QUALITATIVE ANALYSIS OF IGNEOUS ROCKS BASED ON THE PRINCIPLE OF CONFORMITY AND SAFETY LEVEL

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***Abstract*:** *Using rocks in construction is regulated by standards that impose a set of chemical, mineralogical-petrographic, physical-mechanical criteria that rocks must accomplish in order to be used. Their use for different works is only allowed if the rocks accomplish certain quality criteria. In this context, we set out to determine the geo-mechanic properties of some magmatic rocks from South Apuseni Mountains compared to the admissibility conditions imposed by the existing standards in order to use them in different areas: engineering works (roads, railways, concrete and mortars with mineral binders, viaducts, dams, embankments); ornamental-decorative works (internal and external covering). For the qualitative assessment of magmatic rocks such as granites, diorites, gabbrou, rhyolite, andesites, diabases and basalt in order to use them in the form of aggregates, raw stone or in ornamental-decorative works, the developed and applied methodology in this case is based on the principle of conformity assessment and the level of safety taking into account the requirements imposed by the available standards. The purpose of conformity assessment was primarily to verify the compliance requirements of the rocks used as building materials.*

***Key words*:** *igneous rocks, principle of conformity, quality criteria, aggregates, safety level*

1. Introduction

Rocks have multiple uses in construction and in various other civil/industrial sectors. Besides being used as raw material in buildings, roads and a variety of miscellaneous engineering works, depending on their petrographic type, these useful rocks are also used for ornamental-decorative purposes [3], [6], [12], [13].

This wide range of uses today represents an important place the interest for the knowledge of the deposits and of the perspective areas that are not in exploitation, but whose reserves allow an extension of the exploitations in order to capitalize the useful rocks [1], [3], [4], [5], [8]. In order to acquire the desired construction quality of the terrestrial transportation infrastructures, a thorough understanding of the used materials and their behaviour under heavy traffic and weathering factors is required [11], [13].

The specific analysis to be made on the source rocks and aggregates [4], [5], [7], [9], [10], regarding the periodicity of their repetition in case of periodic checks is managed through specific standards which stipulate threshold values of the physical and mechanical properties specific for each domain of utilization [7], [13], [14].

Given all the considerations above, for the qualitative assessment of magmatic rocks such as granites, diorites, gabbrou, rhyolite, andesites, diabases and basalt in order to use them in the form of aggregates, raw stone or in ornamental-decorative works, the developed and applied methodology in this case is based on the principle of conformity assessment and the level of safety taking into account the requirements imposed by the available standards [14]. The purpose of conformity assessment was primarily to verify the compliance requirements of the rocks used as building materials. Conformity analysis is often used in the field of occupational safety and health [2]; in fact, the method that we have proposed is based on the definition of conformity used in the field of occupational safety, so we have established an assessment mathematical model of the rock that takes into account their imposed requirements.

2. Geomechanical assessment methodology of rocks

The proposed method consists in achieving a separate sheet or set of separate sheets for each analysed rock sample; the sheets include the properties corresponding to the general and specific requirements that rocks must meet in order to be used in construction. Each characteristic of the rock has been a quantitative assessment indicator and has been marked by giving it a certain score [12], [13].

Each of the characteristics considered as indicators has associated some weighting coefficients, having a value from 1 to 5, depending on the importance of the requirement and the class in which the rocks are classified in relation to the admissibility requirements or conditions. After the assessment of all the characteristics (the indicators in sheets), the conformity level (NC), the safety level (NS) and the degree of nonconformity (GC) according to the obtained score (PO) and the maximum score (PM) was performed [12], [13].

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Conformity level (NC) is obtained as a ratio between the obtained score (PO) and the maximum score (PM), expressed as a percentage [2]. It expresses the extent to which the requirements of the assessment criteria are respected for the analysed rock, giving equal importance to all requirements.

$$NC = \frac{PO}{PM} \cdot 100 \quad [\%] \tag{1}$$

- Obtained score (PO) is calculated with the relationship:

$$PO = A + B + C + D + E \tag{2}$$

- Maximum score (PM) is calculated with the relationship

$$PM = 5 \cdot (f + g + h + i + j) \tag{3}$$

Nonconformity degree (GNC) is the difference between the maximum percentage value (100 %) and the conformity level value (NC), expressing the manner in which the analysed rock does not accomplish the requirements that form the assessment criteria.

$$GNC = 100 - NC \quad [\%] \tag{4}$$

where: PO represents obtained score; PM – maximum score; A – total scores given to questions having the weight coefficient 5; B – total scores given to questions having the weight coefficient 4; C – total scores given to questions having the weight coefficient 3; D – total scores given to questions having the weight coefficient 2; E – total scores given to questions having the weight coefficient 1; f – number of applicable questions having the weight coefficient 5; g – number of applicable questions having the weight coefficient 4; h – number of applicable questions having the weight coefficient 3; i – number of applicable questions having the weight coefficient 2; j – number of applicable questions having the weight coefficient 1.

The safety level (NS) is the ratio between the obtained score (PO') and the maximum score (PM'), expressing the extent to which the risks of using the analysed rocks are controlled.

$$NS = \frac{PO'}{PM'} \cdot 100 \quad [\%] \tag{5}$$

- Obtained score (PO') is calculated with the relationship:

$$PO' = A \cdot 5 + B \cdot 4 + C \cdot 3 + D \cdot 2 + E \cdot 1 \tag{6}$$

- Maximum score (PM') is calculated with the relationship:

$$PM' = 5 \cdot (f \cdot 5 + g \cdot 4 + h \cdot 3 + i \cdot 2 + j \cdot 1) \tag{7}$$

Insecurity degree:

$$GNS = 100 - NS \quad [\%] \tag{8}$$

where: PO' represents obtained score; PM '– maximum score.

The information obtained by this method refer to unconformities as against the conditions imposed by the standards and which are not fully accomplished, conformity level in relation to the conditions that the rocks must accomplish and the security level when the rocks are used in constructions.

When different classifications for the same type of rock are obtained, the one that indicates the lower class of classification is determinative.

3. Geomechanical assessment of analysed magmatic rocks

For each of the 15 types of analysed rock, choosing the geo-mechanical assessment methodology, the level of compliance, level of safety and unconformity degree was established (table 1-16 and fig.1-15).

