Modelling and analysis of possible displacements over the Mt. Peron niche

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The Mt. Peron historical rock avalanche

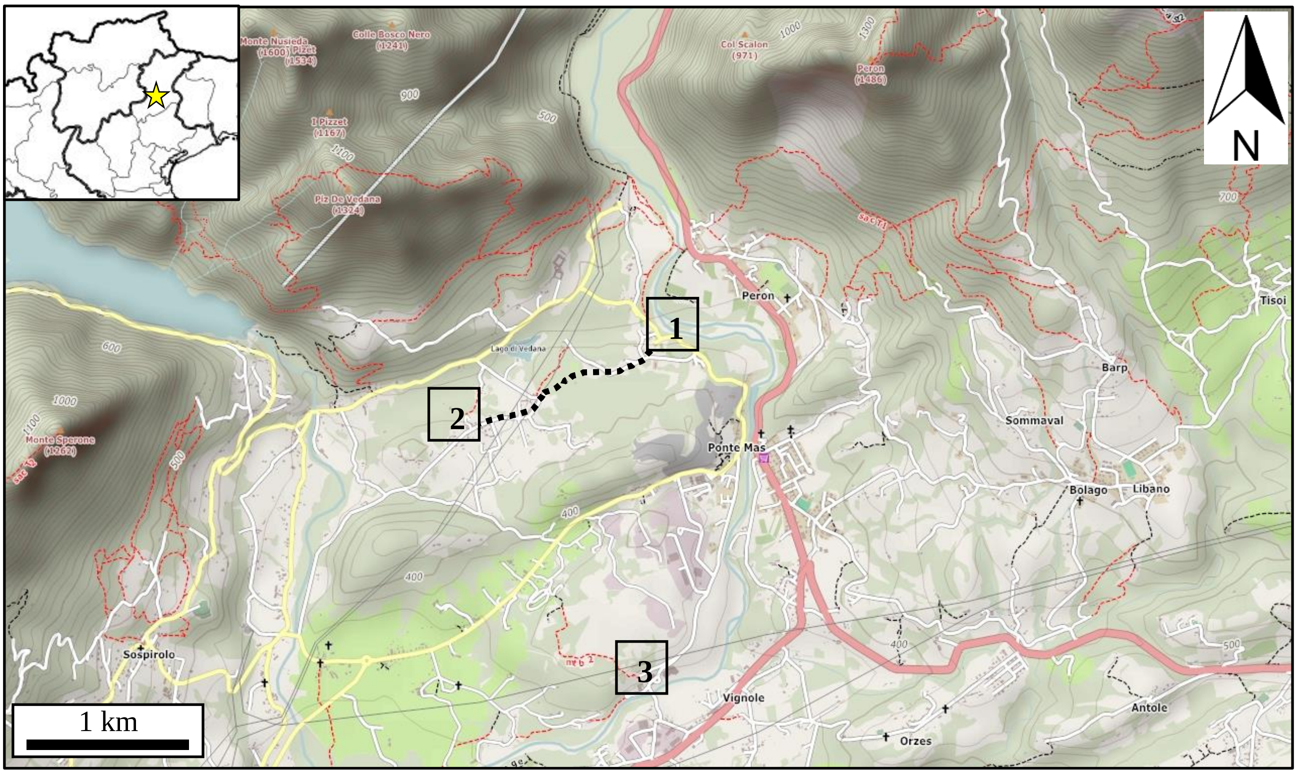

Fig. 1: Topographic map of the excursion area. Numbers correspond to the stops; dashed line indicates a path that will be travelled by foot.

The Mt. Peron rock avalanche is an impressive and complex blocky deposit located in the Venetian Dolomites (National Park of the Belluno Dolomites) of northeastern Italy. In the literature, the deposits have been variously referred to as “Masiere”, “Rovine” or “Marocche” “di Vedana”. This is one of the largest catastrophic events in the Alps, on a scale with event deposits in the Himalaya, and in a densely inhabited area.

Geological and structural setting

The western part Mt. Peron is composed of Jurassic and Cretaceous limestones, forming the nucleus of an ENE-WSW oriented anticline with a vertical-to-very steep forelimb, followed southwards by the Belluno syncline (**Fig. 2**). The eastern part of the Mt. Peron is mainly made of Jurassic and Cretaceous limestones and dolomites. Cenozoic formations crop out west of Mt. Peron, including the ENE-trending bedrock ridge of Castel Cuch, which roughly divides the deposits into two lobes.

