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Outlining and 3-D modelling a faulted conglomerate deposit from Oii Creek, Hășmaș Mountains, Romania

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Abstract

The studied area is marked by the presence of two thrust nappes: a gravitational nappe (the Hășmaș Nappe) and an overthrust nappe (the Bukovinian Nappe). Ontop the Bukovinian Nappe, deposits rests a rudite formation which resembles the Bârnadu conglomerates formation. In order to outline these deposits, several field trips have been made, during which devices with GPS and GLONASS sensors were used. Using the QuantumGIS and a high resolution DTM (Digital Terrain Model), the recorded observation points were correlated, obtaining the boundaries of the studied deposit, which were illustrated on a geological map and a geological sketch. The final process was accomplished by utilizing the Move3D software, where the volumes of the conglomerates and the fault displacement has been calculated.

Keywords: Hășmaș Mountains, thrust nappe, fault, conglomerate deposits, 3-D geological modelling, Move3D.

1. Introduction

Existing geological maps, especially those at a scale of 1:50.000, incorporate very good geological interpretations. However, some of the areas depicted in the maps often need reinterpretations according to the new data acquisition. This paper focuses on such an area, where a reinterpretation was possible due to new field measurements and more precise digital terrain models. Moreover, using current mapping techniques, like 3-D geological modeling, the reinterpretation has also been validated.

The conglomerate deposits outlined in this paper are very similar to Bârnadu Conglomerates Formation and have been described for the first time by Grasu et al. (2012). Based on their study, the authors found out that some characteristics seem to differentiate the deposits from the mentioned formation. Săndulescu (1975) attributes those characteristics to the

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Bârnadu Formation lateral variation, even though some of them are somewhat rare. Based on the information provided by the literature, the deposits could be considered as a part of the Bârnadu Conglomerates Formation, which represents post-tectonic deposits.

The studied area corresponds to a part of the Dămuc 1:50.000 scale geological map (Săndulescu et al., 1975) and it is located in the Hăşmaş Mountains (Fig. 1) from Eastern Carpathians, Romania. The conglomeratic deposits are located on the Oii Creek basin, which is the main contributor to Red Lake's body of water and it has a flow direction from south to north.

2. Geological setting

Geologically, Oii Creek basin is situated on the western flank of the Hăşmaş Syncline that corresponds broadly to the Tulgheş-Hăşmaş-Ciuc Syncline (Grasu et al., 2012). The syncline encompasses a post-tectonic formation (Bârnadu Formation), two thrust nappes (the Hăşmaş Nappe, which is a gravitational nappe, and the Bukovinian Nappe, which is an overthrust nappe) and a Precambrian Bedrock.

However, the mapped perimeter accommodates only a few formations (Fig. 2) from the two thrust nappes mentioned before, along with the post-tectonic formation.

2.1 Stratigraphy

2.1.1 Bukovinian Nappe

This structure is an overthrust nappe and it encompasses formations of ages from Upper Paleozoic to Albian. For the Bukovinian Nappe, Grasu et al. (2012) describe a stratigraphic column, which is the most complete and complexe for the