Table 1. *Classification of Şoimoş granite, sample 1 depending on the NC, NS, GNC and GNS*

Geomechanical assessment of GRANITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
100 – 90	100.00	Very high	Very low risk	Very good
Security level, NS				
100 – 90	100.00	Very high	Very low risk	Very good
Unconformity degree, GNC				
< 10	0.00	Very low	Very low risk	Very good
Unsecurity degree, GNS				
< 10	0.00	Very low	Very low risk	Very good

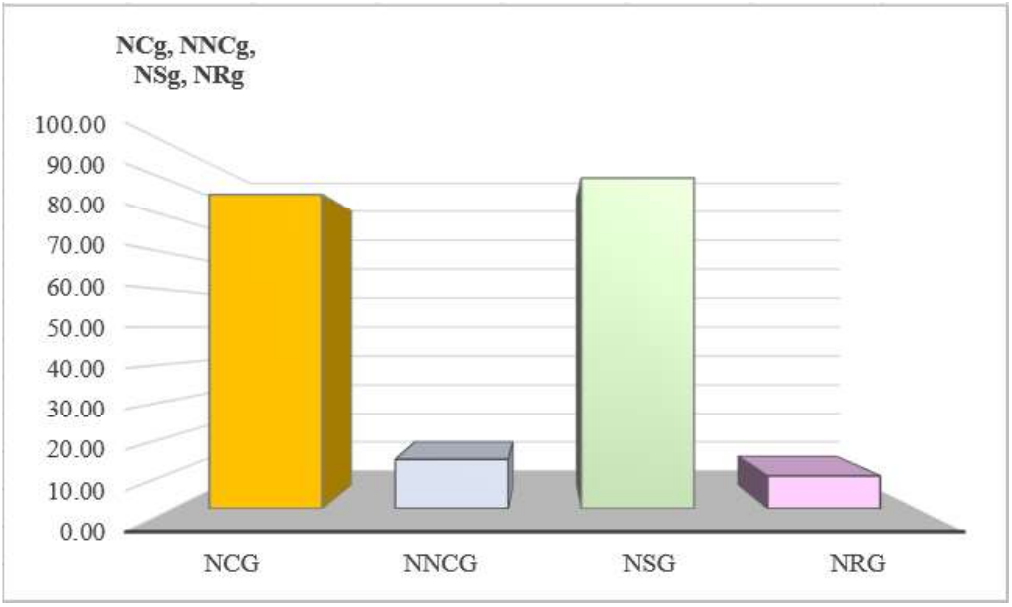

Fig. 1 *Classification of Şoimoş granite, sample 1 depending on the NC, NS, GNC and GNS.*

Table 2. *Classification of Şoimoş granite, sample 2, depending on the NC, NS, GNC and GNS*

Geomechanical assessment of GRANITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
100 – 90	100.00	Very high	Very low risk	Very good
Security level, NS				
100 – 90	100.00	Very high	Very low risk	Very good
Unconformity degree, GNC				
< 10	0.00	Very low	Very low risk	Very good
Unsecurity degree, GNS				
< 10	0.00	Very low	Very low risk	Very good

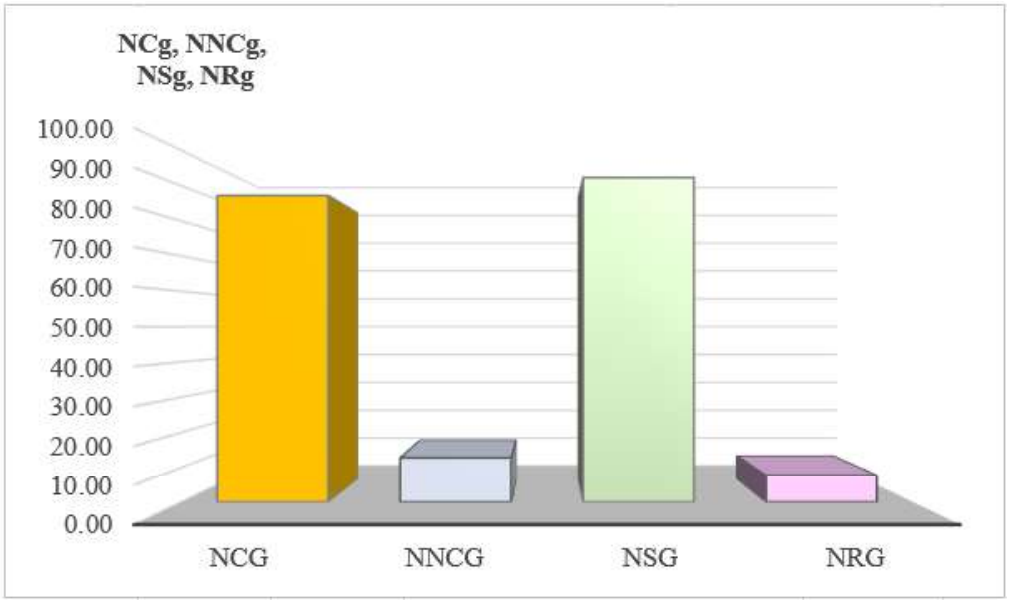

Fig. 2 *Classification of Şoimoş granite, sample 2, depending on the NC, NS, GNC and.GNS*

Table 3. *Classification of Săvârşin granite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of GRANITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
100 – 90	100.00	Very high	Very low risk	Very good
Security level, NS				
100 – 90	100.00	Very high	Very low risk	Very good
Unconformity degree, GNC				
< 10	0.00	Very low	Very low risk	Very good
Unsecurity degree, GNS				
< 10	0.00	Very low	Very low risk	Very good

