Underground Mining of Metalliferous Deposits
Professor Bibhuti Bhusan Mandal
Department of Mining Engineering
Indian Institute of Technology, Kharagpur
Lecture 32
Sampling Practices

SAMPLING

Sampling is a scientific and selective process applied to a large mass or group (a population, as defined by the investigator) in order to reduce its bulk for interpretation purposes.

Often, the principal objective of sampling in mineral industry is to estimate, with a reasonable accuracy, the grade-tonnage relationship of a mineral inventory (the population by taking samples, reducing them in size without any loss of representative character of the sample and then analyzing them with high level precision).

TYPES OF SAMPLING FOR UNDERGROUND MINES

1. Exploration sampling
2. Development Sampling

FACTORS:

Major Factors to be considered in designing a sampling system for a mineral property :

(i) Objectives of sampling

(ii) Population to be sampled

(iii) Data to be collected

(iv) Choice of sampling unit to adequately represent the population

(v) Organization of field data

(vi) Cost involved

COMMON METHODS OF SAMPLING:

Sampling for mineral inventory estimation can be broadly divided into four types:

(i) Channel and chip sampling

(ii) Grab sampling

(iii) Drill hole sampling

(iv) Bulk sampling

APPLICABILITY OF SAMPLING METHODS:

(i) Channel and chip sampling:

- Used for face sampling.
- Most accepted method of sampling which is best suited to bedded, banded, and vein type of deposit.
  - Use for grade control, i.e. the regular monitoring of face grades in active stopes.

(ii) Grab sampling:

- Used for car or wagon sampling.
- To obtain preliminary idea about the nature and the grade of the deposit.

(iii) Drill hole sampling:

- To get core of the rocks from which gearing pressure of the ground can be found out.
- To define assay hanging walls and footwalls, together with the grade over mineable thicknesses, taking into account not only the mineralized zone, but also its potential dilution by low grade or barren material.

- To determine deposit boundaries. To extend existing reserves and attempt to prove new ore-zones accessible from existing underground development.

(iv) Bulk sampling:

- To enable estimation of reserves.
- To assess grades in complex deposits and also provide geological, geotechnical, and geo-metallurgical information.

CHANNEL SAMPLING in underground mines:

In channel sampling, by a diamond saw a groove of uniform width and depth (5-10 cm) is cut across the exposed ore, preferably in the direction normal to the direction of trend or stratification.

Before the sampling groove is cut, the surface is smoothened and, whenever practicable and desirable, a thin layer of the exposed ore is removed to avoid inclusion of weathered ore in the sample.

Efficiency of the sampling program depends heavily on the ability to cut neat, uniform and well-defined channel across the mineral exposure.

All the cuttings and dust from the channel are then carefully collected.

Normally, the channel is divided into sections of 1m to 2m for a massive deposit.

For a more homogeneous massive deposit, the sections may be greater in length, while for heterogeneous mineralization, the channel sections may be of 30 cm to 60 cm in length.

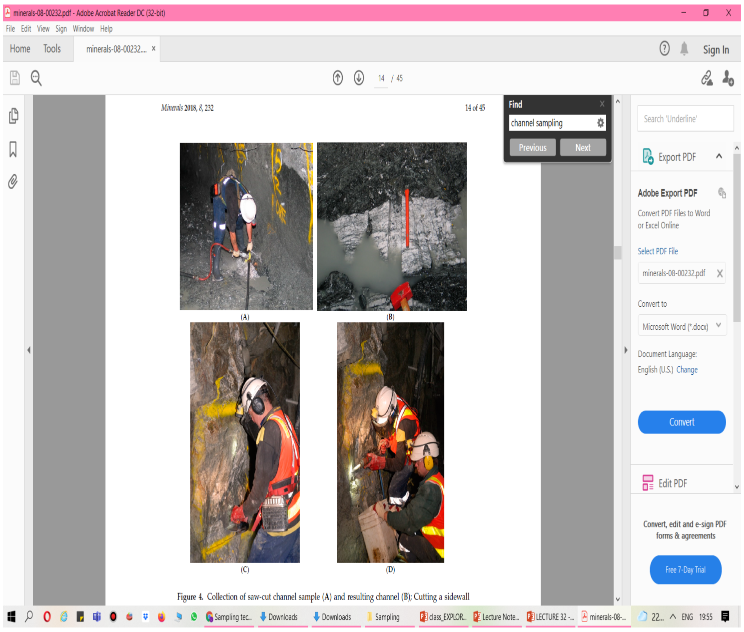

Fig 1: (A) Collection of saw-cut channel sample and (B)resulting channel ; (C) Cutting a sidewall channel sample and (D) using an air pick to remove the sample.

CHIP SAMPLING in underground mines:

In hard ore-bodies, it is often difficult to cut grooves of uniform dimension. Under such circumstances, if the mineralization is uniform, chip sampling is often used as a substitute for channel samples.

Chip sampling is carried out by breaking off small, equal-sized pieces uniformly distributed across the mineral zone.

