



INTERNATIONAL ASSOCIATION OF GEOMORPHOLOGISTS (IAG)
REGIONAL CONFERENCE ON GEOMORPHOLOGY
16 - 18 September, 2025, Timisoara, Romania



Pre-conference fieldtrip

Southern Transylvania: geomorphology, cultural landscape, and geo-heritage



dr. Olimpiu POP
dr. Andrea GAL
dr. Ionela Georgiana RĂCHITĂ

Babeş-Bolyai University, Faculty of Geography
Cluj-Napoca, Romania

12 - 15 September, 2025

Transylvanian Basin – geological and morphological features

Transylvanian Basin, located in central Romania, is one of the most distinctive intramontane depressions in Europe. Enclosed by the Carpathian arc, it represents a large Neogene sedimentary basin with a complex geological and geomorphological evolution (Săndulescu, 1984; Krézsek and Filipescu, 2005).

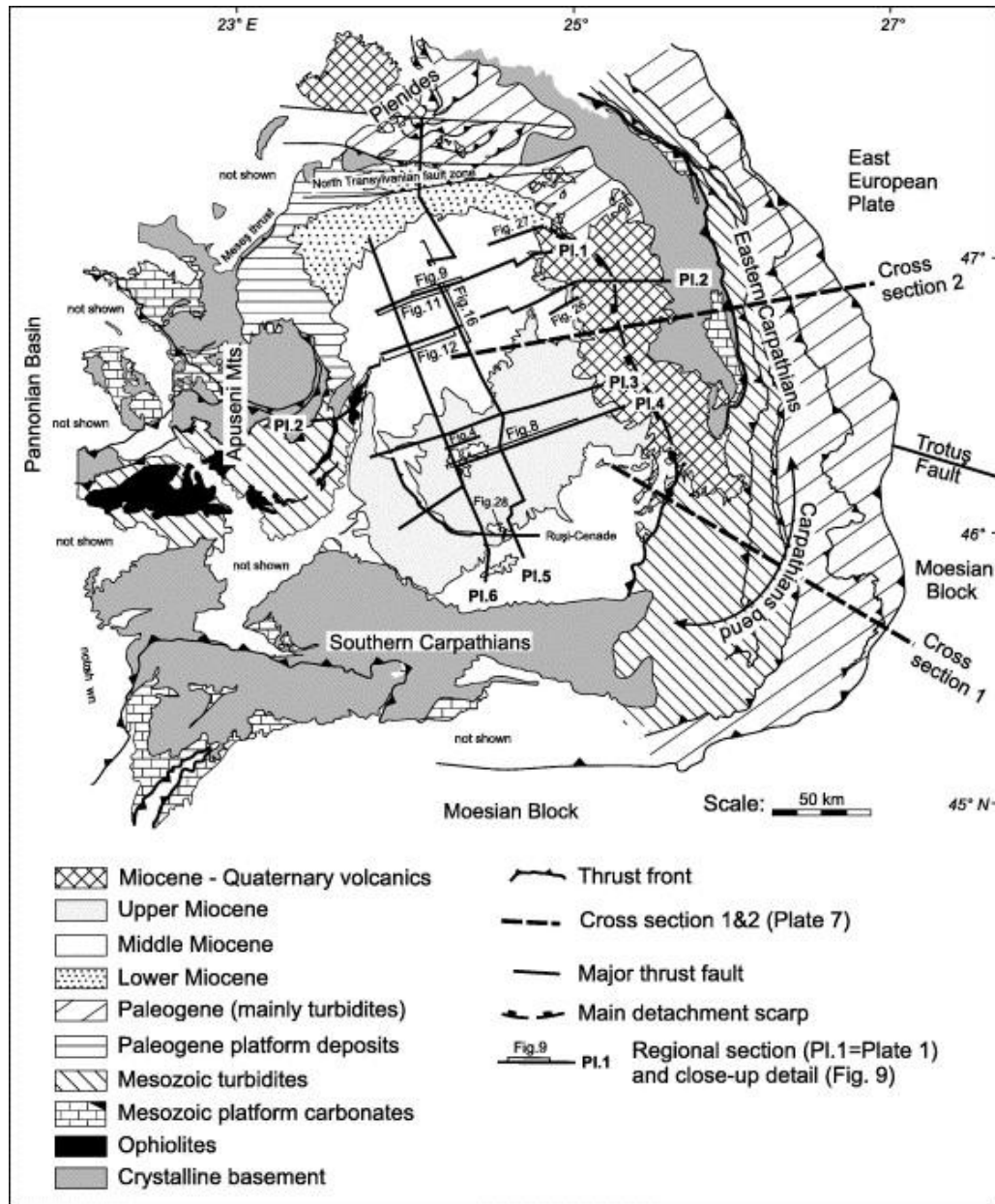


Fig. 1: Geological sketch map of the Transylvanian Basin and surroundings (Krézsek and Bally, 2006)

The basin developed as a back-arc depression during the Neogene, infilled with up to 5,000 m of sediments. The stratigraphy is dominated by Oligocene–Miocene deposits, including marls, clays, sandstones, volcanic tuffs, and widespread evaporites (Ciupagea et al., 1970; Krézsek and Bally,

2006). The sedimentary fill records alternating marine and lacustrine phases, reflecting tectonic subsidence and fluctuating connections to the Central Paratethys (Popov et al., 2004).

