The dimension stone sector: new perspectives on the global market and on the reporting of international mining standards

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Dimension Stone, as also described in the new draft PERC Standard, is a technical/commercial term that includes all natural stones that can be quarried in blocks of different dimensions, are processed by cutting or splitting, and that possess specific technical and aesthetic properties that drive their demand in the building and construction industries.

Dimension stones are distinct, in both mining methods and their end uses, from all other materials derived from natural rock, such as aggregates and granulates, cement materials, crushed stone, or industrial minerals. While aggregates, cement raw materials and crushed stones are almost exclusively used in load-bearing, filling and structural functions in building and construction, and industrial minerals are utilised for multiple purposes in many industries (ceramics, glass, pharmaceuticals, paper, etc.), Dimension Stone materials offer special qualitative features which mean they can perform both structural and decorative architectural functions in building and construction as well as in internal decoration and landscaping projects.

Commercially, dimension stones are generally divided into three categories for business transactions: marbles, granites and stones.

Marbles

Marbles include all materials that can be quarried and processed using the techniques, equipment and tools that are typically utilised for marble, in the strict geological sense. This category therefore also includes several other rock types, such as limestones, serpentinites and other subgroups like travertines and onyx, which are not geologically classed as marble. This is despite the fact that the international market currently distinguishes the term marble (crystalline marble) from materials such as limestones, as is evident from the discrepancies in their respective demands and prices.

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Granites

This term embraces a wide range of rocks of intrusive, volcanic and metamorphic origin that can be quarried and processed using the techniques, equipment and tools generally utilised for granite in the strict geological sense. This commercial group includes granites, granodiorites, diorites,

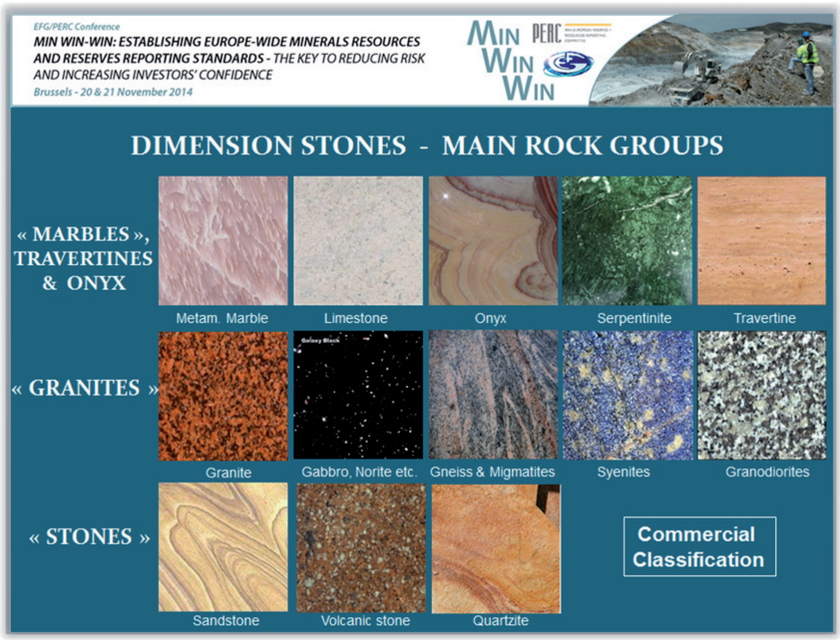

Figure 1: Dimension stones: commercial classification groups.

Figure 2: a. Typical quarrying methods for building stones - b. Building stones in small blocks - c. Building stones as final products (in this case, for cladding).

Figure 3: a. Naturally cleft stone (quartzite) slab - b. Ignimbrite cubes used for paving in the 'porfido' style - c. Quartzite paving slabs laid in style known colloquially as 'crazy paving'.

norites and gabbros (black 'granites'), labradorites, gneisses, migmatites and syenites.

Stones

This term mainly refers to rocks with technical features that differentiate them in overall terms from those of the two previous groups. In general, a 'stone' cannot be polished; it sometimes cannot be quarried in large blocks and it may not always have exclusively decorative functions. It might also be used in functions such as urban landscaping projects (private and public), although also granites (e.g. granite cubes) can be used for that. Examples of stones include volcanic porphyry lava or ignimbrite (see Italian "porfido"), some sandstones, slates, some quartzites, some schists, tuffs, lavas, basalt and dolerite, and in general all the naturally cleft stones (as defined below).

The dimension stones (DS) belongs to a wider group of natural stone materials which includes several other groups with different features and applications. The other categories of natural stone are building stones, naturally cleft stones, ornamental and decorative stones and construction stone materials.

