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LONELY ROCK 3-D VIRTUAL ENVIRONMENT AN EXAMPLE OF PROMOTING AND PROTECTING NATIONAL PARKS

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Abstract: This work proposes a way of promoting and protecting National Parks, by creating a 3-D Virtual Environment of desired areas. The studied area belongs to the Cheile Bicazului – Hășmaș National Park which is situated in the Eastern Carpathians, Romania. Geologically it belongs to the Tulgheș – Hășmaș – Ciuc syncline and encompasses two nappes: the Bukovinian overthrust nappe and the Hășmaș gravitational nappe. To be able to create the virtual environment it have been used seven software: QuantumGIS (for DTM and maps preparation); Move3D and GSI3D for subsurface 3-D modeling; RecapPhoto, Project Memento and Mehslab for "Structure from Motion" Photogrammetry modeling; Sketchup pro trial for anthropic structures modeling; Virtual Terrain Project for combining all the data into a single space, thus making the 3-D virtual environment. The final model can be used both by general public for preliminary exploration and by scientist for different simulations (erosion, forwarding or reversing existing deformations).

Keywords: Cheile Bicazului – Hășmaș National Park, 3-D Virtual Environment, Eastern Carpathians, Romania, Virtual Terrain Project, 3-D geological model, 3-D outcrop model, Lonely Rock

1. INTRODUCTION

For centuries humans tried to map the surrounding environment, but only for the last 30 years maps began to illustrate the world in high quality, immersive, 3-D space. This improvement in map representation has changed our perspective on natural environment, and paved a way for non-scientist to better understand earth's morphology, subsurface structures and processes.

Nowadays a 3-D virtual environment can be represented by two feature types: surface features (Digital Terrain Models, Computer-Aided Design <CAD 3-D anthropic structures>, 3-D vegetation models, and 3-D outcrop models) and subsurface features (3-D faults, 3-D geological formations and the structures formed by those two, with or without any other deformation).

The history of 3-D shows us that at the beginning 3-D modeling software were not conceived for Geographic Information System (GIS) applications. Nonetheless, earth scientists have followed very close this technology and began developing 3-D GIS dedicated software very soon after.

So one of the first 3-D geological modeling papers were published by Egan et al., (1996) representing the geometry of faults and their relation with strata, using one software called Move 3-D.

Developing diferent other specialised software, the 3-D geological study of the earth's subsurface has been improoved over the years and as a result many teams modelled areas from: Alps Mountains (Calgano et al., 2006), Brazil (Terrington et al., 2015), the City of London (Aldiss & Haslam, 2013).

Regarding earth's surface 3-D modeling different software begin to be developed, among which Virtual Terrain Project (VTP). VTP was started in the late '90s by software developer Ben Discoe, as a open-source application and has continued to be improved to this day with help from the comunity that was formed along with it. VTP comprises mainly of to important tools: VTBuilder which is used for 2.5-D tasks (such as importing and preparing raw data for visualisation) and Enviro for 3-D tasks (visualization and editing the data in a 3-D virtual environment).

Moreover VTP has at his core two important libraries (which in many cases are more powerfull then proprietary software): Geospatial Data Abstraction Library (GDAL), which allows geospatial data processing, and Open Scene Graph (OSG), which allows for 3-D redering of all the data. (Discoe, 2006)

VTP has been used in many situations like landscape reconstruction (Pescarin et al., 2005) and earthquake scenarion ilustration (Kato & Yamazaki, 2006).

Although many tools where avaible when we began our project, none provided the option to represend both subsurface and surface 3-D data in the same environment, a essential feature for comunicating a complete picture of the area.

In order to do just that, the VTP software was improved with 3-D subsurface feature visualization capabilities with software's developer help. Now VTP can simultaneous render both surface and subsurface 3-D features in the same virtual environment, providing us the best platform to represent and visualize the area we study.

2. GEOGRAPHICAL SETTING

Geographically the studied area belongs to the Hăşmaş Mountains which are situated in the Moldavian – Transilvanian section, Eastern Carpathians.

The Hăşmaş Mountains are confined by Bistricioara Valley in the north, Mihăileni – Valea Frumoasei in the south, Pintec creek – Dămuc creek – Valea Rece creek in the east and Ciuc Superior Basin – Olt River in the west.

From an administrative point of view, the area is situated in the Cheile Bicazului – Hăşmaş National Park.

