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Fuzzy expert system for economic zonation of an ornamental slate deposit

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Abstract

Investigation of deposits for traditional extraction activities (metals and coal) has generally been based on determining grade, or content, of the required material. In order to apply the grade concept to an ornamental rock such as slate, it is first necessary to define the variables that determine both the geotechnical recovery rate for the rock mass — which conditions the size of the extracted blocks – and the aesthetic features of the slate — which define the quality of the slabs as potential roofing material.

For this research, geotechnical and aesthetic data for a slate deposit were collected from 16 continuous core borehole samples. A fuzzy expert system was then developed using this data, defining the rock mass recovery rate and slab quality in accordance with the criteria of a slate expert, producing as a final output a zonation of the deposit in terms of top quality slate, medium quality slate or waste.

A mathematical model based on fuzzy logic was chosen due to the fact that the boundaries between different quality groups in a deposit are not clearly distinguished. Moreover, quality also depends on a company's infrastructures for transformation of the blocks, and also on its commercial strategies.

Keywords: Fuzzy expert system; Slate; Grade control; Natural stone

1. Introduction

The ornamental rock mining sector in Galicia (NW Spain), and particularly slate extraction for use as roofing material, has developed spectacularly in recent years. This development has led to an increasing need to update and modernise working methods, which, in many aspects, are antiquated. The perspective for the future for the sector is to produce slate slabs of maximum quality at the lowest cost possible, taking advantage of quarry reserves using non-aggressive extraction methods for the rock masses and ensuring an optimal extraction yield (García-Guinea et al., 1997).

An increasingly popular and advanced technology used in slate extraction is in-quarry mechanical cutting using diamond wire machines, ranging arm shearers or disk saws. This approach increases the deposit recovery rate but is more costly than the traditional method using explosives.

In order to optimise the profitability of the mechanical method, it is crucial to know a priori, i.e. prior to planning cutting, the intrinsic quality of the rock in the quarry

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benches and to evaluate the economic value of each area. Failing to detect, in advance, surface indications of discontinuities or other faults in benches may result in poor planning and affect the quality of the blocks obtained, with the consequent financial repercussions.

Quality grading of quarry benches is generally made using visual procedures, i.e. qualitative methods. To date no quantitative method is available that permits the quality of the interior of extraction benches to be calculated, with minimal or at least predictable uncertainty, from the measurement of specific parameters in the rock face.

The elaboration and practical application of a methodology that effectively resolves this question is of great interest to the slate industry in general, since it means that a quality grading system can be established for quarry benches, making it possible to plan extraction using scientific methods and thereby optimising yields and recovery and minimising the possibilities of disagreeable surprises in the bench. It would also permit the exploitation to be planned financially (Bastante et al., 2004).

No system that resolves this problem for slate quarries exists as yet. There have only been tentative efforts to assess the level of discontinuities using purely geometric methods, which, however, fail to take into account the other geotechnical and aesthetic characteristics that affect the quality of slate (García-Guinea et al., 1998).

In terms of evaluating the quality of a mineral deposit, the main difference between traditional extraction activities (metals and coal) and ornamental rock quarrying is that, for the former, a single parameter – ore grade – indicates the quality of the deposit, whereas for the latter a range of variables affect overall quality.

2. Slate grade

The 1960s and 1970s saw considerable advances in terms of mining technologies. One of the main reasons for this was a new concept, developed in the Colorado School of Mines, of mineral as a material whose exploitation generated a benefit. On the basis of this concept, scale economies were applied to mining, and it was quickly demonstrated that large mines (exploitation of large deposits with low mineral content) was more profitable than the exploitation of smaller, richer mines. These changes gave rise to new techniques for calculating the viability of mining projects from a financial perspective, which resulted in large capital investments being attracted to mines. These developments were based on the concept of ore grade, or content of the required material in the extracted materials.

The ore grade concept is highly applicable to the study of metal or coal deposits. However, in growing markets, such as that for ornamental rock, this concept is not so easily applied, and so has rarely been considered or studied. In recent years, however, a great deal of effort has been directed at extrapolating this concept or creating an analogous concept (a quality index), for application to the ornamental rock sector (Taboada et al., 1998). Such an ornamental rock quality index, which would indicate the percentage of material that can be extracted and that is saleable, would, unlike the case for metals, need to include a range of factors and not just indicate chemical content, which makes its definition a complex matter.

The lack of a grade concept for ornamental rock is undoubtedly one of the reasons why Galician ornamental rock extraction operations, and especially those for slate, are under-mechanised and fragmented. Indeed, without a method to estimate grade for these minerals it is not possible to analyse the feasibility of a quarrying project using basic financial indices such as Net Present Value (NPV) or Internal Rate of Return (IRR). Consequently, it is very difficult to attract capital to this sector.

3. Aims

Our first aim is to define each and every one of the parameters that condition both the quality of the rock mass and of the slate slabs. These parameters will be either mechanical — affecting recovery of blocks from the quarry — or aesthetic — indicating the ornamental quality of the slate that will ultimately be used in the construction industry.

Our second aim is, from the defined parameters, to create two quality indexes – geotechnical and aesthetic – indicative of the characteristics of the ornamental rock mass, and equivalent to ore grade as an indicator of quality in metals.

Our third aim is to create an expert system which will combine both indices and reproduce the slate expert's opinion with regard to the data for the different quality variables collected at the deposit outcrops, in free faces of the quarry bench, and above all, from continuous core boreholes (Matías et al., 2004a). This expert system will characterise quality and enable selective extraction tasks to be planned.

To achieve these aims, we aim to design a fuzzy system that classifies slate in one of three groups, namely top quality slate, medium quality slate, and waste (Matias et al., 2004b). This system emulates an expert, who analyses many variables without establishing clear quantitative boundaries between the different deposit grades.