Sampling bias observed in chip sampling is more than the bias normally observed in channel sampling under similar situation; in order to reduce bias, samples of equal size are taken from uniformly distributed grade points.

Depending on geology, the chip-band can be cut horizontally, vertically, or perpendicular to the dip of the ore body (Figure 2).

This technique involves taking a series of chips over a continuous or semi-continuous band using a hammer and chisel. When a series of discontinuous chips are collected, a series of punctual samples result which are effectively “specimens”.

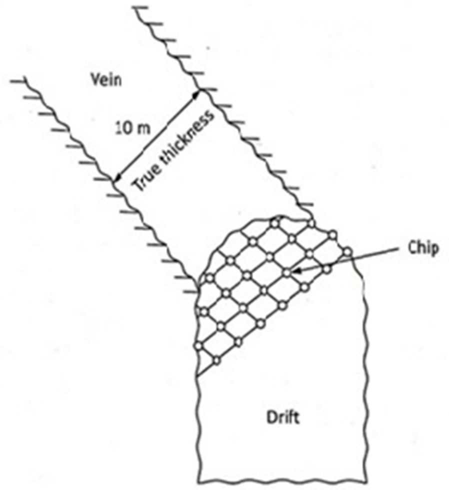

Fig 2: Chip Sampling.

Chip-Channel Sampling involves:

- Panel sample preparation as shown in figure 3(A).
- Large (100 kg) samples were required for metallurgical testing and grade verification.
- Collecting panel samples with hammer and chisel.
- Samples were chipped from the drive sidewalls onto a plastic floor sheet.
- Chip fragment size is reasonably well controlled, with a maximum fragment size of about 8 cm, and most below 5 cm.

GRAB SAMPLING in underground mines:

Geologists in some underground mines collect grab-samples from broken ore as a method of grade control. It is often known as muck or broken rock sampling.

Generally, the goal of grab sampling is to try and reconcile the mined grade at the ore source to the predicted head grade .

Additionally, the samples may be used to verify prior in situ estimates of grade such as those derived from face samples, sludge holes or diamond drilling.

It is often used because of access issues (e.g., non-entry stops), safety (e.g., to avoid unsupported backs) or lack of other sample data.

On surface, grab sampling is often used to monitor the grade of stock piles prior to blending and/or feeding to the plant.

Fig 4: Grab Sampling.

The quantity of material to be collected depends on the size of the largest pieces present in the material to be sampled and the degree of heterogeneity of the material.

The sample size is governed by the Richards-Chechette formula:

Q = $\boldsymbol{kd^2}$ $\boldsymbol{kd^2}$

where,

Q = the reliable weight of the worked down (also initial) sample in kg

d = the diameter of the largest particle in the sample in mm

k = a factor depending on the homogeneity of the mineral

The k factor is determined on the basis of the irregularity of distribution of the principal constituent of the ore.

Table 2: The values of k.

Homogeneous	**0.05**
Non- homogeneous	0.10
Very non- homogeneous	0.20-0.30
Extremely non- homogeneous	0.40-0.50

BULK SAMPLING in underground mines:

Bulk samples are used to assess grades in complex deposits and also provide geological, geotechnical, and geo-metallurgical information.

The term bulk sample is not rigorously defined, but can be taken as the collection of a series of large (often >1 tonne) samples across a mineralised zone for test work.

They are typically undertaken during pre-feasibility and feasibility studies and are seen as an insurance policy by verifying drill- or linear sample-based grade estimates and/or to support metallurgical pilot test work.

Bulk sampling is generally not relevant to routine grade control activities.

However, some high-nugget coarse-gold operations have collected micro-bulk samples (100–250 kg) via face panel sampling for grade control.

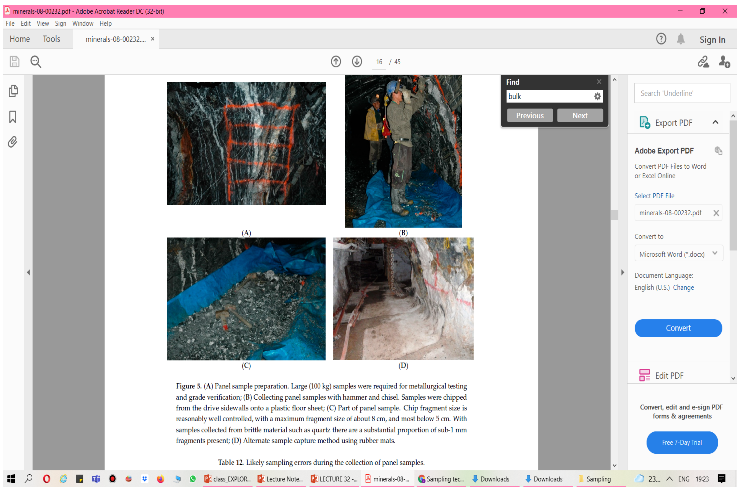

Fig 5: Micro-bulk samples (100kg).

DRILL SAMPLING in underground mines:

Whatever be the degree of meticulousness, with which chip, channel or muck sampling is undertaken, the campaign almost always exhibits low reliability, limiting the applicability of the methods.

