Block Model Based Cement Quarry Optimization

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Introduction

Do you face problems with buildups in the preheater tower? Or thick coating in the kiln? Ring formations? Elevated emissions? Customer complaints? All of that may come from insufficient quality management in the quarry. This is well-known in cement plants, and quarries are being blamed for it.

I used to know a plant manager, who force the quarry manager to sign a commitment to always deliver according to some specified quality constraints. He was very proud of his solution – addressing the problem at the source – but there was a catch: The quarry manager had no means whatsoever to deliver on his commitment!

So, what were the options of a quarry manager? He would go only for those layers where the grade and contamination were not an issue, avoiding certain geological units altogether and remove them to the waste dump. If all this did not help, the plant needed to use expensive correctives for adjusting the kiln feed. All that is fine if you have infinite land reserves and a "friendly" geological setup, but for all others it will end up in an early termination of cement production altogether – because the quarries are exhausted.

In this article we are going to explain some other options and show you how to optimize and schedule your cement quarries for more reliable quality control, lower wasting and correctives consumption and an extended lifetime.

First, we need to take a closer look at the entire raw material quality management process. It includes exploration, analytics and planning, and yes, you will not get it for free: You need to invest in, but at the end you will see a benefit that exceeds these expenses by far!

The impact of raw materials on the cement production process

Raw materials extraction is an essential part of the cement production and contributes significantly to cost and quality of the final product. This is true in two ways.

First of all, a permanent supply of adequate amounts of raw materials is a precondition of operating a cement plant at all. So, this is the first challenge for mines planning and operation: ensure this steady supply following the mining state of art, dealing with weather, natural phenomenon's, environment, biodiversity, communities, OH&S and many more, for the longest possible period of time.

On top of this, qualities do also matter. Plant design is based on average parameters and operation will be optimal if these parameters are always met. But natural raw materials are variable, and if this goes directly into production it will affect cost:

- High electrical energy consumption for homogenizing the raw material.
- High and unstable consumption of expensive corrective materials (e.g. bauxite, high grade limestone etc.).
- High wear of the vertical roller mill if no attention is paid to quartz, often even as flint.
- Higher fuel costs and refractories consumption due to fluctuations in the thermal process.
- Little use of cheaper alternative fuels and raw materials which bring their own variability from other industries, so their usage is extremely risky without proper raw mix control.
- Need to use "cleaner", more expensive fuels, like natural gas, to comply with emission limits.

Often cement raw material supply is only understood in terms of limestone, but even the highest-grade limestone has no value without a second component – clay, shale etc. What counts is thus not only limestone, but the constant delivery of the right mix of primary and second component. In many cases the "lower-grade" limestone is already much closer to the needs of cement production than the very pure "good" material.

Most of the time, additional corrective materials such as high grade ("sweetener") limestone, bauxite, iron ore, sand or others are required as well. But even in small amounts they add considerably to the production cost, so this should be minimized, and suitable inexpensive alternatives need to be permanently evaluated. In the best case these can be found even in the own quarries – if all the materials have been properly explored and analyzed! It happens too often that exploration only looks at the limestone or second component, considering everything else as "waste", so opportunities are missed. In some of my projects I showed that overburden could replace or reduce the use of costly external materials.

Minor elements and oxides (chlorine, magnesium, sulfur, organic carbon etc.) need to be monitored as well because they can either badly affect the process and product quality or lead to emissions above the allowed limits. Controlling them in the quarry is often the only option to do something about them: While main parameters such as silica and alumina ratio can easily be handled with correctives, this is not true for too high amounts of detrimental minor compounds.

Finally, also physical parameters do matter. Depending on geological and climatic conditions, raw materials can be dry or humid and sticky, hard or soft etc. Knowing these parameters in advance is crucial for the plant design – also for the second component: number and type of crushers, bins, weigh feeders, conveyors, preblending piles etc. Plant design issues should of course be known before the plant is built.

At the kiln outlet the results of all previous efforts become evident – with nothing to be done if the results are negative: off-spec clinker cannot be sold, and marginal qualities lead to reputation damage and cost market share.

