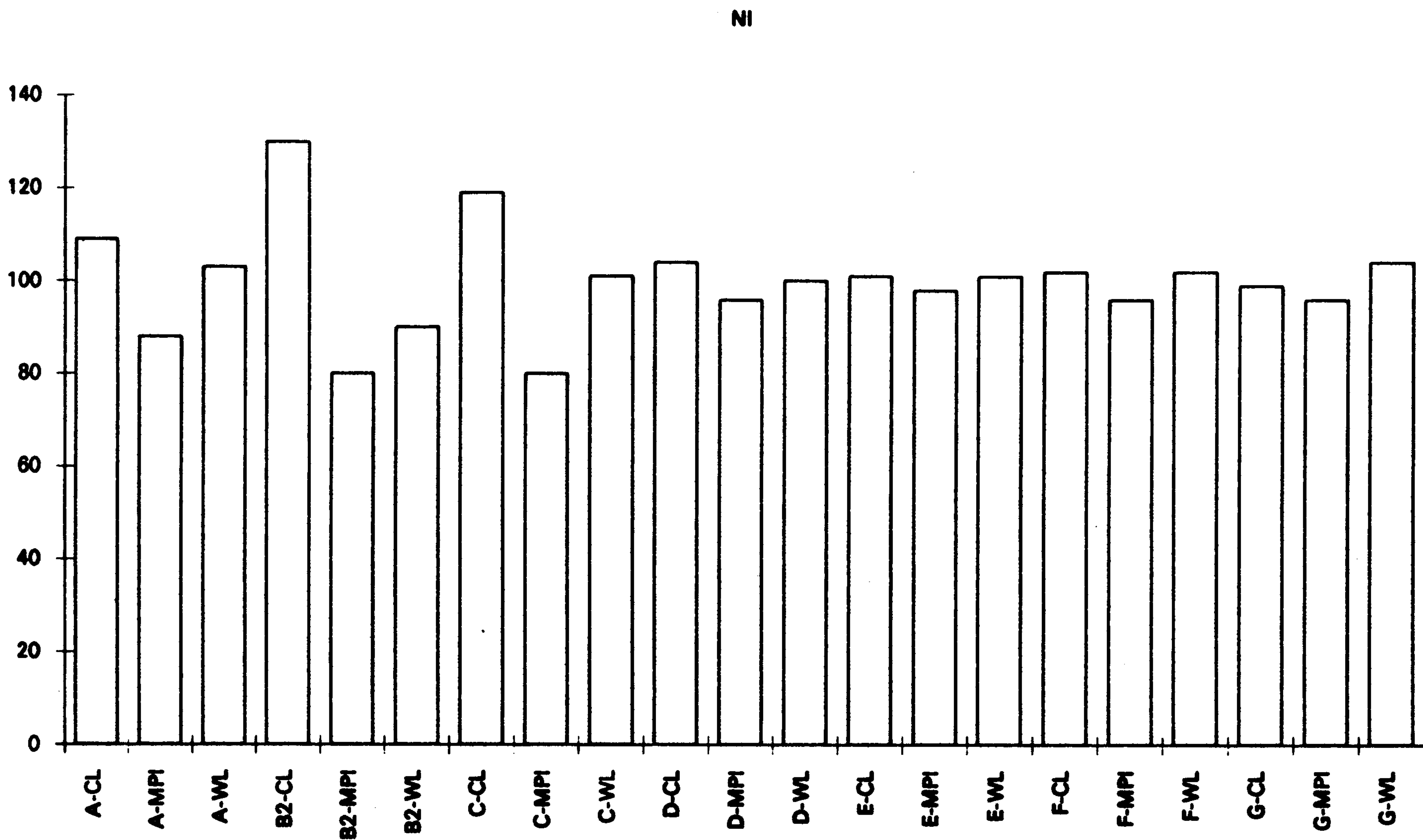


Fig. 16. Nickel content (in percent) in comparison to mean value.