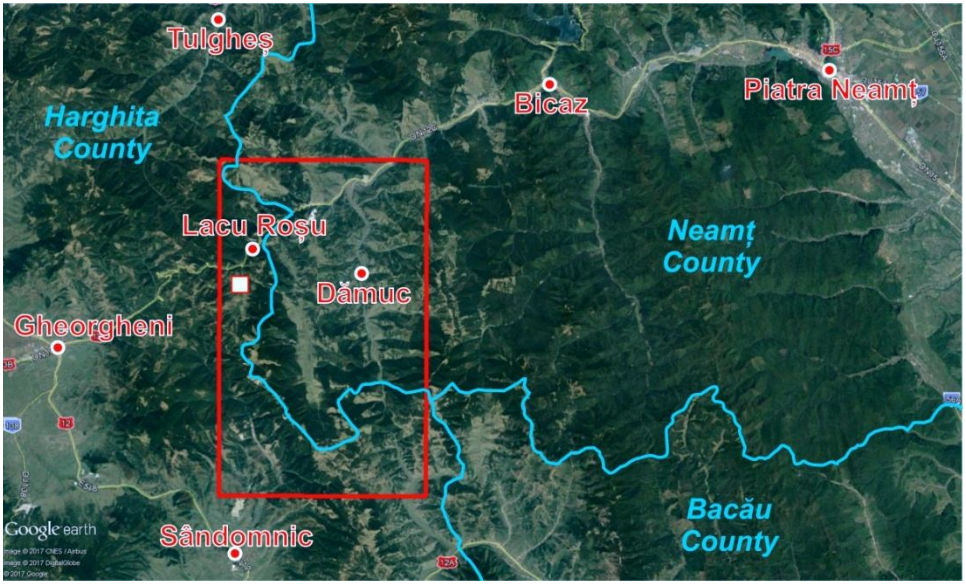

Fig. 1 The Hăşmaş Mountains and surrounding areas. The red rectangle represents a part of the Hăşmaş Mountains, corresponding to the Tulgheş-Hăşmaş-Ciuc Syncline. The red rectangle with white infill represents the studied perimeter.

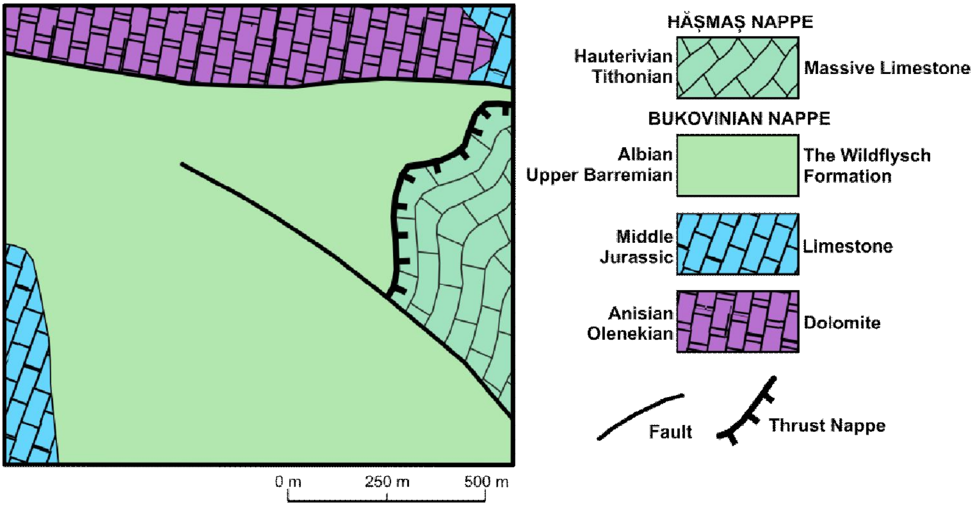

Fig. 2 Geologial map of the studied area (after Dămuc geological map, Săndulescu et al., 1975) without the outlined conglomerate deposits.

Tulgheș-Hășmaș-Ciuc Syncline. The sedimentary suite includes the Hășmaș Breccia of Upper Paleozoic age, Induan conglomerates and sandstones, Induan-Olenekian grey limestones, Olenekian-Anisian massive dolomites, Ladinian limestones with *Diplopora annulata*, Upper Triassic limestones and dolomites, Sinemurian-Upper Pliensbachian limestone-dolomites and sandstones, Middle Jurassic limestones, Callovian-Oxfordian jaspers and radiolarites, Kimmeridgian Formation with *Aptychus* and the Wildflysch Formation of Upper Barremian-Albian age.

In the studied area the Bukovinian Nappe is represented only by Olenekian-Anisian massive dolomites, Middle Jurassic limestone and the Wildflysch formation of Upper Barremian-Albian. The other formations are visible only in cross-sections, as there are no outcrops in the mapped boundaries.

Olenekian-Anisian – dolomites

These dolomites are massive and have a very large areal extent in the Hășmaș Syncline. The deposits have a coarse aspect, a vague stratification and a white-yellowish to red color.