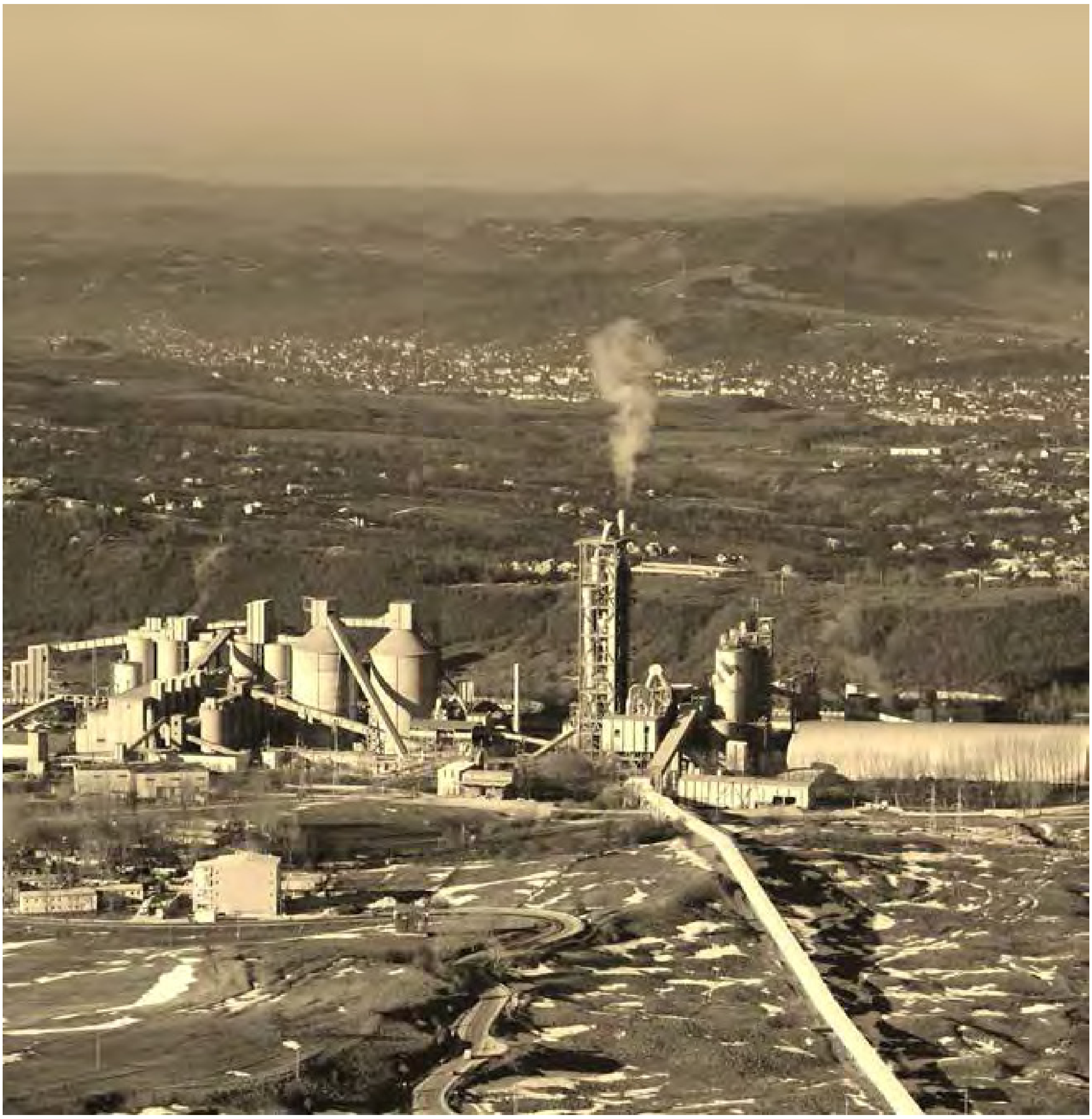

Figure 1 In this article we are looking at the cement plant from the quarry perspective.

Deposit investigation and block modeling

Quality management at the source is the key to handling all the issues described above, and it starts with exploration, modeling and planning. And for all these steps, all the materials that exist in the foreseen deposit area should immediately be included – even if at first they do not look like being useful: It was already pointed out that in some cases this impression may be wrong.

