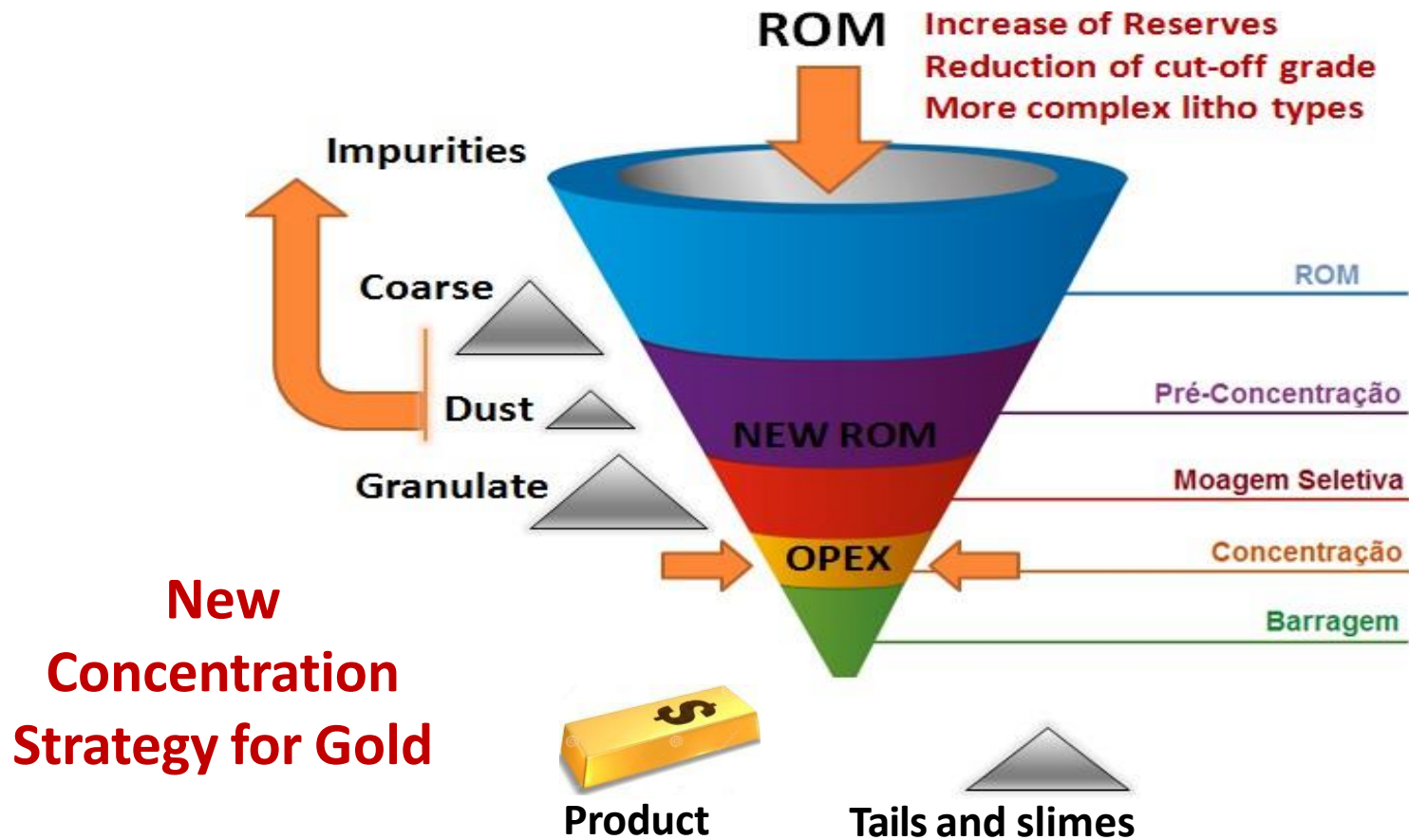


SELECTIVE CONCENTRATION



Abstract

MOPE proposes a shift in focus looking the significant losses of competitiveness of the mining of gold, which are, among others: decreased content and volume of reserves; spread of small deposits; high energy costs; lack of water; Logistical problems; environmental restrictions and lower commodity prices. The option in these last 40 years has been by the gigantism, favoring large equipment manufacturers and harming the environment with excess waste..

In this presentation is discussed and also questioned the gold ore concentration strategy (the part relating to the mechanical processing) that has been followed over the past 40 years, including examples of Chile and Brazil. Are exposed the current problems and MOPE proposed a new technical solution. The diagnosis and the possible solution here indicated, in general, is applicable to various types of ore, not just gold.

The Problem

Trough a insufficient characterization, supported by very theoretical and unrepresentative criteria (such as W_i , T10, P80, head content and others) has been lost the ability to understand the ore (and his gangue) who lives in the deposit and of what this ore expressed when properly fragmented. Along with that, has been lost touch between the geological reality of deposit and the unit operations that are used in their treatment.

Frequently the ores are not treated at the way they needs. There is a misconception when we think that any rock that is removed from the mine should be obligatory sending to the Concentration plant.

The problems identified herein are for almost all types of ore, and not only gold, that's suffering reduction in metallic content and possibly increasing the hardness.



Some Consequences

Although with a highest market price, the mining of gold has a much more serious problems that mining of copper, looking to the rising costs, the fall of gold content, the rising price of energy and the environmental problems. In copper, the plant kills an elephant for to take from this a flea (the elephant's body goes to the dam). But, the gold ore, should get a bacterium that lives in the flea and must kill both: the elephant and the flea, and sending both bodies to the dam in the form of ultrathin waste with cyanide remains.



The fall in gold content has been very serious than in the case of copper in various operations known. Only the best price of gold in the market is that it has allowed confront this challenge by increasing the rate of treatment and costs, but there comes a time that is not more possible. Some mines are sacrificing their cut-off content to maintain high levels of head, and be losing its bookings. Some major projects have been stalled by environmental restrictions.

Fragmentation of the Ore

There are several ways to apply energy to break an ore and, when it is relatively heterogeneous, the best force to be applied is the impact. In laboratory scale is used hammer mill and, at industrial projects, it is recommended the VSI crusher type, Barmac (Metso) or similar. The grinding step that follows receive a more friable ore, suitable for less intensive forces of comminution, consuming less energy.

Many would be surprised if they knew the potential that the ore offers when it is well fragmented and also how are simples and quick the tests that prove so. After a good fragmentation there are huge chances to pre-concentrating the ore, at "dry", thus raising the gold content before proceeding to the plant. Unfortunately this practice is not very common.

