

Distribution of Some Trace Elements in Different Beneficiation Fractions from the Bleikvassli Pyritic Lead-zinc Ore Body, Nordland

ANANDA DEB MUKHERJEE, RANENDRA N. SEN & EILIV STEINNES

Mukherjee, A. D., Sen, R. & Steinnes, E. 1973: Distribution of some trace elements in different beneficiation fractions from the Bleikvassli pyritic lead-zinc ore body, Nordland. *Norges geol. Unders.* 300, 21–25.

The distribution of some minor and trace elements at different stages of sulphide ore beneficiation in the Bleikvassli ore-dressing plant, has been studied using neutron activation analysis. Silver, gold, antimony and selenium are found to be concentrated along with lead. Cobalt is found in the pyrite concentrate. Arsenic is concentrated mainly with pyrite, but a minor fraction is also carried together with lead. Scandium and thorium are shown to be associated with the gangue minerals. Chromium present in the crude ore appears to have been removed to a great extent before the first flotation step.

A. D. Mukherjee, *Geological Institute, University of Oslo, Blindern, Oslo 3, Norway**

R. Sen, *Bleikvassli Gruber, N-8647 Bleikvassli, Norway***

E. Steinnes, *Institutt for Atomenergi, Isotope Laboratories, Kjeller, Norway*

Introduction

The palaeozoic stratabound pyritic lead-zinc ore body at Bleikvassli, Northern Norway (lat. 65° 50'N) has been classified mineralogically by Vokes (1963) as belonging to the fourth class of Caledonian massive sulphide ores (Carstens 1935). This ore consists of two main types (Vokes, *op. cit.*) a pyrite type comprising pyrite, sphalerite, galena, pyrrhotite, chalcopyrite, and a pyrrhotite-rich type comprising pyrrhotite, sphalerite, galena, chalcopyrite, and minor or no pyrite.

An ore-dressing plant situated close to the Bleikvassli mine is used for flotation of the lead and zinc sulphides and pyrite. After crushing and grinding, the usual procedure for selective flotation, involving three steps, is followed. Lead is concentrated in the first step, zinc in the second, and finally pyrite is separated. Copper is mainly separated along with lead, the concentration being 3–4% in the Pb concentrate. Some zinc is also separated in the first flotation step, amounting to 6–8% Zn in the Pb fraction.

The distribution of minor and trace elements between the different fractions resulting from this ore-beneficiation process has not been extensively studied so far. The present work was therefore undertaken in order to extend knowledge on this point, by means of instrumental neutron activation analysis.

* Present address: Department of Geology, Jadavpur University, Calcutta 32, India

** Present address: Department of Geology, Presidency College, Calcutta 12, India

Experimental

Samples for the present investigation were collected from the plant in a continuous series during five days. They are (a) crude ore, (b) concentrates of lead, zinc, and pyrite, (c) tailings of lead, zinc, and pyrite.

The samples were analysed for their content of Ag, As, Au, Co, Cr, Ir, Sb, Sc, Se, and Th, using neutron activation analysis according to a procedure described in detail elsewhere (Steinnes & Mukherjee 1973). Fractions of about 100 mg and appropriate standards of each element were irradiated for 20 hours in the JEEP II reactor (Kjeller, Norway) at a thermal neutron flux of $1.5 \cdot 10^{13}$ neutrons $\text{cm}^{-2}\text{sec}^{-1}$. After fixed intervals the samples were subjected to γ -spectrometry with a Ge(Li) solid-state detector system. Measurements for arsenic (^{76}As), antimony (^{122}Sb), and gold (^{198}Au) were performed after 6 days, while chromium (^{51}Cr), cobalt (^{60}Co), iridium (^{192}Ir), scandium (^{46}Sc), selenium (^{75}Se), silver (^{110}Ag), and thorium (^{233}Pa) were determined about 20 days after the irradiation.

Results and discussion

The results of this work are given in Table 1. Except for Ir, the content of which appeared to be too low for study by the purely instrumental technique employed, specific distribution trends have been observed for all elements investigated. In the following, the results obtained for each element are briefly discussed.

Ag

Silver is shown to be concentrated extensively in the lead concentrate, the average enrichment factor being 16.3 ± 3.7 as compared to the crude ore, which is similar to the corresponding factor for Pb (17.5 ± 1.0) calculated from data on the same fractions available from Bleikvassli Gruber. This can be explained by the well-known fact that silver is readily camouflaged in galena. The contribution of free silver minerals, however, cannot be excluded.

