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A Mine Site Laboratory from Exploration to Closure: A Case Study

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ABSTRACT: Chemical analysis is a vital scientific tool for the mining industry. The key role of the assay-analytical laboratory is to produce this information. At some stage, a decision has to be made to establish a laboratory on site, the earlier the better. The Çayeli on-site laboratory performed 734,707 determinations performed on 175,357 samples over 17 years of operation. Over the past 7 years, savings of USS 4.5m have been made over commercial laboratory rates. Analytical requirements and the feasibility of having an on-site laboratory are discussed, and a case study of Çayeli Bakir İşletmeleri A.S. (ÇBİ) on-site laboratory is presented İn this paper.

1 INTRODUCTION

In mining, from exploration to closure, quantitative measurements are essential. At different phases of project development there are different analytical requirements. In the exploration stages, the emphasis is on analysis of ore samples. At the feasibility base line, environmental analysis of air, soil and water will be needed as well as pilot plant concentrate and tailings measurements. During production, routine analysis of samples for grade control, plant operations and shipment are required as well as on-going environmental checks. At closure, and once the mine has shut down, environmental analysis will continue. The data required by the mining industry should be measurement based, scientifically approved and legally acceptable at all times.

Before creating a laboratory design, in order to fulfill all these requirements, certain criteria should be reviewed, such as: the number and size of the samples, the required determinations, acceptable turnaround time, the required minimum level of accuracy of the assay, and the importance of sample security. Capacity for future expansion İs also important.

Procedures for different purposes may vary and the type of laboratory changes accordingly. However, even in the short-term exploration stage (e.g., 2 years, with a capacity of 10 samples, 2 elements, per day), a mine site laboratory development is advisable and economically justifiable. In addition, access to consulting laboratory facilities is essential for checking, and some quality-control reference samples which represent die matrix of the material on site should be prepared and assayed by a number of independent reputable laboratories.

At Çayeli, the assay laboratory was established during the early stage of the feasibility study and it processed 7000 drill core samples (28,000 determinations) over a period of 3 years. It was expanded during the operation of the pilot plant and was further expanded and relocated when the mine came into production. In its present form, it was planned to process approximately 30,000 samples per year. In the Çayeli site laboratory, the cost per sample to analyse one element İs about US$ 3, which is about 15 % ofcommercial rates.

An on-site laboratory also introduces a high level of training and employment for local people in places remote from major cities.

2 MINING INDUSTRY AND ANALYTICAL SERVICES

2.1 *Necessity of data for a mine*

It is essential for any mining project to have realistic data in order to satisfy all financial and social partners and stakeholders and also, nowadays, the international community. During all stages of a mine's life, from exploration to post-mining, *the* close contact with these parties forces mining companies to identify concerns earlier than ever

before and to take necessary measures to deal with them.

The analytical results used by the mining company play an important part in decision making and strategy definition of the company in all phases of a project Therefore, those data should be objective and acceptable at all times. Realistic data can only be obtained by accurate and careful measurements. Correct monitoring, sampling and reliable chemical analysis are vital tools for mining.

2.2 *Analytical services*

Mining companies often perform the sampling and sample reduction themselves, but three options are available in terms of analytical services:

i. a commercial laboratory anywhere in the world,
ii. a contracting laboratory on or near the site,
iii. an on-site laboratory operated by the mine itself.

Before making a selection or a deciding upon a design, the mission of the laboratory should be determined using a checklist similar to the one presented in Table 1.

Table I. Checklist for design criteria for an analytical laboratory facility.

Order Itena to be examined	
1.	Clear definition of the information required
2	The purpose of the information
3.	Size and slate of the material to be sampled
4	Size and state of the gross sample
5.	Number, size and state of representative samples
6	Full chemical composition and physical properties of the gross material.
7	Sampling and sample preparation methods required
8.	Sample security and sample safety.
9	Anatytes to be determined in the final sample.
10	Concentration range of each analyte in the sample.
11.	Degree of accuracy required for each analyte
12	Detection and lower reporting limits.
13	Degree of quality control and assurance (QCQA)
14	Turnaround lime for each sample and analyte.
15.	Sample *archive/document archive requirement.*
16.	Future analytical needs - expansion flexibility.

An analytical procedure for an analyte is not applicable to all types of samples. The type of laboratory changes with the procedures. Once the design of a mining laboratory is settled, it has a major objective and therefore a scope. Any sample outside this scope should not enter that specific laboratory. This is for the security of the sample and also for the security of the samples İn the lab. For example, a laboratory dealing with rich sulphide minerals or sulphide mineral concentrates should not accept a sample for the analysis *of* trace heavy elements. The work outside the scope of this laboratory should be performed by other consulting laboratories.

