Étude de pré-faisabilité d'une extension de la mine de talc de Rabenwald

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RIO TINTO MINERALS

RAPPORT D'OPTION

PREFEASIBILITY STUDY FOR THE EXTENSION OF THE RABENWALD TALC MINES

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MASTER THESIS

Prefeasibility study for the extension of the Rabenwald talc mines

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SUMMARY

LUZENAC, the subsidiary of Rio Tinto Minerals oriented to the talc sector, is the world leader on its market. Its production comes from several mines wide spread in the world and a consistent part of it is extracted in its 3 main mines in Europe: Luzenac in France, Rodoretto in Italia and Rabenwald in Austria. Four years ago, a first extension project started in Rabenwald mine in order to increase the life of mine by 20 years. The closure of this extension is planned around 2030 and Rio Tinto Minerals is already interested in studying potential extension of the current project. This will require going through a long phase of exploration and a time-consuming permitting process which explains why the study starts so early.

The main assumption was the geological model provided by the resources and planning department on which the complete study is based. This latter consists in an iterative approach of the numerous aspects of a prefeasibility study covering the complete scope of the mining activity from the orebody knowledge to the economical assessment of a project through the design of optimized pits, the development of production method and of subsequent cost models, the elaboration of a capital expenditure plan and the economical assessment of various scenarios.

Thanks to Whittle software, many optimizations were run using the Lerch-Grossman algorithm in order to get optimized pits respecting a few constraints set by Rio Tinto Minerals regarding in particular the overall stripping ratio and the location of the new exploitation. The current production methods have been adapted to the characteristics of the new project and for each designed pit, a cost model has been developed in order to get the economical assessment of each scenario by using the classic economical indexes of profitability: the Net Present Value (NPV) and the Internal Rate of Return (IRR).

Based on a general risk assessment for the new project, a detailed project planning has been developed in order to mitigate the main risks of the project. A particular attention was paid on the needed exploration campaign.

The most favorable project has then been selected and further studies have been done on it. The first direction was the quantification of risks and in particular those related to the ore body knowledge, to the market evolution and to the costs. On the other hand, several sensitivity studies have been done in order to identify the main cost drivers and to define some possible improvements for the selected project. The main idea of this part was to adapt the project to the new parameters: a better stripping ratio and a longer hauling distance than in the current pit.

The two identified improvements are the increase of the average velocity of hauling trucks thanks to an increase of the road quality and a decrease of the average hauling distance thanks to a maximization of fill-in dumping. These two steps make it possible to reduce the needed number of waste trucks and to consistently reduce the mining costs.

For the base case scenario, the economical assessment gives an NPV of 30.1M€ and an IRR of 21.4 % which should guarantee a bright future to Rabenwald. The prefeasibility study meets its objectives to legitimate an exploration campaign within the coming years. However, before launching this project, a few topics deserve to be further studied in order to complete this study:

- Confirmation of the assumptions used to build the geological model
- Study of the possibility to change completely the fleet and to go for bigger truck
- Study of the community acceptability
- Integration of this project in the general Rio Tinto Minerals' strategy.

This last topic is probably the most interesting one for this study has only showed that the new project would be profitable from a local point of view, that is to say for Rio Tinto Minerals Austria, which does not guarantee that it is the best project for the group. Some other scenarios should be studied to define the strategic interest

of Rabenwald such as supplying the process plant associated to the mine with talc from Luzenac mine instead of Rabenwald.

ACKNOWLEDGEMENTS

The work on this master thesis started in January with a first visit on Rabenwald site and was then split into a preliminary phase at the Centre de Géosciences of the Ecole des Mines ParisTECH in Fontainebleau in February and march 2010 followed by a three-month period spent in Rabenwald offices.

A few people of the Ecole des Mines ParisTECH and of Rio Tinto Minerals were involved in this study and brought me a valuable help throughout the last four months.

In particular, my sincere gratitude goes first to Dipl.-Ing. Christian Leiter who is the Rabenwald mine manager as well as my thesis director during the last three months. His support and pieces of advice regarding the general progress of my work were always valuable. I would like to thank as well Dr. Michaela Wurm of the planning and resources department of Rio Tinto Minerals who provided me with the geological block model and with pieces of advice regarding the ore body knowledge.

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INTRODUCTION

Rio Tinto Minerals is the world leader on the talc market. A significant part of its production comes from its three main deposits in Europe: Luzenac in France, Rodoretto in Italia and Rabenwald in Austria. The company sells products which cover all segments of the market and in particular provides paper, polymer, ceramic and paint industries.

Administrative procedures to get authorizations for mine openings or mine extensions are becoming more and more complex and time consuming, which makes it necessary to assess projects to come long in advance. The study in question, which deals with the Rabenwald deposit, is in line with this logic.

A first extension project has been started recently and makes it possible to consistently increase the life of mine. The current prefeasibility study aims at assessing the potential of a south extension of the mine both from the technical and the economic point of view. This study is a first approach for a project that, if it is accepted, will produce its first ton of talc around 2028. Therefore, its goal is not to define completely the new pit but to show that, if the basic assumptions are exact, the project will be profitable. This result will then enable Rio Tinto Minerals Austria to present the project to Rio Tinto Minerals head office and to get the approval to go for a first exploration campaign.

The survey covers all aspects of the opening of a new pit from the ore body knowledge to the economical assessment of several scenarios through the development of production methods, subsequent cost models, risk assessment and sensitivity studies. It relies on a hypothetical geological model provided by the “Planning and Resources Department” of Rio Tinto Minerals Austria. An iterative approach with a progressive increase of precision was adopted to come to the final result.

In this report, the general thought process to complete the study is synthetically described in four main parts:

- Introduction to the study, with a short presentation of the talc sector and of Rio Tinto Minerals. This part of the report focuses then on the current mining and processing activities in Rabenwald in order to get the current cost structure and to understand the complete organization of the site;

- The definition of the new project, starting with the study of the ore body and some optimization with Whittle software. Four scenarios were identified and for each of them an economical model is built to get a first assessment of their profitability. The best scenario is chosen at the end of this part in order to be further studied in the two following parts;

- The development of the pit C which describes the complete planning of the project and highlights the development of the capital expenditure plan and the general design of the new exploitation made with Datamine software;

- Sensitivity studies and potential improvements, which explains the impact of the variation of various parameters on the final result and identifies two directions to improve the chosen production method.

1. INTRODUCTION TO THE STUDY

1.1. THE TALC

Talc is a mineral composed of hydrated magnesium silicate which most remarkable particularity is to be the softest mineral on earth with a Mohs hardness of 1. It can be easily scratched by a fingernail. Its color ranges from white to grey or green and it has a distinctly greasy feel. Its streak is white. Talc is also known for its unique features such as hydrophobicity, platyness and organophily. It has a specific gravity of 2.5 to 2.8. It occurs as foliated to fibrous masses, its monoclinic crystals being so rare as to be almost unknown.

Mineralogy

Talc is a hydrated magnesium sheet silicate with the chemical formula Mg3 Si4 O10 (OH)2. It has a perfect basal cleavage, and the folia are non-elastic, although slightly flexible. Its elementary sheet is composed of a layer of magnesium-oxygen/hydroxyl octahedra, sandwiched between two layers of silicon-oxygen tetrahedral as the figure 1 shows. The main or basal surfaces of this elementary sheet do not contain hydroxyl groups or active ions, which explains talc's hydrophobicity and inertness.

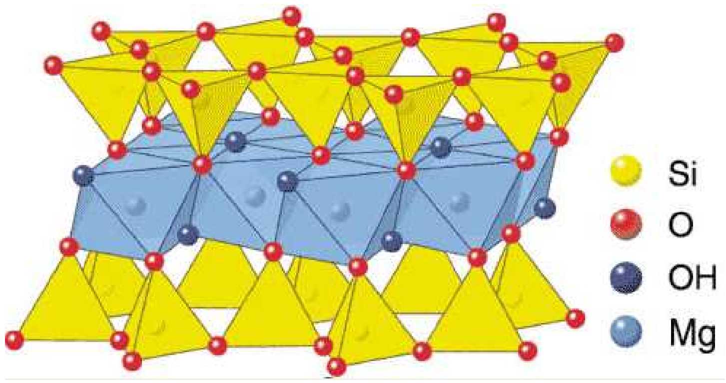

Figure 1 – The mineralogical structure of talc

Geology

Talc deposits result from the transformation of existing rocks under the effect of hydro-thermal fluids carrying one or several of the components needed to form the mineral (MgO, SiO_2, CO_2). Tectonics plays a major role in the genesis of a talc deposit. It enables hydro-thermal fluids to penetrate the rock, creating a micro-permeability that facilitates reactions in the mass. Talc deposits are in general very heterogeneous regarding their shape, their quality and their grade.

Uses

Talc is of course known to the public for its use in cosmetics and for baby powder, but talc has as well numerous industrial applications thanks to its physical and chemical particularities. Talc can be used either in industrial processes as a control agent, either as an additive element to the final product in order to improve its physical characteristics. The paper industry is the first consumer and uses talc for pitch control purpose. Talc is also very used by the plastic industry for its lubricating properties or by the paint industry to reduce cracking and sagging. The other talc consuming applications are ceramics fabrication, roofing, agriculture, foodstuffs, etc.

Talc, an industrial mineral

Due to its numerous and very diverse industrial applications, the talc industry belongs to the sector of industrial minerals. This sector is very different to the commodities sector firstly by the absence of standard products. On the copper market which is one of the most telling examples of commodities, only few standard products such as copper ore with a given grade exist and they cover almost the global copper production. On the contrary, each talc-producer sells between ten and a few hundred different talc products. Each talc product is developed for a particular application and sometimes even for a single particular client, for each client has very specific needs. Therefore, there is no spot price for talc and prices are always negotiated between the talc producer and the client.

This specificity underlines the importance of the marketing team within talc producing companies, which role is to build and maintain a wide network of small and diversified clients as well as to initiate the development of new talc products according to the market needs.

Talc shares also with many other industrial minerals the omnipresence of quality concern. Whereas for a copper ore, the price will mainly depends on the grade, the price of a ton of talc will be set by numerous physical parameters which will define its qualities. The main quality factors for the common talc application are its grading and its brightness, which is unfortunately not an additive quantity. The concentration of other minerals in the talc, its loss on ignition and its quartz content are also influent on the quality and thus on the selling price, which ranges from about 100€/t for the worst qualities to more than 1 000€/t for the best.

This quality concern is present through the complete production process, from the early talc extraction with the excavator to the process plant. Selectivity is one of the cornerstones of the talc production sector and constrains all the production methods.

1.2. PRESENTATION OF THE EXPLOITATION

Rio Tinto Minerals

Rabenwald talc mine belongs to Rio Tinto Minerals, a subsidiary of Rio Tinto which is one of the three greatest mining companies in the world, present on various markets from copper to diamonds, through gold, coal or iron.

Rio Tinto Minerals consists in two main subsidiaries:

- BORAX specialized in borates extraction;
- LUZENAC specialized in talc extraction.

LUZENAC is since a few years the world leader on the talc market with 25% of the global production (about 6Mt of talc per year). It has about 6 main extraction sites spread in North America, Europe and Australia.

The Rabenwald mine is operated by RIO TINTO MINERALS Mineralwerke, the Austrian subsidiary of Rio Tinto Minerals. It employs around 140 people on four industrial sites indicated on the figure 2.

- Two mines:
    - Rabenwald open pit
    - Weisskirchen underground mine,
- Two process plants:
    - Oberfeistritz process plant
    - Kleinfeistritz process plant.

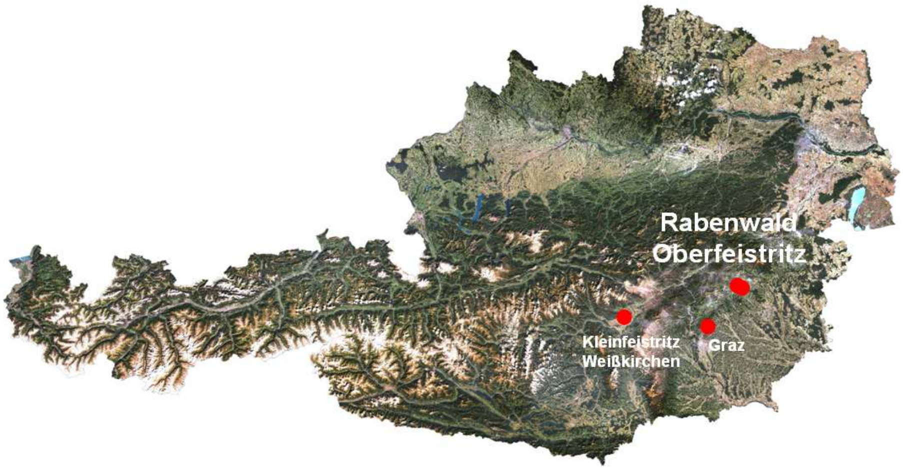

Figure 2 – Rio Tinto Minerals' implantation in Austria

RIO TINTO MINERALS has been pretty affected by the 2008 economical and financial crisis and its yearly production has dropped by almost 40% in between 2008 and 2009. The nominal production corresponding to the 2008 data is 120 000t of talc for a total turnover of over 50M€.

<u>Geology</u>

The Rabenwald talc deposit is located in the eastern margin of the Alps in the Austrian state of Styria. It is one of the biggest deposits in Europe with a length of 5km, a width ranging from 600m to 2km and a thickness of 20 to 60m. The overall view of the deposit is available on the figure 4. The ore body which is currently exploited is located at an elevation between 900 and 1080m and follows the mountain ridge to the south with an average dip of 10 degree. The mine is linked to the process plant which is located down in the valley at about 4 kilometers with a cable way as showed on the figure 3.

Figure 3 - A view of Rabenwald and Oberfeistritz installation from plane

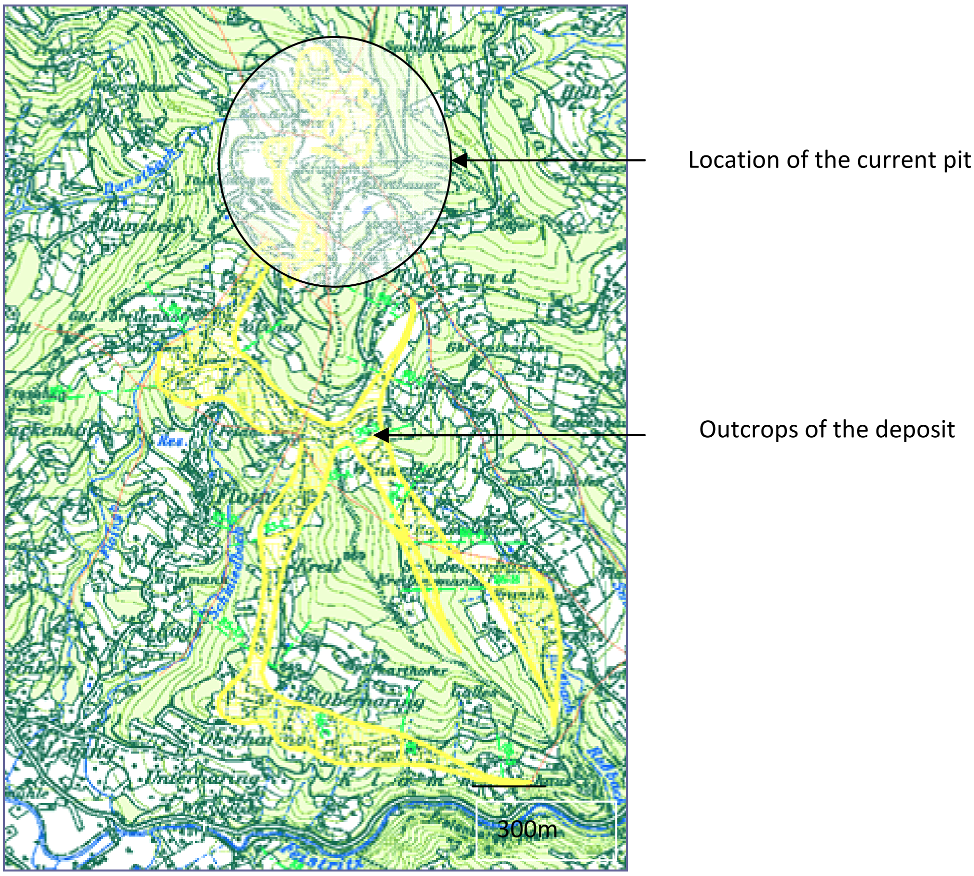

Figure 4 – The Rabenwald talc deposit

The Rabenwald talc deposit is located in the Lower Austro Alpine Unit (LAA) in the eastern margin of the Alps. The LAA is formed as a north orientated polycyclic relief with polymetamorphic cores and permomesozoic covers.

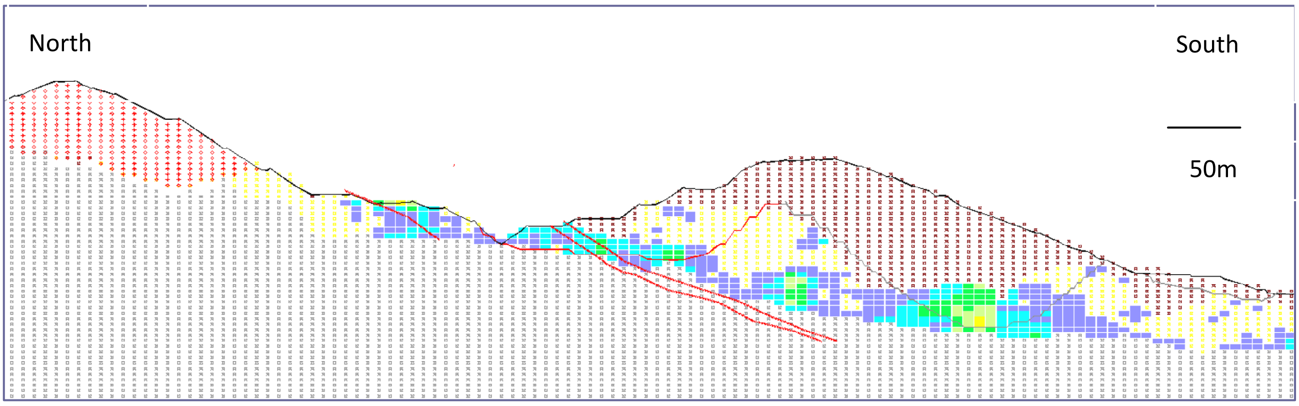

Figure 5 – A North-South section of the current block model

History of the exploitation

As early as the beginning of the 20th century, the Rabenwald talc deposit was exploited as an underground mine. From the eighties, an open pit operation named the "north pit" took over the previous mine in the north sector. At the beginning of the 2000s, this first pit came to its end. An extension project was decided in 2004 and the first talc ton of this new "south pit" was extracted in 2007.

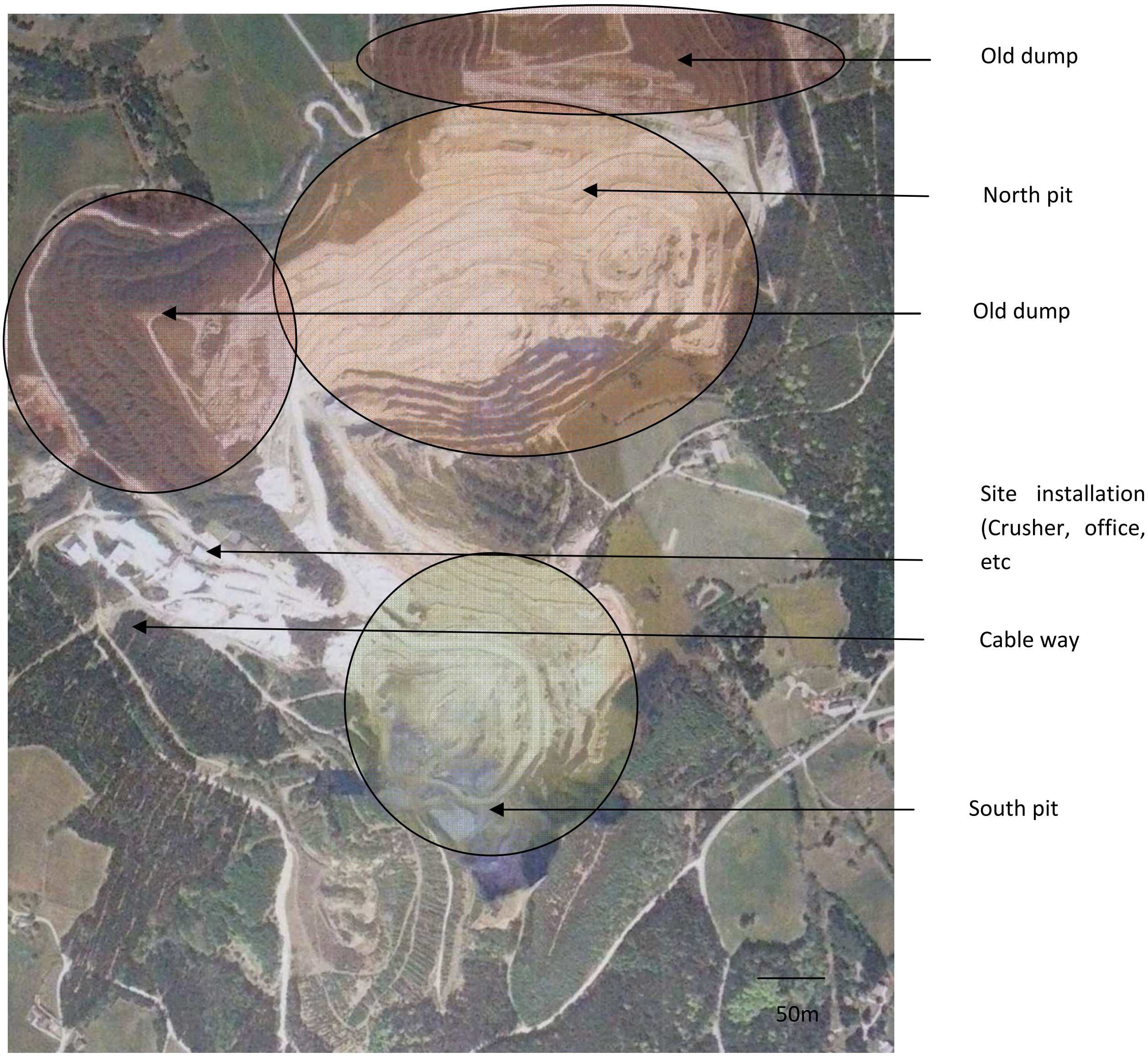

Figure 6 – General design of the current exploitation

The opening of the south pit project started with a long stage of prestripping from 2005 until 2008 which moved more than 4 Mt of waste from the Krughof hill, the emplacement of the south pit. This program aimed at reducing the overburden thickness during the investment phase and the first years of the project in order to get a better stripping ratio and less equipment in normal operations. A North-South section of the current block model on the figure 5 shows the profile of the ore body and the limit of the south pit in red. The figure 6 shows the location of the various pits and dumps as well as the general site installations.

The current exploitation

The current proven reserves of talc provided by the current design of the ultimate south pit reaches 1.83 Mt. These reserves were proved according to the JORC methodologies by a large exploration campaign led between 1999 and 2003.
The south pit was originally designed for a yearly production ranging from 100 000 to 110 000t of talc, a nominal production which was realized in 2007 and 2008. Because of the 2008 economical crisis, Rabenwald's production sunk to 70 000t in 2009 and is to be limited to 80 000t in 2010. The marketing teams in Graz and Toulouse forecast to slowly recover a production of 100 000t/year within the coming years. The life of mine is currently assessed to about 20 years and the end of the south pit is planned in 2030. The inferred resources in south of the current pit are estimated to 8Mt of talc and there is for the time being almost no measured resources in this area.

Pit design

Since 2008, the most amount of talc is extracted from the south pit. The north pit, which provides only a small part of the production, is to be closed by 2010. The dump operations take place on the Wiedenhofer dump as well as in the north pit, which will be slowly filled by waste of the south pit.

1.3. PRODUCTION METHOD

The main peculiarities of the industrial mineral sector are directly reflected by the mining and processing methods. In particular, concerns about quality are present as early as the extraction of talc with the excavator: the various qualities have to be identified as soon as possible and are managed through various mining and processing ways.

Waste removal

The overall stripping ratio of the south pit is about 1 to 17. Thanks to prestripping operations, this talc to waste ratio only reaches 1 to 14 now. The waste production was limited to 1.15 Mt in 2009 and is planned to 1.4 Mt per year for the nominal production.
The waste removal process consists in the 4 usual steps:

- drilling;
- blasting;
- loading;
- hauling – dumping.

Thanks to its low mechanical quality, only 45% of waste material needs to be fragmented with drill-and-blast methods; the rest is soft enough to be directly removed with the excavator.

The drilling process, in addition to its role for blasting, enables the team to get some precise information about the deposit at a given location and to confirm or to modify the resource model. No talc can be recovered if it is mixed with waste and it is very important to be as selective as possible. Holes are drilled down to the first layer of talc which is encountered, and explosive is positioned so that the first meter of waste neighboring talc is not affected by the blast. The magnitude of blasts is also limited for the same reason. On average, one blast fragments about 2700m³. ANFO explosive is mainly used for all the drill-and-blast operations.

All loading stages, whether for talc or for waste, are done by front-end shovels. Indeed, this equipment enables the operator to see what he loads, which is not possible with a classical shovel. Front end shovels are indispensable for selective mining since the best mean to identify the talc quality and to recognize talc from waste is the color of the rock.

The equipment used in Rabenwald mine for waste loading is a Liebherr R 984 HD shovel with a 7m³ bucket. Its average productivity varies between 600 and 750 t of talc per hour according to the situation in the pit.

The off-highway trucks used for waste hauling are Caterpillar 775 D which have a pay-load of over 60t and a total weight in load of about 120t.

Waste material is extracted mainly from the south pit and still a bit from the north pit for the 2 coming years. Dumping takes place in the north pit.

The figure 7 gives an overview of the process for waste removal.

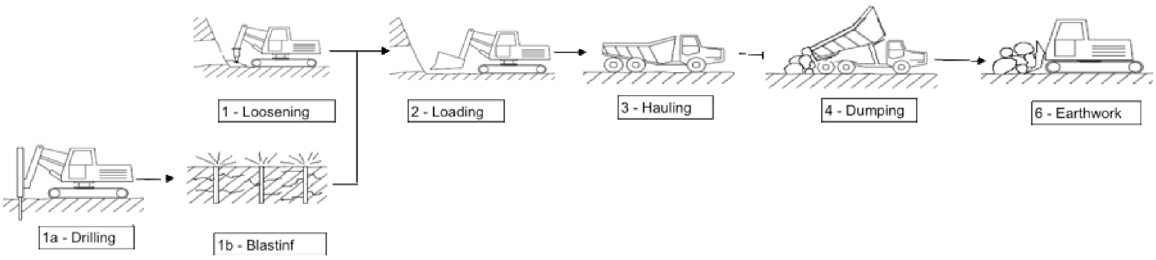

Figure 7 - The waste removal process

The talc production process

Once the overburden is removed, the deposit containing talc is accessible. However, only about 15% of the rock in the deposit is valuable talc. The rest, composed of other metamorphic rocks chemically close to talc such as chlorites or magnesites, is called inclusion and is considered to be waste.

The talc in Rabenwald is soft enough to be extracted directly with a front-shovel excavator. This is not systemically the case for inclusion, which has in general better mechanical characteristics. A hydraulic hammer can be set up on the talc shovel in order to fragment resisting inclusions. If need be, small blasts can be performed to fragment very solid inclusions.

The talc extraction is all done by two Liebherr R 954 B with bucket size of 1.6 or 2.5m³. MOXY articulated dump trucks are used for talc hauling. The inclusion loading is done partly with the talc shovel when precise selective mining has to be done (close to talc) and partly with the waste shovel to gain in productivity when selectivity is not essential. Inclusion is done with the equipment related to the excavator used: MOXY when inclusion is loaded with the Liebherr R 954 B and CAT with Liebherr R 984. The talc process is described on the figure 8.

Thanks to years of experience, the operators are very used to recognize talc from waste and to assess at first sight the talc quality in the deposit. They are able to identify four main qualities and the MOXY are thus loaded with a single given quality.