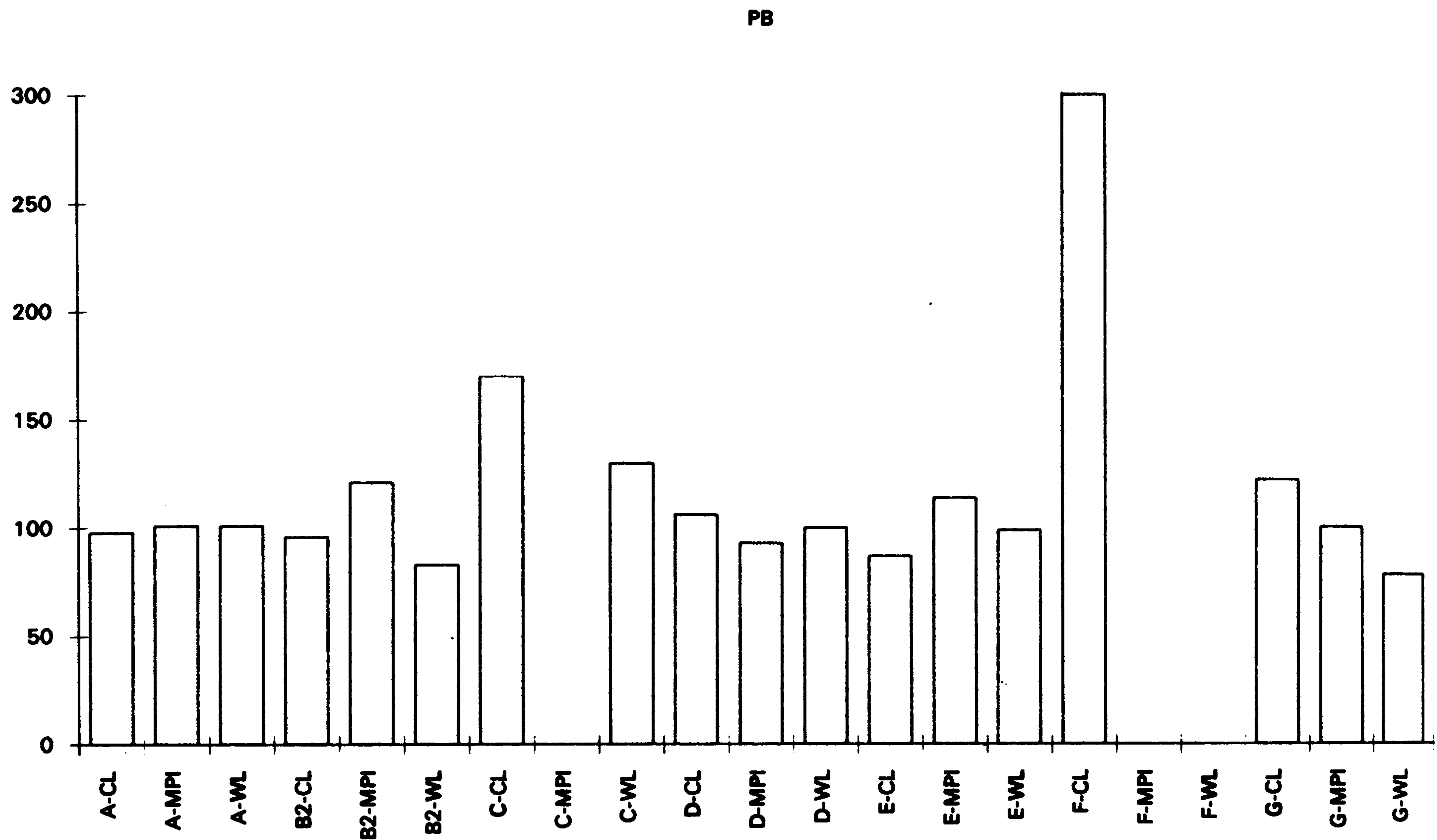


Fig. 17. Lead content (in percent) in comparison to mean value.