The initial exploration steps will be geological desk studies and field work, followed by core drilling and sometimes supplemented with production rig drilling. Drilling is the most expensive part of the exploration process, so it is important to prepare it well by collecting all available geological information in advance and plan the drilling campaign accordingly. Geophysics can also help to complement the geological information.

The resulting database of georeferenced chemical analyses, together with other information, will go into a geological model that represents in 3D the geological units and tectonic structure. Then a block model can finally be calculated (see figure 2). The block model attributes are calculated from the sample database and the geological model using geostatistical methods.

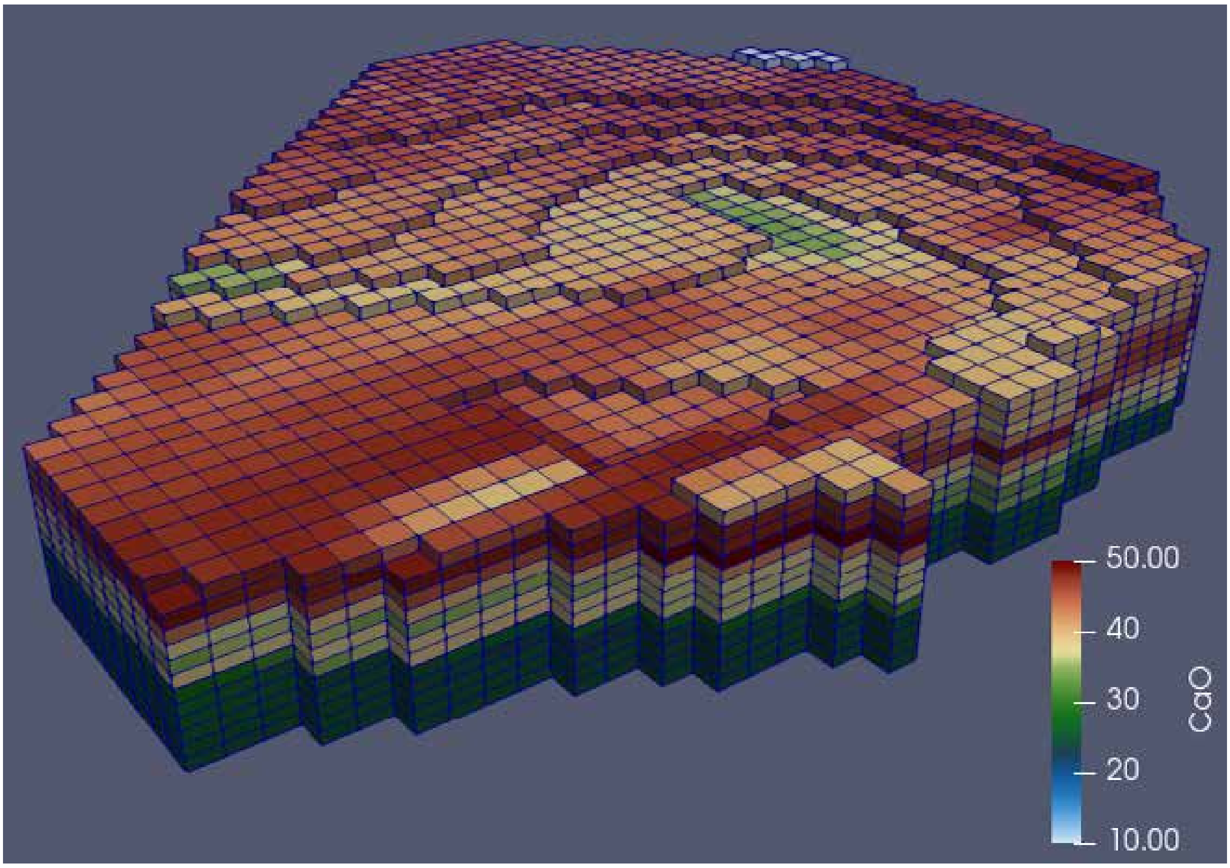

Figure 2 In a block model the deposit rock volume is divided into rectangular blocks. Qualities and other parameters are assigned to every block and can be visualized with colors.

