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Economic Potential of Tin, Fluorspar and Barite occurrences in Saxony

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Abstract

The Erzgebirge / Krušné hory region hosts resources of ore and spar that fit the needs of the global market in quality and quantity. About 50 deposits were assessed, mainly based on archived exploration and data reworked by the "RohSa" study of Geokompetenzzentrum Freiberg and the Saxonian State office of Environment, Agriculture and Geology.
In mutual comparison, Altenberg and Gottesberg are the most perspective tin deposits, yielding mining costs of 22,400 and 18,200 €/t Sn in concentrate, respectively. Even lower costs are assigned to skarn deposits as Tellerhäuser (15,000 €/t Sn), due to higher tin concentrations. However, skarn processing needs further technical development in order to be economically comparable to vein and greisen ores. Barite extraction from the Brunndöbra mine yields 126 €/t $BaSO_4$, fluorspar of the deposits of Schönbrunn and Bösenbrunn can be mined to average costs of 159 €/t CaF_2.

Keywords: Erzgebirge, exploration, fluorspar, lifetime, mining costs, tin

Introduction

In Saxony, ore and spar occurrences have been mined during centuries. However, an amount of more than 500 kt of proved reserves of tin and several million tonnes of fluorspar and barite remained in place. No comparative economic assessment of these occurrences has been carried out during the past 20 years. Expecting a prolonged rise of tin and fluorspar prices and the consumption of the former countries which covered the demand with economical raw materials, there is a high interest for countries owning the resources, such as Germany, to use them. The idea of an assessment with overview character originated from Beak Consultants GmbH that participated in cooperation with three other companies at a new interpretation of German Democratic Republic (GDR) exploration data. In the present study, ore and spar occurrences are compared for their potential mining and processing costs.

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The geological conditions of the occurrences have been considered in a simplified way. The obtained costs must be interpreted with respect to the specific exploration degree of each occurrence.

Overview of the resources under investigation

Tin resources

Figure 1 shows the location of explored tin occurrences in Saxony. The tonnages of the resources are indicated in Figure 2 according to resource classes.

largest presently known tin reserve of Saxony. It is related to an intrusion breccia and extends to more than 1000 m depth.

The occurrence of Seiffen is of similar genetic origin but has not yet been proven to extend to similar depths. The greisen deposit of Altenberg, which produced the main part of tin ore required by the industry of the GDR, yields the largest C_1 reserves. However, the main portion of the reserve is situated in depths of less than 200 m below the town of Altenberg. These parts of the deposit are considered not extractable.

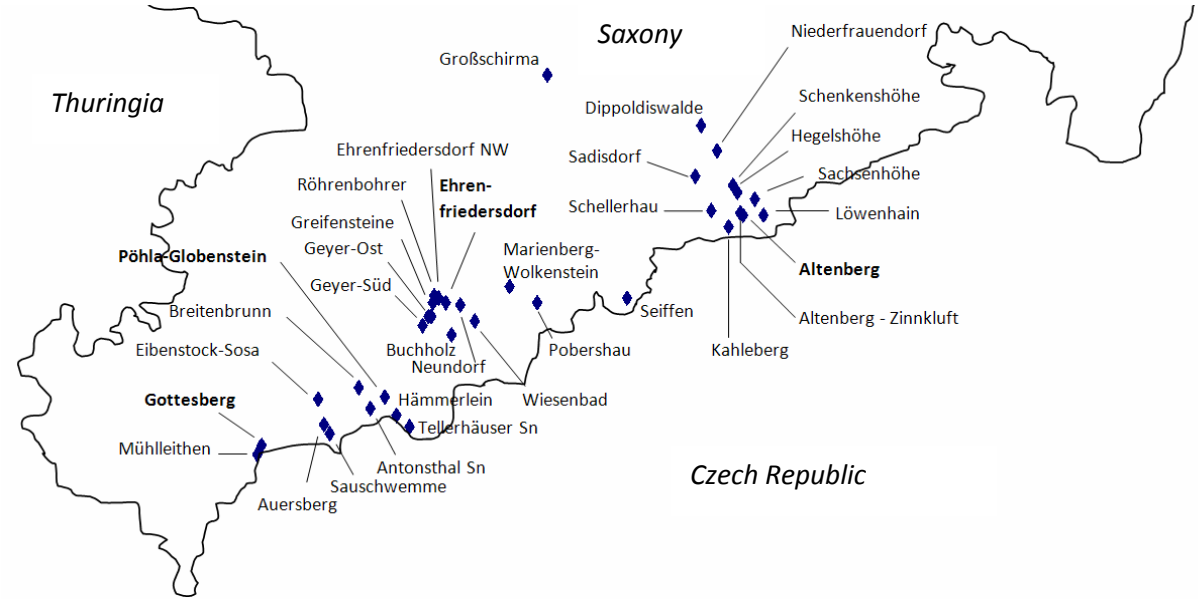

Figure 1: Location of tin deposits and occurrences in Saxony

Most of the original documents use the "A-B-C" nomenclature which is also used in this work. The tonnages indicated in Figure 2 are covered by various exploration degrees and yield various degrees of potential further discoveries. Examples of "low potential" deposits are most of the vein fields of the Ehrenfriedersdorf and Geyer mining districts. As illustrated in Figure 3, for the pneumatolytic vein field "Röhrenbohrer" containing about 10,000 t Sn in C_2 reserves, the zone of intrusion-related brittle deformation is limited in depth. Thus, a prolongation of cassiterite bearing veins in deeper parts of the subjacent granite is little probable.