Au

Although the results clearly reflect the fact that the fractions taken for analysis were not sufficiently homogeneous with respect to gold, it seems clear that this element is also concentrated in the Pb fraction. In a similar study concerning the distribution of Ag, Au, and Hg in concentrates from various Norwegian ores, Rehman et al. (in press) found the highest concentrations of Au in the Cu concentrates, and indicated a possible substitution of gold in copper sulphide minerals. In the Bleikvassli plant, where copper is concentrated along with lead in the flotation process, gold is therefore likely to be found mainly in the lead concentrate.

Co

Cobalt is enriched in the pyrite concentrate, as could be expected from the similar ionic radii of Co^{2+} and Fe^{2+} (0.82 Å vs. 0.83 Å). Only a very minor fraction of cobalt appears to be associated with the gangue minerals.

As

Arsenic is found mainly in the pyrite concentrate, where its concentration is about four times that of the crude ore. A certain amount, of the same order as in the crude ore, is also found in the Pb concentrate. Vokes (1963) in his mineralogical study of the Bleikvassli ore, found that arsenopyrite (FeAsS) occurs sparsely and sporadically in the pyrite type of the ore, and in the sections where it is more abundant, the mineral often appears crystallized together with pyrite in composite grains or crystals. Furthermore, he observed a rather widespread occurrence of fahlerts ($\text{Cu}_3(\text{As,Sb})\text{S}_4$) in the ore, intimately associated with the galena. The distribution pattern observed in the present work is consistent with these observations.

Sb

Antimony shows a strong concentration in the Pb fraction, in accordance with the fact that this element is a common constituent of many hydrothermal galena deposits (Goldschmidt 1954), replacing either S or Pb. Possible Sb occurring in fahlerts would also tend to be concentrated with lead. The minerals gudmundite (FeSbS), boulangerite ($\text{Pb}_5\text{Sb}_4\text{S}_{11}$), and bournonite (CuPbSbS_3) have also been identified in the Bleikvassli ore (Vokes 1963), but these minerals appear to be less abundant than fahlerts. The observed concentration factor for Sb from the crude ore to the lead concentrate (11.6 ± 1.2) is somewhat lower than the corresponding value for Pb.

Se

Selenium, which is present in a concentration of about 10 ppm in the crude ore, also shows a very distinct enrichment in the lead concentrate (average concentration factor 15.7 ± 2.8 , in agreement with the Pb value within the observed standard deviations). This fact may be explained by a substitution of Se for S in galena or chalcopyrite. It could also in part be associated with the presence of Se in one or more trace minerals, possibly together with silver, which is known to have a pronounced affinity towards selenium. Such minerals, however, have not been observed so far in the Bleikvassli ore.

Ir

The iridium content of the present samples is so low (< 0.05 ppm) that no discussion seems to be appropriate at this point.

Sc, Tb

The strongly lithophile character of these elements suggests their association with the gangue minerals, an assumption which is supported by the occurrence

of these elements in the pyrite tailings while their abundance in the metal concentrates is very low.

Cr

This element exhibits a somewhat peculiar behaviour. While apparently present in the crude ore at a concentration level of about 150 ppm, it has not been observed in any of the fractions studied. It might have been present in part in the Zn or Pb concentrates, where analytical interference did not permit its determination at levels below 100 ppm. Some fractions were therefore re-analysed for Cr using a radiochemical variant of neutron activation analysis. In this case, the irradiated samples were decomposed with $\text{Na}_2\text{O}_2/\text{NaOH}$ in the presence of 10 mg inactive chromium carrier, and the insoluble hydroxides occurring upon leaching the melt with water were removed. By this means, most of the analytically interfering radionuclides were eliminated. The results thus obtained are given in the extreme right hand column of Table 1. The occurrence of Cr in the crude ore samples is confirmed, while the content in the Zn and Pb concentrates appears to be very low. Consequently the major part of chromium seems to be removed before the first flotation step. This seems difficult to explain, unless the Cr observed in the crude ore samples is present in an easily soluble mineral, or simply due to contamination from the equipment used during crushing and grinding of the ore. As neither of these possibilities seems very likely, the virtual disappearance of Cr during the processes involved still remains unsolved.

Acknowledgements. - The authors are grateful to Professor J. A. W. Bugge, Institutt for Geologi, Universitetet i Oslo, and Professor F. M. Vokes, Institutt for Geologi, Universitetet i Trondheim, Norges Tekniske Hogskole, for valuable discussions. Thanks are due to Fangel & Co. A/S for permission to publish the results.