A block model approximates the reality in terms of qualities. The reliability of the model depends on input data, methods used and not the least on the skills and experience of the modeling expert. Doing all this properly costs of course money but saving here in the wrong place costs much more! Figure 3 illustrates schematically the cost structure of the entire exploration and modeling campaign and shows that in order to save cost:

- spend enough effort for a good planning of the drilling campaign (desk study and field geology), to minimize the number of required drillings, and
- spend money for a high quality, certified laboratory for sample analysis, and invest in the generation of good geological and block models – because otherwise even the most expensive drilling campaign will only deliver unreliable information.

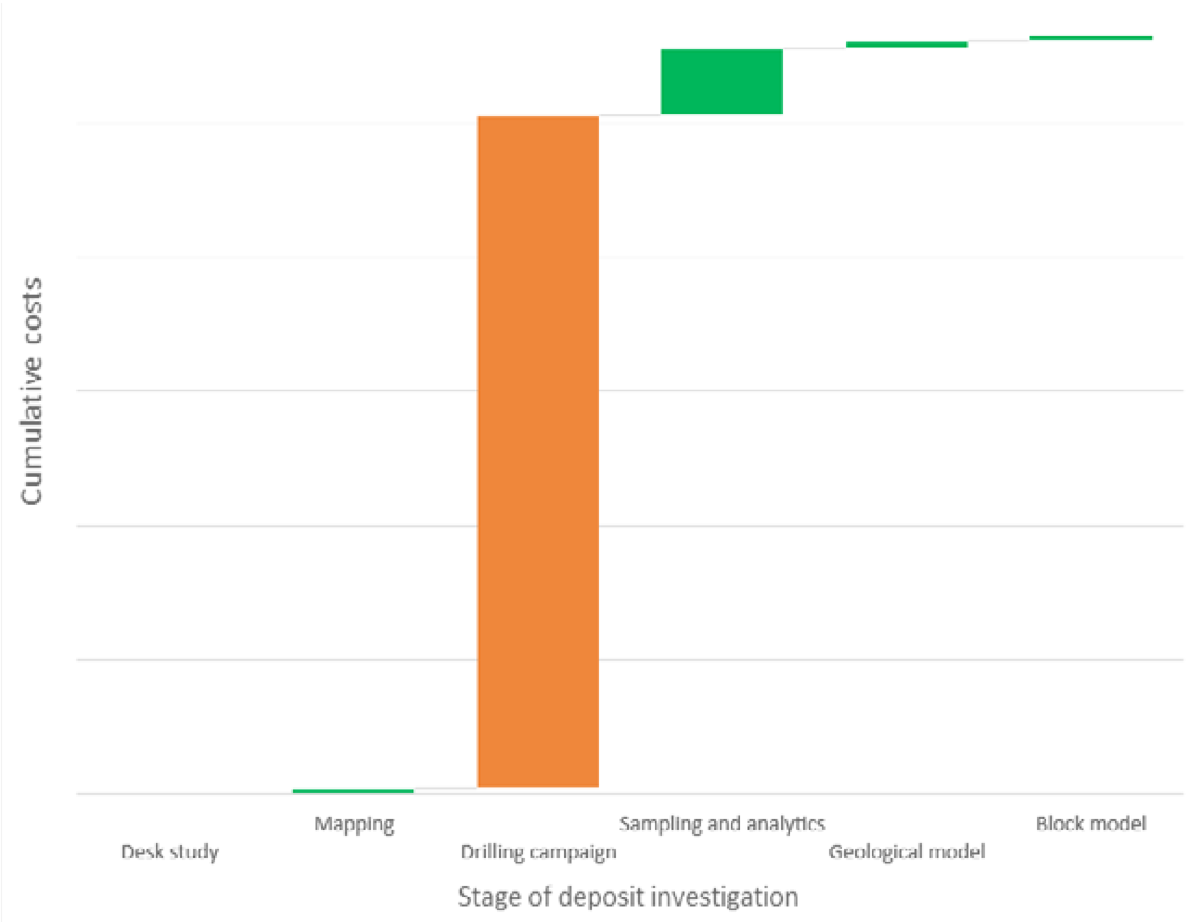

Figure 3 Cost structure of an exploration campaign: By far the most expensive step is the drilling campaign, but the reliability of the result equally depends on the quality of every single step: the chain is as weak as the weakest link.

