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# GEOLOGICAL MODELS AND STABILITY ANALYSIS

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**Abstract:** *Geological models are built to serve various purposes (e.g. reserve evaluation, rock stability analysis, etc.). Several software packages dedicated to geological modeling and rock stability analysis are currently available. The paper presents the workflow for rock stability analysis performed with Slide3 software from Rocscience. An important step is to build the 3D geological model both from the perspective of geometry and rock properties. Doing this in Slide3 is not an easy task and for this reason, we turned to GEOVIA Surpac. The steps were exemplified for the northern area of the Ruschita marble deposit.*
**Keywords:** *geological modeling, slope stability analysis, Slide3 Rocscience software, GEOVIA Surpac software, Ruschita marble*

## 1. Introduction

To perform a slope stability analysis, several software packages are currently available. One of these is Slide3 from Rocscience. Slide3 is designed to be as straightforward as possible to use, for a fully 3D numerical analysis program. The general workflow involves the following steps: 1. Project Settings (Units, Analysis Methods, etc.), 2. Geometry (Add Geometry, Set External, etc.), 3. Groundwater, 4. Define/Assign Materials, 5. Support, 6. Loads, 7. Surface type/Search Method (Slope Limits), 8. Compute and 9. Results [1].

Geometry is by far the most complicated aspect of creating a Slide3 model. Slide3 models can range from simple 2D extrusions to complex 3D geometry requiring many steps to create.

A wide array of geometry modeling tools allows the creation of any complexity of 3D slope model with any number of material regions. Since the steps required to create Slide3 model geometry will vary greatly depending on the model and its complexity, and there are multiple ways to achieve tasks, it is impossible to provide a simple checklist of required steps for geometry creation that apply to all models.

In the case of very complex 3D geometry, importing the 3D model created with other modeling software is much easier than building the 3D geometry in Slide3. In the following, it is presented how the 3D model of the northern area of the Ruschita marble quarry was built, using GEOVIA Surpac 6.9 for this purpose.

## 2. Location and general information on Ruschita marble deposit

The Ruschita marble is a metamorphic stone with high crystallinity and medium-size crystals (until 0.2-0.5 mm). Has the basic color from white and grey to pink, with many intermediary nuances generally given by grey veins and less by impurities from the internal structure. Ruschita marble can be found at Parliament buildings in Bucharest (Romania), Wien (Austria), Budapest (Hungary) and many other places around the world [2].

Located in Poiana Rusca mountains (Figure 1), developed in a large metamorphic area, the marble deposit from Ruschita perimeter is the most important Romanian source of ornamental stone, the old quarry has been operative since 1883.