Then, the talc truck dump each load in a single pile on the day storage area, next to the laboratory. Whenever a new pile is unloaded, the laboratory operator takes a sample of it and performs some basic analyses to get the three main characteristics which define the talc quality: the brightness, the loss on ignition and the quartz content.

Once the quality of the pile is defined, the operator loads the talc pile into the crusher thanks to a Liebherr L551 loader. The crusher is therefore fed with only one quality at a time. After the crusher, the talc is stored sorted by quality in one of the 18 storage boxes, each of which can store about 500t. The talc of each quality is also sorted according to its grade. A first grid after the crusher takes the rocks bigger than 16mm apart and stores them in the boxes for gravel. The rest of the talc is crushed until reaching a grading smaller than 16mm. Taking apart the bigger rock is a mean to do a first sorting on the quartz content. Indeed, high quartz content results in more resistant blocks and conversely, the most resistant blocks of talc have in general a higher quartz concentration. The figure 9 shows the talc process and highlights the crusher process.

The next step of the talc production process is the transport to the processing plant which is located in Oberfeistritz at a distance of 4.5km as the crow flies. A cable way situated next to the storage box takes the talc directly to the plant. More than 90% of the talc transport is performed thanks to its cable car. Two roads serve the mine and transport by trucks is sometimes necessary when the meteorological conditions do not permit the functioning of the cable way (wind, snow). A small part of the production is also transported by truck to the Weisskirchen processing plant where it is needed for specific products.

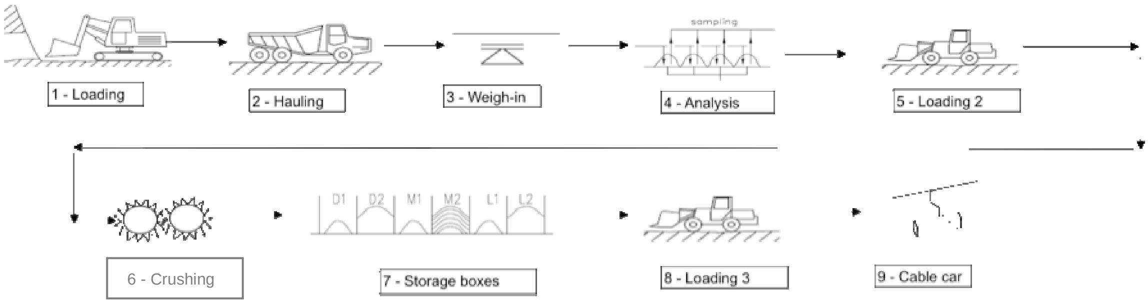

Figure 8 - The talc mining process

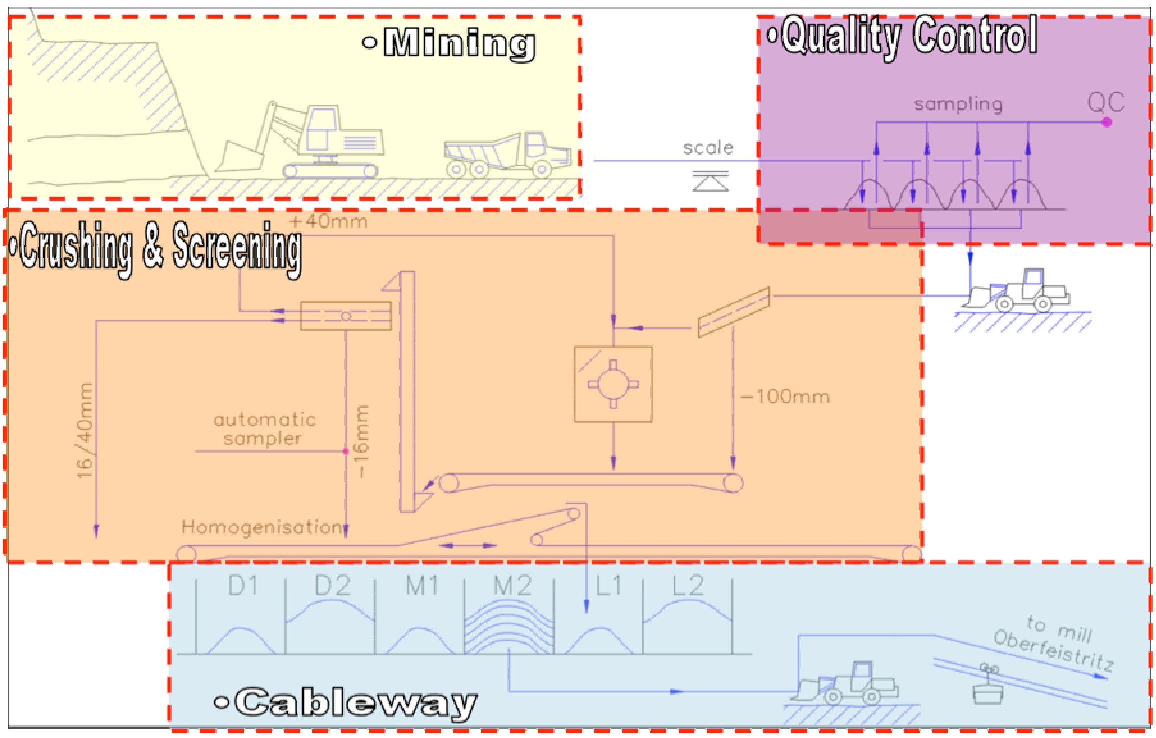

Figure 9 - The general mining process

The shift

Since 2008 and the crisis, the Rabenwald mine, which used to have two shifts, runs only one-shift operations. The Rabenwald mine has adopted some policies of the Austrian government to reduce the working time of its employees with no need of layoff. This policy is called “kurz arbeit” which means part-time.

The waste shift needs one operator for the R 984 shovel and two to three drivers for the CAT 775, according to the extraction point and to the distance to the dump. The talc shift is less usual because it is adapted to the particularities of talc. A talc shift fleet consists in the two shovels, one articulated dump truck pro shovel and only two operators in total. Each operator drives alternatively his shovel and his truck: he loads his MOXY with the shovel, gets out of the shovel, gets in the MOXY, drives to the day storage area and drives back to his shovel. This system has the advantage of avoiding any dead time, which could be very long given that the talc extraction time varies a lot according to the situation in the pit, to the deposit shape at a given place, to the talc quality, etc.

The mine planning

As it is already said, the mine has still between 18 to 21 years of life according to various forecasts. During this period, the waste extracted in the south pit will be dumped in the north pit. A small part of this waste will also be dumped in front of the south pit in order to build a visual barrier to the neighboring villages. The visual aspect of the exploitation is actually an important concern for the mine management for Styria is a pretty touristic region. But more generally speaking, the mine management is very aware of inhabitants in the neighborhood. Indeed, in Austria as in lots of places in Europe, the community acceptability is a major issue regarding legal authorization for production and for exploration. The visual barrier is one the expressions of these concerns.

The final pit, to be reached between 2028 and 2031, was designed during the 2004 feasibility study of the south pit. Based on the 1999-2003 exploration campaign, a very detailed block model was built. The dimensions of blocks in the model were 10x10x5m and each block definition consisted in the content in the 5 main qualities and in the waste quantities. Numerous studies about geotechnics and underground water were made by independent consultants. The results of one of these studies are the geometrical characteristics of the new pit as well as of the dump, which condition the design of benches. Waste benches in the pit are 12 m high and have an overall slope of 42°. The benches in inclusion and in talc are both 5m high and have respectively a 40° and a 29° overall slope. The geotechnical data are illustrated by the figure 10, 11 and 12.

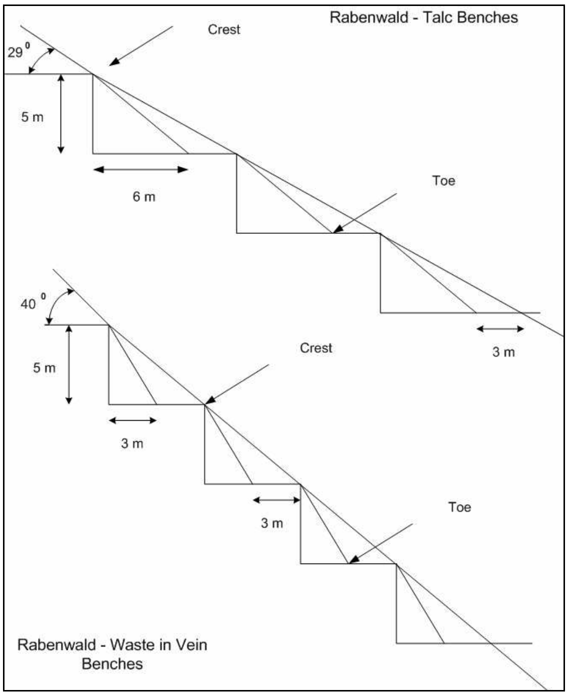

Figure 11 - Geotechnical parameters within the deposit

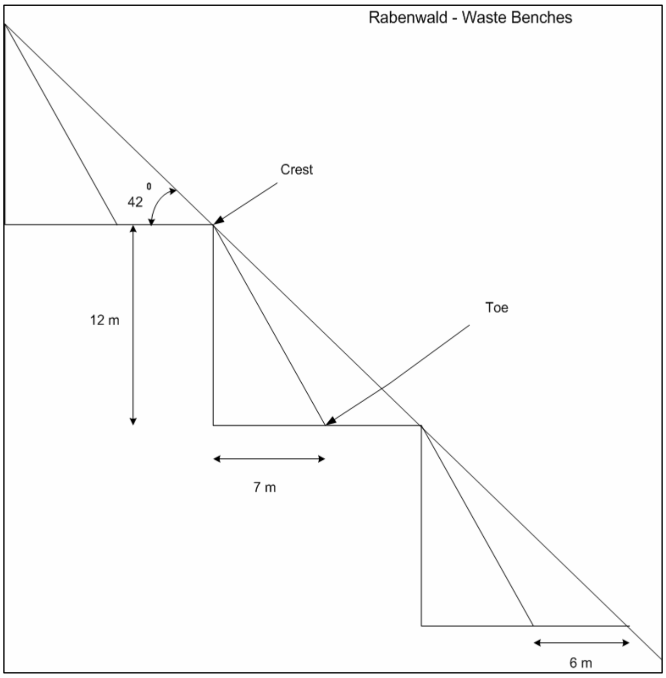

Figure 10 - Geotechnical paramaters in waste

The dump benches have an overall slope of only 26° and a height of 20m.

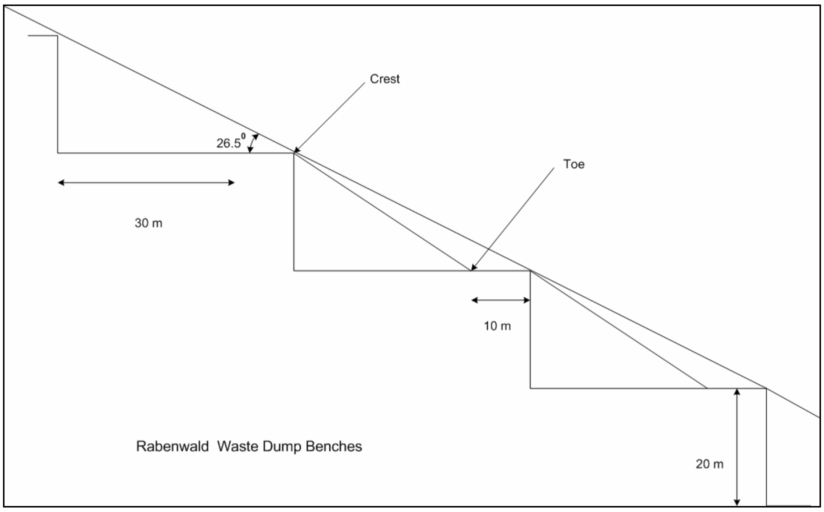

Figure 12 - Geotechnical parameters for dump design

The current pit design and the ultimate pit are available in the annex 1.

1.4. THE COST STRUCTURES

The plant in Oberfeistritz and the Rabenwald mine work in very close relation. More than 90% of the production from Rabenwald is performed through the Oberfeistritz plant. For the assessment of new mining projects, it is thus impossible to isolate only Rabenwald in the assumptions. Indeed, Rabenwald and Oberfeistritz activities are so closely linked that their performances are evaluated together within Rio Tinto Minerals. No intermediary sales price between Rabenwald and Oberfeistritz is defined.

All activities of Rabenwald and Oberfeistritz must be included in the assessment of a new project. Therefore, it is necessary in a first part to understand the cost structure of each of these industrial installations.

Besides, in order to give a good reflect of the functioning of the exploitation, the costs used for this study are the actual costs of the year 2008. In 2008, the nominal production of about 110 000 t of talc, for which the mine and the plant were designed, was done whereas it has dropped in 2009 and 2010. The 2008 costs give a more representative image of the cost structure. As it is explained later, one of the economical assumptions of the new project is the adoption of a sales plan of 100 000 t of talc per year.

The cost-accounting system of Rabenwald splits costs over the main activities which are:

- overhead and administration;
- talc extraction;
- waste extraction;
- crushing;
- transport.

The waste removal represents about 40% of the cost, the overhead about 30%, the talc production about 20% and the rest only a few percents. The figure 13 shows the cost breakdown.

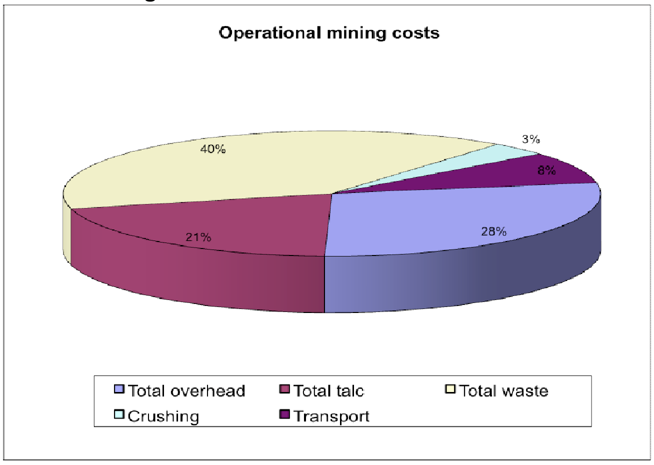

Figure 13 - The breakdown of operating mining costs

The overhead costs include as usual:

- the management costs;
- the facility costs (maintenance of buildings and general installation);
- the Health, Safety and Environment (HSE) department;
- A part of the workshop costs (workshop management and workshop facilities);
- The social costs;
- The information system.

The figure 14 gives a representation of these costs.

The total costs of the overhead is about 1.3M€ per year for total mining costs of 4.6M€.

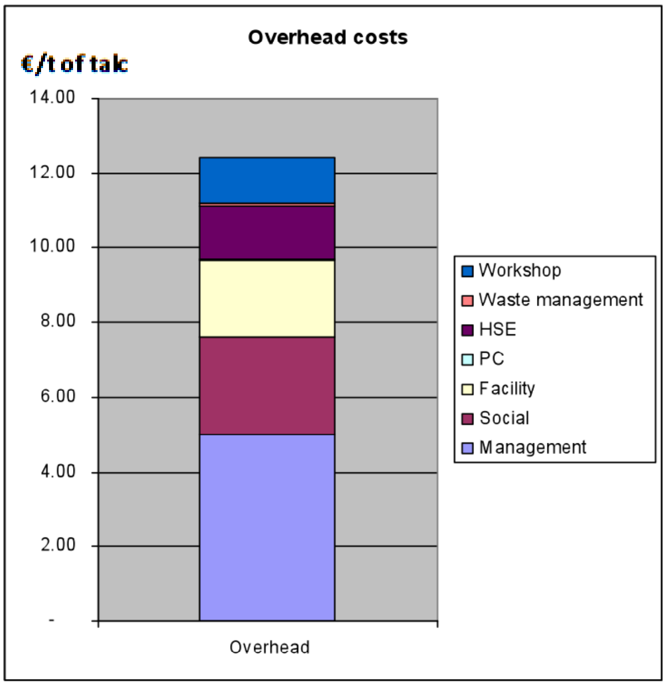

Figure 14 - The mining overhead costs per ton of talc

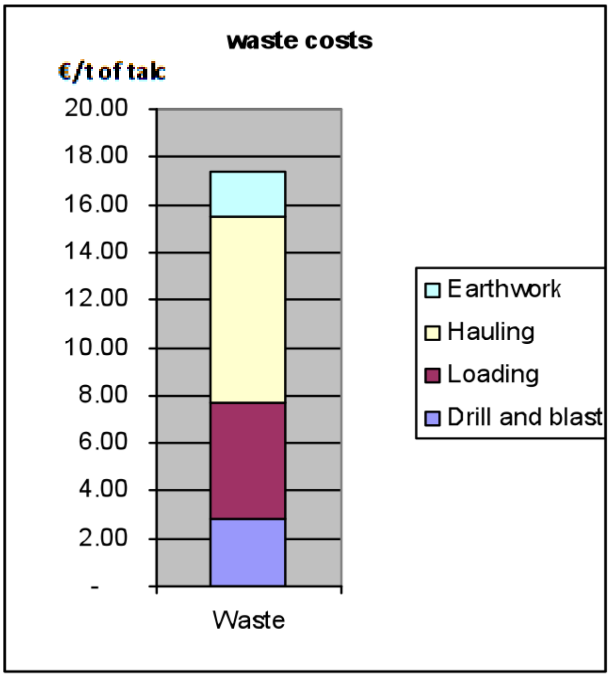

Figure 15 - The waste cost per ton of talc

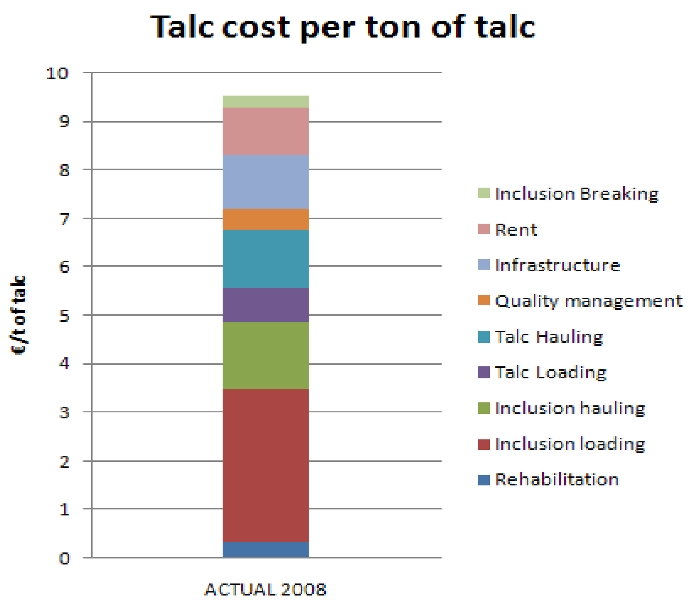

Figure 16 - The talc mining costs per ton of talc

<u>The waste extraction costs</u>

They take into account all costs which are directly related to the waste extraction and which are basically:

- drilling costs: energy for drilling equipment, maintenance and consumables of drilling equipment, operator wages, etc;
- blasting costs: explosives costs and related operator wages;
- loading costs: all costs related to the waste excavator (Liebherr 984) and the subsequent workforce costs;
- hauling costs: all costs related to the waste truck (CAT 775D) and the subsequent workforce costs;

- earthwork: all costs related to bulldozer and the subsequent workforce costs.

These costs are described by the figure 15.

The talc extraction costs

The costs allocated to the talc extraction process are much more complicated than for the waste removal process for many costs which have no direct links with talc are actually broken down on talc. The other difficulty in defining the talc costs is that a few processes are not performed in practice as they are registered in the accounting system.

First of all, all costs related to rehabilitation, forest work and complementary exploration are allocated only to talc. The same is true for the infrastructure costs, which mainly consist in the costs of the pit road construction and maintenance, that is to say the costs generated by the grader and its workforce.

Some parcels of land on which talc is extracted do not belong to Rio Tinto Minerals. For these parcels, the firm has to pay a yearly rent to their owner called "land use". Another particularity of the region is that there was another private talc producer on Rabenwald deposit a few years ago. This company belonged to Mr. Reithofer who is also the owner of large parcels of land on the eastern part of the exploitation. Rio Tinto Minerals found an agreement with him in order to be the only talc producer. In exchange, Rio Tinto Minerals must pay him a royalty of about 3.3€/t of talc extracted. The costs for land use and royalties are once again only broken down on talc costs.

All the costs for inclusion removal are as well counted on the talc account. These costs are composed of:
- the inclusions breaking (hydraulic hammer and drill and blast when need be);
- the inclusions loading;
- the inclusions hauling.

Finally, we find the talc direct costs:
- the talc loading costs;
- the talc hauling costs;
- the quality management costs (laboratory).

However, the break down between inclusions costs and talc costs is not always simple:
- the cost of the two shovels (fuel and maintenance) is only allocated to the inclusions loading. The talc loading only consists in the workforce costs;
- the cost of the four MOXYs (fuel and maintenance) is only allocated to the talc hauling. The waste hauling only consists in the workforce costs and in practice waste in vein or inclusion is hauled with the CAT 775D.

These costs are described by the figure 16.

The crusher and the transport activities are recorded on their own account and are managed as independent processes. However, they are in practice allocated to talc. They include direct costs for the crusher and the cable way as well as loading costs from the day storage to the crusher, and from the storage boxes to the cable way.

2. THE DEFINITION OF THE NEW PROJECT

2.1. THE NEW EXTENSION

The current pit project was approved in 2004 and produced its first ton of talc in 2007. Today, it still gives at least 18 years of life to the mine. In these conditions, it is legitimate to question the interest of studying now a project of a new extension all the more than the economical situation is not favorable to big investments and to very long term projects.

They are of course several valid answers to this question. The first one is a fact: nowadays in Europe, the permitting process and obtaining the legal authorization, first for exploration and then for exploitation, are becoming always more time-consuming and uncertain. Generally speaking, the mining laws in Western Europe countries are always more constraining and on top of that come little by little the European regulations.

The inertia of this process is as well increased by some specificities of the mining sector. Getting a good knowledge of a deposit requires years of exploration and geological studies, and in spite of this, a geological risk always remains.

In this time of economical difficulties, investments are often frozen for the coming years and it is good to know as early as possible when an investment such as an exploration campaign will have to be done.

In that logic, this master thesis must not be seen as the development of a new pit but as a demonstration which shows that, if the given assumptions are correct, and in particular if the geological model is valid, a new project will be feasible from both technical and economical point of views. The goal of this document is to show the potential of the project in order to unfreeze some funds and to go in a first exploration campaign.

2.2. THE ASSUMPTIONS

The bases of this study are the data and the assumptions given at the beginning by the mine management and the planning and resources department. The most important assumption is a geological model provided by the planning and resources department, which extends the current block model in the south region. At this stage, this model is very hypothetical since only based on studies of the current pit. No outcrop or drill holes confirm it.

In addition to this geological model, the mine management fixes some simple and general assumptions regarding:

- a sales plan of 100 000t of talc per year;
- an average sales price of 237,85€/year;
- the financial department based in Graz gave later the economical assumptions to insert in the economical assessment of the project such as the inflation rate or the discount rate for the Net Present Value calculation;
- a lot of other assumptions concerning the development of a new block model, the capital expenditure plan, the Rio Tinto Minerals' standards for economic calculation, etc.

As for the geological part of the work, Rio Tinto Minerals provided the Datamine software, with the open pit design extension. Thanks to the Centre de Geosciences at the Ecole des Mines de Paris, I had an access to the license of another program: GEMCOM Whittle.
Datamine is a mine design software which makes it possible to manage data such as block models, drill holes, topography, etc. Datamine is very practical for its very good quality in 3D visualizing and for its relative easiness. Whittle is asoftware for pit optimization studies using the Lerch-Grossman algorithm. I worked mainly with Datamine and switched to Whittle only to lead some short optimization studies.

For practical reasons, I tried to work as much as possible with Datamine when it was possible for I could not use Whittle in the office: I had to connect to the license server stored in Fontainebleau, which I could not do from the secured connection in Rabenwald. I made this choice in order to not waste too much time in driving between the office and my place. In that logic, some of the handling I did, especially regarding block models, were done in Datamine whereas it would have been more rigorous to do it in Whittle.

<u>The geological model</u>

The geological model provided by the resource department is based on the block model for the current pit and extends it on 3 km towards south. Contrary to the current block model, the new one contains information on only one average quality of talc since it is really too early to introduce several qualities in the model and to enter into more detailed studies. The impact of various talc qualities within the deposit will be treated later with some sensitivity study.

The dimension of the blocks in the model are $20x20x10m^3$ and the model has about 230 000 blocks in total: between 10 and 40 blocks vertically, 140 blocks from north to south and 75 blocks from east to west.

The information contained in each block is:

- the dimension on X, Y and Z axis (Xinc, Yinc, Zinc). X is the West-East axis, Y the South-North axis and Z the vertical ascending axis. Some blocks are split in order to follow better the deposit and the topography;
- the position of the center of the block (Xcen, Ycen, Zcen);
- the block number;
- a talc grade TT which is a percentage of the total volume;
- a zone number: number 1 for the hanging wall, number 2 for the deposit and number 3 for the footwall.

For the calculation of talc and waste quantity within a pit, some applications are available in Datamine to get the total volume and the average talc volume for each bench of the pit. To convert this volume to a tonnage, some standard densities are used for Rabenwald:

- waste density: 2.5;
- talc density: 2.7

<u>The limit of the block model</u>

The block model covers an area of 420 ha which is partly on the current pit. The figure 17 shows the extension of the block model.

There are actually some data available for a small part of the area covered by the block model. In 2003, at the end of the 1999-2003 drilling campaign for the south pit extension, a small exploration campaign was led in the southwest part of the exploitation. Indeed, at this time, it was believed, based on some geological studies, that this area was the best candidate for a further extension of the current south pit. As early as 2003, the management of Rio Tinto Minerals was already interested in the successor of the current pit, which was to start 4 years later!

About 25 holes were drilled in a triangular region highlighted in red on the figure 18. On the following figures, the talc blocks are always in green, the hanging wall in blue and the footwall in red. Unfortunately, this campaign was not successful at all for only three holes mainly located at the eastern boundary of the drilled area, showed a small presence of talc. All the other did not encounter talc on more than a few decimeters. Therefore, it was decided to give up exploring this area and to postpone the study and the exploration for a further extension.

The block model that I got was not updated with the results of this drilling campaign and the first thing I had to do was to reconciliate it with the data from this exploration. It mainly consisted in erasing talc in a large area of the block model. The area to be erased is outlined in red on the figure 19.

Once this area was removed from the model, a first geometrical study of the deposit in Datamine was led. By studying the general aspect of the deposit and by looking at the east-west and north-south section through the south region, it became quickly clear that the most interesting part of the block was situated about 2 km directly south from the current pit. This region is highlighted in green on the figures 18 and 20.