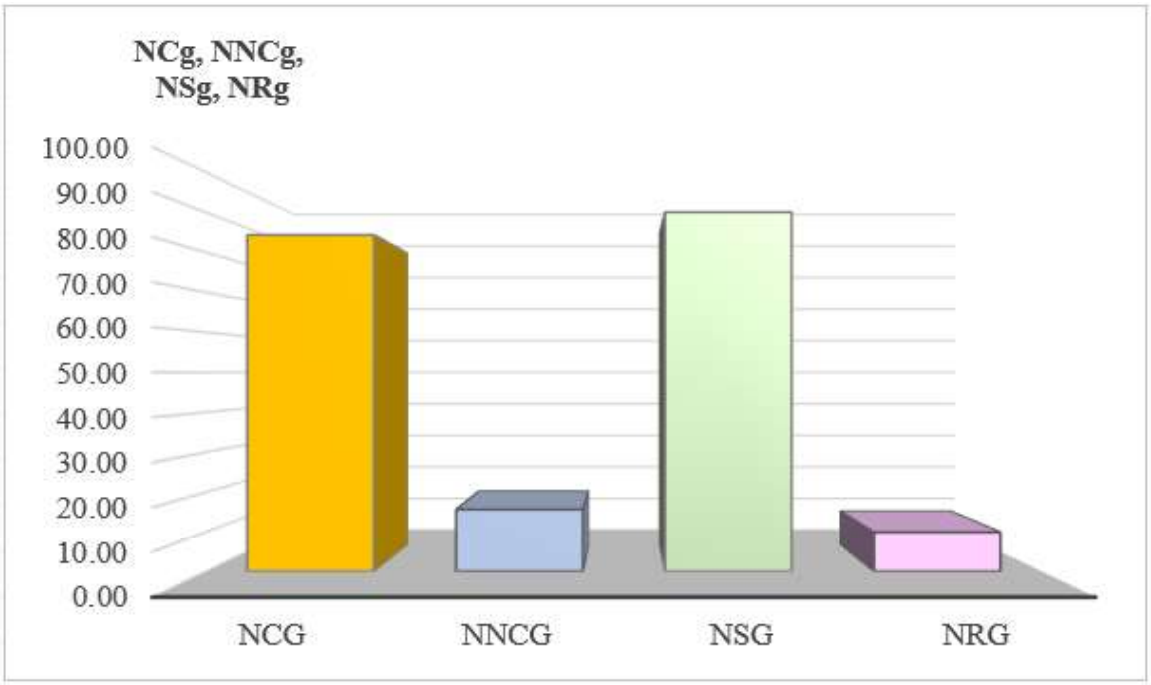

Fig. 3 *Classification of Săvârşin granite depending on the NC, NS, GNC and GNS*

Table 4. *Classification of Şoimoş diorite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of DIORITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
100 – 90	100.00	Very high	Very low risk	Very good
Security level, NS				
100 – 90	100.00	Very high	Very low risk	Very good
Unconformity degree, GNC				
< 10	0.00	Very low	Very low risk	Very good
Unsecurity degree, GNS				
< 10	0.00	Very low	Very low risk	Very good

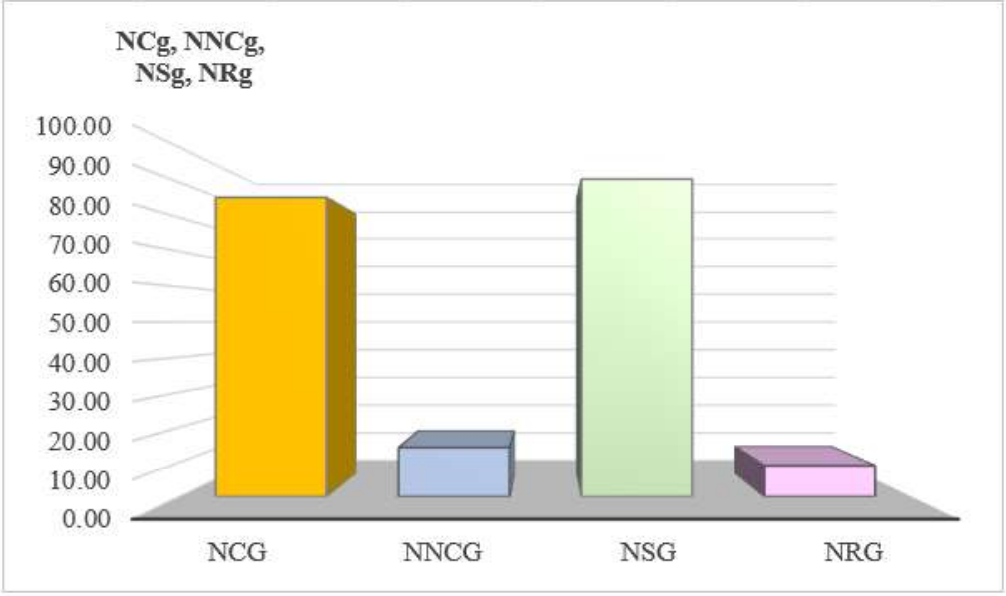

Fig. 4 *Classification of Şoimoş diorite depending on the NC, NS, GNC and GNS*

Table 5. *Classification of Căzăneşti gabbrou depending on the NC, NS, GNC and GNS*

Geomechanical assessment of GABBROU				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
100 – 90	93.33	Very high	Very low risk	Very good
Security level, NS				
100 – 90	94.28	Very high	Very low risk	Very good
Unconformity degree, GNC				
< 10	6.66	Very low	Low risk	Very good
Unsecurity degree, GNS				
< 10	5.71	Very low	Very low risk	Very good

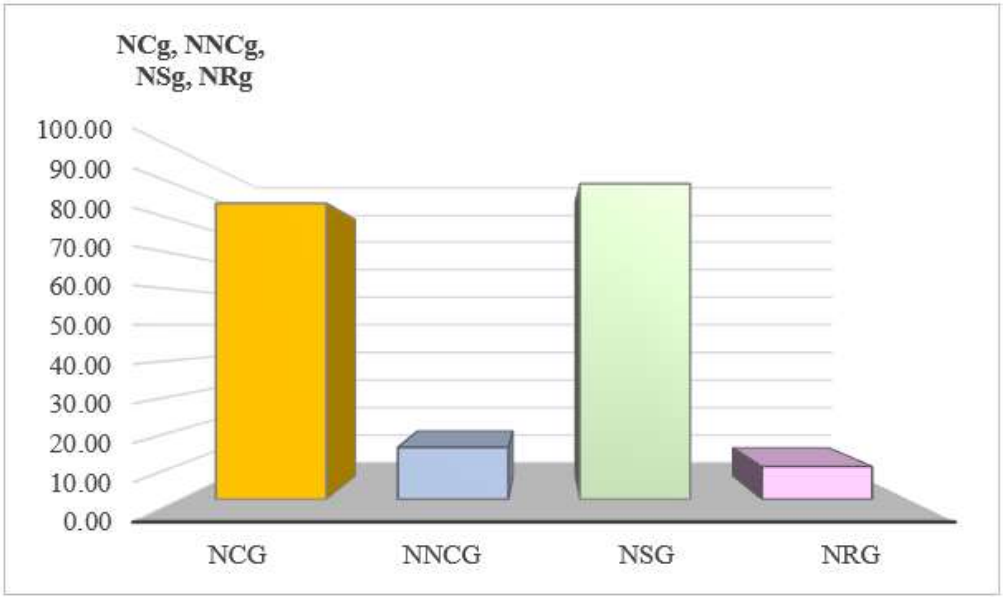

Fig. 5 *Classification of Căzăneşti gabbrou depending on the NC, NS, GNC and GNS*