MOPE established experimental procedures in agreements with laboratories in Chile and in Brazil



OPPORTUNITY SURVEY

OPERATING PLANTS

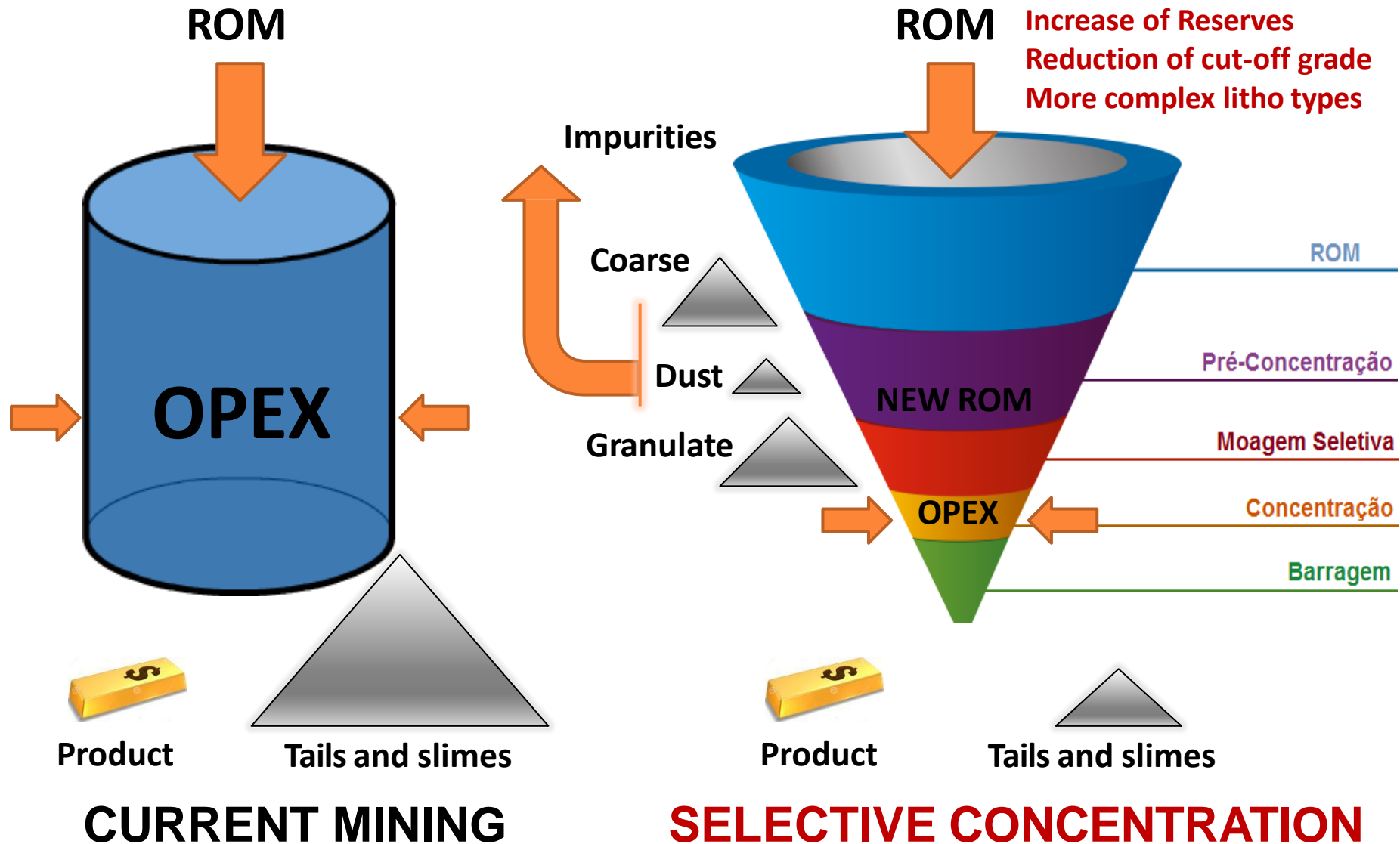
Assess fragmentation and liberation by sizes;
Check quality of products and tailings;
Improve metallurgical and mass recovery;
Flowchart simplification;
Separation into operational groups;
Control of operation / process management;
Advanced Control Systems



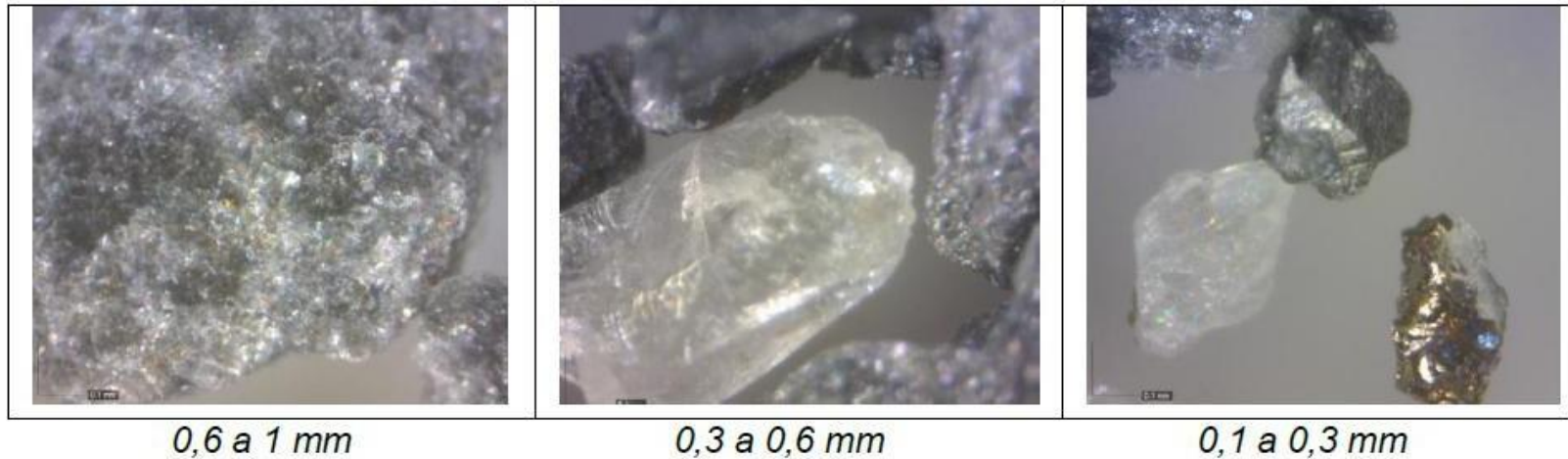
INVESTMENT PROJECTS

Fragmentation and characterization tests;
Selective grinding and pre-concentration tests;
Optimized process route;
CAPEX and OPEX;
Sizing of equipment;
Trade off studies;
Conceptual Engineering