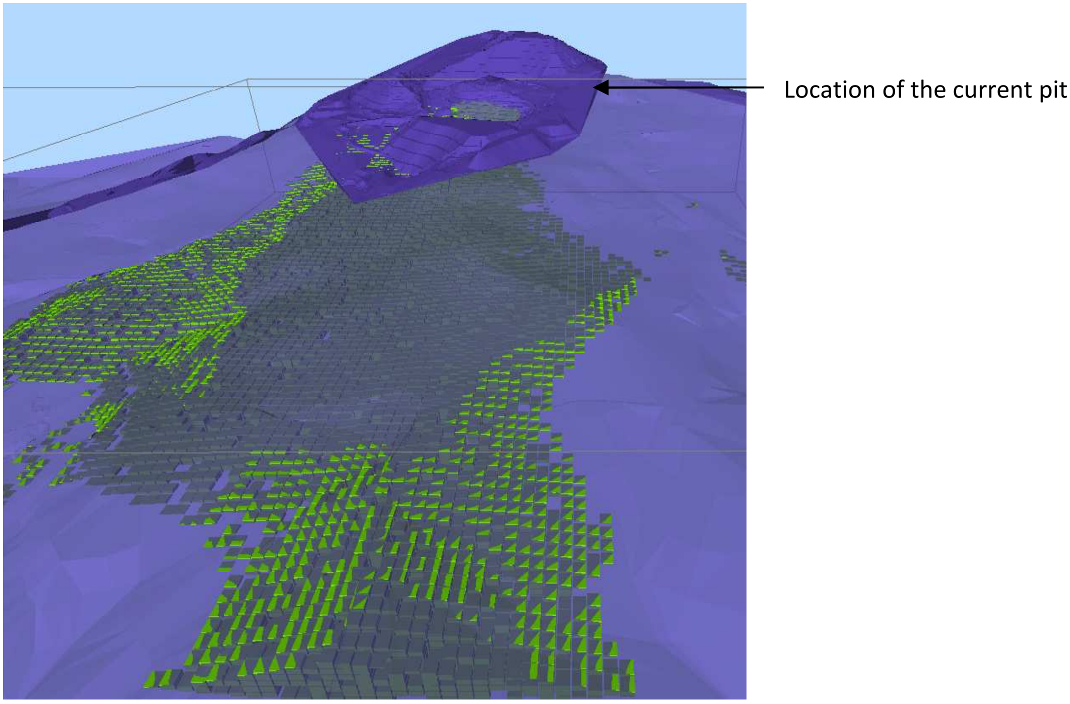

Figure 17 - The complete block model

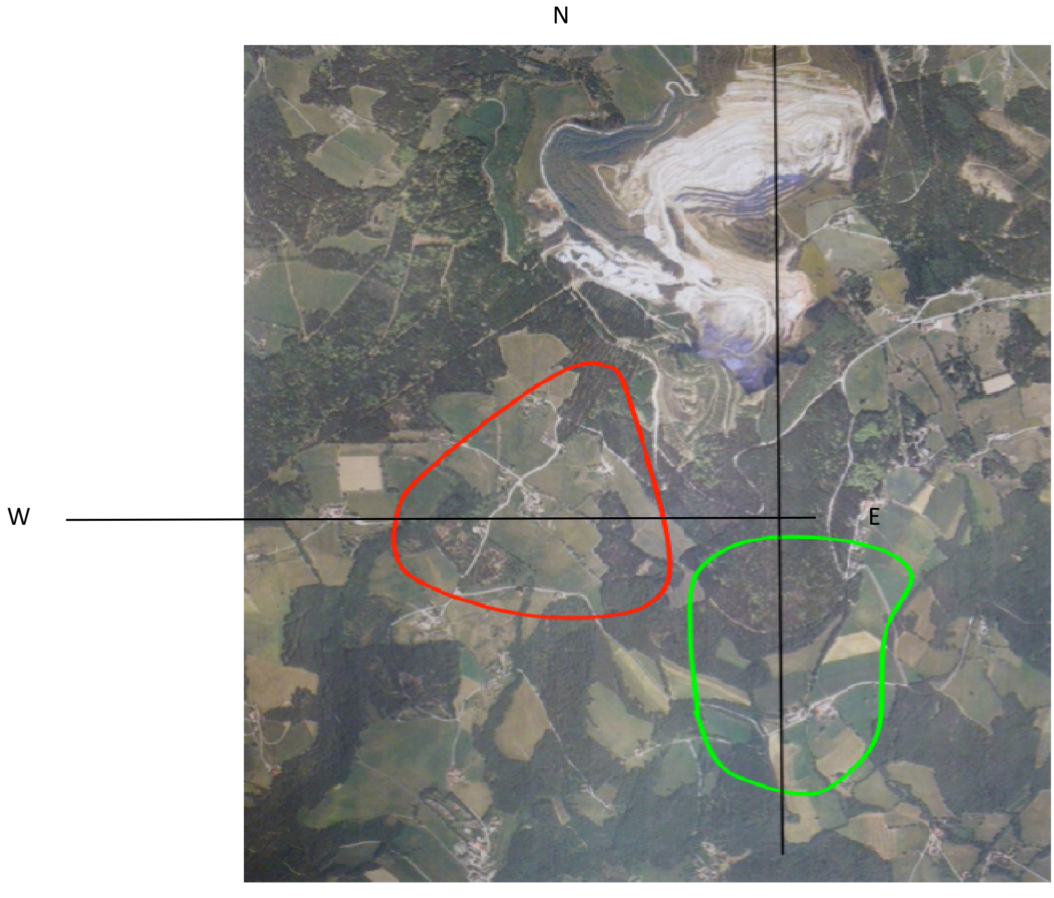

Figure 18 - The geological interesting area

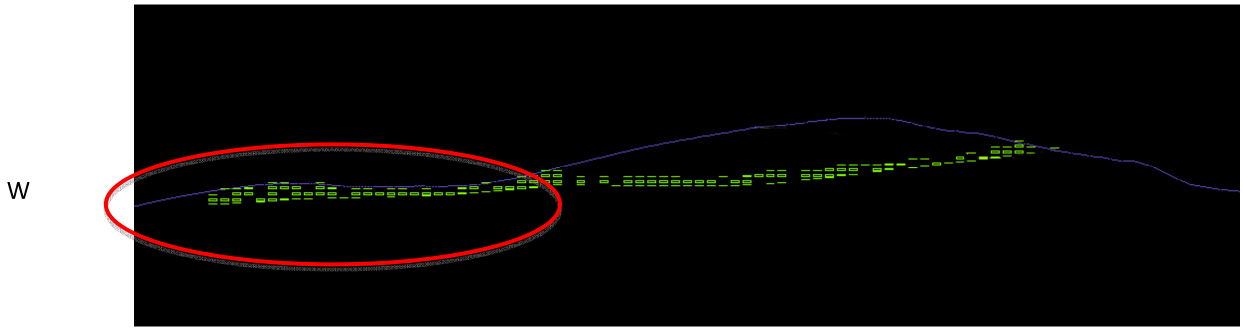

Figure 19 - An East - West section of the deposit

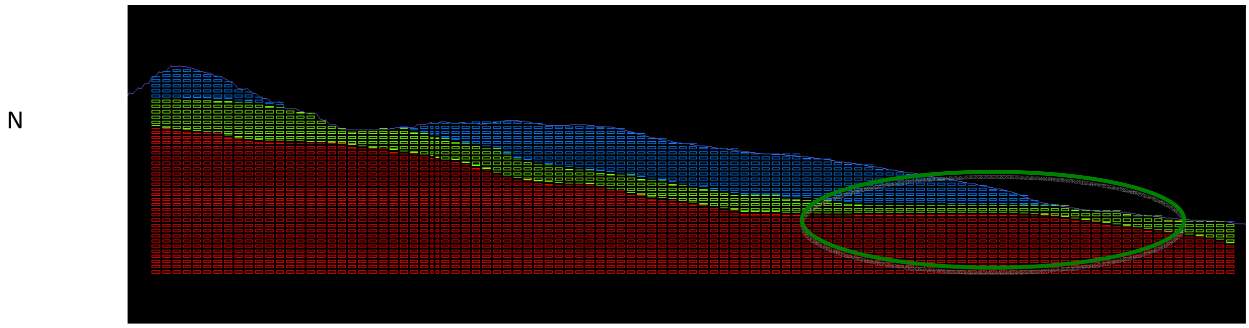

Figure 20 - A North-South section of the deposit

2.3. THE THOUGHT PROCESS

A few first draft pits showed that the new exploitation, if it was to be situated in the green area (which will be confirmed later in Whittle), will be pretty different of the current pit from 2 main aspects:

- the stripping ratio (better in the new pit);
- the hauling distance (much longer with the new project).

At this stage of the study, the first priority was to design a first optimized pit using Whittle in order to be able to develop a detailed cost model for this pit. Given some particularities of the talc business and of internal policies of Rio Tinto Minerals, the optimization to be run are a bit different from usual optimizations for commodities exploitations such as copper for instance.

<u>Rio Tinto project assessment method</u>

The first particularity within Rio Tinto Minerals is the competition between projects in various countries. Indeed, a new project always needs some investments from the Rio Tinto Minerals holding as the subsidiaries are not big enough to finance them by themselves. For instance, the authorization for a new project and funds for exploration campaign are given by Rio Tinto Minerals. It is important to know that Rabenwald is a particular exploitation for Rio Tinto Minerals: its deposit is very inhomogeneous and the average talc quality is very low compared to the other talc mines. In that logic, Rabenwald undergoes a lot of competition from other mines within the group.

The main consequence is that, according to Rio Tinto Minerals team, a project can be accepted in Rabenwald only if it presents a very good stripping ratio compared to the other mines. The first constraint from the company was thus to design a pit with a stripping ratio lower than 1 to 15, which is the overall stripping ratio of the current south pit. At first sight, it is clear that reducing as much as possible the stripping ratio will imply to have a shallow pit to extract all talc which is almost outcropping.

The other constraint set by Rio Tinto Minerals was related to the goal of this thesis: to get some money for exploration. An exploration is all the more easy to justify that the potential reserves are high. I was then pushed in completely different directions than reducing the stripping ratio which was to maximize the potential reserves.

Finally, the cost model I had for the current exploitation would probably not fit the new exploitation: the longer hauling distance and the better stripping consistently change the cost structure.

It was then decided to proceed according to the following method:

- design one pit maximizing the reserves with keeping a stripping ratio lower than 1 to 15;
- design one pit with a stripping ratio of 1 to 11;
- develop a cost model for each of these pits;
- compare the results and re-run the optimization with the adapted model.

<u>The software</u>

This method consists in several steps between Whittle and Datamine:

- export the Datamine block model to Whittle;
- enter a basic cost model in Whittle: the current cost model was used to run the optimization. The accuracy of the cost model for the new operation is actually not important as we are only interested in getting the stacked optimized pits and then choosing among them the two with the wanted characteristics;
- run the optimization in Whittle;
- export the Whittle optimized pit to Datamine;

- design the pit in Datamine;
- develop a new cost model for the new pit;
- re-run the optimization in Whittle with the new model to confirm the results.

The figure 21 illustrates this method.

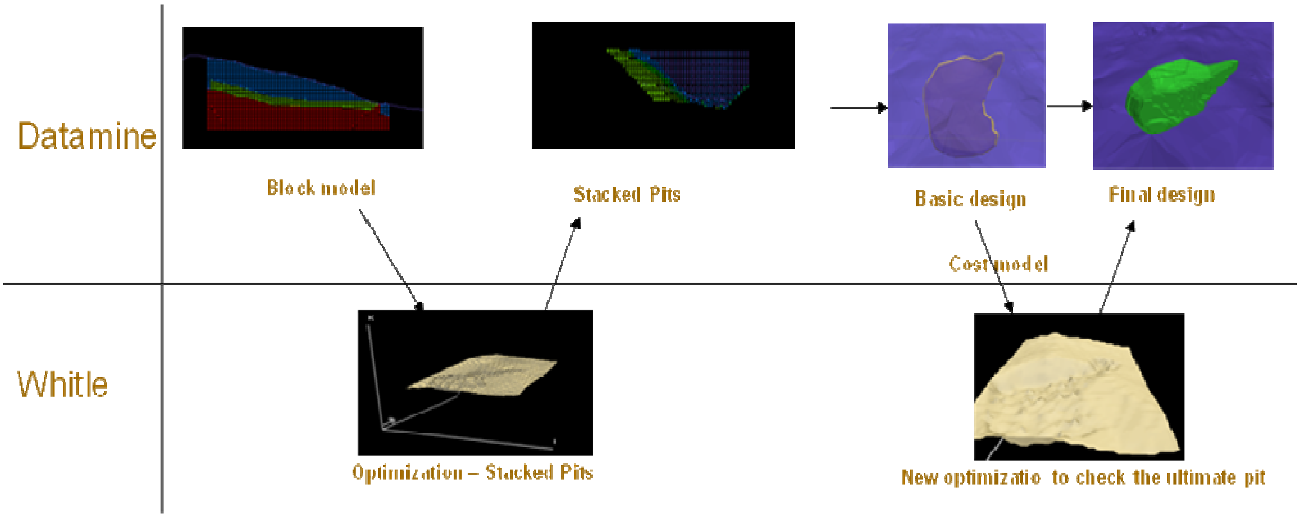

Figure 21 - The optimization process

Finally, a last constraint was applied on the pit design. The first south limit of the new pit was first set to the road highlighted in red on the figure 21 which is at an altitude of 800m. A few houses are lining the road. This limit was given because going southern would imply to rebuild the road further and to relocate all houses. We thought at the beginning that this increase of investments would be huge for the project. This limit was also a psychological limit. The hauling distance from the current installation to the new pit is very long, and no one could believe that a mine with such a hauling distance could work.

On the other hand, we realized that the most interesting talc resources were situated just south of this road. We then decided to study four scenarios:

- the pit is limited to the road:
  - Pit A: the stripping ratio is set to 1 to 11;
  - Pit B: Maximization of the reserves with a stripping ratio lower than 1 to 15;
- the pit is not limited by the road and goes as far as the block model goes:
  - Pit C: the stripping ratio is set to 1 to 11;
  - Pit D: Maximization of the reserves with a stripping ratio lower than 1 to 15.

<u>Optimization with Whittle</u>

A first optimization in Whittle confirmed the fact that the most interesting area was indeed the green area. In order to speed up all calculations, 2 block models limited to the appropriate areas were created in Datamine and re-exported to Whittle:

- one for the pits A and B;
- one for the pits C and D.

The figure 22 shows the limited block model for the pit C and D.

The first one was created by erasing all talc in blocks situated south of the limiting road. The road line was projected downward with an angle of 40° which represents the average slope of the pit given by the geotechnical studies in order to be sure that Whittle would not optimize the pit by taking blocks that could not be extracted for geotechnical reasons.

The new block model for pits C and D is simply a version of the original block model but limited to the north, east and west to limit its size and to speed up calculations.

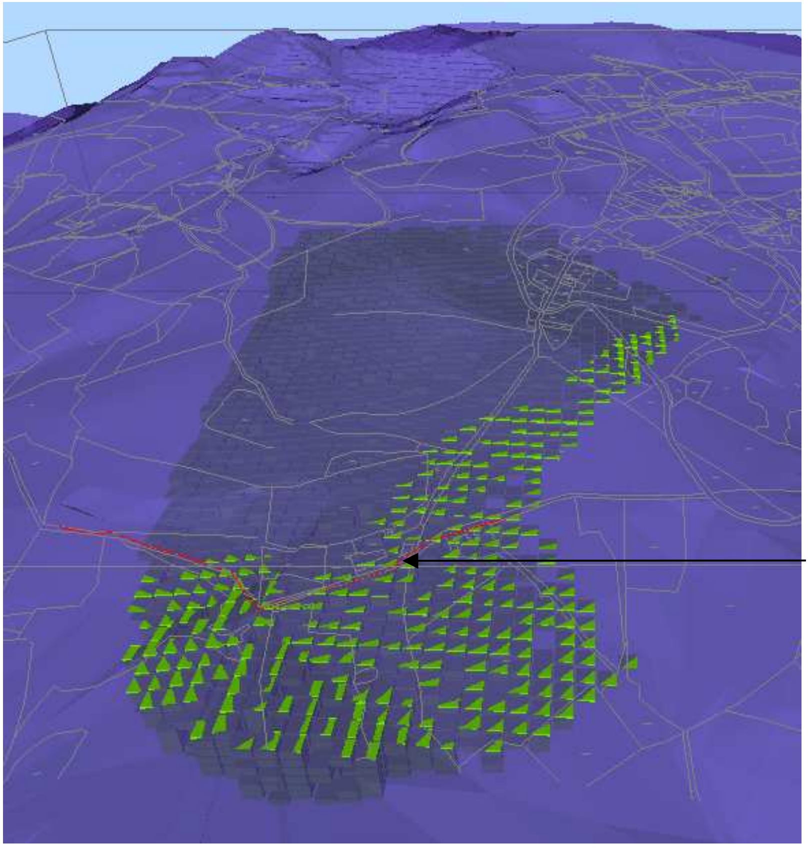

Figure 22 - Block model limited to the interesting area for pit C and D

In order to run this first phase of optimization, the cost model of the current exploitation was used. Running optimization in Whittle requires entering a complete set of parameters to perfectly define the stacked pits.
The first step is to import the Datamine block model and to indicate to Whittle which data contained in a block represents the quantity of waste and the quantity of talc. Originally, each block in Datamine contains two important parameters giving the percentages of volume occupied by waste and talc. It was easier in Whittle to deal with quantity instead of percentage so two columns were added in each block in Datamine: the weight of waste and the weight of talc.

It is then necessary to enter the geotechnical data for the pit optimization. At this stage, an average slope of 40° coming from the average of the geotechnical slopes given in the figures 10, 11 and 12 was used. The next step is to enter all the economical data, for which the main parameters are the average sales price, the costs for talc production and the costs for waste removal.

Regarding mining costs, it is possible to enter different costs for waste costs and for talc costs. Process costs are then entered to get the total costs. In order to simplify the entering of parameters, the real process costs, the crusher costs and the transport costs were subtracted of the average sales price so that there was no need to enter these costs in the Whittle model. At the end, the model in Whittle consists in an average sales price per ton of talc, the costs for the production of one ton of talc and the costs for the removal of one ton of waste.

Pit	Revenue factor	Total rock	Waste	Talc	Stripping ratio
1	0.3	1 254 407	1 005 939	248 468	4,0
10	0.48	9 005 507	7 732 863	1 272 644	6,1
20	0.68	13 897 927	12 194 896	1 703 031	7,2
30	0.88	16 604 850	14 729 766	1 875 084	7,9
40	1.08	18 997 706	16 992 301	2 005 405	8,5
50	1.28	23 868 617	21 651 489	2 217 128	9,8
57	1.46	31 475 867	28 982 195	2 493 672	11,6
58	1.48	109 206 944	104 065 267	5 141 677	20,2
60	1.52	109 648 396	104 492 017	5 156 379	20,3
70	1.72	111 253 205	106 048 136	5 205 069	20,4
80	1.96	114 040 646	108 760 230	5 280 416	20,6

Figure 23 - Characteristics of the stacked pits

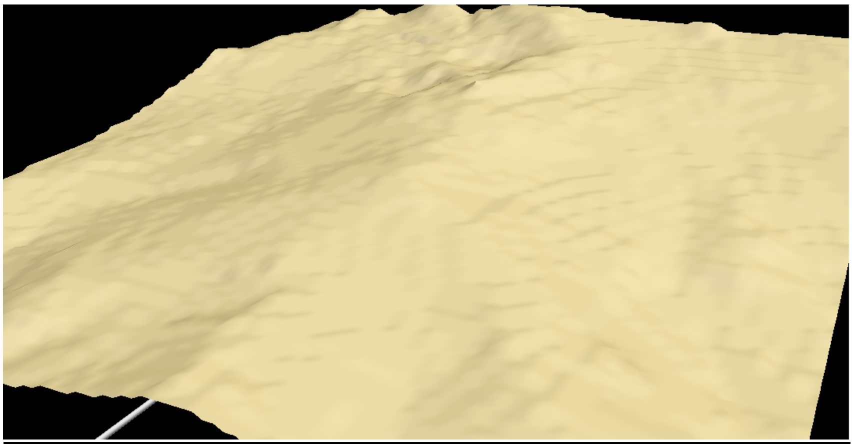

Figure 24 - The original topography in Whittle

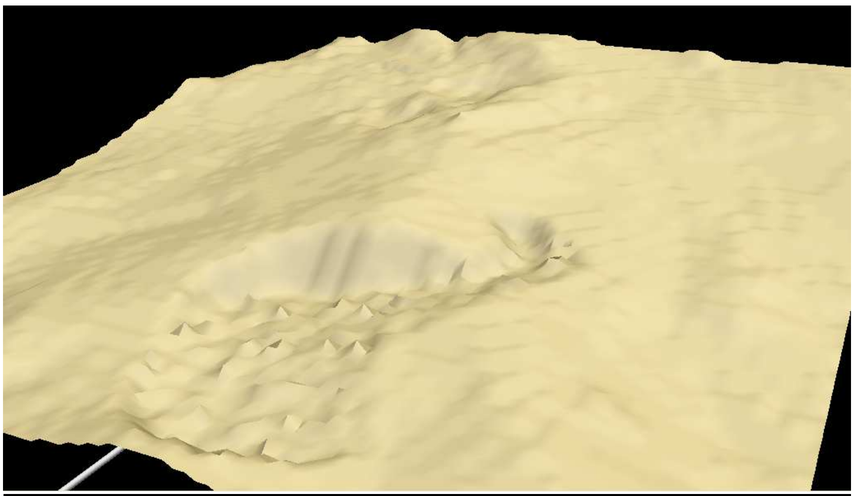

Figure 25 - The pit 57 in Whittle

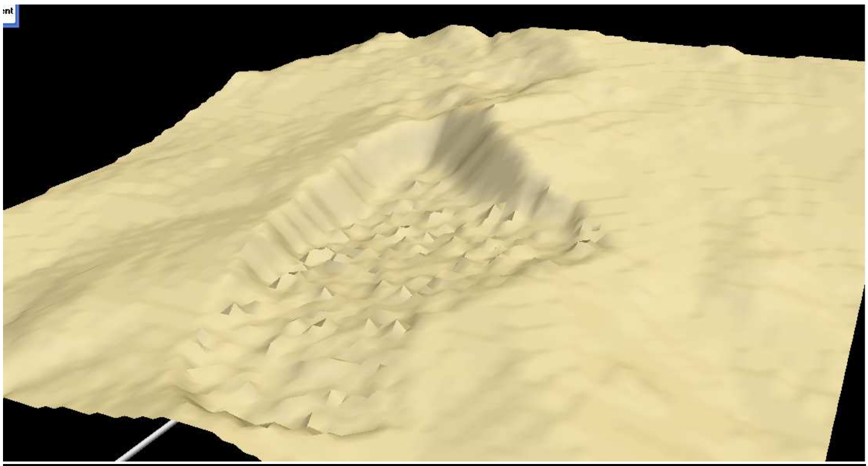

Figure 26 - The Pit 58 in Whittle

The optimization method

Whittle obtains the series of stacked pits by using the Lerch-Grossman algorithm and by varying one parameter: the revenue factor, that is to say the average sales price. Each pit is obtained by multiplying the average sale price by a factor between 0.3 and 2. For each step of the revenue factor, Whittle calculates the optimal pit and gives the total tonnage and the tonnage of talc. From this data, it is easy to calculate the stripping ratio and then to choose the 4 pits that interest us. The figure 23 gives the characteristics of a few stacked pits.

The gap

No problem occurs to get the optimal pits A, B and C. However, some difficulties occur to obtain the pit D. Indeed, as we can see in the table shown in figure 23, there is a huge gap between the pit number 57 and the pit 58. The stripping ratio goes suddenly from 11.6 to more than 20. This huge gap is very clear on the figures 24, 25 and 26 which give the representation of the stacked pits 57 and 58 with the Whittle visualization. The figure 24 is the original topography. The pit 58 is almost three times as big as the pit 57. This gap was at first sight not understandable. How can such a difference exist whereas the revenue factor has only increased by 2% between these two pits?

A lot of tests were done in order to detect a bug in Whittle or to understand which parameters were responsible for this sudden gap. The answer was discovered later by studying the geometrics of the deposit. At the north limit of the pit 57, several phenomena occur at the same place:

- on a North-South section, the deposit is almost horizontal whereas the topography goes up while going towards north;
- on an East-West section, the deposit goes down while going towards east ;
- the deposit is locally thinner.

These three combined phenomena explain the fact that there is no economical optimum between the pit 57 and the pit 58. It was though still interesting to get a pit bigger than the pit C with a stripping ratio around 1 to 14 even if it was not an optimal pit for this optimization. Indeed, the goal of this optimization is only to obtain four pits corresponding to the wanted stripping ratio and reserves. These pits do not need to be optimal pit for the current optimization for the economical model for these pits will be different as the current one.

It was impossible to get an interesting pit between the pit 57 and 58 in Whittle. The pit D was then designed directly in Datamine and was based on the pit C. Several designs regarding the north limit of the pit D were done in order to get a manually-optimized pit with a stripping ratio of 1 to 14.

Export of the stacked pit to Datamine

Once the optimization was done with Whittle, I selected the two interesting pits for each limit. Whittle creates a new block model giving the stacked pits. Each block contains a pit number, which gives the smallest pit in which this block will be extracted.

With this block model in Datamine, I designed four basic pits. The pits designed in Whittle are only theoretical and it was thus necessary to take into account some practical details such as the minimum mining width in order to design some realistic pits.

This phase resulted in the design of the four pits with the characteristics given in the figure 27.

	Reserve Talc (kt)	Total waste (kt)	Striping ratio
Current pit	955	9,860	15.0
PIT A	955	9,860	10.3
PIT B	1,329	19,189	14.4
PIT C	2,270	25,095	11.1
PIT D	3,052	44,561	14.6

Figure 27 - Characteristics of the four pits

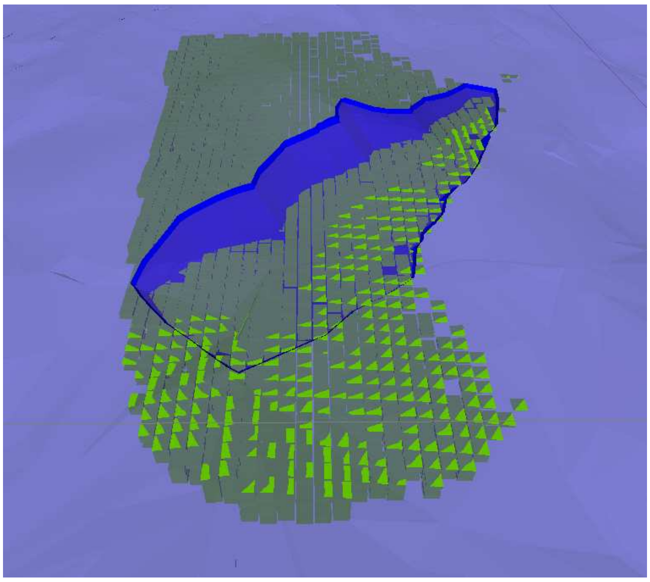

Figure 29 – Basic design of pit A

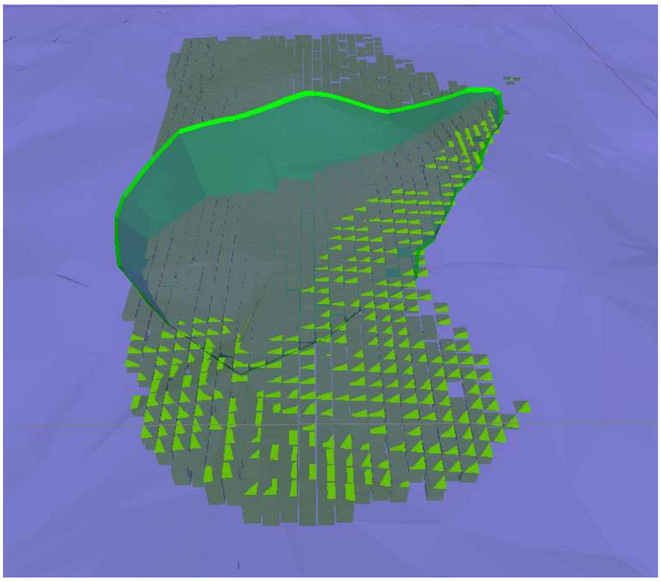

Figure 29 – Basic design of pit B

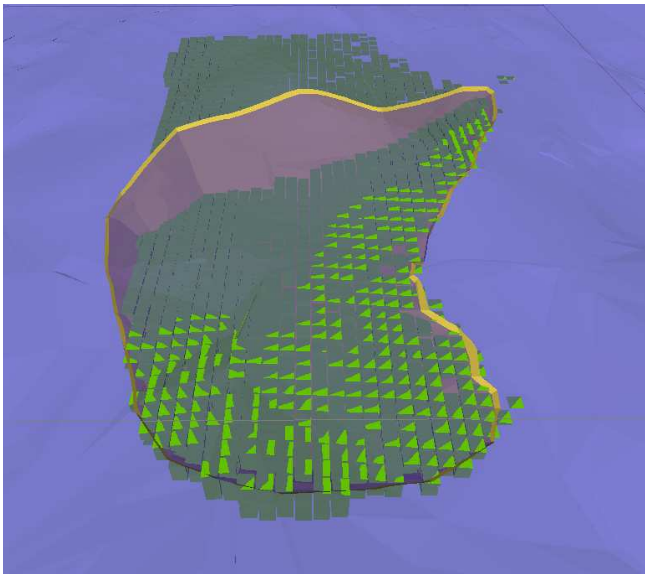

Figure 31 – Basic design of pit C

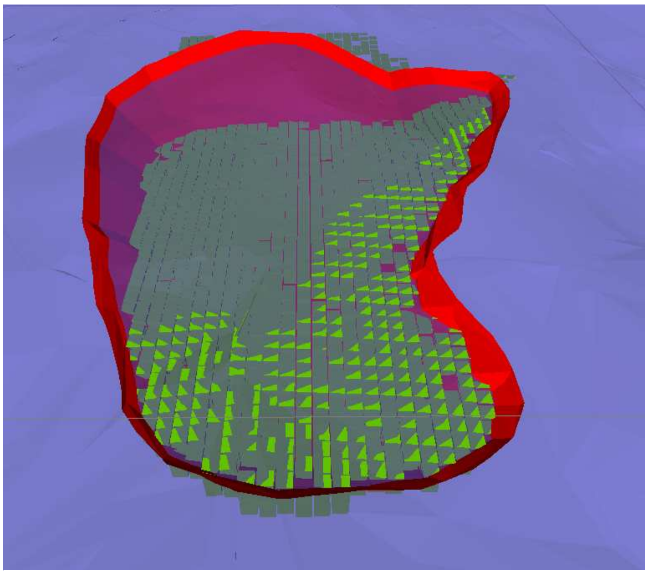

Figure 30 – Basic design of pit D

For this first study, it was assumed that the waste from the new pit could only be dumped in the current south pit, which will be empty in 2028. Currently, the waste from the south pit is dumped in the north pit. Indeed, it is almost impossible to get the legal authorization to dump elsewhere than in an existing pit.