Other occurrences yield higher potential, e.g. with 120,000 t Sn, the greisen ores of Gottesberg yield the

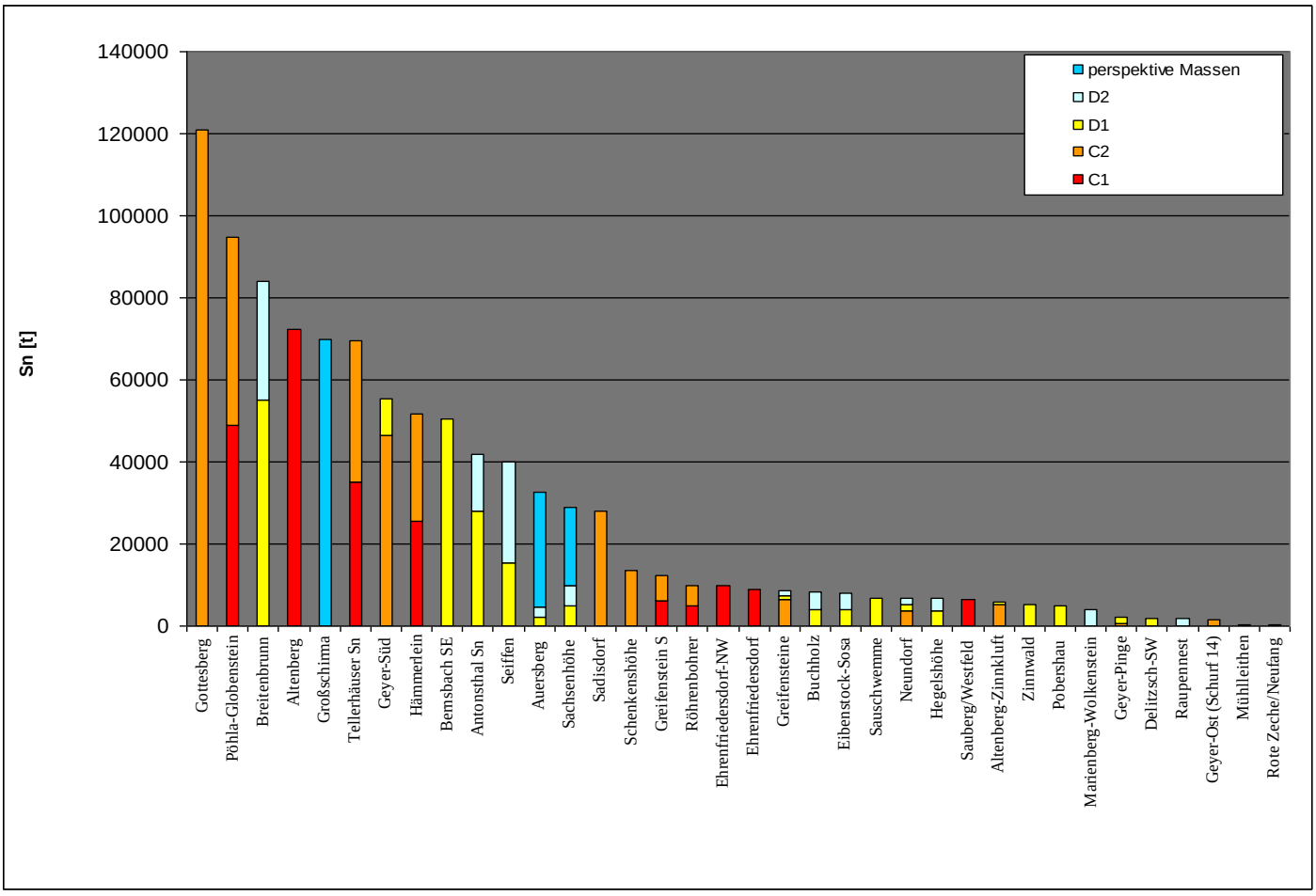

Figure 2: Tonnages of tin contained in the occurrences according to exploration degree (C1 – indicated resources, C2 – inferred resources, D1 and D2 – prognostic resources; the term "perspektive Massen" or "pM" refers to a resource class of lower certainty than D_2)

