CORE DENSITY COMMENTS AND DISCUSSION

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Introduction

This paper summarizes some of the author's observations and comments on current industry practices as they relate to density determinations on core samples.

Sample Selection

Samples will be selected by individual core loggers while the core is being logged. Because the grade of material present in an interval is not known when the core is logged, samples will be collected based on the core loggers' identification of lithological boundaries. Sampling should begin near the collar of the hole and continue down the hole on 5–10 m intervals, respecting lithological boundaries. Shorter intervals are appropriate where complex ore-waste intervals or variable ore types are present. The length of the sample (along the centerline of the core) must be recorded along with the rock type involved.

There is some benefit in following a set of rules for selecting core pieces for density, such as the instruction that samples are collected every 5 m, respecting lithological boundaries. The benefit is that every time a sample location is moved, i.e., not on 5 m intervals, a reason can be logged, and this provides a gauge on the possible selection bias for a particular rock type. Numerous shifts in sample locations are a red flag for selection bias for a particular rock type.

Samples should be whole core between 15–20 cm in length, with shorter samples selected only when longer samples are not available.

Half-core is acceptable, but the smaller the sample, the larger the relative error.

Samples should be labeled and placed in a plastic bag by the core loggers. A tag or block must be placed in the core box to indicate where the sample was collected. That block should record the "from-to" interval, the reason for sampling and the ID of the person doing the sampling.

Sample Preparation

Samples should be carefully cleaned to remove any loose material attached to the core. This can be accomplished, for most samples, by placing the sample under running water and gently brushing the sample.

The sample should then be weighed and the "wet" mass recorded.

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The sample is then dried in an oven at temperatures no higher than 105^{o} ±5^{o}C. Higher temperatures can induce changes in the clay mineralogy and thus in the density of the rock in question. The samples should be dried for at least 12 hours or until dry to ensure that all water has been removed from pores in the sample. The most reliable drying method is to dry to constant weight. In this approach, the sample (usually while in the drying tray, which has a known weight) is weighed, returned to the drying oven, and after some time, weighed again. The process is repeated until there is no downward trend in the sample weight. Standards Association of Australia (1977a) and Standards Australia (2005a) discuss standard procedures for drying samples.

Note that some clay minerals lose hydration waters at temperatures below 50^{o}C with some significant losses above 75^{o}C. Loss of hydration water may involve volume changes so, clay-rich units should be carefully tested to determine whether, or not, drying at this temperature causes volume changes. If volume changes are apparent, the temperature should be reduced to 50^{o} C and the time increased. The sample must be dried to dry no matter what temperature is used.

Analytical Procedure

Analysis of the sample begins by weighing and recording the weight of the dry sample in air.

The sample is then dipped in a hot, molten wax of known density. Pure beeswax has a density of about 0.96; paraffin has a density of 0.4 to 0.9 depending on the source and specific composition. Wax is highly flammable, no open flames or sparks should be allowed within five meters of the container and the area should be ventilated and free of other flammable material, in case the wax ignites. A fire extinguisher should be kept within easy reach. It is best if the temperature of the molten wax is only a few degrees above its melting point. This will provide a thicker, more water-resistant coat, and less wax will soak into the rock sample. Also, the low temperature will ensure the wax solidifies rapidly when the sample is lifted out of the molten wax.

The weight of the waxed sample is then determined and recorded. This weight will allow the density of the sample to be adjusted to compensate for the weight and buoyancy of the wax. In the case of paraffin or thin films, the effect of the mass is usually negligible, but some published methods stipulate this correction and best practice is to do the correction. The sample is then weighed while completely submerged in water (but not in contact with the bottom or side of the water vessel) and the weight recorded. The temperature of the water should be recorded to correct for temperature variations. For cold water, this correction is also negligible. The density can then be calculated, correcting for the wax coating and temperature.

Exceptions

In cases where the ore is contained in intensely argillized, clay-rich zones and in extremely broken zones (rubble) that are not amenable to normal protocols, the following modifications to the protocol may be required.

Clay-Rich Zones

Clay-rich zones should be handled similarly to normal core protocols, but they cannot be dried prior to wax sealing and they are very fragile. The samples should be handled and cleaned gently; they will tend to disintegrate in water.

These samples should be weighed wet and then immediately sealed in wax to retain their water content and to allow the samples to be handled. The wet density should then be determined as above.

The sealed sample should then be opened and dried slowly at a temperature <35^{o}C to prevent melting and loss of wax which begins to melt at about 37^{o}C.

After the sample has dried, the weight should be determined and recorded. This will allow the wet density to be corrected to a dry density.

Broken or Rubble Zones

The density of broken (rubble) zones is extremely difficult to determine. A possible solution is to carefully measure the length of a broken zone and then weigh the core from that zone. This will allow for direct calculation of the density of the sample, but it is necessary to have 100% core recovery and a very accurate measurement of the length of the core. This may be accomplished by only using intervals between driller's blocks, but *there will always be uncertainty about the recovery.*

Alternatively, it is possible to determine an adjustment factor to use for this type of material when solid (unbroken) material is adjacent to broken (rubble) zones by determining the density of the solid material volumetrically (using a pycnometer or other method) and decreasing the density by the porosity determined by saturating the dried sample (assuming that it does not disintegrate in water).

Volumetric density determinations are performed by cleaning, drying, and weighing the sample followed by placing the sample in a container of water and very accurately measuring the volume of the water displaced by the sample. The density is then calculated by dividing the weight of the sample by the displaced volume of water.

This type of material is difficult to obtain robust density determinations from, and no procedure will produce completely reliable results.

If the material is exposed at the surface, the most reliable determinations will only be produced by large-scale (mine-scale) excavation techniques.

Vuggy Zones

Vuggy zones are common within ore zones and have distinctly lower bulk densities than the surrounding zones without vugs. These samples must be prepared somewhat differently than the non-vuggy samples.

This type of material will be prepared by first drying the sample and then sealing the sample with wide packaging tape before it is sealed in wax. The tape will ensure that the decreased density due to vugs will be accounted for in the final density determination. Density will then be determined using the coated immersion procedure.

Care must be used with this method because if the tape is too thin, it will deform when the sample is dipped in wax. If the tape is too thick, it will not faithfully follow the contour of the core. This is something of a last resort procedure that will provide useful, but not totally reliable data.

A better method, if the core is competent, is to carefully cut the ends of the samples perpendicular to the core axis, and then use calipers to measure the average length and diameter of the core. This method is generally more reliable than the than the tape and immersion method, but requires very competent core.

Additional Considerations

At the time of logging, geologists typically know very little about the details of metal distribution within mineralized zones.

It is possible that most of the metal is contained in very small parts of intervals or that it is evenly distributed within the interval.

The current industry best practice is that a full diameter core is used for the density determination, therefore, the samples are typically selected prior to assaying, and it is necessary to assay the sample after the density has been determined.

Wax can be removed from the sample by boiling the sample in water (tape can be difficult). The cleaned sample can then be assayed and the assay value proportioned back into the interval if it is substantially above or below the value determined for the interval.

Recorded sample and interval lengths are necessary to perform this calculation.