Thanks to Datamine, it is possible to measure the new talc and waste hauling distance:

- talc: average hauling distance from the pit to the crusher: 6.7km (2.6km currently);
- waste: average hauling distance from the new pit to the current south pit: 7.3km (3.1km currently).

2.4. THE PRODUCTION METHOD

At this stage of the project and as a first approach of the economical assessment of the four scenarios, it was decided to keep the same production method then for the current pit:

- shovel Liebherr 984 and CAT 775D for waste;
- couples shovel/Liebherr 954 and MOXY for talc.

It was then necessary to enter into the details of the cost structure to adapt them to the new parameters such as the new hauling distance and the better stripping ratio.

The first step of this assessment was to define the number of equipment needed for this new pit. Most of the data needed for the following studies were obtained thanks to the data collection system in Rabenwald which is very complete and easy to use. Each operator on site has at his disposal a PDA device linked by a wireless network to the central database. It is possible for him to enter every operation related to each process:

- the MOXY drivers enter the time of each step of the talc hauling process: loading, hauling, weighting, unloading, etc;
- the talc shovel operator do the same for the talc loading process;
- Ibid. for waste hauling and waste loading;
- the laboratory analyses the talc in the day storage and types the subsequent qualities in the database;
- etc.

A huge amount of information is thus available in the database since the installation of the system in 2006. In particular, it is possible to access for each piece of equipment to the following data:

- number of operating hours per time period;
- quantity of talc/waste/etc processed;
- the availability;
- the utilization;
- the maintenance stops.

From this data, it was easy to calculate an overall productivity for each piece of equipment in the current exploitation:

- CAT 775 D: 250t/h;
- MOXY: 60t/h;
- waste shovel: 750t/h.

The productivity for talc shovel is almost impossible to get from the data collection system for two reasons:

- the work of these shovels depends a lot on the pit situation, the talc quality, the inclusion hardness at a given time;
- the talc shovel operators do not correctly enter the data related to inclusion work in the PDA.

For the hauling equipment, a cycle analysis was led to define the impact of the new hauling distance on the productivity. For MOXY, for instance:

- the current productivity is 60t/h;
- the current average cycle lasts about 30 min;
    - o 15 min for loading, weigh-in, unloading and maneuvering;
    - o 15 min of driving;
- the current hauling distance for talc is about 2.6 km;
- the new hauling distance will be 6.7 km

This new parameter gives a new productivity of 32 t of talc/h. To calculate the yearly production per MOXY, we assume there are 50 weeks of 40 hours worked per year in Rabenwald, multiplied by an availability of 95% and a utilization of 90% (standard data for talc mine within Rio Tinto Minerals) which gives a total number of working hours: 1710h/year. The yearly production is 56kt of talc/MOXY. Therefore, it is necessary to have two MOXY to transport the 100kt of talc planned per year.

The same principle has been used for the waste hauling truck, and the results are:

- current productivity: 225t/h;
- new productivity: 105t/h.

As the quantity of talc to be extracted will be the same, the same number of talc shovel will be needed. As for the waste shovel, we assumed that the productivity will be the same as today for the hauling distance has a very low impact on the loading operations. The number of equipment for each scenario is summarized on the figure 32.

				Needed equipment			
	Reserve Talc	Total waste	Striping ratio	CAT	MOXY	Talc shovel	Waste shovel
Current pit	955	9,860	15.0	3	2	2	1
PIT A	955	9,860	10.3	6	2	2	1
PIT B	1,329	19,189	14.4	8	2	2	1
PIT C	2,270	25,095	11.1	7	2	2	1
PIT D	3,052	44,561	14.6	8	2	2	1

Figure 32 - Needed equipment for each pit

The only thing that will change regarding the talc method is the number of drivers. So far, there was only one driver for a couple Shovel/MOXY. This system is sufficient to do all works related to talc for the four scenarios. However, since the hauling time is longer, there is less time to do all works related to inclusion, that is to say in general sorting talc out of the waste in the deposit. In order to do these works, three drivers will be necessary to drive the two couples shovel/ MOXY. One couple will still work with only one driver and the other will work with one driver in each piece of equipment. In the cost model, the cost of an additional driver was thus added in order to reflect this change. The production methods are now defined.

2.5. THE COST MODEL

The goal of this part of the report is to get to an economic assessment of the 4 pits. This assessment is based on standard index for project evaluation: the Net Present Value (NPV) and the Internal Rate of Return (IRR). To calculate these indexes, we need first to build the cash flows for the new project. It implies to build:

- the operating costs of the new exploitation (Rabenwald and Oberfeistritz);
- the non-cash costs (Rabenwald and Oberfeistritz);
- a project planning and an investment plan (including exploration, studies, infrastrure, etc).

<u>The project planning</u>

It is now necessary to define a first planning for the project in order to split the investment costs over the year. The assumptions we took is to start the production in 2028 with only one fourth of the total targeted production of 100 000t of talc per year. The production of the new pit will ramp up between 2028 and 2031 to reach its full production when the current south pit will be exhausted.

Four main phases will take place before the beginning of the production:

- a phase consisting in exploration and general studies (studies to get legal authorization for drilling, etc);
- a feasibility study phase (optimization studies, geotechnical studies, etc);
- a phase with preliminary works and construction of infrastructure;
- the beginning of production.

This is only a very simplified planning for the various pits. A detailed planning and the method to develop it are explained is the last part of this report. This first planning showed on the figure 33 is only for information and to give an idea of the breakdown of investment costs over the "preparation phase".

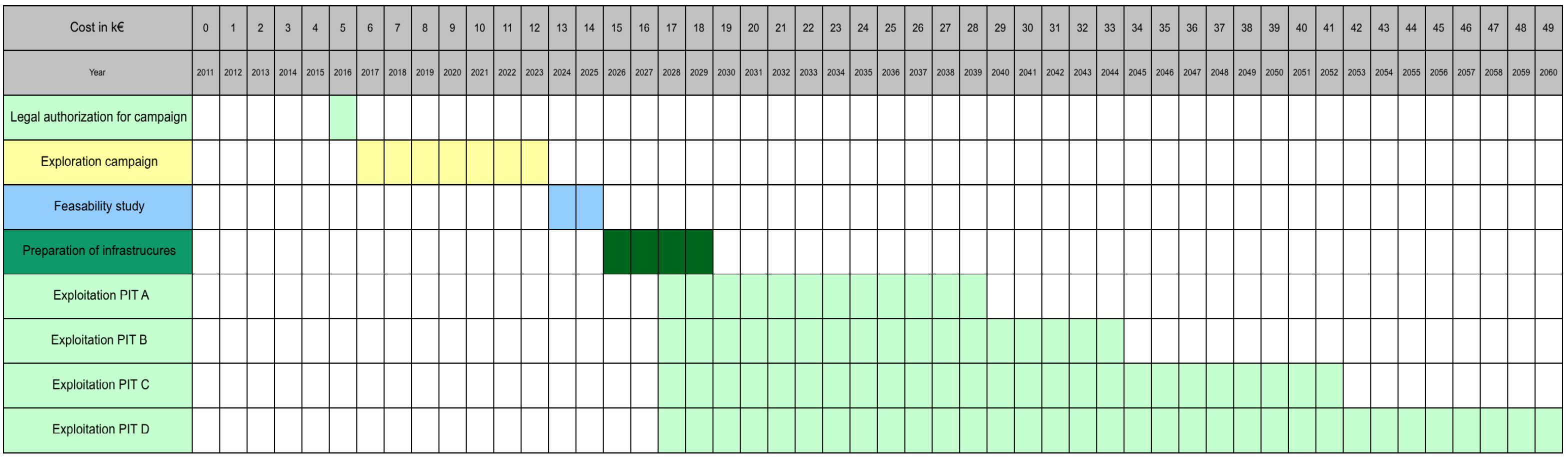

Figure 33 - Project timing

We can notice here that the life of mine for each project ranges from 11 years for the Pit A to 32 years for the pit D. Indeed, the sales plan of 100 000t of talc per year is the same for the 4 projects so the life of mine is directly related to the reserves of the pit.

The operating mining cost model

Based on the accounting analysis made in the first part of this report, a new cost structure has been developed. For this, each cost item of the current structure was taken apart and its main drivers were defined. For instance, the fuel costs for the waste shovel are directly linked to the amount of waste to remove each year. The wages cost for talc hauling is related to the new productivity of the MOXY, itself linked to the hauling distance: an operator will transport less tons of talc per hour, etc.

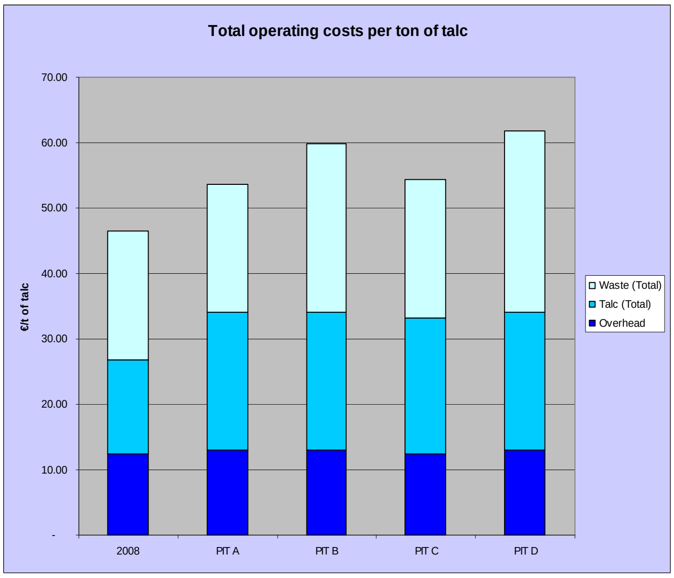

Figure 34 - Mining costs per ton of talc

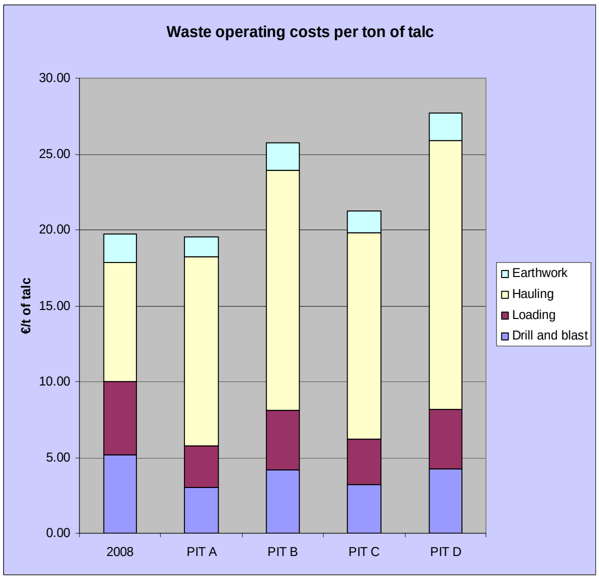

Figure 35 - Waste mining costs per ton of talc

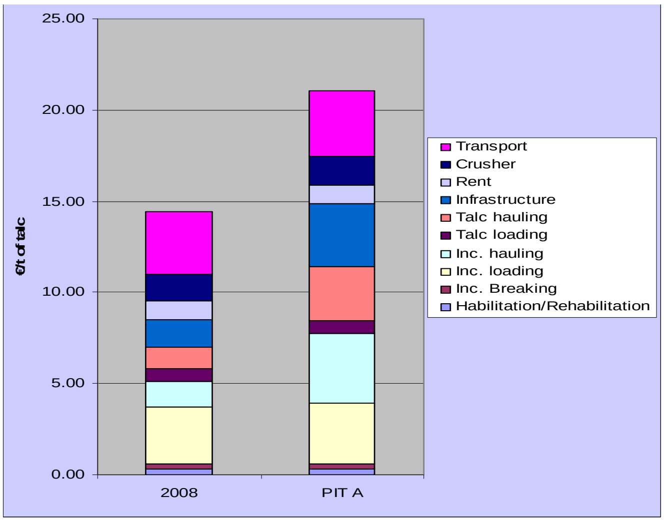

Figure 36 - Talc mining costs per ton of talc

According to this method, we have the following changes:

- talc costs:
  - rehabilitation: no change;
  - inclusion breaking: proportional to the quantity of inclusion removal – no change;
  - inclusion loading: ibid.;
  - inclusion hauling: proportional to the inclusion quantity and the productivity of CAT775D;
  - talc loading: proportional to the talc production;
  - talc hauling: proportional to the talc production and the productivity of MOXY;
  - infrastructure: costs of road maintenance – proportional to the hauling distance;
  - rent: for this first study, we assume that there is no change of the rent costs per ton of talc; this question will be approached later;
- crusher: Proportional to the talc production;
- transport: proportional to the talc production;
- waste costs:
  - drill and blast: proportional to the waste to remove;
  - loading: ibid.
  - hauling: proportional to waste to remove and to productivity of CAT775D;
  - earthwork: proportional to the quantity of waste.

We assume that the overhead costs are fixed and we take the same costs as in 2008. The figures 34, 35 and 36 show respectively the evolution of the total mining costs, the waste removal costs and the talc costs.

On the figure 34, we can see that there is an increase of 7 €/t of talc for the pits A and C in comparison to the 2008 costs, and an increase of 14 €/t of talc for the pits B and D. For the four scenarios, the costs associated to talc are the same because the talc production and the talc hauling distance are the same. There is almost no increase of costs for the pits A and C which have a better stripping ratio; for them, the longer hauling distance is compensated by the stripping ratio. For the pits B and D which have almost the same stripping ratio as today, the increase of the hauling distance implies an increase by 7€ of the waste costs per ton of talc. The impact of the various factors on the mining operational costs will be studied in detail in the last part of the report.

<u>The mining non-cash cost</u>

In parallel of the mining cash costs, we need to account the mining non-cash cost. These costs mainly consist in:

- the replacement of mining equipment;
- some small investment projects.

Among the small investment projects, we find on a regular basis

- projects to maintain or improve the cable way;
- projects to maintain or improve the lab;
- projects to maintain or improve the workshop;
- some HSE and various overhead projects.

To assess the impact of these investment projects on the new exploitation, I decided to study all projects that were done within the past ten years on Rabenwald and to use them as a basis for their counterparts in the new project. This average has the following profile:

- cable way: 50k€ every five years;
- laboratory: 10k€ every year;
- workshop: 35k€ every year;
- various projects: 50k€ every year.

Regarding the costs for the replacement of equipment, it was necessary to set up a replacement plan based on the life of each piece of equipment. Although there are no Rio Tinto Minerals standards regarding life of equipment, there are some implicit standards. Considering the current operating hours per year, we have for instance the life of the following pieces of equipment:

- MOXY: 20 years;
- Shovels: 25 years ;
- CAT: 25 years;
- Etc.

The figure 37 gives an example of replacement plan for equipment.

Equipment costs (K€)	15	16	17	18	19	20	21	22	23	24	25	26	27	28
	2 026	2 027	2 028	2 029	2 030	2 031	2 032	2 033	2 034	2 035	2 036	2 037	2 038	2 039
Replacement Moxy 1			485											
Replacement Moxy 2								517						
Replacement CAT Nr. 1					906									
Replacement CAT Nr. 2												965		
Replacement CAT Nr. 3														
Replacement CAT Nr. 4			892											
Purchase/Replacement CAT Nr. 5			878											
Purchase/Replacement CAT Nr. 6		-												
Purchase/Replacement CAT Nr. 7		-												-
Replacement overburden shovel	1 250													
Replacement Talc shovel 1						618								
Replacement Talc shovel 2														724
Replacement rehabilitation shovel							251							
Replacement Drilling equipment (2015)										593				
Replacement Bulldozer 1				466										
Replacement Bulldozer 2											520			
Replacement loader 1			242											
Replacement loader 2												280		

Figure 37 - Purchase/Replacement plan for the project C

With this mean of calculation, the total non-cash costs per ton of talc are:
- Pit A: 7.5€/t of talc;
- Pit B: 6.9€/t of talc;
- Pit C: 5.5 €/t of talc;
- Pit D: 6.2 €/t of talc.

We can notice that the non-cash costs are lower for the scenarios C and D than for the A and B. This is mainly due to the short life of mine of the project A and B: a lot of equipment has to be bought at the beginning of the production in 2028 and the life of mine is too short to really make those pieces of equipment profitable.

<u>The process costs</u>

The process cash costs:
To build the cash cost model, the data from the 2008 actual costs of the plant were used. The plant produces about 100 various products; the average of these production costs has to be calculated and integrated in the new cost model. The figure 38 gives the breakdown of the process costs on overhead costs, packaging, micronisation, milling and drying.

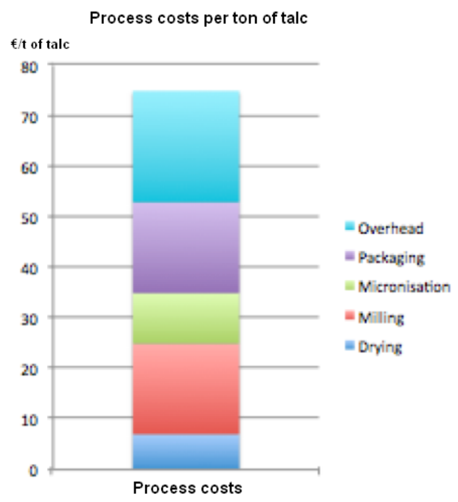

Figure 38 - Structure of the process costs

Regarding the non-cash costs, the same principle as for Rabenwald small investment projects was adopted. An average of the investment projects for Oberfeistritz was calculated and integrated every year in the cost model.

Finally, we need to add a last cost in order to obtain the final cost structure for a ton of talc. As written previously, talc belongs to the industrial mineral sector. One of the characteristics of this sector is the important role played by marketing and so by the commercial team in Rio Tinto Minerals' head office in Graz but also in LUZENAC's head office in Toulouse. The overhead costs of these structures have to be added on top of the production costs. A debate took place in order to know if the overhead costs for Toulouse should be included in the marketing costs. Finally, it was decided to not include them in the NPV calculation so that this new economical assessment could be compared with the assessment of previous projects for which only the costs related to the Graz office were taken into account. The figure 39 gives the breakdown of costs for each project.

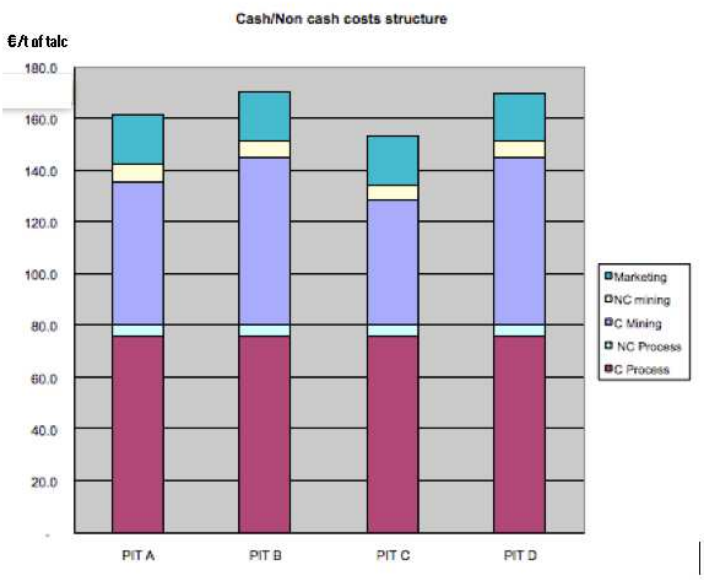

Figure 39 - Global cost structure

The capital expenditure plan

In this part of the report, only the results of the study for the development of the capital expenditure plan and the general way to proceed are given. A detailed explanation of these 2 points is given for the particular pit C in the last part of the report.

The capital expenditure plan is divided into four main cost items:

- the exploration campaign;
- studies:
    - feasibility studies;
    - environmental and social studies;
    - geotechnical studies;
    - pit optimization studies;
    - etc;
- the preliminary works;
- the purchase of equipment to fill the gap between current and needed equipment.

The preliminary works are composed of two different cost categories: works for public infrastructures or infrastructures of the community, and infrastructure for the new exploitation.

Regarding works for public infrastructure, we find the relocation of public roads that go through the new pit area, relocation of houses and water project to supply neighboring houses which are water dependent on some springs situated on the emplacement of the new project.

The main work for the infrastructure for the new exploitation will be the cost of the access road to the pit and the digging of the new retention pond. Some small other investments have to be planned such as the extension of the data collection system and the construction of a new explosive storage closer to the new operational field.

The purchase plan for new equipment took also into account that the new project was a brown field project, that is to say a project which takes over a previous project and thus takes advantage of the already existing infrastructure and the available equipment. At the beginning of the new project, some CAT and MOXY of the current pit will be available as well as the talc shovel with a remaining life of a few years. The waste shovel was changed in 2009 and will come to its end with the end of the current south pit. It will thus be necessary to buy a new one in 2028. The figure 40 gives an overview of the investment costs which range from 11M€ for the pit A to 20M€ for the pit D.

Figure 40 - Investment costs per pit

2.6. THE ECONOMICAL ASSESSMENT

We have now all we need to build the cash flows of the complete project and to calculate the 2 main indexes for economical evaluation: the Net Present Value (NPV) and the Internal Rate of Return (IRR). The figure 41 gives the cash flows in function of time.

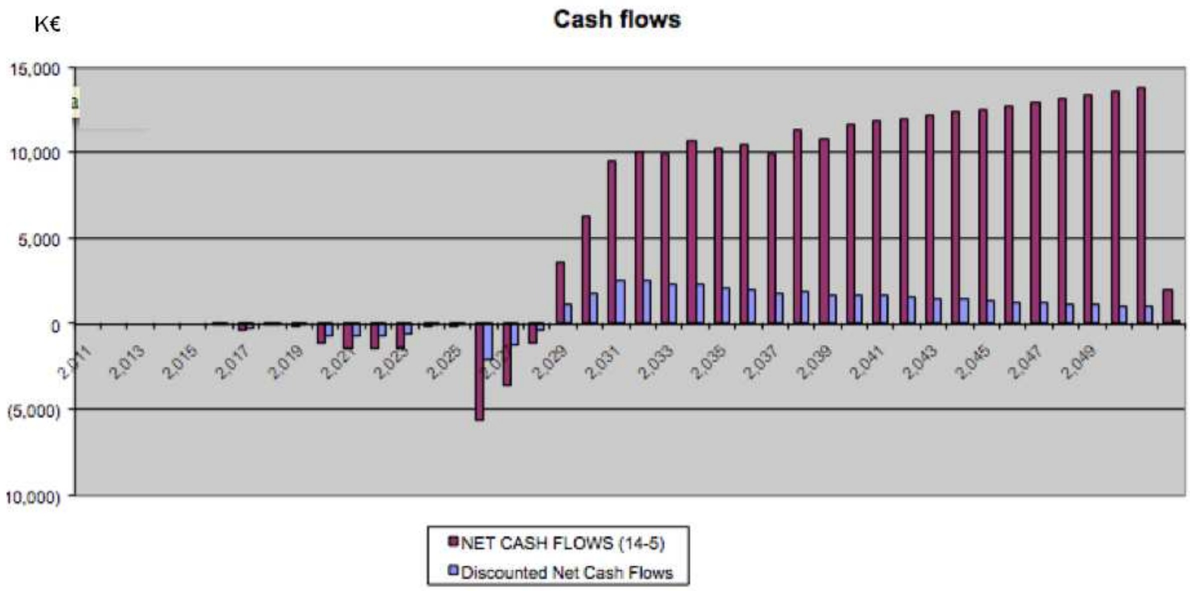

Figure 41 - Cash flows of the project B

<u>Some details about the calculation</u>

According to the sales plan and the previous cost model, an expenses and incomes plan has been created for each scenario. Regarding the inflation rate, some standard rates edited by Rio Tinto Minerals for each country in the world were used: the average inflation rate is 1.6% per year. The same is true for the discount rate for NPV calculation: the rate used is 7%.

There were some discussions regarding the amortization of investment and how they should be integrated in the model. Austria has some very particular policies regarding amortization; indeed it is allowed to amortize absolutely all investment whereas this is not the case in France for instance. What is at stakes here the legal amortization, that is to say the amortization on taxes: it is generally possible to reflect the depreciation of an investment during its operating life, which is considered 8 years for a truck in Austria for instance. Every year, an eighth of the original price of the truck will be subtracted of the taxable income. This process enables companies to save a part of their investment costs thanks to tax reduction. Its goal is to encourage companies to invest.

The question was thus: Should all investments be amortized (which will be the case in practice in Austria) or do we have to use some Rio Tinto Minerals standards? The last proposition was finally adopted in order to be able to compare the project to other LUZENAC's projects and to present it to the LUZENAC's management in France.

To toe the line, it was decided that all investments except the exploration costs should be amortized. Regarding equipment, they are amortized on their legal operating life, which is the most often between 5 and 8 years. As for cost of studies and preliminary works (infrastructure, house relocation, etc), they start being amortized as soon as the first ton of talc is extracted and they are amortized on the complete length of the project. The used tax rate is the average Austrian rate of 25%.

For all economic calculations, a worksheet template of Rio Tinto Minerals was used and is available in the annex 2. The investments to be amortized are entered in the capital expenditure line. The exploration and investments that are not amortizable are entered in the start-up costs line.

The results

After consolidation of the results for each pit, we obtain the chart 42.

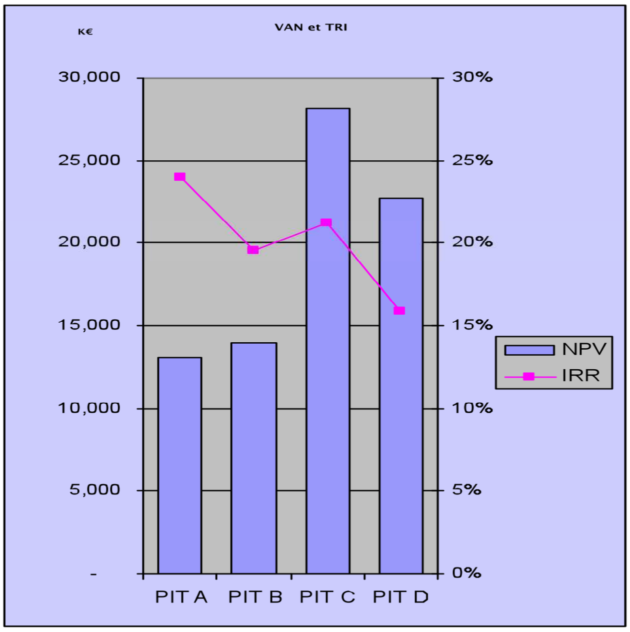

Figure 42 - NPV and IRR of the four scenarios

	Reserve Talc	Total waste	Striping ratio	NPV	IRR
PIT A	955,359	9,860,172	10.32	13,072	24.0%
PIT B	1,328,992	19,188,975	14.44	13,992	19.5%
PIT C	2,270,339	25,094,835	11.05	28,172	21.3%
PIT D	3,052,112	44,560,835	14.60	22,778	15.9%

Figure 43 - Summary of NPV and IRR results

The results are summarized in the figure 43. The first very good surprise coming from the results is the fact that all projects have a positive NPV, which first confirms the interest of this new project. The second remark applies for the two smallest pits: their NPV is much lower than the NPV of the two biggest projects: only 13 and 14M€ respectively for pits A and B versus 28 and 23M€ for pits C and D. It seems that the projects A and B have too short life of mine to justify the big investment needed to start them: indeed, the purchase of new equipment and in particular of the additional CAT and of the new waste shovel is too expensive to be very profitable on a length of only 11 to 15 years. However, the internal rate of return is at best for the smallest projects.

