DENSITY SAMPLING

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Introduction

Density determinations are physical measurements of samples of the rock in the mineral deposit. The most common sample type is a short piece of core from exploration holes on a property. Other sample types include blocks of rock collected at the surface, excavated surface (or underground mine) samples, rock chips, and powders.

This paper outlines some considerations to be aware of when conducting density measurements.

Sample Representivity

No matter what the type, samples chosen for density determinations must be representative of the material to be mined and selection of those samples can be difficult. In order to perform the determinations, core must be somewhat competent; in some deposits, the areas of interest are clay-rich or friable which limits the sample selection. Typically, this will lead to a selection bias because only the most competent, and least representative, samples are chosen for the determinations; these typically have a higher density than the more broken pieces, leading to a global overestimate of density for that rock type. In some cases, it is appropriate to adjust density data for this bias. In many cases, that factor can be determined by collecting surface or underground samples of similar material and comparing those data to drill core data. On one project that I am aware of, densities determined on core were adjusted downward by 2 to 9% to account for the selection bias based on mining experience.

Another problem is collecting samples that adequately represent the porosity of the in-situ material. This is particularly difficult when large, open fractures are present. Samples to be used for density determinations will most likely not have open fractures and analysis of those samples will result in a bias in the data that is rarely accounted for. The determined density may be biased high by 1–10% (possibly more) compared to the actual bulk density of rock, but for the most part, the bias is typically on the order of 1–3%. Geological observations are required identify rock units that carry this risk.

Some materials like wet saprolite or friable kimberlite are exceedingly difficult to sample and significant creativity is required. And, the answer is likely to be wrong. It is best to collect lots of data and use averages. The error will be minimized, but bias will not be removed. It may not be possible to effectively remove bias in wet saprolite or friable kimberlite.

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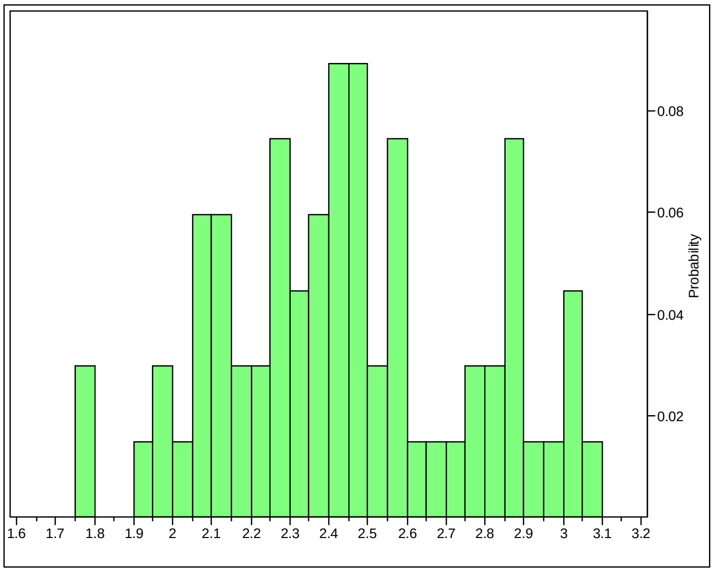
Number of Measurements Required

The number of measurements of density required for Mineral Resource estimation is also difficult to determine. In some deposit types, (e.g. potash, trona, etc.) density of the ore will be uniform over very large distances. Waste will be mined only until the ore is reached by shaft or ramp thus large numbers of waste rock densities are not necessary. Ore with uniform density will be mined from the time that it is intersected onward. A single sample may be adequate to estimate the density over much of the deposit. However, if only a single sample is collected, no estimate of the uncertainty of the measurement can be made. For that reason, it is desirable to collect at least three samples of each rock type, so that the uncertainty of the mean can be calculated. For major ore units like potash, the 95% confidence in the mean should be no larger than ±2.5% of the mean value (i.e. the 95% confidence interval is no larger than 5% of the mean value). Otherwise, the density is not known to three significant figures as it is usually stated (e.g. 3.01 g/cm^3 rather than 3.0 g/cm^3). In some cases, ore density is nearly constant over large distances and density is assumed to be the same for the entire deposit. Potash in Saskatchewan is an example where density of the potash ore is assumed to be 2.08 g/cm^3.

On the other end of the spectrum are skarn deposits which can have significant mineralogical and thus density changes over centimeter to meter ranges. Ideally, each assay would have a corresponding density determination. This is rarely necessary because density rarely varies as abruptly as grade does (but, skarns are sometimes an exception).

As a general rule, a minimum of 35 samples of each ore and waste type is needed to adequately characterize the density of each of the waste and ore types. This number of samples will produce a sufficiently narrow confidence interval and will also provide a reliable estimate of the mean. In addition, it may reveal multimodal density distributions in a particular rock type that need to be addressed by refining geologic observations to identify the sub-populations that have different average densities. Figure A shows data from a single ore type in an iron ore deposit. Two populations are obvious, one with an average density of 2.4–2.5 g/cm^3 and a second with an average density of about 2.9 g/cm^3. There may be two additional populations, one at about 2.05 g/cm^3 and another at 3.05 g/cm^3.

Figure A: Bimodal (Multimodal?) Density in Soft Ore from an Iron Ore Deposit



Note: units are g/cm^3

Sampling for density must provide good geographic coverage of the area of interest. Otherwise, a significant pocket of low- or high-density material may go undetected, and the local resource estimate will consequently suffer. Those samples must be collected from throughout the deposit.

This minimum is a guide and is only applicable to deposits where density changes little from rock type to rock type or from area to area. In many deposits, density changes are so commonplace that a systematic sampling program is required. Many projects collect a density sample on either side of each lithological change and at specified distances down holes (5 m or 10 m is common). This procedure will generally generate sufficient data to adequately estimate the densities for each ore and waste type. Waste rock densities must be estimated in order to adequately estimate the tonnage of waste to be moved. In some deposits, each assay must have an associated density determination in order to adequately model the density.

Saprolite deposits typically exhibit strong vertical trends and should be tested at 1–5 m intervals in every drill hole, if accurate local estimates of tonnage are required.

Density Models

Density models should be constructed whenever sufficient data are available. These models will more accurately represent the variation of density across the deposit than will models that assign average density rock (ore and waste) type or an average is used across the deposit. In some deposit types, such as potash, changes in density across the deposit are negligible; hence, no model is necessary. Others, saprolite deposits for example, have strong vertical density gradients and significant data are required to adequately account for the vertical gradient.