THE CONCEPT BEHIND THE SOLUTION



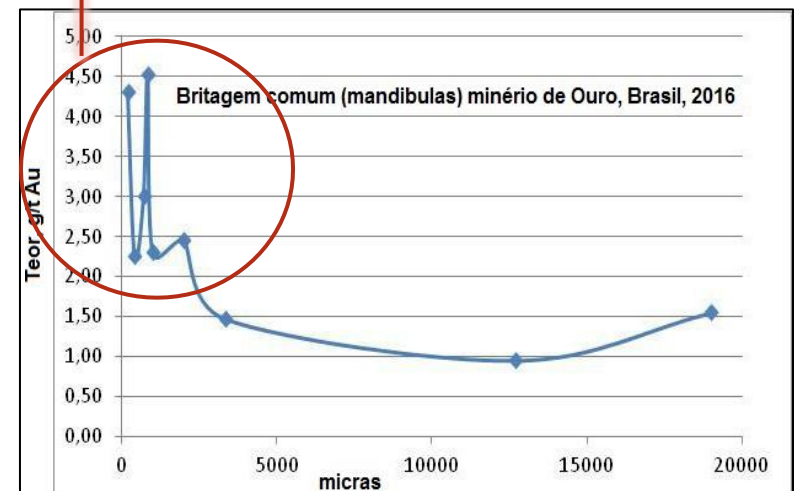
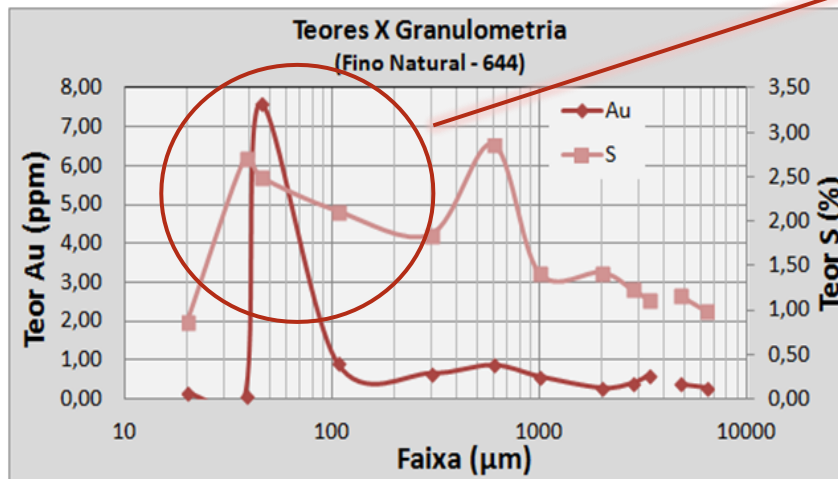
WHAT THE ORE INDICATES?



There is enough
fragmentation and liberation?

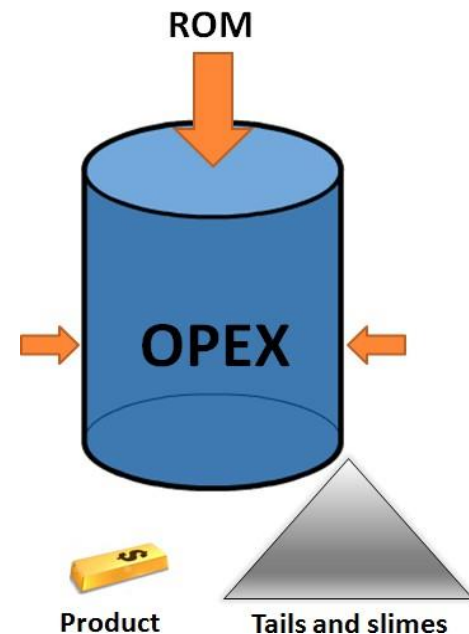
Liberação do minério

Where gold really is situated?



Wrong comminution

The SAG mill technology is showing its historical errors, both by the misguided strategy of using an expensive grinding equipment to run a simple crushing - with 4 or 5 times less energy, such as by the fact - also wrong - of want to drive all the ore to a certain size, without questioning their heterogeneity. This applies to the entire universe of the Mining.



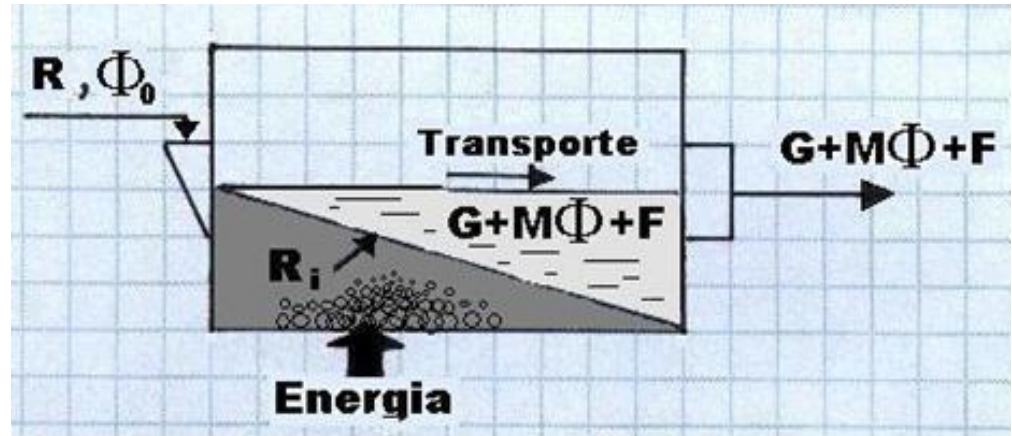
Wrong comminution (cont.)

To try to mitigate the mistake to have deployed a SAG mill, some plants includes secondary crushers in the SAG feeding or put crushers for the recycled pebbles, also some try to use more explosives in the mine to maximize fragmentation. That is, they has done everything to defend a wrong decision, even spending more money. Some new projects have observed this, and then extirpated the SAG mill from its original design (there are several cases in Brazil for various types of ore), but there are some projects who, without understanding the concept of selectivity in comminution, have changed the SAG by other also inadequate equipment such as HPGR, which is suitable for homogeneous ore, where there is no selectivity in fragmentation.