This park has a surface of about 67.93 km^2 which is separated into four zones of interest: very high protection zone, high protection zone, medium protection zone and low protection zone. (Grasu et al., 2010)

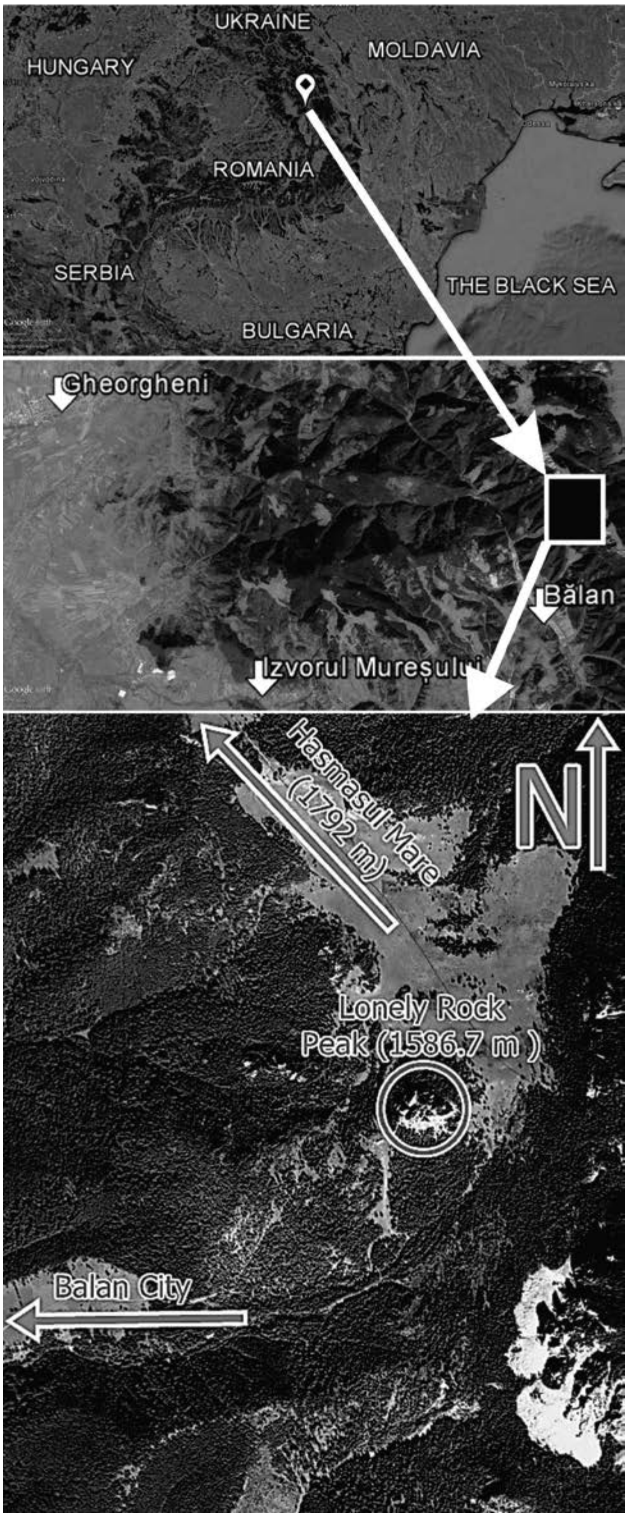


Figure 1. Lonely Rock Peak aerial image. (Up – Google Earth image showing the studied area position in Romania, Middle – Google Earth image showing the position of the area in a regional context, down – aerial image of the studied area)

The modeled area is situated in the high protection zone and encompasses area of approximately 3.859 Km^2. The vegetation consists mostly of conifers with an average height of 20 m.

The highest peak here is 1586.7 m high and it is called Lonely Rock. From here one has access to Trei Fântâni village in the east and Balan city at west. Also the highest peak in Hăşmaş Mountains (Hăşmaşul Mare – 1792 m high) is about two hours walking from Lonely Rock to the north, following a ridge track (Fig. 1).

3. GEOLOGICAL SETTING

The internal geological structure of the area is quite complex and it encompasses almost the entire stratigraphic column of the Tulgheș – Hășmaș – Ciuc syncline (Fig. 2).

