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Edited by
Károly Németh and Szabolcs Kósik

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Volcanism in a rapidly changing environment relating to an atypical plate margin

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Newly identified debris avalanche deposits (DADs) in the North Harghita Mts. (Romania): emplacement history and tectonic significance

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Geological mapping in old, poorly exposed volcanic areas has been recently improved by using digital elevation models (DEM). Here we document two old debris avalanche deposits (DADs) belonging to two adjacent volcanoes, Ostoroş and Ivo-Cocoizaş located in the North Harghita Mountains of the Călimani-Gurghiu-Harghita volcanic range (CGH) in the East Carpathians, Romania (Fig. 1).

CGH consists of twelve juxtaposed medium-sized composite volcanoes as well as several close-by isolated monogenetic cones. Volcanological observations and K/Ar geochronology attest that CGH is the result of a nearly continuous eruptive activity that migrated from NNW to SSE between 10.2 and 0.03 Ma (e.g., Pécskay et al., 2006 and references therein). Detailed geological mapping, petrographic observations, and K-Ar geochronology carried out in the past two decades led to the identification of a series of major edifice failure (e.g., Szakács & Seghedi, 1995, 2000). Several SSW-oriented DADs have been identified in association with the main volcanic edifices: Rusca-Tihu at ~7.8 Ma in Călimani Ma, Fâncel-Lăpuşna (~6.8 Ma) in Gurghiu, Vârghiş (~4.8 Ma) in North Harghita, as well as Luci-Lazu (~4.0 Ma) and Pilişca (~1.7 Ma) in South Harghita.

A series of new volcanological, petrographic, and geomorphic observations reveal two previously unidentified DADs generated close to each other at the Ostoroş and Ivo-Cocoizaş composite edifices at ~5Ma. The main difference from the other CGH DADs is their E-SE-directed displacement.

The Ostoroş (O) and Ivo-Cocoizaş (IC) composite volcanoes initiated their activity by phreatomagmatic eruptions, and continued as effusive cones delivering amphibole-pyroxene and pyroxene-bearing andesites in O and chiefly pyroxene andesites in IC. The two edifices form a buttressed system along with the Vârghiş volcano (Fig. 2). The activity of both volcanoes ended with major sector collapse events in the eastern part of their edifices, toward the Upper Ciuc Basin that developed in the same time (Mureşan & Szakács, 1996). The magmatic feeding systems of the volcanoes are indicated by hydrothermally altered volcanic rocks and associated small intrusions (red circles in the figure 2).

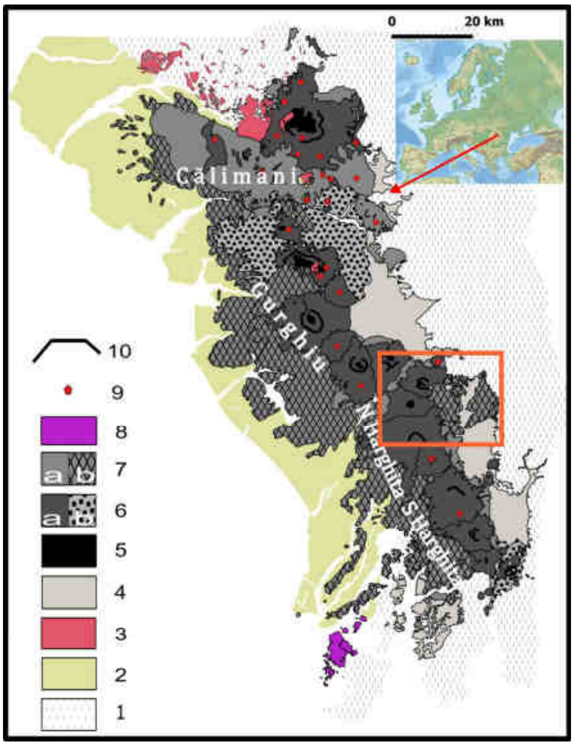

Fig. 1 – Simplified volcanic facies map of CGH. Inset shows location in Europe, frame indicates the studied area. Legend: 1. East Carpathian basement; 2. Transylvanian Basin formations; 3. Subvolcanic intrusions; 4. Intra-mountain Basins; Volcanic edifices: 5. Central facies; 6. Proximal facies: a. dominantly effusive; b. dominantly explosive; 7. a. medial-distal facies; b. debris avalanche deposits; 8. Perşani Mts. alkali basaltic field; 9. Volcanic center; 9. Caldera/crater/edifice failure rim.