The validity of the indexes

One of the specificities of this study is the fact that it is a very long-term project. The pit A, which is shortest one, will end in 2039, that is to say 28 years after its assessment. In general, common industrial projects are assessed on a shorter basis: 10 to 20 years maximum. The mining sector is already very particular since it has lots of long-term projects and this project is particular by its length within the mining sector.

Therefore, we can question the legitimacy of such an assessment. The first bare fact that questions it is the comparison between the cash flows and the discounted cash flows. The figure 41 shows that the discounted cash flows at the end of the project are negligible compared to the original cash flows.

A cash flow in 2040 discounted to 2011 with a discount rate of 7% is divided by 1.07^29 = 7.1. It has a very little influence on the final result. This fact makes some studies senseless such as the study of the closure cost on the final NPV. Indeed, the addition of a closure cost of 10M€ in 2053 changes the final NPV only by a few hundred thousand Euros.

The NPV is though not too affected by the fact that the project is very long term: it is possible to calculate the NPV later, in 2025 for instance by "actualizing" the past cash flows in the other way as usual. The NPV calculated in 2025 will be exactly the NPV of 2011 multiplied by 1.07^(2025-2011).

The IRR is much more affected by the timing of expenses and incomes and it is not possible to do the previous experiment for it. Since the first incomes are very far from the date of assessment, they do not have a lot of impact on the IRR calculation, which explains why the four IRR values for the four projects are very close. The validity of the IRR indexes is debatable here and our attention was more focused on the NPVs. This index does not take into account the life of mine and compares without any differences projects A and D with respectively 11 to 32 years of production.

Some calculations were made according to the method detailed two paragraphs above (calculation in 2025 with actualization in the other way of the past costs). It enabled me to better understand the differences between the various projects but, as this is not a common tool in project assessment, it was completely unusable for comparing with other projects or to present my results. I thus decided to use only the classical NPV calculation at the date of the assessment.

The decision

After discussion with Rabenwald management, it was naturally decided to focus now on the pit C, which presents from far the best NPV and also a good IRR compared to the other projects. This first result also shows that the optimal pit for the new extension is stacked between pit B and pit D and must probably not be very different from the pit C.

The next step of my study was then to elaborate on the scenario C in order to:

- understand the cost drivers;
- analyse the main risks;
- suggest an adapted project planning to mitigate the subsequent risks;
- run some sensitivity studies in order to characterize these risks;
- use the sensitivity study in order to find some improvement drivers for the project.

Analysis of the project C

When I obtained my first results of NPV calculation, I was actually surprised to get so good figures. Indeed, I always heard in the open pit sector that the hauling distance was one of the major cost drivers. Now, I designed a new exploitation with a hauling distance which is more than twice as long as the current distance, for which the exploitation was originally designed. How come I get so good results?

A first answer to this question has to be found in the cost structure revealed by some previous charts. Indeed, if we look at the figures 14, 15 and 16, it is actually clear that the part of hauling costs in the total costs (including processing) is pretty low, and it is still the case if we look only at the mining costs.

The percentage of hauling costs is only about 30% of the mining costs and 15% of the total costs. We can then understand that the sensitivity of the NPV to the distance is pretty low. This affirmation will be confirmed later by a proper sensitivity study.

The other answer to the question has actually already been given. The game “longer hauling distance” versus “better stripping ratio” is actually a draw. It is here interesting to study the driver of the costs increase of the project C compared to the current pit.

The only costs that increase are the costs related to talc and the costs related to talc and to waste

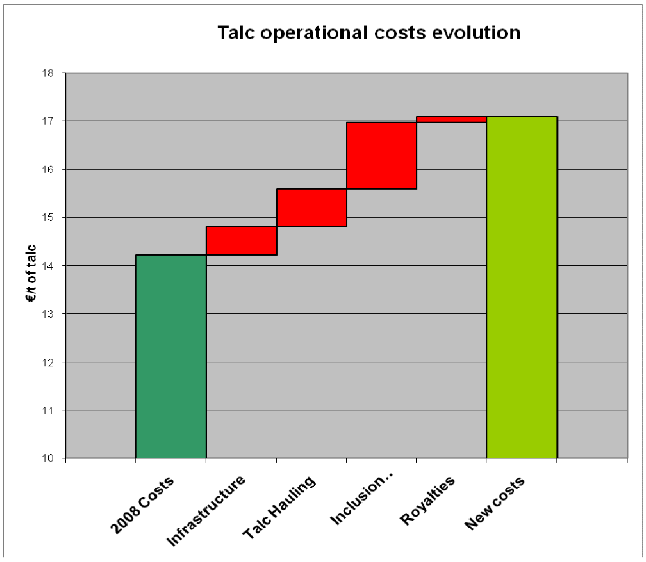

Figure 44 - Evolution of the cost of talc per ton of talc

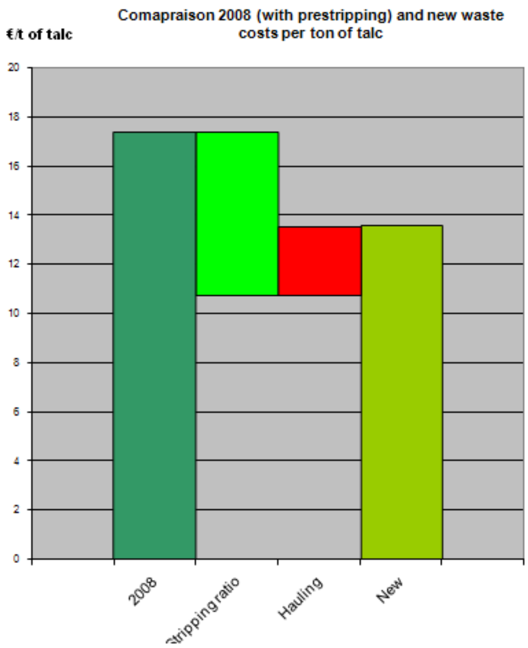

Figure 45 - Evolution of the costs of waste removal per ton of tal

The figures 44 and 45 give the evolution of the talc and waste costs. For talc, the change is mainly due to the longer hauling distance which increases the cost by 2.5 €/t of talc. On the other hand, the total costs of waste per ton of waste is more expensive in the new exploitation but this increase is more than compensated by the stripping ratio if we look at the cost of waste per ton of talc. The decrease of waste costs compensates the increase of talc costs to finally get a total cost similar to the current pit.

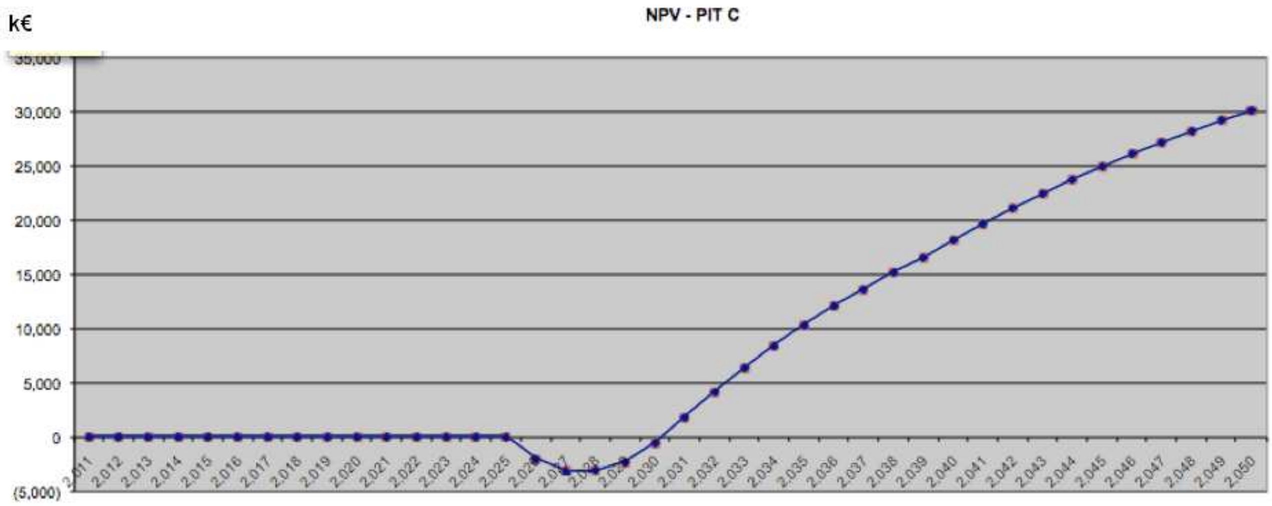

Figure 46 - Evolution of the NPV of the project C in function of time

Finally, we can have a look on the evolution of the NPV of the project in function of time in order to know how fast the project can become profitable. The figure 46 shows that 5 years after the main investments (in 2025) the project starts being profitable. This chart also shows that the project does not look very sensitive to investment costs.

3. DEVELOPMENT OF THE PIT C

The scenario C has now been chosen and it is time to study it in detail. The first step of a prefeasibility study is to register and assess the risks that jeopardize the success of the project. Once those risks analyzed, the name of the game is to mitigate them by building an appropriate project planning.

3.1. THE RISK ASSESSMENT

Risk register

In order to do this risk assessment, some templates provided by Rio Tinto Minerals were used. The risk definition adopted by Rio Tinto Minerals, which is a widespread standard, is to define a risk as a likelihood multiplied by a consequence. Those two parameters are the two axes of a matrix, which define the magnitude of the risk. This matrix is given by the figure 48. For each type of consequences (Health and safety, Environment, Community, cost, production and NPV), some standards consequences are defined and explained by the figure 47.

Descriptor	Health & Safety	Environment	Community	Damage or Cost Impact	Production Interruption	Overall Business NPV
Catastrophic	Fatality or permanent disability	Offsite environmental impact with permanent damage	Adverse national media coverage	>€5M	>1 week	>€20M
Major	Major injury /illness (LTI)	Offsite impact with severe damage	Adverse statewide media coverage	€1M - €5M	1 day - 1 week	€5M-€20M
Serious	Moderate injury or illness (Medical Treatment)	Off-site impact with localised damage	Adverse local media coverage	€100k - €1M	1 shift – 1 day	€1M - €5M
Medium	Minor Injury / Illnes (First Aid)	Onsite environmental impact with recoverable damage	Minor community issue	€10k - €100k	1-8 hours	€0.5M - €1M
Minor	No injury or illness not requiring treatment	Single on-site events causing negligible harm	Isolated public relations issue	<€10k	< 1 hours	<€0.5M

Figure 47 - The standard risk matrix

The various degrees of likelihood are defined as:

- rare: would occur only under exceptional or once in ten years;
- unlikely: not like to occur in more than five years;
- possible: has happened elsewhere or could happen once every five years;
- likely: has happened before or could happen twice a year;
- almost certain: occurs at least once per month.

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Likelihood	Consequence: Minor	Medium	Serious	Major	Catastrophic
Almost Certain	Moderate	High	Critical	Critical	Critical
Likely	Moderate	High	High	Critical	Critical
Possible	Low	Moderate	High	Critical	Critical
Unlikely	Low	Low	Moderate	High	Critical
Rare	Low	Low	Moderate	High	High

Figure 48 - The classification of risks

According to the level of risk, various steps must be done and for each high or critical risk, a risk reduction plan has to be developed.

The risk assessment was done as if it was the very first time the project was studied in order to register all risks, including those we were already aware of. The complete risk register is available in the annex 4.

<u>Results of this risk assessment</u>

This first risk assessment reveals the existence of numerous risks, a few of them being high or even critical. Lots of these risks run on the confirmation of the adopted assumptions.

The first and most obvious risks are related to the deposit knowledge. Indeed, the geological model suggested by the planning and resource department is reasonable but completely hypothetical. The geological risk splits into two main risks:

- the risk on tonnage: a tonnage lower than the one expected would have a catastrophic impact on the NPV. The validity of the model has to be checked as well as an important assumption taken: the level of the reconciliation rate. Currently, there is a reconciliation rate of 61% between the resources shown in the block model and the real production of the south pit. This reconciliation factor takes all factors into account:
    - the recovery rate: some talc present in the model cannot be recovered. In particular it is lost when located in thin layers (under 50cm);
    - the fact that the current south pit was in the past an underground mined area: some of the talc has already been exploited;
    - error in the block model.

  For the new exploitation, this factor was set to 75% because the new area was never mined before. This parameter is a very big assumption and the risk on tonnage is a critical risk;

- the risk on quality: a different quality of talc, being better or worse, will have a big impact on the marketing of the product. It is no certain that client will be found for a different quality. This risk is high;

- the social risk: related to the community acceptability of the new project. This risk is high for several reasons. This new project will be much further south than the current activities and so closer to the surrounding villages. A visual barrier will probably be more complicated to set up and less efficient due to the topography of the new pit. Moreover, the hauling distance is longer, which may imply more noise pollution, air pollution and dust production. This risk could imply a lot of difficulties to get the legal authorization;

- the duration of permitting processes is difficult to assess. In case of conflicts with the local communities, the permitting process can be delayed several years. Ongoing authorization process can be stopped by new European or local laws. At first sight, this risk is high too;

- the geochemical risk: the current talc extracted in Rabenwald is free from fibers which may not be the case for the talc extracted in the new pit. The presence of fibers will imply lots of concerns regarding health, environment, social issues and production method. This risk has a low likelihood but huge consequences, it is classified high;

- risk related to land use: 95% of the area of the new exploitation does not belong to Rio Tinto Minerals. Some agreements will have to be found with the current landowners regarding land use or land purchase, if need be;

- market risks: a loss of market share or a decrease of the average sales price would have a very big impact on the economical success of the pit. The market risk is quite well known by Rio Tinto Minerals/LUZENAC/RTM marketing team but a reliable forecast on 20 years is impossible to get. However, this risk will not be completely studied in this report for this is the job of the commercial team;

- some other lower risks:

    - geotechnical risks: the geotechnical situation of the new pit may be not as good as the current one;
    - environmental risks regarding biodiversity and underground water;
    - etc.

The risk profile

The overall risk profile is given by the figure 49. The first risk to be mitigated is of course the risk related to the deposit knowledge which is the only critical risks. All the other main risks described previously are classified as high risks.

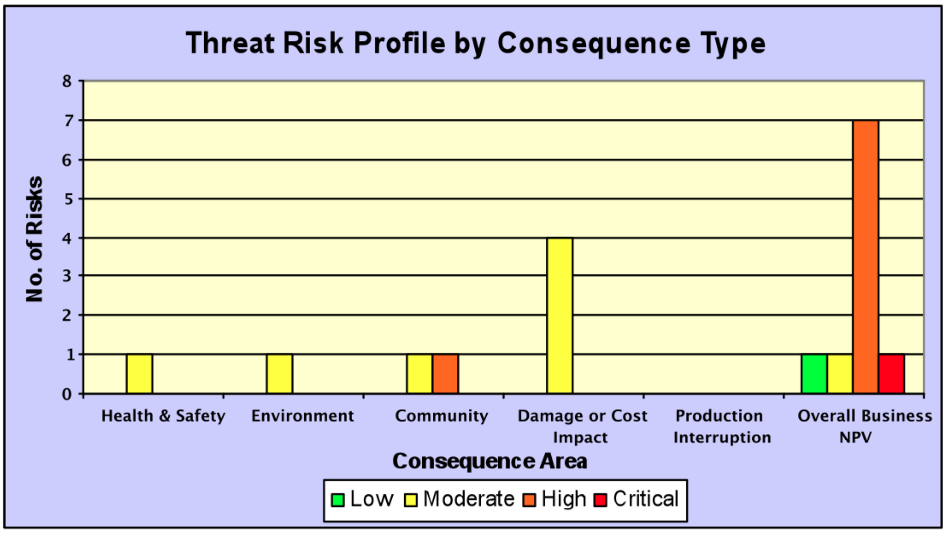

Figure 49 - The risk profile per type of consequence

The exploration campaign

The exploration campaign has two roles:
- to get rid of the geological risk;
- to transfer the inferred resources into measured resources according to the JORC methodology.

Transferring resources from “inferred” to “measured” is actually a major stake for the opening of a new project. The overall measured resources are one of the main parameter on which a mining company is assessed and the authorization for a new project is given by the holding at the condition that the resources are measured. This is the role of the exploration campaign and of the geological studies. The prefeasibility and later the feasibility studies are here to convert these resources into reserves: reserves are resources that are economically exploitable. The figure 50 explains the functioning of the JORC standards.

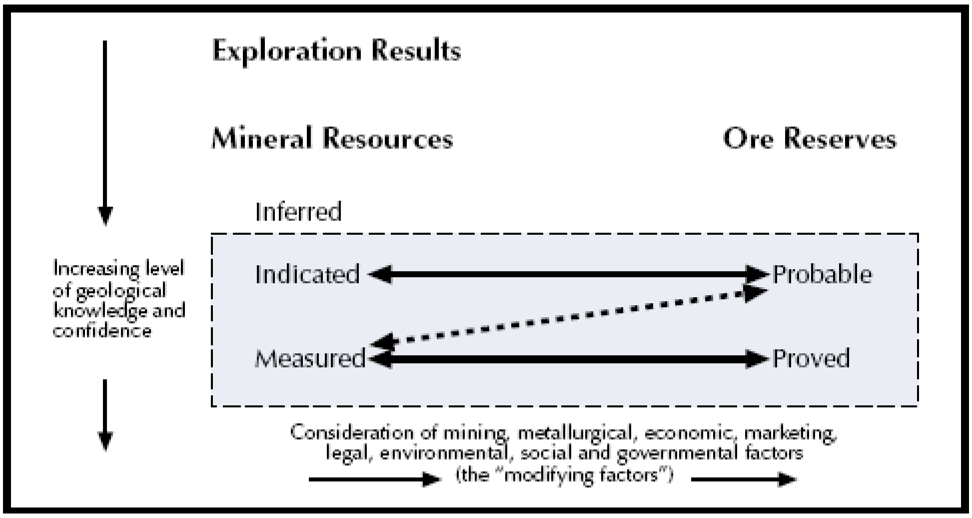

Figure 50 - JORC classification

The conditions to declare a deposit as measured resources are pretty complicated and are based on the analysis of variograms by an expert who is called the competent person. Regarding talc within Rio Tinto Minerals, the competent experts are the people for the planning and resources department, and in this case Michaela Wurm the geologist supervisor for Rabenwald mine.

Generally speaking, a mineral deposit is classified as measured if a dense enough drilling campaign confirms its presence. For talc in Rabenwald, the usual parameters of the drilling campaign are:
- to register the deposit as indicated => a drill grid of 70m
- to register the deposit as measured => a drill grid of 30m.

In reality, if we look in detail the variograms of the existing Rabenwald deposit, a drill pattern of 20 to 25m is necessary to measure the resources. However, this figure would involve high exploration costs and no one would pay for it. The grid adopted in practice in 30m.

3.2. THE EXPLORATION PHASE

The total footprint of the pit C is about 45 ha that must to covered with a 30m grid, which represents a huge investment. In order to reduce the risk of not encountering talc and of the subsequent waste of money, the exploration will be split into two campaigns:

- a first campaign with a 100m grid to have a first confirmation of the validity of the model;
- a second campaign with a 30m grid to measure the resources.

For readers with a very rigorous mathematical spirit who are already trying to build a regular 30m grid on the base of a 100m grid, the emplacement of the drill holes depends a lot on the local situation and a margin of a few meters is allowed.

The reverse circulation method is an economical destructive method, which enables the geologist to access only the cuttings of the holes. The core drilling is more expensive but produces intact sample cores, which can be used for mapping geotechnical characteristics of the rock and for mechanical tests.

After discussions with the planning and resources department, we agreed on the following method for exploration:

- the first exploration with a 100m grid
    - o the core drilling method must be used as early as the hole is more than 5m deep and on the total remaining length of the holes;
    - o the holes must go 20m under the deposit;
- the second campaign with a 30m grid:
    - o the core drilling method must be used only in the deposit and the reverse circulation can be used for the remaining length;
    - o the holes must go 5m under the deposit.

With these characteristics, I obtain a drilling profile for the pit C which is detailed in the figures 51 and 52.

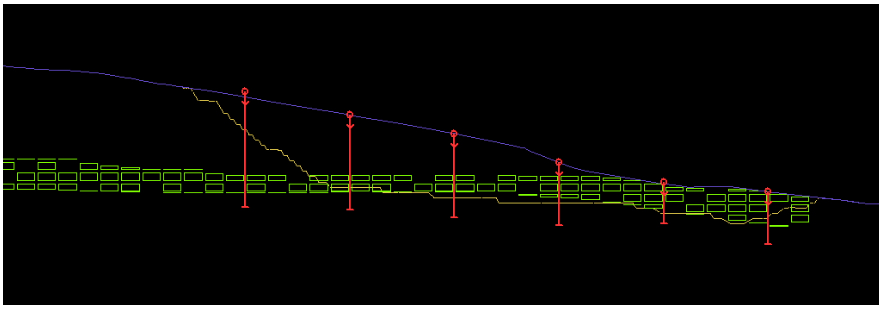

Figure 51 - A North-South section of the drilling campaign

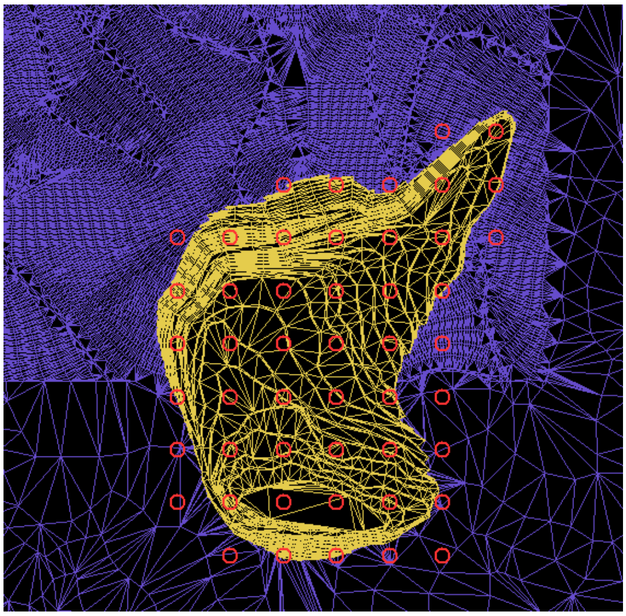

Figure 52 - Overview of the first drilling campaign

The total costs for exploration are calculated on the basis on some quote from drilling companies in the region.

Exploration 1	PIT A	PIT B	PIT C	PIT D
Number of drills	22	32	51	64
Length (m)	1585	2795	3760	5330
Drilling costs (k€)	156	274	369	523
Analysis costs (k€)	33	59	79	112
Total cost (k€)	189	333	448	635

Figure 53 - Summary of the first drilling campaing

Exploration 2	PIT A	PIT B	PIT C	PIT D	South Pit
Length (m)	15,720	28,740	37,470	54,360	65285
Drilling costs (k€)	1,696	3,101	4,043	5,866	7,045
Analysis costs (k€)	331,549	606,153	790,276	1,146,502	1,376,920
Length (two) geologist) (in years)	1.43	2.61	3.41	4.94	5.94
total cost (k€)	2,028	3,707	4,834	7,013	8,422

Figure 54 - Summary of the second drilling campaign

The figures 53 and 54 summarize the exploration costs for the first and the second campaign. For the pit C, the first one will cost about 450k€ and the second one about 4800k€. The decision to split the exploration into two drilling campaigns makes it possible to highly reduce risks. The major remaining risk is now on the first drilling campaign: the maximum loss is now 448k€.

3.3. THE PROJECT PLANNING:

The two main steps of the project planning are the two exploration campaigns. The other phases are organized around the two mains. A large part of the time before the beginning of the production will be allocated to time-consuming processes such as permitting.

<u>The drilling campaign</u>

The length of each exploration stage is given by the figures 53 and 54: the first campaign will last less than one year if we assume that a full time geologist works on it. The second will last between 3 and 4 years if we assume that two full time geologists work on it. It is generally agreed that a geologist can manage between 5000 and 6000 drilled meter per year.

The pre-project will start one year before the first exploration campaign. This year will be allocated to do the drilling planning, to get funds for the campaign and to get the legal authorization for the first campaign. This later will take place during year two of the project. If talc is found, the project will keep on and two years will separate the first and the second drilling campaign. This period is here to get a first agreement with the administration regarding a future exploitation and thus to mitigate the legal risk. In parallel, funds and authorization will have to be obtained. It will also be interesting to do some preliminary geochemical studies to be sure that no fibrous material is present in the talc and that this latter has an appropriate quality.

The second drilling campaign will last for 4 years for the pit C. The feasibility study will start one year after the beginning of the campaign and will stop a few months after it. Two years will then be available to get the final legal authorization and to lead many necessary studies.

The studies

All the studies to be done are given in the figure 55 with the subsequent dates. Numerous studies such as environmental studies and social investigation must be done by independent consulting companies. The total cost of studies for the project C is about 1200k€.

Study costs (in k€)	Date	Pit A	Pit B	Pit C	Pit D
Credits obtention for exploration campaign 1	2012	16	16	24	24
Legal authorization for exploration campaign 1	2013	16	16	24	24
Credit obtention for exploration campaign 2	2016	48	48	72	72
Legal authorization for exploration campaign 2	2017	48	48	72	72
Feasability study	2020 - 2023	96	128	160	192
Climatic study	2020	50	50	50	50
Groundwater study	2021	100	133	167	200
Biodiversity study	2021	50	50	50	50
Geotechnical study	2022	100	133	167	200
Optimiation study	2023	50	67	83	100
Social and environmental investigation	2023	100	133	167	200
Legal authorization for exploitation	2024	96	96	144	144
Total		770	919	1,179	1,328

Figure 55 - Summary of costs for studies

As soon as the permitting process is over, the preliminary works can start. They will last for about two years before the beginning of production and will still last for two years after it. The total duration of the pre-project stage is 12 years so if the production is to start in 2028, the first legal authorization for exploration has to be obtained in 2016. The project planning is given by the figure 56.

Cost in k€	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054
Prefeasibility study																																												
Credits obtention for exploration 1						24																																						
Legal authorization for campaign 1						24																																						
Exploration campaign 1							448																																					
Legal authorization for exploitation								36	36																																			
Credit obtention for exploration 2									72																																			
Legal authorization for exploration 2									72																																			
Exploration campaign 2										1,209	1,209	1,209	1,209																															
Feasability study											226	226	226																															
Social and environmental investigation														83	83																													
Legal authorization for exploitation														72	72																													
Land purchase																734																												
Preparation of infrastrucures (roads, houses, etc)																3,190	3,190																											
Preparationnary works (Retention pond)																469	469	469	469																									
Exploitation																1,250	0	3,341	1,258	1,710	1,435	1,082	1,431	857	1,464	1,405	2,144	913	1,652	943	958	973	989	1,005	1,021	1,037	1,054	1,070	1,088	1,105	1,123	1,141		
Closure																																												

Figure 56 - Planning of project C

The preliminary works

The preliminary works will first consist in doing some work for the community. The works that are identified so far are:

- the relocation of 2.8km of public road on the area of the new pit;
- the relocation of 6 houses;
- 2 water supply projects: at least two springs are currently located on the area of the new pit and supply the neighboring village with water. It will be necessary to install water pipe and supply system in order to provide neighboring houses south of the pit with water from farther springs.

These works are detailed on the figure 57.

