Geomechanic Study Regarding the Stability of the Surface Mining Constructions Belonging to the Mining Perimeter of Certej

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Abstract
Within the context of the extended economic crisis, as a whole, gold and silver ores are now largely paid attention to by investors. In Romania, they have carried out, during the last years, a large number of researches regarding the prospection and planning of the exploitation of new Au-Ag ore deposits. The University of Petrosani, owing to its Laboratory of Rocks Mechanics, largely contributed to such research works, through the geomechanical analyses gathered from the mining areas of the “Golden Quadrangle” in the Apuseni Mountains. This paper presents the results of these geomechanical studies made in perimeters mentioned. The hereby paper displays conclusions determined by the geotechnical researches of the mining perimeter of Certej, performed in the Geomechanics Laboratory of the University of Petrosani, with a view to opening and exploiting the gold and silver deposit as part of a new mining project.

Keywords: geotechnical study, constructions stability, gold deposits, mining

Introduction
Raw materials are fundamental to Europe’s economy, growth and jobs and are essential for maintaining and improving our quality of life. While the importance of energy materials, such as oil and gas, has often been highlighted, historically, the
indispensable role of metals, minerals, rocks and biotic materials has had a lower profile. The EU has many uncharacterised and unexplored deposits; however, the existing economic and regulatory climate, combined with growing land use competition limits the exploitation. Secondary supplies can reduce the demand for primary materials. However, for many materials very little recycling and recovery occurs. Therefore much of Europe’s industry and economy is reliant on international markets to provide access to essential raw materials [4].

However, more recently, securing, reliable, sustainable, and undistorted access to crucial non-energy raw materials has been of growing concern in economies, such as those of the EU, US and Japan. Raw materials are also an integral part of the Europe 2020 strategy [7] to ensure smart, sustainable and inclusive growth and are closely linked to the flagship initiatives - "Industrial policy for the globalization era" [5] and "Resource efficient Europe" [6].

The European board in the field of the policies regarding trade and investments with a view to improving the access to the primary resources enumerates a series of operations required in order to: (i) promote exploration and support the idea that such an exploration performed by companies is regarded as a research activity; (ii) promote research in the field of processing minerals, of extracting out of former dumps, of extracting deep deposits and exploration as a whole, mainly according to the European Union basic programs in the domains of research and technology (iii) promote development, a positive management as well as the capacity and transparency of the extractive industries in the countries under development, especially in terms of critical raw materials; promote a durable exploration and extraction both within and outside the European Union.

Those European countries with important gold reserves have invested in the building of a serried of modern and efficient exploitations for the extraction of the gold ores. The most relevant examples in the field are Turkey, Sweden, Finland, and Greece.

The **Strategy of the mining industry from Romania during the period 2012-2035**, updated in 2012, in terms of the Au-Ag ores, reveals the following, according to the SWOT analysis [10]:

**Strengths**: existence of resources rising to 760 million tons of ore; existence of the infrastructure involving the CIP-CIL procedure processing; existence of the capacity of administering medium-term mining scraps; existence of geological researches in the oxidation area including the opportunity of developing surface exploitations; existence of mines whose opening and preparation works suit the modern exploitation technologies; existence of the opportunity of developing technological clusters of the type: one plant – several sources.

**Weaknesses**: the underground mines undergo a termination process; there are no large capacity technological installations for the processing of the gold ore; metallurgic industry decreased or ceased its activity; resuming underground exploitation requires increased investments.

**Opportunities**: gold ore market is stable and continually growing during the last years; the processing of both the waste belonging to the previous ponds and of the stocks of gold arsenious pyrites determine the greening of large areas where these deposits are located; positive social consequences capable of decreasing unemployment.

All these facts represent guarantees for the foreign investors willing to invest in the field.
Consequently, Romania displays a significant investment potential able to determine the carrying out of the exploration operations and the re-evaluation of the perimeters already thoroughly investigated. Meanwhile, recent geological and geophysical activity has shown that there are a large number of perimeters exhibiting an important potential for supplemental investigations, which also offer opportunities for the investors interested in the country’s mineral resources.

1. Aspects Regarding Gold Exploitation in Romania

At present, the activity of Romania’s mining field is regulated by the Mines Law no. 85/2003 and the methodological standards regarding its implementation, approved by the Government Decision (H.G.) no. 1208/2003, which represents the main legislation in the domain.

There are currently, two exploitation licenses and seven gold and silver exploration licenses are valid, according to the data displayed by the National Agency for Mineral Resources: Roşia Montană, Alba – Roşia Montană Gold Corporation S.A. and Certej, Hunedoara – Deva Gold S.A. If the two projects that have operating licenses would start gold production, Romania would go first in the ranking of the largest gold producing countries in Europe [1].

