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AN APPROACH TO DESIGNING A CLASSIFICATION OF THE UNDERGROUND ORE MINING METHODS

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ABSTRACT

An approach is proposed permitting every mining method to be expressed by a concrete logical formula. For the purpose, an alternative graph is constructed that takes into account the alternative elements of the mining technology. The general sequence of the elements supposed to construct the technical and economic model of each mining technology is determined by means of a logical formula. This is a decisive step in the procedure related to the technical and economic comparison and selection of an optimal mining technology for particular natural conditions.

A great number of classifications of mining methods and technologies are used the underground ore mining practice. In different regions and at different times different features have been used thus resulting in more than 50 known classifications. Each one formulates differently the set of similar elements eventually termed classes of mining methods. With improving the mechanization of the production processes a change can be noted in the tendencies for selecting a classification feature or features in designing a given classification. The large extent of variability of the natural factors and the low degree of mechanization during the 1930s presupposed the design of classifications combining over 200 various ways of mining the mineral deposits. The approach is the same, viz. building structures consisting of classes, groups, variants and subvariants of mining methods. Of the well-known classifications we should note M.I.Agoshkov's classification. It is based on the feature *stope state*. R.P.Kaplunov's classification is widely used. It is built up on the feature *rock pressure control*. V.R.Imenitov's classification is based on the *method of stope maintenance* during the ore extraction. In the western literature (mainly American, British and Australian reference sources) the concept of mining method is usually associated with the procedure for selecting an optimal variant of mining technology. Hartman's classification considers jointly the openpit and underground mining methods. It is based on the subdivision of the mining methods into classes and subclasses and for each one it gives the method of working and type of mineral mined. Morrison's classification is based on the geomechanical aspects, and in particular, the possibilities for accumulating the energy of the rock mass deformations. From this point of view we determine the method of maintaining the stope: without supports; with supports; with filling; with pillars.

Nicholas determines the applicable mining methods by using the weight coefficient He introduces this coefficient to account for various factors: orebody shape, rock characteristics in the hanging and foot walls, distribution of the valuable constituents in the ore.

D.M.Bronnikov elaborates on the question of the classification of mining methods and selection of an optimal mining technology by specifying the mining conditions of particular relevance in the form of a systematized table: *wallrock stability, ore stability, ore value*. These are the three features that determine the set of applicable mining methods for each combination between them. This is one of the modern perspectives for designing a classification that uses several features at the same time.

At least two are the characteristic features that should be taken into account in designing a classification of the mining methods at present.

First.

The designs of the machines used for the production processes at the extraction face are very sophisticated thus making them adaptive to the high degree of variability of the natural conditions (orebody thickness, slope angle, ore and wallrock stability). It is not necessary any more to design classifications consisting of many classes in order to achieve complete correspondence between the features on which they are based and the real natural factors.

Second.

Modern software and hardware products create practically unlimited possibilities for indetifying every mining technology. The problem is how to derive the factors of greatest weight so as not to burden unnecessarily the search for an optimal solution. From that point of view, the use of a graph with a suitable architecture can serve as a basis for ordering the features to be used in describing the respective mining technology.

The problem is reduced to determining the number of levels N and number of alternatives of each level M_N. Fig. 1 shows the construction of an alternative graph. It represents the structure of the elements constituting the core of the mining method. The alternative graph consists of six levels, i.e. N = 6. The six levels determine the classification features on the basis of which we design our classification of mining methods. The levels are ordered in the following sequence:

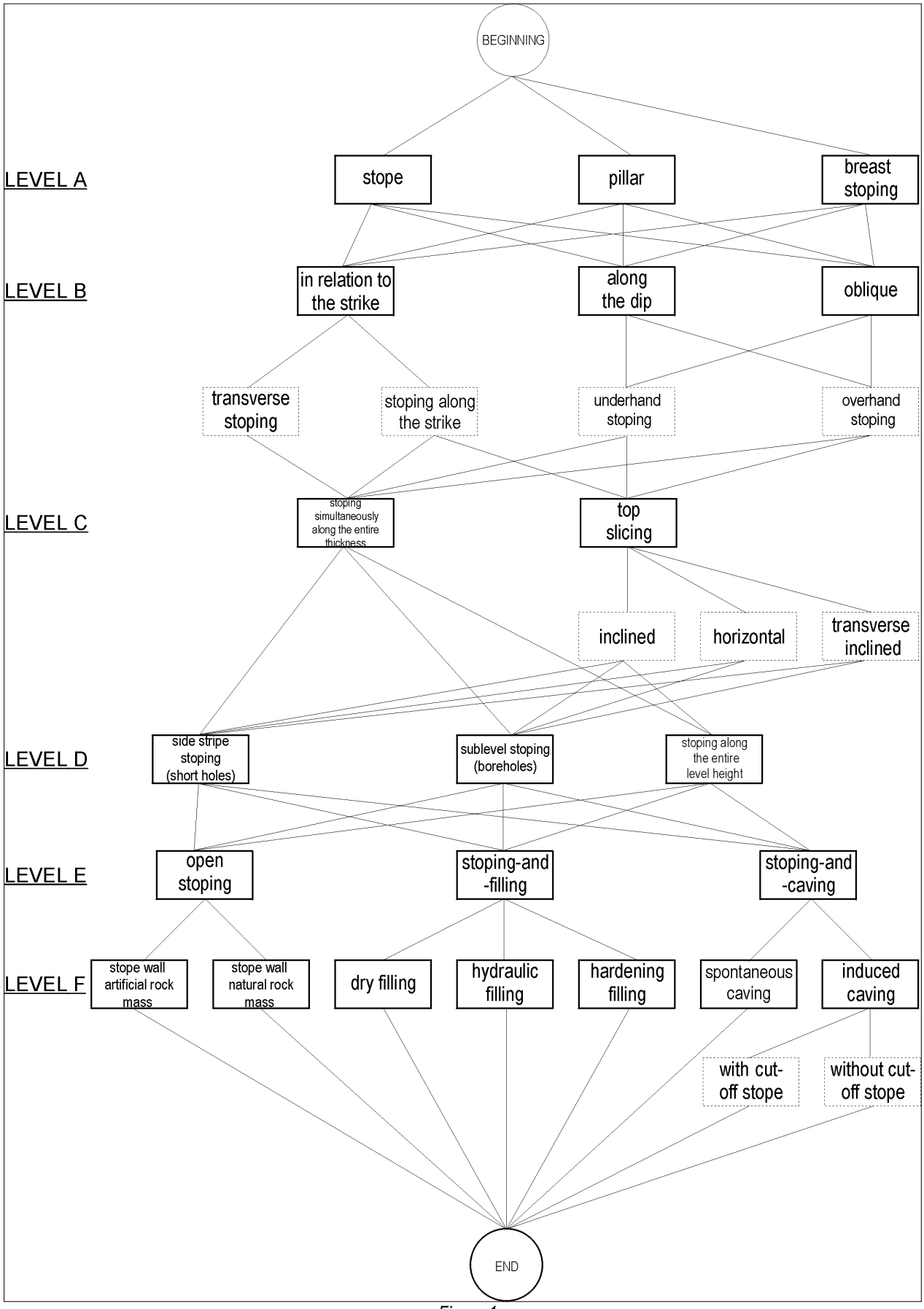
BEGINNING
LEVEL A
stope
pillar
breast stoping
LEVEL B
in relation to the strike
along the dip
oblique
transverse stoping
stoping along the strike
underhand stoping
overhand stoping
LEVEL C
stoping simultaneously along the entire thickness
top slicing
inclined
horizontal
transverse inclined
LEVEL D
side stripe stoping (short holes)
sublevel stoping (boreholes)
stoping along the entire level height
LEVEL E
open stoping
stoping-and-filling
stoping-and-caving
LEVEL F
stope wall artificial rock mass
stope wall natural rock mass
dry filling
hydraulic filling
hardening filling
spontaneous caving
induced caving
with cut-off stope
without cut-off stope
END

Figure 1.

Level A. Type of main production unit for performing the mining operations.