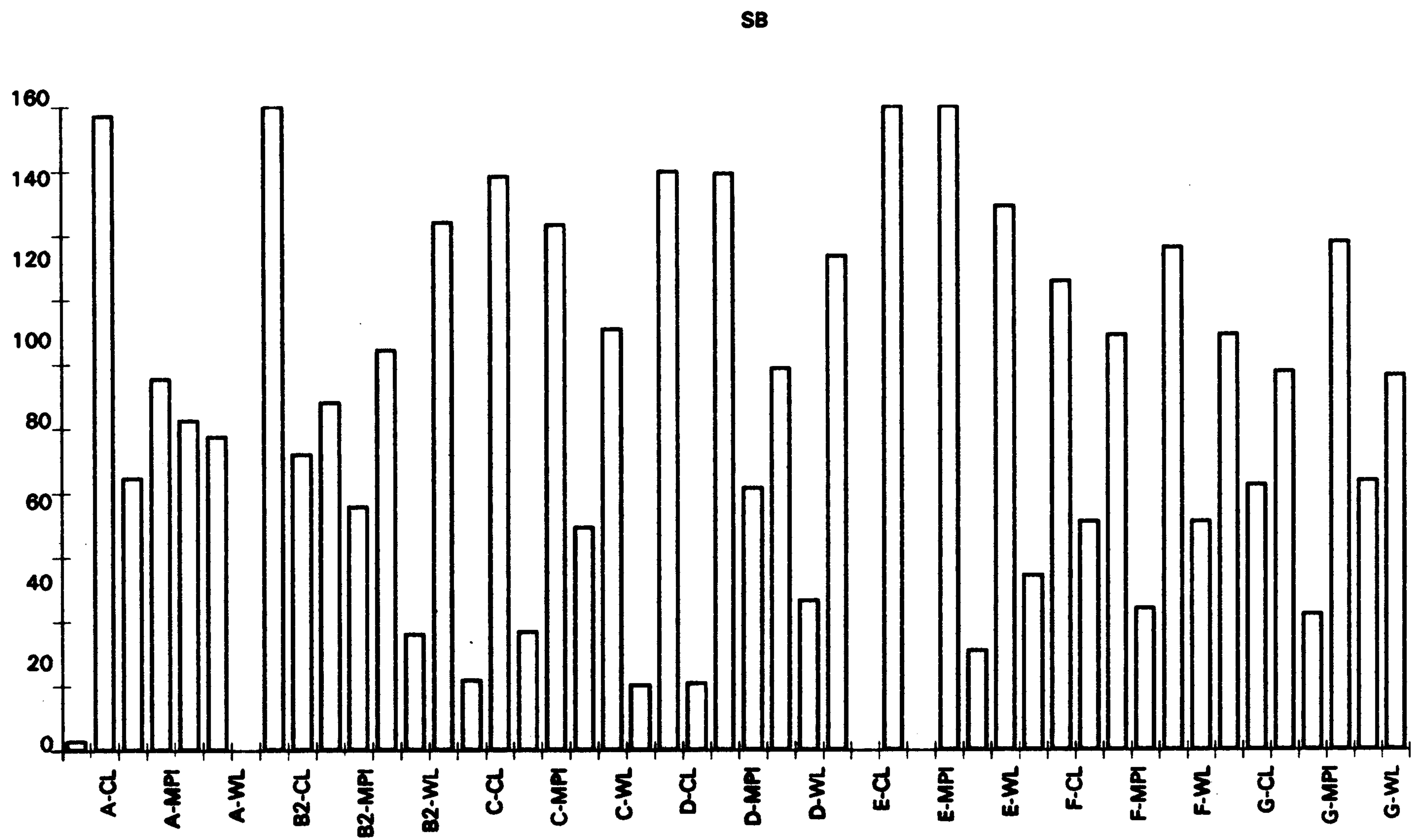


Fig. 18. Antimony content (in percent) in comparison to mean value.

