Role of Applied Mineralogy in Mineral Processing

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I have worked in applied mineralogy and mineral dressing for a number of years and I will try to convey to you some of the benefits of doing the applied mineralogy in mineral dressing. I will also try to point out what should be done so that it can be useful.

In many cases, mineralogy has not really been directed to mineral dressing, and in such cases, it becomes more often a routine exercise to the mineralogist in identifying minerals, which is not particularly useful to mineral dressing.

I would like to diverge from that to some extent and I feel that, in designing a process plant for high recovery of minerals a thorough understanding of mineral charecteristics of an ore is necessary. With this view we have developed an approach to find out the mineralogical characteristics of an ore. In this approach, we considered the objectives of the ore-dressing operation and the objectives and capabilities that can be done in mineralogy. I like to consider the obiective of an ore-dressing operation is to concentrate particles of specific mineral and to obtain satisfactory grade and metal recoveries.

As to concentrate minerals, the mineral particles must either be free or contain only small amount of other minerals. To become free, the mineral must be liberated by reducing the size of the ore successfully, first in a crusher, then in a grinder and lastly in the ball mills often in close circuit with a cyclone.

The objective of applied mineralogy related to ore-dressing in this context is to provide guidance for grinding the ore and for concentrating the mineral particles of interest.

To this approach, first we need to study the uncrushed solid ore / hand specimen in order to predict what is likely to happen when an ore is ground, and then, we have to study the mineral particles of the mill products from selected points in the mill to assess what is actually happening.

In all our studies the first thing that we require is to identify all the minerals that are present in an ore. Identification of all the mineral species in an ore is necessary, because, in many cases, those minerals which appear insignificant and small in quantities may end up in a smelter and pose problem. After identifying all the minerals, we should determine their quantities and finally we should determine the size distribution of the minerals of interest in the uncrushed ore.

From the size distribution study, we get a general prediction of the minimum grind and optimum grind for the ore. So at the time when we deal with difficult ores, we can have an idea whether we have reached or have passed the point of over-grinding. To elaborate it, let us consider the case of sphalerite in a base metal ore. If we grind the ore to the size distribution of sphalerite obtained from our study on uncrushed ore, that is the minimum grind required to liberate most of the sphalerite as free grains, and should be able to recover about 90% of the free sphelerite with minor quantities of unliberated grains. So the metal recovery that we can expect in bench flotation test at the minimum grind is nearly around 65%. If we grind the ore to finer mesh size, the increase in liberation will be very little besides producing large amount of slimes, and hence it is

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not economical to grind the ore any further. All the above predictions can be made from our studies on uncrushed ore. Although it is not a precise value it gives valuable preliminary information.

Having performed preliminary study on the uncrushed ore, the next step is to study the mineralogy of the mill products to evaluate the actual response of the ore to ore-dressing. The mineralogical evaluation also gives us an opportunity to assess the performance of a plant. It also helps us to establish whether any modifications are necessary or not.

To evaluate the actual response of an ore to ore-dressing, we need to study the mineralogy of a set of samples viz the feed, concentrate and the tailings. In each of these, we have to identify the mineral species, their percentages and, the percentage of free and unliberated grains. It is also necessary to characterise the unliberated grains and also their size distribution.

As a first step of approach we determine the percentage of minerals that are present as free grains and those of which remain as locked particles in the polished sections of different sized fractions of the feed sample obtained just after the ore is ground and before any flotation test is done on the sample. From the percentages of the free grains and their size distribution data, we may find out the optimum grind. It is therefore another check on the data obtained from the study of solid ore as well on grindability.

After determining the grind when we identify and quantify mineral percentages in the concentrate, middlings and tailings, we perform a material balance study.

Before we do any evaluation we should know a little bit about how the ores behave in a treatment plant.

We have studied a series of zinc concentrates from six different concentrators in Canada to see how much recovery we get in the concentrators from the ore. From our mineralogical study we found that when the size of the grains are smaller than 100 microns the recovery was about over 90% zinc in all the concentrators. As the size had gone down below 10 microns the recovery in most of the cases was fairly satisfactory. But the recovery in the case of 2 micrometer sphalerite was something of the order of 70% and for 1 micrometer it was about 50%. The sliming effect was found to come in within 1 to 3 micrometers range of sphalerite.

