THE INFLUENCE OF ROCK TEXTURE ON MINERAL PROCESSING

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INTRODUCTION

Developers and operators of mining and mineral processing operations face constant challenges to become more efficient, but are faced with increasingly complex ore bodies. This complexity is characterised by multiple mineralisation events, leading to variation in ore types. This inconsistency can often be explained by changes in the ore texture, or the relationship between minerals present in the ore. Understanding the ore texture can be a very useful tool in developing a process flowsheet or optimising an existing circuit. For complex ore bodies with multiple ore textures this understanding becomes essential to manage the variability through blending or optimisation of process conditions.

The texture of an ore domain can be an important influence on plant efficiency, grade and recovery, and operational economics. Given the challenges of todays processing operations to reduce costs, improve recovery and produce a higher quality final product, it is no longer good enough for operations to simply track and base decisions on grade alone. This ever increasing ore body complexity demands that the information we access for decision making must in turn become increasingly more comprehensive if operations are to succeeded.

WHAT IS ORE TEXTURE?

The term ‘ore texture’ can be defined in a number of different ways depending on the context of it’s use. In the context of mineral processing the geometallurgical definition of texture simply refers to the relationship between the minerals of which a rock is composed (Wikipedia definition). It includes the size, shape, distribution and association of the mineral grains in the rock.
Understanding the geology and history of an ore will help unravel the complex nature of the textures that may be encountered, and help predict how and ore will behave, during processing.

All textures, including crystallinity, grain boundary relations, grain orientations, fractures, veinlets etc have a bearing on processing ores, but the sizes of the mineral grains, and the bonding between the grains are the main characteristics that influence ore breakage and mineral liberation (Petruk 2000).

Defining ores based on texture allows for a more sophisticated mine plan than the traditional reliance on grade variation. When considering grade alone two ore types may be found to have the same grade; however, there is nothing to suggest these two ores will have the same processing characteristics. One may contain very finely disseminated target minerals associated with deleterious minerals, whilst the other may be coarse grained and easily liberated. Conversely, two ore types with different grades may well have very similar, or even complimentary processing characteristics.

**WHY IS TEXTURE IMPORTANT?**

The ore texture is a fundamental parameter in defining the most appropriate process flowsheet for a given resource. Understanding the texture and variations in textural characteristics between ore domains can be the driving factor in whether an operation is sustainably economic or fails to achieve planned potential.

The texture of an ore will define the:

- grain size distribution(s) and target grind size;
- grindability of the ore;
- degree of liberation of the target mineral(s);
- phase specific surface area of the target mineral(s);
- amount of fines;
- number of coarse composite particles.

These factors will have a major influence throughout an operation, from mining strategy through to blending, processing, target grade and recovery, and tailings management.

**THE FORMATION AND CLASSIFICATION OF TEXTURE**

Various attempts have been made to classify ore textures with specific reference to their influence on the processing characteristics of an ore, with the earliest of these made by (Amstutz 1961).

Butcher (2010) presents two broad classes of texture by describing the size distribution of minerals in a rock as either equigranular (grains of similar size) or inequigranular (grains with different size distributions). This description can be used to describe the size distribution of a particular mineral, which may have grains that are all of a similar size, or have grains with several size distributions. Subsequent alteration of the rock will then overprint any existing textures. Figure 1 builds on the broad classifications made by Butcher (2010), by showing how ground water and
oxidation can result in rims and altered surfaces on ore grains, and how hydrothermal alteration and metamorphism can further change the texture.

Figure 1. Example of textural changes due to oxidation and deformation, from (Butcher 2010)

To expand on this further, it may be that the element of interest is distributed across multiple minerals, each potentially with different size distributions. By way of example, Evans (2010) highlights how copper deportment may be across multiple primary and secondary Cu-minerals (Figure 2).

Figure 2. Example of how copper may deportment across multiple minerals and therefore present an inequigranular texture for the Cu-minerals (Evans 2010).
DEFINITIONS AND TERMINOLOGY

GRAINS AND PARTICLES

In this paper, a “grain” is classed as a single mineral, whilst a “particle” is made up of one or more mineral grains. Figure 3 provides an example of a single “particle” that contains four mineral “grains”.