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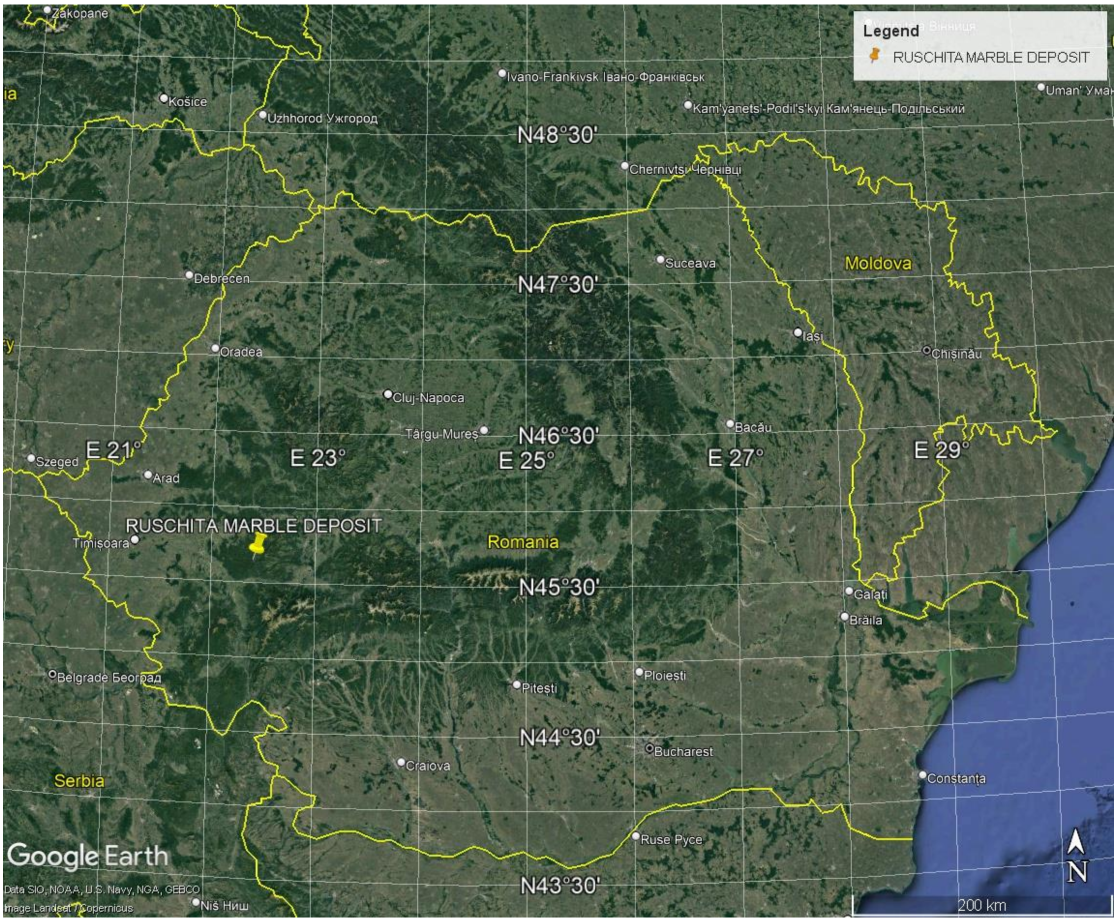

*Fig. 1. Location of the Rușchița marble deposit*

The northern area of the old Ruschita quarry has a complex 3D geometry, involving areas with marble, schist, mixed materials and heaped marble rocks of irregular shape and variable sizes (from cm to tens of cm). The general slope of the old Ruschita quarry extends from elevation 630 to elevation 748 (Figure 2).


*Fig. 2. Overview of the Rușchița quarry before the start of the inner dumping on the floor of the old quarry*

After an attempt at underground exploitation of the marble reserve in the northern area of the old quarry, it was abandoned due to the low degree of recovery of the extracted marble in blocks and on the floor of the old quarry started the dumping of marble rocks of irregular shape and variable sizes with no commercial value. At the time of modeling, the inner dump had an extension of 80 meters at the top and a vertical development between elevations 630 and 671, being used as a temporary storage for the marble extracted in the form of blocks (Figure 3).

*Fig. 3. Overview of the Rușchița quarry with the inner dump on the floor of the old quarry*

**3. Model of the northern area of the Ruschita marble deposit**

In addition to the available geological information, two exploratory drillings were carried out with core recovery, V101 vertical executed in marble at elevation 734, with a length of 50 m and O102 horizontal at elevation 688, with a length of 105 m which intercepted marble zone, mixed zone (transition from marble to schist) and schist zone.

With the help of a drone, a flight was made to acquire surface points. The cloud of points obtained with the drone together with the situation plan in .dwg format [3] was the basis of the modeling in GEOVIA Surpac [4] of the current situation of the terrain morphology and the configuration of the steps of the northern slope of the old Ruschita quarry (Figure 4).

Considering the need to import the information into SLIDE3 to build the geometry for the stability assessment, a virtual box was built in GEOVIA Surpac and all the modeled elements were cut out, keeping only the part inside the virtual box.