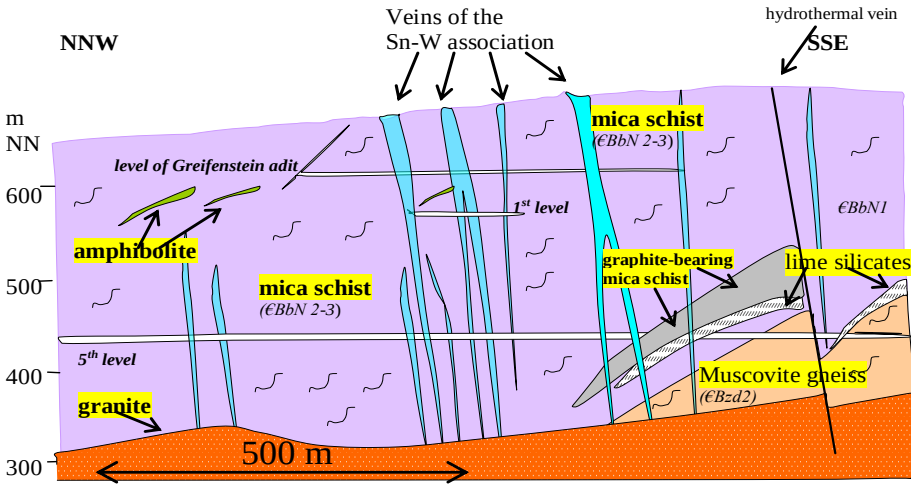

Figure 3: Section of the Röhrenbohrer occurrence, Ehrenfriedersdorf district

Fluorspar resources

Since all barite ores explored in spar occurrences of Saxony contain hematite or other impurities, they cannot be used as colour spar. Barite can thus be considered as by-product of fluorspar, used for the chemical industry, as load or heavy suspension for hydrocarbon production. The location of fluorspar and barite deposits is shown in Figure 4. Differently to tin, the major part of the Saxonian occurrences of the two industrial minerals ranges only among prognostic resource classes. Entirely related to hydrothermal veins, the occurrences are difficult to forecast in their average widths and maximum depths if no drillhole data exist. Figure 5 shows only the fluorspar reserves.