Middle Jurassic – limestone

Separated into three units (a lower thick limestone unit, a middle spongolitic limestone unit and an upper limestone to sandstone unit) by Grasu et al. (1995), the Middle Jurassic limestone displays a whitish-yellow to red color and often intercalates with dolomites which Grasu et al. (2012) consider that highlights a dolomitization process.

Upper Barremian-Albian – Wildflysch Formation

The Wildflysch Formation represents the only Cretaceous deposit of the Bukovinian Nappe, being described for the first time by Băncilă (1958) and Patrulius (1960), who have assigned to it a Lower Barremian-Apțian age. Later, Săndulescu (1975) separated the Wildflysch into three units: a lower jasper unit, a unit consisting of a shaly matrix and different types of lenticular deposits and a flysch-type unit that consists of sandstones-mudstones, mudstones and shales, limestone-sandstones and sandstones.

2.1.2 Hăşmaş Nappe

Acording to Săndulescu (1975), the Hăşmaş Nappe is a gravitational nappe and it is characterized by the allochthonous sediments of the Hăşmaş Syncline. The nappe incorporates Triassic limestone and sandstone-limestone, Kimmeridgian limestone, Tithonian-Hauterivian limestone and mudstone-limestone, and Valanginian-Lower Aptian limestone.

In the mapped area the only present type of allochthonous sediments are the Tithonian-Hauterivian limestone.

Tithonian-Hauterivian – limestone

These deposits form the main unit of the Hăşmaş Nappe and rest mostly at west from the syncline axis. Săndulescu (1975) separates these limestones into a lower unit, which consists of massive limestones with very faint stratification, and an upper unit which consists of limestones with a well-defined stratification.

2.1.3 Post-tectonic deposits

Săndulescu (1969) was the first to distinguish these deposits from the Wilflysch Formation and to prove their post-tectonic nature. Later, Săndulescu (1975) describes them as polymictic conglomerates with elements from both Bukovinian and the Hăşmaş nappes.

2.2 Tectonics

The study perimeter is marked by the presence of two thrust nappes (the Bukovinia Nappe and the Hăşmaş Nappe) and a post-tectonic formation (Bârnadu Formation).

The Bukovinian Nappe is an overthrust nappe and although its quite large displacement, the internal structure is fairly simple, with few to none overturned folds. Săndulescu (1975) sets the nappe overthrust between the sedimentation of the Wildflysch formation and the Bârnadu Formation, which corresponds to the Austrian tectogenetic phase.

According to Săndulescu (1984), the Hăşmaş Nappe movement took place during Middle Cretaceous, in the Austrian tectogenetic phase, by an initial process of obduction and a secondary one of gravitational sliding.

The last deformations that affected the Hăşmaş Syncline were the post-paroxysmal deformations. These deformations affected the Bukovinian Nappe deposits, Hăşmaş Nappe deposits and the post-tectonic deposits; according to Săndulescu (1975), they were formed during either the Laramic phase or the Savic or Stiric phases.

3. Materials and methods

In order to outline the Post-tectonic deposits found in the Oii Creek basin, several field surveys were carried out. The area was mapped using both a Garmin 62CSX GPS and a XCOVER 2 Smartphone (with GPS and GLONASS sensors).

The first field observations revealed the occurrence of the studied deposits in seven points. These points have later been correlated using the 30 m resolution DTM (Digital Terrain Model) and the Dămuc geological map (Săndulescu et al., 1975), inside QuantumGIS software. The results outlined a southern, raised block and a northern, lowered block, separated by a normal fault (Dumitriu and Huţu, 2013).

