Facility for Gamma Activation Analysis with 8 MeV, 10 kW Linear Accelerator.

Mikhail Demsky, CORAD Ltd, St.Petersburg, Russia (www.corad.pro)
Vladimir Gostilo, Alexander Sokolov, BSI, Riga, Latvia (bci.lv)

Yury Burmistenko, Moscow, Russia

Low energy electron beams for industrial and environmental applications
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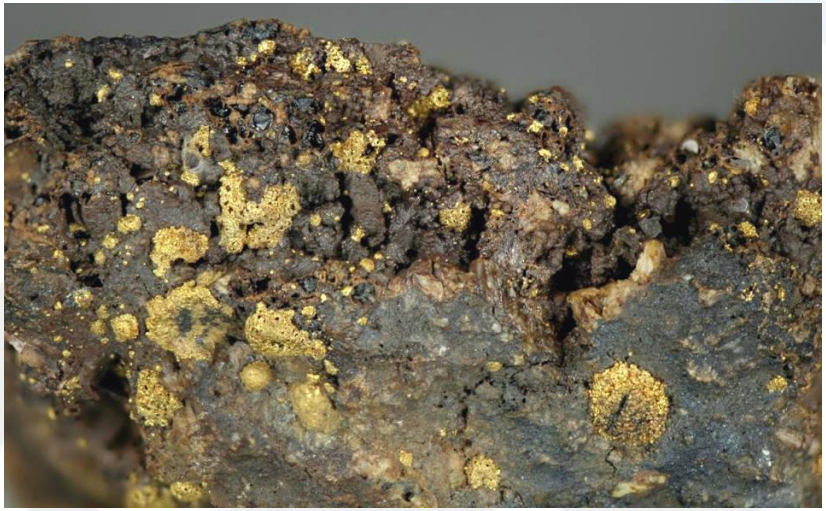
- **Gold is unevenly distributed inside ore as a dust in a small concentration of several g/t.**
- **The efficiency of gold mining is secured by testing of many ore samples that are extracted from drilled wells for explosives placement. It allows to select for further processing only the sites having a profitable concentration of gold instead of processing all ore.**
- **The necessary number of tests for one mine is usually as high as about 250,000 in a year.**

The analysis of samples on gold can be made through the following ways:

- **fire assay**
- **neutron activation analysis**
- **gamma activation analysis**



The fire Assay method

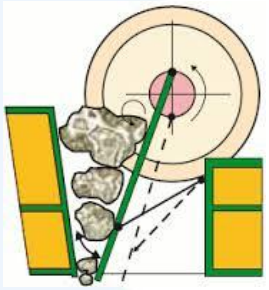
Contains 3 steps:

1. **Preparation** (Grinding, mixing)
2. **Collection** (Lead fusion)
3. **Separation** (Cupellation)

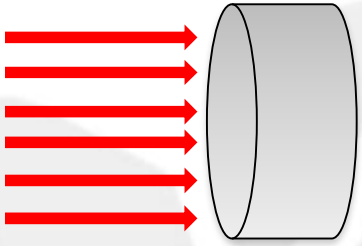
Disadvantages:

- **Labor intensive:** test of one sample takes 1 day
- **Low throughput:** the laboratory with equipment price of $ 1,5M can carry out 250-400 samples per day
- **High price of components:** ~30% of equipment price per year

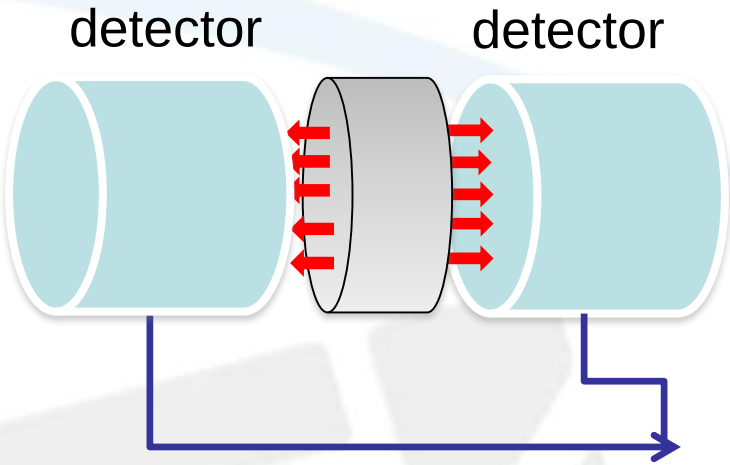
Scheme of Neutron and Gamma Activation Analysis



1. Sample preparation (few minutes)



2. Sample Activation



3. Measurements

Method and particle source	Weight of samples g	Size of components mm	Sensitivity g/t	Total time of analysis min
Gamma Activation (GAA) 8 MeV, 5 kW electron accelerator with W target	500 - 700	0,07-3,0	0.2-0,5	0.5
Neutron Activation (NAA) 15 MeV electron accelerator with Pb-Be target	3 - 20	0,07	0,01 – 0,05	10

GAA has the following advantages compared to NAA:

- better representation
- more fast
- samples not contain long-lived isotopes

In the same time the sensitivity of GAA is usually enough to separate the gold ore that should be processed.

Gamma Activation Analysis Advantages

- high penetrating ability of gamma-radiation provides good representatives due to using samples of 500-1000 g weight;

- due to short half-life of excited gold nuclei the duration of the analysis does not exceed 20-30 s;

- provides the necessary sensitivity and accuracy of analysis

- the analysis results practically do not depend on chemical composition of the sample;

- the method is ecologically favorable;

- samples remain unchanged after the analysis;

- the method allows multi-element analysis over the course of a single cycle of the study and measurements;

- the method can be fully automated;

Three laboratories of activation analysis were established in former USSR as the result of collaboration between the Efremov Institute (NIIEFA) and the Institute of Radiation Technologies:

1. Laboratory AURA at Muruntau deposit (Zarafshan, Uzbekistan) with two 8 MeV and one 15 MeV linear electron accelerators: since 1976 - ongoing.
2. Laboratory in Magadan with 8 MeV and 15 MeV linear electron accelerators: 1979 – 1999.
3. Laboratory in Batagay (Yakutia) with 8 MeV and 15 MeV linear electron accelerators: 1986 – 2014.