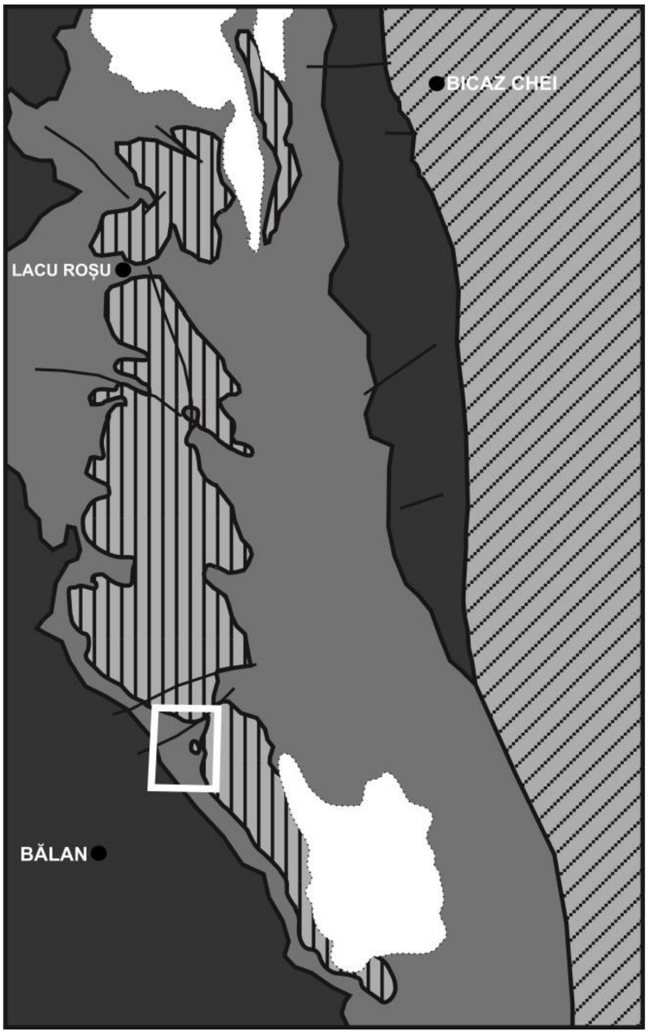


Figure 2. Tulgheș-Hășmaș-Ciuc Syncline geological map (modified after Dumitriu et al., 2015). The yellow box represents the modeled area.

Post-tectonic Formation
Hășmaș Nappe
Bukovinian Nappe
Rock Base
Ceahlău Nappe
Faults

Together with Rarău syncline Tulgheș – Hășmaș – Ciuc syncline forms the External Marginal Sincline.

From Săndulescu (1975) we find that this area was shaped by the movement of two different nappes: an overthrust nappe (the Bukovinian nappe) and a gravitational nappe (the Hășmaș nappe).

3.1. Straigraphy

3.1.1. Bedrock

In the studied area the bedrock is represented by a formation known as Hășmaș Granitoid, which along with other metamorphic layers forms the Bretila – Rarău group.

The Precambrian - Hășmaș Granitoid formation consist of massive rocks with almost none stratification represented by granodiorite and gneiss diorite.

3.1.2. Bukovinian nappe

The Bukovinian nappe has the most complete stratigraphic column from all the nappes in the External Marginal Syncline, (Grasu et al., 2012)

Here the formations from the Bukovinian nappe have ages between the Upper Paleozoic and Barremian-Albian.

The Hășmaș Breccia (Upper Paleozoic) consists of large clasts welded in heterogeneous cement. The formation can be found both on the eastern and western flank of Tulgheș – Hășmaș – Ciuc syncline, but it has the highest prevalence on the western flank.

With a thickness of approximately 30 m, the Bukovinian Lower Induan contains white, yellow or reddish conglomerate and sandstone, (Grasu et al., 2012).

Massive or with vague stratification, yellowish or red color with a harsh aspect, the Induan-Olenekian formation has the largest prevalence from all the Bukovinian nappe's Triassic formations.

The next package of rocks (Ladinian limestone) are yellowish-white or grey, has a very high content in carbonates which indicates a pure limestone. (Grasu et al., 1995) The thicknesses of this package can vary from 10 to 60 m, with a maximum of 180 m in some areas.

The upper Triassic is represented by red or whitish-yellow limestone which often interpolates with pink, reddish or yellowish-white dolomite with calcite diaclases, in a 20 to 100 m thick stack.

The Middle Jurassic limestone has been divided by Grasu et al., (1995) into three members with different characteristics: a lower member which has a macroscopic appearance of limestone; a middle member which consists exclusively of spongolitic limestone; an upper member that consists of limestone-sandstone with incarbonized plant remains.

The last formation is the Wildflysch Formation. This Albian - Barremian formation has a very high prevalence on both of the syncline's flanks. Although it has an impressive lithological variation, Săndulescu (1975) managed to separate the Wildflysch into two types: a typical wildflysch which consist with a shale matrix with different types of intraclasts and an atypical wildflysch which has a lot of flish like features.

3.1.3. Hăşmaş nappe

Compared to the Bukovinian nappe, the Hăşmaş nappe has a much smaller stratigraphic column, encompassing formations with ages between the Kimmeridgian and Tithonian-Neocomian.

This Lower Induan limestone has a red color and it found only in the form of blocks embedded in the wildflysch formation mass.

The kimmeridgian is formed by two types of rock (a red limestone and a greenish-grey limestone), and it has a thickness of 30 to 40 m.

The last pack of rocks has a total of 200-300 m thickness and a color which varies from yellowish-white to gray. Lithological the limestone consist with two alternating units: “Stramberg” Limestone (Tithonian age) and neocomian limestone (Lower Cretacic age).

3.2. Tectonics

The Bukovinian nappe is an overthrust nappe with a very large displacement and a fairly simple internal structure. The folds are commonly normal and hardly ever overturned.

The Hăşmaş nappe is a gravitational nappe which formed between Barremian and Albian periods. The gravitational slide of the nappe was very slow, moving towards east about 60 to 70 km. When the nappe no longer had sufficient tilt it stopped near the basin's axes where the wildflysch formation was deposited.