Today, the mineral industry relies exclusively on drill hole sampling, whenever a reliable estimate of the mineral inventory is sought.

Two types of samples obtained from drilling:

i. solid core

ii. rock chip cutting in various degrees of fineness.

However, for Diamond-drill core (solid core) recovery of core may be poor in fractured, soft or friable formations. Under such circumstances, in addition to cores, drill sludge samples are also collected, that considerably adds to cost and effort.

Sludge Drilling:

- Sludge or blast-hole drill sampling involves using a jumbo, long-hole, or air-leg drills to create open holes and collect the cuttings in catchers or strategically placed containers.

- Sample mass can vary from 2 kg/m for air-leg drills up to 12 kg/m for long-hole rigs.
- Diamond-drill core is generally regarded as the most useful type of drill sample for analysis, visual inspection and testing.
- Diamond core drilling is relatively slow and costly. Chief advantages of diamond drill are mobility and flexibility.
- Diamond core samples are generally the highest quality samples that can be produced when core recovery is above 85%.
- Core can be oriented spatially in 3D for geological and rock mass characterisation.
- Coring in broken ground may require more expensive large-diameter core and triple-tube drilling techniques to achieve acceptable recoveries.

Sampling Method	Advantages	Disadvantages
CHANNEL SAMPLING	• Potentially a high quality sample • Can be quite quick to collect a saw-cut sample • Any reasonable number of samples can be collected, but will take more time than chip • Higher quality sample provides high accuracy	• Expensive • Slow to cut by hand, 30 min or more for 1 m sample • Labour intensive and can require compressed air saw
CHIP SAMPLING	• Suitable for hard ore-bodies • Can be collected with minimum preparation	• Generally low quality sample • Labour intensive

	• Any reasonable number of samples can be collected • relatively quick and cheap	• May lead to ore/waste misclassification
GRAB SAMPLING	• Relatively easy to undertake • Relatively quick and cheap	• Prone to numerous sampling errors • May lead to ore/waste misclassification
DRILL SAMPLING	• Diamond drill has high mobility and flexibility • High accuracy • Most reliable	• Diamond drill is relatively slow and expensive, which may pose some restrictions on close-spaced drilling. • Not suitable for fractured, soft and friable rock.
BULK SAMPLING	• It verifies drill- or linear sample-based grade estimates. • It assess grades in complex deposits. • It provides geological, geotechnical, and geo-metallurgical information.	• Not relevant to routine grade control activities.

Ex-1: Three groove samples cut at every 4^{th} blast in a Breast stope have 10 mm depth and 25 mm width each. The assay value × length of the samples are 1.03% Copper × L_1, 1.22%

Copper × L_2, and 0.92% Copper × L_3. Where, the lengths are 70cm, 75cm and 92 cm respectively. Calculate the average grade of the samples.

Solution: $L_1 = 70cm;\ \ L_2 = 75cm;\ L_3 = 92cm;\ \ A_1$

$L_1 = 70cm;\ \ L_2 = 75cm;\ L_3 = 92cm;\ \ A_1$ =1.03%;

$A_2 = 1.22\%;\ A_3 = 0.92\%;\ W_1 = W_2\ A_2 = 1.22\%;\ A_3 = 0.92\%;\ W_1 = W_2$ =

$W_3\ W_3$ = 2.5cm; $D_1\ D_1$ = $D_2\ D_2$ = $D_3\ D_3$ =1cm

$$Average\ grade = \frac{(L_1 \times W_1 \times D_1 \times A_1) + (L_2 \times W_2 \times D_2 \times A_2) + +(L_3 \times W_3 \times D_3 \times A_3)}{(L_1 \times W_1 \times D_1) + (L_2 \times W_2 \times D_2) + +(L_3 \times W_3 \times D_3)}$$

=

$$\frac{(70\times2.5\times1\times1.03) + (75\times2.5\times1\times1.22) + (92\times2.5\times1\times0.92)}{(70\times2.5\times1) + (75\times2.5\times1) + (92\times2.5\times1)}$$

$$\frac{(70\times2.5\times1\times1.03) + (75\times2.5\times1\times1.22) + (92\times2.5\times1\times0.92)}{(70\times2.5\times1) + (75\times2.5\times1) + (92\times2.5\times1)}$$

= 1.047%

Ex-2: In an underground mine, a sampling is carried out by using Grab Sampling method. The diameter of the largest particle in the sample is 5cm and the uniformity of the ore from which the samples are collected is non-homogeneous.

Calculate **(Q)** the reliable weight of the worked down (also initial) sample.

Solution:

We know that, the sample size is governed by the Richards-Chechette formula:

Q = $\boldsymbol{kd^2}\ \boldsymbol{kd^2}$

where,

Q = the reliable weight of the worked down (also initial) sample in kg

d = the diameter of the largest particle in the sample in mm

k = a factor depending on the homogeneity of the mineral

Given that, d = 5 cm = 50 mm

k = 0.10 (i.e., for non-homogeneous)

$$Q = 0.10 \times 50^2$$

$$= 250 \text{ kg}$$