Outcrops of Pleistocene fluvial gravels are located just to the west of the present course of the Cordevole River (near Vignole, **Fig. 3**).

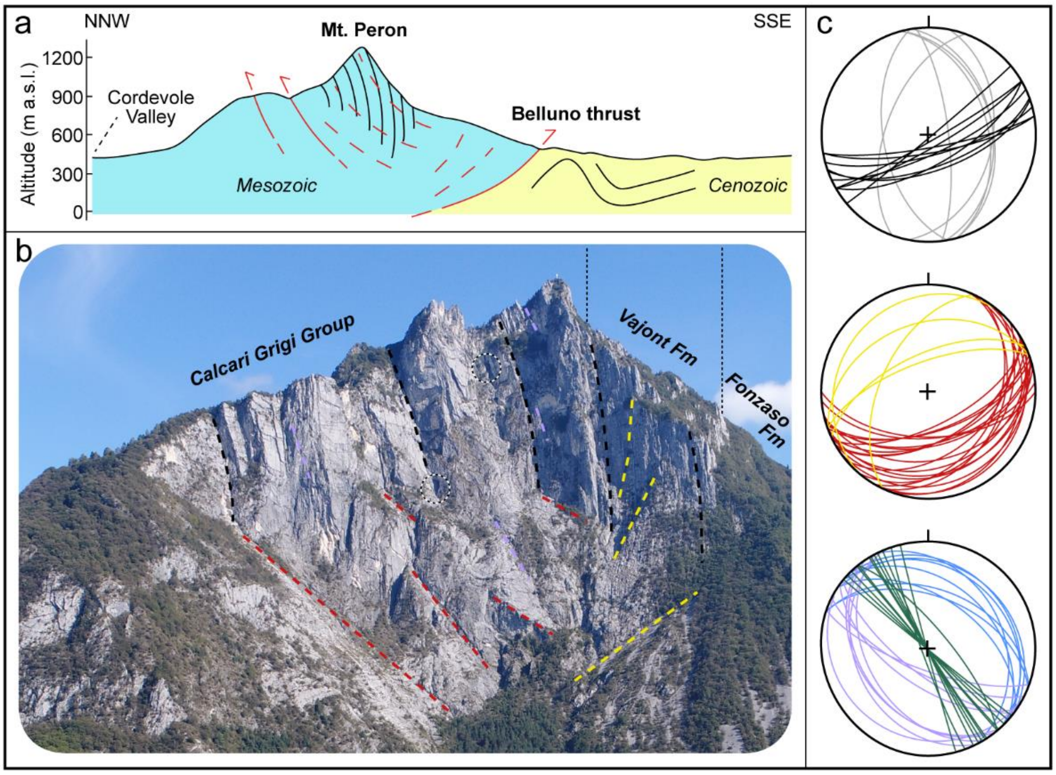

Fig. 2: Structural scheme of the Mt. Peron release scarp. **a)** Schematic geological cross-section. **b)** Photograph with major structural elements and larger karst caves (black-and-white circles) highlighted. **c)** Lower hemisphere stereographic projection of principal structural elements. Colours in b) and c) correspond to the following: bedding (black), N-S Jurassic fault-related planes (grey), basal trenches and other high-angle fractures connected to the Belluno thrust (yellow) and backthrust (red), fractures related to the NNW-SSE fault system (light blue), their conjugates (pink) and high-angle fractures with the same orientation (green). (Source: Rossato et al., submitted)

The Mt. Peron niche is 700 m wide and 600 m high, S-to-SW facing partially circular scarp. Well visible on the wall are numerous faults and fractures belonging to five main discontinuity sets (shown in the stereograms of **Fig. 2**). These comprise: (1) bedding, (2) WSW-ENE directed frontal thrust planes, (3) NW vergent backthrusts, and (4) NNW-SSE aligned local conjugate fracture planes sets, (5) persistent N-S oriented Jurassic faults. Today myriad large and small individual rock prisms bound by these discontinuities are present at high elevation in the release area.

The deposit

The rock avalanche deposit spreads over about 9 km^2, with a total volume of more than 150 Mm^3, and a mean thickness of about 20 m. Based on spatial pattern, boulder lithology and morphological character, we distinguish five sectors of the deposits: Peron, Vedana, Torbe, Masiere and Roe (Roe Alte and Roe Basse).