In order to check the reliability of these laboratories, the mining company should introduce some reference-check samples and quality control - quality assurance measures for every group of work. There are commercially available certified reference samples. Initially these will be used. But these do not have the same matrix as the mine samples so, a mining laboratory must prepare its own internal reference samples from their own ores and carry out an inter-laboratory data correlation with the contribution of at least 10 different reputable consulting laboratories using different analytical techniques. Inter-laboratory correlation work should continue at intervals throughout the life of the project. A mining company, even though it might have its own laboratory, will continue to support commercial laboratories worldwide with a considerable amount of work in order to maintain the reliability of data.

2.3 *Feasibility of on-site laboratory*

Analytical works and their control are very intensive and should be under the strict control of the mining company. Therefore, it is better to have major jobs done on site. Cost, of course, is another concern. A comparison of site laboratory versus commercial laboratory costs during exploration and pilot plant operation is presented in Table 2. For this study, the site laboratory used to compile mis table analyses 10 samples per day for 2 elements using instrumental methods with a very high degree of accuracy and precision though, in fact, it would have a much higher capacity.

Table 2. Site lab versus commercial or contracting laboratory.

Cost Items	Site Lab. *	Contracting or Commercial Lab.
Sample Preparation	Included	USS 4-
Sample Archive	Included	extra charge
Sample Shipment	Included	US$2-
Number of Analytes	2	2
Assay Cost/Sample	USS 6.-	USS 20-40 **
No of Duplicates	All	1/10
No of Replicates	1/ 10	1/20
No of QC Samples	1/10	1 / 10
Cost - Check and QC Samples	Included	USS 20-40
Turnaround Time	<1 day	2 - 20 days'**
Work unit	10 samples	10 samples
Total Cost per Sample	US$6-	US$ 24 - 46
LAB. INVESTMENT		
Building (45 sq.m)	USS 25,000	No
Equipment and Lafa Ware	ÜSS 75,000	

* 250 days a year / 6 days a week / two shifts - *2* chemists, *6* technicians.
** Taken from quotations of various laboratories.
*** More Ihan 30 days observed.

Based on the model above, a mine site laboratory is economically and technically feasible and yields an internal rate of return (IRR) of 43%/year and a high net present value (NPV) for an initial investment of US$ 100,000 at an average assay cost of US$ 3 per element (Table 3).

Table 3. Feasibility of a site laboratory.

	Saving by use of Contracting Lab (24 USD / sample)	Saving by use of Commercial Lab (46 USD *I* sample)
Annual Cost Difference" (Saving)	US$45,000	USS 100.000
IRR (10 years, i = 12%)	43%	100%
NPV	USS 125,000	USS 386,000

* Saving = (Site Lab. - Contracting or Commercial Lab Facilities)

3 SITE LABORATORY OF ÇBİ

3.1 *History of lab development at Çayeli mine site*

The ÇBİ on-site laboratory was initially planned and developed in May 1984 to perform copper and zinc analysis on drill core and rock samples, at a rate of 10 samples per day, within error limits of 10% using an atomic absorption spectrometer (AAS). The staff consisted of one chemist and two technicians in an area of 45 square meters. After a short while, in 1985, as a result of growing demand for analytical services, the lab was extended to an area of 125 square meters to perform Cu, Zn, Pb, Fe, Ag and Cd determinations by AAS with 99% correlation witfi a capacity of 50 samples (i.e., 250 assays) per day. This capacity was achieved by addition of a rented AAS and a second ring mill pulveriser to the capital equipment, with a staff of two chemists and six technicians working in two shifts.

In 1992, during the site development stage, a new 300-square-metre assay laboratory was planned. The existing laboratory equipment was transferred to its final location with the addition of a second AAS, a portable energy dispersive XRay Fluorescence Spectrometer (XRF), a ring mill pulveriser and a jaw crusher in August 1994. The total investment of establishing the site laboratory was approximately US$ 600,000. The capacity of the present laboratory is timely and accurate (at 95% confidence level) analysis of 150 samples of various types per day on a routine basis, with a staff consisting of 4 chemists and 8 technicians working 7 days a week on two shifts.