The history of the ore processing in these last 40 years, has followed global waves that led to mining for construction projects of increasing size, with higher CAPEX and OPEX, supported only by the good market prices. This phase finished!.

SELECTIVE GRINDING

The ore itself helps to control its comminution by externalizing peculiarities along with the release of the minerals inserted in the rock, and these peculiarities must be exploited in favor of the selectivity and the lower costs.



From Book: "Engenharia da Cominuição e Moagem em Moinhos Tubulares" (A. Yovanovic, Brasil, 2006)

CONCEPT

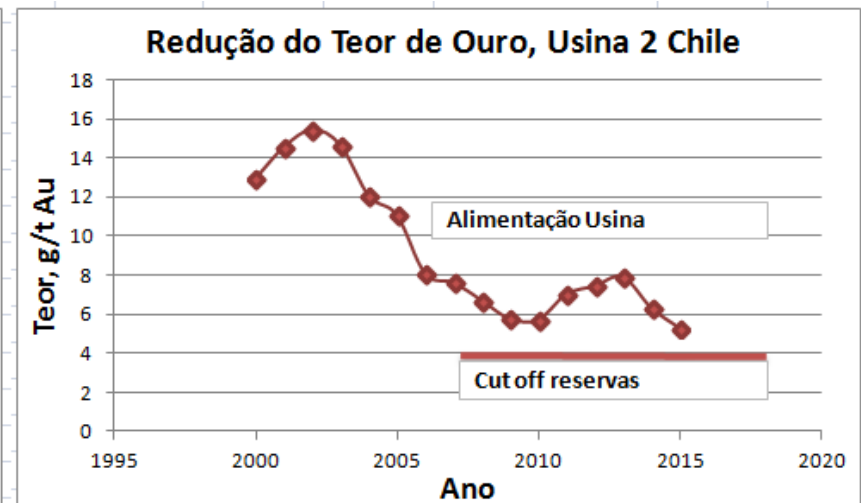
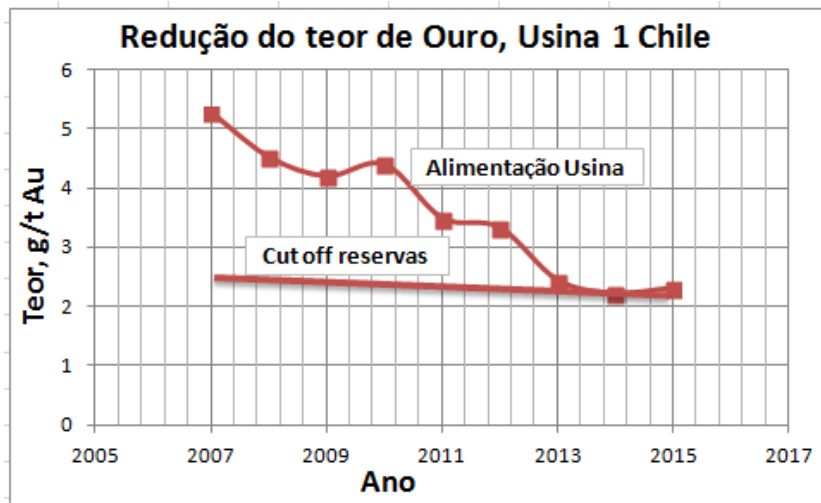
Within the mill, the larger and / or heavier particles will be sedimented, and being preferentially ground, that is, in a "selective" way.

Mineral	Gravidade Específica
Ganga	2,8
Willemita	3,9 – 4,2
Hematita/Goethita	5,3
Sulfetos*	5,0 – 7,0



The significant reduction of gold content

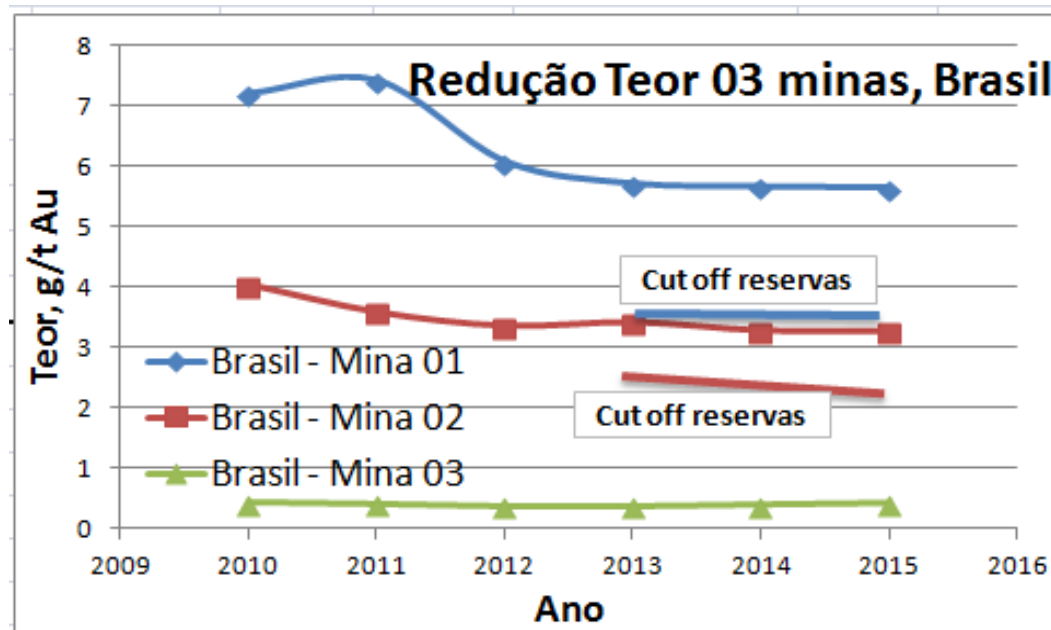
As with any mineral type, over time, the tendency is to reduce the size of deposits and, if nothing is done, also is reduced the ore content that feeding the concentrating plants. This reduction also affects the reserves, while maintaining high "cut-off" grade to mitigate the effect of reduction of the ore content in plant, and also, through the expansion of production facilities to treat more mass to produce the same amount of metallic gold. That is, going to rising the cost and with lower productivity, even with a great deal of capital to afford the expansion of concentrating units.



The fall of gold content in two Chilean plants

The significant reduction of gold content (cont.)

The level of gold content reduction in Brazilian deposits has not been as dramatic as in the Chilean case, although the trend for the near future is inevitable. In the case of the plant 02, there is much similarity between the cut-off grade with the gold content that feeds the plant. The mine 03 operates with one of the lowest gold content in the world, and so far has managed to be competitive thanks to the huge scale of production..