- The **Peron** sector includes the talus apron deposits at the foot of Mt. Peron, the rock avalanche deposits on the east side of the river and the terrace of Peron town (at about 380 m a.s.l.).

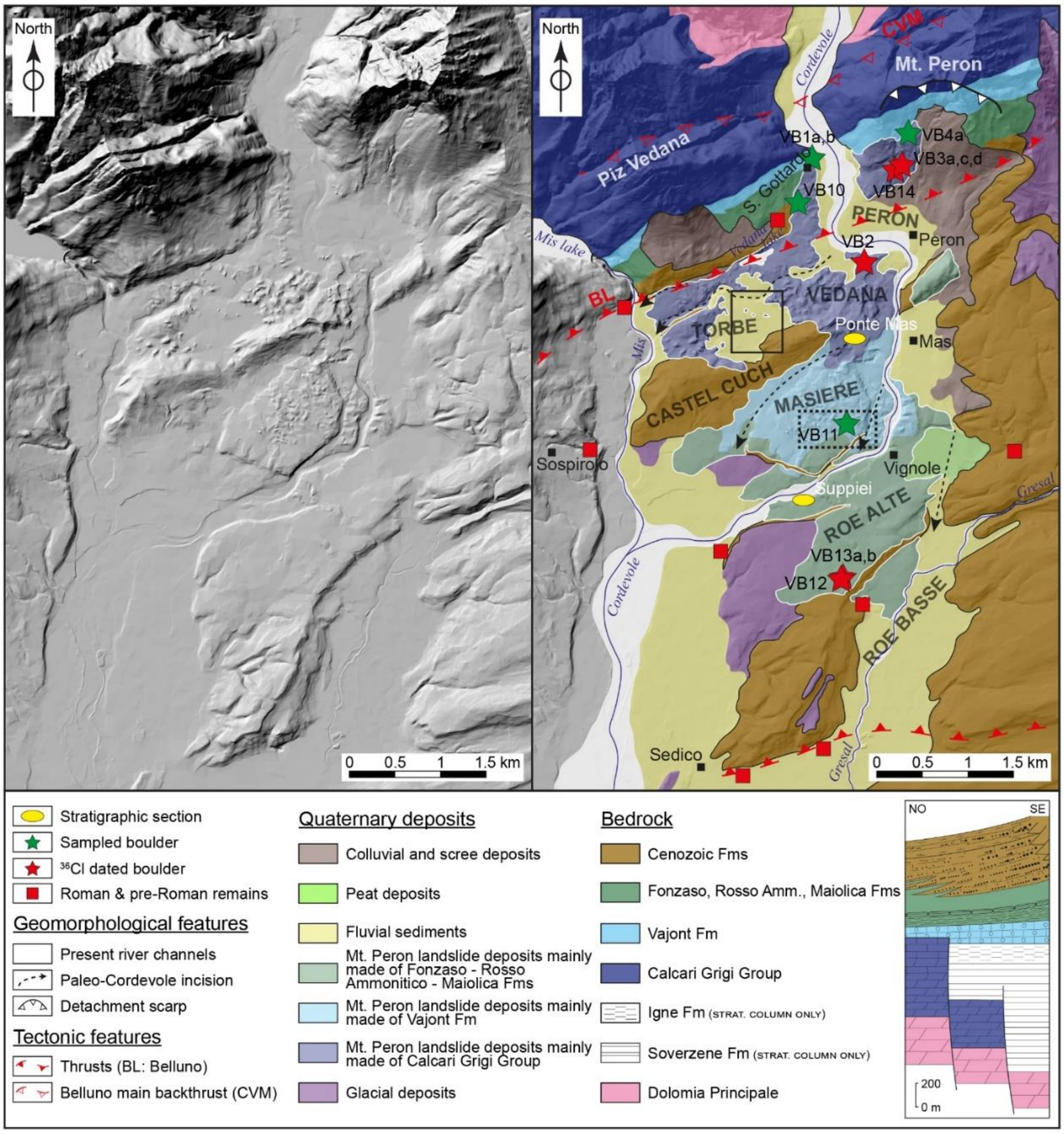

Fig. 3: Geological map of the study area. The boundary of Mt. Peron rock avalanche deposits is marked **with solid white line**, whilst the contact between Quaternary sediments and bedrock is shown with **solid black line**. The location of boulders sampled for dating (**red stars**) and/or thin section analysis (**green stars**) are shown. Archaeological findings are indicated by **red squares**. Location of stratigraphic sections (**yellow ellipses**) and paleo-Cordevole paths (**black dashed arrows**) are shown. In the lower right, a stratigraphic sketch of bedrock formations cropping out in the Belluno area is given (modified from Costa et al., 1996). (Modified from: Rossato et al., submitted)

- In the **Vedana** sector, the rock avalanche deposit displays a highly irregular, thinly forested topography with huge blocks hundreds of cubic meters in size. Locally, glacial sediment is incorporated into the base of rock avalanche.