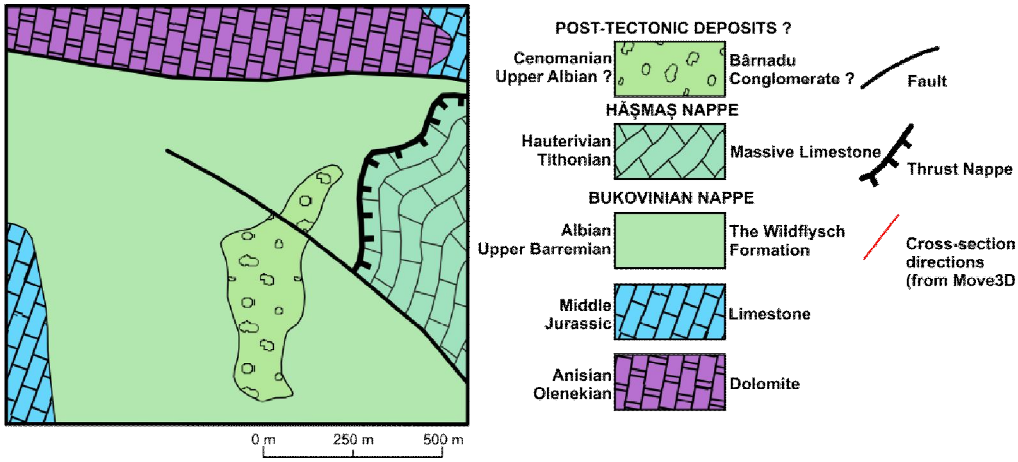

Fig. 3 Geological map of the conglomerate deposits from the Oii Creek, Hăşmaş Mountains.

Although initial calculations showed the boundaries of the deposits to a certain precision, additional data was needed to correctly asses the true extents of the formation. Therefore, using the GPS devices mentioned above, more points were collected from the field. The resulted new points as well as the old ones were overlaid onto the geological map, using the QuantumGIS software.

First of all, the GPS points from the field observations were roughly correlated using simple lines. Then, using a high resolution DTM (5 m resolution Digital Terrain Model), the lines were readjusted and correlated to form the final boundaries of the deposits, taking into account the morphology of the terrain in that area. The newly created boundaries were then outlined on the map, utilizing the International Stratigraphic Chart for the ages color RGB codes (Cohen et al., 2014), thus creating a new small geological map of that region (Fig. 3).

After performing the surface delineation of the deposits, the Move3D software has been used in order to reconstruct their whole volume. As the study was focused only on the already mentioned rudite deposits, a geological sketch has been created to be used into Move3D software (Fig. 4). The geological sketch differentiate only the major structural units, emphasizing the studied deposits.

The data processing with help of Move3D software allowed the use of a 5 m resolution DTM along with the geological sketch previously created. As mentioned, the studied formation is delimited into two blocks by a normal fault. In order to reconstruct the volume of these blocks, the fault had to be modeled first. Using the dip and strike measurements and representations from the Dămuc geological map (scale 1:50.000, Săndulescu et al., 1975) along with the tools provided by the Move3D software, the fault surface line has been digitized and used then to create its 3-D surface (Fig. 5). The study perimeter encompasses another fault, located north of the one already modeled. Applying the same techniques as before, this fault was also modeled.

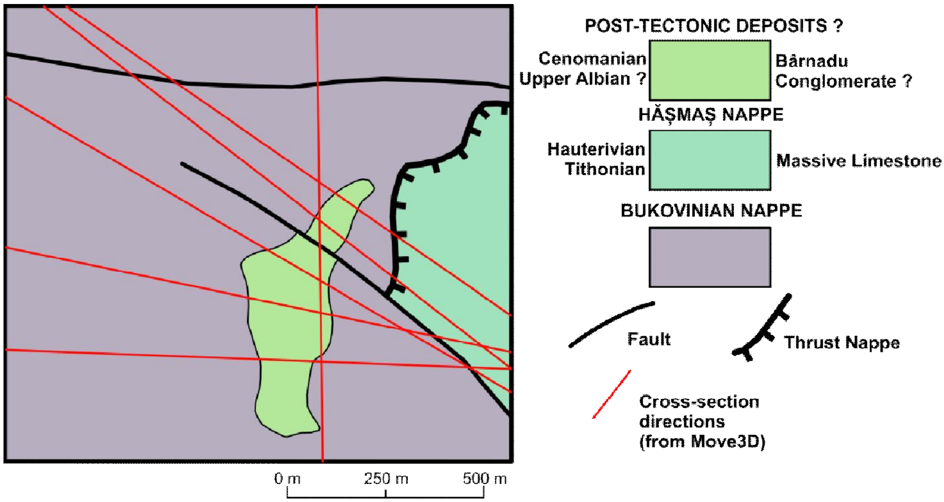

Fig. 4 Geological sketch showing the conglomerate deposits from the Oii Creek, Hășmaș Mountains.