The internal structure of the studied area is represented by these two nappes with their deposits (the Bukovinian nappe and the Hăşmaş nappe) and by two faults (one strike-slip and one reverse fault). The strike-slip fault (which displaces deposits from the Tithonian-Lower Cretacic Limestone to the Hăşmaş Granitoid, moving the formations both vertically and horizontally) and the reverse fault (which displaces deposits from the Middle Jurassic Sandstone-Limestone to the Hăşmaş Granitoid, moving the formations only vertically) form between them a horst structure.

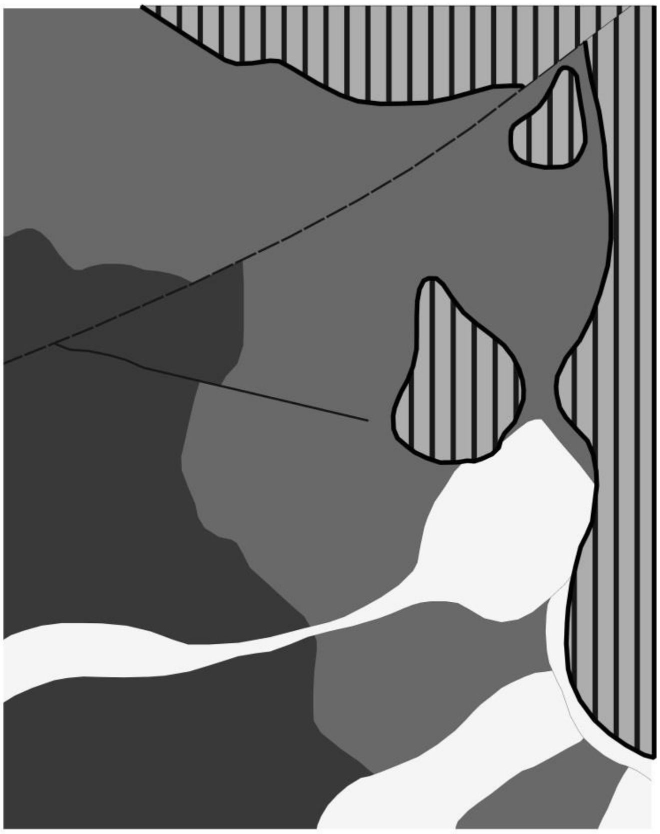


Figure 3. Geological map of the studied area with shaded relief.

Holocene - Slides
Hăşmaş Nappe (Lower Induan – Lower Cretacic)
Bukovinian Nappe (Upper Paleozoic – Barremian)
Rock Base (Precambrian)
Strike-Slip Fault
Normal Fault

4. METHODS

The final 3-D virtual environment was accomplished using Virtual Terrain Project (VTP), software for 3-D visualization and analysis of surface data, developed by Ben Discoe and improved after initiating a collaboration with the author by providing geological data, information and know how. The collaboration had resulted in the introduction of the option of study of the subsurface 3-D features. Therefore the 3-D models used for the environment can be separated into two different sets: ones that are found on the surface and ones that are found in the subsurface.

VTP consists of three parts: CManager (for managing and preparing 3D models), VTBuilder (for managing and preparing GIS spatial data), Enviro (for 3D visualization of all the data provided).

Because Enviro creates a 3D space by joining existing 3D models, the process of modeling must be made using other dedicated applications.

Therefore modeling began by transforming the existing subsurface models (Dumitriu et al., 2015), obtained through field work, geological interpretation and 3-D modeling of the internal architecture of the studied area with QuantumGIS, GSI3D and Move3D, into readable formats for Enviro. This process was done by exporting the subsurface model to a DXF format using Move3D interface and transforming it to an ITF format using VTBuilder.