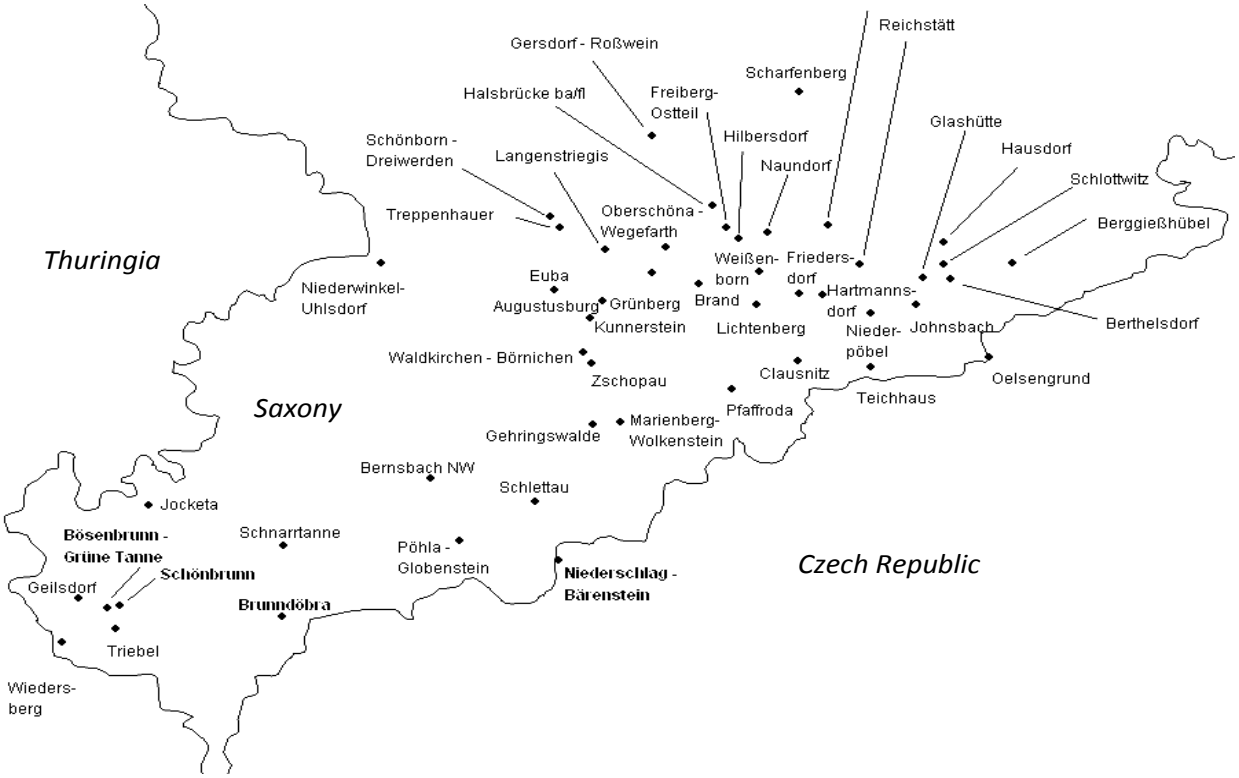

Figure 4: Location of fluorspar and barite deposits and occurrences in Saxony

Most of the fluorspar produced in the last decades of the GDR was mined from the adjacent deposits of Schönbrunn and Bösenbrunn in SW Saxony, which are comparatively well explored. Detailed exploration was carried out also for the vein deposit of Niederschlag where the SDAG WISMUT mined uranium in the 1950s. Differently to Schönbrunn, fluorspar and barite extraction did not commence at the deposit of Niederschlag to date. Since the occurrences are related to narrow veins, the specific mining costs are higher for fluorspar and barite than for example for tin greisens of high volume. Processing costs, in contrast, are lower i.e. not only the energy consumption entailed by the milling of fluorspar is less than for tin ore, but also the flotation of spar requires less expensive chemicals than cassiterite flotation.

Methods of Calculation

Mining for metal ores in Germany ceased in 1991, thus, the range of regional cost references is limited. The costs of hypothetical mines are determined after examples from abroad and handbook formulas.

Considering deposit size, mineral concentration, shape, and depth of the ore bodies as well as information about historical mining activities, a mining method is chosen and mining costs are calculated. In particular, capital costs, i.e. pre-production investments, and operating costs are distinguished. The approach is briefly illustrated in Figure 6.

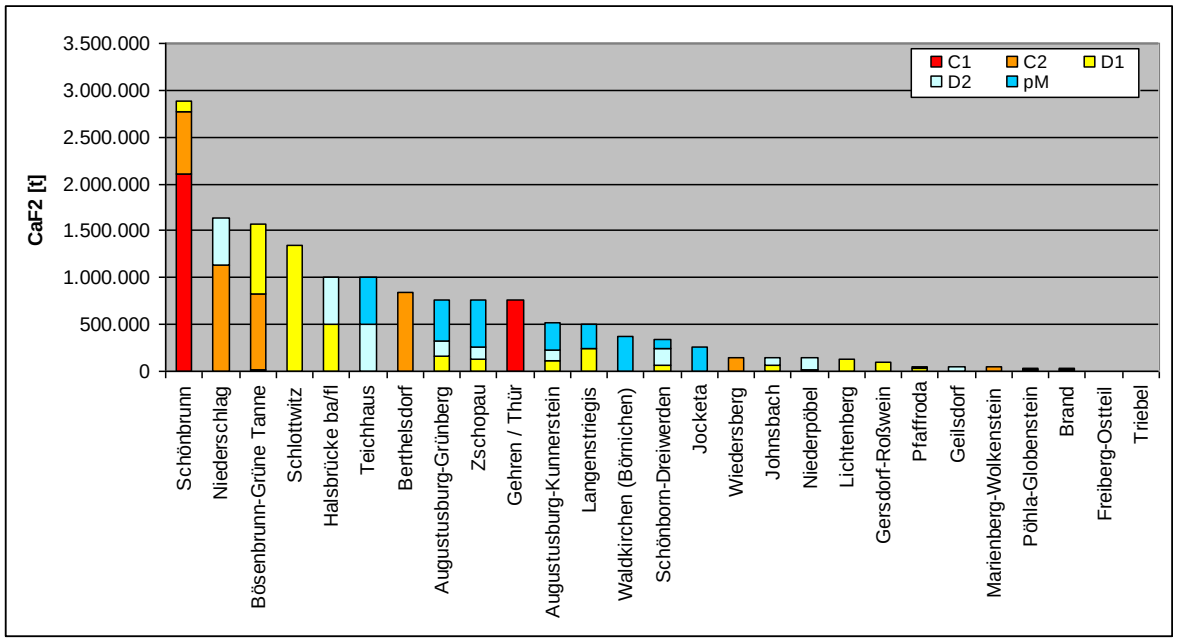

Figure 5: CaF_2 amounts of the main fluorspar occurrences in Saxony according to exploration degree. Resource classes are classified as in Figure 2. Several occurrences contain also barite, as indicated in Figure 9