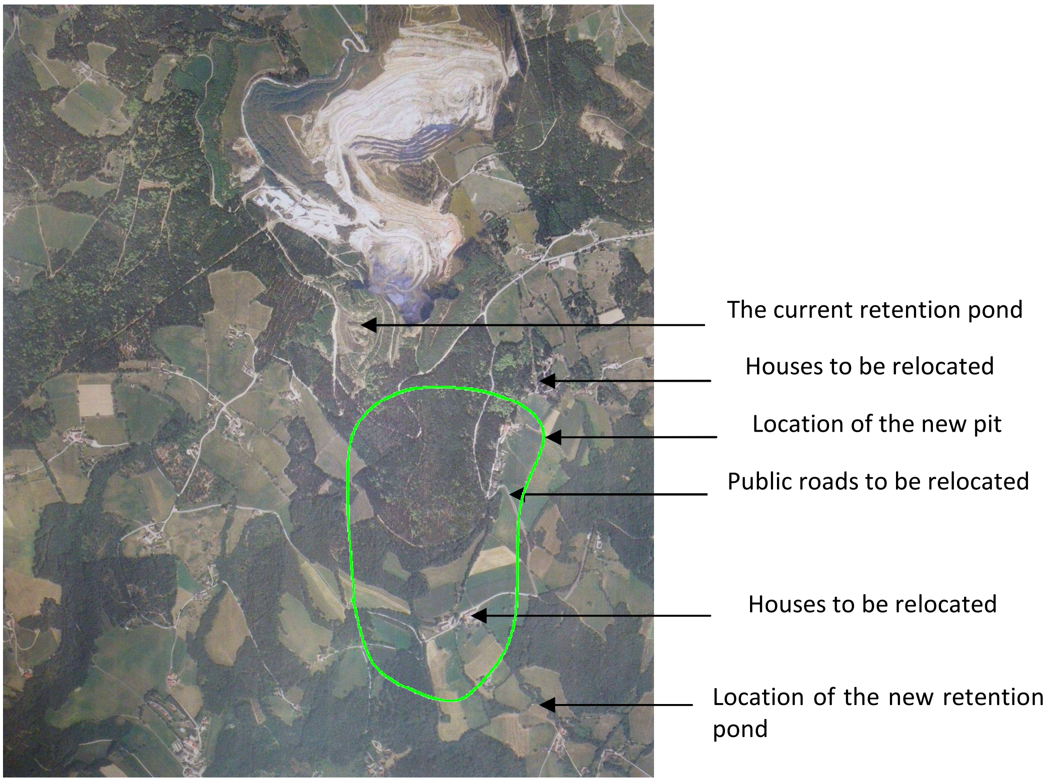

Figure 57 - Preliminary works

The retention pond

For every open pit operation in Austria, it is necessary according to the law to build a retention pond in order to collect water streaming in the pit. The water is collected in a retention pond where potentially polluting particles have time to settle down. As the area of the new pit is similar to the current pit, a retention pond of the same size has to be dug down of the new pit.

The total weight of waste to be extracted for this pond is 995 000t. Its construction will start two years before the beginning of the project and will last for two more years. The fact that it is not achieved when the pit will be opened is not an issue for the area of the pit will be very small at the beginning and the water streaming from it too.

3.4. GENERAL DESIGN OF THE EXPLOITATION:

The pit design

For the design of the pit, the same geotechnical parameters than for the current pit are used. The design of the benches only consists in taking the general outline of the basic pit designed previously and to follow it as closely as possible by designing the toe and the crest of benches.

The only real difficulty of a pit design is the design of the road within the pit. In that case, it was important to minimize as much as possible the driving distance, which is already very long. However, the designed pit is not an optimized pit. My only goal was to show a feasible way to design it. The figure 58 shows a view of this pit.

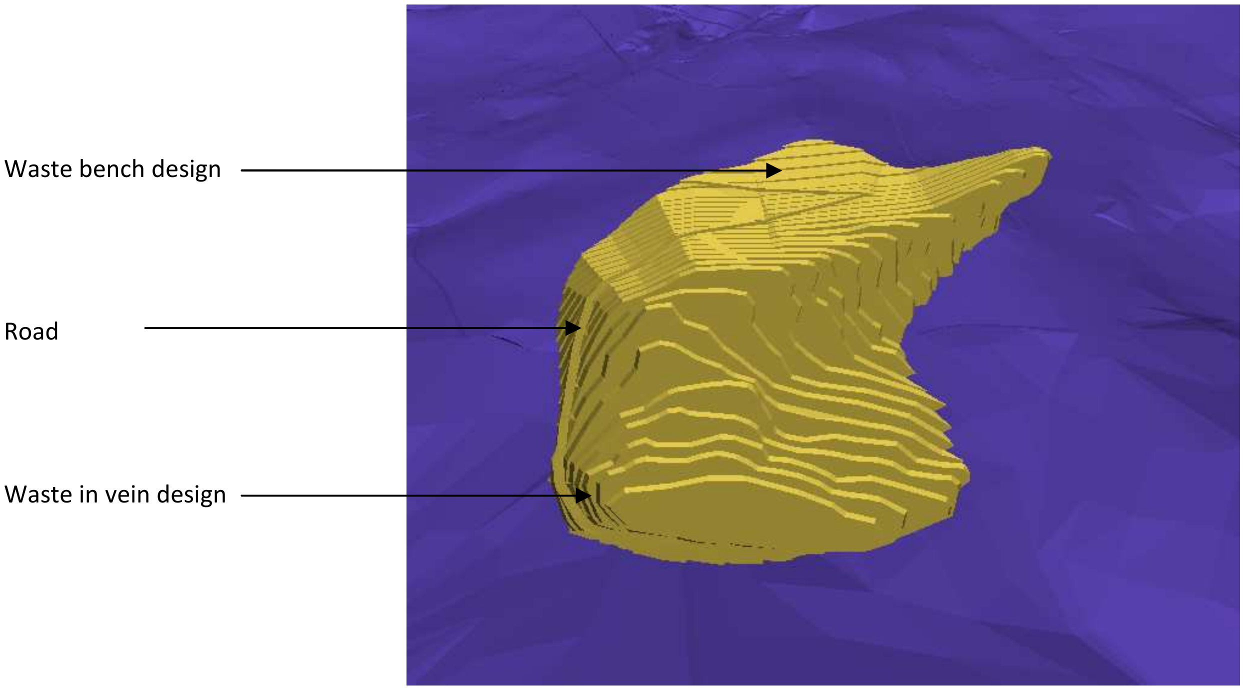

Figure 58 - The design of the ultimate pit

Dump design

A few environmental and landscape rules constrain the dump design. The most constraining of them is the fact that the final dump design cannot exceed the original topography. The bulk density for waste ranges between 1.8 and 2. In these conditions, only 18Mt of waste fit in the current south pit when it will be exhausted.

General design

The general design of the new exploitation was not a big issue as no other choices were possible for the pit and the dump emplacement. The only questions were regarding the location of the access road to the pit and of the retention pond.

As for the access road, I tried to use as much as possible some existing roads in order to limit the capital expenditure costs. The new road will be built on the base of the current public road that leads to the current offices.

The retention pond is to be placed south east of the pit, in the more natural place so that water streams in by itself. Some pumping may however be necessary when the final bottom of the bit will be reached for it is 20m lower than the crest of the pit in the direction of the retention pond. The figure 59 shows the general arrangement of the new project.

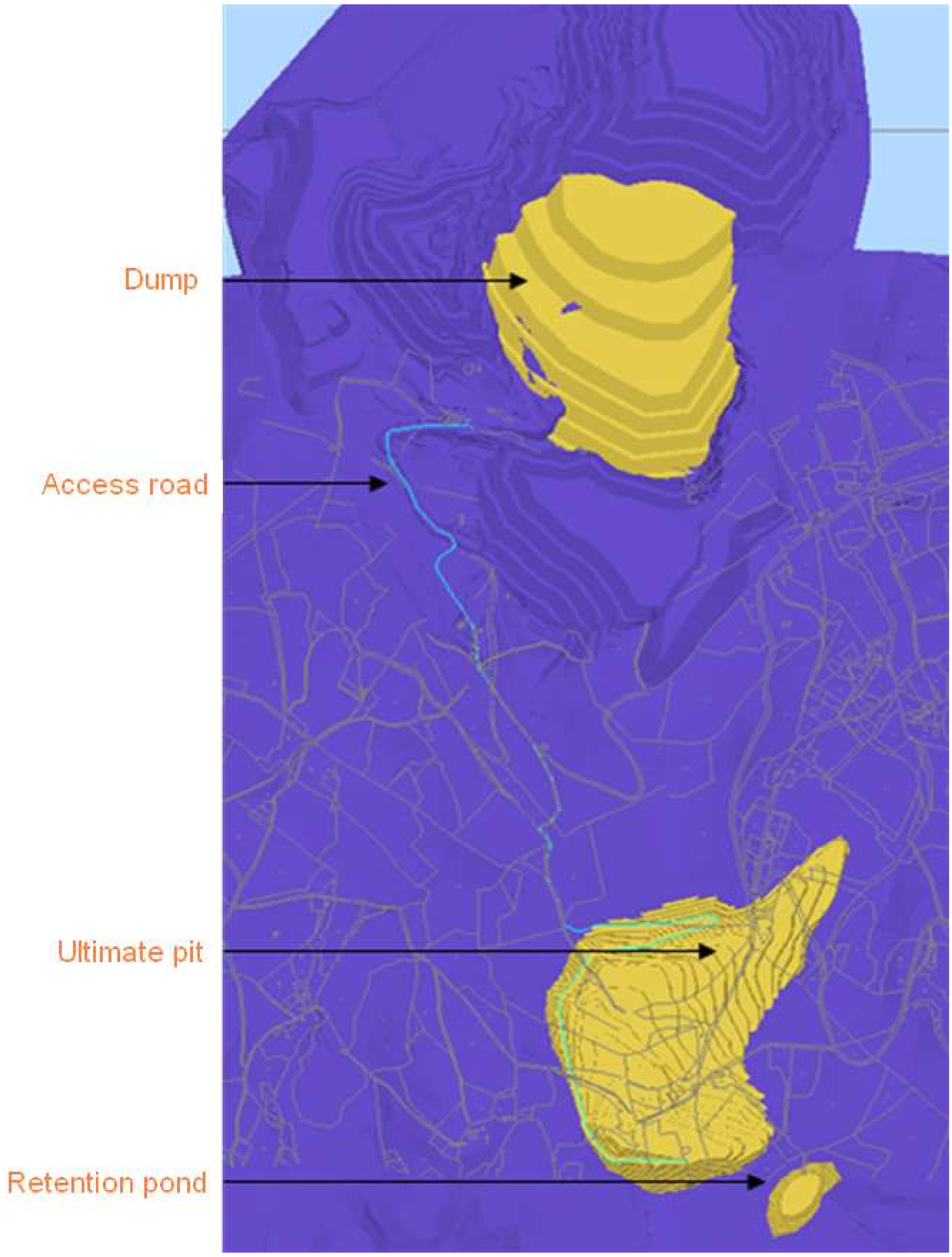

Figure 59 - General design of the new mine

3.5. THE LAND MANAGEMENT QUESTION

The final footprint of the exploitation is now fixed. The pit in itself represents an area of 45 ha and the area to be occupied by the whole exploitation including the retention pond and a buffer area around the pit will be 73 ha.

Rio Tinto Minerals has, for historical reasons a few parcels of land in the region of the new pit. However, these properties only represent 5% of the total needed surface. A land management solution has to be found.

Currently, Rio Tinto Minerals owns 70% of the lands on which the south pit is located. These properties represent the west part of the exploitation. The 30% remaining on the east part belongs to Mr. Reithofer, who was too a talc producer a few decades ago. As the market is too small for two producers, an agreement was found between Rio Tinto Minerals and Reithofer and this latter accepted to stop his activities and to lend his lands to Rio Tinto Minerals at the condition that Rio Tinto Minerals pays him royalties on each ton of talc extracted from his properties. In 2010, this royalty was 3.34 €/t of talc.

In addition to these royalties, Rio Tinto Minerals must as well pay for each hectare of land that it uses and that it does not own. This land use has to be paid for every parcel of land and it does not matter, whether it belongs to Reithofer or to any other owners. In 2010, the cost of this land use is 0.22 €/m².

The question of the land use for an open pit exploitation is often a bone of contention with the neighboring landowners and can thus be a severe risk. It was necessary to approach this topic at this early stage of the project. In general, Rio Tinto Minerals tries always to find some renting agreement with the landowners instead of purchasing the land. It was believed at this time that one major risk for the project would be the need to buy all lands instead of renting them. This would “dramatically” increase the capital expenditures and then jeopardize the profitability of the project.

To study this question, I needed the land register as well as the average costs for land purchase in the area. The neighboring town council provided these pieces of information. There are actually three average prices for land purchase: one for crop land, one for forest and one for meadow/building land.

The comparison was done between the two following scenarios:

- all lands can be rent starting from the first production;
- all lands must be purchased one year before the start of the work.

The land occupation is given by the table 60 and the figure 61 gives the map of the various types of land.

Land use	m²	%
Total	730000	100.00%
Rio Tinto Minerals	30000	4.11%
Reitoffer	50000	6.85%
Crop	0	
Meadow	0	
Forest	50000	
Other	650000	89.04%
Crop	420000	
Meadow	55000	
Forest	175000	

Figure 60 - Surface of land to be used

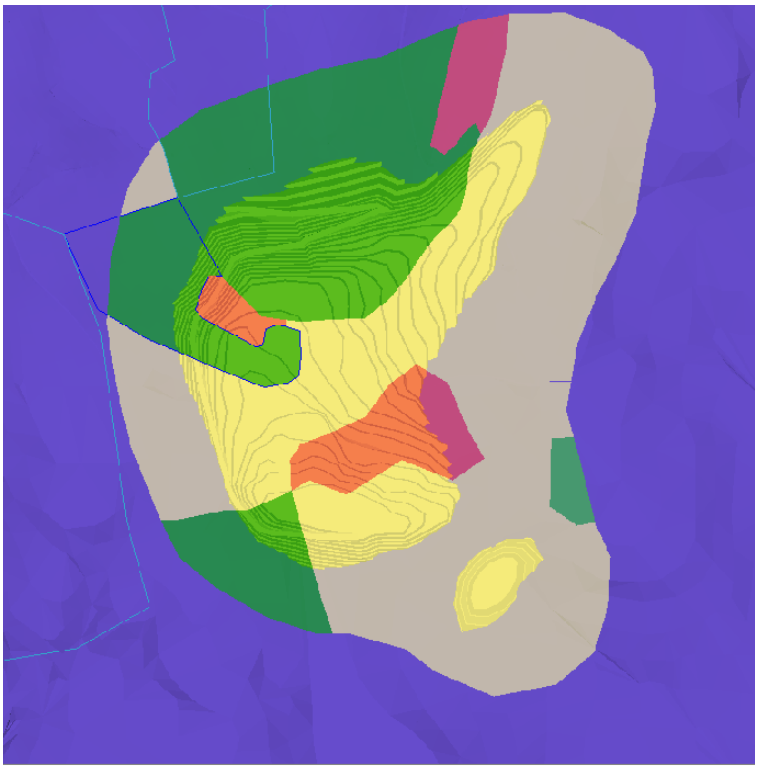

Figure 61 - View of lands to be used

Based on this data, the two scenarios were compared by building their yearly cash flows and calculate their discounted costs per square meter.

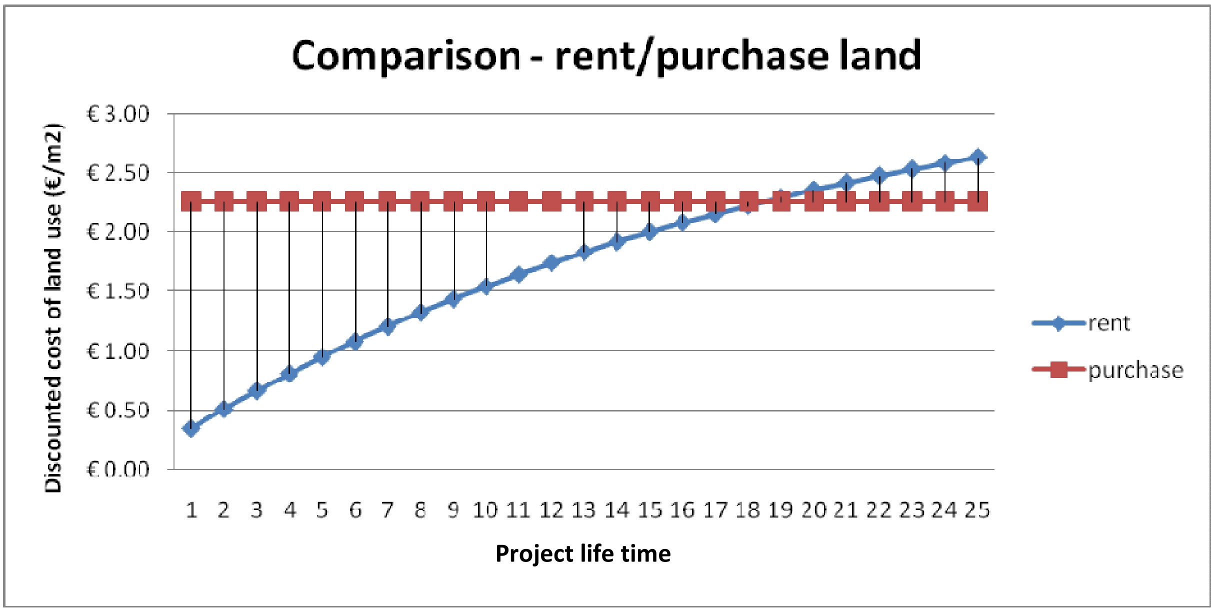

Figure 62 - Comparison between renting and purchasing needed land parcels

The chart 62 actually shows two things:

- for a project with a life of mine of about 20 years, the two solutions give almost the same results;
- for a longer project, it is even more interesting to buy the lands at the beginning than to rent them.

The risk of land use is then very low since in both scenarios the results are the same.

4. SENSITIVITY STUDIES AND IMPROVEMENT OF THE SCENARIO

4.1 SENSITIVITY STUDY

The usual last step of a prefeasibility is the sensitivity study. The concept of this study is to understand the influence of various parameters on the economical results of the project. Each important parameter will be taken apart and we will study the impact of the variation of this factor on the NPV and the IRR, all other things being equal. The study of the NPV will be privileged as it is shown previously that the IRR is not a good index for very long-term projects.
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<u>Presentation of the study</u>

Sensitivity studies in general use as a complement of the risk assessment. The risks registered during the first risk assessment process are converted into variations of economical parameters. For instance, the market risk, a risk which is very often studied with sensitivity studies, can be converted into:

- a decrease of the average sales price (if the quality is not as good as expected, or if a fierce competition occurs);
- a decrease of the yearly sales plan (if the products do not meet the market needs).

The variation of these two parameters will impact the NPV and result in a quantitative assessment of the risk.

In our case, the sensitivity study will have a second role. We have so far designed the new exploitation as an adapted version of the current one. The question that rises is undeniably: is there no other way to exploit this new part of the deposit, which is quite different from the current one? The sensitivity study will then enable us to find the main cost drivers and to see what could be improved.

<u>The selection of parameters</u>

Regarding the risk assessment part of the sensitivity study, it is necessary to list the main parameters that may impact the economical results.

The main risks to study and their subsequent parameters are easily extracted from the risk assessment:

- geological risks:
  - o tonnage: variation of the total tonnage of the pit which results in a decrease of the yearly production (which is fixed by the waste extraction method);
  - o quality: if the quality is not met, it will result in a decrease of the average sales price and/or in a decrease of the yearly sales;
- market risks: the main market risk is a decrease of the average sales price;
- risks on the capital expenditures: some difficulties may be encountered during the pre-project phase and lead to an increase of the costs for preliminary works;
- risks on the operating costs: what would happen if the calculated costs are not feasible in practice?

<u>The external parameters</u>
It is legitimate to start this study with parameters on which Rio Tinto Minerals has no (or very little).

<u>The sensitivity to the tonnage</u>

The deposit knowledge represents at this stage of the project the greatest risk. It is logical to study first the sensitivity to the total tonnage, which was done by playing on the total recovery factor which is one of the parameter of the calculation sheets used to build the economical model.

The assumptions taken for this study are:

- variation of the total tonnage;

- the amount of waste removed every year is constant (the same as for the normal scenario);
- the length in year of the exploitation does not change;
- the yearly talc production varies with the total tonnage.

The charts presented in this part of the report give results that are slightly different from the figures given in the previous part for they already integrated some improvements in the production method which are explained in the paragraph about the improvements of the production method (at the end of this report). Each chart gives the evolution of the NPV and of the IRR versus the variation of the chosen parameter. The horizontal line gives the original value of the NPV.

The figure 63 gives the evolution of IRR and NPV versus the percentage of the total tonnage assumed for the previous study, that is to say 100% represents 2.3 Mt of talc.

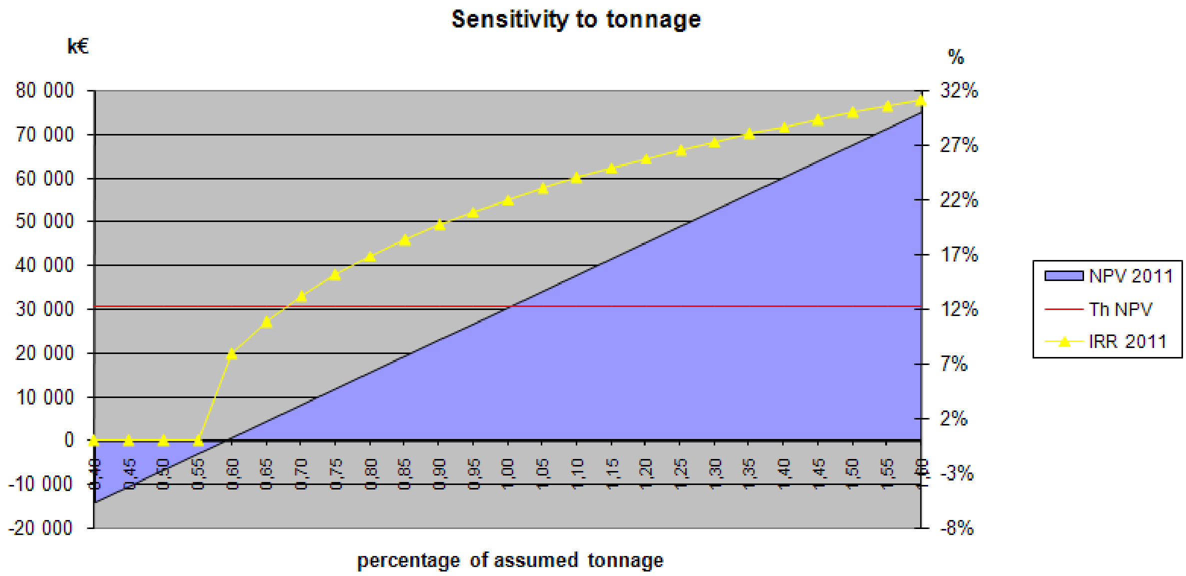

Figure 63 - Sensitivity of NPV and IRR to tonnage

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As the figure 63 shows and as we expected it, the economical results of the project are very sensitive to the total tonnage. At least 60% of the assumed reserves must be found to have a positive NPV for the complete project. This is equivalent to keep constant reserves but to have a total recovery factor of 0.60*75/100=45%. With the current recovery rate of 61% which amounts to a percentage of the assumed tonnage of 81%, the NPV would lose about 13M€.

However, these results do not systemically mean that, if the total tonnage found during the exploration campaign is smaller than 60% of the assumed tonnage (that is to say 0.6*2.3=1.38Mt) the project will not be profitable. Indeed, only the total tonnage varies here but not the geometrical position of the deposit. It is perfectly conceivable to have lower reserves but better situated so that the exploitation would still be profitable. The study of the pit A and B shows actually this result. If the expected tonnage is not reached at the end of the first campaign, a new study has to be done with the new parameters to see if the new exploitation could be profitable as the figure 64 shows.

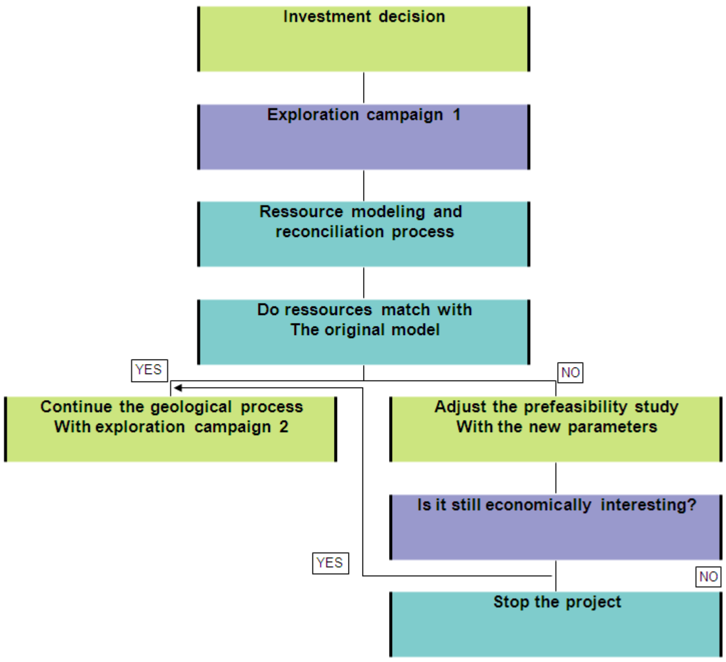

Figure 64 - The decision scheme after the first exploration campaign

Sensitivity to the average sales price

The other main parameter on which Rio Tinto Minerals has a very small influence is the average sales price. Indeed, all calculations were done based on the 2010 value. It is completely impossible to forecast the evolution of the average sales price for the 40 coming years. Lots of factors could make this price vary a lot such as:

- evolution of the need;
- invention of talc substitute;
- development of new products;
- etc.

For the sensitivity study, it was assumed that:

- only the average sales price varies;
- all other parameters such as yearly production, mining and processing costs, etc are constant.

The figure 65 gives the evolution of the NPV and the IRR of the project versus a percentage of variation of the assumed sales price.

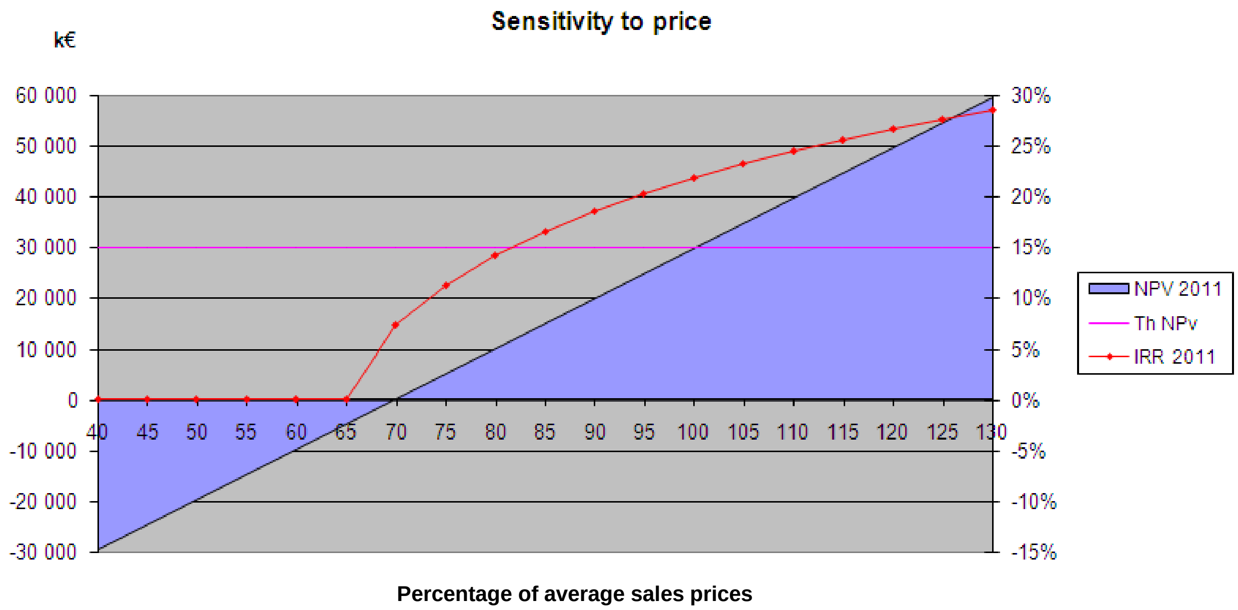

Figure 65 - Sensitivity of NPV and IRR to average sales price

Once again, as expected, the sensitivity of the NPV to the average sales price is very high: a decrease of 30% of the average sales price will make the NPV null. This is all the more a crucial parameter when we know that the average sales price of talc produced by Rio Tinto Minerals has increased by more than 20% (corrected of inflation) within the past 6 years. This increase was possible thanks to the development of new products of higher quality for new applications in the paint industry. The current trend of Rio Tinto Minerals is to target higher quality markets than during the past years. These results show the huge influence of strategic decision and of a good marketing in the sector of industrial minerals. Rio Tinto Minerals and LUZENAC are far from being only mining companies; they have very important commercial teams.