At present, the laboratory is preparing to add the capacity to cany out classical methods for zinc and copper analysis on concentrate sales samples to the present instrumental methods. It is also researching the techniques for additional tests and analysis of environmental samples related to the closure plan and different ore geology studies. Splits of all samples that have been processed by the laboratory are in the sample archive and are accessible for inspection. Analytical services from outside laboratories are routed through, and the reports are checked by the on-site laboratory.

3.2 *Functions ofÇBİ on-site laboratory*

The main objective of the ÇBİ on-site laboratory is to perform sample preparation and quantitative analysis of: ore, mineral, mine and mill products, shipment samples, tailings, soil, sediments, plant, surface and underground water samples (Table 4).

Table 4. Main scope of ÇBI on-site laboratory.

Elements/ Analytes	LLD*	Lower Report Level	Method
Cu, Zn, Pb, Fe	1 ppm	001 %	Flame AAS
Ag	1 ppm	lOg/T	Flame AAS
Cd	1 ppm	lOg/T	Flame AAS
Au	1 ppm	O.IgH"	Extraction / Flame AAS
Cu Zn	001 %		Wei chemical / Classical

LLD = Lowrr Limit of Delecuon

The sample preparation facility of the lab consists of a heavy-duty drying oven and dryers, and weighing, sample splitting and size reduction equipment - Jones rifflers, a laboratory-type jaw crusher, a cone crusher, a disc mill pulveriser and 3 ring pulverisers, a dust extraction system and a sample storage and sample archive area.

In addition to routine assays of Cu, Zn, Pb, Fe, Ag, Cd and Au, the laboratory can perform tests and analysis of 11 other analytes ($CN\backslash$ $SO_4^{=}$, $SO_3^{=}$, SO_2, COD, pH, hardness, Ca**, Mg^{++}, NH_3, heavy metals). It can also test for ore oxidation, buffer capacity of rock and the quality of material like lime, xanthates and copper sulphate, using various analytical methods.

3.3 *Annual production figures*

In the 17 years since it started work, a total of 734,707 determinations have been performed on 175,357 various samples in the laboratory (Table 5).

The total cost of laboratory operation in die year 2000 was USS 383,500 (Table 6). Compared to commercial laboratory rates, savings of US$ 4.5 million have been achieved over the last 7 years of operation by having an on-site laboratory (Table 7).

Table 5. Production summary of Çayeli laboratory.

Year	No of Samples	No. of Determinations
1984	1,200	1,500
1985	1,700	3,000
1986	3,800	7,000
1987	700	5,000
1988	–	–
1989	2,600	9.000
1990	184	1,042
1991	708	2,108
1992	825	3,500
1993	1,580	6,575
1994	7,716	35,390
1995	22,358	93.973
1996	26,864	107,899
1997	26,862	111.306
1998	22,573	101,102
1999	27,506	123,295
3000	28,181	123,017
Total	175,357	734,707

Table 6. Cost of Çayeli lab operation - Year 2000

Cost Items	USS/year
Operating Salaries	256,000
Operating Material / Services	35,000
Power Consumption	40,000
Depreciation of Construction	20,000
Depreciation of Capital Equipment	20,500
Consulting Lab Costs	12,000
Annual Total Cost (Year 2000)	383,500

Table 7. Savings in last 7 years of Çayeli lab operations (since mill start-up) compared with commercial laboratories.

	USS
Estimated Commercial Lab Charges USS 44 rate per sample (4 elements)	7,130,640
On-site Lab Cost (7 x 383,500)	2,684,500
Saving over 7 years	4,446,140

3.4 *Reliability of analysis*

In order to maintain the reliability of the analysis done by the on-site laboratory, the following quality-control systems are employed in every operation and assay batch in a shift:

i. only certified calibration standards are used,
ii. internal reference samples are added to every batch,
ui. a blank sample is added to every batch,
iv. some samples from the p-evious day are re-read,
v. some settled survey - umpire lot samples are added to every batch,
vi. duplicate analyses at a rate of 10% are performed,
vii. all results are checked with another method,
viii. 5% of samples are re-assayed on another day,
ix. some dummy samples are sent to consulting laboratories,
x. some blind duplicate samples are included in every batch,
xi. certified reference samples are used,
xii. a good record of data and data analysis is maintained.

As a result of this intensive quality-control and assurance program, the assay results of the Çayeli on-site laboratory agree within relative error limits of 1 %, and a good correlation of data with the survey-umpire laboratories is maintained (Figures I-5).