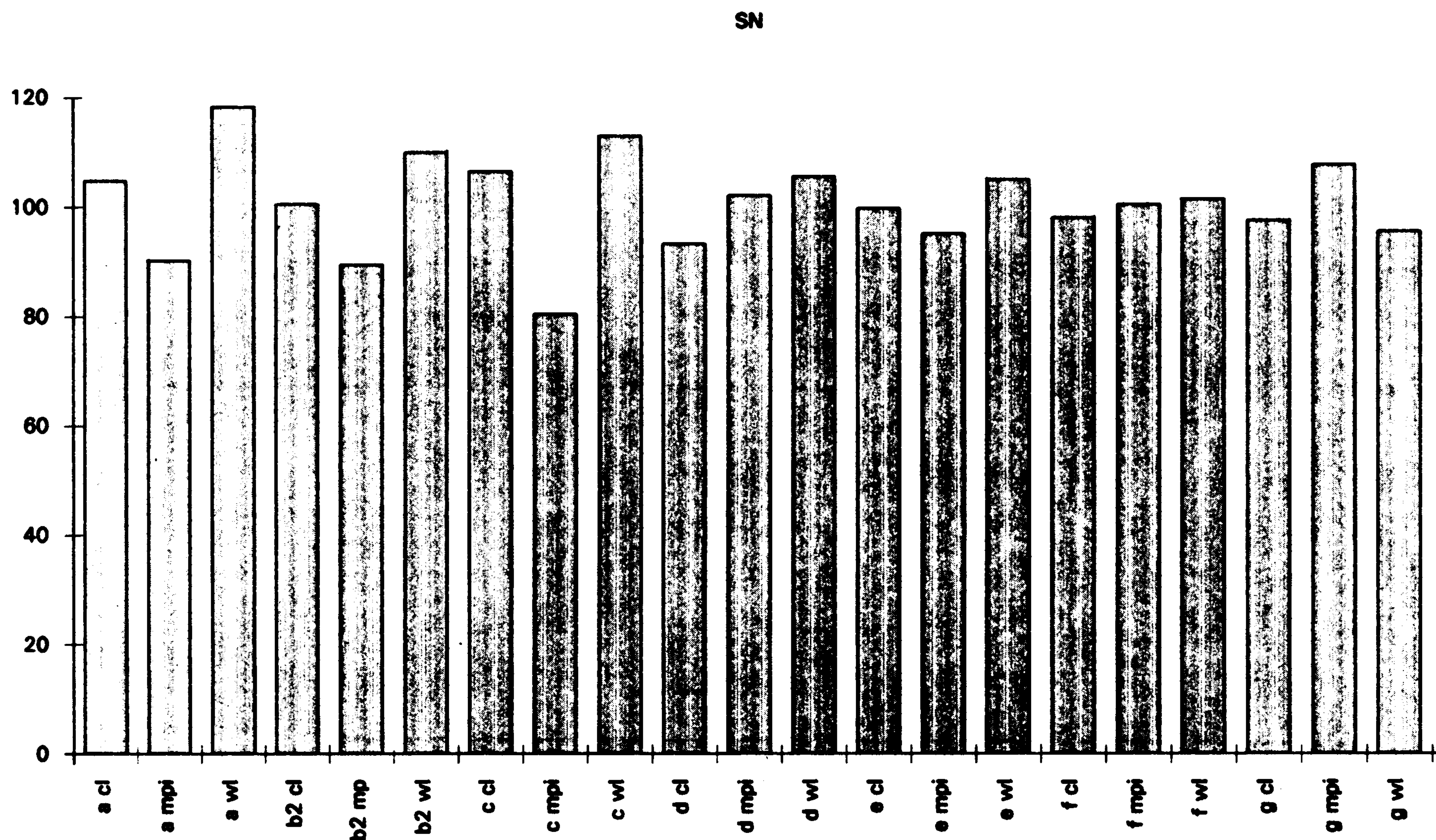


Fig. 19. Tin content (in percent) in comparison to mean value.