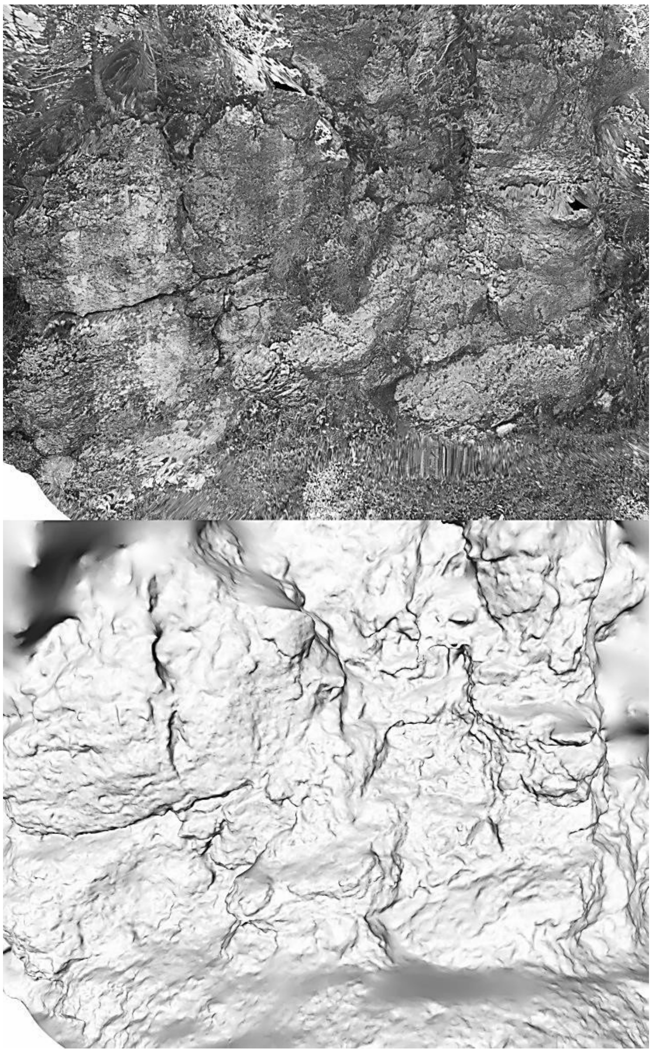


Figure 4. Outcrop of Ladinian Limestone from Bukovinian Nappe.
Top – The 3D mesh of the outcrop with texture
Bottom – The 3D mesh of the outcrop without texture

In order to make the virtual environment accessible from any type of computer the subsurface models were merged into five groups: the Holocene Slide group, the Hășmaș nappe group (with Tithonian – Lower Cretacic Limestone, Kimmeridgian – Limestone and Lower Induan – Limestone), the Bukovinian nappe group (with Albian-Barremian - The Wildflysch, Middle Jurassic - Sandstone-Limestone, Upper Triassic - Limestone and Dolomite, Lower Induan – Conglomerate and Sandstone and Upper Paleozoic - Hășmaș Breccia) and Precambrian - Hășmaș Granitoid group (Fig. 3).

After this process the resulting subsurface 3-D models have been inserted into Enviro using "Elevation Layers" option from the "Extra" submenu, "Edit Properties" menu.

The next step in finalizing the 3-D virtual environment of the area surrounding the Lonely Rock was to model and prepare the surface 3-D models (Digital Terrain Model with and accuracy of 5 m, outcrop and klippe 3-D models, 3-D anthropic models <CAD> and vegetation 3-D models).

It was started by preparing the Digital Terrain Model (with an accuracy of 5 m), used in the 3-D geological modeling process, for visualization in Enviro, by resampling and transforming it to BT format using VTBuilder.

The 3-D environment obtained so far contained only the subsurface 3-D geological models and the terrain model, therefore the next processes were focused on populating the surface with related 3-D models.

First, the outcrop of Ladinian – Limestone (Fig. 4) (located west from the Lonely Rock) and the klippe of Tithonian – Lower Cretacic Limestone (Fig. 5) (located north from the Lonely Rock) were modeled using 20 georeferenced photos for the outcrop and 60 georeferenced photos for the klippe. The photos were processed through"structure from motion" photogrammetry web-based software called RecapPhoto (Dumitriu, 2013) obtaining two 3-D models of the structures mentioned above. Afterwards the models were checked, cleaned and resized using Project Memento and MeshLab software. The final models were then transformed into OSG format using CManager and inserted into Enviro for visualization, geo-positioning and export to a VTST format.

The 3-D CAD models were modeled with Skethup using photos taken from the location as reference. The models were made by considering as much as possible the original architecture of the anthropic structures. From this process it was obtained the Lonely Rock 3-D cottage, store house and weather shelter. These three models were exported to an obj format using SkethupPro trial version and transformed to osg format using CManager. As with the outcrop and klippe models, these 3-D models were also processed using Enviro, resulting, another VTST format file.