Building stones

Building stones are stone products generally sourced from raw stone materials that can be extracted in artisanal or semi-artisanal ways and utilised for building and other construction purposes (walls, housing, cladding, gardening, etc.). They can also be produced by processing the stone waste of other production lines.

Naturally cleft stones

Naturally cleft stones are hard and resistant stones that undergo natural splitting due to structural layering, schistosity or regular jointing (e.g. quartzite, slate, limestone) and that are typically used for paving in both exterior and interior environments (roads, squares, houses, gardens). Like building stones, these can be quarried and processed by hand and by simple mechanical equipment. The stone paving cubes produced by mechanical splitting guillotines belong to this group.

Ornamental and decorative stones

Any coloured or attractive stone that can be worked to produce small decorative elements for internal decoration can be classified as an ornamental or decorative Stone, for example coloured tuff, ignimbrite, sandstone and limestone. Some examples of ornamental stones can also be defined as part of the DS production group, such as cut-to-size architectural decorative products like columns and fireplaces.

Construction stone materials

Construction stone materials, including the materials used for cement, are mainly made up of aggregate and sand but are important to consider as part of the overall natural stone value chain, because these materials are generally derived from processing the waste of other natural stone types, including DS.

Valuation methodologies in the dimension stones sub-sector

The dimension stones mining sub-sector is very particular, with its own rules, features and driving factors. Consequently, the valuation of DS projects needs to be approached and evaluated using sector-specific methodologies and tools, different from those used in other sectors. Resource-reserve calculations of DS projects should also be made considering slightly different factors to those typically considered for general mining projects.

In general most Dimension Stone projects cannot be evaluated and valuated like all other mining projects…..they are totally different. This is the reason why a specific paragraph for dimension stones is proposed in the PERC Standard, a first for an international set of standards.

In a DS mining project, the mineral ore body is not a mineral assemblage contained within the rock mass (country rock). Instead, it is the rock mass itself! To evaluate and measure this material, it is not

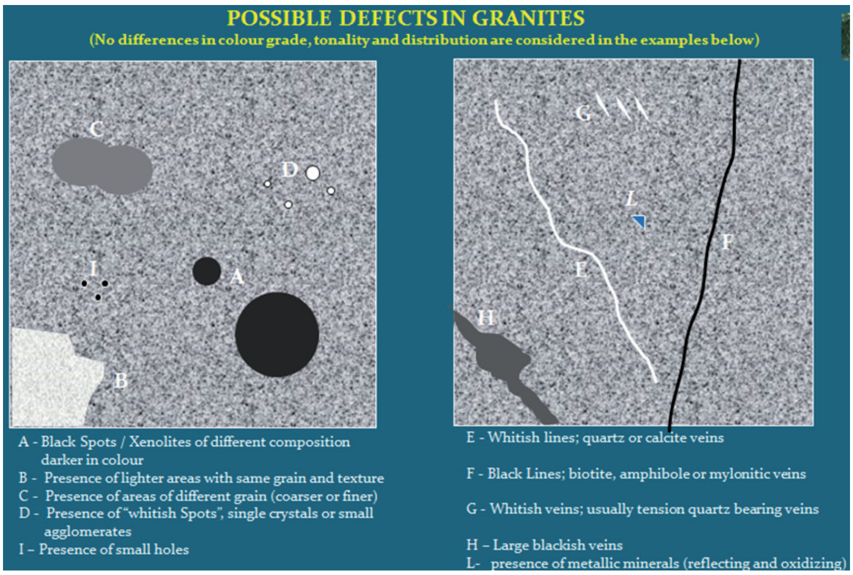

Figure 4: Most typical defects in granites.

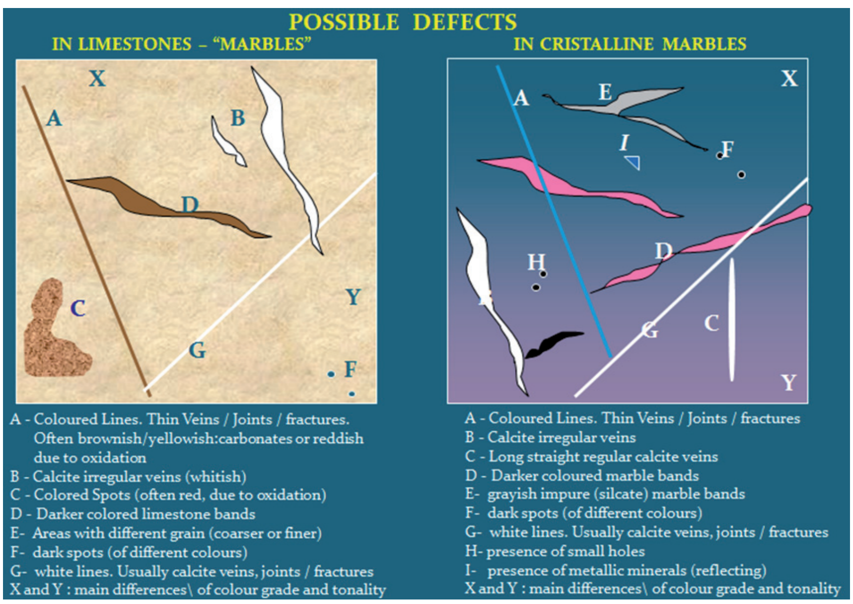

Figure 5: Main possible defects in marbles.