That was a test to determine the recovery of free grains. If the plant is operating properly, it is designed to concentrate free grains. Therefore, the way to test it is to look how it recovers free grains. We cannot look it from analysis point of view; we have to do the mineralogy. So what we have to do is to measure the free grains and to determine their recovery.

In order to evaluate the performance of a circuit, we have to study how the ore has responded to that process and also see whether there is anything wrong with the circuit. As all the concentrators we are discussing are zinc concentrators which are expected to recover free sphalerite, the way we did this—we determined the quantity of free sphalerite at each grain size and then we added up all the percentages of free sphalerite in the feed sample. Then the percentages of free sphalerite is plotted against the size on a log linear scale at an equal interval. By plotting at an equal interval we get a relative amount of sphalerite in each size range. The area under the curve thus plotted for the feed and the concentrates are proportional to the amount of free sphalerite grains present in the feed and the concentrates. In case of base metal ores where we get several products, there it helps to know how much free sphalerite is going in the middlings and how much we are losing in the tailings.

Out of the six zinc concentrators, one was found to recover 95% of free sphalerite that was in the feed and the other could recover only about 75%. The reason for this low recovery was mainly due to large amount of sphalerite was found still to be unliberated and some of these unliberated grains were recovered in the concentrate and a large amount was lost in the tailing. Examining the tailing, we found that the size of sphalerite going in the tailing is larger than 10 micrometres and went upto 100 micrometres, which was the size of the free sphalerite recovered in the concentrate. Therefore, to improve their recovery it could be recommended to regrind the middling portion. Based on this, a series of pilot plant trials were carried out and we found that this was in fact so and when we calculated the value of the improved recovery it was found to be about 3 million dollars.

That was the type of information we can obtain from the study of free grains. It is quite evident that there may be some middling grains, i.e. locked particles. In such case we need to classify them i.e. what type of locked particles they are and also how much they are present in the sample. We classify them into several groups on the proportion of valuable mineral to that of the gangue. We call the particles with 80—90% group, i.e. the particle which contains 80—90% valuable mineral, as free mineral, and we have found particles with 65% and above valuable mineral generally and up in the concentrate, whereas particle with 30% and less valuable mineral generally go in the tailing. So far I have discussed about the type of information that we should be looking for and the type of analysis we should perform in this as the type of result we can expect.

Now I will tell you about the set up we have in our mineralogical laboratory to obtain this information. In our laboratory over the years of experience we have found that image analysis system is very good for obtaining liberation information on free and unliberated grains. We have an image analysis system using an optical microscope in the begining, but we have found that the optical microscope has some drawbacks to identify some minerals. So we wanted an automatic system with image analyser capable to identify the minerals. We therefore placed a scanning electron microscope at front end to produce an image. We have a E.D.X. image analyser and an energy dispersive X-ray analyser. The energy dispersive X-ray analyser is used to identify/determine the composition of a mineral particle.

The image analyser has two screens. When we place a polished section to the scanning electron microscope, the image that we get on its screen is transfered to the screen of the image analyser. We can collect any image, but we use electron back-scattered image. Electron back-scattered image is useful because in this image minerals that have elements with low atomic number appear dark grey and those with higher atomic number become quite light grey to white. We have control as settings, i. e., threshold settings, to adjust two families of grains. Therefore when we get images on the screen of the image analyser we find a number of grey levels based on the compositions of the minerals. We can steer the beam to a particular grain and identify it by its composition on energy dispersive X-ray analyser. In about 15 minutes we can identify minerals of every grey level.

To quantify the minerals, we use 14 computer memories attached to our system. We feed optical image into one memory. Then we take out every grey level and then put them into different memories for analysis. We can determine the size distribution and percentage of each mineral. When two fall in the same grey level then we can analyse the grain, one by one by transfering the image on the image analyser on to the scanning electron microscope. There we steer the beam to scan the particle as the spectrum thus obtained is fed to the energy dispersive system to identify the mineral. The spectrum is compared to a mineralogy file and the mineral is identified. Our system is capable to analyse about 50 to 100 grains per minute along with other properties.