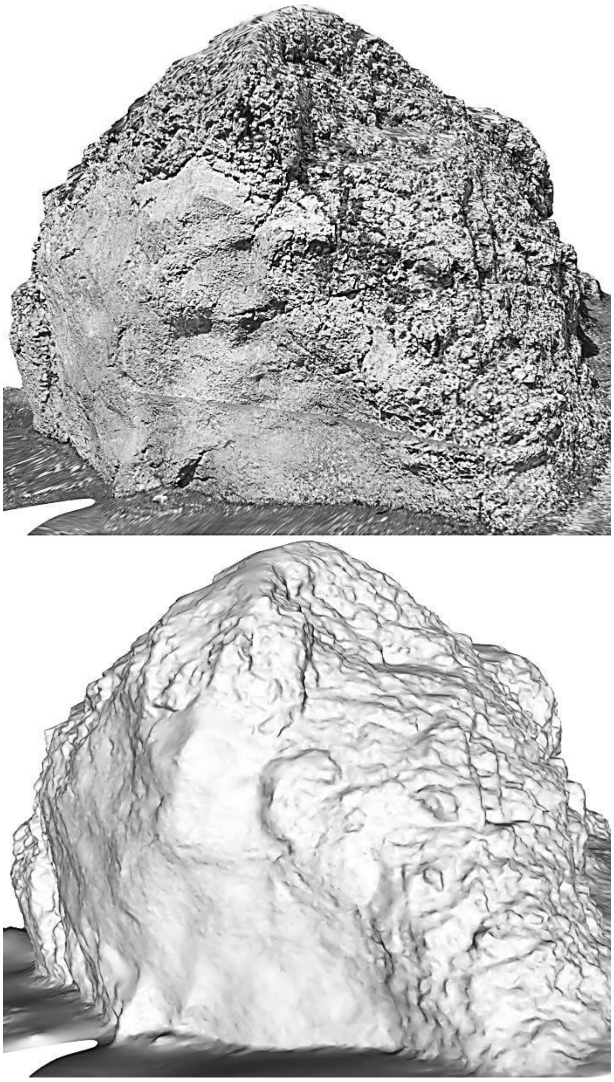


Figure 5. Klippe of the Tithonian – Lower Cretacic Limestone.
Top – The 3D mesh of the klippe with texture
Bottom – The 3D mesh of the klippe without texture

The last 3D surface models made were the trees found in the studied area. For this process it was used the build-in feature of Enviro for vegetation placement. Based on the information provided by the topographic maps of that region (medium heights of the trees and medium spacing between them), the trees were placed on the specific areas of the aerial imagery. Afterwards the results were exported into a VF format file.

The resulting 3-D models (surface and subsurface) were inserted afterwards into Enviro using software's Edit Properties menu and choosing the corresponding submenu for each type of model:

- Primary Elevation submenu for inserting the digital terrain model in bt format from Grid Filename and aerial imagery from Primary Texture;
- Extra for inserting the subsurface 3-D models in a ITF format;
- Plants for inserting the 3-D models of trees in a VF format;
- Structures for inserting the CAD anthropic, outcrop and klippe 3-D models in a VTST format.

5. RESULTS

The purpose of using this methodology was to obtain a 3-D virtual environment of the Lonely Rock region (Fig. 6, Plate 1) that could be used for future study of the both subsurface and surface features.

The 3-D virtual environment also allows general population to participate in the management of the area by providing a platform that distributes all the information about the area in a more accessible way. (Malinverni, 2006)

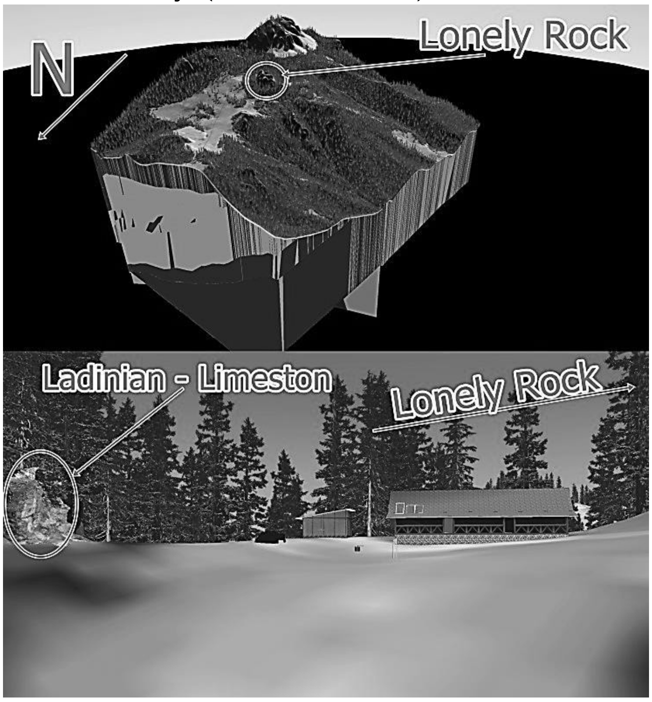
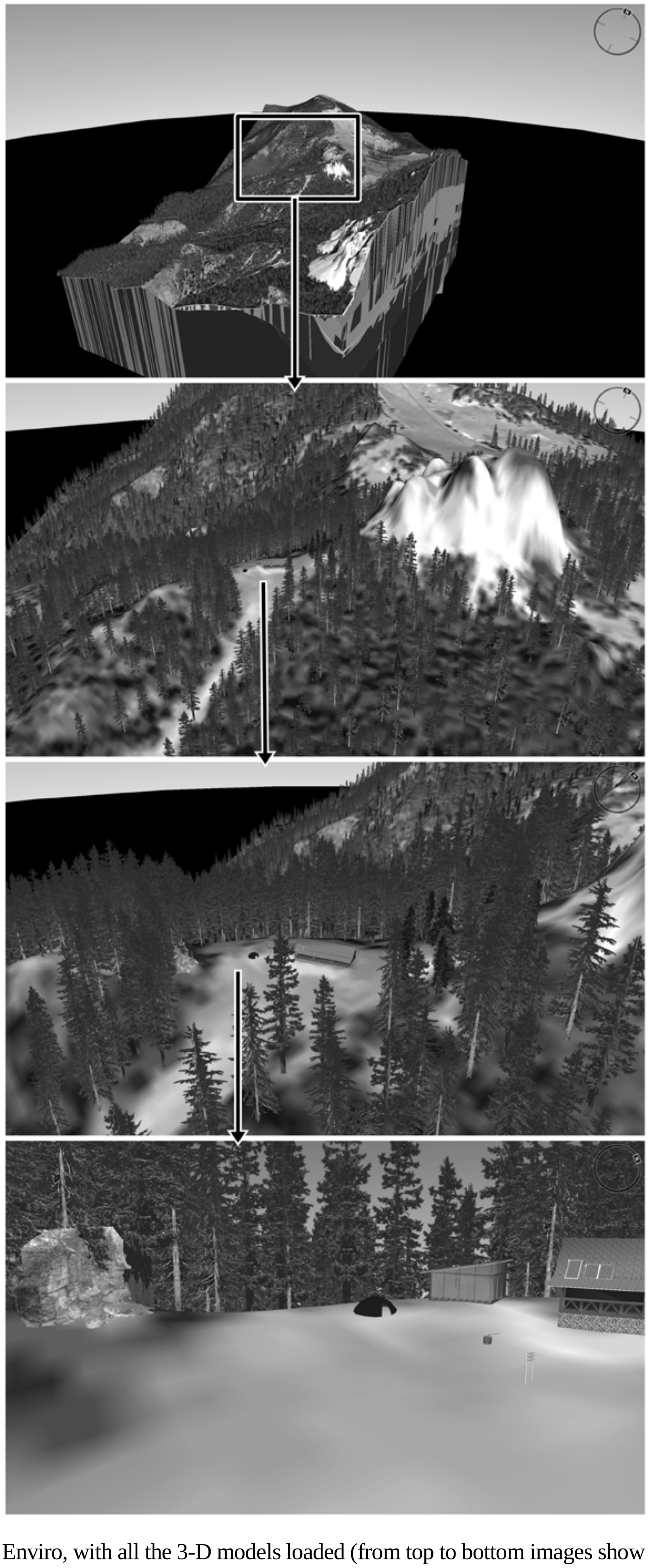