Figure 6: Regular large granite blocks, mined by drilling and splitting.

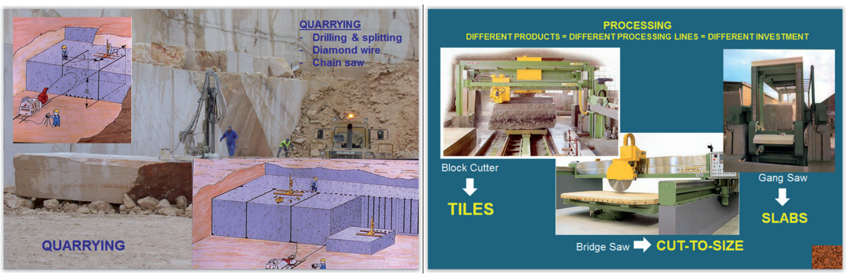

Figure 7: Methods of mining Dimension Stones.

enough to define its geometrical characteristics (the volume). It is also necessary – and in fact, more important – to consider its market quality.

In principle, any dimension stone can be sold on the market; however, only projects with competitive features will have any chance of success. The salient features of a successful dimension stone project are:

i. the right mineral texture and colour and their regular and homogeneous distribution;
ii. no particular defects;
iii. correct evaluation of reserves according to the real market value;
iv. low transport costs to both the factory and the market;
v. correct professional market evaluation and preliminary tests;
vi. accurate and sector-specific market knowledge;
vii. appropriate quarrying method and equipment, according to the target material and its geo-structural situation;
viii. quarried blocks of large enough size with regular shape[1].

In general, dimension stones can be quarried in regular and/or unshaped blocks by using different mining methods and can be processed to produce either semi-finished products (slabs) or finished products (tiles and other cut-to-size products).

Producing the best possible large and regular block, in terms of shape and quality (colour, grain and texture), is the key to a successful DS mining project. This depends on:

I. professional geological evaluation;
II. good knowledge of the market demand;
III. professional mining design in line with the target stone geo-structural features;
IV. appropriate mining methods and equipment.

There are various methods of mining Dimension Stones, and the method used is determined by the geological and structural features of the ore body and by the nature of the final product being produced. Typical mining methods include:

I. drilling and splitting (generally utilised for granites);
II. diamond wire cutting (utilised for marbles and also in some granite quarries);
III. chain sawing (in some limestone quarries, with well-organised bench structures).

Once extracted from the quarry, DS blocks can also be cut and processed in different ways, based on both the characteristics of the rock and the market strategy of the company, to produce various types of semi-finished and finished products. These include slabs (semi-finished), tiles (finished) or cut-to-size products like tables, table tops, stairs or columns, for example (finished).

The global dimension stone market

The demand for dimension stones dates back several thousand years ago to many of the world's ancient civilisations and as such, DS mining is one of the oldest of man's mining activities. Today, DS mining represents a dynamic industry in many areas of the world. Following early market leadership by European countries such as Spain, Italy, Greece and Portugal, new countries such as the BRICS members and others in the Far East, like Taiwan and Indonesia, entered the game during the 1990s, opening up strong new markets in emerging global economies. China and Indonesia, in par-

1 In general, it is better to produce small regular blocks with good colour and textural characteristics than large blocks with defects and/or lower colour and texture quality.

Ore bodies of gold or any other metal, as well as of most industrial minerals, can be evaluated and described relatively easily by a series of sampled drillings or trenches, together with the chemical analyses of those samples, representative of a certain thickness. This provides a clear and comprehensive picture of the volume and grade of the ore body, as the chemical analyses can give precise information on the quality and grade of the target mineral. From this type of report, it is relatively straightforward to determine if the material is of low, medium or high quality in relation to market demand and/or to define the content of the mineral in a unit volume or length. In general, the geo-mining and market values of a DS ore body and its grade cannot be defined by laboratory tests such as the chemical tests that are performed for most other minerals. Nor can its objective market value be easily presented by numbers alone.