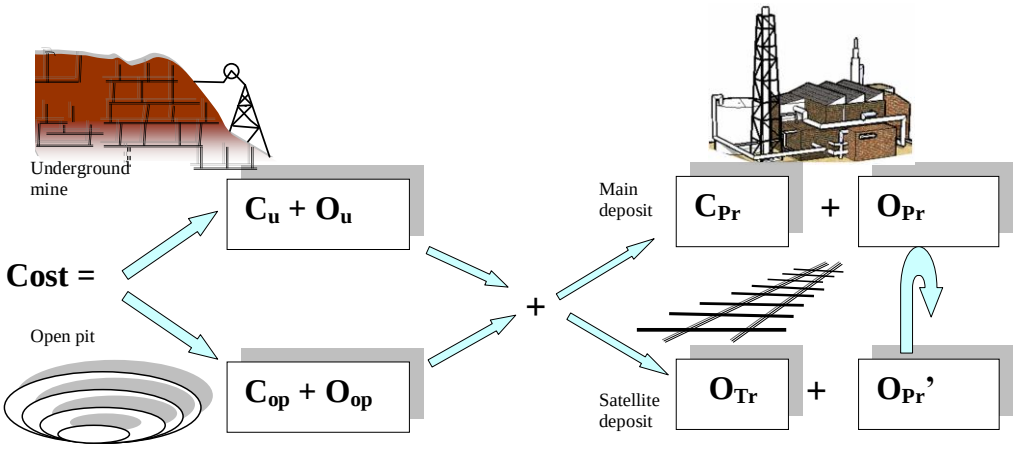

Figure 6: Calculation scheme applied for the determination of direct costs of the potential mines. Capital letters*: C = capital costs, O = operating costs;* indices*: $_u$ = underground; $_{op}$ = open pit; $_{Pr}$ = processing; $_{Tr}$ = transport*

Assuming a situation in which several tin mines operate simultaneously, own processing plants are suggested for mines extracting large deposits. These plants may additionally treat ore delivered by smaller mines from closer or further distance. Capital costs C_{pr} and operating costs O_{Pr} of the plants are shared between the mines in proportion of the ore quantities they produce. Transport costs (O_{Tr}) are assigned to the mines in function of their distance to the plant.

For the tin mining districts of Ehrenfriedersdorf and Pöhla-Globenstein consisting of various subfields, central processing plants are suggested.

Three calculation variants for the forecasting of mining costs are applied: A "global cost", variant 1, is based on analogies mainly to North American mines. Variant 2 sums a variety of particular cost items of hypothetic mines, the sizes and lifetimes of which are determined by simplified geological parameters.

In variant 3, the total operating costs are established as a function of the labour required for mines and processing plants.

The capital and operating costs employed for variant 1 are composed as follows:

Capital costs (investments)

- The capital costs of the mine are determined incorporating size and depth of the deposit ore occurrence.
- The capital costs of the processing plant are determined after the cost guide of the SME Mining-Engineering Handbook

Additional capital costs that are not assignable to mine and mill make up 15 % of the capital costs.

Operating costs:

- The operating costs of the mine are assigned to five categories referring to block caving (9 €/t), sublevel caving (12 €/t), sublevel stoping with backfill (~ 21 €/t), room and pillar (20 €/t), overhand and shrinkage (30 €/t) and cut and fill stoping (44 €/t ore). Backfill as optional component was calculated with 5 €/t.
- The operating costs of the beneficiation plant are determined after three ore types (vein 5.50 €/t, greisen 11.00 €/t and skarn 16 €/t ore) and combinations/ore mixtures in between.

The formulas employed for the cost items considered in variant 2 and the labour costs as a base of variant 3 are determined according to the SME Mining Engineering Handbook. Former mines were considered reusable for the development of future mines in a few cases. In the mines of Schönbrunn and Brunndöbra, ramps for trackless transport were drifted in the 1980s that are probably reusable. The inclusion of elements of former mines was expressed by reduction factors around one third of the development costs (variant 1) or by leaving out the according items (variant 2).

Results

Considering present tin prices, the extraction of the metal in Saxony with costs of more than 15,000 €/t in concentrate is not economic.

The average mining costs of the three calculation variants for tin occurrences are reported in Figure 7. The deposits of Altenberg and Gottesberg are the most perspective with average mining costs of 22,400 and 18,200 €/t Sn in concentrate. Lower costs are assigned to the skarn deposits of Tellerhäuser (15,000 €/t Sn) and Pöhla-Globenstein as well as to the "felsite horizon" of Großschirma with ca. 17,000 €/t Sn due to their comparatively high tin concentrations. However, cassiterite in skarns ore occurs disseminated and partly enclosed in the rock forming minerals. Thus, the costs obtained for skarn beneficiation cannot be compared to those for vein and greisen ores, even if the costs were varied according to the ore type as mentioned under "operating costs". The assumed recovery rate of 55-65 % has not been reached in practice to date.

Generally, smaller deposits yield higher costs due to higher percentages of investments for development, infrastructure and beneficiation. As an example, the deposit of Altenberg yields the largest reserve explored with degree C_1. However, only parts of the remaining reserve can be mined without menace to the town. Thus, three theoretical options are proposed for the deposit referring to distinct mining priorities: Option 1 suggests mining of the entire deposit by caving methods (See Figure 7). According to option 2, only a quarter of the reserve is mined, in order to protect houses and infrastructure, whereas option 3 refers to extraction of the entire deposit by selective mining methods with backfill.