The exploration licenses are the following ones:

- Băişoara, Alba – Rom Aur S.R.L.
- Băişoara, Cluj – Rom Aur S.R.L.
- Rovina, Hunedoara – Samax România S.R.L.
- Aluniş, Piatra Handal – East area, Maramureş – Romaltyn Exploration S.R.L.
- Poprad, Maramureş - Romaltyn Exploration S.R.L.
- Aluniş, Piatra Handal – West area, Maramureş – Romaltyn Exploration S.R.L.
- Camarzana Nord, Satu Mare - Romaltyn Exploration S.R.L.

Rosia Montana Gold Corporation, RMGC, obtained the concession license for exploitation in 1999, in order to exploit the gold and silver ores in the Roşia Montană area. The mining perimeter of RMGC has a surface of 21.45 square kilometres and it overlaps the area of Valea Roşia River and its junction with Abrud River. The project covers 25% of the surface of Roşia Montană, a traditional mining community, located in the Apuseni Mountains [8].

The gold mining project in Rosia Montana is one of the most important investments in Romania, during the last years. The implementation of this project may lead Romania to the top of the gold producers in the European Union. The project is operated by Rosia Montana Gold Corporation (RMGC), which represents an association between the Canadian company called Gabriel Resources (76%) and the Romanian state, through Minvest Company in Deva (24%).

Roşia Montană Mining Project includes the following objectives: the processing plant, Corna Valley Tailings Dam, 4 open pits: Cetate, Carnic, Jig and Orlea, the waste dams of Gura Roşiei and Valea Săliştei. In addition to these main access roads, service roads will be constructed to connect the plant site, four open pits (Cetate, Ciörnic, Jig and Orlea), waste rock dumps (Cetate and Ciörnic) and the TMF, Corna Tailings Dam [1, 8].

Certej project regards the extraction and concentration through flotation of an average amount of 30 million tons of gold ore, followed by the processing of 315
thousand tons/year of gold concentrate, during 11 years, together with the storage and management of the waste resulting from mining and processing.

Certeju de Sus is an old mining centre in Hunedoara County, located in the South-Eastern part of Apuseni Mountains. The settlement is part of the “Golden Quadrangle” of Apuseni Mountains, in the area of the following towns: Deva, Brad, Baia de Arieș and Zlatna. 80% of Certej mining project belongs to the Canadian company called Eldorado Gold, while less than 20% belongs to the Romanian state. The gold deposit within Certej perimeter, evaluated at 45.5 million tons, with a concentration of 1.8 g/t Au, and 10 g/t Ag, proposes for exploitation a surface of 456.2 ha. Characterized by 16-year duration and a processing capacity of 3 million tons of ore per year, Certej mining project implies clearings, stripping, the carrying out of an open quarry, two huge dumps, and the use of cyanides in order to get gold as well as two ponds measuring 63.6 ha [9].

Ore processing is expected to be carried out in several stages, owing to the following techniques: the 1st stage – ore floating and obtaining of a gold concentrate and of a floating sterile; the 2nd stage – oxidation of the concentrate of gold pyrite (Albion process); the 3rd stage – cyanidation of oxidized concentrate, electrolytic retrieval of gold and silver, and casting into bullions of Dore alloy [9]. The main dam of the cyanidation pond CIL is going to be placed on Macris River, at about 1.8 km upstream from its junction with its right affluent, Avram’s stream. The dam is projected so that it is able to support, upstream, the whole amount of flotation sterile, namely 25 million tons, which comes from the ore processing plant, during the entire period of the deposit’s exploitation. It is estimated that, for the maximum cant quota, 4.5 million tons of cyanidation sterile are going to be stored in the pond.

2. Geotechnical Study of the Rocks Within Certej Perimeter

Certej mining perimeter displays as the valley of the stream called Valea Băiegii, with slopes whose bent ranges between $\alpha = 3...32^{\circ}$; here and there, this bent becomes more abrupt. The slope diluvium is made of dust, colloidal argyles, sandy and dusty argyles, argyle and sandy dusts, argyle sands with spare gravel and high humidity ($w = 2.336 - 44.22\%$), either in consistent state or lax on a surface with $I_p=13.82 - 61.01$.

The southern slope displays permanent springs, which maintain a high humidity of the surface grounds and determine the decrease of their mechanic and resistance characteristics. The frost depth of the foundation ground, $Z$, has been calculated according to the type of the ground, to the frost index, and to the adverse hydro-geological conditions, for all types of rocks: argyle dusts, argyles. The frost depth of the foundation ground for the categories of grounds identified within the location is: $Z = 0.80...1.50$ m, in case of rigid road structures, $Z = 0.75...1.10$ m, in case of non-rigid road structures: for heavy and very heavy traffic classes, $Z = 0.70...1.0$ m, in case of non-rigid road structures: for medium, light and very light traffic classes.