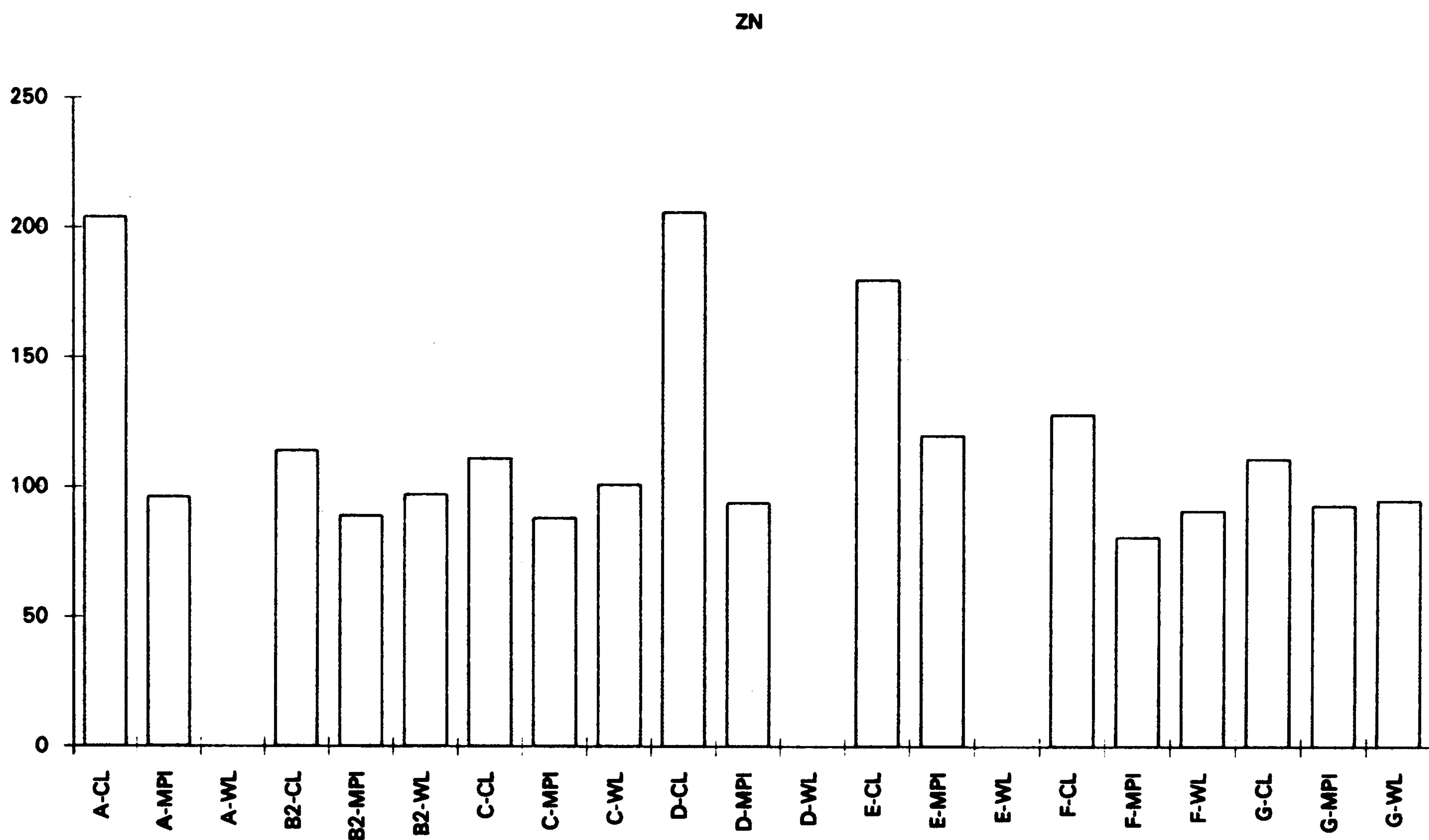


Fig. 20. Zinc content (in percent) in comparison to mean value.

III. CONCLUSIONS

The comparisons of results obtained in Stuttgart, Heidelberg and Warsaw are characterised by a good agreement of results. All analyses conducted in these laboratories are comparable between themselves in terms of the components covered in the survey (while noting the differences identified). In the process of interpretation it is necessary to take into account the differences occurring in the results obtained for iron. With reference to the low content of zinc and lead in the tested samples, the data presented above will be useful in the consideration of analyses of ancient copper alloys. The problem of the comparison of results obtained in the CL with those of TI RAA is more complex. In this group of investigations which used a relatively large number of differing alloys, the differentiation of results was equally great. The best agreement in this group was noted in the determination for nickel and the determinations for antimony less than 0.5%. In the case of silver and lead, the agreement of results can be regarded as sufficient. Unfortunately the comparison of results for other elements demonstrates the existence of differences in the assessment of their proportions in alloys. One of the causes of this may be the use of different standards, where part of the results are the results of extrapolation. It is not however possible to explain all differences in this manner. An exact evaluation of this phenomenon, especially apparent in the comparison of results obtained using different methods, will only be possible after the completion of further analyses.