Table 6. *Classification of Roşia Montană rhyolite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of RHYOLITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
75 – 50	50.00	Medium	Medium risk	Acceptable
Security level, NS				
75 – 50	57.33	Medium	Medium risk	Acceptable
Unconformity degree, GNC				
25 - 50	50.00	Medium	Medium risk	Acceptable
Unsecurity degree, GNS				
25 - 50	42.66	Medium	Medium risk	Acceptable

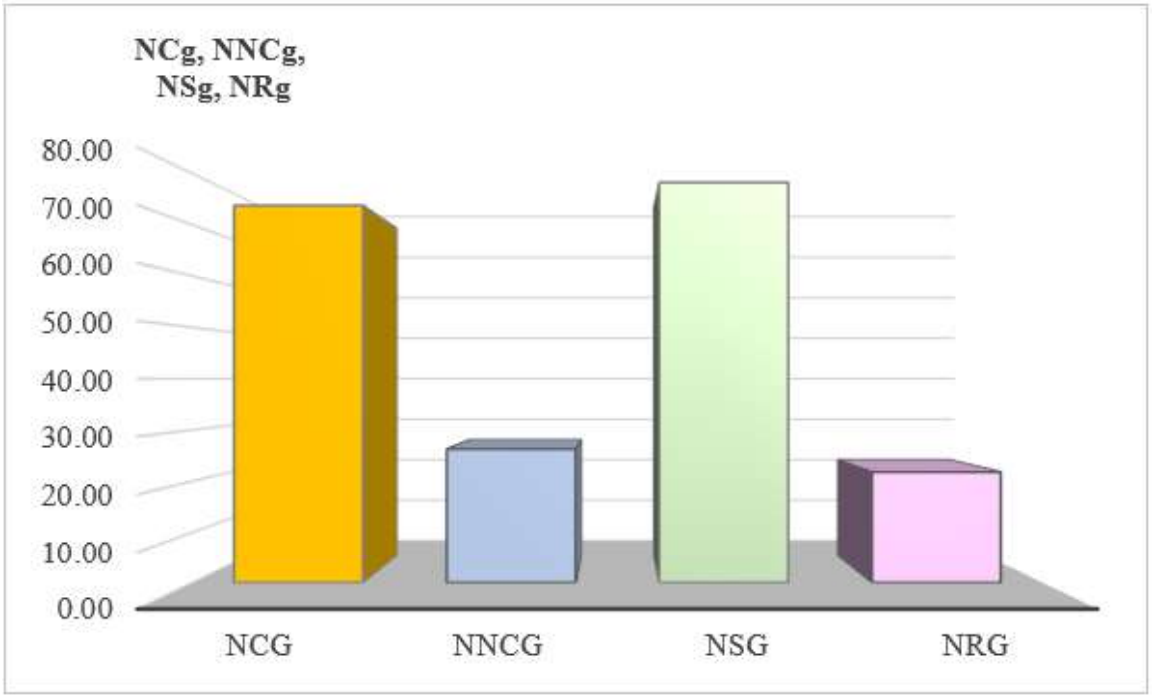

Fig. 6 *Classification of Roşia Montană rhyolite depending on the NC, NS, GNC and GNS*

Table 7. *Classification of Valea Căpitanului andesite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of ANDESITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
75 – 50	76.66	Medium	Medium risk	Acceptable
Security level, NS				
90 – 75	82.60	High	Low risk	Good
Unconformity degree, GNC				
10 - 25	23.33	Low	Low risk	Good
Unsecurity degree, GNS				
10 - 25	17.39	Low	Low risk	Good

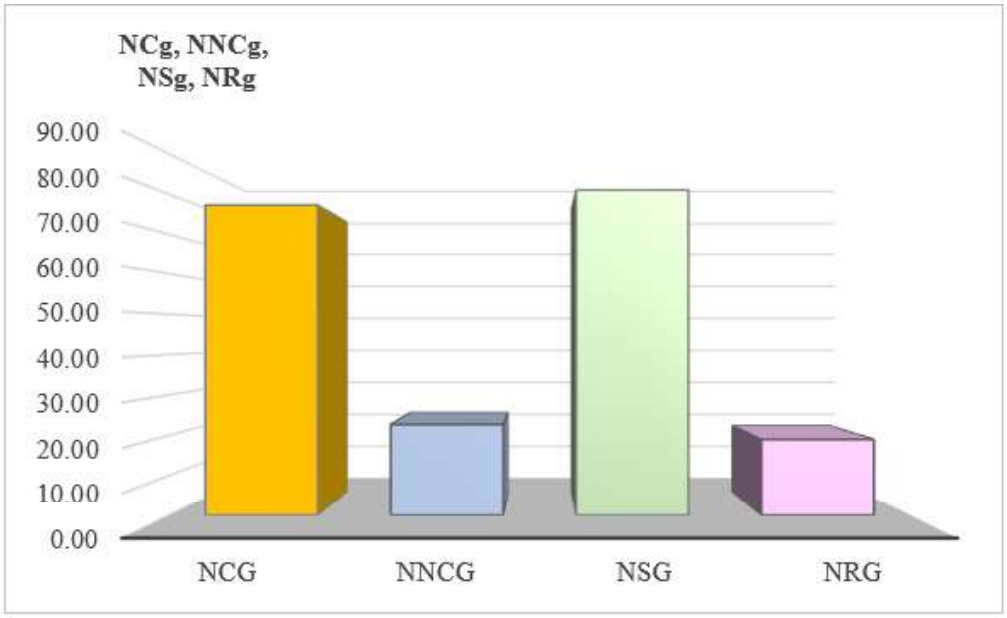

Fig. 7 *Classification of Valea Căpitanului andesite depending on the NC, NS, GNC and GNS*

Table 8. *Classification of Dealul Motor andesite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of ANDESITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
75 – 50	60.00	Medium	Medium risk	Acceptable
Security level, NS				
75 – 50	64.44	Medium	Medium risk	Acceptable
Unconformity degree, GNC				
25 - 50	40.00	Medium	Medium risk	Acceptable
Unsecurity degree, GNS				
25 - 50	35.55	Medium	Medium risk	Acceptable