Transylvanian Basin is structurally controlled by buried thrust sheets and inherited fault systems from the Carpathians (Săndulescu, 1984). The most striking features are the salt diapirs, which pierce overlying sediments and deform them into domes and anticlines. These diapiric movements are still active in places, producing surface deformation, hydrogeological anomalies, and slope instability (Ștefănescu et al., 2000; Matenco and Radivojević, 2012).

The architecture of Transylvanian Basin was interpreted using regional seismic data and deep wells. E–W and N–S sections (Fig. 2, Fig. 3).

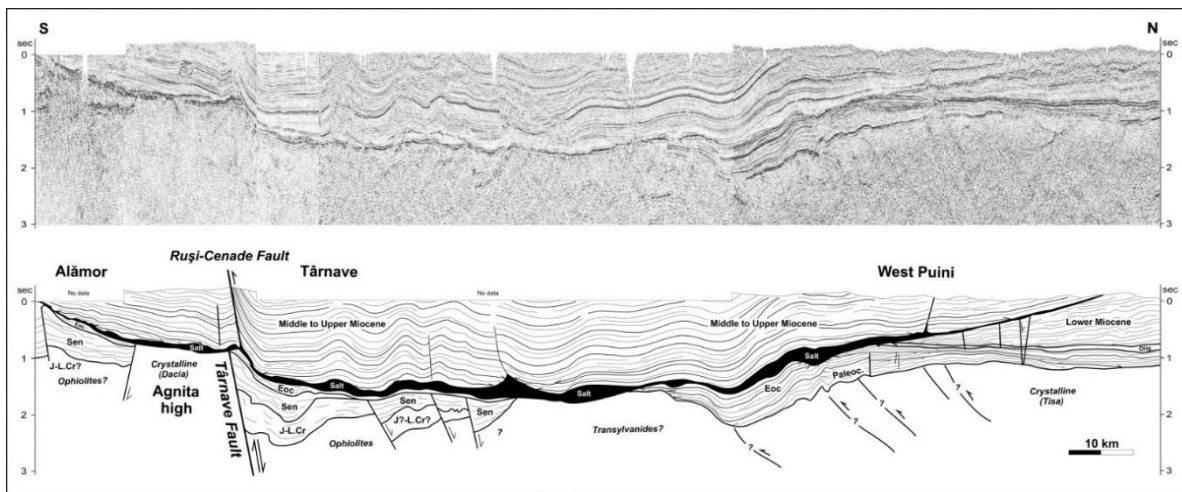


Fig. 2: North–south oriented regional section. (Krézsek and Bally, 2006).