Figure 6. Top – Final 3D virtual environment of the Lonely Rock area (with surface and subsurface features)
Bottom – The Lonely Rock cottage with surrounding elements.

Moreover the created environment allows for on the fly and dynamic changes to be made helping research teams to collaborate much easier.

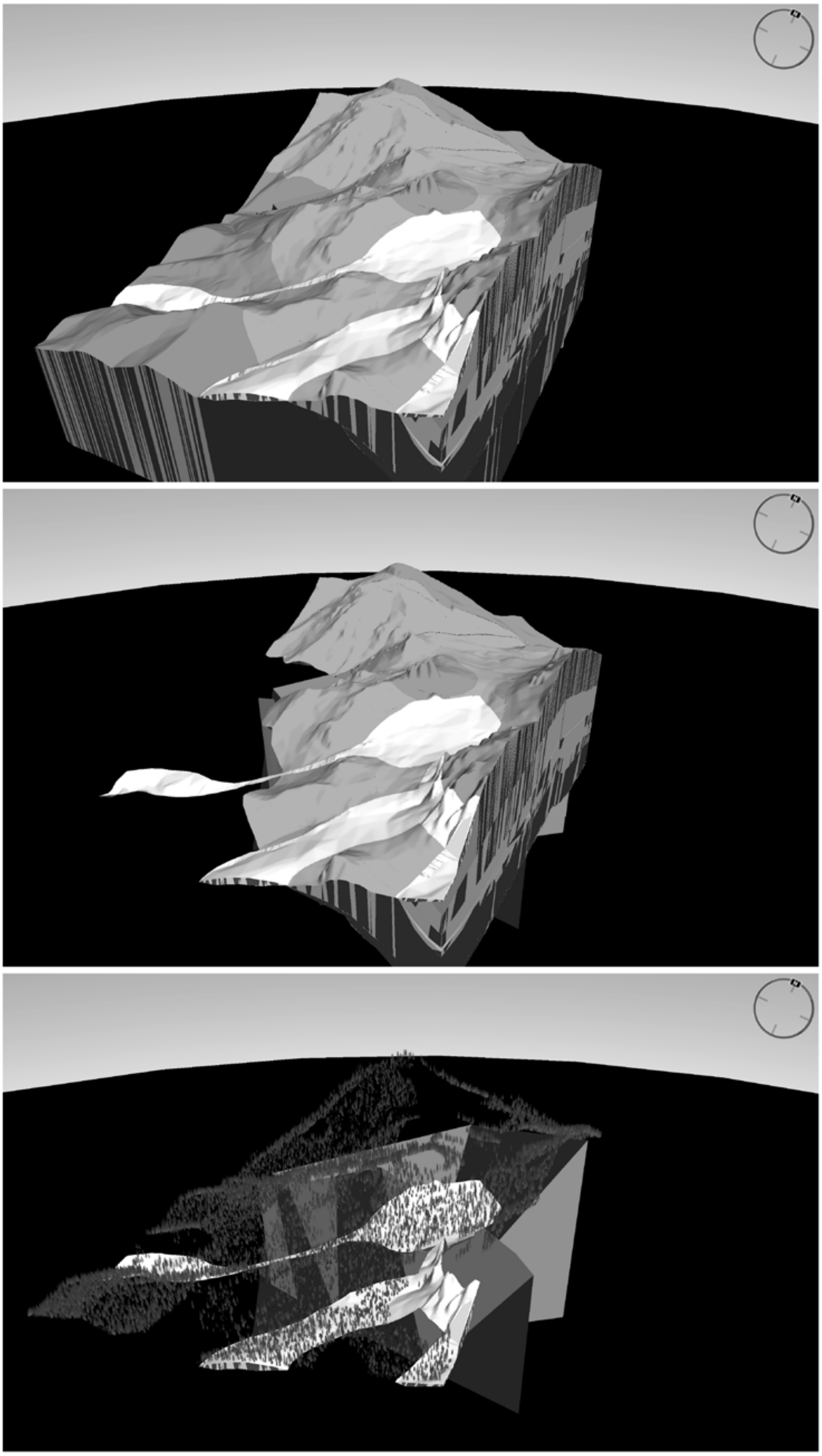
From the subsurface modeling it was obtained volumes for both nappes (near 65.000.000 m^3 for Hășmaș nappe and near 1.000.000.000 m^3 for Bukovinian nappe) and surfaces for faults (near 1.500.000 m^2 for the normal fault and 2.300.000 m^2 for the strike-slip fault).