In order to carry out the Geotechnical Study on the location of the surface mining structures, a series of geotechnical drillings have been made within the analyzed perimeter. The rocks in Certej mining perimeter have been analyzed in the Laboratory of Analyses and Trials in Constructions of the University of Petrosani. The geotechnical parameters that have been determined owing to trials carried out in the area and in laboratory are displayed in Tables 1, 2 and 3 [9].
Table 1. Physical characteristics of the rocks

<table>
<thead>
<tr>
<th>No.</th>
<th>Specific weight $\gamma$ [kN/m$^3$]</th>
<th>Bulk density $\gamma_a$ [kN/m$^3$]</th>
<th>Porosity n</th>
<th>Natural humidity W [%]</th>
<th>High plasticity limit Wc [%]</th>
<th>Low plasticity limit Wf [%]</th>
<th>Plasticity index Ip</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>26.80</td>
<td>1.70</td>
<td>30.22</td>
<td>25.992</td>
<td>36.15</td>
<td>21.65</td>
<td>14.50</td>
</tr>
<tr>
<td>2</td>
<td>26.32</td>
<td>17.31</td>
<td>34.23</td>
<td>44.222</td>
<td>51.32</td>
<td>32.57</td>
<td>18.75</td>
</tr>
<tr>
<td>4</td>
<td>25.27</td>
<td>19.58</td>
<td>22.52</td>
<td>21.776</td>
<td>43.80</td>
<td>25.26</td>
<td>18.54</td>
</tr>
<tr>
<td>5</td>
<td>25.98</td>
<td>17.96</td>
<td>30.87</td>
<td>34.802</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>27.30</td>
<td>24.98</td>
<td>8.50</td>
<td>2.336</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>23.78</td>
<td>18.03</td>
<td>24.18</td>
<td>42.550</td>
<td>103.00</td>
<td>41.99</td>
<td>61.01</td>
</tr>
<tr>
<td>8</td>
<td>26.26</td>
<td>18.71</td>
<td>28.75</td>
<td>24.660</td>
<td>40.2</td>
<td>26.38</td>
<td>13.82</td>
</tr>
<tr>
<td>9</td>
<td>26.06</td>
<td>17.47</td>
<td>32.96</td>
<td>23.329</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The position of these drillings has been decided in a manner that could allow the determination of the tilt steering of the layers that compose the slope diluvium on the slopes, the colluviums on the valley, and their thickness.

The rocks that compose the foundation of surface mining constructions are located at depths ranging between ± 0.00 m and -25.00 m.

These rocks are characterized by high humidity, and, due to this reason, the consistency of such cohesive and poorly cohesive grounds appears as a viscous stuff, determining their turning into potentially sliding grounds.

According to the modules of eudometric deformation, these grounds are characterized by a very high deformability; meanwhile, under vertical loadings, $p = 200$ kPa, specific deformations may occur in the interval $\varepsilon_{p=2}=4.00 \ldots 9.61\%$ (cm/m). The strength characteristics display very low values, a fact that allows the classification of such grounds within the category of very poor shear resistance grounds.

The rocks that exhibit a vigorous and solid condition have very low deformability characteristics and very good shear resistance. These rocks are considered to be stable grounds, where no phenomena of instability through gliding occur in case they are protected against deep water penetration. The rock samples of this type, once in contact with water, rapidly turn into plastic condition and even into fluid condition, according to the tests carried out in the laboratory.

According to the characteristic in Tables 1, 2, and 3 [9], clay rocks at the surface of the foundation ground are contractile rocks, belonging to the category of grounds with important swellings and contractions (PUCM); they are ranged in the category of active and very active grounds, while foundation on such rocks is possible according to Standard NP 126 – *Foundation of construction on grounds with important swellings and contractions* [2].
From a geotechnical point of view, we consider that the instability phenomena of the slopes occur in saturated surface grounds, with very high deformability [2].
In case of the rocks with important swellings and contractions, the swelling phenomena determine the increase of the active pushing coefficient, which may attain the following values $K_a = 0.700...0.800$. This increase of active pushing is witnessed in case of the foundation works on embankments occurring during the dry months, in summer, when the phenomenon of ground contraction is quite important; in autumn and winter, the phenomenon of swelling occurs, allowing the supplemental manifestation of the pushing forces on buried elements.