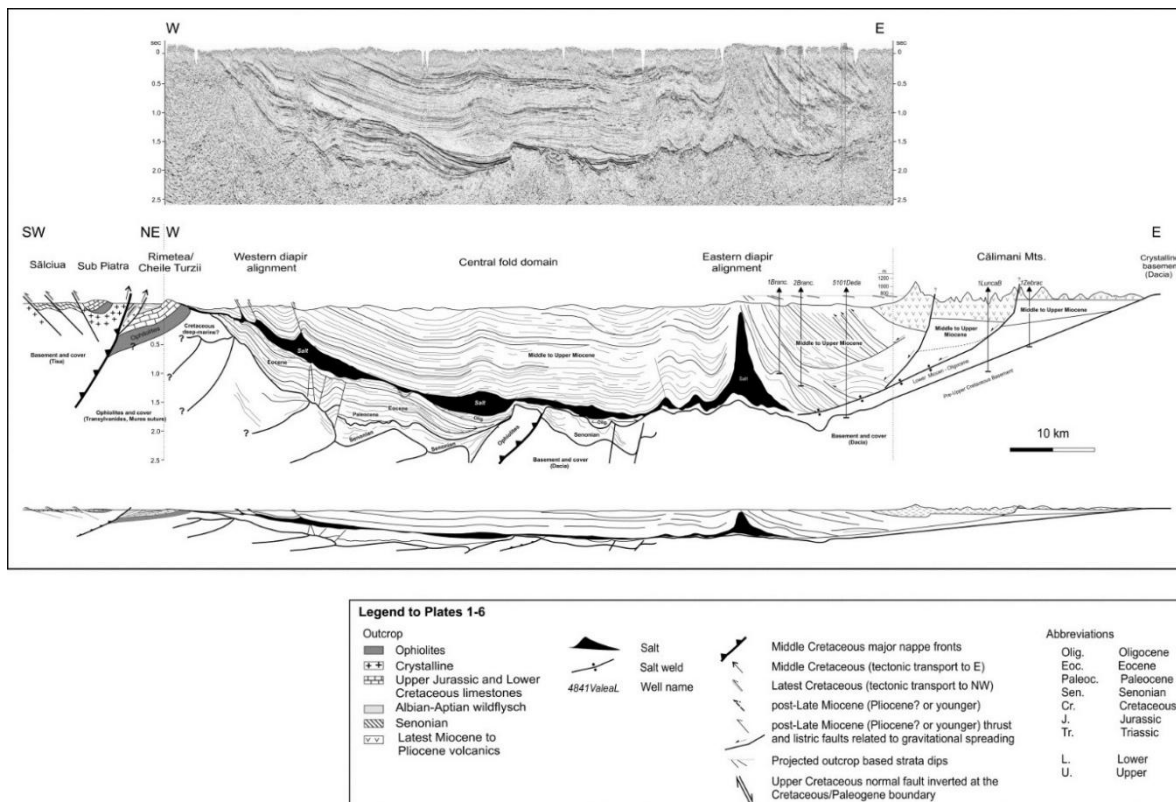


Fig. 3: East–west oriented regional section. (Krézsek and Bally, 2006).

References

Ciupagea, D., Pauca, M., & Ichim, T. (1970). *Geology of the Transylvanian Depression*. Romanian Academy Publishing, Bucharest.

- Kr zsek, C., Bally, A. W. (2006). The Transylvanian Basin (Romania) and its relation to the Carpathian fold and thrust belt: insights in gravitational salt tectonics. *Marine and Petroleum Geology*, 23(4), 405–442.
- Matenco, L., Radivojevi , D. (2012). On the formation and evolution of the Pannonian Basin: Constraints derived from the structure of the Carpathians. *Tectonics*, 31(6), TC6007.
- Popov, S. V., R gl, F., Rozanov, A. Y., Steininger, F. F., Shcherba, I. G., & Kovac, M. (2004). Lithological–paleogeographic maps of Paratethys. *Courier Forschungsinstitut Senckenberg*, 250, 1–46.
- S ndulescu, M. (1984). *Geotectonics of Romania*. Romanian Academy Publishing, Bucharest.

F g ra  Mountains and the Transf g ra an Alpine Road

Southern Carpathians, often called the *Transylvanian Alps*, extend for more than 250 km between the Prahova Valley and the Iron Gates. Among these, the F g ra  Mountains represent the highest and most massive mountain range in Romania, with Moldoveanu Peak (2,544 m) and Negoiu Peak (2,535 m) rising above deeply incised glacial valleys (Fig. 4).

Morphologically, the F g ra  Mountains form a compact crystalline massif, predominantly composed of metamorphic rocks (gneisses, mica schists) intruded by granites, while the sedimentary rocks are on the marginal areas. Steep slopes, narrow ridges, and glacially sculpted cirques are the dominant features.

The massif exhibits strong morphometric asymmetry. Northern slope is steep (up to 1,700 m vertical drop in <10 km), deeply incised by short valleys (B lea, Arpa , Vi tea, S mbata). The southern slope is longer, gentler gradients, drained by the Arge  headwaters. The crest zone is a continuous alpine ridge exceeding 2400 m over ~70 km, dotted with glacial lakes (Fig. 5) and separated by narrow cols.

The climatic conditions in the high mountain areas of the are cold, with the mean annual temperature of 0.2 C and mean annual precipitation of 1246 mm at B lea-Lake weather station (2038 m a.s.l.) (Urdea et al., 2011).