The block model is now the base for numerical optimization and scheduling of the quarry production based on quality constraints.

Again, there is a cost related reasoning that easily justifies the efforts done for planning and more selective mining in the quarry according to the plans. The important question is: What is the cost of handling quality deviations at the different stages of the process between quarry and market (see figure 4)? The answer is clearly: the later the deviations occur the higher the cost for correction or mitigation – up to the loss of production that results from off-spec clinker.

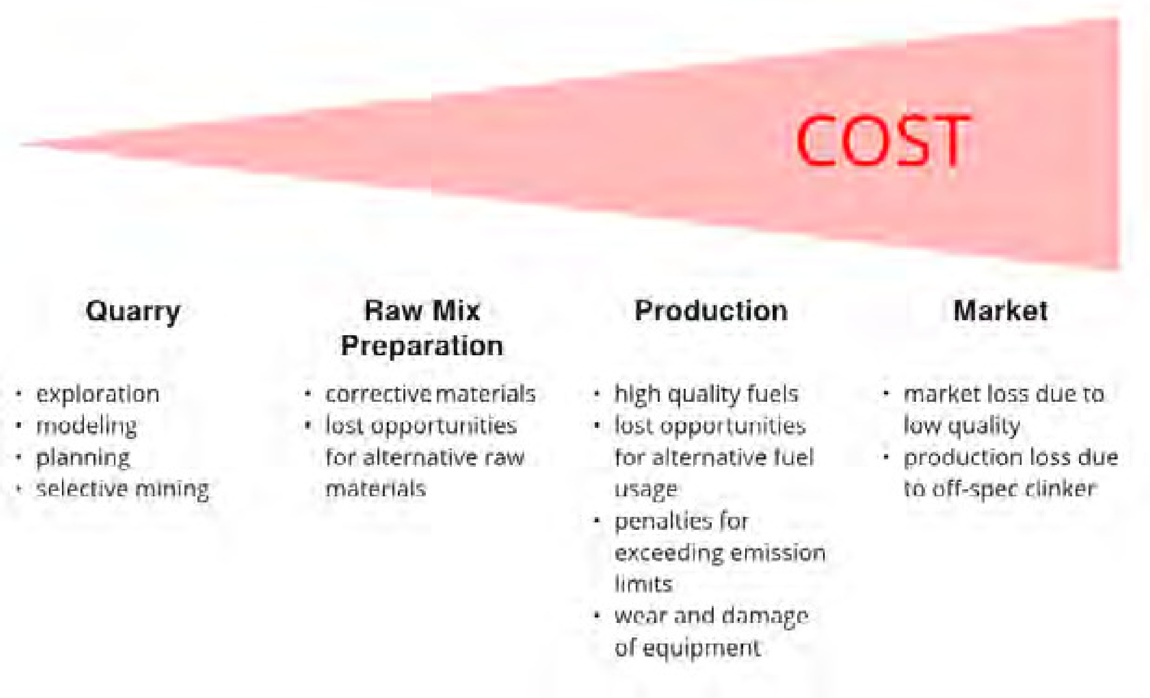

Figure 4 Cost for correction or mitigation of quality deviations at different stages of cement production between quarry and market

Planning software – a historical background

In the 1960-ies first attempts were made to define algorithms and use computers for optimized planning in the mining industry, based on block models. The metal miners were forerunners, and until now their needs are dominating the market of planning tools – see figure 5.