Level B. Direction of development of mining operations within the production unit.

Level C. Method of ore extraction with respect to orebody thickness.

Level D. Method of ore extraction with respect to the geometry of the production unit.

Level E. Stope state during ore extraction.

Level F. Computer hardware and software for designing the stope state.

The generalizing parameters of the alternative graph are presented in Table 1. The following rules are adopted for designating the alternatives and sublevels. The serial number of the alternatives for each level is found in the interval 1, M_N. Let us take, for example, **Level C.** ***Method of ore extraction with respect to the orebody thickness***, two alternatives are possible, i.e. $M_3 = 2$. Stoping simultaneously along the entire thickness, ***C1***; top slicing, ***C2***. The maximum number of alternatives on the sublevels is three (see Table 1). They are designated by symbols ***a, b, c***. Let us take the example with level C. In terms of the direction of development of the mining operations within the production unit ($M_2 = 3$) there is a sublevel that is described by the following alternatives: stoping along the dip in a descending order, ***B2a***; stoping along the dip in an ascending order, ***B2b***; oblique stoping in a descending order, ***B3a***; oblique stoping in an ascending order, ***B3b.***

Table 1

No	Designation of levels	Alternatives		No of alternatives in the sublevels
		No	Design-ation	
1	Level A $\Rightarrow$ N = 1	3	$M_1 = 3$	-
2	Level B $\Rightarrow$ N = 2	3	$M_2 = 3$	4
3	Level C $\Rightarrow$ N = 3	2	$M_3 = 2$	3
4	Level D $\Rightarrow$ N = 4	3	$M_4 = 3$	-
5	Level E $\Rightarrow$ N = 5	3	$M_5 = 3$	-
6	Level F $\Rightarrow$ N = 6	7	$M_6 = 7$	2

The levels of the alternative graph are the classification features on which the classification of the mining methods is based. In this case their number is N = 6. It should be noted that a similar approach was not used in designing such a classification. Another well-known classification is that of O.A.Baykonurov's. He adopts the matrix recording but the elements are two and correspond to the number of columns and rows in the designed table.

The methods of logical algebra are used to describe the forming set of possible combinations for the separate members of the alternative graph. They are used to translate into machine language the general equations of the production processes, engineering and technological solutions depending on their local parameters. Each system considered, according to the structure of the alternative graph, can be written by its logical formula. For example, the logical formula of stope filling with hydraulic filling, according to M.I.Agoshkov's classification, will be written as follows:

$$A1 \wedge B2b \wedge C1 \wedge D1 \wedge E2 \wedge F4$$

In this case the sign "$\wedge$" means conjunction (logical multiplication) of the following logical variables:

- ***A1*** - Extraction within the stope boundaries;
- ***B2b*** - Overhand stoping along the dip;
- ***C1*** - Stoping simultaneously along the entire strike;
- ***D1*** - Side stripe stoping with short holes;
- ***E2*** - Stoping-and-filling;
- ***F4*** - Stoping-and-hydraulic filling;

The use of six classification features at the same time shows that most classifications known until now should be compatible with the one proposed in this paper. Taking into account the number of levels, sublevels, alternatives (local parameters of variables), incompatible connections, the number of methods involved in the classification amounts to 1000. This number covers the applicable mining methods under real natural conditions.

The proposed classification of mining methods has several advantages that can be reduced to:

- Prerequisites are created for generating new technological solutions that have not been developed yet, but with the development of mining mechanization they will inevitably be resorted to;
- Multi-stage mining technologies are practically considered and not only combined methods as is the case with most classifications known until now;
- By changing the structural elements of the mining methods it is possible to optimize the dimensions of the main production unit: stope, stope pillar, stope (exploitation) field;
- The architecture of the alternative graph by which the classification of the mining methods is described, enables us to use the same approach in the further detailed presentation of the basic technologies: open stoping, stoping-and-filling, stope caving.

The logical formula by which each mining method is written, enables us to move to the next step – constructing a suitable technical and economic model for evaluation of the efficiency in comparing a set of applicable technologies under certain conditions.

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