The careful systematization of the area in terms of collecting meteoric waters is required so that the infiltration of the meteoric waters into the foundation ground would not affect, in time, the physical and mechanic characteristics of the rocks that compose the perimeter.

3. Rocks’ Use for the Infrastructure of Roads

The possibility of using the rocks resulted from the excavation within Certej mining perimeter for the infrastructure of terrestrial communication ways and the in dam of the decantation pond has also been analyzed. Their ranging within admissibility classes according to the standards afferent to their use in constructions have been checked, too. Rocks from several locations of the perimeter have been analyzed with a view to decide upon the best location of the surface mining constructions [2].

In order to use the rocks for the infrastructure of terrestrial communication ways and the concretes employed for the foundations of surface industrial constructions, they have to meet Standard SR 667/2001. According to the standard, the rocks having resulted out of quarry products are classified in five categories: A, B, C, D, E, depending on their main intrinsic physical and mechanic characteristics: apparent porosity at normal pressure; strength at dry compression; wear, through Los Angeles type machines; strength at crushing through dry compression; and strength at frost – defrost [1].

The products of natural rock used for the infrastructure of terrestrial communication ways and concretes should come from: magmatic rocks, metamorphic or sedimentary rocks [2].

The rocks employed in order to get the products of natural rock classified according to their intrinsic characteristics, used for the infrastructure of terrestrial communication ways and the concretes for road works, should range within admissibility classes, according to the standard in force. The results of the trials performed on the rocks resulted from the analyzed drills belonging to Certej mining perimeter show that they range within class A and could be used for the surface mining constructions that are going to be carried out in Certej mining area as show in Table 4.

The rocks should be: homogeneous in terms of their structure and their petrography and mineralogical composition; without visible traces of physical or chemical degradation; lack pyrite, limonite or soluble salts; lack microcrystalline or amorphous silica that might react with the alkalis in the concrete [3].

It is forbidden to use natural aggregates containing granules made of more than 10% of altered, lax, friable, porous, and vacuole rocks, in case of crushed stone, and 5% in case of chippings.
Table 4. Conditions of admissibility

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Rock class</th>
<th>Value obtained from tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity at normal pressure %, (maximum value)</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Compressive strength, in the dry state, N/mm²</td>
<td>160</td>
<td>140</td>
</tr>
<tr>
<td>Wear on the machine type Los Angeles, %, (maximum)</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Strength crushing by compression in the dry state %, (minimum)</td>
<td>70</td>
<td>67</td>
</tr>
<tr>
<td>Resistance to freeze - thaw:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- frost coefficient ($\mu_{25}$), %, max.</td>
<td>max. 3</td>
<td></td>
</tr>
<tr>
<td>- Sensitivity to frost ($\eta_{25}$), %, max.</td>
<td>max. 25</td>
<td></td>
</tr>
<tr>
<td>- Resistance to freezing by treatment with sodium sulphate, %</td>
<td>max. 5</td>
<td></td>
</tr>
</tbody>
</table>

One may notice that the analyzed rocks range within class A and could be used for surface mining constructions and the infrastructure of terrestrial communication ways that are going to be carried out within Certej mining perimeter.

**Conclusions**

Romania exhibits a significant investment potential required in order to perform exploration operations and to re-evaluate the perimeters already displaying consistent data.

The researches undergone up to the present moment show that the slopes adjacent to Certej mining perimeter exhibit a sliding potential, as instability issues of solid ground are accustomed in the history of this area.

These rocks are characterized by high humidity, and, due to this reason, the consistency of such cohesive and poorly cohesive grounds appear as sticky and turn the rocks into potentially sliding grounds.

The surface rocks include two large types of rocks. In terms of geotechnical characteristics, we consider that the phenomena of slope instability appear in case of surface saturated grounds, displaying a high deformability, which compose the 1<sup>st</sup> horizon.

The second type of rocks is considered to be stable; no instability phenomena through sliding occur in case they are protected against deep water infiltration.

It is recommended to carefully systematize the area in terms of collecting meteoric waters, so that water infiltration into the foundation ground would not alter, in time, the physical and mechanical characteristics of the rocks that compose the location of the future surface mining constructions.
Clay rocks on the surface of the foundation ground have a contractile character and range within the category of swelling and high contractions rocks, being classified among the category of active and very active rocks.

The rocks used for the infrastructure of terrestrial communication ways and concretes should come from: magmatic rocks; metamorphic or sedimentary rocks.

The analyzed rocks coming from Certej perimeter range within class A, according to all their determined characteristics, and may be used for the surface mining constructions and terrestrial communication ways that are going to be carried out in Certej mining perimeter.

References


Arad V., Arad S., Cosma V., Geomechanic Study Regarding the Stability
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