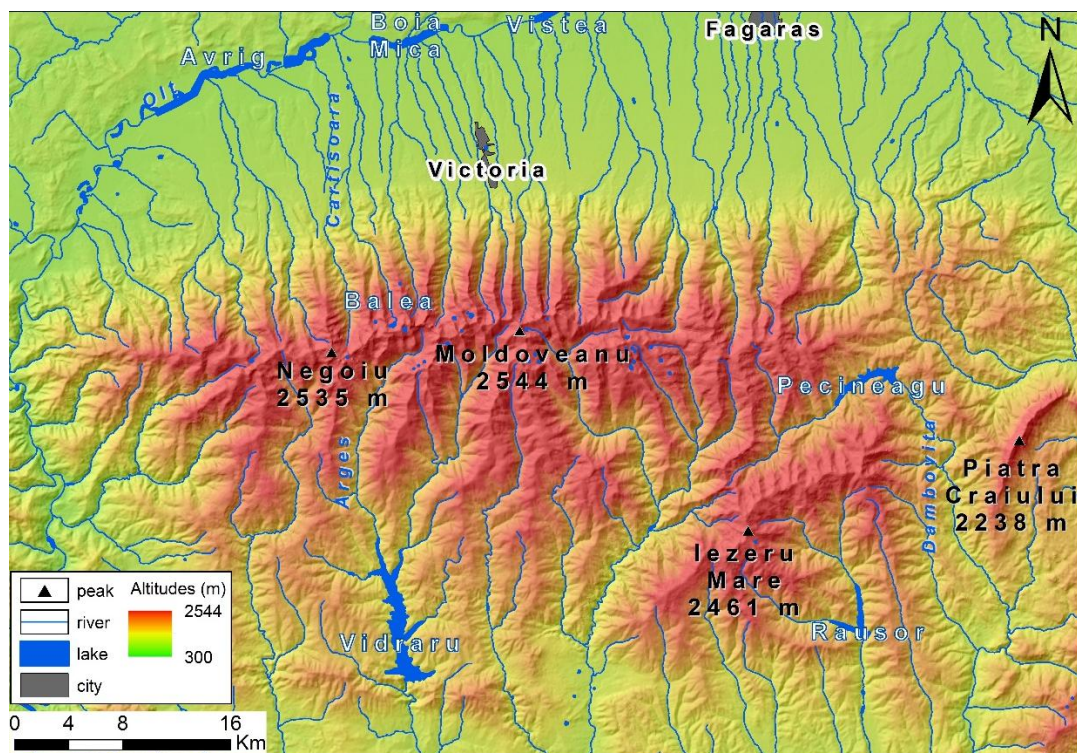


Fig. 4: Location of the Moldoveanu and Negoiu peaks in the F g ra  Mountains.

The relief was shaped by a combination of tectonic uplift, fluvial incision, and Pleistocene glaciation, which superimposed spectacular glacial landforms. During the Pleistocene glaciations, the Făgăraș Mountains hosted some of the most extensive glaciers in the Romanian Carpathians (Urdea et al., 2011). On north-facing valleys, glaciers extended to altitudes as low as 1300–1200 m a.s.l. Valley glaciers reached lengths of 6–8 km (e.g., Bâlea, Capra, Arpaș), forming classic U-shaped valleys. Over 40 cirques have been identified, many housing glacial lakes such as Bâlea, Capra, Podragu, and Călțun. Moraine systems (terminal, lateral, and recessional moraines) are preserved in valley floors. During the Late Glacial, periglacial processes (frost weathering, solifluction, etc.) played a key role in shaping ridges and slopes.

Although glaciers have disappeared nowadays, geomorphic activity remains intense. Periglacial activity persists above 2000 m, with active screes, solifluction lobes, and frost-shattered ridges. Snowpatches and nivation hollows contribute to slope undercutting. Rockfalls and debris flows occur frequently on steep cirque headwalls and talus slopes. Snow avalanches remain a major process in winter and spring seasons, shaping avalanche paths and feeding talus accumulation.

Climate change, with rising temperatures and decreasing snowpack duration, is expected to reduce seasonal snow cover but may shift the period of snow avalanches and increase the frequency of extreme rainfall-triggered debris flows.



Fig. 5: Bâlea Lake.

The Transfăgărașan Alpine Road

The Transfăgărașan Alpine Road (Fig. 6) is one of Romania's most spectacular engineering works. Built between 1970 and 1974 under the leadership of Nicolae Ceaușescu, the road was intended as a strategic military route across the Făgăraș Mountains, linking Valahia (Muntenia) with Transylvania.

The construction involved enormous effort. Over 6000 tons of dynamite were used to blast through crystalline rocks. Approximately 40 viaducts, tunnels, and bridges were constructed. The workforce included thousands of soldiers and engineers, working under harsh alpine conditions.

Road construction profoundly altered the natural geomorphological landscape. Slope oversteepening by blasting and excavation destabilized cirque headwalls and valley sides, triggering rockfalls and debris slides. Cut-and-fill terraces created along slopes, and tunnel construction interrupted natural slope profiles and modified subsurface drainage, occasionally redirecting groundwater flow. Glacial and talus deposits were removed or reshaped by excavation during road alignment. Mobilized debris and accelerated erosion led to short-term aggradation in torrent channels.



Fig. 6: Transfăgărășan Alpine Road.

Even today, the Transfăgărășan remains geomorphologically unstable. Frequent rockfalls and debris flows affect road stability, especially near Bâlea Waterfall and Capra Valley. Snow avalanches close the road for most of the year (November–June). Permafrost-like conditions and freeze–thaw cycles cause road deformation and cracking at high altitudes. Slope stabilization works (retaining walls, netting, drainage) are in continuous need of maintenance (Gratton et al., 2015).

The Transfăgărășan Road is an outstanding example of how infrastructure reshapes mountain environments, but also of the long-term costs of maintaining transport routes in high-relief, geomorphologically active terrain.

References

- Urdea, P., Onaca, A.L., Ardelean, F., Ardelean, M., 2011. New Evidence on the Quaternary Glaciation in the Romanian Carpathians. In *Developments of Quaternary Science – Quaternary Glaciations-Extent and Chronology*, vol. 15, Ehlers J., Gibbard P.L., Hughes, P.D. (eds.), Elsevier, pp. 305-322.
- Gratton, M., Morin, S., Germain, D., Voiculescu, M., Ianas, A., 2015. Tourism and natural hazards in Balea glacial area valley, Fagaras Massif, Romanian Carpathians. *Carpathian Journal of Earth and Environmental Sciences* 10 (2): 19 – 32

Piatra Craiului Mountains

The Piatra Craiului Mountains are situated in the easternmost part of the Southern Carpathians, bordered by Bran-Rucăr-Dragoslavele tectonic corridor (in the east), the upper courses of the Bârsa-Dâmbovița-Tâmaș valleys (in the west), and the Brașov hollow basin (in the north).