The market risks for the coming years are very well-known thanks to the work of these teams and it was thus decided to stop the sensitivity study on price at this stage. The complexity of the talc market prevents any neophyte to do a study on the evolution of talc prices in a few weeks.

In the logical order, the next parameters to study are the other contribution to the cash flows construction: the costs.

Sensitivity to investments

The capital expenditure plan, detailed in the previous parts, deserves now to be studied in detail. Among the expenses for investment, we find four main categories:

- exploration;
- studies;
- preliminary work;
- equipment.

The costs related to the various studies to be done and to the purchase of equipment has little chance to change a lot from what is planned. Indeed, prices and number of equipment have no risk to vary and the costs of studies are already well-known by Rio Tinto Minerals who led several extension projects by the past.

On the other hand, the cost of exploration in order to transfer 2.3Mt of talc from inferred resources to measured resources has a huge chance to vary. Hundreds of parameters can change the costs of an exploration campaign. The same is as well true for the preliminary works. Some difficulties or delay of the works may occur and have a big impact on the total costs of the capital expenditures plan. It is thus necessary to study what will be the impact of a global increase of the investment costs on the economical results.

For this study, I multiply all investment costs (studies, exploration, works and equipment) by a factor varying between 0. 6 and 5 and calculate the subsequent NPV and IRR. The evolution of these indexes is given in the figure 66.

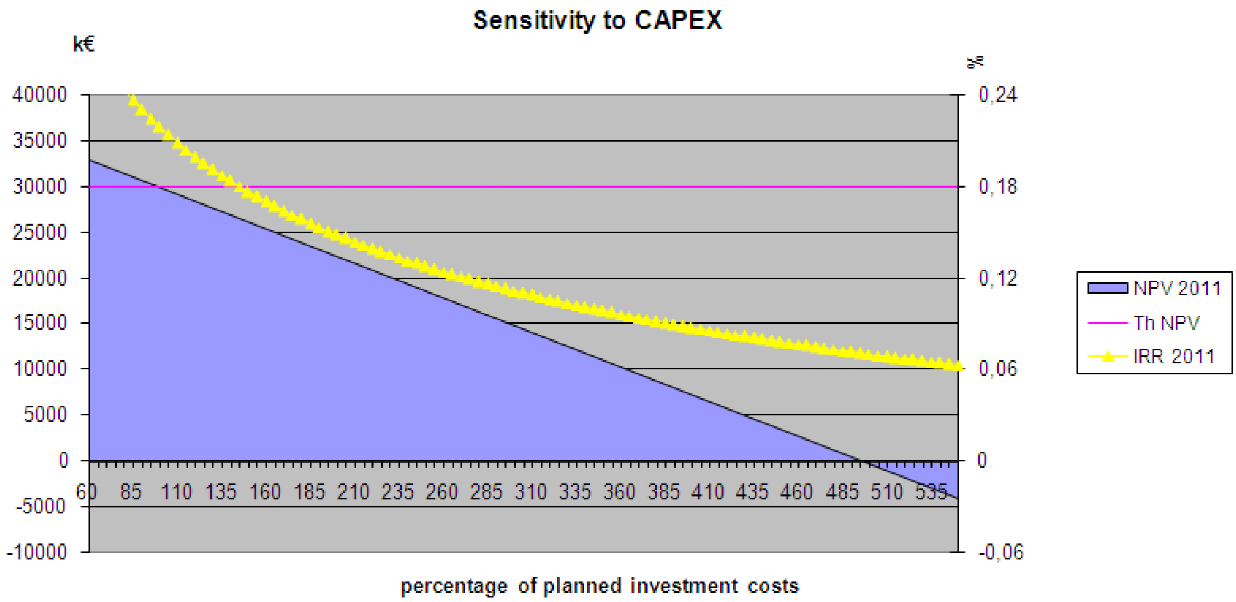

Figure 66 - Sensitivity of NPV and IRR to investment costs

The first surprise coming from the charts is the fact that the investment costs could be multiplied by five before the project reaches a negative NPV! It shows then that the project is not very sensitive to the investment costs, or much less sensitive to these costs than to variations of price.

Regarding the general project management, it implies that it should not be feared to encounter some difficulties during the early stages of the project since it will not have big impacts on the success of the project.

This result actually confirms a first impression coming from the comparison of the cash flows resulting from the investment phase and the cash flows of the operational phase. Indeed, these latter are much more consistent.

Sensitivity to costs

The other side of a sensitivity study to costs is now the sensitivity to operating costs. What would happen if the conditions of production are not as good as expected? The operating costs could increase for several reasons: one of them could be that the rock in the new pit is harder than in the current one. It would result in an increase of the blasting and in an increase of the total waste removal costs.

The first step of the study was to make all operating costs vary, that is to say costs related to mining and to processing. The evolution of the NPV and the IRR of the project versus the previous parameter is given in the figure 67.

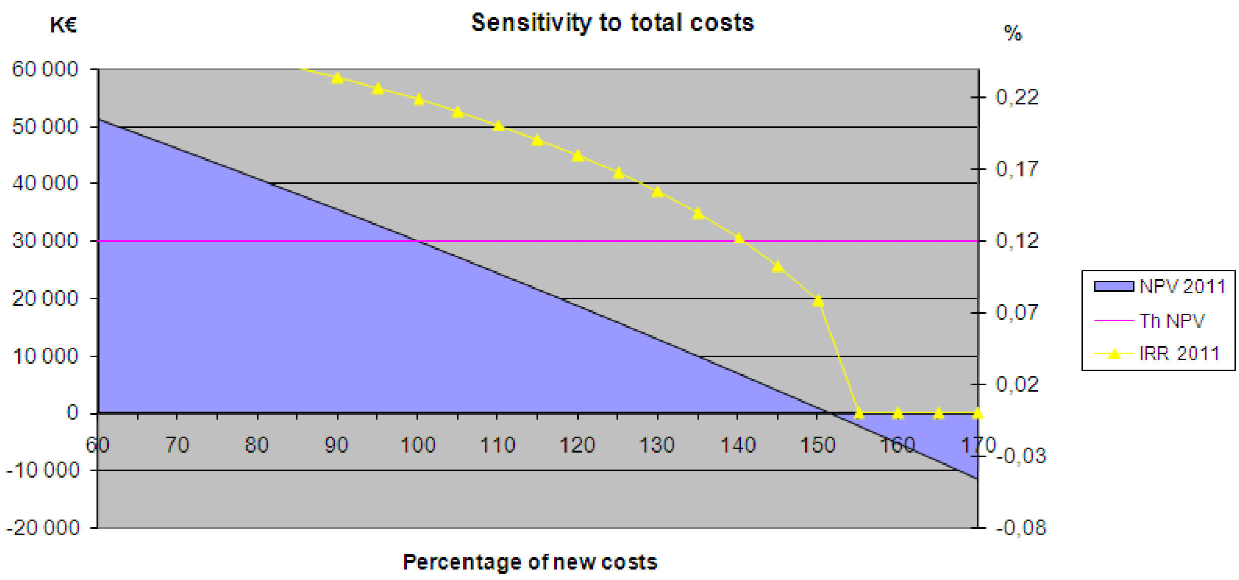

Figure 67 - Sensitivity of NPV and IRR to total costs

As expected, the sensitivity to total costs is high and has a general shape comparable with the sensitivity to average sales price, but of course seen in a mirror. An increase of about 55% of the total costs would make the project not profitable anymore.

These results have to be considered with precaution; all costs vary here. Now, the process costs are very well-known and the process plant in general has a very stable production and stable costs. There is then very little chance that processing costs increase dramatically. It is now interesting to see what would be the impact of the increase of the mining costs only.

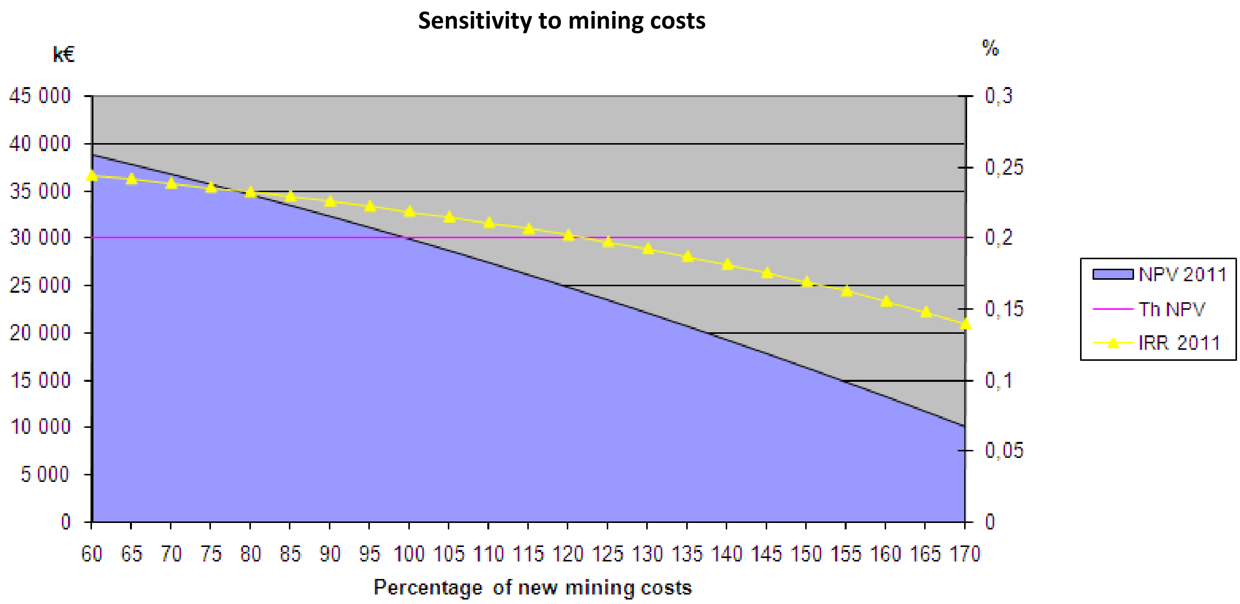

Figure 68 - Sensitivity of NPV and IRR to mining costs

As the figure 68 shows, the sensitivity to mining costs is about twice less important than the sensitivity to total costs. This result matches the general costs breakdown between mining and processing costs. This chart shows that the total industrial installation including Rabenwald and Oberfeistritz is a pretty strong exploitation. Each installation produces about a half of the added value, so even with an increase of more than 70% of the mining costs, the global exploitation would still be profitable. A null NPV would be reached if the mining costs were multiplied by 2.

Comparison of the various sensitivity studies

In order to compare the impact of each parameter on the NPV, a chart summarizing the previous results has been done and is available in the figure 69. On this chart, each parameter from the previous studies varies from 80% to 120% of its assumed value, all other parameters being constant.

The chart confirms the general impression we had so far. In a decreasing order, the project is sensitive to:

- average sales price;
- tonnage;
- total costs;
- mining costs;
- investments.

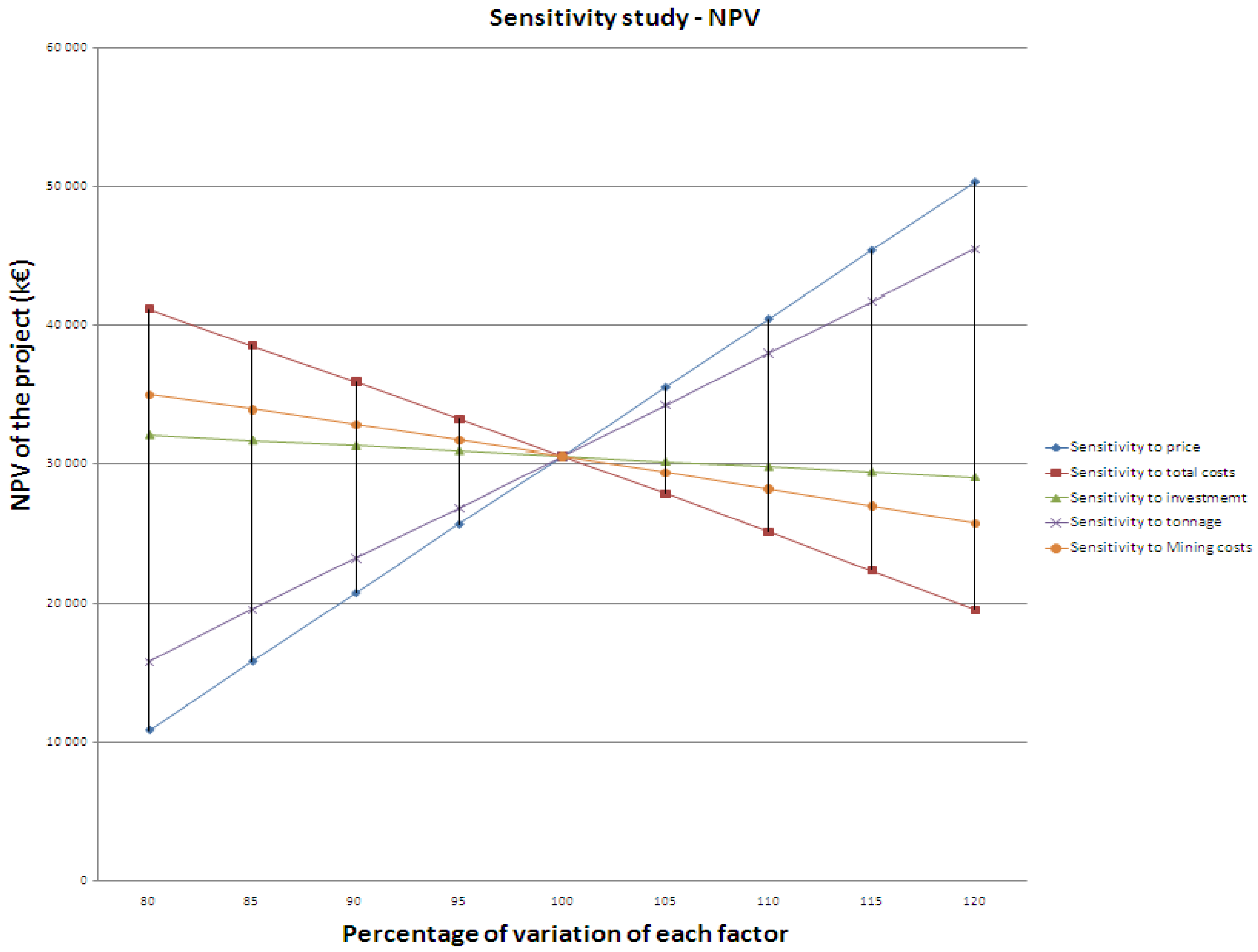

Figure 69 - Summary of the sensitivity study

4.2 THE IMPROVEMENT OF THE CURRENT PRODUCTION METHOD

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As it was previously said, the general production methods are the same as for the current project whereas the main characteristics such as the hauling distances and the overall stripping ratio are different in the two projects. The logical question that rises is: is there no way to develop more adapted production method.

Change the equipment?

The first idea to answer this question was to study new type of equipment for the talc and waste process. Indeed, a longer hauling distance should justify the purchase of bigger equipment to decrease the total hauling costs.

This idea was only briefly studied and was abandoned for various reasons. The first one is related to the nature of the changes in the new exploitation: the stripping ratio will be lower, which will imply less waste to remove and to haul and the hauling distance will be longer. To decrease the hauling costs, bigger waste trucks should be bought. In the same time, the amount of waste to be removed is smaller, which would justify buy a smaller shovel.

For productivity reasons, it is proved that only a few types of shovels can efficiently load a given type of truck. Indeed, it is generally agreed that the optimum of productivity is reached when a shovel loads a truck with 4 to 8 buckets. Purchasing bigger trucks will require buying bigger shovels too, which will increase the investment costs as well as the loading operating costs. Indeed, a bigger shovel is more expensive and not needed to remove so little waste. The increase of costs resulting from the purchase of the shovel will be broken down on less waste and the loading costs per ton of waste will thus increase a lot.

The other reason why this solution is difficult to set up is the fact that the new project will be a brown field project: it will take over the current exploitation. A lot of equipment from the current mine will still be available with a remaining life duration ranging from a few years to 10 years. This is taken into account in the replacement plan of equipment and purchasing a complete fleet of new trucks and shovels at the beginning of the new project will completely change the cost structure.

Finally, this solution was abandoned for trivial practical details such as the lack of reliable data regarding new equipment and the lack of time to make a decent study. In the mean time, some other improvement parameters were identified and I privileged to work on these parameters than on a change of equipment. However, this question would deserve to be further studied within the next few years to confirm or not the legitimacy of keeping the same equipment.

Impact of the hauling distance

As the figures 44 and 45 show, the slight increase of new mining costs is due to a major increase of the hauling costs resulting from a longer hauling distance and a decrease of the total waste costs per ton of talc thanks to a better stripping ratio. The first step of the improvement study is to understand the real impact of the new hauling distance on the total costs. The same method as for the previous sensitivity studies was used here to assess the sensitivity of the project to the hauling distance.

The talc and waste hauling distance are multiplied by a factor ranging from 0.4 to 3. From this new hauling distance, all the calculation sheets regarding cycle analysis, number of needed equipments, etc are updated and result in a new cost model. Then for each distance, the NPV and the IRR of the project was calculated. The results of this study are given in the figures 70 and 71.

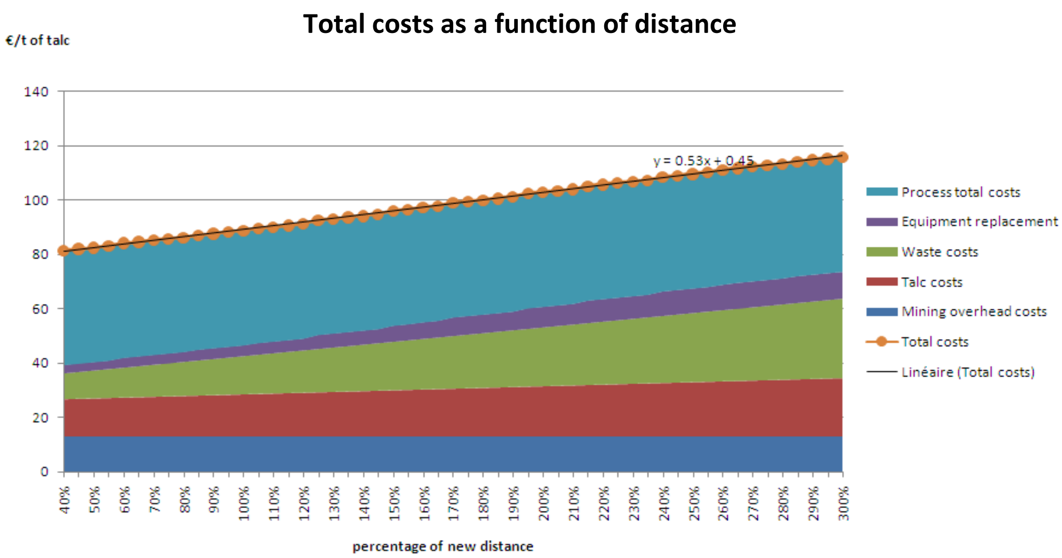

Figure 70 - Evolution of operating costs versus the average hauling distance

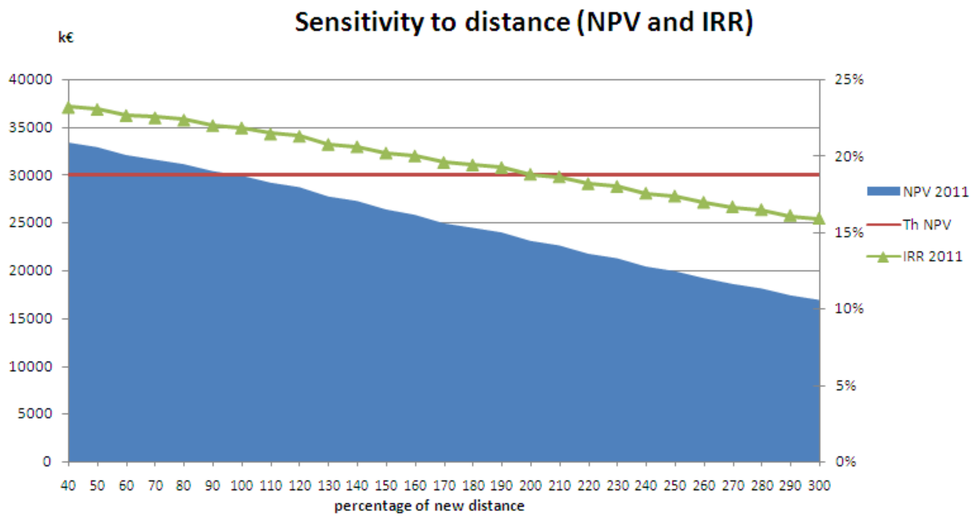

Figure 71 - Sensitivity of NPV and IRR to distance

These two charts reveal a lot:

- first, the sensitivity to hauling distance is not as high as feared; the new hauling distance could be more than multiplied by 3 before the project has a negative NPV;
- it confirms the fact that the south limit of the pits A and B is only a psychological limit and that the new pit can go further south;
- it also shows that we should no fear to go southern for the exploration campaign. The current exploration campaign stops where the block model comes to its end in the south. It is conceivable that there is as well talc in the south of the block model and the previous charts show that this talc would be economically interesting too.

The increase of the hauling distance results in:

- an increase of the number of talc and waste trucks, which has not a huge impact on the project as it is proven that the project is not very sensitive to variations of investment;
- an increase of the operational hauling costs.

These two parameters are taken into account in the new cost model. However, some other phenomena are not considered in the model. If the hauling distance is three times longer than the new hauling distance, the number of needed CAT will be higher than 10. In these conditions, there would be probably a lot of other cost increases that are not taken into account here:

- the overhead costs and in particular the management costs will be higher;
- a fleet of 10 CAT would require new infrastructures such as garage and a bigger workshop, which would increase the investment costs.

The previous charts show that if talc is found southern than expected, it will still be interesting to exploit it. However, a more elaborated study would have to be done to clearly understand the impact of the hauling distance.

The main parameter to work on in order to decrease the total mining costs is thus the talc and waste hauling costs, which are directly related to the hauling time. Indeed, experiments show that the operating costs of a mining truck in normal conditions is proportional to its operating hours and not systematically to the driving distance. In order to reduce the duration of a hauling cycle, we have two possibilities:

- decrease the hauling distance;
- increase the speed of equipment.

Increase the speed of equipment

This idea came from the observation that the average speed of equipment in the current pit is pretty low and that it was probably not too difficult to improve it. The low average speed is mainly due to the quite low quality of the pit roads. Indeed, the average hauling distance is today short and there is no need to have perfect roads in order to follow the shovel productivity with the CAT truck.

Currently, the maintenance of roads is done by a non-specialized employee. In Trimouns mine which has a bigger yearly production, there is a full time operator for grading. The same could be done in Rabenwald; it would increase a bit the wages costs and improve a lot the average road qualities. A new grader will also be purchased at the beginning of the new project in order to meet the new needs of the exploitation.

The other idea which makes it possible to improve the average speed is to remark that with the new hauling path, a consistent part of the access road to the pit will be fixed: the road between the site installation (offices, crusher, etc) and the entrance of the pit. This part of the road is about 1.8km long. The fact that it is fixed implies that it is possible to build there a road with a better quality during the preliminary works phase. In order to enable equipment to drive faster, this road should be wider than the usual pit roads that are between 10 and 12m wide in general. An average width of 15 to 18m for this part of the road will be built. Since the road will be fixed, it is also interesting to invest in a good covering: in the improved scenario this part of the road will be covered with asphalt.

Finally, the last argument that confirms a possible improvement of the speed is the comparison of the overall slope profiles for the current and for the new pit.

On the figure 72, we can see a comparison of the slope profile. In purple, it is the current average slope profile for the waste hauling path and in red the average slope profile for the new exploitation. The hauling path for the new pit will evolve throughout time, and in function of the mine planning. The shortest distance will be reached if waste is extracted at the entrance of the pit and is dumped at the bottom of the current south pit (green graph). The longest distance will be reached if waste is extracted at the furthest point of the new pit and dumped on an already high waste dump located above the current south pit (blue graph).

However, we can sensibly assume that with a good mine planning, it is possible to compensate the increase of hauling distance due to the progression in the pit by an appropriate dump location. On average, we can consider a constant hauling distance from the new pit to its dump in the current south pit given by the red curve.

Figure 72 - Slope profile of the current and the new pits

The main observation from these slope profiles comes from the average slope of the hauling path. For the current pit, the slope is almost always at its maximum allowed in Rabenwald: 10%. For the new pit, the part of the road in the pit and on the dump has a slope of 10%. Elsewhere the slope is lower and in particular on the fixed part, the slope is less than 5%. This decrease of the average slope let us hope a possible increase of the average speed.

In order to quantify the possible speed improvement, I got the performance charts for CAT 775D and for MOXY articulated dump trucks. Among these charts, there is one giving the average speed in function of the load and of the effective grade of the road. The effective grade of the road is the sum of the real grade of the road and of a resistive force due to the friction of the road. This resistive force is translated into a grade to get this effective grade.

According to these charts (available in annex 3), I obtained the results presented in figures 73 and 74

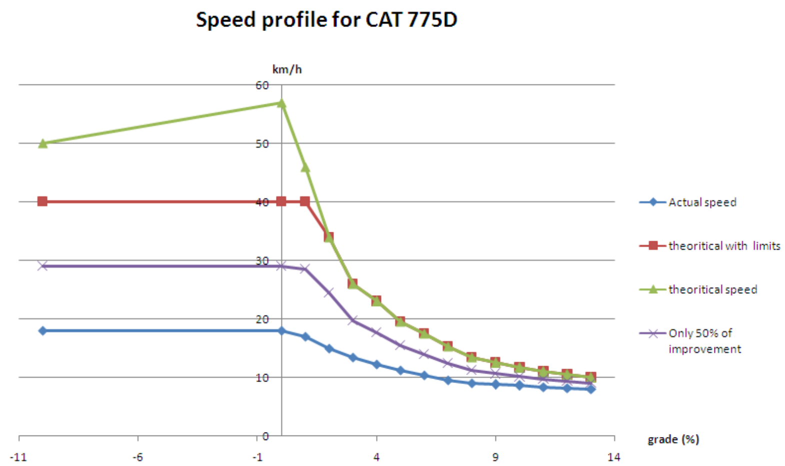

Figure 73 - Speed profile of the CAT 775D

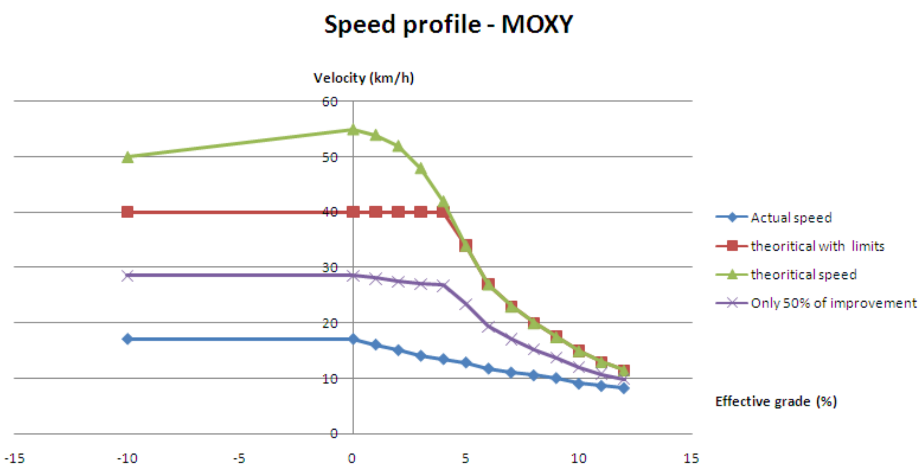

Figure 74 - Speed profile of the MOXY

The green graph is the best possible velocity according to the performance charts. The red one is based on the green one but with the inclusion of speed limits on site (maximum speed of 40 km/h). The blue one is the actual speed of equipment. These graphs were done by measuring the hauling time on different parts of the current exploitation with various grades. The purple line is an average of the red and blue line and gives the new velocity if we assume that only 50% of the speed improvement is feasible.