First laboratory of Gamma Activation Analysis AURA in Zarafshan (Uzbekistan) - 1976

Bourmistenko, Y.N.,“Photonuclear Analysis of Composition of Materials”,.- M.: *Energoatomizdat*, 1986.-200 p.(rus)

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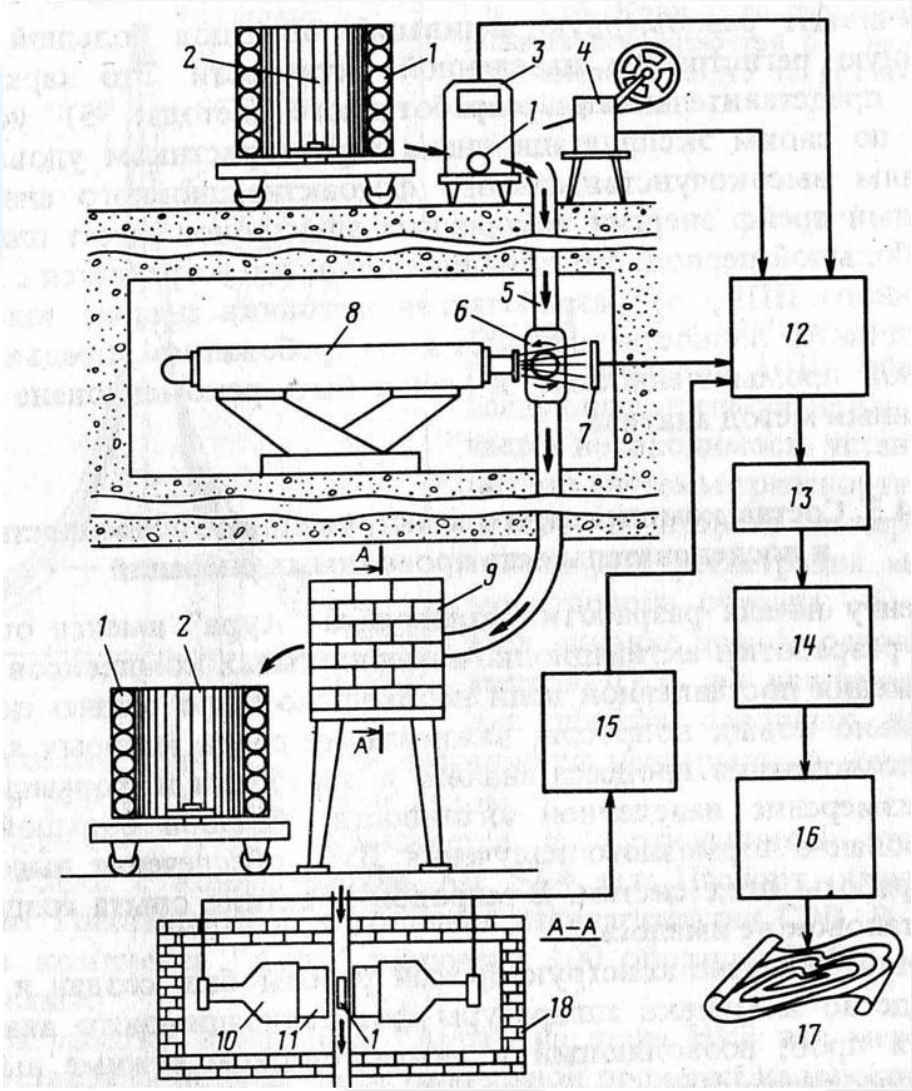
Laboratory AURA in Zarafshan (Uzbekistan) - 1976



Sketch-view of the system

1. Plastic containers with samples
2. Loading drum
3. Weighting device
4. Sample's coding device
5. Channel of samples movement
6. Irradiation device
7. Radiation monitoring device
8. Linear electron accelerator
9. Lead shield of radiation detectors
10. Photomultiplier
11. NaI(Tl) crystal
12. ,13,14,16,17 – devices of collecting and processing of information
15. Detectors of the induced activity

Bourmistenko, Y.N.,"Photonuclear Analysis of Composition of Materials",.- M.: *Energoatomizdat*, 1986.-200 p.(rus)

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Laboratory AURA in Zarafshan (Uzbekistan) - 1976

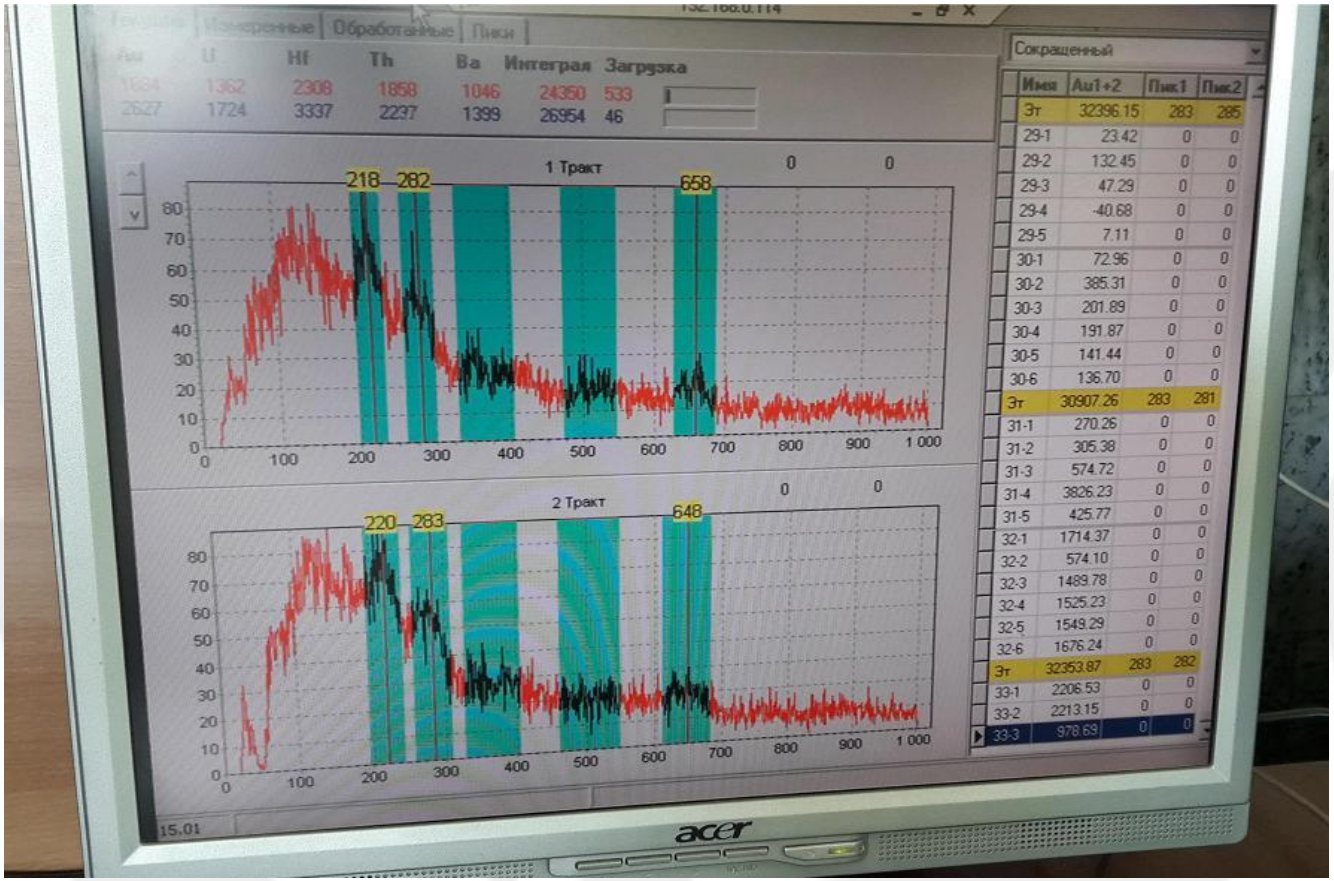
Laboratory AURA in Zarafshan (Uzbekistan) -1976

