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Exploitation planning in slate quarries by merging the recovery and quality indices

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ABSTRACT: The rational exploitation planning of slate quarries requires to forecast the in situ value of the material to be extracted, in order to include this value in the detailed production scheduling programme of the venture. Two components that relate the observable geological/technological attributes to the above considered in situ value are considered in this paper: the quality index of the plate and the recovery index of the exploitation. Once established these two indices by Correspondence Analysis and detected their spatial continuity by variography (auto and cross correlation), they are estimated in the exploitation volumes by Co-Kriging. The estimated value of the combined index is the basis for further planning.

A case study, referring to the Valdeorras slate quarry, is presented for the purpose of illustrating the methodology. The estimated values are validated by using real data supplied by the exploitation experts of the quarry.

Key words: Slate quarry; Regionalised variable; Recovery index; Quality index; Correspondence Analysis; Variography; Co-Kriging.

1- INTRODUCTION

When planning the exploitation of slate quarries, two components of the objective function should be taken into account: the costs of exploitation and the value of the material to be extracted. The first component, apart from other factors, depends on the exploitation recovery; the second component is related to the quality of the material to be extracted, for a given market situation. These two components - recovery and quality - are summarised by the methodology given in Pereira et al., 92 and two indices are produced, each one of which reflecting a specific feature of the evaluation problem. In order to combine these two indices, conveying information from recovery to quality and conversely, a new step was added to the original methodology. This step consists of calculating the cross-variogram of the two indices by:

\[ \gamma_{12}(h) = \frac{1}{2} \sum_i \left[ I_1(x+h) - I_1(x) \right] \left[ I_2(x+h) - I_2(x) \right] \]  \hspace{1cm} [1]

\[ I_1 \text{ - Quality index} \]
\[ I_2 \text{ - Recovery index} \]
\[ x \text{ - co-ordinates} \]
\[ h \text{ - lag} \]

and estimating the two indices in the exploitation units by Co-Kriging (Journel & Huijbregts, 1978), applying the system [2], where \( n \) is the number of samples and \( \lambda_{ij} \) are the Co-Kriging weights.

\[ \sum_{i'=1}^{n} \gamma_{ij} (x_{i'}, x_{ij}) + \mu_{ij} = \gamma_{ij0} (x_{ij}) \]
\[ \forall i'=1, \ldots, n \quad \forall j \neq i, i' \]

\[ \sum_{i=1}^{n} \lambda_{ij} = 1 \]  \hspace{1cm} [2]

\[ \sum_{i} \lambda_{ij} = 0 \quad \forall j = i, i' \quad \forall j \neq j' \]

The proposed methodology, generalised to cope with the problems arising from the exploitation planning of slate quarries, was applied to the...
Valdeorras quarry, located in Spain. The geological and geotechnical factors that influence the slate quality and exploitation conditions are of stratigraphic, structural and metamorphic nature.

2 - DATA CAPTURE

The basic attributes on which the recovery and quality depend were scrutinised as given in table I:

Table I - Recovery and quality attributes to a slate exploitation

<table>
<thead>
<tr>
<th>RECOVERY INDEX ($I_1$)</th>
<th>QUALITY INDEX ($I_2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n° fractures/m</td>
<td>Ultrametamorphised slate</td>
</tr>
<tr>
<td>n° Kink bands/m</td>
<td>Kink-bands</td>
</tr>
<tr>
<td>Alteration</td>
<td>Quartz - veins</td>
</tr>
<tr>
<td>RQD</td>
<td>Sand - laminations</td>
</tr>
<tr>
<td></td>
<td>Oxidation</td>
</tr>
<tr>
<td></td>
<td>Carbonates</td>
</tr>
<tr>
<td></td>
<td>Multicrenulated slate</td>
</tr>
<tr>
<td></td>
<td>Crenulation</td>
</tr>
</tbody>
</table>

These two sets of attributes were captured in 9 drill-holes, by counting the occurrence of their categories in 5m supports. The classification was made by direct observation of the selected attributes on the core samples using video images and pericel information.

