Mine vs Mill

I recently spent some time at a rather remote gold/silver project, working on some of our equipment and providing my wisdom as I often do, whether requested or not. While there, the staff were called to a conference call. Upon their return they were all shaking their heads as they had been attending a 'donkey barbeque' with the corporate group... to explain again why the mill grade did not match the mine grade, with the related apparent loss of production. The takeaway was:

A) There must be something wrong with the mill sampling or
B) with the assaying or
C) theft might be occurring at some point between the mine and the mill!

I mused for a moment about how little had changed in the time since I was in operations at a mine site. I can recall many years ago having a recurring annual dialog with the head of finance for a company I worked for as to why the stockpile did not contain the highest-grade ore. By his calculations, the mine had sent X tonnes into the stockpile at Y grams per tonne for a total of Z ounces, while the plant had only processed A tonnes at B grams per tonne for C ounces (C being substantially lower than Z of course.) That meant that those grams (Z-C) were in the stockpile, and that there was a stockpile full of juicy high-grade sitting there waiting to be tapped, right? Every year I had to explain how this was not so. Every year my explanation was received with glassy-eyed, blank stares, followed by the question "So why isn't it there?"

So here I go again, and this time I am going to try to show with simple examples WHY the mill grade will always be lower than the mine grade, even if sampling and assaying are performed without any errors. (If you don't get it this time, I'm not explaining again.)

Sampling in an open pit or in an underground is carried out using drills, with either cuttings or bits of core representing a volume of material that varies depending on drill hole spacing and depth. One can take as many duplicate cuts as you like, with replicates at every point of the sub sampling process, but it does not change the fact that one drill hole represents a certain number of tonnes. The grade that the assay lab reports for the mine sample is inserted into a brightly colored map with an array of other data indicating grade, tonnes, ore classification and other information of interest only to geologists (and Rainman). The grade of an area to be mined is calculated based on selective mining units, considered as the smallest number of holes represented on the brightly colored map with 'blocks', so they call it a block model. Geologists are a real hoot that way.

Process samples are taken on a time basis from crushed ore on a belt or from a slurry stream from the mill, or a combination of these. These represent material processed over time, and each cut is composited usually for a shift sample that will represent the grade for the tonnage processed during that shift. Lab nerds are assigned to go pick these samples up at the end of

each shift, which gives the operators a chance to relieve their boredom, and on occasion their bladder or bowels, by messing with the sample containers. I used to be one of those nerds and can tell you horror stories about what I have found in these buckets, bags, and bottles. The samples are processed at the same laboratory that analyzes the mine samples, placing the lab geeks directly in the line of fire between the Mine and the Plant, which means that they are treated something like the Balkan 'punching bag' countries were between the USSR and the West back in the day.

The financial officers, lifting their heads up on a monthly basis from their ledgers, and removing their green shaded visors, pulling up their sleeve bands, see the above as an opportunity to make yet another batch of numbers that have nothing much to do with each other fit into the same space. "Look here at these ounces and there at those!" they say, "These should be the same and should not oppose!" in their best Dr Seuss imitation. Then they realize that they only have 30 days until the next month end and go back into their caves or wherever they go to do whatever it is that they do to keep the haul trucks running and the mills turning.

So, to all those accountants and business majors I dedicate this little instructional note.

To illustrate that the mine grade will always be higher than the mill grade, we only need to look at the selection process in the mine, who are the ones in charge of what gets shipped to the Mill.

Let's consider that the selective mining unit mentioned above is a bowl, and that the bowl is filled with either pudding or sand. Not only that but the bowl is either 99% pudding 1% sand or 99% sand 1% pudding.

99% Sand/1% Pudding

99% Pudding/1% Sand

If we use a spoon to take a small sample from each bowl randomly there are 2 outcomes possible for each bowl – The sample could either contain sand or it could contain pudding. If the sample from the Sand/Pudding bowl contains sand, we send the bowl to the waste bin. But if the sample from the Sand/Pudding bowl happens to be taken where the 1% pudding is in the bowl then we send it to the kitchen. Similarly, if the sample from the Pudding/Sand bowl contains pudding then we send the bowl to the kitchen, but if it is taken from the 1% sand it, we send it to the waste bin. Assuming we always want to send the Pudding/Sand to the kitchen (we can take a bit of sand in our pudding) and the Sand/Pudding to the waste bin, we derive the following potential outcomes:

	To Waste Bin	To Kitchen
Pudding/Sand	Pudding Loss	Correct
Sand/Pudding	Correct	Pudding Dilution

As you can see from the chart, if the Pudding/Sand goes to the waste bin, we suffer Pudding Loss, and this never gets a chance to be seen by the kitchen staff. If the Sand/Pudding gets sent to the kitchen, we experience Pudding Dilution in the kitchen. From this you should be able to see that the only opportunity is for the big bowl of pudding made up of all the bowls sent to the kitchen to be of lower quality than the 99/1 pudding/sand that is desired as there will be a certain number of Sand/Pudding samples that get sent to the kitchen and will be mixed in with the Pudding/Sand. Although there are also Pudding/Sand samples that indicate the bowl contains waste, these are sent to the trash bin and are not available for the kitchen. Remember there is no human error in any of this. Sampling protocols have been followed properly with no mistakes.

In the same way as described above, selective mining units that are marked as ore, but are predominantly lower grade material or waste get sent to the mill feed and provide a lower grade when sampled at the mill than what is estimated from the mine samples. The mill samples have been crushed and somewhat blended through stockpiles and in the milling process. Since the selective mining units that are ore but are marked as waste never get to the mill, the only opportunity is for the mill to show a lower grade than the mine. There is no fault in the sampling in the mine, nor at the mill or assay lab.

In order to compensate for this effect, the Mill ore grade/Mine ore grade ratio must be monitored. This can then be tracked to determine what the inherent dilution factor is for the location. This should remain relatively constant over time. If there is a sudden change, this can be an indication of an actual case of human error, and the cause can be investigated.

So, the next time your financial types and accountants look up from their computers, show them this brief explanation. Then wait because I am guessing after they read it, they will ask once again “But why are the numbers not the same?”

Now let me finish my pudding. Or sand as it may turn out to be.

Tim Miller
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