Based on the existing information on the situation plan and those obtained from the exploratory drillings, the marble-mixed and mixed-schist contact planes were modeled (Figure 5).

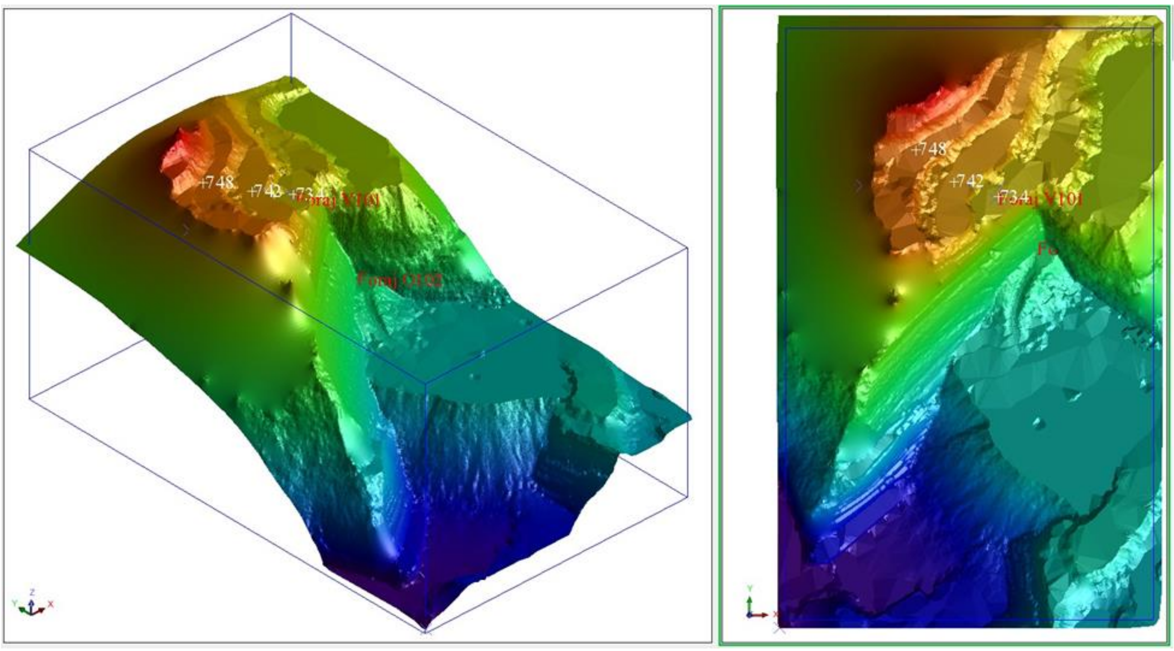


*Fig. 4. The current situation of the northern slope of the old Ruschita quarry*

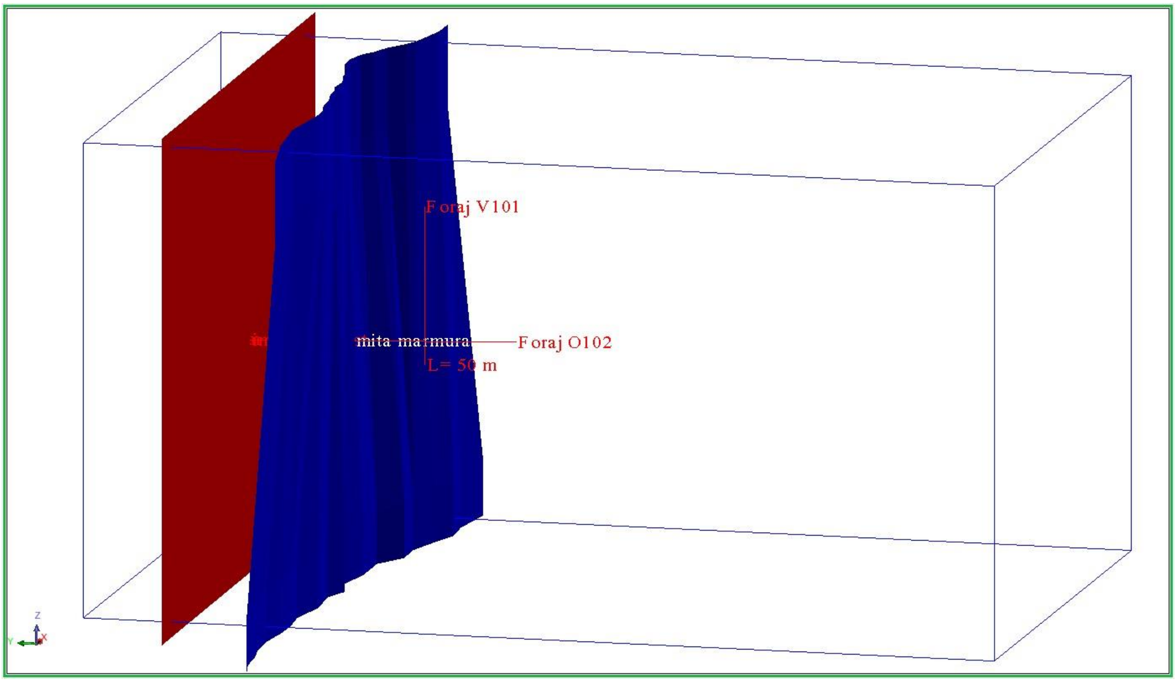


*Fig. 5. Marble–mixed (blue) and mixed–schist (red) contact planes together with the two exploratory boreholes*

The existing information on the older situation plans allowed the modeling of the slopes of the old quarry, currently covered by the inner dump [5].

All this information was imported into SLIDE3 and the 3D geometry of the northern area of the old Ruschita quarry was built. It is composed of the following areas:

- marble reserve of the northern area of the old Ruschita quarry (Figure 6),
- inner dump of the old Ruschita quarry (Figure 7),
- schist model behind the marble (Figure 8),
- mixed zone model, with an estimated width of approx. 30 m, that has in its composition gray marbles, breccia marbles with limonitic veins, intensely cracked cherry marbles, reddish-white to cherry cracked marbles, pink marbles, schist marbles, calcareous shale, amphibolite schist with calcareous intercalations, gray-green massive schist, caverns, cavernous crystalline limestone, brown clay, pyrite mineralization (Figure 9),

 