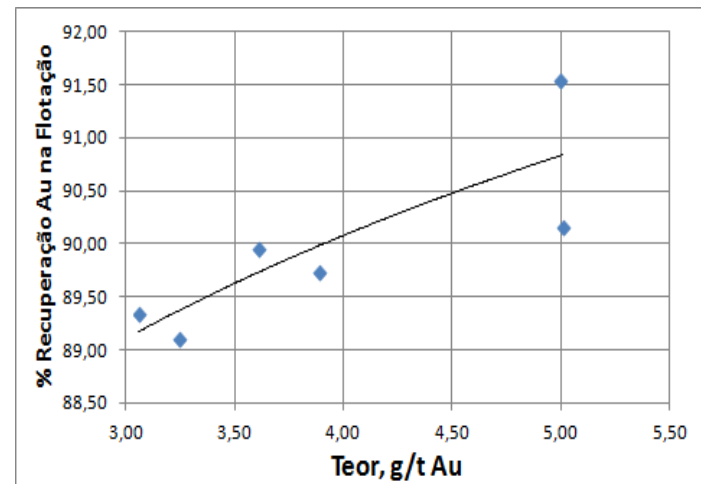
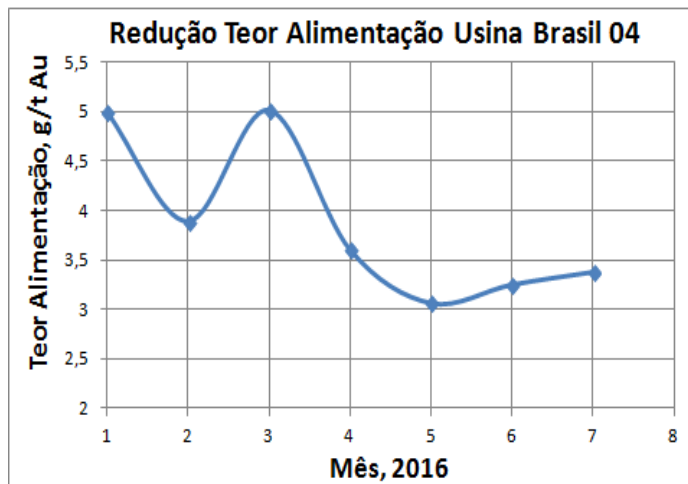


The fall of gold content in tree Brazilian plants

The significant reduction of gold content (cont.)

A recent study performed by MOPE showed a sharp drop in the gold content of the feed of a concentrating plant in Minas Gerais, only during these first months of 2016. Obviously, the metallurgical recovery of gold in flotation also fell significantly.

Rather than investing in the expansion of plants to treat increasingly ore (although poorer) we recommend working in selective fragmentation and pre-concentration of ore to raise the head content, adapting the same existing facilities in the plant for an Selective Concentration route.

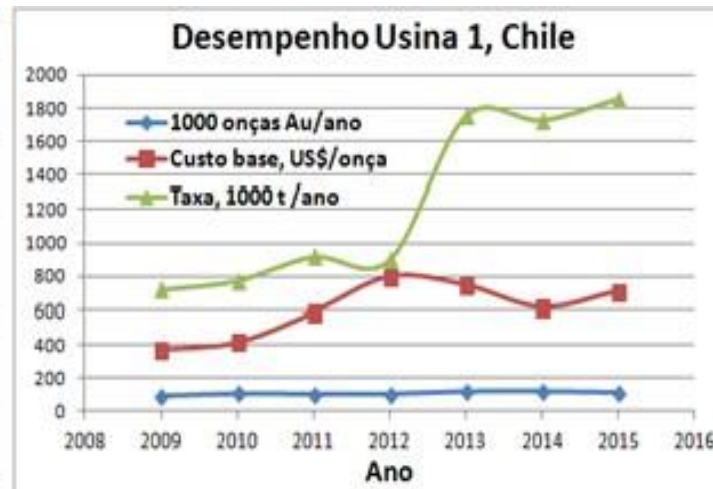


Reducing in productivity in gold ore beneficiation

To deal with the fall on gold content, the policy pursued over the past few years has been the expansion of concentrating units to treat more ore, just to keep the production of metallic gold at the end of each year.

In the figure below, from data in the annual company reports, where comes down the plant's historical performance 01 (Chile), it is observed that the expansion from 2012 led to a slight reduction of the cost of production, but only up to a certain point wherein the gold content falls further, going up the cost and also slightly reducing the production of metallic gold.

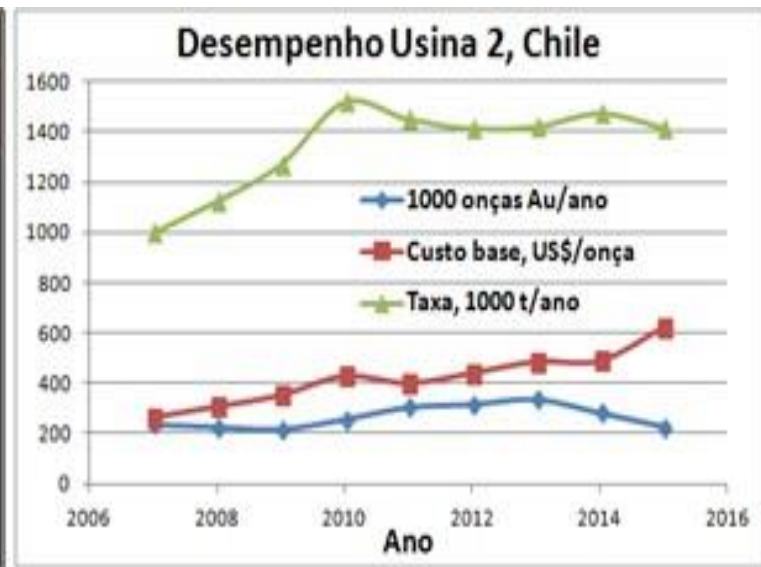
Año	t usina x 1000	Ley g/t Au	%Recup.	Producción onzasx1000	OPEX, US\$/oz
2007	74	5,28	81,7	10,7	243
2008	472	4,53	84,2	64,6	398
2009	723	4,21	82,3	91,9	373
2010	778	4,41	83,7	105,6	416
2011	920,4	3,5	84	102,7	591
2012	902,8	3,34	81,1	103,8	797
2013	1755	2,45	76,1	118,6	747
2014	1730	2,23	80,8	119,6	617
2015	1857	2,32	81,1	112,6	712