- The **Torbe** sector encompasses the distal rock avalanche deposits of the lobe north of Castel Cuch where isolated conical hills and hummocks emerge from a flat topography, “toma”. In the flat area a few meters of silty sands cover the rock avalanche deposits, likely due to the Cordevole activity.
- The **Masiere** part is a bleak, vegetation-free, desert-like sea of limestone blocks. Boulders are meter-size and abundant angular and sub-angular clasts, lacking fine matrix in the surficial deposits are observed.
- The areas of **Roe Alte** and **Roe Basse** comprise the distal sector (**Fig. 3**), very few boulders immersed in a sandy matrix are scattered in the meadows. The Roe Basse sector is made of alluvial sediments which mantle the rock avalanche deposit on the northwestern side. Locally, the rock avalanche shows direct and sharp basal contact with glacial sediment.

The age of the event

Boulders from across the deposit have been sampled ^{36}Cl surface exposure ages. Dates and historical records collected will be discussed during the excursion.

Triggers and current hazard

Progressive increase of rock fatigue and the formation then subsequent weathering of shear planes were essential predisposing factors. The present understanding of the processes required for such a failed rock mass to achieve excessive runout speaks for a single huge catastrophic event for the whole deposit.

The Belluno region is prone to seismic activity and has experienced several major earthquakes in the last few hundred years, some up to Mw 6. The Mt. Peron rock avalanche may have been triggered by a meteorological event, possibly in conjunction with a sequence of low magnitude seismic shakings. Nevertheless, no exceptional event may be required for such rock avalanches to occur, as accumulation of damage markedly lowers the energy needed to trigger failure.

Today, numerous partially detached rock prisms are evident along the upper part of the Mt. Peron rock wall. As the same predisposing factors that likely led to the rock avalanche (pervasively fractured rock, vertical strata, fracture planes cutting the stratigraphic sequence) and triggers (seismicity and/or extreme rainfall events) are still present, the hazard remains.

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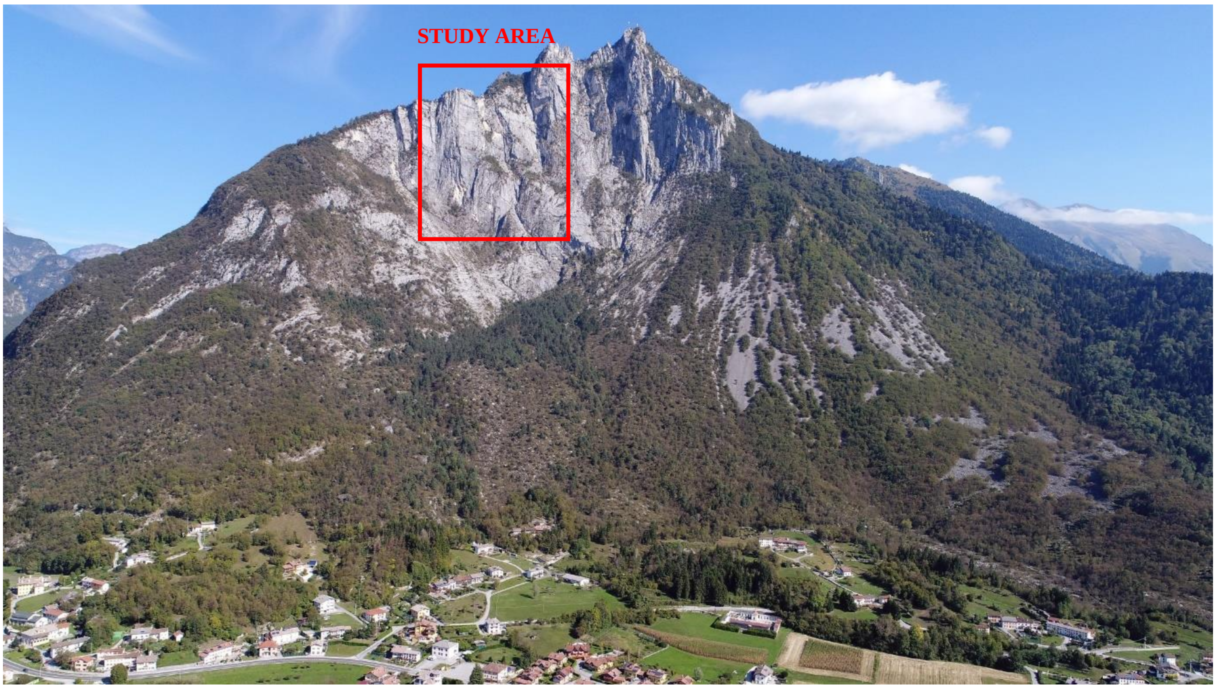