The main ridge, oriented NE–SW, corresponds to a flank syncline which consists predominantly of tectonized Jurassic limestones (Onac and Goran, 2019) (Fig. 7).

The area is situated in a highly fragmented space belonging to the Median Dacite tectonic unit and is located at the eastern extremity of the Getic Canvas (Săndulescu, 1984). The massif comprises a basement of crystalline schists over which is a Mesozoic cover represented by limestone (Kimmeridgian-Tithonic), polymictic conglomerates with calcareous elements (Upper Aptian), conglomerates with crystalline elements (Vranconian-Cenomanian), sandstones (Vranconian-Cenomanian), red limestones and radiolarites (Callovian-Oxfordian), marly flysch with calcarenite (Barremian), sandy limestones, etc. (Patrușiu, Dimitrescu and Dessila-Codarcea, 1968) (Fig. 8).

The massif represents a distinct type of karst, called unitary limestone bar, characterized by the appearance of a unique limestone ridge with a varied and complex karstic and periglacial relief (Onac and Goran, 2019).

Limestones are included in the so-called Piatra Craiului Group, which comprises two different lithostratigraphic units: the Spiral Formation (consisting of red limestones, radiolites of Oxford age), and Kimmeridgian-Tithonic formation (made of limestone, stratified reefs strongly intersected by faults) (Panaiotu, 2000). The Piatra Craiului Group and Upper Aptian conglomerates cover a 20 km

in length and 1.8 km in width area, marking the massif's highest elevations and the most spectacular geomorphological landscapes (Cruceru et al., 2025) (Fig. 9).

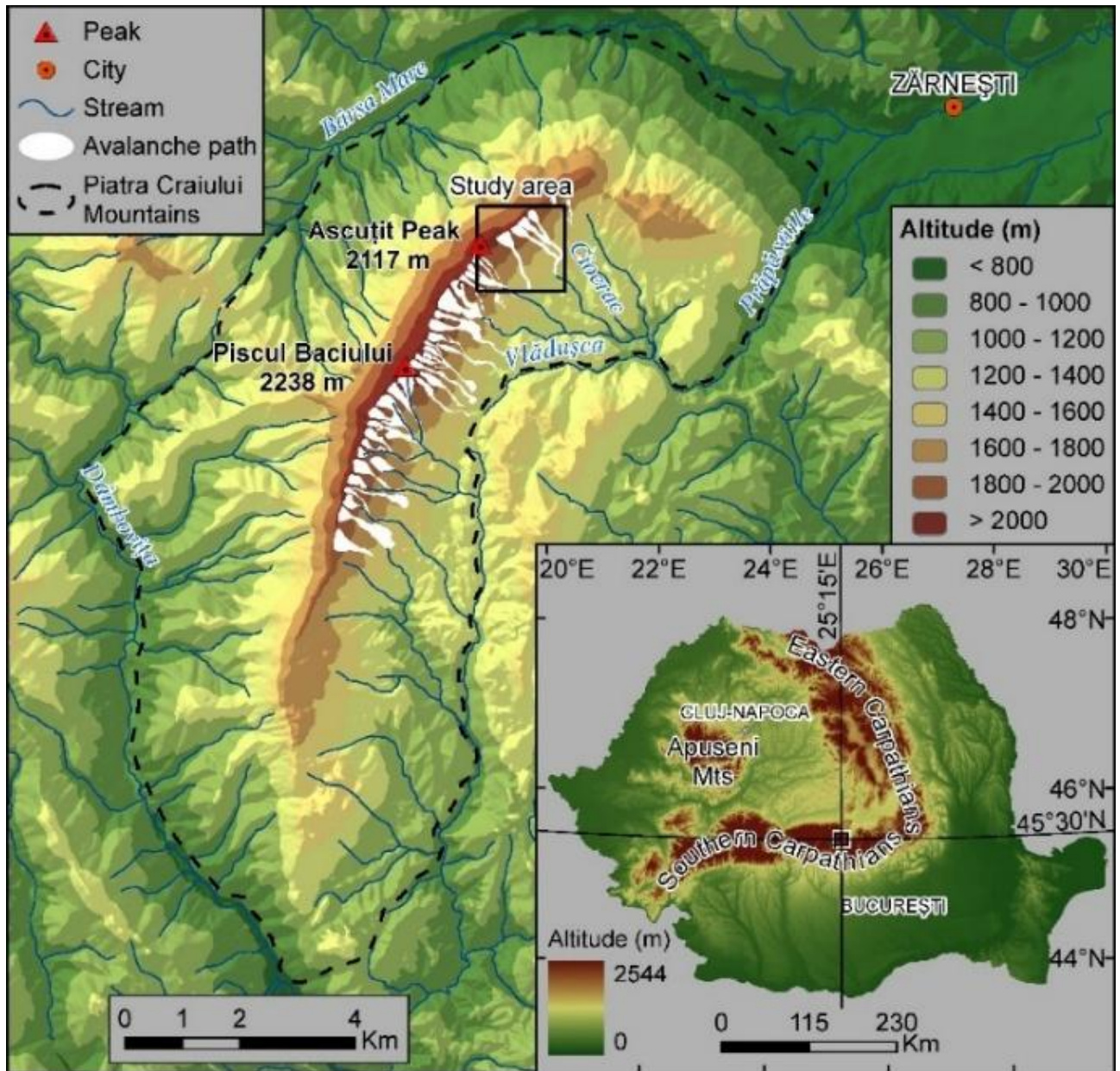


Fig. 7: Location map of the Piatra Craiului Mountains.