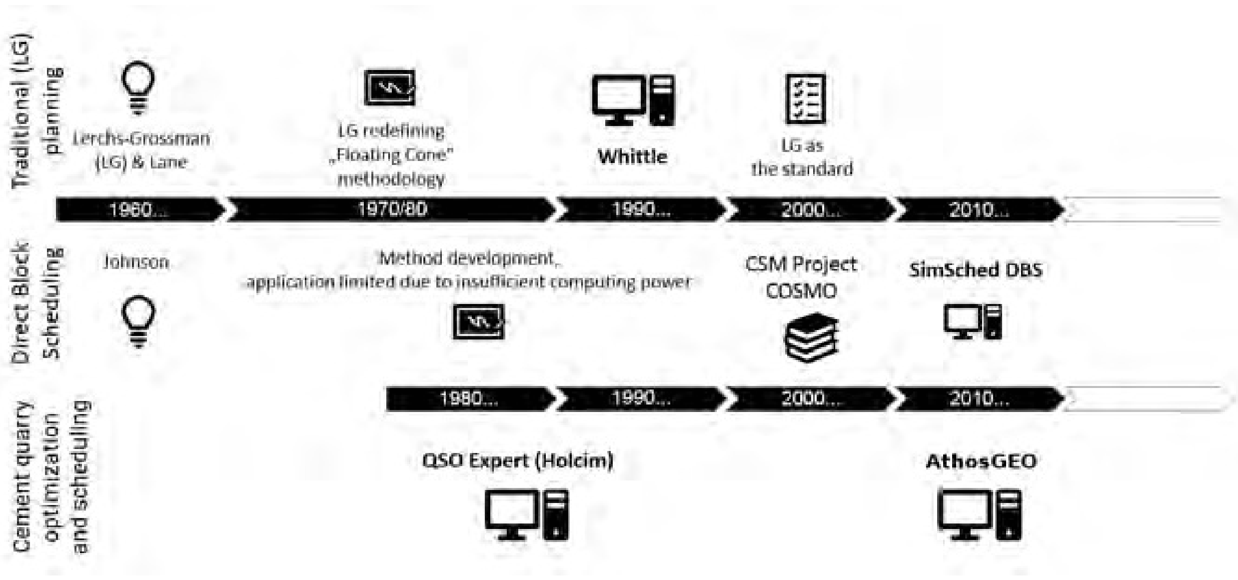

Figure 5 Development of computerized mines planning concepts. The methods going back to Lerchs-Grossman (LH), like the Whittle software, are nowadays dominating the resources and reserves estimation in metal and other major mining industries. Direct Block Scheduling (DBS) methods are solving the same optimization problems in a stricter way, but they require computing power (like 64-bit hardware) that is only recently available. However, mining for cement faces different challenges and the market of available software is much more restricted.

Mining for cement raw materials must solve different optimization problems from different starting points. Since these mines tend to be much smaller, the market of available software is much more limited. The differences can best be summarized with the following table:

	Ore mines	**Cement raw materials**
Value of a block	depends on the "ore grade", like %Cu, Fe etc. and market situation	cannot be defined because it depends on mixing opportunities with other blocks and materials
Cost of a block	for mining, handling and processing	dto.
Cutoff grade	below which the cost for handling and processing exceeds the value, so the "ore" becomes "waste"	does not exist
Main optimization target	net present value (NPV), i.e. the discounted benefit (value minus cost) of all blocks together. Discounted means that a benefit has the more value the sooner it can be realized	maximum quarry lifetime, thus maximizing the clinker and cement production of the plant, always providing constant raw mix quality, to generate the highest possible return from the investment in the plant

A first software that was independent of all the ore mining tools but specialized for cement raw material mining was developed at Holderbank (later Holcim, now LafargeHolcim) in the 1980-ies: QSO Expert (Quarry Scheduling and Optimization). Initially it was sold also to externals, but since the end of the 90-ies it is restricted to plants within the group. QSO can optimize multiple deposits, handle many different constraints for each one of them and include external corrective materials.

This is where the new AthosGEO software is supposed to step in. It's going to be a brand-new software, ready for production only within a few months. Still it is based on many years of experience of working with QSO and its concepts in many different geological, economic and legal environments throughout the world. Like SimSched DBS it also uses the opportunity of more advanced computer hardware, namely 64-bit technology, to address a problem that could not be handled by QSO yet: the simultaneous production of several products, like raw mix and a high-grade filler limestone.

AthosGEO in nutshell

AthosGEO supports the specific needs of cement producers at three different levels:

1. Know the characteristics of your deposit. Visualize qualities inside the deposit (block model) in 3D, display charts and tables (see figure 7).

[3]For more information, see https://cobo.bockemuehl.ch.