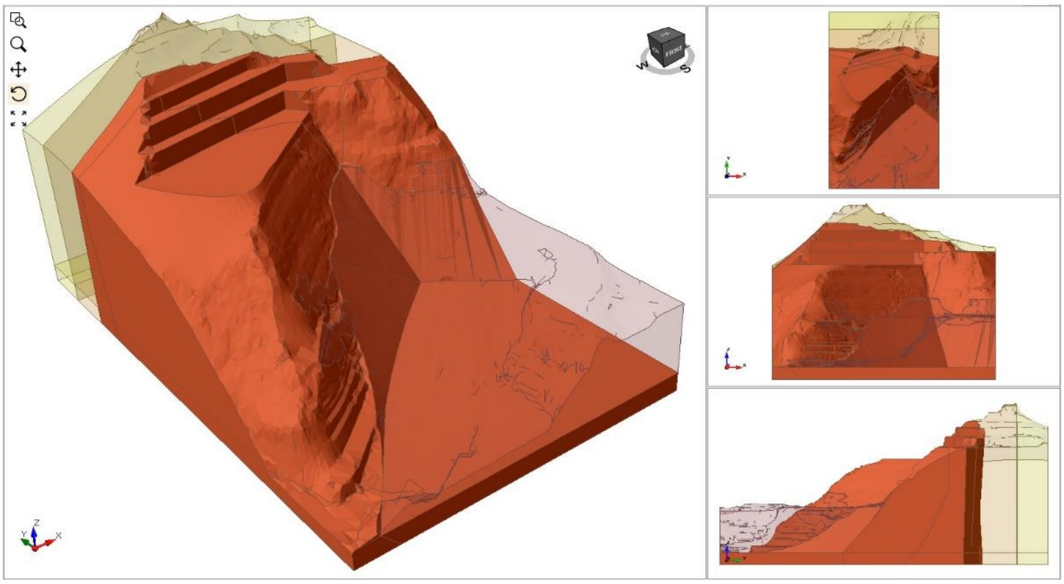

*Fig.6. Marble reserve model*

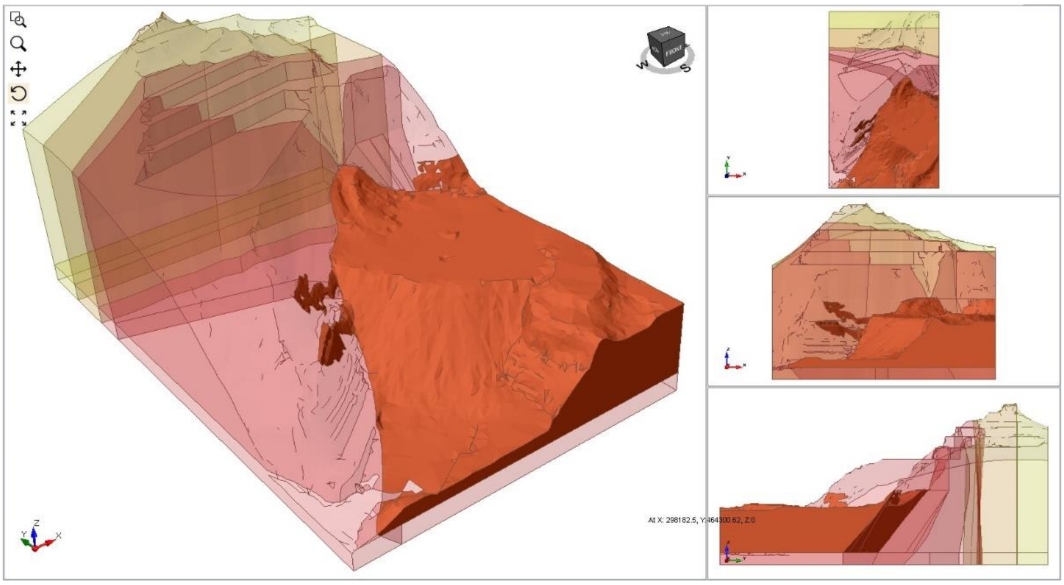

*Fig.7. Inner dump model*

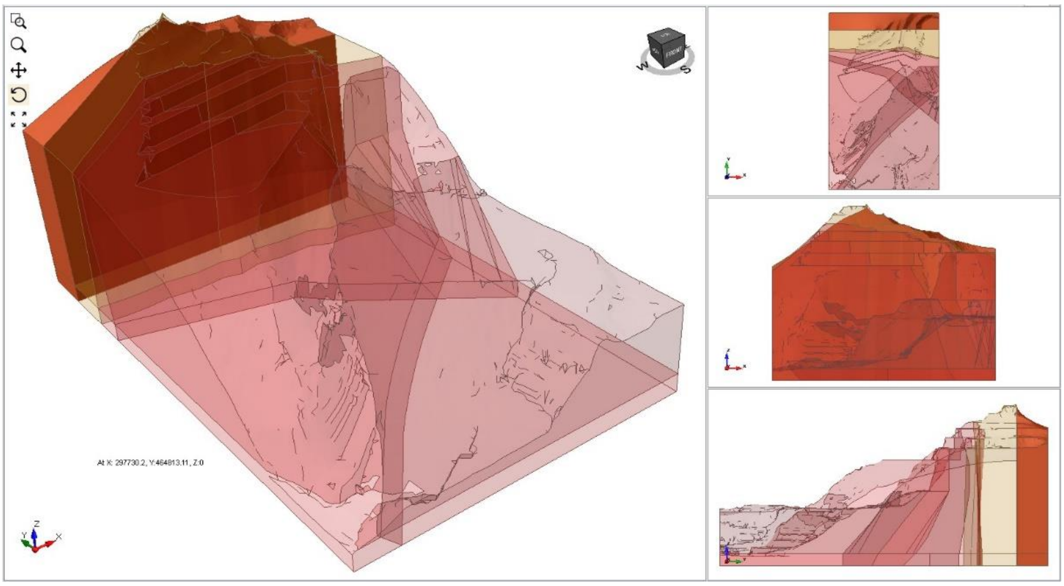

*Fig.8. Schist model*

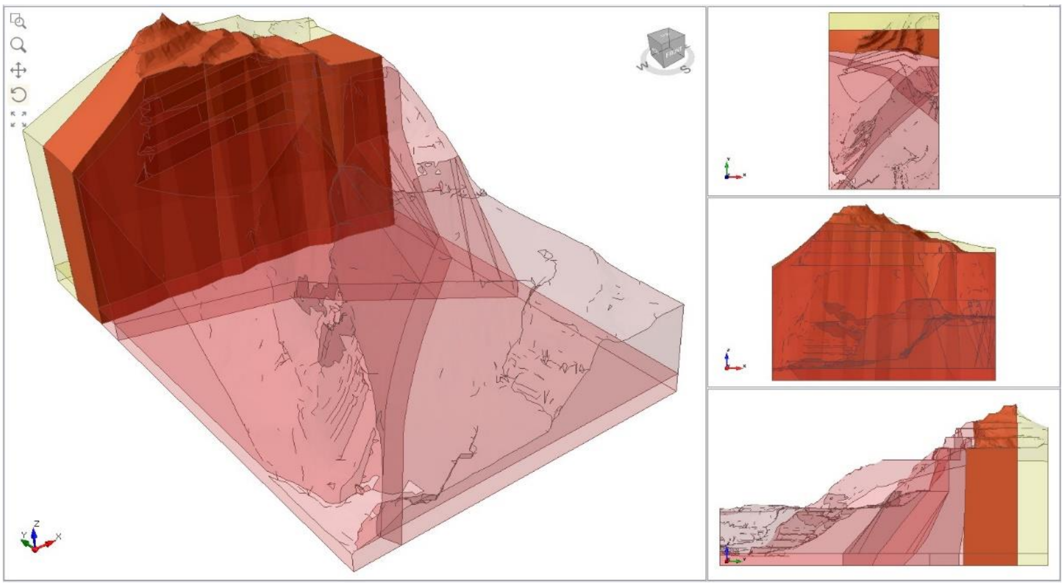

*Fig.9. Mixed zone model*

**4. Conclusions**

Using GEOVIA Surpac facilitated the construction of this complex 3D geological model of the northern area of the old Ruschita quarry to perform the stability analysis in Slide3.

The cores recovered from the two drillings were processed in the form of cylindrical samples on which the physical-mechanical properties of the intercepted rocks were determined in the rock mechanics laboratory at the University of Petroșani. The values determined for the rocks in a saturated state (table 1) were used to evaluate the stability of the northern area of the old Ruschita. In this case, the minimum value of the stability factor Fs is 2.6 in the inner dump area and the stability factor's value in the slope area of the quarry is greater than 4 (Figure 10).

To increase the value of the stability factor Fs in the area of the inner dump, it is proposed to divide the initial step of the dump into two steps of approximately 20 meters height with a berm between them of 10 meters wide, located at elevation 651.

