UNITED
NATIONS

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Economic and Social Council

Distr.
GENERAL

ENERGY/1999/8/Add.6
8 October 1999

ENGLISH ONLY

ECONOMIC COMMISSION FOR EUROPE

COMMITTEE ON SUSTAINABLE ENERGY
Ninth session, 9-11 November 1999
Item 4(a) of the provisional agenda

PRACTICAL APPLICATION OF THE UNITED NATIONS FRAMEWORK CLASSIFICATION FOR RESERVES/RESOURCES

Calculation of dimension stone: The Kinama migmatite deposit, Minas Gerais, Brazil

(Submitted by the German Association for Mining, Metallurgy, Natural Resources and Environmentally-sound Technologies (GDMB)) */

SUMMARY

A newly developed procedure to calculate reserve/resource figures of dimension stone deposits based on geological research and mining records is presented in detail using the Kinawa migmatite deposit, Minas Gerais, Brazil as an example.

In addition to the general and specific problems of defining reserves/resources and grade categories of dimension stone deposits, the principal geological and mining problems related to marketing and sales criteria are outlined.

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GE.99-32871

For the assessment and documentation of reserve/resource figures, the UN Framework Classification was applied and the results are discussed.

I. INTRODUCTION

The application of reserve/resource categories in the mining sector of industrial rocks is occasionally problematic due to some special characteristics and economics of such commodities. This applies especially to the dimension stone sector. Historically the extraction of raw blocks of siliceous and calcareous composition for use in industry (building and construction as well as monumental) is typically linked with small scale mining, generally without geological investigations or technical/mine-economic studies (exploration mining).

One of the major problems in assessing reserves/resources in the dimension stone sector in relation to market economic criteria is the determination of the grade or the yield of such deposits. The In-situ-raw block content of a dimension stone deposit cannot be measured applying the conventional analytical methods as for example for metal ore mining or for certain industrial minerals.

Since approximately five years - parallel with the operational task - detailed and comprehensive research regarding the geology, mining technology, grade, recovery as well as the assessment of the reserve/resources inventory of dimension stone is in progress and carried out by Deutsche Steinindustrie AG and its subsidiary companies in South Africa, Namibia, Zimbabwe, Angola, Brazil, USA, Norway, Sweden as well as exploration projects in India, China, Mongolia and Nigeria.

Parallel with deposit related research, a detailed market research regarding quality and customer/processor requirements was carried out. These results, important for the raw block evaluation (economics) were summarised in an In-house-Quality Standard.

The first results are published in Nelles and Diehl (1995), Nelles (1996) and Diehl et al. (1996). Other attempts to define reserves/resources of dimension stone deposits were made by Singewald (1992).

II. RESERVES/RESOURCES CALCULATION, DEPOSIT PARAMETER AND DEFINITIONS

With the introduction of modern mining technologies and systematic investigations on natural stone deposits of different types and shapes throughout the world it became necessary to introduce and subsequently adjust and re-formulate the conventional mining terminology to meet the needs of the dimension stone mining industry. Consequently, intensive geological studies were necessary with parallel mining-technological investigations as well as the establishment of proper mining-record data bases. With the help of these records collected from operating mines and exploration projects, it is now possible to present a new method of calculating the reserves/resources of dimension stone deposits. With the exception of some commodity specific alterations the calculation is based on conventional reserves/resources calculation methods. In the following, geological and mining reserves/resources are distinguished (see Figure 1).

One of the major differences to conventional mining is the fact that it is not possible for dimension stone to determine the grade of a deposit by means of analytical laboratory methods, as for example applied to metal ore deposit or certain industrial minerals. Consequently, the geological estimate of the percentage of the raw block content of a deposit (B_{geol}) needs to incorporate economic market criteria (first/export grade) for the raw block.

These criteria for export quality blocks are described in detail and are standardised for the different types of deposits and rock-types [Nelles and Diehl (1995), Nelles (1996) and Diehl et al. and are summarized in Figure 2. Geological parameters influencing the estimated raw block content are summarised in Figure 3.

Appropriate exploration methods can contribute to estimating the geological In-situ-raw block inventory (B_{geol}) as closely as possible. Methods applied are: diamond core drilling, detailed geological mapping of surfaces and mine benches and levels, panel wall mapping as well as increasingly geophysical methods: e.g. areomagnetics and deep penetrating radar.

The results of the research programme are very encouraging and AgradeA distribution plans of dimension stone deposits could be produced. These maps, together with mining records allow giving geologically estimated production forecast figures at a very high level of confidence. In the following the Kinawa migmatite deposit, Minas Gerais, Brazil is used to demonstrate the various and complex geological, technical and economic facts and the way to incorporate them into the proposed reserve/resource calculation procedure.