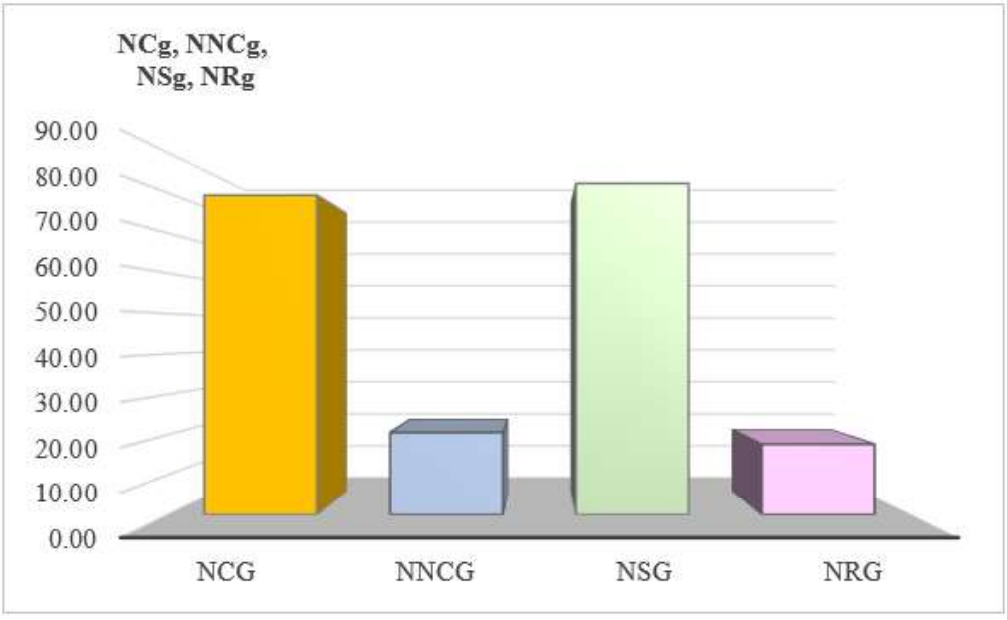

Fig. 8 *Classification of Dealul Motor andesite depending on the NC, NS, GNC and GNS*

Table 9. *Classification of Criscior andesite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of ANDESITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
90 - 75	86.66	High	Low risk	Good
Security level, NS				
90 - 75	87.69	High	Low risk	Good
Unconformity degree, GNC				
10 - 25	13.34	High	Low risk	Good
Unsecurity degree, GNS				
10 - 25	12.31	High	Low risk	Good

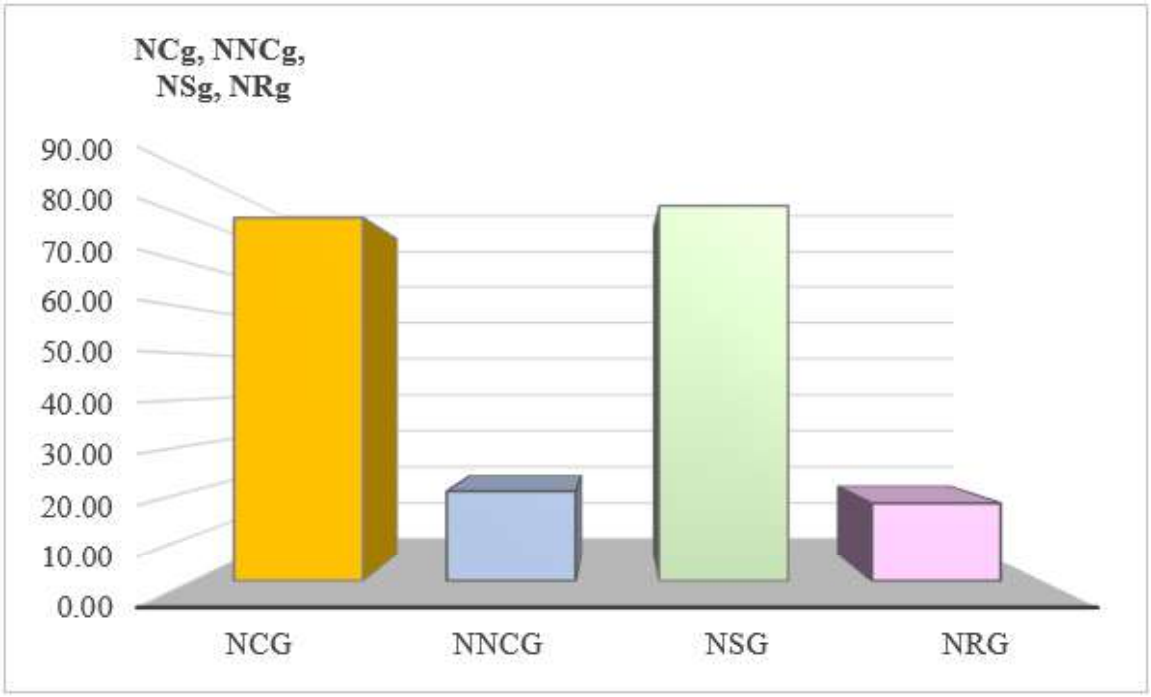

Fig. 9 *Classification of Criscior andesite depending on the NC, NS, GNC and GNS*

Table 10. *Classification of Săcărâmb andesite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of ANDESITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
75 - 50	50.00	Medium	Medium risk	Acceptable
Security level, NS				
75 - 50	54.66	Medium	Medium risk	Acceptable
Unconformity degree, GNC				
25 - 50	50.00	Medium	Medium risk	Acceptable
Unsecurity degree, GNS				
25 - 50	45.33	Medium	Medium risk	Acceptable