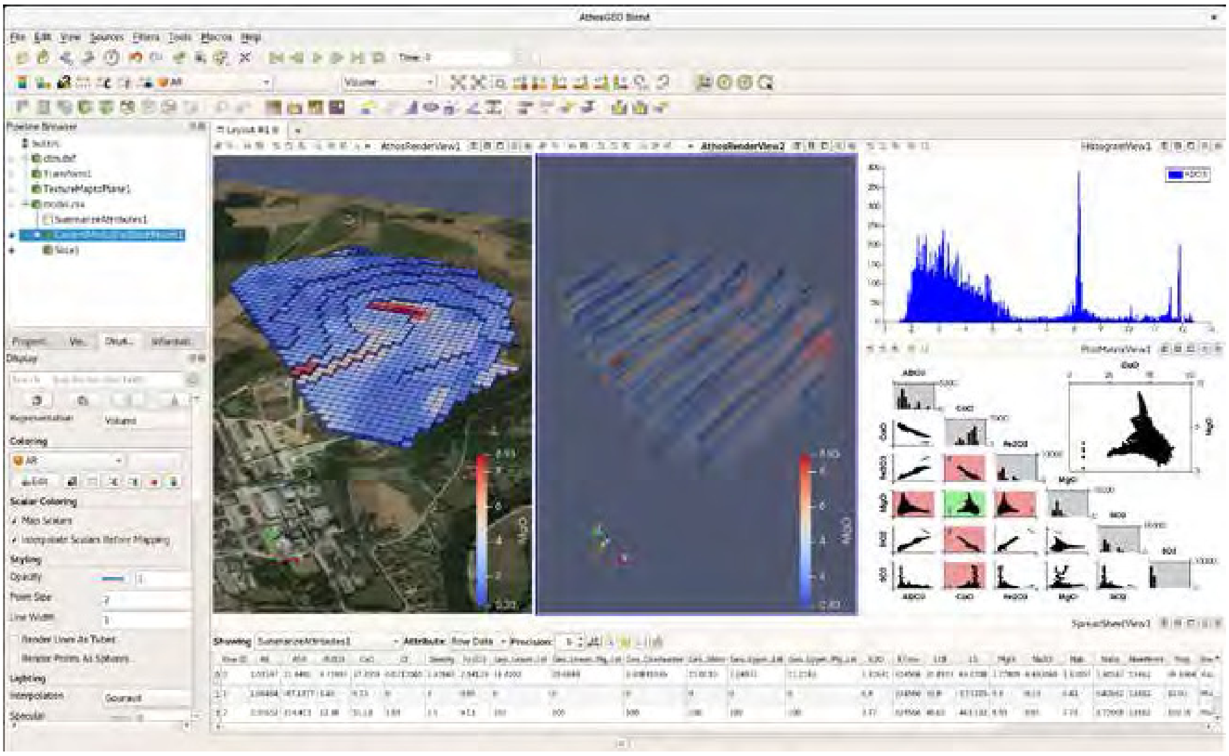

Figure 6 This screenshot illustrates many ways how AthosGEO supports a better understanding the characteristics of a quarry.

2. Understand the maximum raw mix potential. A linear optimization module calculates the maximum of raw mix that a deposit can produce, depending on quality and many other constraints, including the use of external corrective materials
3. Step by step mining simulation. In a semi-automatic, interactive process the user finds an optimum feasible schedule for the short, medium or long term.

The software will exist in two variants:

- AthosGEO View is for the visualization and assessment of the deposit – the first "level" as explained above. This variant will be offered as Open Source, like the visualization software on which it is built (ParaView). With the option to also visualize planning results it is the right tool for the customers of a planning expert.
- AthosGEO Blend is for the planning experts, doing the optimized planning and scheduling by proper blending of materials .

Summary

In this article we looked at the entire cement production process, but always from the raw materials and quarry perspective. Once you understand how relatively little efforts in the quarry can generate much higher benefits further down the line you will no longer hesitate to invest in proper deposit exploration and quarry planning. Figure 7 summarizes once more some of these positive effects.