III. MINING RESERVES OF THE KINAWA MIGMATITE DEPOSIT, MINAS GERAIS, BRAZIL

(a) Locality

One of the major dimension stone mining areas in Brazil is located in the southeastern region of the state of Minas Gerais southwest of the Quadrilátero Ferrífero geographically defined by the towns of Divinópolis, Oliveira, Campo Belo and Formiga.

The Kinawa migmatite deposit - owned by Fontex Importadora e Exportadora Ltda. of which Deutsche Steinindustrie AG (DESTAG) holds 50 % of the shares - consists of two dome-shaped massifs flanked by boulder occurrences.

Historically, extraction of raw blocks for export to European markets was restricted to the so-called loose formation of mega-boulders. Systematic exploration and mining of the solid formation was started in 1992/93 with the development of the Kinawa IV bench and level quarry.

(b) Regional Geology

Geologically, the Kinawa migmatite belongs to the Archean basement rocks of the São Francisco Craton that is bound by mobile belts and sedimentary basins of different ages. These basement rocks were overprinted by multiple deformation and metamorphism until the stabilisation of the craton.

The earliest event is the generation of the source rock for the Kinawa migmatite. This source rock was then folded, boudinaged with stretching and thinning of the original layers and intruded by dike rocks of mafic composition. Advanced metamorphism, segregational processes and partial melting including the decomposition of most of the mafic dike rocks gave rise to a distinct foliation fabric. At a later stage, the rock was affected by shearing accompanied by a second generation of partial melts along the shear planes. Due to cooling and up-lifting of the migmatite, brittle deformation caused the generation of fractures and joints. At the current level of exposure the rock has reacted on the decompression stress by the formation of unloading fractures parallel to the topography.

(c) Deposit Characteristics, Geology and Mining

The geological work carried out for the Kinawa IV deposit is documented in a feasibility study (detailed geological study + proven saleability) including: Detailed geological mapping at scales 1:500 and 1:200, panel wall (bench and levels) mapping at scale 1:100, technical description of geological/mineralogical features, diamond core drilling, the modelling of the size and shape of the mineable >granite= body, grade distribution maps and the presentation and evaluation of the reserve/resource inventory.

Quality control and standardisation of the produced raw blocks was one of the key criteria for the market economic evaluation of the raw product. To standardise a nebulitic migmatite with a wide range of colours, structures, textures including natural defects - lowering the recoverable rock volume for a stone processor - hand specimens were collected and evaluated regarding colour and mineralogy. It was found that the colour of the migmatite can be described by the ratio of pink, white and black. Thus, the colour can be depicted in a colour triangular diagram of which each corner represents the predominance of one of the three colours. A division into seven colour fields proved to be practical.

In contrast, the structure and the texture of the Kinawa migmatite was analysed using raw block surfaces as well as bench and level exposures. Four structure-types occur within the deposit and are classified as: Foliated, Folded, Granitic and Patchy.

Regarding the natural defects of the rock, mechanical and aesthetic blemishes are distinguished. Mechanical defects are geological features such as joints, fractures and cracks which negatively influence the physical properties of the rock and consequently the slab/tile recovery out of a raw block. Aesthetic blemishes are mineralogical inhomogeneities such as colour variations, veins, schlieren, patches and enclaves that disturb the overall characteristic view of the rock which allows immediate identification (e.g. Kinawa Classico). The evaluation of such features as an aesthetic blemish may vary from customer to customer, however, is strongly dependent on the final use of the product, e.g. tombstone versus building and construction.

The detailed mapping of benches and levels exposed during mining (panel wall mapping) is carried out at a scale of 1:100 and focuses on the application of the described standard with the documentation of all geological features lowering the production volume of export grade raw blocks. In addition, the panel wall mapping results act as geological records to update the geological level plans and to improve the geological understanding of the deposit.

The results of the detailed mapping activities are presented in Figure 4 showing a generalised geological map of the Kinawa IV quarry.

Panel wall mapping is an important tool to forecast production figures from primary blocks and the results are incorporated into the grade distribution plan.

Where no sufficient information can be collected from surface geology, diamond core drilling is carried out. The boreholes are drilled both vertically and horizontally between 15 and 25 m in length. Due to the steep dip of the deformation fabric, the maximum core information is obtained from horizontal drilling results. The results are collected including the reference of the position within the deposit and kept on data base for the compilation of mining records.