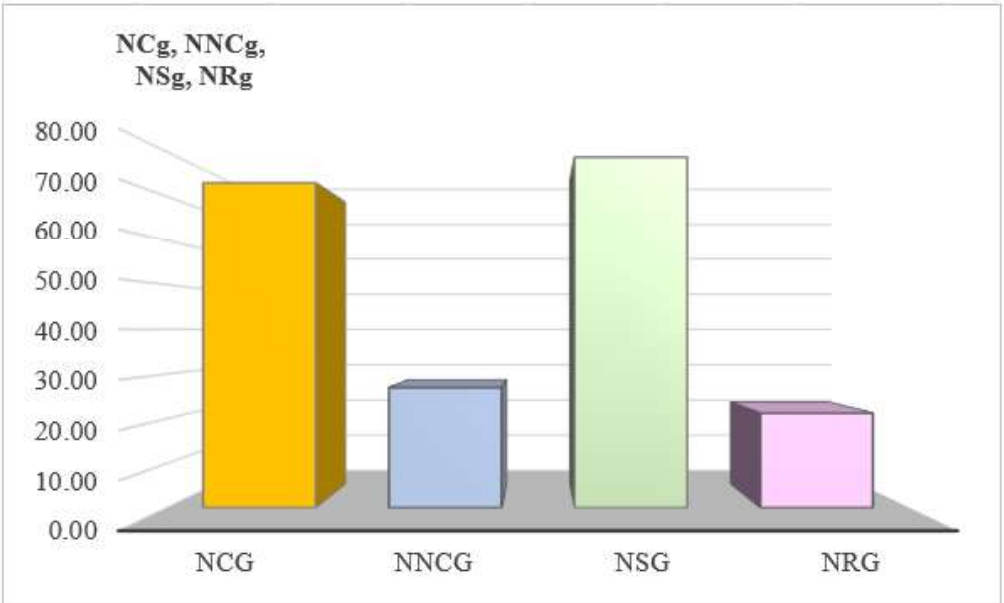

Fig. 10 *Classification of Săcărâmb andesite depending on the NC, NS, GNC and GNS*

Table 11. *Classification of Albinii-Haneş andesite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of ANDESITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
90 - 75	90.00	High	Low risk	Good
Security level, NS				
100 - 90	91.11	Very high	Very low risk	Very good
Unconformity degree, GNC				
10 - 25	10.00	Low	Low risk	Good
Unsecurity degree, GNS				
< 10	8.89	Very low	Very low risk	Very good

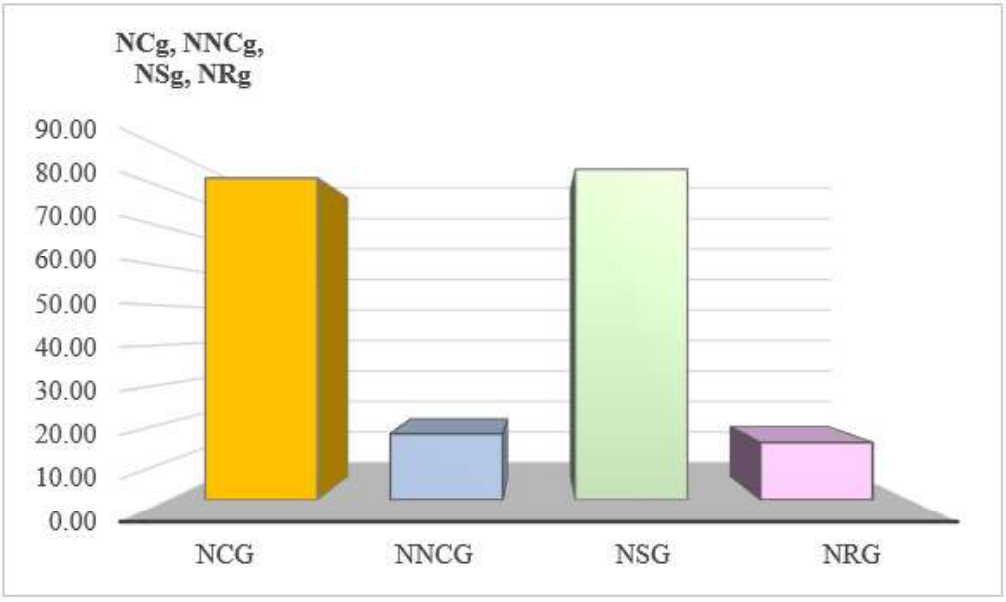

Fig. 11 *Classification of Albinii-Haneş andesite depending on the NC, NS, GNC and GNS*

Table 12. *Classification of Roşia Montană andesite depending on the NC, NS, GNC and GNS*

Geomechanical assessment of ANDESITE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
90 - 75	76.66	High	Low risk	Good
Security level, NS				
90 - 75	79.13	High	Low risk	Good
Unconformity degree, GNC				
10 - 25	23.34	Low	Low risk	Good
Unsecurity degree, GNS				
10 - 25	20.87	Low	Low risk	Good

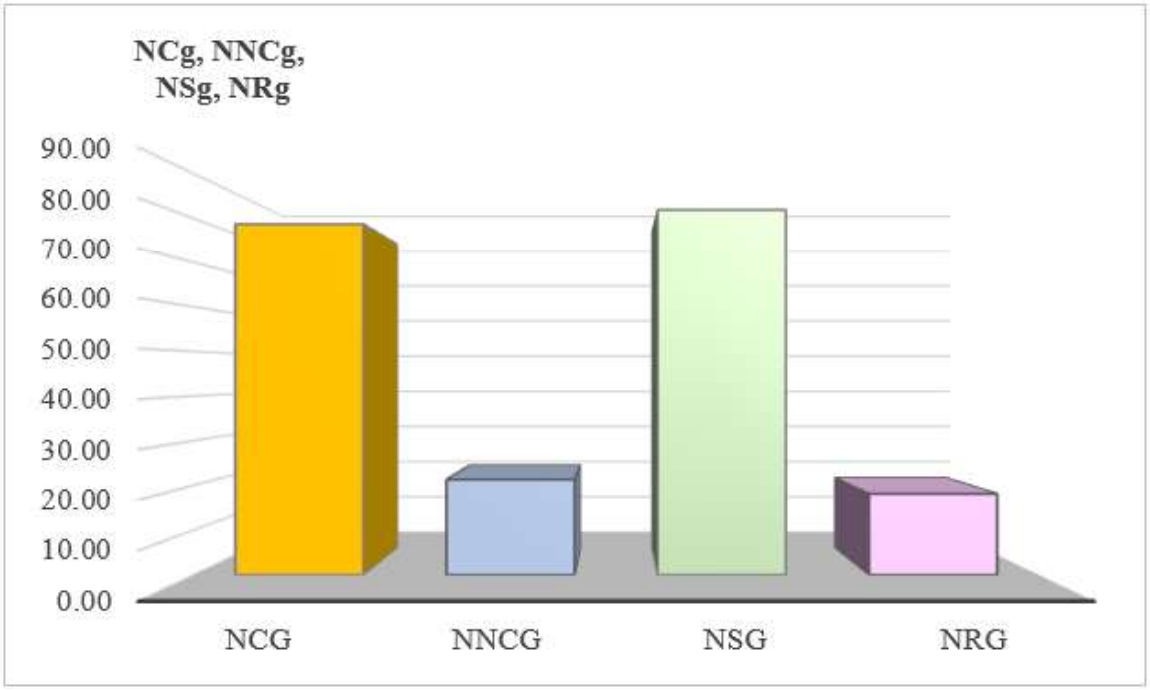

Fig. 12 *Classification of Roşia Montană andesite depending on the NC, NS, GNC and GNS*