The overall morphology corresponds structurally to a suspended syncline flank. The mountain unit of Piatra Craiului is presented as the western flank of this syncline (Constantinescu, 2009). This hogback reaches a maximum altitude of 2238 m a.s.l. in Piscul Baciului Peak. The syncline flank of the main ridge is well represented on the eastern slope, particularly in the central part, which is fragmented by a fault line. It is crossed perpendicularly by numerous valley couloirs that descend from the slope collected by the Vlădușcăi and Seaca Pietrelor valleys. Almost parallel to the Tămaș valley, there are also two segments of anticline with low impact on the landscape (Cruceru et al., 2025).

The syncline flank is decisive in the typology of morphostructural subunits: hogback (Great Stone Peak in the north) and cuesta (Pietricica Peak to the south). The hogback of Piatra Mare, characterized by its structural steepness (the ends of the strata) to the northwest, has a slightly arched shape with a northeast-southwest direction and slopes with a large and almost symmetrical incline.

On the northwest and west side, there are structural shelves, branes, sometimes secondary slopes - tectonic and tectono-erosive, e.g., under Grind Peak (Velcea and Savu, 1982).

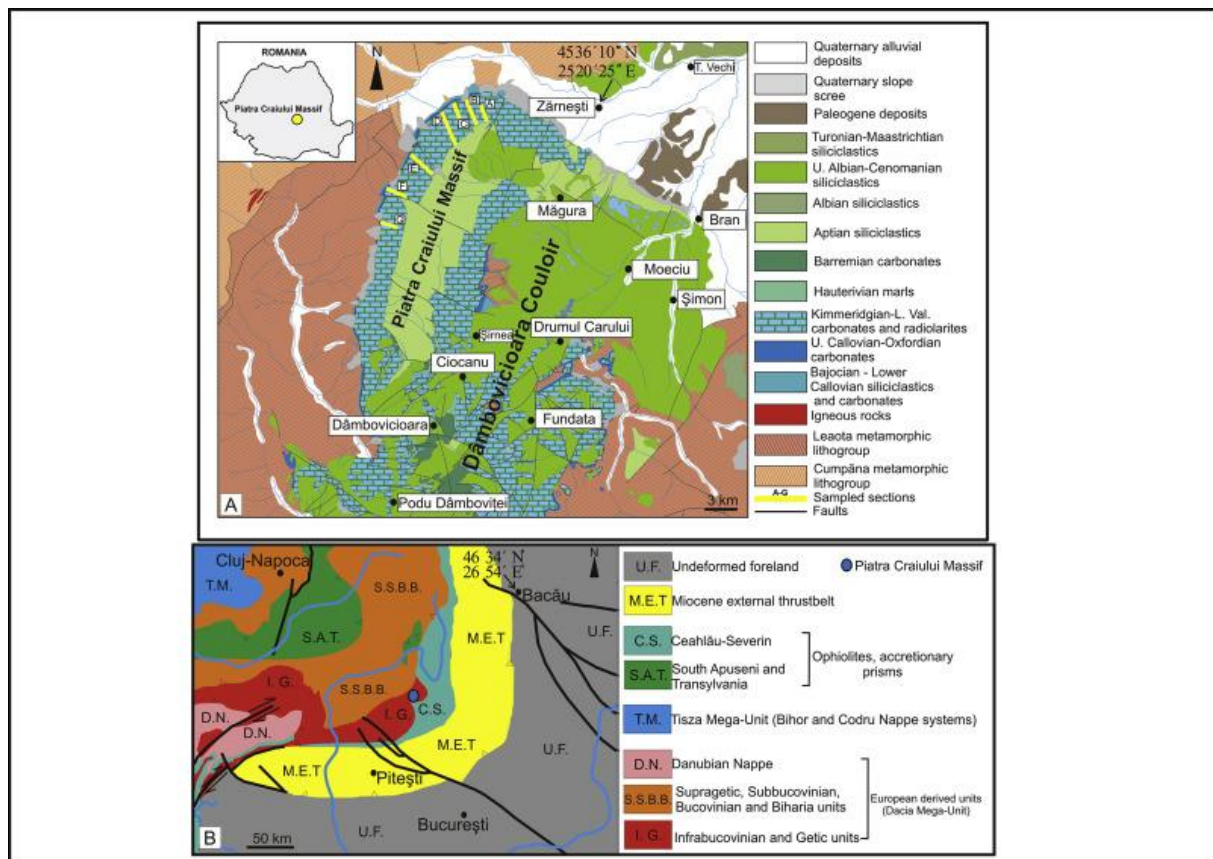


Fig. 8: Geological map of the Piatra Craiului Mountains (Mircescu et al., 2019); 7B Location within the Median Dacides. It includes a general presentation of the most important tectonic units from the Romanian Carpathians.