ticular, have evolved from being merely source countries for DS raw resources to become key DS producers and consumers themselves, with market demand increasing tremendously in recent years. In these and other Southeast Asian countries, existing DS companies are enlarging and new groups are entering the market with interest in investing in new DS mining projects both in Asia and across the world. Several of these groups have also signed agreements and formed formal partnerships to acquire DS quarries and processing facilities further afield, in Turkey, Europe (mainly Spain and Portugal, at present) and the United States. As a result, the global DS industry has grown steadily since around 1980, at average rates of between 7 and 9 % per annum. While the sector is by no means a leading sector within the mainstream mining industry, it boasts a current annual global turnover estimated at between US$70 and 90 billion, with more than 140 million tons of material traded. Starting in 2011, several DS companies have also begun the process of listing on various stock exchanges, mainly on the Hong Kong Stock Exchange. Although they have faced several challenges, most notably a lack of experience and knowledge of the DS industry on the part of many dominant stock exchange players, five of them have completed the IPO process to date. There is also currently one DS group listed on a European exchange, specifically London's LSE.

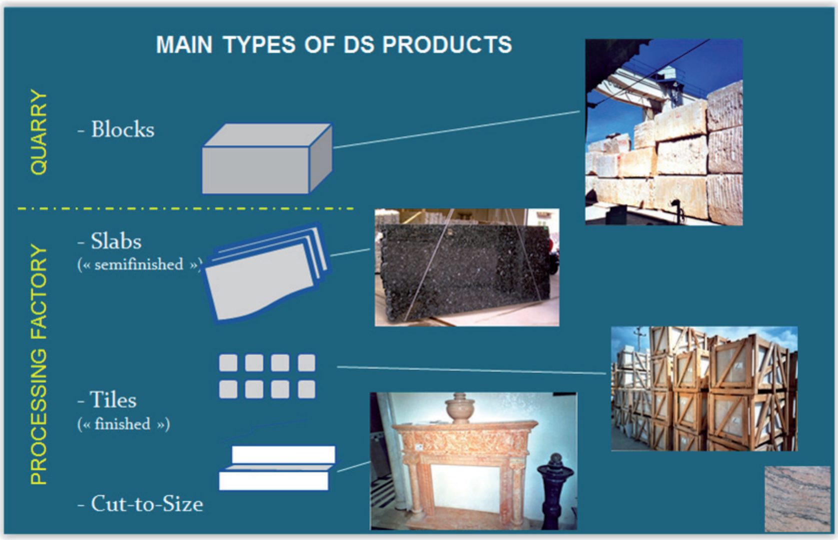

Figure 8: Dimension Stones: main products.

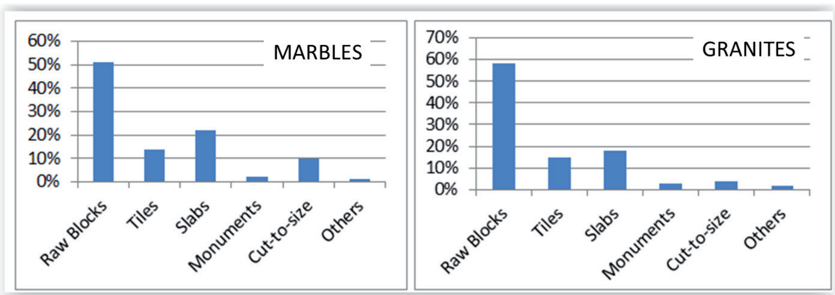

Figure 9: Global market profiles for 2012 for marbles (left) and granites (right) by different product form (source IMM Carrara-Italy).

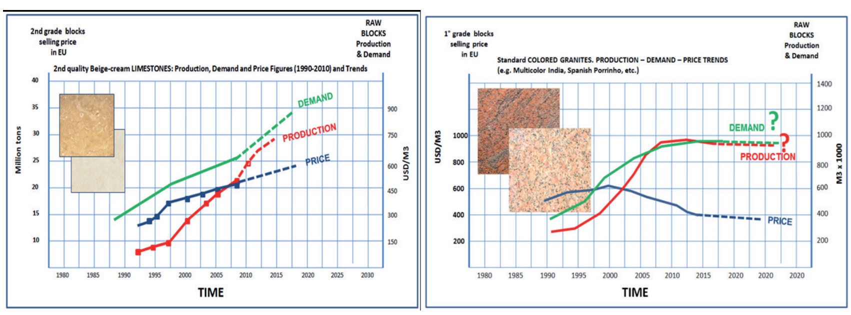

Figure 10: a. Market trends for 2nd quality beige limestones, 1980-2020 - b. Market trends for standard coloured granites, 1980-2020.