Option 2 is considered the only realistic, whereas the mineable proportion is to be determined examined in more detail. For the deposit of Gottesberg, option 1 refers to the mining of the entire deposit by sublevel stoping. Option 2 previews an open pit extracting the superiour 25% of the cylindrical ore bodies, with change to underground mining afterwards (See Figure 8).

Besides Gottesberg, open pit mines where suggested only for Geyer Süd, Großschirma, the tourmaline deposit of Auersberg with tin as by-product and for the tributary deposit of Altenberg-Zinnkluft. In the most cases, property rights, houses, roads and natural protection areas are assumed as obstacles for open pit mining even if the specific costs as a rule are much lower than for underground mines.

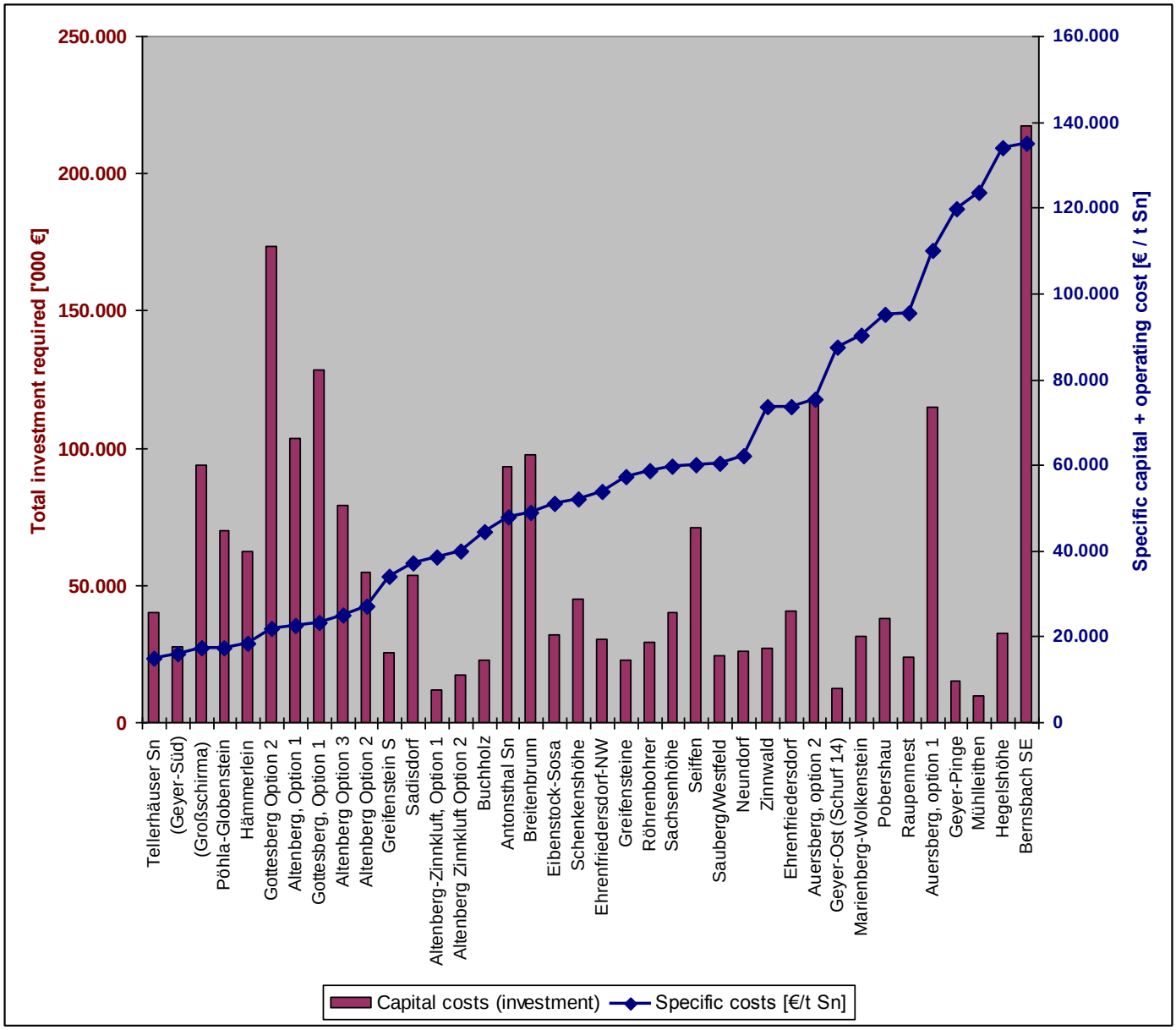

Figure 7: Tin bearing deposits and occurrences sorted after specific costs [fin.-math. average costs, €/t Sn in concentrate] (line). Columns mark the investments necessary to prepare and develop the mine and construct the processing plant. The costs of objects shared between several occurrences are assigned to them in proportion to their production rate