The ridge features two contrasting slopes with a tectono-structural landscape (asymmetrical slopes, steps, structural shelves, etc.), one periglacial and another with representative karst characteristics (dry valleys, karren, dolines, to which are added gaps, underground ditches developed along the fault lines, and cave galleries located at different altitudes). The western slope is highly varied with steep walls developed at the ends of the layer, where it predominates: edges, chimneys, towers, needles, structural shelves, gelifractions accumulations (scree slopes), etc. The eastern slope is more uniform and more accessible from a tourist point of view, due to the existing structural surfaces and the lower slope at the bottom of the slope (Cruțeru et al., 2025).

The relief fragmentation suggests an important morphodynamical potential, by the fact that between Baciului Peak (the highest water infiltration point) and Izvoarele Domnilor (karst springs located at the bottom of the massif), there is a vertical drop of 1480 m, the second in the country from the point of view of the hydrocarstic potential, after the Retezat Mountains) (Constantinescu, 2009).

Karst morphology in the Piatra Craiului Mountains varies distinctly between the two slopes: the western flanks, characterized by near-vertical strata, are dominated by residual landforms, while the eastern slopes, forming the inner side of the syncline, facilitate water infiltration and the formation of deep cave systems.

The relief fragmentation suggests an important morphodynamical potential, by the fact that between Baciului Peak (the highest water infiltration point) and Izvoarele Domnilor (karst springs located at the bottom of the massif), there is a vertical drop of 1480 m, the second in the country from the point of view of the hydrocarstic potential, after the Retezat Mountains) (Constantinescu, 2009).

Karst morphology in the Piatra Craiului Mountains varies distinctly between the two slopes: the western flanks, characterized by near-vertical strata, are dominated by residual landforms, while the eastern slopes, forming the inner side of the syncline, facilitate water infiltration and the formation of deep cave systems.