REFERENCES

- Carstens, C. W. 1935: Zur Genese der Kiesvorkommen des Trondhjemgebietes. *K. norske Vitensk. Selsk. Skr.* 11, 40 pp.
- Fazal-Ur-Rehman, Brunfelt, A. O. & Finstad, K. G., (in press): Gold, silver and mercury in materials from Norwegian sulphide mines. *Norges geol. Unders.*
- Goldschmidt, V. M. 1954: *Geochemistry*. Clarendon Press, Oxford. 477 pp.
- Steinnes, E. & Mukherjee, A. D. 1973: Instrumental neutron activation analysis of a sulphide ore and some ore beneficiation products. *J. Radioanal. Chem.* 14, 129-138.
- Vokes, F. M. 1963: Geological studies on the Caledonian pyritic zinc-lead orebody at Bleikvassli, Nordland, Norway. *Norges geol. Unders.* 222, 126 pp.

Table 1. Results for some trace elements in samples collected from the mineral dressing plant at Bleikvassli.
All values are given in ppm

Date (1970)	Fraction	Co	Ag	Au	As	Sb	Se	Ir	Cr	Sc	Th	Cr*
2.11	Crude ore (CO)	39	46	<0.04	157	73	14	<0.05	154	1.8	21	159
"	Zn concentrate (ZnC)	6.5	51	0.29	9.3	35	43	<0.3	<100	-	<5	2.9
"	Zn tailings (ZnT)	47	<5	0.01	200	23	<5	<0.05	21	2.5	22	
"	Pb concentrate (PbC)	13.8	690	3.0	150	950	190	<0.3	<100	-	5.0	<10
"	Pb tailings (PbT)	44	12	0.03	188	23	7.0	<0.05	14	2.3	22	
"	Pyrite concentrate (PyC)	146	4.8	<0.04	640	32	<5	"	18	<0.5	6.3	
"	Pyrite tailings (PyT)	2.5	<5	<0.01	13	14.6	<5	"	10	2.4	29	
3.11	CO	43	44	0.23	194	80	14	<0.05	143	2.0	21	151
"	ZnC	<5	<50	0.08	3.8	28	<40	<0.3	<100	-	<5	3.7
"	ZnT	49	<5	0.07	174	25	<5	<0.05	13	2.2	22	
"	PbC	5.6	840	0.78	116	890	200	<0.3	<100	-	<5	<10
"	PbT	45	12	0.19	171	27	13	<0.05	18	2.3	20	
"	PyC	167	8.5	0.04	620	26	2.9	"	14	<0.3	5.5	
"	PyT	5.5	<5	0.01	22	17.6	<5	"	13	3.1	27	
4.11	CO	31	68	0.17	117	93	11	<0.05	162	2.6	23	172
"	ZnC	4.6	51	0.03	17	29	<40	<0.3	<100	-	<5	1.6
"	ZnT	41	<5	<0.02	144	17.7	<5	<0.05	15	2.9	35	
"	PbC	16.5	760	0.71	128	960	167	<0.3	<100	-	5.3	<10
"	PbT	36	8.1	0.02	142	23	5.5	<0.05	13	3.7	27	
"	PyC	140	<5	0.05	550	35	<5	"	24	<0.4	6.4	
"	PyT	1.1	<5	<0.01	8.3	19.1	<5	"	<10	4.1	28	
5.11	CO	35	39	0.05	138	80	8.8	<0.05	132	3.0	28	
"	ZnC	4.7	<50	0.02	13	22	<40	<0.3	<100	-	<5	
"	ZnT	41	<5	<0.02	178	18.0	<5	<0.05	14	3.4	25	
"	PbC	<5	770	16.8	148	970	173	<0.3	<100	-	4.5	
"	PbT	34	<5	0.04	153	15.9	<5	<0.05	12	3.1	26	
"	PyC	109	5.1	0.04	510	30	<5	"	21	<0.4	4.7	
"	PyT	0.9	<5	<0.02	5.8	7.6	<5	"	7.1	4.5	29	
6.11	ZnC	5.7	55	<0.02	12	57	<40	<0.3	<100	-	<5	
"	ZnT	46	5.3	<0.02	157	20	<5	<0.05	18	2.8	24	
"	PbC	<5	1250	1.3	179	1640	220	<0.3	<100	-	<5	
"	PbT	38	15	0.12	152	33	4.2	<0.05	10	2.9	26	
"	PyC	139	<5	0.09	520	42	<5	"	14	0.2	4.6	
"	PyT	2.7	<5	0.02	9.1	12.1	<5	"	7.9	4.1	30	

* Values obtained using radiochemical separation of ⁵¹Cr.