Fig. 1: Position of the study area of the Mt. Peron niche. Photo taken through the drone during the photogrammetric survey.

The Mt. Peron presents as a very exposed niche about 800 m large and 700 m high from 700 m a.s.l. to 1486 m a.s.l. (highest point of the crest). The study area in **Fig. 1** is composed by three main pillars, possibly unstable. This area is difficult to reach due to the isolation of the mountainside.

Field survey data acquisition and interpretation

For the 3-dimensional representation of the study area, a photogrammetric survey was performed taking 150 photos using a commercial drone/UAV (Unmanned Aerial Vehicle). From those images a points cloud (**Fig. 2**) and a triangular mesh have been built using the SfM (Structure form Motion) tecnique through the software Agisoft Photoscan©.

Fig. 2: Drone used during the surveys activities and points cloud generated using the acquired images.

The point cloud allowed the measures of the planes of the bedding joints and fractures visible over the mountainside difficult to reach with a classic geomechanical survey. Totally, a number of 159 planes were taken. This approach can be considered as a “remote geomechanical survey” that is commonly performed nowadays thanks to drones features.

Fig. 3 shows the 4 sets of discontinuities observed over the mountain side and the stereographic plot of the poles of those planes.

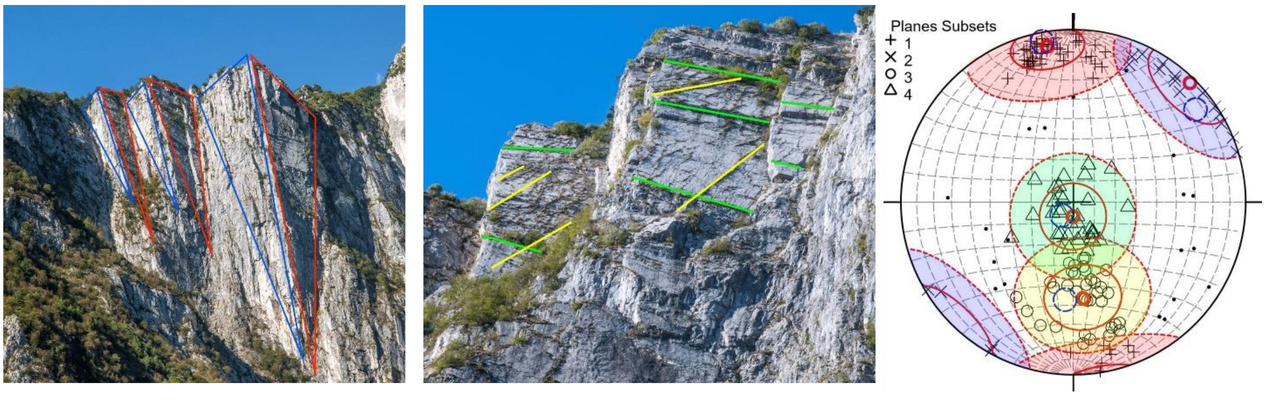

Fig. 3: Planes sets measured on the points cloud and correspondence with the ones observed over the mountain side.

Modelling

The stability analysis was performed through the software 3DEC by Itasca, which exploits the Distinct Element Method (DEM). Four sets of joints are introduced in the model as a Discrete Fracture Network (DFN), linking the geometrical parameters for each set to the statistical elaboration of the planes measured on the points cloud.

The 3-dimensional mesh generated from the points cloud is then extruded in order to obtain the block forming the study area.