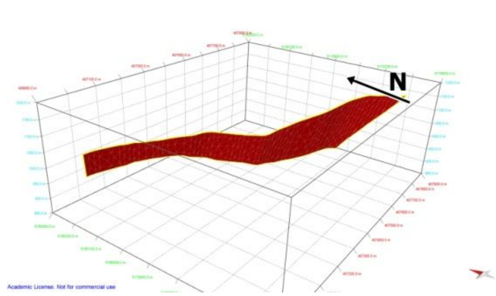

Fig. 5 The 3-D surface of the fault that crosses the conglomerates.

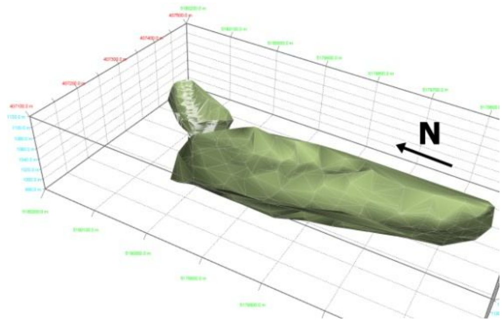

Fig. 6 The 3-D surfaces of the base of the studied deposits.

After modeling the fault and overlaying the geological map onto the DTM, eight geological cross-sections (west to east and south to north direction) were created (Fig. 4). Using the already created cross-sections and the surface modelling algorithms of the Moves3D software, the base surface of the deposits was reconstructed (Fig. 6). Utilizing both the newly created base of the deposits and its top (represented by the DTM), the setting up of volumes was possible (Fig. 7).

Because the modeled faults and conglomerate deposits could only be understood when viewed in a larger framework, the deposits of Bukovinian and Hășmaș Nappes needed to be roughly modeled using the same techniques as above.

By merging all the created 3-D models into a rough assembly of the area structure (Plate 1), the studied conglomerates can be easily interpreted.

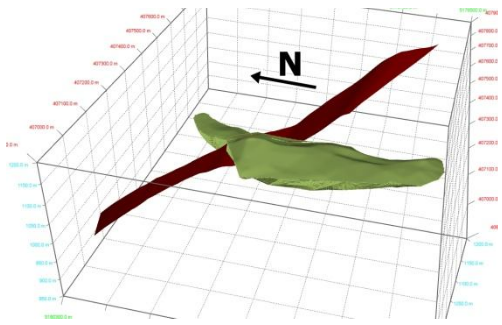

Fig. 7 The 3-D volumes of the conglomerate formation and the 3-D surface of the fault that displaces it.

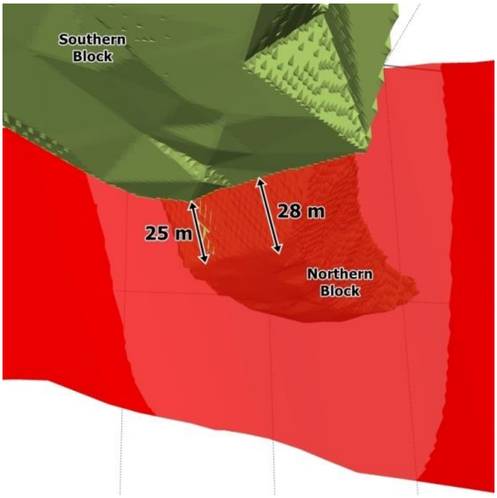

Fig. 8 The minimum and maximum displacements of the fault that crosses the conglomerate formation (southern block and northern block).

4. Results and conclusions

In the Oii creek basin, a rudite deposit has been identified. From the field observation, the rudite deposits are quite large and lie on top of the Wildflysch Formation. Using devices with GPS and GLONASS sensors, the target area has been mapped and the derived information correlated into a geological map which, together with a DTM, contributed to the creation of the 3-D geological model of the studied deposits inside Move3D software.