8 MeV, 5 kW linear Electron Accelerator LUE-8-5A

Scintillation detectors

Laboratory AURA in Zarafshan (Uzbekistan) - 1976

Spectrum registered by NaI detectors:



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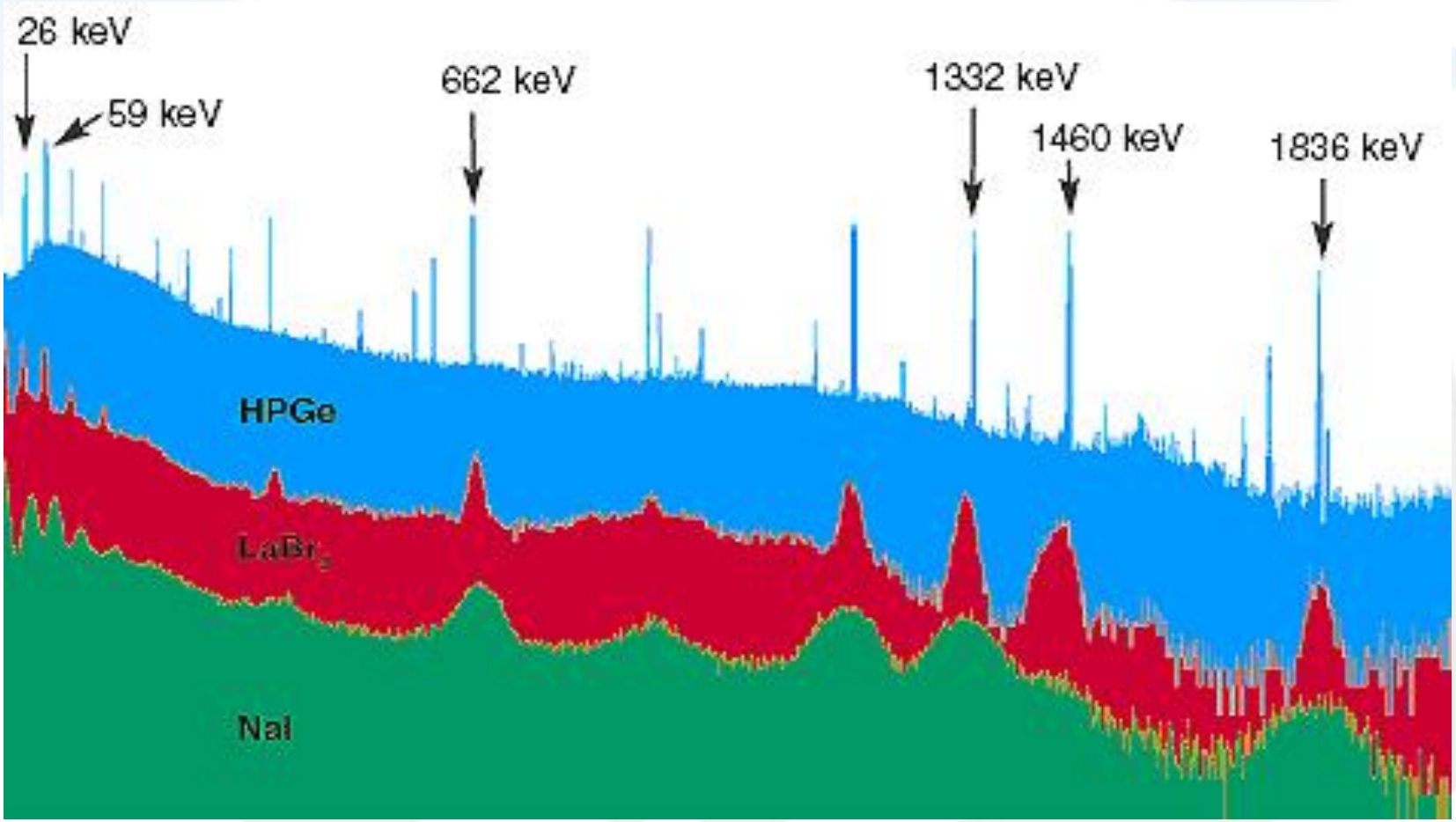
MAIN RESULTS OF THE AURA ANALYTICAL LABORATORY:

- About 800,000 analyzes per year
- Increased throughput of gold mining due to more precise contouring of the ore bodies and its selective mining
- Detection of the failures in the gold extraction process by express-analyzes of waste

Comparison of various detectors



1st line - Upgrade (2016)