Reducing in productivity in gold ore beneficiation

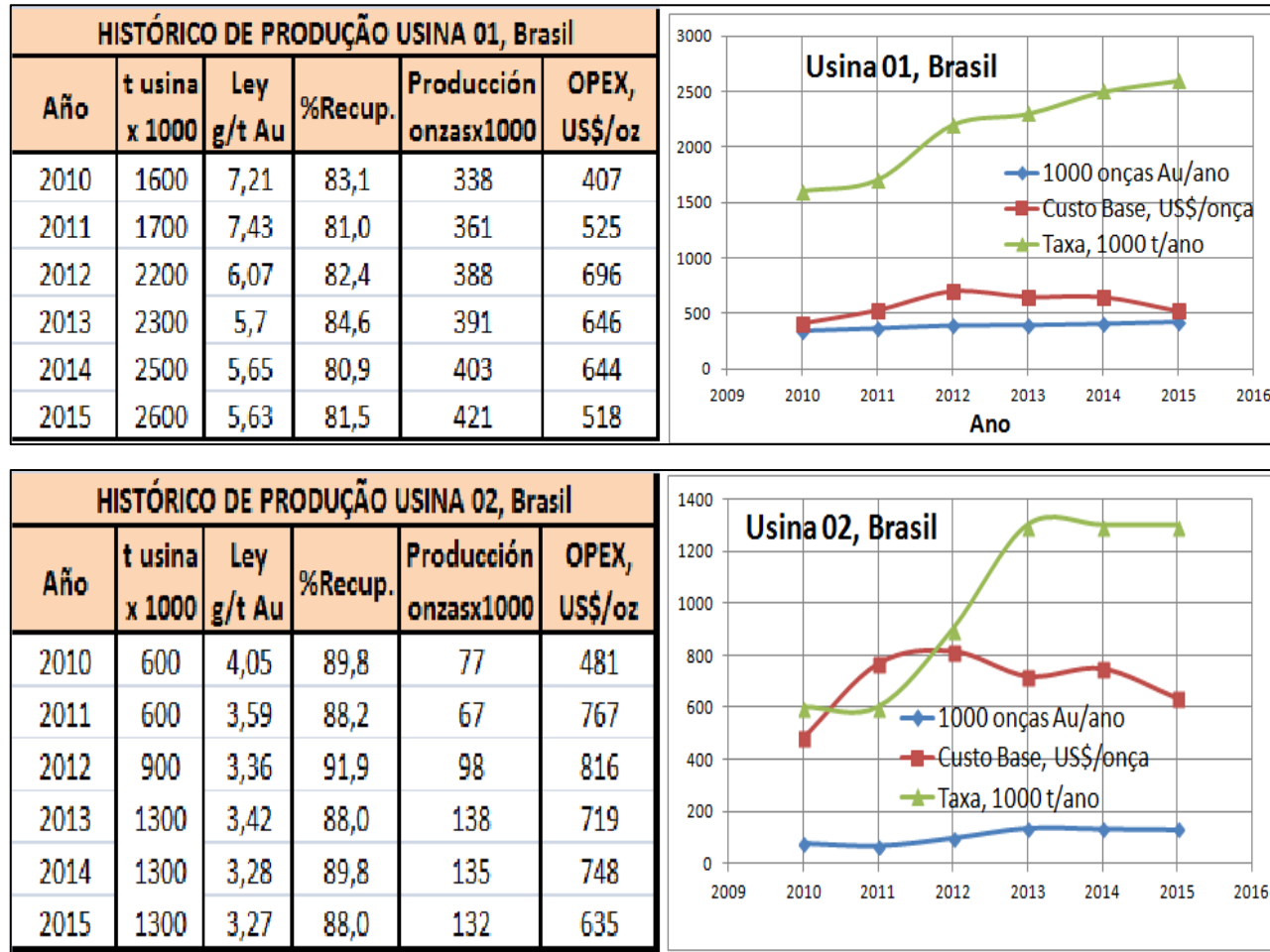
In plant 02, after two consecutive expansion projects, now falls the production of metallic gold and it can notes the trend of rising production costs. What would be the next step, invest in a new expansion? They will have to grind more gangue ?. The plant faced the production cost and was sustained the production of metallic gold almost solely based on physical expansion of the plant, to treat more ore. Until recently, the mining strategy was based only on the expansion of the mills. We believe that this paradigm may change.

Año	t usina x 1000	Ley g/t Au	%Recup.	Producción onzasx1000	OPEX, US\$/oz
2007	999	7,64	94,2	235	265
2008	1125	6,73	91,9	225	308
2009	1272	5,79	91,3	216	353
2010	1522	5,74	91,1	257	428
2011	1452	7,05	93	306	400
2012	1415	7,47	93,5	318	440
2013	1422	7,94	93	338	485
2014	1476	6,36	93,3	283	488
2015	1418	5,32	93,6	227	621



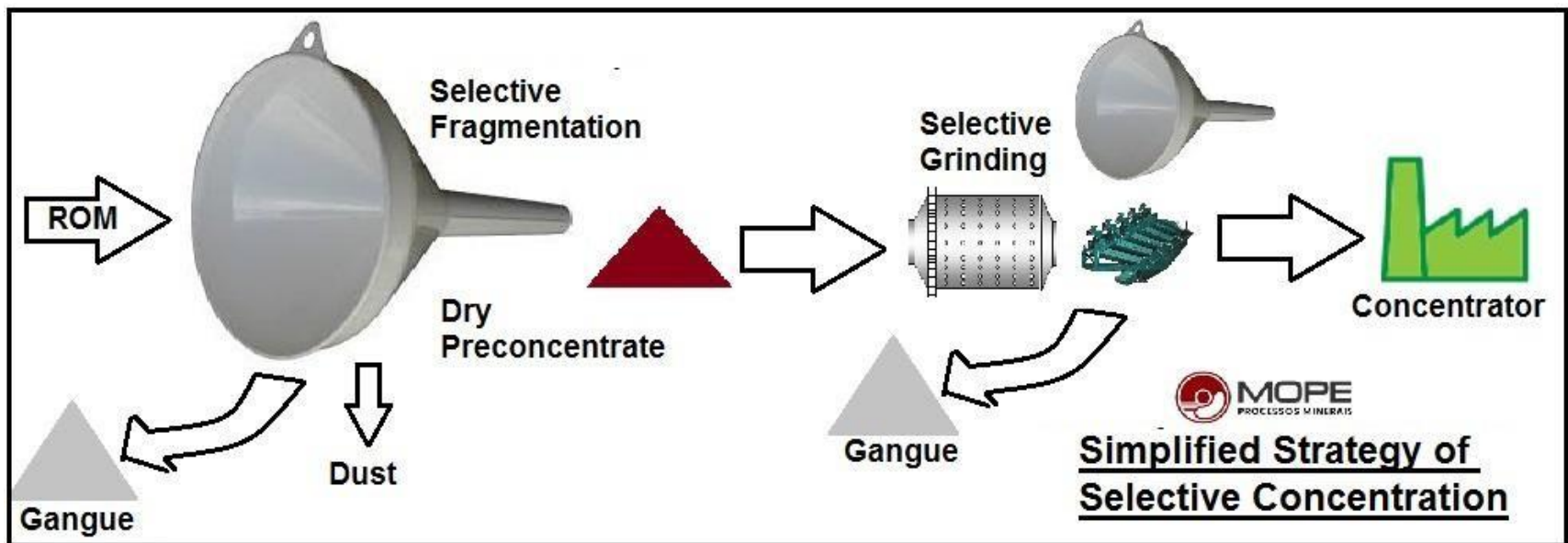
Reducing in productivity in gold ore beneficiation