However, despite this overall positive trend, it is important to emphasise that different DS materials have different market fundamentals. While some materials sustain steady long-term demand (e.g. black granites, white crystalline marbles, beige limestones) others fluctuate strongly, with market demand highly variable over time and for different geographical areas. This is the case for several coloured granites and other specific DS materials such as black marbles (see below some examples of market trends often utilised in DS market analyses).

Notwithstanding these possible variations in the market, this steady growth has also triggered a significant general trend in many countries towards the adoption of a more professional and technical approach to DS mining, both in the exploration phase and in the operation of DS quarries. Production technologies have developed rapidly over the past three decades, particularly in the developed world where labour costs are high, and developing countries such as Brazil, China and India have also developed their own equipment manufacturing industries in the last 15 to 20 years. This trend, among others, has allowed the start-up and development of new quarries of DS in many countries of the worlds, including some developing countries.

Furthermore, in traditional mining regions in the developed world, such as the European Union and the United States, this development trend has been accompanied by a period of increased attention to the environmental impacts and safety risks associated with mining, and many of these regions have experienced increased regulation during the past decade. The growth of the dimension stone industry in the Far East has also begun to follow a more mature development process, particularly in the past five years, following the economic boom in China, however the relevant environmental and social issues are not yet priorities in many of these areas. For these reasons any official evaluation report, and in particular all Competent Person Reports, must include paragraphs regarding environmental, social and safety issues. Furthermore, most of the international mining standards (see CRIRSCO standards) are now discussing the officially inclusion of these issues as "modifying factors" for the reserves estimation.

The reporting and evaluation of dimension stone projects

The International Valuation Mining Standards (Valmin, JORC, CIM, SME, SAMVAL, PERC) at present do not include any specific chapters and notes regarding the Dimension Stones sector and are not currently prepared for this new developing trend. Currently the best available standards for the valuation of DS projects are some of the very general notes regarding the valuation of industrial minerals and construction materials, such as those contained in JORC and PERC, both of them already including the general concept of 'quality'.

In order to change this, PERC, first of the international bodies, launched a specific Dimension Stone Committee in 2014, coordinated by the author in collaboration with Mr. Steven Henley of the PERC Board. One of the main aims of the committee is to collect input from all European Dimension Stones experts and from other PERC members for the necessary formulation of a new modern method to evaluate DS projects and to calculate DS resources and reserves. This method will then be proposed and promoted to the international geo-mining community as a reference instrument to try to homogenise and standardise the way in which the particular and unique features of DS projects are evaluated. Innovation and standardisation are considered two of the keys to the modernisation, international growth and development of the DS sector.

Based on this input, PERC is also currently drafting a new Standard text that will include some points specifically for Dimension Stones. The new text will not include or propose any specific methodology for DS project evaluation or the calculation of DS reserves and resources. This is left to the Competent Person (CP) responsible, based on his/her own experience. The new version should be officially available in 2015 to 2016, following approval by CRIRSCO.

Here below is described the first input of the author from his direct experience in project evaluation and in the drafting of Competent Person's Reports (CPRs) for DS projects in China, Turkey, Indonesia and India, several of which will be entering the initial public offering phase in 2015.

Firstly, a DS project should preferably be evaluated by a DS CP, with sufficient knowledge and experience in the geology and mining of DS materials and in the relevant market areas. It is crucial in fact, for a DS CP to be fully up to date with current market rules and trends, in addition to his/her knowledge of the technical features of the project in question. Without this knowledge it is impossible to correctly evaluate the potential quality of the target material and consequently its likely value in different markets. In fact the quality, as mentioned above, represents the most important factor in dimension stone project evaluation and resources-reserves estimation, which as a modifying factor can be in principle compared with the "grade" of other mining ores. Detailed market and price benchmark analyses should therefore always be included in evaluation CPRs in order to estimate the quality of the identified resources, so that the final economic reserves can be accurately calculated (see the section on proposed modifying factors below).

Secondly, it is now widely understood in the global mining industry that the economic, social and environmental aspects of the production of metals and minerals are irrevocably linked to one another. The products of mining need to be sustainable. What is a sustainable product? This is an economically profitable product that has been produced under ecologically and socially justifiable circumstances whereby the potential for affected people to provide for themselves is not compromised, in either the present or in future generations (UN definition). The DS sector needs to become more closely aligned with these principles. A DS CPR therefore should include all available information on the safety, environmental and social aspects of the project, with comments and evaluation on the project's sustainability from these and any other relevant non-financial perspectives.