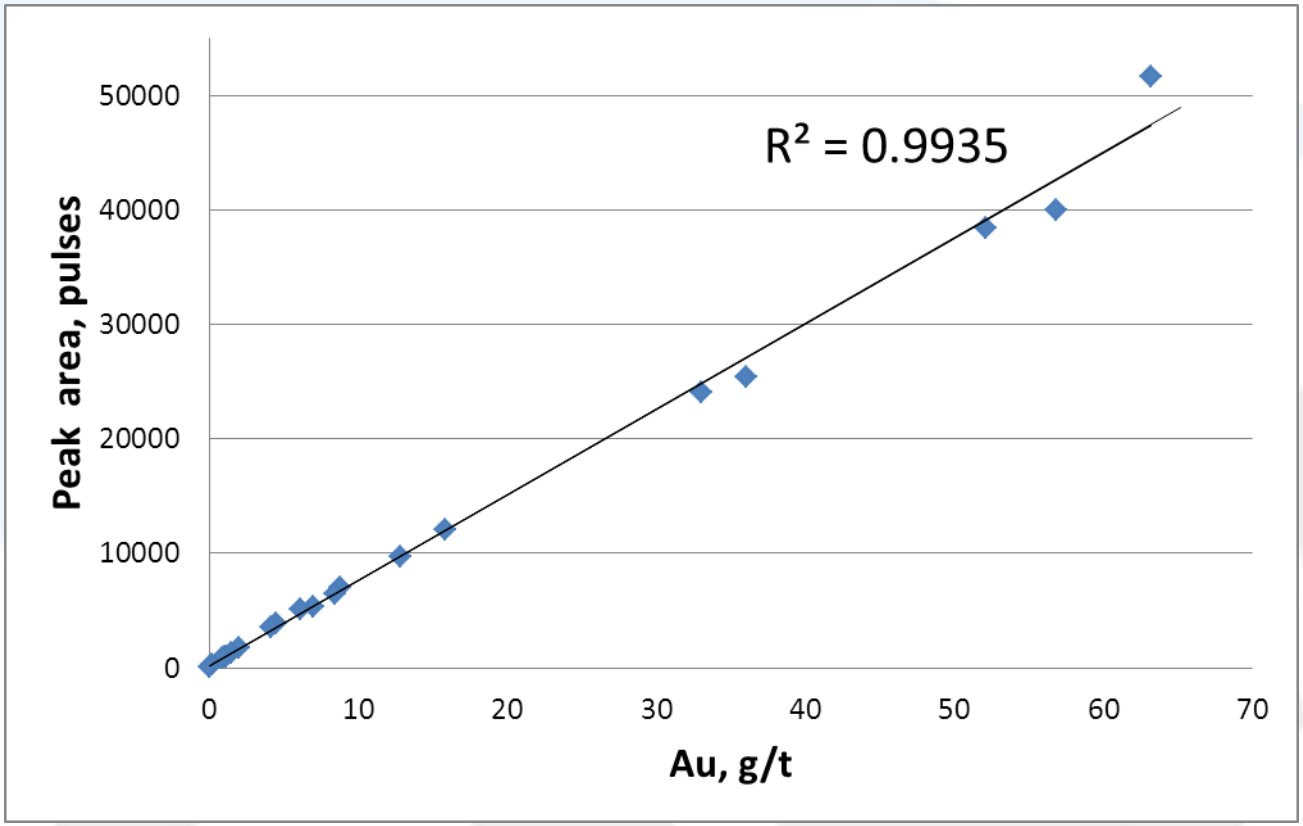
Linear Electron Accelerator UELV-8-5A

E=8 MeV;
P=5 kW

1st line - Upgrade (2016)

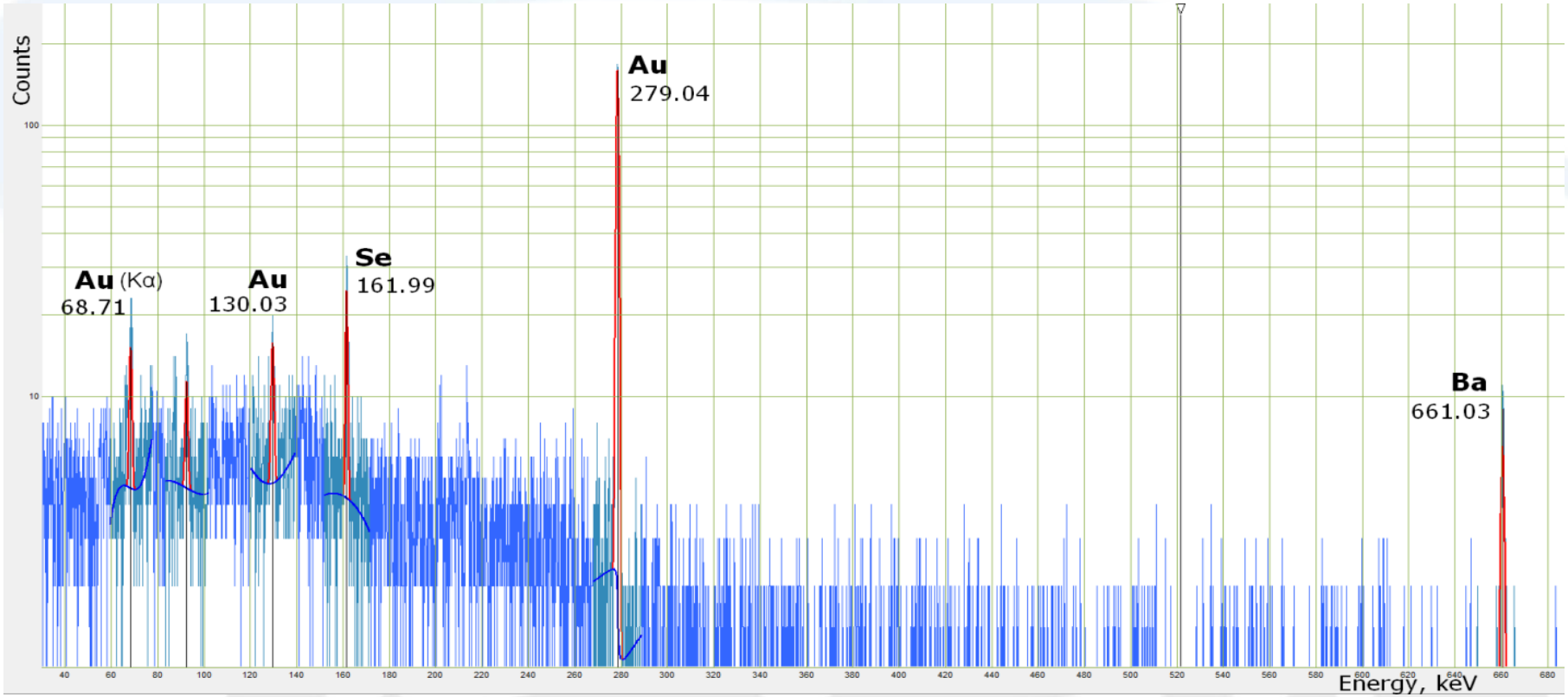
The measuring part of gamma activation complex: 1 –multi-crystal High Pure Ge (HPGe) detectors; 2 –spectrometric cabinets; 3 – lead shield against radiation noise of the accelerator.