Plate 1



3-D Virtual Environment in Enviro, with all the 3-D models loaded (from top to bottom images show different level of detail)

Plate 2



3-D Virtual Environment in Enviro, only the 3-D geological models loaded (top image shows the whole 3-D geological model, middle image shows only the Hăşmaş Nappe, Bukovinian Nappe, Landslides and Faults, bottom image shows only the Landslides, Faults and trees)

From the surface modeling, using Enviro forest generation, along with information about medium spacing between trees and their prevalence interpreted from the aerial image, it was possible to estimate the approximate number of trees present in the studied area, a number of about 11.000 trees.

6. CONCLUSIONS

By enhancing Virtual Terrain Project with subsurface capabilities, the 3-D virtual environment created is a complete detail representation of the studied area contributing to Cheile Bicazului – Hăşmaş National Park promotion.

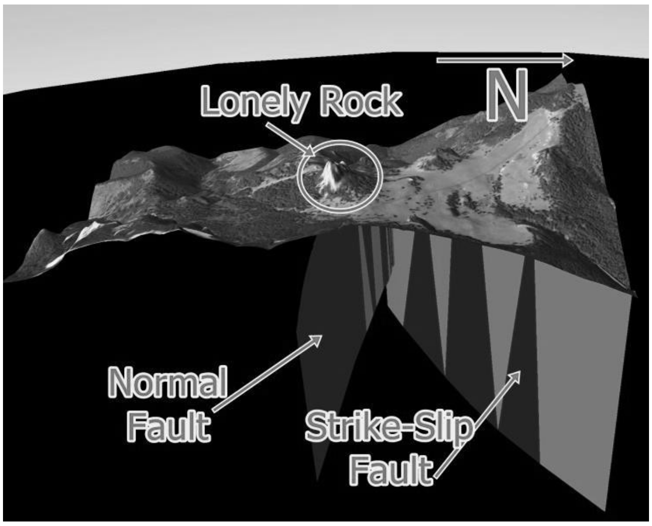


Figure 7. Final 3D virtual environment of the Lonely Rock area with surface features and subsurface faults.

By distributing these models in a digital form over the internet, both regular and geological tourism can be improved by raising awareness among more possible tourists. In this way tourists can plan their trip with high accuracy by knowing more details about the area.

Moreover by providing this free and easy to use platform, which general public can access, one can easily draw attention on natural environment protection and legislation in the national park, showing directly the parts that need protection.

From the scientific point of view, the ability to integrate different information into the same virtual environment at a large scale on small or large areas helps to highlight the relations between numerous data sets (geological, geographical or anthropic).

By using this 3-D model one car run different simulations like erosion and tectonic movement (forwarding the existing deformations or reversing them), (Fig. 7, Plate 2)

Furthermore the association and the visualization of the surface and subsurface data into the same space, helps the researchers to take important decisions and plan any future survey with very high precision, therefore reducing the campaign costs.

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