According to our calculations, the studied formation has a surface of about 100,000 m^2, from which the northern block has a roughly 15,000 m^2 and the southern block, 85,000 m^2. The resulting volumes of the same deposits are about 380,000 m^3 for the northern block and 3,360,000 m^3 for the southern block, summing up a total of 3,740,000 m^3.

Also, the 3-D model developed in the present study (Plate 1) reveals the whole fault displacement. Using the Move3D measurement tools, the maximum and minimum displacements have been determined (Fig. 8).

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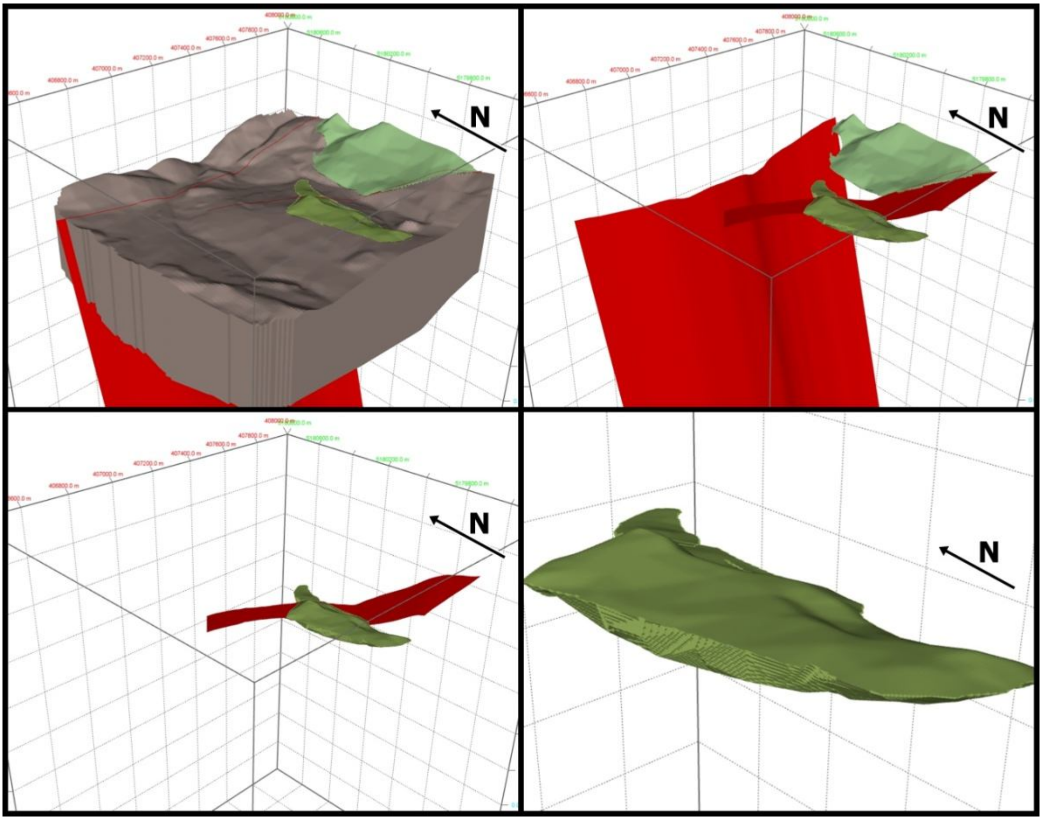
Plate 1



The 3-D geological representation of the study perimeter. Top left – the whole model with the Bukovinian Nappe deposits (3-D volume), Hăşmaş Nappe deposits (3-D volume), conglomerate deposits (3-D volumes), as well as the two faults that cross this area (3-D surfaces). Top right – only the Hăşmaş Nappe deposits (3-D volume), conglomerate deposits (3-D volumes) and the two faults that cross this area (3-D surfaces). Lower left – the conglomerate deposits (3-D volume) and the fault that displaces them (3-D surface). Lower right – the conglomerate deposits (3-D volumes).