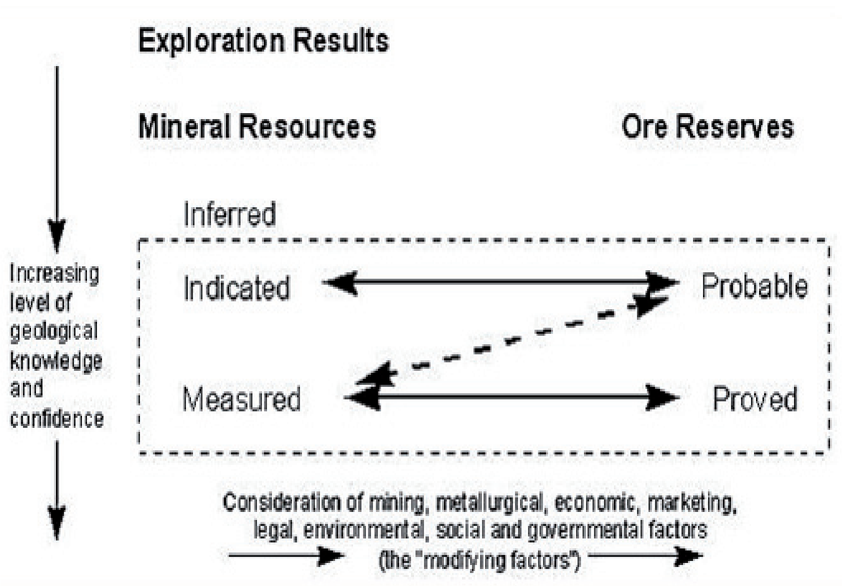

Figure 11: Correlation between mineral resources and reserves (source: PERC and JORC Standards).

Proposed modifying factors for the current evaluation of DS reserves

This section focusses on known and new proposed modifying factors to the current methods used to transform DS resources into reserves. For the sake of clarity, the resource evaluation and calculation phase is also mentioned briefly.

Phase 1: The calculation of resources (inferred, indicated and measured)

Resources are calculated using various data and field evaluation techniques, such as core drillings, trenches and pits and regular sampling. In particular cases, for example well-exposed steep cliffs or steep rocky pyramidal-shaped hills, a professional geo-structural and sampling section carried out along a clean outcropping rock slope could substitute for a core drill.

Phase 2: The calculation of reserves.

Taking into consideration the PERC/JORC correlation scheme for the transformation of resources into reserves (see figure below), the following modifying factors scheme for DS reserves calculations are proposed, keeping in mind that these are suggested for use in combination with the traditional standard factors considered in reserve calculations.

The modifying factors suggested are based on the concept of market quality, which is new and unique for DS projects, as for some construction materials and industrial minerals. Market quality considers the effective volume of resources that could be realistically sold on the present market, depending on real market demand.

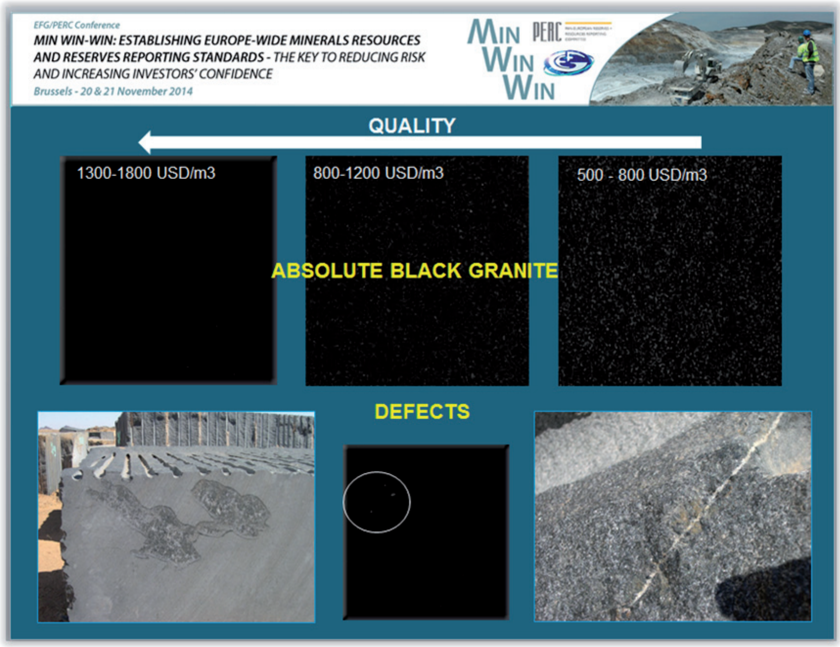

Figure 12: Example of defect in "Thaila Black" black granite currently quarried in Mauritania.