3 - INDEX CALCULATION

By applying the equation (Pereira et al., 1992),

$$f(i) = \frac{1}{\sqrt{\lambda} \cdot q} \cdot \sum_{k=1}^{q} W(k) \cdot \sum_{l=nc(k)+1}^{I} x(i,l) \cdot p(l)$$  \[3\]

where

- $f(i)$ is the index of support $i$
- $\lambda$ is the eigenvalue associated with the discriminant axis
- $q$ is the number of attributes $k$
- $W(k)$ is the weight given to attribute $k$
- $nc(k)$ is the number of categories of attribute $k$
- $x(i,l)$ is the grade of membership of support $i$ to category $l$
- $p(l)$ is the projection of category $l$ onto the discriminant axis

The two indices were calculated on the basis of the attributes given in Table I. The system of weights $W(K)$ and the attribute classes were modified interactively until a validation was reached against the expert opinion of the quarry management. Also, the archetypes of the poles of discrimination for both indices were established according to the experience of what is considered the extremes of recovery and quality by the quarry management.

Fig. 1 - (a) and (b) Semi-variograms for $I_1$ and $I_2$. (c) Cross-variogram of $I_1 I_2$. 

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4 - ESTIMATION OF THE INDICES IN EXPLOITATION UNITS

The omnidirectional variograms and cross-variogram of the two indices were calculated as shown in Fig.1:

Hence, the variogram parameters are summarised in Table II:

Table II - Theoretical spherical models parameters

<table>
<thead>
<tr>
<th></th>
<th>C₀</th>
<th>C₁</th>
<th>A₁</th>
<th>C₂</th>
<th>A₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>I₁</td>
<td>0.20</td>
<td>1.00</td>
<td>20m</td>
<td>6.120</td>
<td>120</td>
</tr>
<tr>
<td>I₂</td>
<td>0.03</td>
<td>0.14</td>
<td>20m</td>
<td>0.007</td>
<td>120</td>
</tr>
<tr>
<td>I₁I₂</td>
<td>0.00</td>
<td>0.18</td>
<td>20m</td>
<td>0.130</td>
<td>120</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The proposed methodology allows the construction of two indices in slate quarries, each one of which reflects features of the material to be extracted: the recovery index is linked to the exploitation costs and the quality index summarises the value of the slate.

The two indices were calculated in the available drill-holes and their estimation in the production zone was performed by Co-kriging.

When the image of a working face is available, the recovery index can be calculate in the same support as drill-holes and the recovery index for that face can be inferred by the Co-kriging estimation procedures, permitting to guide the short term exploitation planning. This is the main advantage conveyed by the proposed Co-kriging method, since it is most possible to capture, in the face, the attribute in which the quality index is based.

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REFERENCES


FROM THE SAME PUBLISHER:

Hoeck, E., P.K. Kaiser & W.F. Bawden 90 5410 186 5
Support of underground excavations in hard rock
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discussions on different types of underground support.

Demirel, Hamit & Salih Ersayin (eds.) 90 5410 513 5
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1994, 25 cm, 596 pp., Hfl. 195 / $110.00 / £72
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techniques; Modelling, simulation & control. 80 papers.

Jeremic, M.L. 90 5410 113 X
Rock mechanics in salt mining
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(Student edn., 90 5410 103 2, Hfl. 95 / $55.00 / £35)
5 chapters consider general geology, folding & faulting structures
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chapters deal with the exploration & opening of salt deposits with the
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water inflow into the mine. 3 chapters analyse deformation & failure
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5 chapters discuss strata mechanics & control for different mining
systems of flat, inclined & massive salt bodies, as well as solution
mining & excavation for storage. The last chapter presents the sta-
bility analyses to the mine structures in regard to salt mining sub-
sidence. Author: Laurentian Univ., Sudbury, Canada.

Bawden, W.F. & J.F. Archibald (eds.) 90 5410 325 6
Innovative mine design for the 21st century – Proceedings of the
international congress on mine design, Kingston, 23-26 August 1993
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management; Research & development.

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Mine planning and equipment selection 1994 – Proceedings of the
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ment; expert systems; mine and equipment information systems.

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Human factors and safety, miscellaneous; Reliability and mainte-
nance of mining systems. Editors: Luleå Univ. of Technology.

Hustrulid, W. & M. Kuchta (eds.) 90 5410 173 3
Fundamentals of open pit mine planning and design
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(Student edn., 90 5410 183 0, 2 vols, Hfl. 125 / $65.00 / £46)
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Introduction; CSMine property description; CSMine tutorial;
CSMine user’s manual; VariO tutorial & user’s guide; VariO refer-
ence manual.

Szwedzicki, T. (ed.) 90 5410 321 3
Geotechnical instrumentation and monitoring in open pit and
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