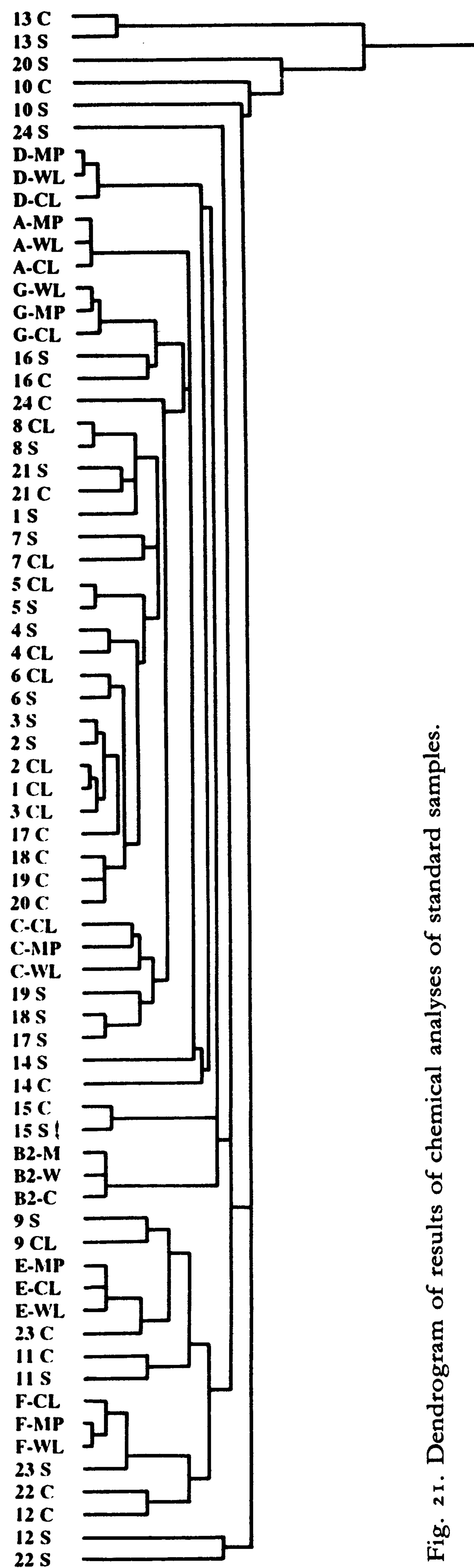


Fig. 21. Dendrogram of results of chemical analyses of standard samples.

In order to study further the problem of the differences appearing in analyses carried out independently in different laboratories, the following statistical experiment was conducted. All the analyses were treated as a collection of analyses of artefacts which were analysed by a typical statistical treatment of cluster-analysis (Marek 1989) (Fig. 21). As shown above there was good agreement of the results from the laboratories CL, WL and MPI (the greatest differences were seen in alloy C and the best agreement in alloys A, B₂ and E). The agreement between the results obtained by CL, and TI RAA was however different. In this group we can regard groups 8, 5 and 15 as in agreement, while sufficiently similar results come from samples 7, 16, 13, 1, 2, 3, 6, 4, 11, 9.

The analyses have unequivocally demonstrated that it is impossible to eliminate the demonstrated differences between analyses carried out in different laboratories by simply applying a universal correction coefficient, due to the random character of this phenomenon. It has also been unequivocally demonstrated the worth of attempting a standardisation of investigations of the analysis of artefacts.

This work has a preliminary character, and cannot be read as a criticism of the quality of work in the laboratories taking part in the experiment. Further work should include all laboratories involved in the analysis of artefacts and the composition of the analysed materials should be at least close to the alloys used in the Polish—Swedish experiments.

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