1st line - Upgrade (2016)



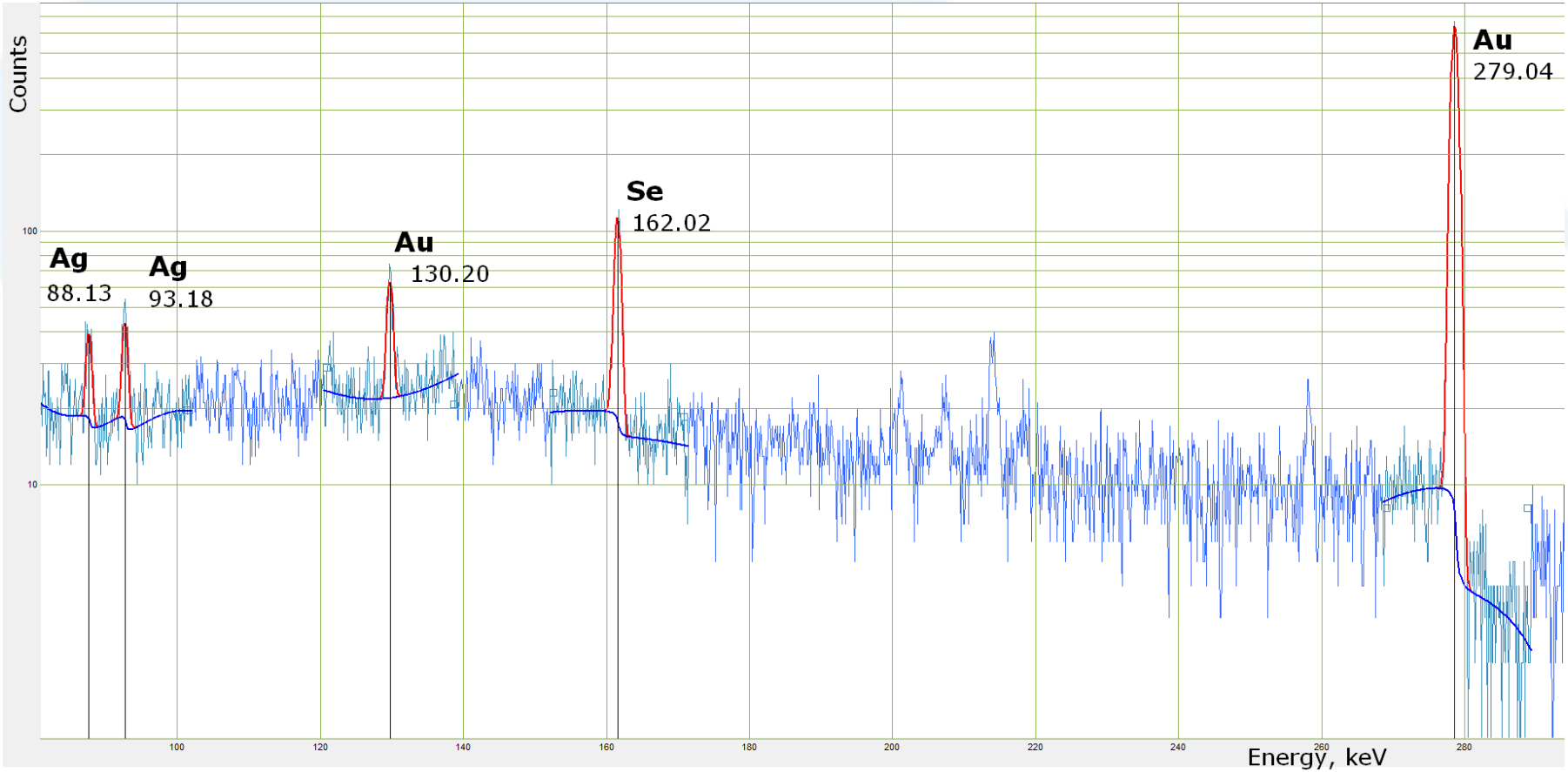
Regressive dependence of peak area on gold content in the samples.

1st line - Upgrade (2016)



