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Investigating concentration distributions of arsenic, gold and antimony in grain-size fractions of gold ore using instrumental neutron activation analysis

M. Nyarku [a,*], B.J.B. Nyarko [b], Y. Serfor-Armah [c], S. Osae [c]

[a] National Radioactive Waste Management Centre, National Nuclear Research Institute, Ghana Atomic Energy Commission, P.O. Box LG 80, Legon-Accra, Ghana
[b] Department of Nuclear Engineering and Materials Science, National Nuclear Research Institute, Ghana Atomic Energy Commission, P.O. Box LG 80, Legon-Accra, Ghana
[c] Department of Chemistry, National Nuclear Research Institute, Ghana Atomic Energy Commission, P.O. Box LG 80, Legon-Accra, Ghana

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ABSTRACT

Instrumental neutron activation analysis (INAA) has been used to quantify concentrations of arsenic (As), gold (Au) and antimony (Sb) in grain-size fractions of a gold ore. The ore, which was taken from the Ahafo project site of Newmont Ghana Gold Ltd., was fractionated into 14 grain-size fractions using state-of-the-art analytical sieve machine. The minimum sieve mesh size used was 36 μm and grains >2000 μm were not considered for analysis. Result of the sieving was analysed with easysieve® software. The <36 μm subfraction was found to be the optimum, hosting bulk of all three elements. Arsenic was found to be highly concentrated in <36–100 μm size fractions and erratically distributed in from 150 μm fraction and above. For gold, with the exception of the subfraction <36 μm which had exceptionally high concentration, the element was found to be approximately equally distributed in all the size fractions but slightly "played out" in 150–400 μm size fractions. Antimony occurrence in the sample was relatively high in <36 μm size fraction followed by 600, 800, 400 and 36 μm size fractions in that order. Gold content in the sample was comparatively far greater than arsenic and antimony; this is indicative of level of gold mineralization in the concession where the sample ore was taken. The concentration of gold in the composite sample was in the range 564–8420 ppm as compared to 14.33–186.92 ppm for arsenic and 1.09–9.48 ppm for antimony. Elemental concentrations were correlated with each other and with grain-size fractions and the relationships between these descriptive parameters were established.

1. Introduction

Ghana, formerly called "The Gold Coast", is known to abound in gold deposits and gold ore bodies (Kesse, 1985; Nyarko et al., 2003). Geologists employ various techniques in order to exploit gold from its ore. Geochemical and geophysical methods and thin section analyses are some of the common techniques that are often employed (Wikipedia Journal website; Amanor, 1979). Some of these techniques to a large extent reveal minerals rather than elements. Elemental concentrations within grains of a rock can be investigated by analysing the concentrations of elements of interest in the various grain size fractions within the rock. This is because grains in most geologic media have in situ properties and have not been affected by anthropogenic contributions. Since grain is the basic motif of a rock, analysing for elements in various grain fractions of a rock provide information on how elements in the rock vary as a function of grain sizes (Ahmad et al., 2005). Most studies carried out in Ghanaian gold mines have all mostly focused on total content determination of arsenic and antimony as pollutants (Ahmad et al., 2005; Ahmad and Carboo, 2004; Bortoleto and Cadore, 2005). There is, however, a growing awareness of the importance of gathering information on elements concerning their levels, distributions and interactions in today's scientific world (Overwater, 1994). Owing to their association with gold in gold deposits leading to their use as pathfinder/indicator elements in gold exploration, and their toxicity to organisms and plants, arsenic and antimony are considered as important elements. Information on the distribution mode(s) of these elements in grain fractions of gold ore is needful in knowing the optimum grain size(s) that is, grain size fraction(s) that host greater amount of each of the elements.

Instrumental neutron activation analysis (INAA) has been used to quantify the concentrations of arsenic, gold and antimony in grain size fractions of a gold ore. INAA is a powerful analytical technique that is based on nuclear reactions whereby both elements and their contents are determined. INAA is cost effective and affordable for small and large sample quantities, and offers superior sensitivity to many elements (Alfassi, 2005; De Soete

* Corresponding author. Tel.: +233 21 401272/400310; fax: +233 21 400807.
E-mail address: mawuutorli@yahoo.com (M. Nyarku).

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et al., 1972). This study has established the relationships between concentrations of As, Au, Sb and grain-size fractions; and the optimal size fractions for As, Au and Sb for the ore analysed. These give useful clues to exploration geologists, geochemists, geophysicists and small-scale gold miners in Ghana who are interested in the occurrence of these elements in gold ore. Results of this study also serve as a source of accurate data on content of Au in the ore that was analysed (to Newmont Ghana Gold Ltd.). These results have also provided information on background levels of As and Sb in the concession where the sample was taken so that an environmental monitoring could be planned.

Table 1
Easysieve output result of sieve analysis.