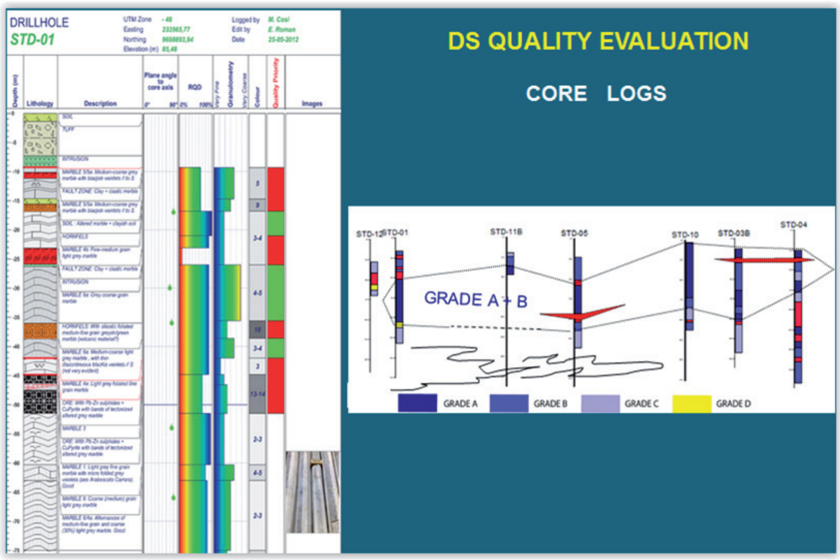

Figure 13: Examples of graphic representation of quality grades in core logs and sections.

The concept is necessary in order to quantify the estimated percentage of volumetric reserves of target rock that can realistically be considered as marketable reserves, and as such, to assign a more accurate real market value to a DS project. Market quality can be calculated as a single 'Market Quality Factor' (MQF). For DS projects, the MQF can generally be compared with the ore body grade reported for most other mineral ore bodies, which is usually estimated using a combination of unit volume chemical analyses and calculated volumes. However, the component factors that combine to determine the MQF of a DS project are not easy to evaluate and calculate and are often not precise. What is clear is that it cannot be evaluated by chemical or any other laboratory analyses!

The MQF has to be evaluated, together with other geological and structural modifying parameters, from drill cores, direct analysis and/or from other rock sampling data. It should also be justified by comparison with similar materials already priced and sold on the market, as well as by the specialist expertise of the DS CP. Each evaluation of the MQF of a DS project should therefore contain an in-depth detailed professional benchmark analysis of similar materials.

There are five main parameters that define the MQF and the value of a dimension stone:

- Colour;
- Texture;
- Grain;
- Presence of defects (each material has its own set of particular possible defects);
- Volume distribution of the four parameters above.

The quality of stones, formed by a mix of these parameters, directly influences the demand and the selling prices (see the example for black "granites" in ***figure 12***).

Quality can be estimated by the analysis and evaluation of the target rock mass from samples, trenches, quarry faces and obviously drill cores. Then core logs should include columns regarding this key parameter and justification for the quality categorisation. In particular each quality "family" should be described for each project. The graphic representation of quality grade will also allow the drafting of indicative quality sections and 3D block models (see ***figures 13 and 14***).

Other modifying factors, in addition to the quality factor, are proposed for inclusion in the estimation of mining reserves:

- Joint-fissures opening factor (JOF): Percentage of absent target rock due to voids produced by the opening of joints, fissures, holes and caves. This is usually described for limestones and marbles not directly produced by karstic phenomena.
- Karstic factor (KF): Percentage of voids due to karstic phenomena (determined by core logging and from field analysis)
- Weathering Factor (WF): Percentage of weathered rock that cannot be mined (determined by field analysis and core logging). In some particular cases (e.g. some yellow granites) the superficial weathered rocks, often of yellow colour, represent saleable target rocks for some markets. Even if weathered, reserves can still be calculated in this particular environment, due to the new resin and back netting techniques, although only when the WF is very low.
- Mining Factor (MF): Portion of target resources that cannot be included as reserves due to the mining plan/design (e.g. final bench quarry shape, reserves that cannot be economically mined, etc.)

- Mining Lease Life Factor (MLF). This varies from case to case and from country to country.
- Joint Factor (JF): Determined by a comprehensive joint structural analysis and the related evaluation of various geo-mechanical parameters (e.g. VP, JV index, etc.). A correct analysis and evaluation of the JF is necessary for accurate estimates of the minimum, average and maximum values of the volume of unfractured rock mass, and therefore to predict the percentage of solid unfractured blocks that can be mined from the analysed rock mass. The JF is exclusively and directly linked to the recovery rate of the final blocks (the percentage of massive marketable blocks exploited). The recovery rate may vary in relation to the final target product (type, shape and size of block) and may also depend on the company's market strategy.

It is important to bear in mind that some modern sophisticated technologies exist to analyse and measure joints and other planar anisotropies (bedding, schistosity, etc.) directly from the quarry face and outcrops, and these are becoming more widely utilised in quarry dimension stone project analysis (e.g. drone aerial photogrammetry analysis and laser scanning).