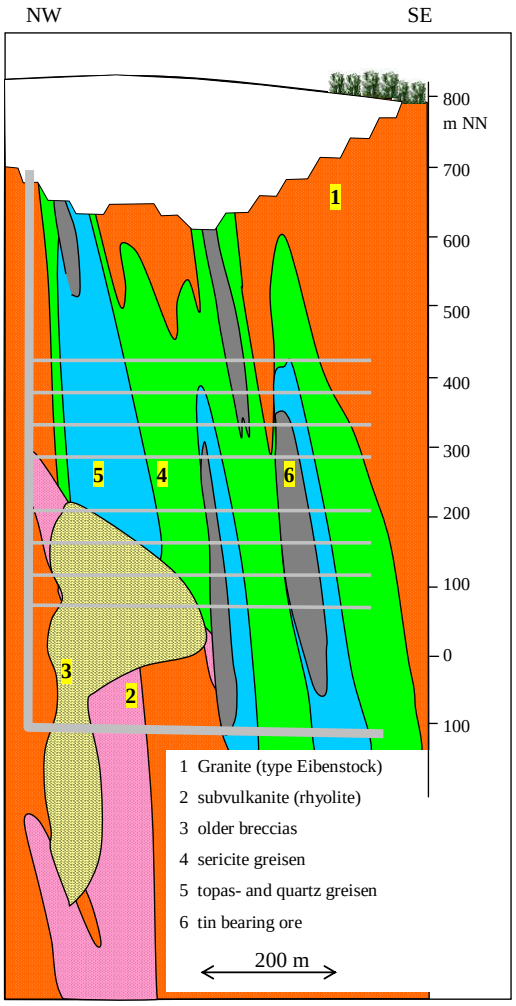

Figure 8: Section of the central part of the Gottesberg tin deposit and proposed extraction by open pit and sublevel stoping according to option 2

The price of Chinese refined fluorspar presently amounts to around 500 €/t. Even if the assumed beneficiation costs do not account the last refining steps, the costs for fluorspar extracted from the deposits of Schönbrunn / Bösenbrunn and Niederschlag range far below the present fluorspar price. Thus, fluorspar mining has the potential to be economically profitable. Barite from the mine of Brunndöbra can be extracted to static costs of below 100 €. However, the price for barite that cannot be used as colour spar does not cover the expenses. For the numerous "ba/fl" mixed ores, as shown in Figure 9, the costs refer to the tonne of minerals assuming that both fluorspar and barite can be sold at the market.

Conclusion and Outlook

Considering present tin prices of around 10.000 €/t Sn, the extraction of the metal in Saxony can only be economic, if by-products can be extracted by the same processing procedure. The extraction of barite from the partly reuseable mine of Brunndöbra requires 126 €/t $BaSO_4$. Calculations for fluorspar mining from the deposits of Schönbrunn and Bösenbrunn yield average costs of 159 €/t CaF_2. Thus, the extraction of the industrial mineral fluorspar seems economically feasible.

Benefits of ore and spar mining in Saxony are undoubtedly related to an increase of employment. Even if the numbers of staff of modern mines range far below those of GDR times, the mechanization degree especially for narrow vein deposits is limited due to their tectonical disruption and limited size. Thus, a significant proportion of manual work will be required by all mining operations. Since the history of the Erzgebirge region is closely related to mining, a positive disposition of the population towards mining activities can be assumed.

The determination of recoverable by-products of tin production (e.g. tungsten and molybdenum), and of fluorspar (e.g. copper in sulphides) is topic for future investigation. The duration of a modern mining period is difficult to forecast: only in some cases (Gottesberg, Schönbrunn), the calculated lifetimes of particular deposits reach a human generation. On the other hand, not all perspective deposits will be mined simultaneously and the potential of increasing reserves due to new exploration exists.

Due to the simplification of geological influences and the number of bodies examined, the absolute values of the given costs probably deviate significantly from reality. Thus, the results have overview character and could be used as indication for occurrences where detailed studies on an engineering level are recommended.

A representative overview over the tin and spar resources related to the formation of the Erzgebirge / Krušné hory requires geographical enlargement of the area under consideration.