Table 13. *Classification of Căzăneşti diabase depending on the NC, NS, GNC and GNS*

Geomechanical assessment of DIABASE				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
90 - 75	90.00	High	Low risk	Good
Security level, NS				
100 - 90	92.59	Very high	Very low risk	Very good
Unconformity degree, GNC				
10 - 25	10.00	Low	Low risk	Good
Unsecurity degree, GNS				
< 10	7.40	Very low	Very low risk	Very good

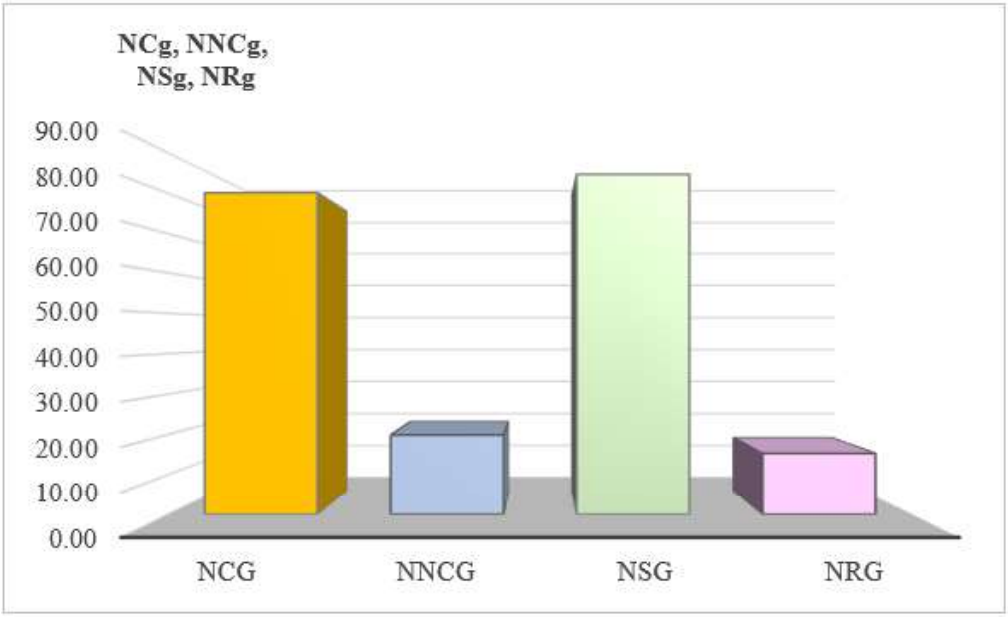

Fig. 13 *Classification of Căzăneşti diabase depending on the NC, NS, GNC and GNS*

Table 14. *Classification of Brănişca basalt depending on the NC, NS, GNC and GNS*

Geomechanical assessment of BASALT				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
100 - 90	100.00	Very high	Very low risk	Very good
Security level, NS				
100 - 90	100.00	Very high	Very low risk	Very good
Unconformity degree, GNC				
< 10	0.00	Very low	Very low risk	Very good
Unsecurity degree, GNS				
< 10	0.00	Very low	Very low risk	Very good

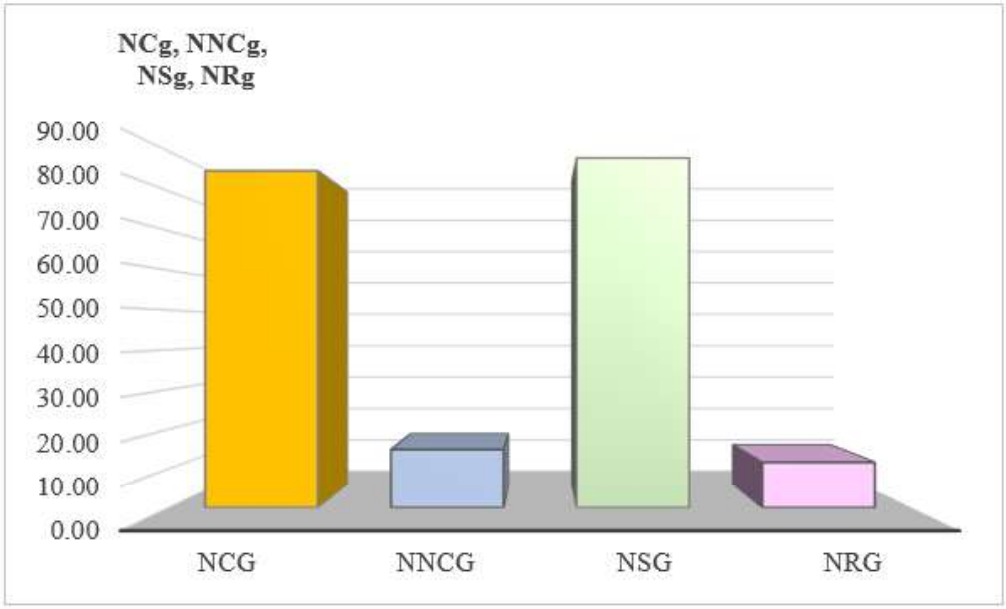

Fig. 14 *Classification of Brănişca basalt depending on the NC, NS, GNC and GNS*

Table 15. *Classification of Dobra basalt depending on the NC, NS, GNC and GNS*

Geomechanical assessment of BASALT				
Given values by classification	Obtained values	Classification	Use risk	Characterization
Conformity level, NC				
100 - 90	100.00	Very high	Very low risk	Very good
Security level, NS				
100 - 90	100.00	Very high	Very low risk	Very good
Unconformity degree, GNC				
< 10	0.00	Very low	Very low risk	Very good
Unsecurity degree, GNS				
< 10	0.00	Very low	Very low risk	Very good