In Brazilian plants the problem is similar, as illustrated below



The Selective Concentration

In Chile, unfortunately, metallurgical consultants and laboratories are directed to comminution studies considering homogeneous minerals, which mistakenly assumes that any fragment has the same composition as the original rock. MOPE has established agreements with laboratories and pilot plants in Chile and Brazil to study the application of this new approach for any type of ore.



Selective Fragmentation

Crushing operations can be more or less selective depending on the force used. The HPGR applies high pressure to the whole ore, "looking for a specific F80", ignoring the selectivity in fragmentation. In jaw crushers and cone crushers, force is applied more randomly (without localized pressure), only "to reduce size".

On the other hand, an impact crusher is extremely selective in their comminution action, which is applied depending on the particular characteristics (grain size, relative density and hardness) of each of the various components of rock, in order to "liberate" the ore of interest.

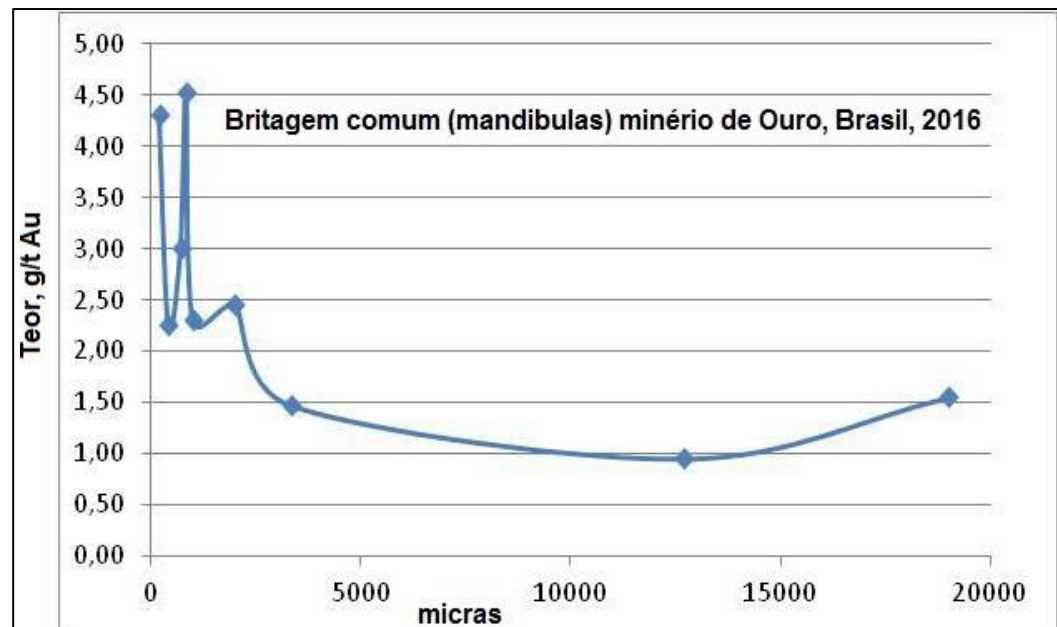


The action of the impact is how to extract the peanut kernels without breaking them unnecessarily. The selective fragmentation properly liberates the mineral from its gangue, with the maximum P80 as possible.

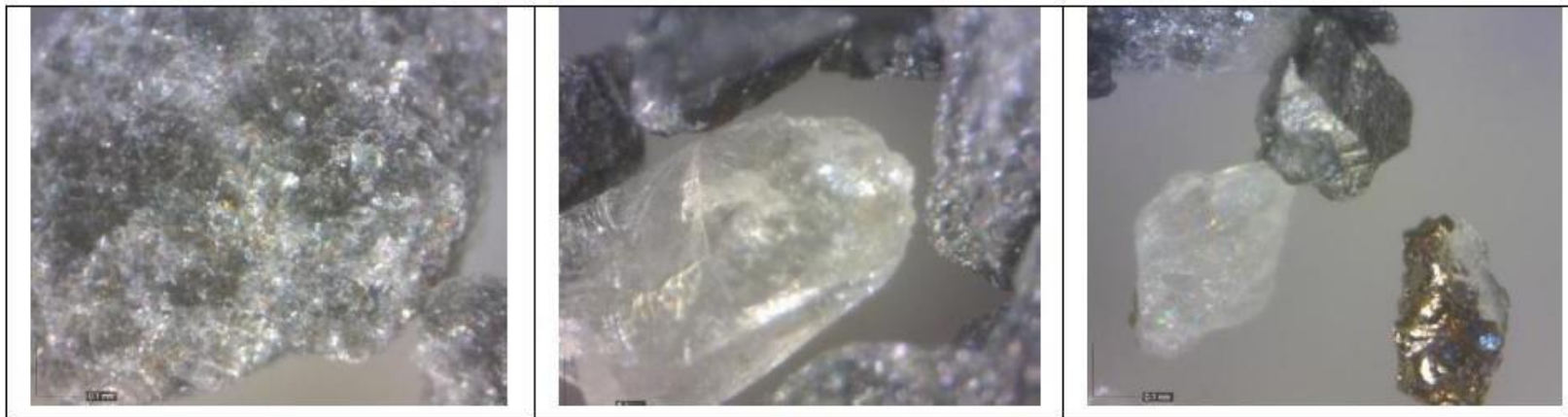
Selective fragmentation of Gold Ore

Although it was crushed in jaw crusher, the mineral presented in example below shows that much gangue could be discarded if the product of crushing were screening, for example, $\frac{1}{4}$ inch (6300 μm). On the other hand, in a grinding operation, there is usually a significant selectivity to the product, especially in open milling circuit (or with low circulating load), and low filling balls, which we define as: selective grinding.