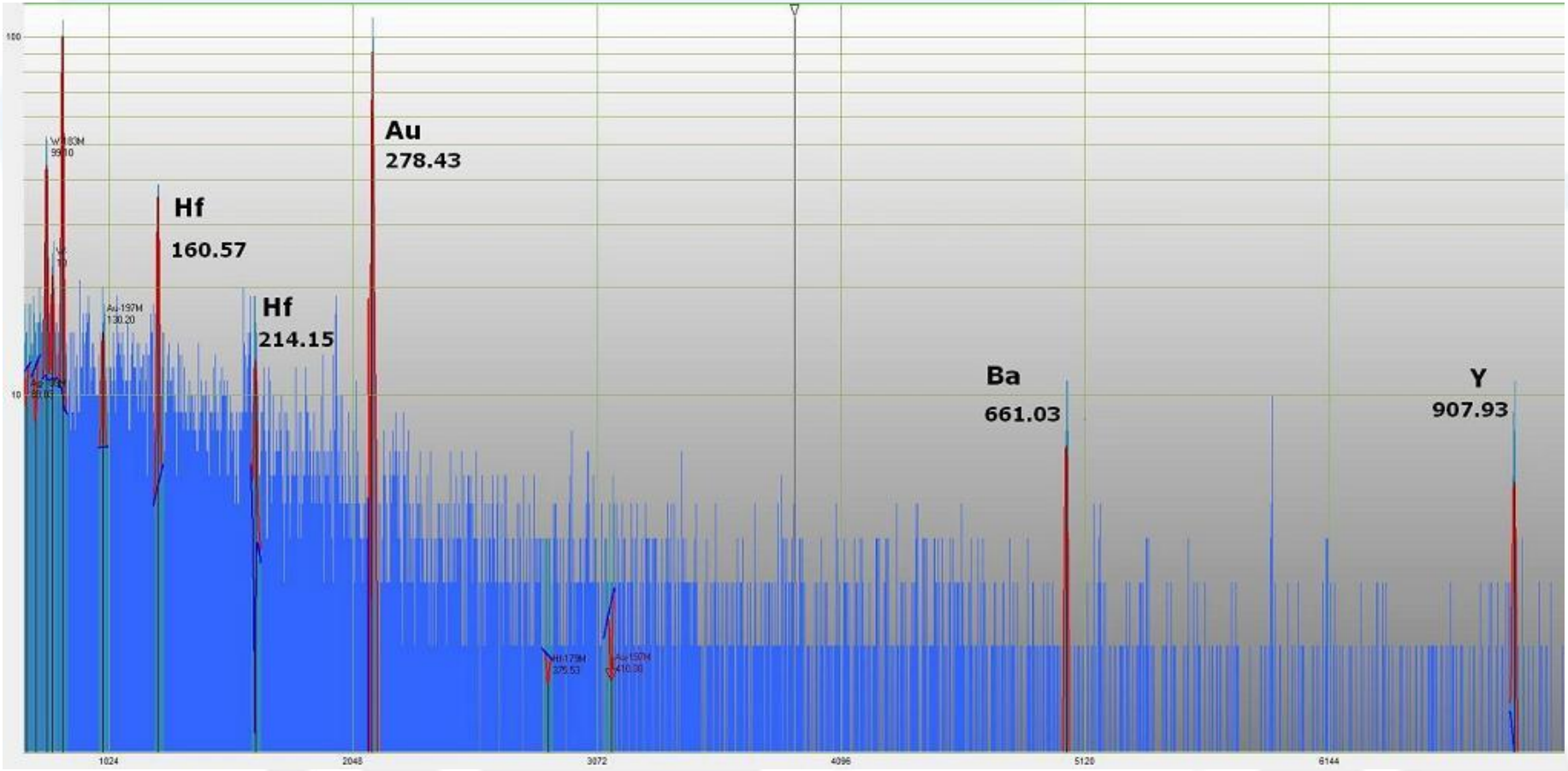
Gold sample spectrum 12.8 g/t. Beam power 5 kW; radiation time -10 s; measurement time - 15 s.

1st line - Upgrade (2016)



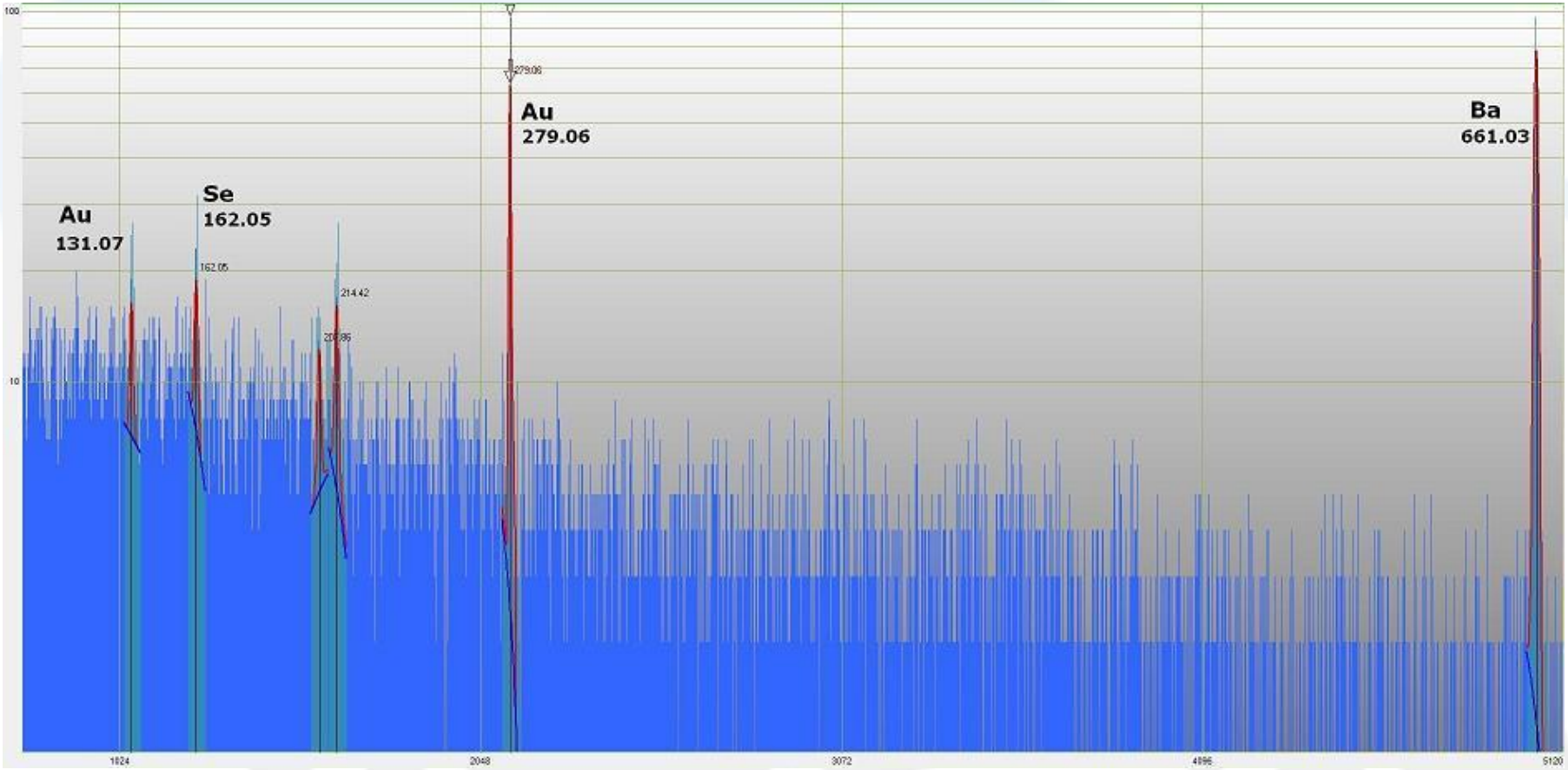
Sample spectrum of gold 12.1g/t and silver 24.6 g/t. The beam power 5 kW; radiation time-10 s; measurement time - 15 s.