Size fraction (μm)	p3 (%)	Q3 (%)	Δm (g)	$\sum \Delta m$ (g)
< 36	0.4	0.4	4.40	4.40
36–40	0.4	0.8	4.00	8.40
40–50	0.8	1.6	8.40	16.80
50–63	1.2	2.8	11.70	28.50
63–80	1.8	4.6	18.60	47.10
80–100	3.0	7.6	31.00	78.10
100–150	2.2	9.9	22.80	100.90
150–200	3.2	13.1	32.80	133.70
200–250	3.0	16.1	30.80	164.50
250–400	9.1	25.2	92.50	257.00
400–600	9.7	34.8	98.90	355.90
600–800	10.9	45.8	111.40	467.30
800–1000	8.8	54.5	89.50	556.80
1000–1400	23.2	77.7	236.80	793.60
1400–2000	22.3	100.0	227.80	1021.40

2. Materials and methods

2.1. Sample and sample preparation

A metasedimentary gold ore rock sample collected from exploration field of the Ahafo project site of Newmont Ghana Gold Ltd. in the Brong-Ahafo region of Ghana was used for the analysis. The quantity of the sample that weighs 2851.60 g with bulk density determined to be 2.57 g/ml was prepared for the analysis. The sample ore was first broken into fragment chips using a geologic hammer. Then the fragment chips were reduced into fractional grains using a jaw crusher to form a composite sample. The crushing was carefully done to retain in situ properties of ore grains. For the purposes of this research, grains of the composite sample >2000 μm were excluded from further analysis which then reduced the quantity of composite sample analysed to 1061.50 g.

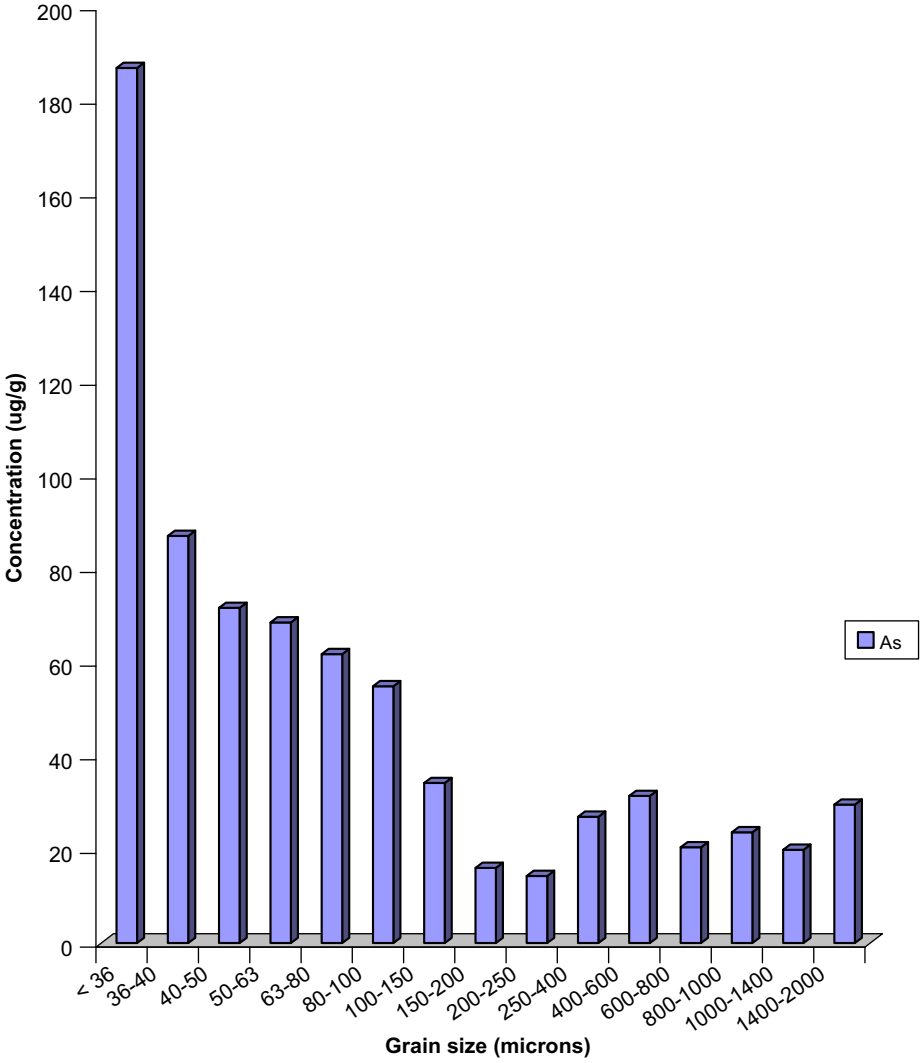

Fig. 1. Concentration distribution of arsenic in various size fractions.