When more heterogeneous is the ore, more mass could be withdrawn and returned to the mine, normally with lowest g/t Au than the mine cutoff, preventing its transport to the concentrator and "enriching" the new ROM.



SELECTIVE FRAGMENTATION OF GOLD ORE, 2015



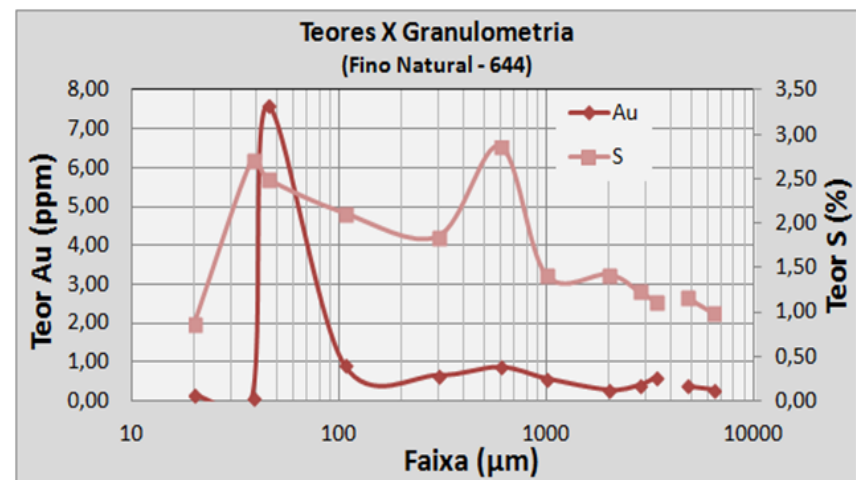
0,6 a 1 mm

0,3 a 0,6 mm

0,1 a 0,3 mm

Liberação do minério

The selective fragmentation takes the gold for the finer portions of the flow, allowing eventual discard of coarse gangue before entering the mill.



MOPE TOOLS



The **OPERATIONAL MODEL** developed by Eng. Alexis Yovanovic since 1987 and published in two books of own authorship provide the basis for MOPE solutions.

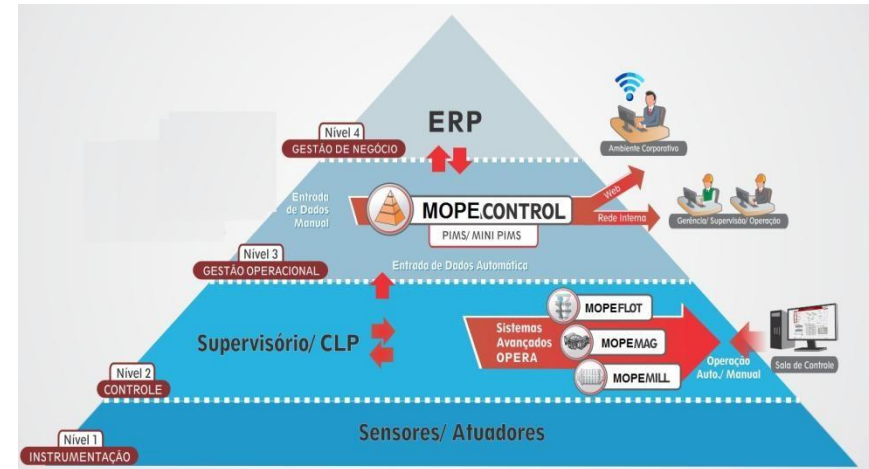
MOPE has two digital microscopes, which permit to evaluate liberation and grain size for both ore and gangue.



Partnership and operational basis at Magnesita Laboratory (Contagem, MG)



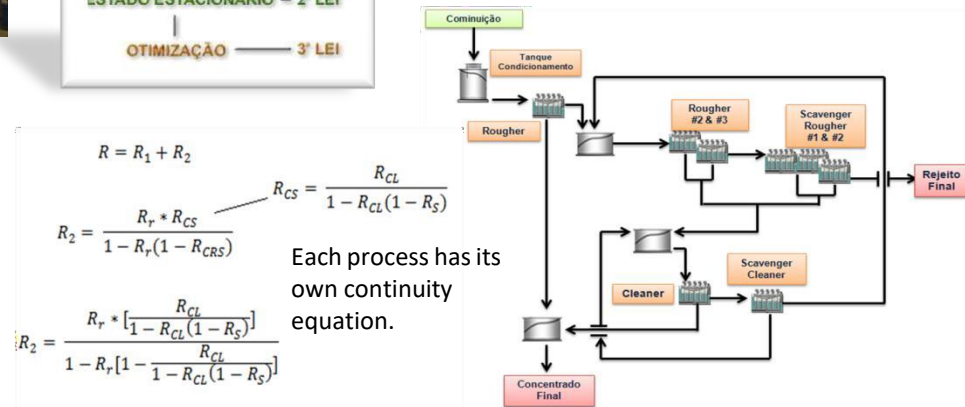
MOPETOOLS is a box of tools for internal use, developed using operational model as a basis, for calculations and simulations of various unit operations.



Original series of advanced solutions for optimization and control



Original phenomenological model for assessment, simulation and optimization of several ore processing unit operations .



SUMMARY OF THE NEW STRATEGY

**Selective
Fragmentation
tests**



PRÉ-CONCENTRAÇÃO

**Selective
Grinding and pre
concentration
tests**

**Best processing rout
Optimization of
Concentration
plants**



**Open Circuits
HF Screens**

MINING

- More Reserves;
- Optimized Pit;
- Lower relation waste/ore;
- Operational flexibility.

PLANT

- Lower size(< CAPEX);
- Lower rate(t/h);
- More rich and soft ore*;
- Stable feed;
- Radical reduction of OPEX.

TAILS

- Less fine tailings;
- Fewer environmental problems.



** Because of the selective fragmentation*

Best performance with minimal CAPEX, OPEX and lower environmental risks



**Rua Califórnia, 281/103 – Bairro Sion
Belo Horizonte, Minas Gerais
CEP 30315-500
+55 31 3285-3923
contato@modelooperacional.com.br**



Alexis Yovanovic | Diretor
+55 (31) 3285 3923 +55 (31) 98474 3655
ayovanovic@modelooperacional.com.br
www.modelooperacional.com.br
skype:apyovanovic