By coupling this speed profile chart with the slope profile chart, it is easy to get the average possible improvements which are given in the table 75.

Velocity (km/h)	Current velocity (current pit)	Current velocity (new pit)	Best possible velocity (new pit)	Only 50% of improvement (new pit)
CAT 775D	12	14	24	19
MOXY	11	13	28	20

Figure 75 – Reachable speed in function of various assumptions

The impacts of this new speed in the economical model are:

- the decrease of the average hauling costs for talc and waste;
- the decrease of the number of needed CAT 775D:
    - with the current speed: 7 CAT;
    - with 50% of the possible improvements: 5 CAT;
    - with 100% of the possible improvements: 4 CAT.

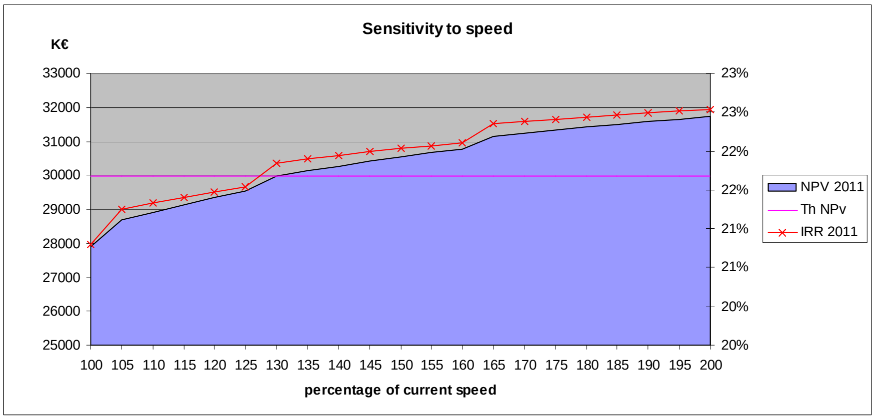

Figure 76 - Sensitivity of NPV and IRR to speed of equipment

The figure 76 shows the sensitivity of the final NPV to the average speed of CAT and MOXY. The first observation is that this chart presents a few steps. These steps correspond to the decrease of the needed number of CAT or MOXY in function of the speed. An increase of the average speed of 50% of the current speed will permit to save two CATs and an increase of 100% of the current speed would save three CATs. The table 77 summarizes these improvements.

Needed number of equipment	Current speed	150% of the current speed	200% of the current speed
CAT	7	5	4
MOXY	2	2	2

Figure 77 - Needed equipment in function of velocity

<u>Decrease of hauling distance</u>

The decrease of hauling distance could be possible by dumping waste elsewhere closer to the new pit than the current south pit. However, this solution is almost impossible to set up due to an enormous permitting process to be allowed to dump elsewhere than in an old pit.

The other idea, which is much more easily feasible, for reducing the hauling distance is to dump a part of the waste directly in the new south pit in operation. This process is called fill-in dumping and it is currently done in the south pit.

This is possible if two conditions are checked:

- the pit is big enough to support at the mean time extraction in one region and dumping in another;
- the mine planning is adapted to the fill-in dumping: at the time of designing push-backs during the feasibility study, the possibility of fill-in dumping must be considered.

More than possible, fill-in dumping is even in some case mandatory to go through the permitting process for it allows the mine to build a visual barrier and to isolate the open pit to the public eyes.

The fill-in dumping can be performed only 4 or 5 years after the pit opening, when the pit is big enough. According to experimented mine engineers within Rio Tinto Minerals, fill-in dumping can absorb between 30% and 50% of the total waste to be removed in function of the pit situation and of the mine planning.

The three final scenarios

The general method for project assessing within Rio Tinto Minerals requires the development of 3 scenarios. A base case is studied and then from the results and from some further studies such as sensitivity studies, a few possible improvements are identified. These improvement are in general very difficult to quantify and in order to give an idea of their impacts on the project, two other scenarios are developed. The best scenario, based on the base scenario, describes the project for which all possible improvements perfectly work. On the other hand, the worst scenario describes the project for which no improvement works.

In our case, we are going to develop these three scenarios for the pit C.
The base scenario is the following one:

- increase of the average speed of equipment by 50% of the possible improvement;
- after the 5th year of the project, 40% of the waste is dumped in the south pit.

The best scenario is:

- increase of the average speed of equipment by 100% of the possible improvement;
- after the 5th year of the project, 50% of the waste is dumped in the south pit.

The worst scenario is:

- no increase of the average speed;
- after the 5th year of the project, 30% of the waste is dumped in the south pit.

The results are shown on the figure 78.

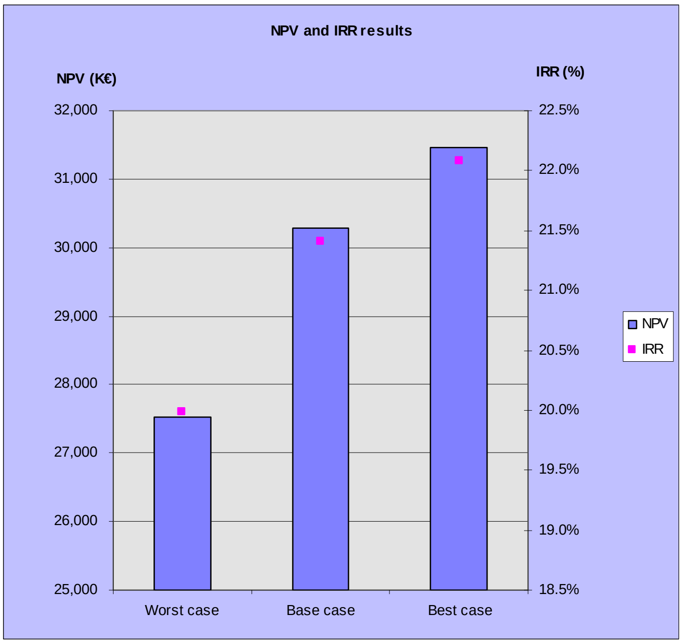

Figure 78 - Economical assessment of the final scenarios

These improvements enable to increase the NPV by 3M€ between the worst case scenario, which is the original scenario, and the base case scenario. This increase of 3M€ does not look very impressive on a 30M€ NPV but it is actually very consistent. Indeed, among the 30M€ of NPV of the project, about half of them are generated by the process plant and the other half by the mining part. The parameters which enable us to define the base and the best cases affect only the mining part of the project. Therefore, the increase of 3M€ has to be compared with the part of the NPV which is produced by the mine only, which is about 15M€. It is thus clear that those two improvements have a major impact on the economical efficiency of the project. Reflecting the increase of

NPV, the IRR increases from 19.9% to 21.4% between the worst and the best cases and by 0.7% between the base and the best cases.

The final risk assessment

The last step is to do another risk assessment of the project after the study and to see how risks have been mitigated. The complete risk register and risk assessment is available as an excel file and the figures 79 and 80 summarize those results.

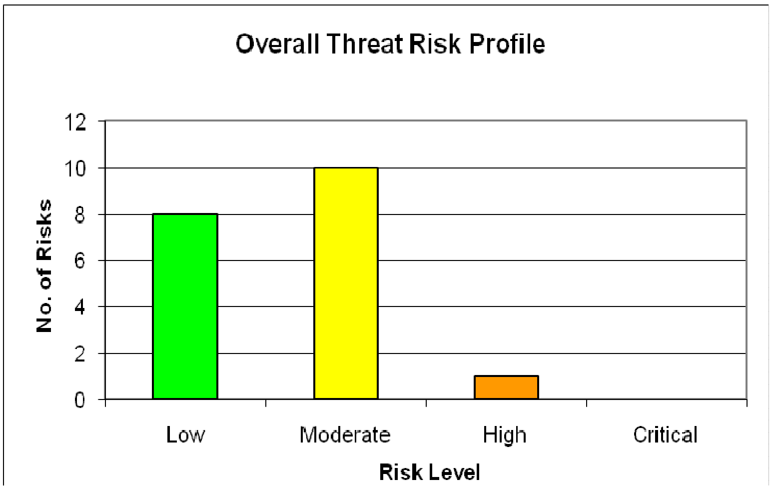

Figure 79 – Overall risk profile

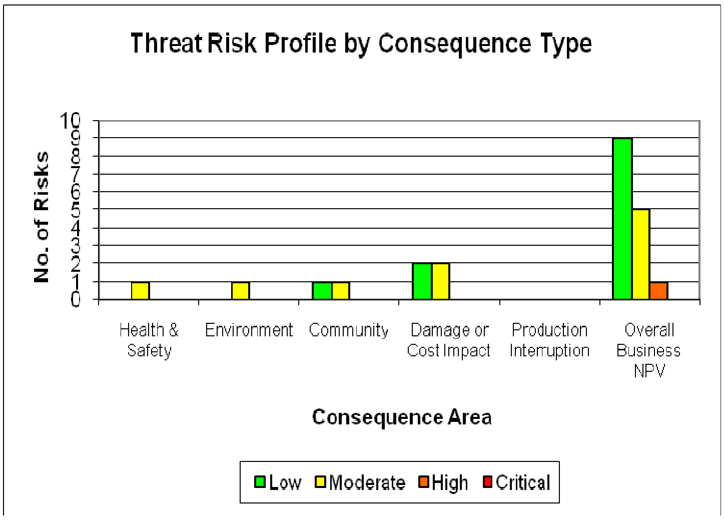

Figure 80 – Risk profile by consequence type

This new risk assessment shows several things:

- the critical risk does not exist anymore and only one high risk remains;
- the remaining high risk is the risk that the first exploration campaign is not successful. In that case, the associated loss will 448k€;
- the other high risks have been transferred to the moderate or low risk classes;
- there are more low and moderate risks due to the transfer of high risks to these classes and to the fact that those risks have been more precisely studied and split into several smaller risks.

The priority of the project is thus to confirm the existence of the geological resources.

CONCLUSION

The goal of this master thesis was to prove the economical and technical feasibility of a project of an extension of the Rabenwald talc mine to the south and in this sense the study is a complete success.

Outputs of the study

Regarding the ore body knowledge, the use of two programs, Datamine and Whittle, enabled us to design an optimized pit and a feasible and sensible general organization of the new project. Based on this result, the production methods of the current exploitation were adapted to the new characteristics of the project and several cost models were built to reflect these adaptations. These cost models were then used in order to obtain the cash flows of the project and to calculate the two most important indexes for project assessing: the net present value and the internal rate of return. This result enables us to choose the most favorable scenario and to elaborate on it.

Alongside this, general risks of the project were registered and the overall risk profile was built. A detailed project planning was elaborated in order to mitigate as much as possible the existing risks and to present a sensible way to proceed for the investment phase. A capital expenditure plan focusing on the geological exploration in order to transfer the inferred resources into measured resources was suggested.

Once the chosen project was completely defined, the economical assessment was run once more. Based on this model, several sensitivity studies were done in order to understand the impact of several parameters on the final results. These studies had three main goals:

- quantifying some risks such as the geological risk, the market risk, etc;
- identifying the main cost drivers of the new exploitation;
- identifying potential improvements for the new pit.

Two main improvements were chosen in order to increase as much as possible the NPV and the IRR:

- the increase of the average velocity of equipment thanks to an increase of the road quality and a decrease of the average slope;
- the decrease of the average hauling distance by considering fill-in dumping.

These two steps enabled us to reduce the needed number of trucks for waste hauling and to consistently improve the economical indexes. The final assessment for the base case gives the following results:

- NPV: 30.1M€;
- IRR: 21.4%.

The next steps

This study shows clearly that the new project can be profitable and it will be necessary soon to go for an exploration campaign if the project is accepted. In order to respect the assumption of the start of the production in 2028, the first exploration campaign must be done in 2016 and subsequent concerns and studies should be approached within the coming years.

It is now clear that the identified area has a strong potential. However, this study is probably not sufficiently elaborated in order to present the project to investors and to get the needed funds to start the project. Several topics need indeed to be further studied.

The ore body knowledge

The ore body used for the study is a very hypothetical model which is based on any drill holes. The sensitivity studies has shown that the geological risk is huge and that it is the only remaining high risk at the end of the prefeasibility study. The assumption on which the block model is based should be seriously studied and maybe questioned by a geologist before going in a first exploration campaign.

The production method

One of the major questions in this study was how to adapt the current production method to the new characteristics of the project and more particularly how to take advantage of the better stripping ratio of the new pit to compensate the much longer hauling distance. The decision of keeping the same general method and the same equipment was taken for several practical and technical reasons and the improvement was found in the increase of the velocity. Another approach should be studied before going further in the project: is there no other production method that would be better as simply upgrading the current method? In particular, we can think about changing the equipment such as the waste haul trucks in order to remove waste more efficiently with bigger and faster trucks.

The community acceptability and the permitting process

Another major concern that should be studied is the community acceptability of the new project. Indeed, it will be southern, closer to the neighboring villages, producing more dust and sound because of the longer hauling distance, etc. How will the neighboring villages react? This question is closely related to the question of the permit obtaining, which is a consistent risk for the project.

The strategic development of RTMA

Finally, the topic of Rio Tinto Minerals' strategy was discussed at the very end of the thesis and should be much deeper studied. Indeed, this study was made at a local extent and has shown that the defined project can be profitable for the Austrian structure. However, it does not prove that investing in Rabenwald would be the best strategy for Rio Tinto Minerals. The group owns about ten mines in the world and Rabenwald is known for the quite bad quality of its talc in comparison to the other mines. Why would Rio Tinto Minerals invest on this mine whereas other mines such Trimouns produce much better talc with easier and sometimes more efficient methods?

Therefore, this study has to be integrated in a global vision of the company and many other scenarios including interactions with the other implantations of Rio Tinto Minerals. Oberfeistritz plant is one of the more profitable within Rio Tinto Minerals and it will for sure be kept. Some scenarios are sensible:

- stop mining activities in Rabenwald and supply the process plant in Oberfeistritz with talc from other mine such as Trimouns;
- ibidem but with buying the talc from other mining companies;
- outsourcing most of the mining costs in Rabenwald such as the waste removal operations;
- etc.

In conclusion, I would say that this study has reached its objectives to prove the potential of the south area of Rabenwald and that it needs now to be further studied in order to better assess the risk identified in the study in question, to suggest other production methods to reduce mining costs and to understand the stakes of investing in Rabenwald from a strategic point of view. Therefore, a few very interesting questions arise from this report and we can legitimately imagine that this master thesis will not be the last one in Rabenwald.

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Florian LANZI, 2008, Geological modelling and economical pit optimization tests with Whittle for an industrial deposit of kaolin (Melbur and Virginia western area- Cornwall-UK)

LIST OF FIGURES

ANNEXES

ANNEX 1 – THE CURRENT PIT AND THE ULTIMATE SOUTH PIT

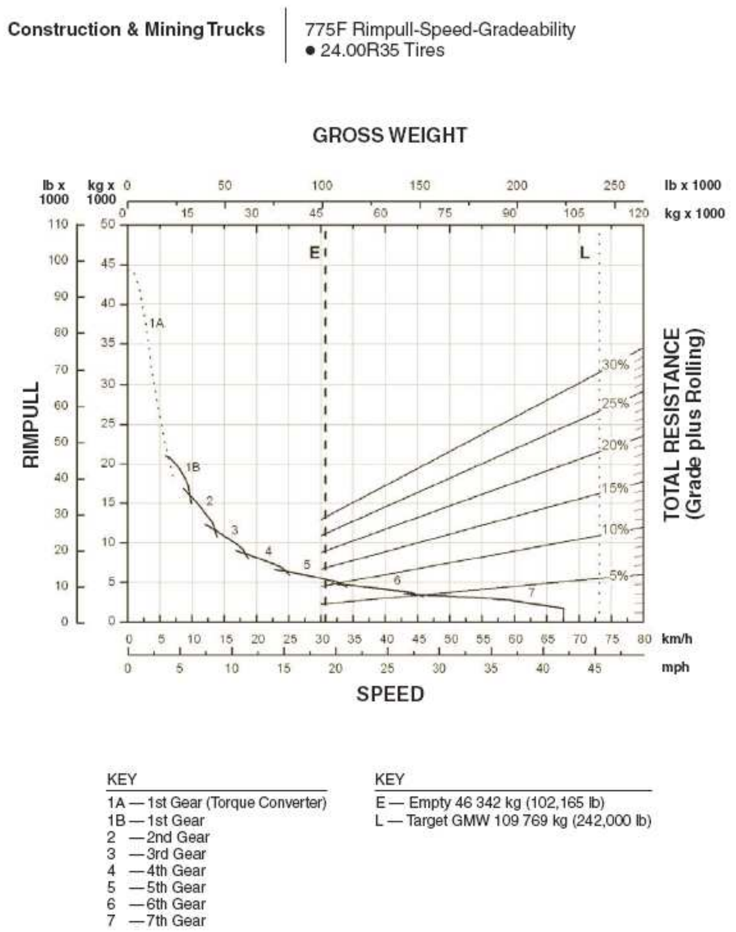
The current pit

The ultimate south pit (2028) – the dump is not represented

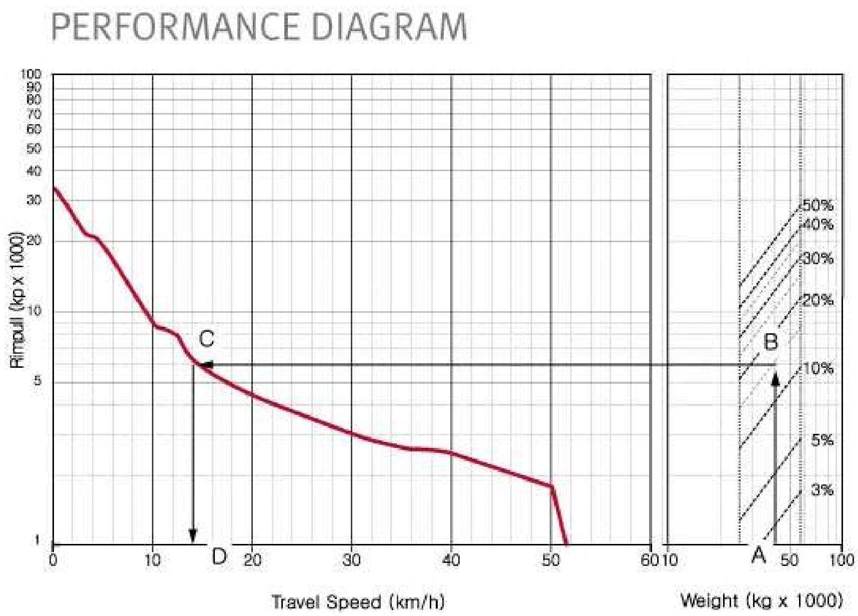
Project life			0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Years			2 011	2 012	2 013	2 014	2 015	2 016	2 017	2 018	2 019	2 020	2 021	2 022	2 023	2 024	2 025	2 026	2 027	2 028	2 029	2 030	2 031	2 032	2 033	2 034	2 035	2 036	2 037	2 038	2 039
1-Capital Expenditure			0	0	0	0	0	(48)	(448)	412	(180)	0	(226)	(226)	(226)	(155)	(155)	(5 643)	(3 659)	(3 810)	(1 727)	(1 710)	(1 435)	(1 082)	(1 431)	(857)	(1 464)	(1 405)	(2 144)	(913)	(1 652)
2-Incremental working capital																															
3-Closure costs (if any)																															
4-Start up costs							0	0	0	(448)	0	(1 209)	(1 209)	(1 209)	(1 209)	0	0	0	0												
5-CASH OUTFLOWS (1+2+3+4)			0	0	0	0	0	(48)	(448)	(36)	(180)	(1 209)	(1 434)	(1 434)	(1 434)	(155)	(155)	(5 643)	(3 659)	(3 810)	(1 727)	(1 710)	(1 435)	(1 082)	(1 431)	(857)	(1 464)	(1 405)	(2 144)	(913)	(1 652)
6-Revenues (or cost savings)																				7 286	14 805	22 562	30 564	31 053	31 550	32 055	32 568	33 089	33 618	34 156	34 703
Less:																															
7 Cash Costs																				(3 923)	(7 971)	(12 148)	(16 237)	(16 423)	(16 686)	(16 953)	(17 224)	(17 499)	(17 779)	(18 064)	(18 353)
8 Other																															
9																															
10-Operating Cash Flows (6-7-8-9+10)				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3 363	6 834	10 414	14 327	14 630	14 864	15 102	15 344	15 589	15 839	16 092	16 350
11- Deflated Tax Depreciation				0	0	0	0	0	0	0	0	0	0	0	0	0	0	(123)	(121)	(494)	(530)	(605)	(652)	(664)	(699)	(580)	(621)	(445)	(503)	(421)	(423)
12- Tax payments	25,0%	%		0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	30	(717)	(1 576)	(2 452)	(3 419)	(3 492)	(3 541)	(3 631)	(3 681)	(3 786)	(3 834)	(3 918)	(3 982)
13- Other Group Contributions (net of taxes)																															
14-NET OPERATING CASH			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	30	2 646	5 258	7 962	10 908	11 139	11 323	11 472	11 663	11 803	12 005	12 174	12 368
NET CASH FLOWS (14-5)			0	0	0	0	0	(48)	(448)	(36)	(180)	(1 209)	(1 434)	(1 434)	(1 434)	(155)	(155)	(5 612)	(3 628)	(1 164)	3 531	6 252	9 473	10 057	9 892	10 614	10 200	10 398	9 861	11 261	10 716
Discounted Net Cash Flows			0	0	0	0	0	(35)	(309)	(23)	(108)	(680)	(754)	(705)	(659)	(67)	(62)	(2 104)	(1 271)	(381)	1 081	1 788	2 532	2 513	2 310	2 316	2 080	1 982	1 756	1 875	1 667
Project Lead Time	0	Months	0	0	0	0	0	(48)	(496)	(532)	(712)	(1 921)	(3 355)	(4 789)	(6 223)	(6 378)	(6 534)	(12 146)	(15 774)	(16 939)	(13 408)	(7 156)	0	0	0	0	0	0	0	0	0
Pay Back Period	15	Years																													
Internal Rate of Return (IRR)	21,4%		0,0	0	0	0	0	(18)	(140)	(9)	(38)	(211)	(206)	(170)	(140)	(12)	(10)	(306)	(163)	(43)	107	157	196	171	138	122	97	81	64	60	47
Underlying Inflation	1,6%																														
NPV	30 291,4																														
i rate = 7,0%																															
			30 129																												
Test NPV	29 283,8																														

Tax Depreciation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	(156)	(156)	(647)	(705)	(818)	(895)	(927)	(991)	(835)	(909)	(662)	(760)	(646)	(660)
Deflated Tax Depreciation		0	0	0	0	0	0	0	0	0	0	0	0	0	0	(123)	(121)	(494)	(530)	(605)	(652)	(664)	(699)	(580)	(621)	(445)	(503)	(421)	(423)

ANNEX 3 – THE PERFORMANCE CHARTS



Performance charts for CAT 775D



Performance charts for MOXY

ANNEX 4 – THE FIRST RISK ASSESSMENT

Ref		Risk Description			Risk Rating							Risk Level / Class							Risk Management Planning
Category	Item	Risk Title	Triggers/Indicators	Impact	Likelihood	Health & Safety	Environment	Community	Damage or Cost Impact	Production Interruption	Overall Business NPV	Health & Safety	Environment	Community	Damage or Cost Impact	Production Interruption	Overall Business NPV	Highest Risk Level/Class	Risk Reduction Measures
A		Resource																	
A	1	Risk on tonnage	The model used for the prefeasibility study is based only on the current model for south pit and not on any drilling campaign. It is thus very hypothetical. The reconciliation factor is set to 75% and higher than the one of the current pit (61%) for there was no underground mine in the new pit area.	Decrease of the reserves Decrease of annual sales or of life of mine Decrease of NPV which is very sensitive to tonnage	P						Ma						C	C	A first exploration campaign with a 100m pattern Reconciliation process of ressources model Definition of a new project in case the expected reserves are not reached
A	2	Risk on quality	The model used for the prefeasibility study uses only one average talc quality, based on the average quality of the current pit. There is a lot of chance that this quality slightly changes from one pit to another	Loss of market share and decrease of annual sales Decrease of ASP Decrease of NPV which is very sensitive to ASP	P						S						H	H	A first exploration campaign with a 100m pattern Creation of a block model with talc qualities
B		Physical risks																	
B	1	Geotechnical risks	The geotechnical parameters for the prefeasibility study are taken from the current pit design. The geotechnical situation of the new pit may be not as good as the current one	New slope profile increase of the stripping ratio Slight decrease of the NPV	P				Me						M			M	Geotechnical study to be led during or at the end of the second exploration campaign
B	2	Geochemical risk - presence of fibrous material	The current talc extracted in Rabenwald is free from fibres which may not be the case for the talc extracted in the new pit. The presence of fibres will imply lots of concerns regarding health, environment, social issues and production method	New process for waste extraction Steps for environment protection Steps for health protection	U	S		S	S		Ma	M		M	M		H	H	Ask for a first chemical study between the two exploration campaign
B	3	Geochemical risk - presence of impurities	The ASP of talc highly depends on ist quality and in particular in ist quartz content and ist loss on ignition. This parameters may vary in the new pit	Decrease of the yearly sales and of the ASP Decrease of the NPV	U						S						M	M	A complete geochemical study during the second exploration campaign Development of new products
C		Environmental risks																	
C	1	Biodiversity, underground water, etc	The environmental situation of the new pit should not be very different from the one of the current pit. However, appropriate studies have to be made to confirm this assumption.	Difficulty to get the legal authorisation	U		S						M					M	Environmental studies to be led during and after the 2nd exploration campaign
D		Social risks																	
D	1	Community unacceptability	This new project will be much further south than the current activities and so closer to the surrounding villages. A visual barrier will probably be more complicated to set up and less efficient due to the topography of the new pit. Moreover, the hauling distance is longer, which may imply more noise pollution, air pollution and dust production	Difficulty to get the legal authorisation Bone of contention with the local communities	U			Ma						H				H	Frequent public information Particular attention will be paid to dust and noise mitigation measures The question of the visual barrier will have to be seriously considered in the feasibility study.
D	2	Land use/land purchase	95% of the area of the new exploitation does not belong to Naintsch. Some agreements will have to be found with the current landowners regarding land use or land purchase, if need be. H. Reithofer owns a small part of the land of the new pit; the agreement with him will need to be extended. For the economical assessment, it was assumed that all lands will be rent and that the current agreement with h. Reithoffer will be extended.	Forced to buy lands instead of renting them Difficulty to get the legal authorisation Increase of the rent price	P				Me		S				M		H	H	Start the negociation with the landowners long in advance
E		Legal risks																	
E	1	Difficulty to get the authorization for exploration	The duration of permitting processes is difficult to assess. In case of conflicts with the local communities, the permitting process can be delayed several years. Ongoing authorization process can be stopped by new European or local laws.	The project will be postponed by a few years Decrease of the NPV because of the delay	U						Me						L	L	Stay updated about regulations Stay in close contact with the local communities
E	2	Difficulty to get the authoriztion for production	ibid.	The project will be postponed by a few years Decrease of the NPV because of the delay (exploration investment will be already made)	U						Ma						H	H	Stay updated about regulations Do a first attempt after the first exploration campaign
F		Market risks																	
F	1	Decrease of the market	The market risk is quite well-known by Naintsch/Luzenac/RTM marketing team but a reliable forecast on 20 years is impossible to get	Decrease of the yearly sales and production	U						Ma						H	H	?
F	2	change of the demand	ibid.	Decrease of the yearly sales, production and of the ASP	U						Ma						H	H	Develop new products
F	3	Decrease of the ASP	ibid.	Decrease of the NPV	U						Ma						H	H	?

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