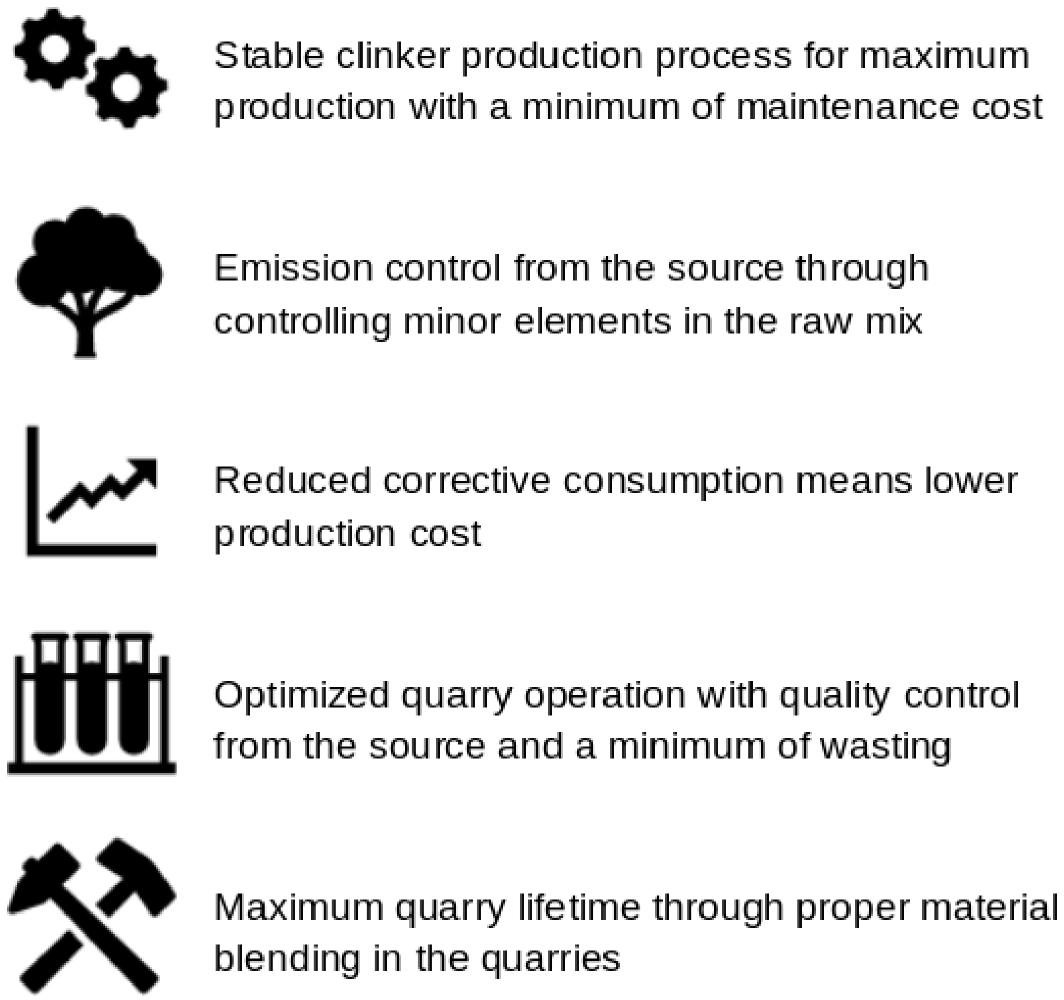

Figure 7 benefits of block model-based scheduling

The new AthosGEO can support your efforts in that direction, but the key to make it happen is not a software, but it's always you and your team! Using the block model for a deeper understanding of the characteristics of your deposit and its potentials is already a first benefit because it means a major change in mindset: miners will stop mining rocks and start mining quality instead. Which may finally trigger a new and better way of working together between plant and quarries – far beyond blaming each other for shortcomings.

The immediate financial benefit depends on the situation. During our careers in Holcim the top saving estimated amounted to 4 Mio. US$, and in a short time over 1 Mio US$ has been achieved. Which is a rather quick payback for the planning efforts (the major drilling campaign was not included) – and is only one of the positive aspects!
The gain in quarry lifetime, often less emphasized by the managers because mostly not affecting short term benefits, should not be underestimated: end of quarry lifetime is often also the end of plant production if additional resources cannot be obtained (land, permits etc.).

Finally, do not forget the relative benefit for your surrounding and environment – by reducing emissions and consuming less of the valuable non-renewable natural resources (rocks).

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