The collapse scars are morphologically well exposed, being larger at IC; they are filled with toreva block, especially at IC. The original scars are now disrupted by subsequent degradation processes, soil formation and vegetation growth.

DADs deposits within the amphitheater are best observed in the O edifice, where tilted, hydrothermally altered amphibole-pyroxene lava blocks of several cubic meters (toreva) are associated with monogenetic clast-supported lithic breccia. Outside amphitheaters, in the medial area, DEMs indicate numerous hummocks and various mound-shaped topographic features; these are well preserved, suggesting that no significant erosional processes occurred in the past 5 Ma. They are mostly covered by thin Quaternary deposits and soil, but are available to observations in several quarries. The two DADs tend to overlap and are thus difficult to distinguish in their medial sections.

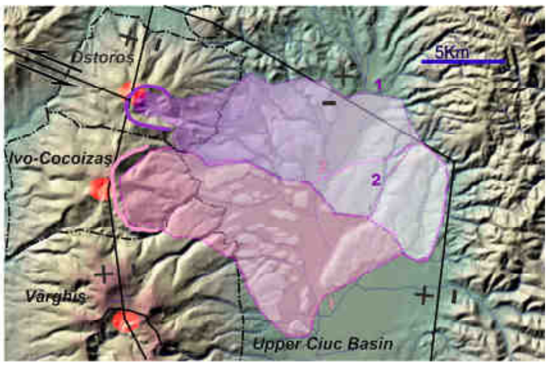

Fig. 2 – DEM of the studied area showing the distribution of hummocks as well as and ridges in the distal DADs. The outline of volcanoes, their collapse scars, their inferred central feeding systems (red circles) are highlighted; normal and strike-slip faults are shown as black lines. Contours 1 and 2 mark two alternative DAD models discussed in the text.

In the medial section of DADs hummocks show various shapes. In the block facies dominated IC-DAD they appear as 60m high, ~500m wide, and 150-2000m long E-W elongated ellipsoids, and are locally associated with debris flows. Medial hummocks in O-DAD are dominated by matrix facies commonly associated with debris flow deposits; they too are E-W elongated, but display larger front widths up to ~2000m.

In the distal zone, both DADs show large hummocks oriented normal to the transport direction. There is a middle ridge between two N-S oriented hummocks in the front of O; the ridge in the front of IC displays a slight shift in orientation toward SW. If the two ridges and hummocky deposits developed simultaneously, but involved different lithologies, it is possible that the resulting contrasting mechanical behaviors have led to dissimilar emplacement dynamics (Valderrama et al., 2016).

The existing data allow us to formulate two depositional models (Fig. 2). The first model (M1) proposes that all the northern hummock groups including large volume of hydrothermally altered rocks belong to O, whereas the southern hummock groups dominated by block facies belong to IC. In this case, volume estimates for O-DAD and IC-DAD are 8.6 km^3 and 10 km^3, respectively. The second model (M2) proposes that the entire frontal ridge belongs to IC-DAD, which has formed first, whereas the spreading of the subsequent O-DAD has been limited by the IC-DAD frontal ridge. In this scenario, O-DAD and IC-DAD mobilized 6.1 km^3 and respectively 12.6 km^3 material. Further observations are required test these models.

The edifice failure events affecting O and IC appear to be closely related to a series of tectonic processes that followed the along-range growth of new volcanoes and the opening of intra-mountain basins in a post-collisional setting (Fielitz and Seghedi, 2005). After the concurrent formation of the Upper Ciuc Basin and activation of volcanism in North Harghita (6.5-5Ma), the initial strike-slip faults continued operating as normal faults, thereby facilitating edifice failures at O and IC as well as the displacement of their DADs toward E-SE. This situation represents an exception from the other DADs in CGH, which are displaced toward the SSW from their source volcanoes, most likely following the preexisting topographic slope toward the Transylvanian Basin (Seghedi et al., 2017).

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