Laboratory tests for the classification of dimension stones

With regard to the use of laboratory tests for the classification of DS materials, there are only a few tests that are generally requested. These are mainly physical-mechanical tests (compressive strength, flexural strength, porosity and water absorption, abrasion and friction resistance, bulk density), as well as a gloss test to evaluate the polishing attitude of the stone and finally a radioactivity test (only required for certain markets, such as China for instance).

A second phase of further physical-mechanical as well as chemical-mineralogical analysis can also help to define other characteristics of the identified stone, concerning its processing and attitude (cutting and polishing, for example, such as the gloss test mentioned above) as well as the potential for weathering and alteration after its installation as a finished product.

Although the text is not exhaustive and complete, the author hopes that this first general paper on dimension stones can open a fruitful discussion among mining consultants in order to finally find a professional modern method to evaluate DS projects and their resources and reserves. Moreover, investors and financial key decision makers, usually not yet skilled in this particular unique mining industry, should also begin an interaction with the DS industry for better final decision making.

With this aim and hope in mind, the author intends to participate to international conferences and workshops and to write more detailed papers on this issue, focussed on specific aspects, with the main scope being to stimulate productive discussion. Input from colleagues operating in the specific sector and with experience in project evaluation is welcome.

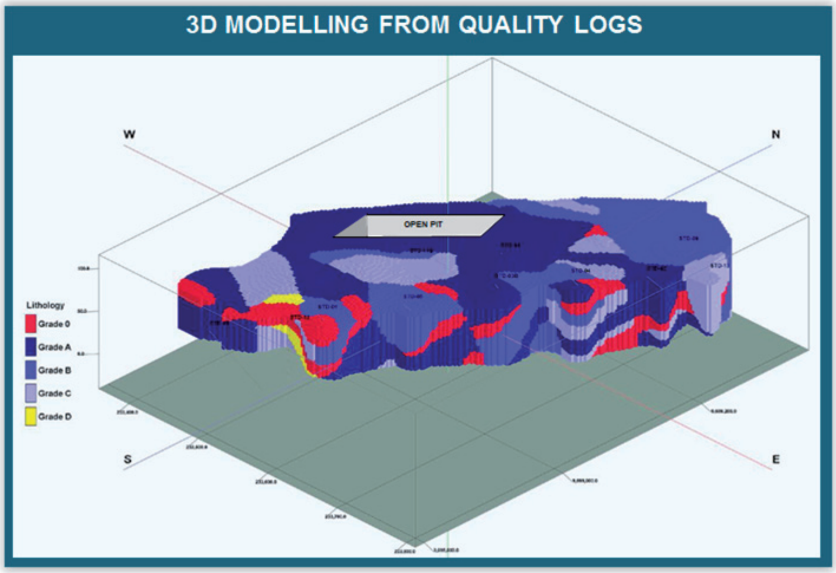

Figure 14: Example of quality 3D block diagram.

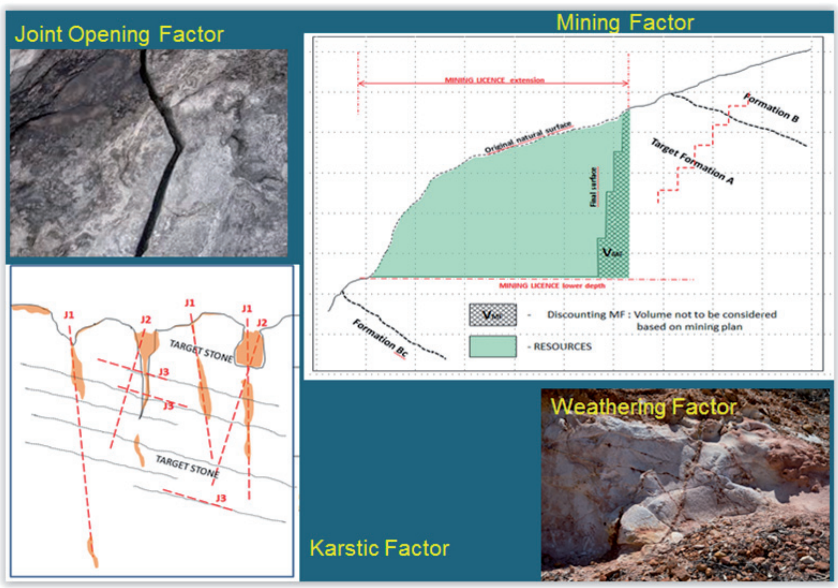

Figure 15: Other modifying factors to be utilised also for dimension stones.