1st line - Upgrade (2016)



Sample spectrum of gold 4.6 g/t. The beam power 5 kW; radiation time-10 s; measurement time - 15 s.

1st line - Upgrade (2016)



Sample spectrum of gold 1.1g/t. The beam power 5 kW;
radiation time-10 s; measurement time - 15 s.

Conclusions from our research on 1st line – Upgrade in 2016:

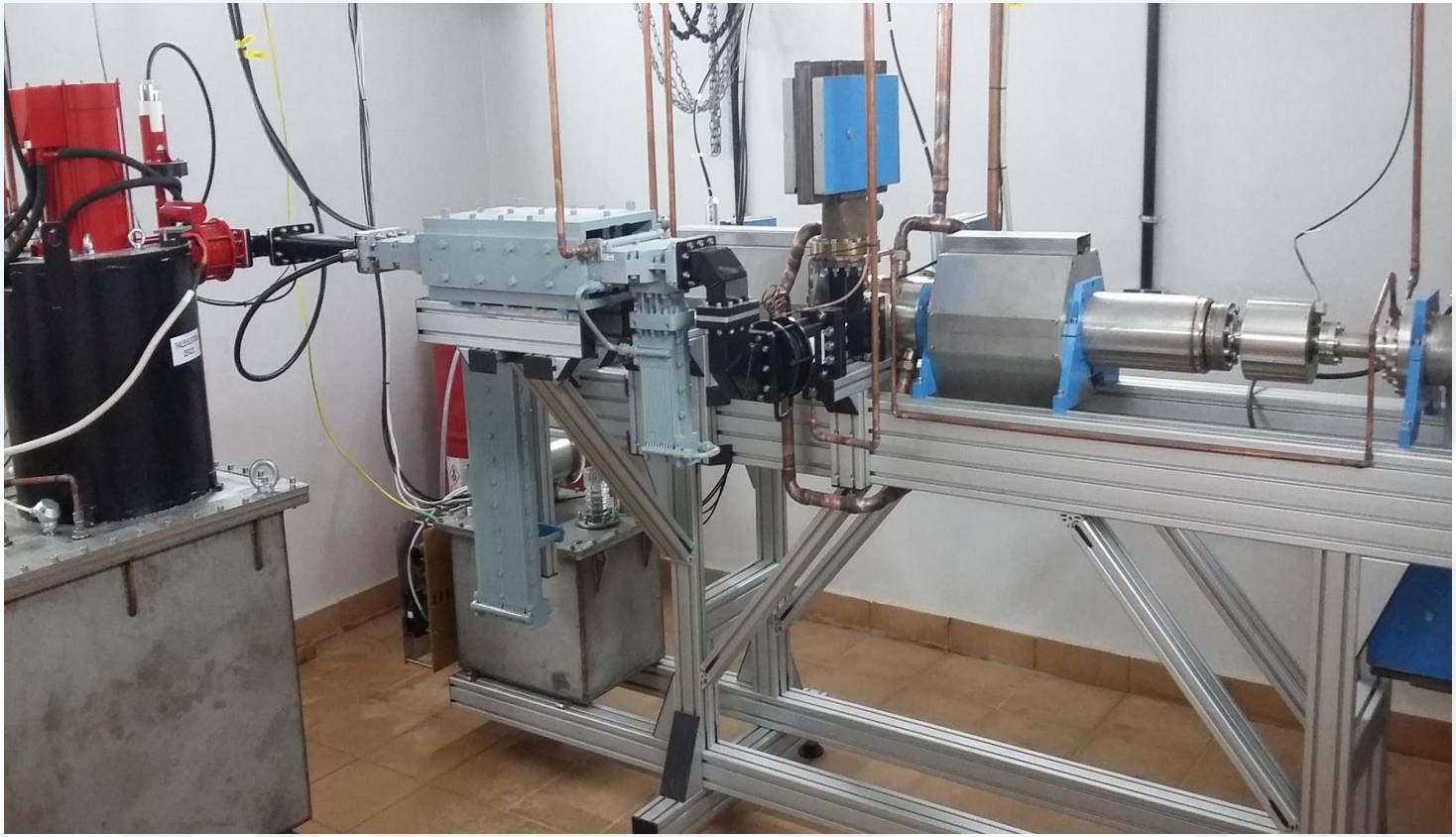
- The research results point to the capability to determine the concentrations of multiple associated elements in ore samples: Au, Ag, As, Ba, Br, Cd, Er, Ge, Hf, Hg, In, Ir, Lu, Pb, Pt, Rh, Se, Sn, Th, U, Y, W;

- The detection limit for gold in 15 seconds of measurements was 0.08-0.20 g/t depending on barium and hafnium content;

- The registration sensitivity for 1 g/t per 15 seconds of measurements was 500 to 650 pulses;

- The ore assay system has the capacity to perform analysis of over 120 samples per 1 hour period;

2nd line - Upgrade (2017-18)



8 MeV, 10 kW linear electron accelerator UELR-8-10A

2nd line - Upgrade (2017)

The measuring part of gamma activation complex: 1 –multi-crystal HPGe detectors; 2 –spectrometric cabinets; 3 – lead shield against radiation noise of the accelerator.