Mine Layout

The mining method at Kinawa is characterised by level and bench mining, ramp access to every level, primary cutting with diamond wire saws (vertical and horizontal), and secondary drilling. The primary cuts form a saw tooth pattern (angle of 45 degrees always present). As a result of this approach various workable faces have been opened. The mining direction and direction of extraction form an angle of 90 degrees to each other (Figure 5). Two main criteria are applied to determine the extraction sequence of the primary blocks. The first depends on the optimum blending of primary blocks to reach the budgeted production without high-grading the deposit. The second criteria depends on how to accomplish a smooth sequencing of activities. The overall removal rate has been established at 1000 m;/month. At least 3 primary blocks are mined per month with primary block dimensions theoretically of 9.0 m x 9.0 m x 3.8 m - 6 m (length x width x height). The volume of one primary block is regarded as the smallest reserve block. The total volume of mineable rock body V_t is calculated by adding the volumes corresponding to each planned primary block. A plan view of the Kinawa 4 quarry with its basic layout characteristics is shown in Figure 5. Details are given in Junge (1996).

(d) <u>Distribution of Grades</u>

From the very beginning of the mining activities at Kinawa IV the actual mined raw block volume of first/export grade has been recorded, based on individual primary blocks. For each primary block the actual mined raw block volume is calculated as the percentage of the total volume of such a primary block (9 m x 9 m x 6 m). Hence, the percentage of recovered raw blocks from a primary cut (B_m), is a reflection of in-situ grade or yield of such a mining unit (B_{geol}).

At Kinawa IV the grade of the individual primary blocks units mined ranges from 0 vol.-% to up to 60 vol.-%. Figure 6 illustrates the grade distribution based on mining records from 88 primary blocks located throughout the deposit and on different levels.

Five grade categories or classes are distinguished:

very high (B_m)	45 vol.-% - maximum
high (B_m)	30 - 44 vol.-%
medium (B_m)	20 - 29 vol.-%
low (B_m)	10 - 19 vol.-%
very low (B_m)	0 - 9 vol.-%

The achieved production percentage of the mining units were plotted on level plans and the different production areas are delineated (see Figure 7).

These production (grade) distribution plans are important for forecasting the production (B_m) for the underlying levels and finally for calculating the reserve/resource inventory.

Projecting all available production data onto one single plan (see Figure 7) reveals that the migmatite body is composed of a high production/grade central zone which is bordered by low-grade zones. These plans are regularly used for sequencing of primary blocks especially as blending is necessary for production planning.

(e) Reserve/Resource Calculation and Assessment

The reserve/resource figures presented in the following for the various categories were calculated using the formula $R_m = V_t$ _ B_m (see Figure 1) and are regarded as extractable mining reserve of the Kinawa deposit.

For the presentation of the results, the UN Framework Classification matrix was applied which provides information about

A. the degree of economic viability
B. the stage of mineability assessment and
C. the stage of geological assessment

given in code (ABC).

The codified classes presented are based on the following criteria.

1 = Economic
1 = Feasibility Study + Mining Report
1 = Detailed Exploration
2 = Potentially Economic
2 = Prefeasibility Study
2 = General Exploration
3 = Intrinsically Economic
3 = Geological Study
3 = Prospecting

Definitions of these terms and the application procedure is given in document ENERGY/WP.1/R. 70 (1997).

The calculation of the reserve/resource figures is based on the grade distribution maps and the actual raw block yield documented in mining reports as shown in Figure 7.

Figure 8 illustrates the procedure of calculation the proved mineral reserves for Kinawa IV in detail.

According to the procedure and definition above, the Total Mineral Resources of the Kinawa migmatite deposit were calculated and assessed using the UN Framework Classification matrix as shown in Figs. 9 and 10.

IV. DISCUSSION AND CONCLUSION

The method presented in this paper for the calculation of reserves/resources in the dimension stone sector has proved to provide accurate results and is successfully applied for financial budgeting and production forecast purposes. However, it also shows that the UN Framework Classification can be directly applied to assess dimensional stone deposits and reserves/resources.

One of the major results of this study - especially as the complexity of these deposits is commonly underestimated - is the fact that the mining and evaluation of dimension stone deposits requires detailed exploration and test quarrying.

Reliable reserve figures, especially proved reserves, can only be presented at an advanced stage of a dimension stone project at which a mineability assessment can be carried out.

Acknowledgement

The authors are indebted to Deutsche Steinindustrie AG and Fontex Importadora e Exportadora Ltda. for giving permission to publish these results.

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