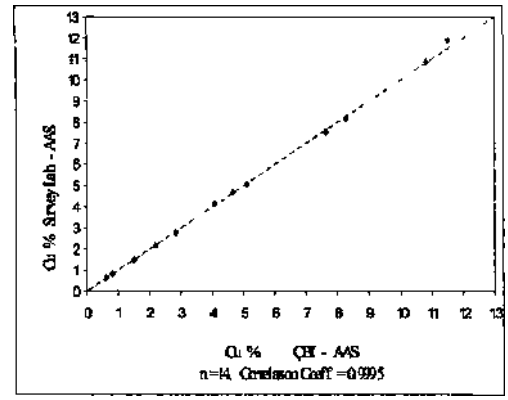


Figure 1. Copper assay correlation on ore samples - ÇBİ site lab versus surveyor laboratory (Nov. 2000).

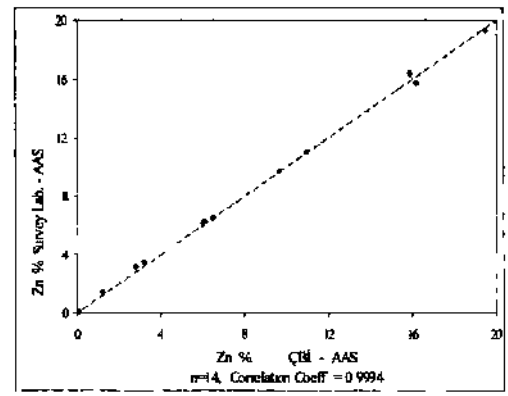
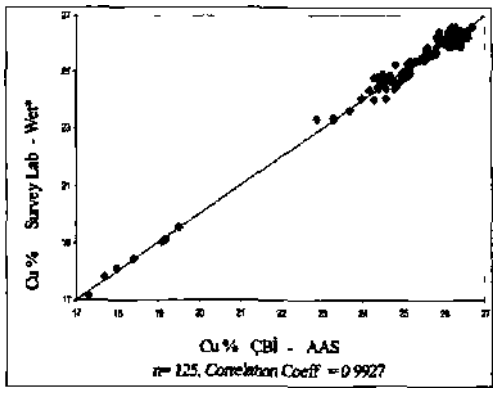


Figure 2. Zinc assay correlation on ore samples - ÇBI site lab versus surveyor laboratory (Nov. 2000).



* Wet = Wei chemical - Classical assay methods

Figure 3 Copper assay correlation on concentrate shipment samples (Year 2000)

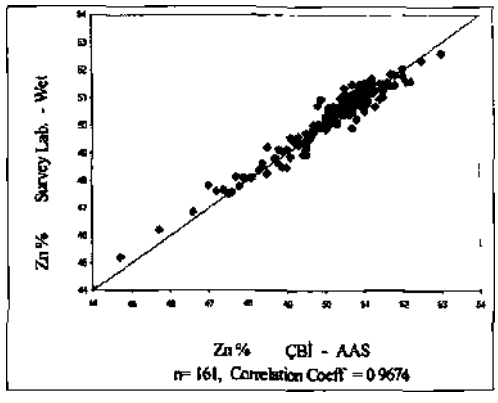
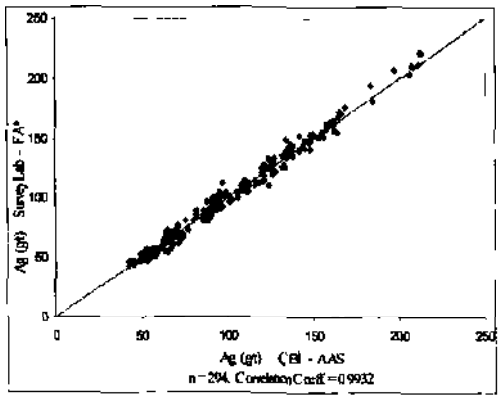


Figure 4 Zinc assay correlation on concentrate shipment samples (Year 2000)



FA = [ırc Assay

Figure 5. Silver assay correlation on concentrate shipment samples (Year 2000)

3.5 *Contribution to the community*

More than 15 workers previously employed in the agricultural sector and 10 chemists have been employed and trained for laboratory work in the 17-year period.

Training in basic chemistry, analytical laboratory work, on-the-job and off-site safety, industrial hygiene and health and environmental issues is a regular daily practice. This high level of training has significantly improved the lifestyle of the employees and their families.

4 CONCLUSIONS

Experience at Çayeli has shown that a mine site analytical laboratory has a very high rate of return on investment and makes a great contribution to the operation and the community. İt İs strongly advised that a laboratory be established early in the life of any mining project, particularly when it is in an area remote from major cities

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