![Figure 3. Example of a “particle” (white and black areas) containing four mineral “grains” (black)](image)

HOW TEXTURE INFLUENCES GRADE AND RECOVERY

Texture of particles plays a pivotal role in both mineral recovery and grade in the concentrate. Theoretical curves can be generated based on the mineralogy and texture to indicate the maximum grade-recovery possible for a given feed ore at a defined particle size distribution (PSD), and if the actual concentrate plots below this curve (as inevitably happens) this is either a result of feed texture and mineralogy, or the operating conditions of the process (Figure 4). A fundamental limit is set by this theoretical grade-recovery curve; no amount of changes to plant conditions (reagents, pH, acid strength, time etc) will improve the grade-recovery beyond this curve due to the physical limitation set by the texture of the feed ore (and in particular liberation and surface area). To improve this theoretical grade-recovery curve, changes need to be made to the feed; for example by increasing liberation or free surface area, or reducing fines.
Figure 4. (A) Ore texture defines the theoretical grade recovery curve. Particle images are used to show how high target mineral recovery will typically also mean some recovery of gangue, reducing the grade. (B) If actual grade/recovery is less than the theoretical, then changes to operational conditions may improve this (1). If grade/recovery above the theoretical curve is required, then the texture of the feed will need to change (2), for example by increasing liberation of composite particles such as those shown in (A).

Texture will strongly define the grade and recovery potential, and therefore the quantity and quality of the final product. By way of example, in iron ore the tailings are often found to contain minerals like iron silicates. When a total iron assay is done, these show up as iron in the tailings and make the plant take a hit on iron recovery. The truth of the matter is however, that no matter how fine you grind these silicates or how hard you treat them with conventional means, the iron will not liberate and grade will be diminished by their presence. In short, this iron just isn’t worth going after, and a lower recovery has to be accepted so as not to end up with an unacceptable grade. It is therefore essential to understand the texture in order to be able to decide what this cut off point is, and manage the associated risks.

**HOW TEXTURE IS CLASSIFIED: LIBERATION AND FREE SURFACE AREA**

Liberation measurements estimate the volumetric grade distribution of a mineral as a measure of the quality in a processing stream (Spencer & Sutherland 2000). Put simply, it is based on the area % of the mineral grain in the particle. The degree of liberation of a mineral is generally calculated from examining 2D sections of a statistically representative set of particles containing the mineral of interest (although 3D estimates are possible) (Figure 5). Particles are usually classed in to particle grades of various incremental steps: these steps might be 10% increments (100% liberated, 90-100% liberated, 80-90% liberated etc), or as broader 30% steps such as <30% (locked), 30-60% (middlings) and >60% (liberated).
This calculation of ‘liberation’ is distinctly different to an estimate of the free surface area (or PSSA - phase specific surface area) of a mineral in a particle. The free surface area is again typically based calculations from examining 2D sections of a statistically representative set of particles, however as the name suggests it is an estimate of the % of the grain(s) of interest that has a free surface, and therefore have a surface accessible by bubbles in a flotation cell, or acid on a heap leach pad for example (Figure 6).

Figure 7 shows the same example particles containing ore mineral grains classified by both liberation % and free surface area %. These examples serve to highlight the influence of particle and mineral texture for grade and recovery calculations, and how critical it is to understand both degree of liberation and the free surface area. Both these textural classifications are critical for mineral processing, with the ideal particle of course having 100% liberation (and therefore by inference, 100% free surface area).

Figure 5. Example particles showing ore mineral liberation at 100%, 75%, 50% and 25% by area
Figure 6. Same example particles as above, but classified by % free surface area.

Figure 7. Same example particles classified by liberation and free surface area.
SUMMARY

Rock and mineral texture play an integral role all the way through the mine-to-metal process; from the way a rock will fragment when blasted, through comminution, to recovery and tailings management; regardless of the recovery process used. In summary:

• Grade alone is not enough to track how a rock will process. The texture of the rock must also be understood and monitored.
• Mineral grain size distribution may be:
  o Equigranular, with the ore and gangue minerals having similar size distributions
  o Inequigranular, with the ore and/or gangue minerals with different size distributions
• Metal distribution may be across multiple minerals, each with their own size distributions, alteration types, and associations
• Formation of-, and/or alteration events post- deposit formation will influence the textural complexity.
• Understanding these factors will help guide metallurgical test work, flowsheet design, mine planning and metal recovery optimisation
• Both liberation and free surface area should be considered when examining a feed ore
• Understanding the mineralogy and it’s texture will allow development of a theoretical grade-recovery curve, setting the upper limit for recovery with a certain concentrate grade. Overlaying this on actual grade recovery results will help interpret these, and identify potential improvements or fundamental limitations for that feed material
• Improving grade-recovery beyond this theoretical curve requires a change to the feed up-stream of the circuit being examined (e.g. in milling or blending strategy)

REFERENCES


Evans, CL 2010, ‘Development of a methodology to estimate flotation separability from ore microtexture’.


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