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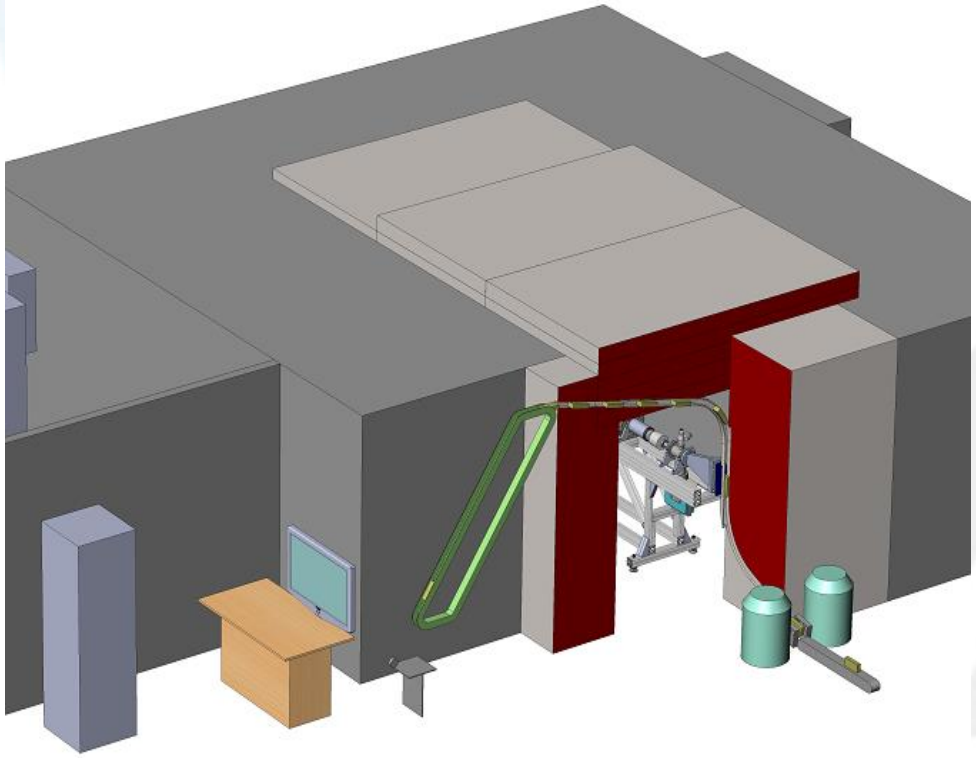
WE OFFER COMPACT GAMMA-ACTIVATION ASSAY SYSTEM FOR GOLD ORE ANALYSIS

“Au-Isomer”



Radiation shielding made from concrete and steel with dimensions:

8 x 7.5 x 2.7

The total installation area ~100 sq. m

Total power consumption: less 100 kW

Based on the estimated costs mining customers should be able to recover their investment in gamma activation ore assay system in less than two years!

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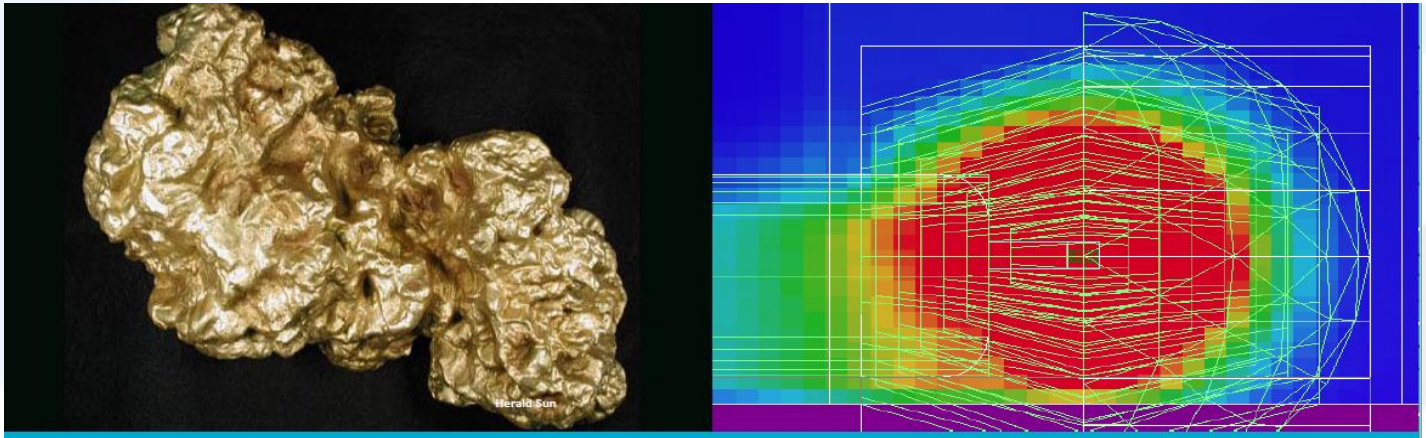
“Au-Isomer”

INDUSTRIAL GAMMA-ACTIVATION ASSAY SYSTEM FOR GOLD ORE ANALYSIS

Achievable results

Parameter	Value
Measurable elements (depending on system configuration, ore composition):	Au, Ag, As, Ba, Br, Cd, Er, Ge, Hf, Hg, In, Ir, Lu, Pb, Pt, Rh, Se, Sn, Th, U, Y, W,
Sample weight, grams	500-1000
X-ray source	7-9 MeV, 10 kW, Linear Electron Accelerator
Productivity of system for gold analysis (analyzed samples per hour)	120
Minimal detection sensitivity (for gold), g/t	(0,07 - 0,15)

Similar project of Commonwealth Scientific and Industrial Research Organisation (CSIRO) (Australia)



Designing an Industrial Facility for Assay of Gold and Other Elements in Mineral Samples using Gamma Activation Analysis

Chanel Tissot
Postdoctoral Fellow

James Tickner
Project Leader

Justin Delaney
PhD Student

ARPS 2016
13 September 2016

MINERAL RESOURCES – INTELLIGENT MINING
www.csiro.au

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CSIRO project

Goals and Capabilities

Develop a novel industrial-scale assay facility as an alternative to conventional methods

- Fully-automated assay system
  - 24/7 operation
  - ~1000 samples per day
  - ~$10-50 per sample
  - Assay in minutes
- Accurately assay range of samples
  - Non-uniform samples
  - Samples with low or varying concentration
- Non-destructive assay
  - Repeat measurements
  - Return of samples to customer
- Capability for “in field” or “on-site” analysis
  - Containerization: small and lightweight
  - Unit + shield must fit within a 20’ shipping container

Minimal operator intervention

Thank you for your attention!