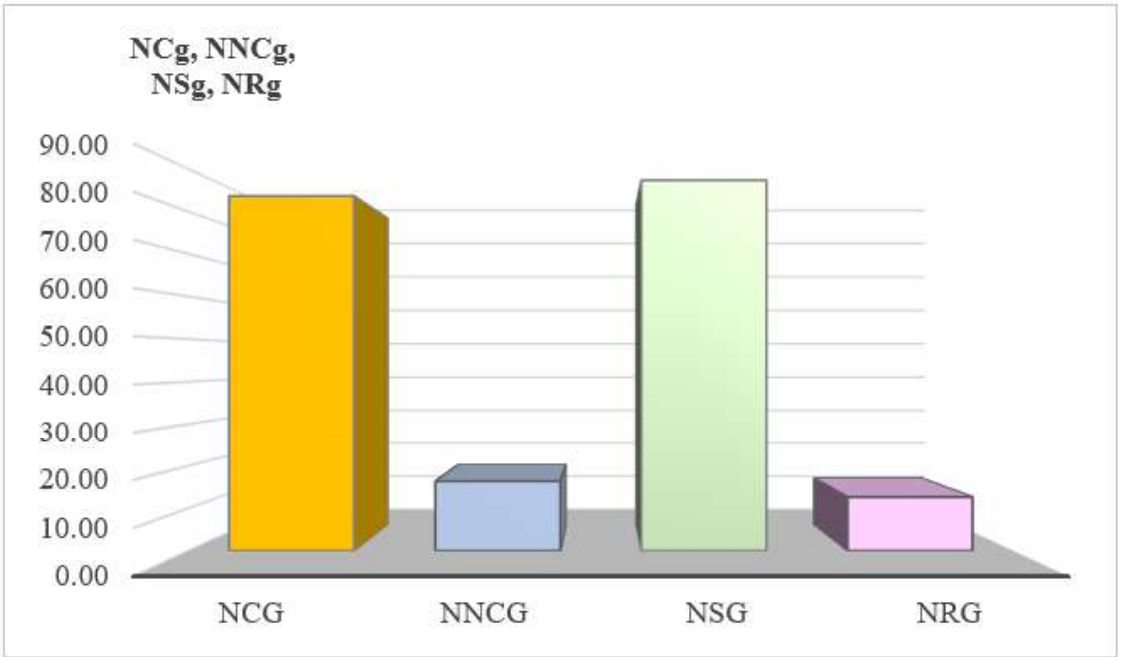

Fig. 15 *Classification of Dobra basalt depending on the NC, NS, GNC and GNS*

Table 16. *Analysed rocks classification depending on NCg, NSg, NNCg and NRg*

Given values by classification	Analysed rock type	Classification	Risk of use	Characterization
General Conformity Level, NCg				
100 – 90	-	Very high	Very low	Very good
90 – 75	Şoimoş Granite 1; Şoimoş Granite 2; Săvârşin Granite; Şoimoş Diorite; Căzăneşti Gabbro; Dealul Motor Andesite; Crişcior Andesite; Haneş Andesite; Roşia Poieni Andesite; Căzăneşti Diabase; Brănişca Basalt; Dobra Basalt	High	Low	Good
75 – 50	Roşia Montană Rhyolite; Valea Căpitanului Andesite; Săcărâmb Andesite	Medium	Medium	Acceptable
50 – 25	-	Low	High	Poor
< 25	-	Very low	Very high	Very poor

General Security Level, NSg				
100 – 90	Șoimoș Granite 1;Șoimoș Granite 2; Săvârșin Granite; Șoimoș Diorite; Căzăneşti Gabbro	Very high	Very low risk	Very good
90 - 75	Săvârșin Granite; Roşia Montană Rhyolite; Valea Căpitanului Andesite; Dealul Motor Andesite; Crişcior Andesite ; Săcărâmb Andesite; Haneş Andesite ; Roşia Poieni Andesite; Căzăneşti Diabase; Brănişca Basalt; Dobra Basalt	High	Low risk	Good
75 – 50	-	Medium	Medium	Acceptable
50 – 25	-	Low	High	Poor
< 25	-	Very low	Very high	Very poor
General Unconformity Level, NNCg				
< 10	-	Very low	Very low	Very good
10 - 25	Șoimoș Granite 1;Șoimoș Granite 2; Săvârșin Granite; Șoimoș Diorite; Căzăneşti Gabbro; Valea Căpitanului Andesite; Dealul Motor Andesite; Crişcior Andesite; Haneş Andesite; Roşia Poieni Andesite; Căzăneşti Diabase; Brănişca Basalt; Dobra Basalt	Low	Low	Good
25 – 50	Roşia Montană Rhyolite; Săcărâmb Andesite	Medium	Medium	Acceptable
50 – 75	-	High	High	Poor
75 – 100	-	Very high	Very high	Very poor
General Risk Level, NRg				
< 10	Șoimoș Granite 1;Șoimoș Granite 2; Săvârșin Granite; Șoimoș Diorite; Căzăneşti Gabbro	Very low	Very low	Very good
10 - 25	Roşia Montană Rhyolite; Valea Căpitanului Andesite; Dealul Motor Andesite ; Crişcior Andesite; Săcărâmb Andesite; Haneş Andesite; Roşia Poieni Andesite; Căzăneşti Diabase; Brănişca Basalt; Dobra Basalt	Low	Low	Good
25 – 50	-	Medium	Medium	Acceptable
50 – 75	-	High	High	Poor
75 – 100	-	Very high	Very high	Very poor

4. Conclusions

Depending on the imposed conditions of admissibility, rocks of origin were classified in classes from A to D. Applying this evaluation system allows to determine the specific parameters of the rock quality requirements, namely the conformity and unconformity degree, that is the safety level these rocks provide if they are used in the construction field, either as aggregates or as construction materials.

The proposed method constitutes an appropriate instrument for the assessment and verification of the requirements regarding the quality of rocks used in construction. Concerning the proposed classification relating to the correlation between safety criterion, respectively the risk of rocks use and their admissibility in construction, the obtained results show that from the analysed types of rocks, more than 80 % of these fall into the class of rocks with high and very high safety level, which means that the

risk of use is very low to low, in some cases being even completely absent, which means a high and very high conformity level.

Relative to the imposed conditions of admissibility, provenience rocks were classified in classes from A to D, as follows: granite, diorite, basalt and a part of andesite rocks type falling in class A, as being rocks with high degree of safety and very good for constructions; diabases and a large part of andesites are included in class B with a high level of safety and conformity; andesites from Deva – Certej area are included in class C, with a medium level of security and conformity; Săcărâmb andesite and Roşia Montană rhyolite have been identified in class D from the viewpoint of their conformity and safety level.

Rock assessment criteria are explicit and correspond to the general and specific requirements of the existing standards. In the proposed method, rock characteristics were considered as indicators of quantitative assessment, and the scoring system, through the scores given, allows the classification of rocks in the admissibility classes.

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