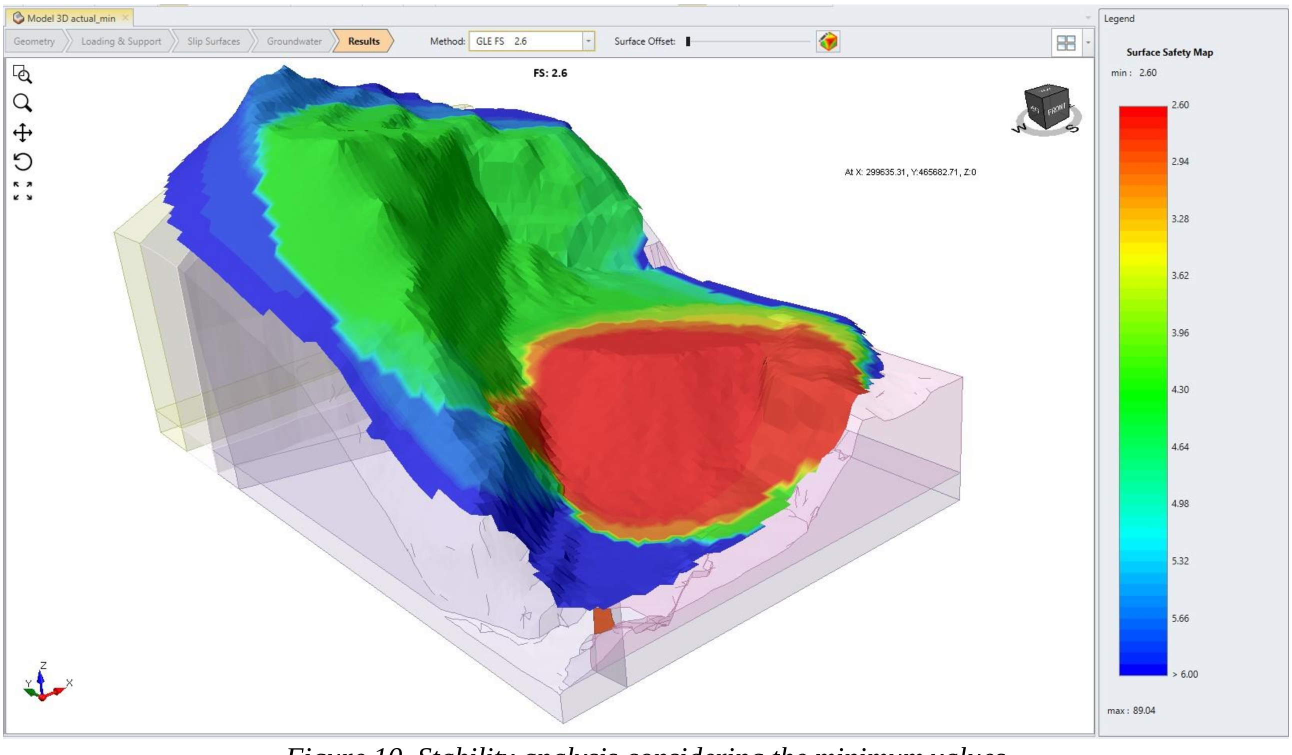


*Figure 10. Stability analysis considering the minimum values of the mechanical properties of the rock mass (under saturated conditions)*

*Table 1. The minimum values of the mechanical properties of the rock massif determined with RocData taken into account for the assessment of the stability*

| **Rock type** | **Unit weight [kN/m$^3$]** | **c [kPa]** | **φ [º]** | **σrtmassif [kPa]** |
|---|---|---|---|---|
| Marble | 27.1 | 741 | 43.674 | 110 |
| Schists | 29.1 | 797 | 45.473 | 81 |
| Mixed rocks | 28 | 740 | 43 | 81 |
| Heaped rocks | 27 | 188 | 24.533 | 8 |

Note. Marble is the rock as it is seen in Figure 6, Schists is the rock as it is seen in Figure 8, Mixed rocks is the rock as it is seen in Figure 9 and Heaped rocks is the rock as it is seen in Figure 7.

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