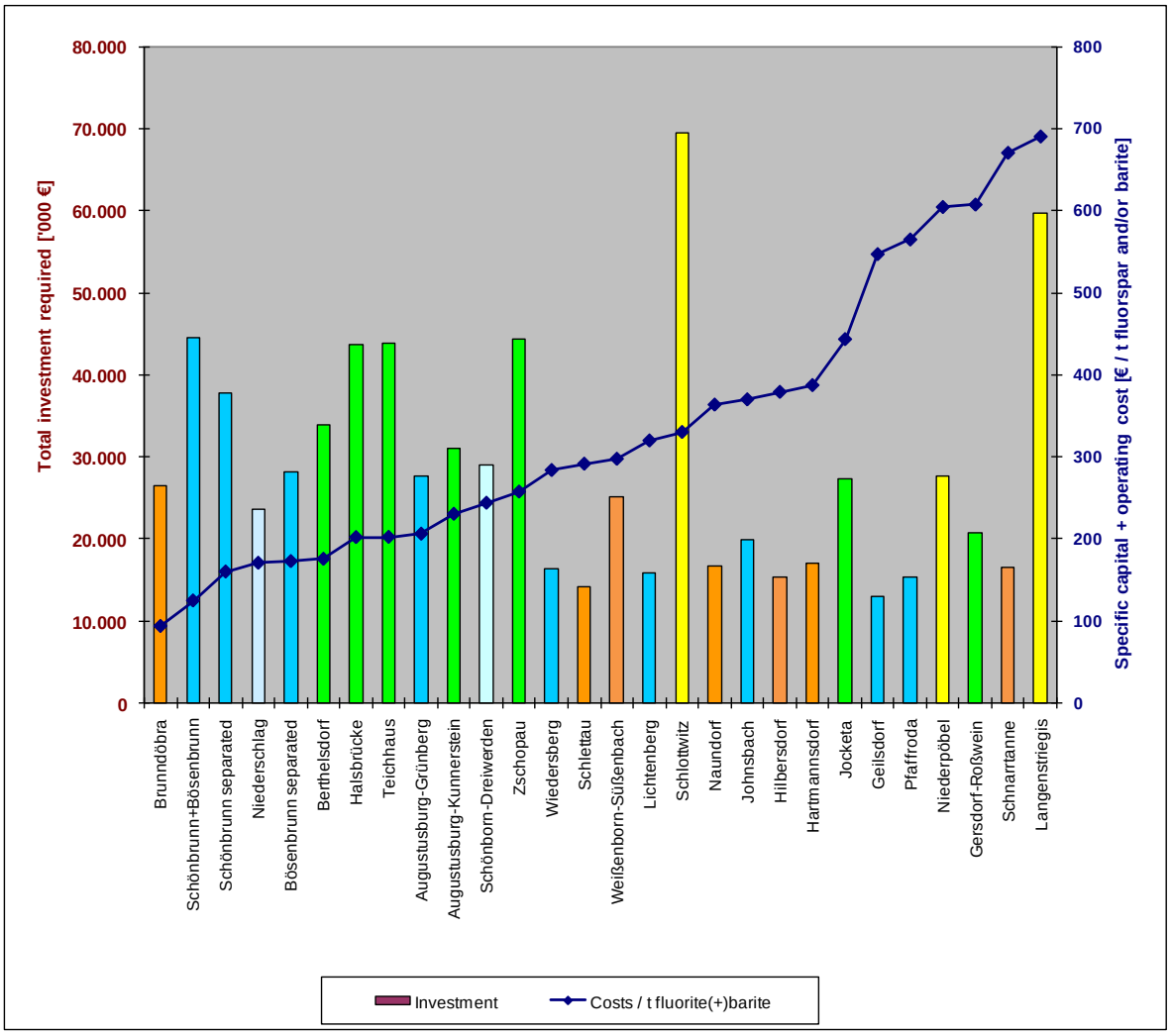

Figure 9: Fluorspar and barite deposits and occurrences sorted after specific costs [statical costs, €/t barite or fluorite] (line). Columns mark the investments necessary to prepare and develop the mine and to construct a processing plant

First, one third of the amount of tin mined to date originates from the Czech territory of the Erzgebirge. Several large deposits extend to both sides of the border. Especially for the construction of processing plants and infrastructure, scale effects may determine the decision for a mining project. Second, the example of the sulphide occurrence of Delitzsch north of the city of Leipzig demonstrates that ore and spar exploration can be successfully extended to basement rocks of the prolongation of the Erzgebirge covered by Tertiary and Quaternary sediments.Taking into consideration the changes of metal and spar prices and supply conditions, the protection of presently uneconomic occurrences against soil sealing and avoidable surface use is a major task in order to assure the access to these resources in the future.

References

O'Hara, A.T. & Suboleski, S.C. (1993). Costs and Cost Estimation. In Society for Mining Metallurgy & Exploration (Ed.), *SME Mining engineering handbook.*

Geokompetenzzentrum Freiberg e.V. (2006) Neubewertung von Spat- und Erzvorkommen im Freistaat Sachsen, report and database.

Hruschka, F. (1993). Grenzgehalte – Pro und Contra. *Scientific publications* Vol. 2, Department of Mining Engineering and Mineral Economics, Montan-University Leoben.

Wellmer F.-W., Dalheimer, M. & Wagner M. (2008) *Economic Evaluations in Exploration* (2nd Ed.), Springer.

Mining monographs of the SLfUG (1998 – 2007) for the occurrences of Altenberg Ehrenfriedersdorf, Geyer, Pöhla-Globenstein, Niederschlag, Schönbrunn / Bösenbrunn / Wiedersberg, Brunndöbra / Schnarrtanne