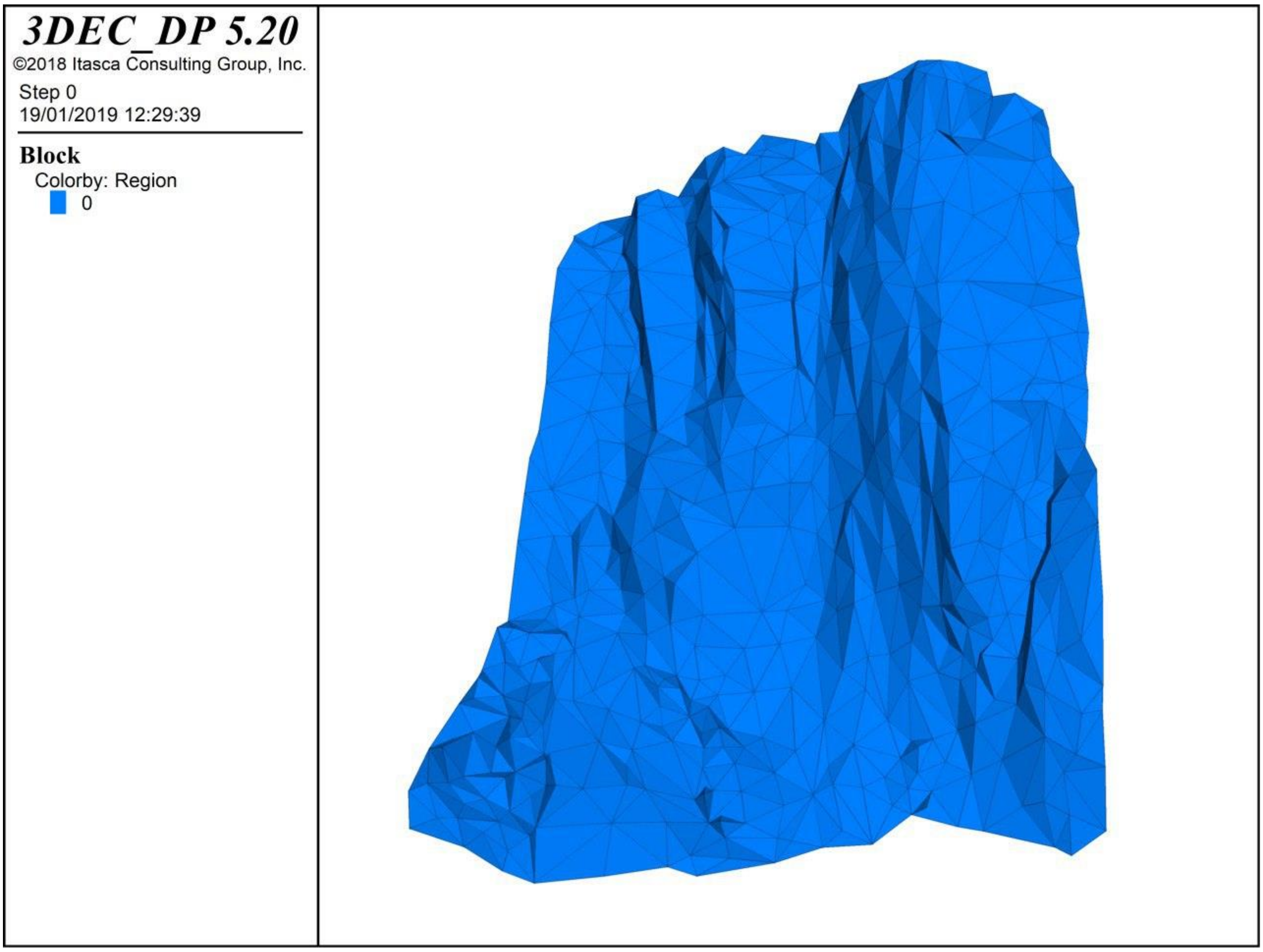

Fig. 4: Extruded block from the 3d mesh.

The mechanical parameters of the rock mass and of joints were set on the base of ??.

The mechanical parameters of the rock mass and of joints were set on the base of a previous survey by Di Giusto (2012). The measurement of the friction angle and cohesion of some joints were considered as representative of all the simulated joints. A sensitivity analysis over joints friction angle, cohesion, and joints distribution is currently undergoing searching for statistically reliable values of joints properties.

The Factor of Safety Calculation is performed in order to define the stability condition of the mountainside under dry or wet condition (joints completely filled by water). Moreover, the evaluation of the Maximum Out-of-Balance Force is used to check if the system is going towards stability conditions or not. As final output the numerical model gives the displacements in x, y and z directions for all the blocks that build the geometry and the stresses for each joint.