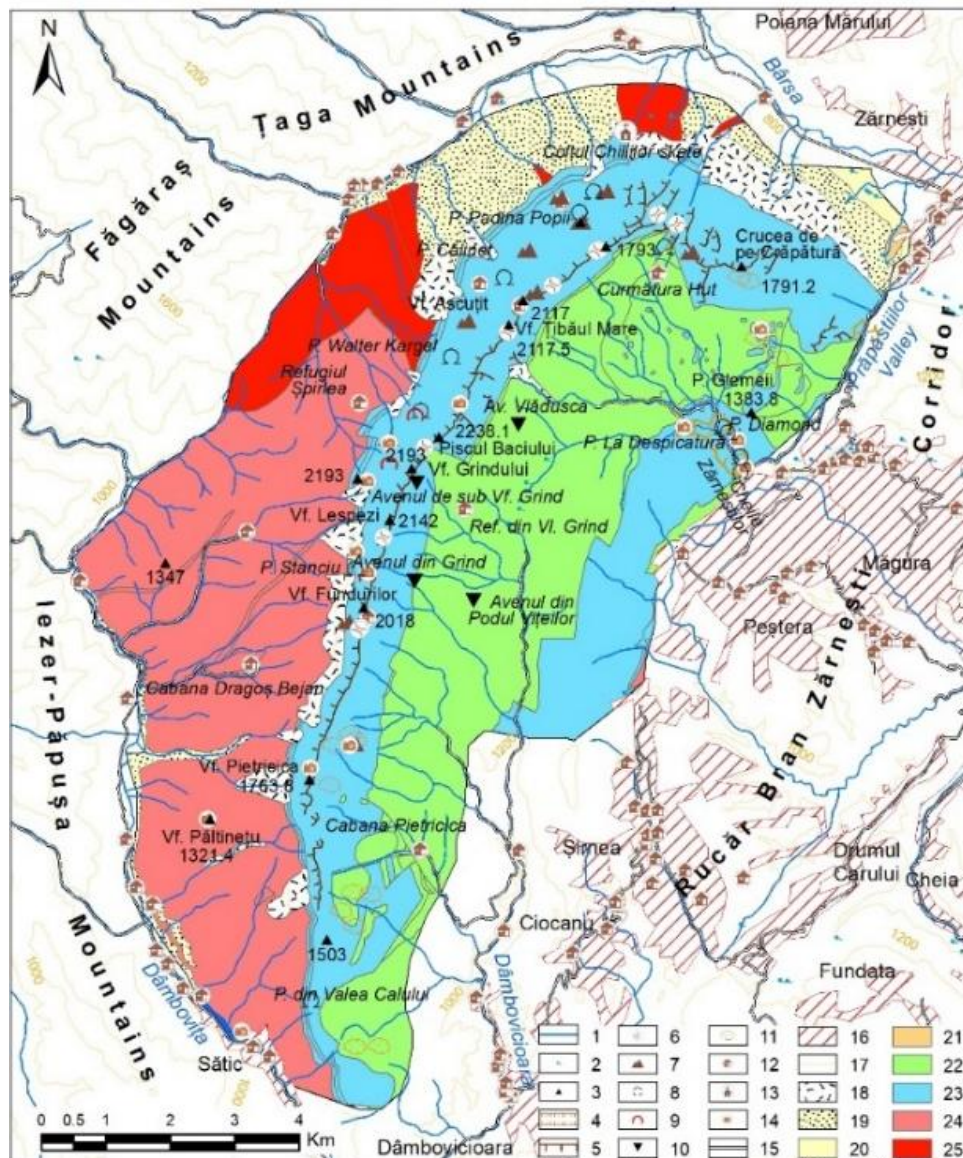


Fig. 9: Lithological and geomorphological map: 1. river; 2. spring; 3. peak; 4. gorges; 5. scarp; 6. saddle; 7. rocky slope; 8. cave; 9. arches; 10. Pits; 11. Dolines; 12. Hut and refuge; 13. Hermitage/monastery; 14. Landmark; 15. Road; 16. Locality; 17. Limits of the Piatra Craiului Mountains; 18. Coluvio-proluvial and detritic deposits; 19. Sands, gravels, and clay (Holocene); 20. Sands, gravels (Quaternary); 21. Marls, sandstones, micro-conglomerates (Paleogene); 22. Conglomerates, limestone, sandstone (Cretaceous); 23. Limestone, sandstone (Jurassic); 24. Crystalline schists (Paleozoic); 25. Crystalline schists (Proterozoic) (Cruțeru et al., 2025).

The exocarst is well represented by karst valleys, gorge sectors located mainly at the periphery of the massif (Zărnești Abyss, Dâmbovița and Dâmbovicioara), dolines (La Sălăstruc, La Stâna Pietricica, Poiana Mare, etc), areas with karren surfaces (limestone pavements), chimneys (Hornul Închis, Hornul Grind, Hens, etc.), and karst valleys (Fig. 3). These are the most representative exocarst forms in the landscape of Piatra Craiului ridge (Vlădușca, Podurilor, Șpirlea, Călineț, Crăpăturii, etc.) (Cruțeru et al., 2025).

Endocarst forms are represented by over 500 caves, most of which are relatively short. As a result of the peculiar geology, infiltrating waters are quickly drained along fissures and near-vertical

bedding planes, resulting in narrow and mostly steeply descending galleries. The deepest cave is Avenul de sub Vârful Grind, which at -769 m is also the deepest cave in Romania (as of December 2019). The cave drains large amounts of water, especially during spring snow melt and summer storms, leading to numerous *karren* on the passages' walls. The final outflow of these waters is yet unknown (Cruceru et al., 2025).

The geomorphological landscape is completed with periglacial and structural forms. The first category highlights the steep hog-back type structure, and the second category includes the periglacial edges (Munchia Padinii Popii, Edge of the Three Tanks, Sunny Edge, Pine Edge, Red Edge, Ivan's Edge, etc.), witnesses such as needles, fangs and tanks (Sentinel, Crack Needle, Călineț's Finger, Dwarf's Corner, etc.), lathes, and at the base of the cliffs there are cones and trains of rubble (talus slope) (*Marele Grohotiș*, from Funduri, under the "Chicken Horn", the rubble from the Beautiful Skates) (Cruceru et al., 2025).

Constantinescu (2009) identifies nearly 60 periglacial windows known as “subaerial gaps” along the Piatra Craiului ridge. These are narrow (3-10 m) and very short (30-100 m) valley sectors (3-10 m) starting below the edge of the ridge and having a relatively flat bottom, often accompanied by cones and scree slopes.

The overall configuration of the massif and the slope morphology favor the gravitational movement of the snow and materials along the slopes or valley floors. The steeper western flank is more prone to debris flows (Fig 10), while snow avalanches mainly impact the eastern flank (Fig. 11).

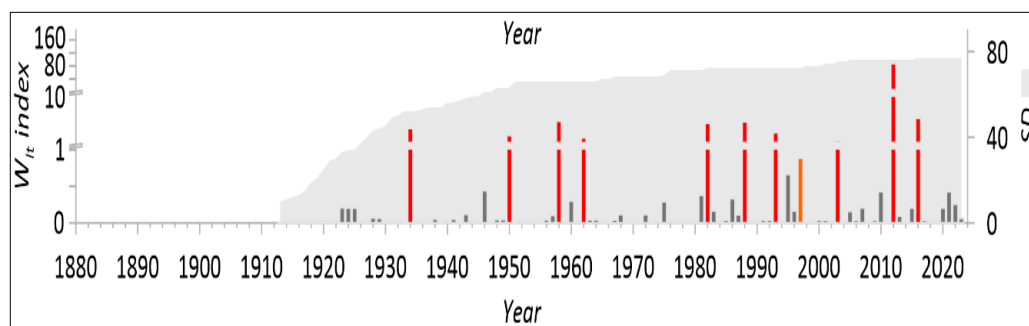


Fig. 10 Debris-flow activity reconstructed from tree rings in Piatra Craiului. Red bars indicate confirmed debris-flow events, orange bars represent potential events, and grey bars denote years with insufficient growth disturbances and low index values.

Most avalanche paths originate below the main crest and extend downslope, reaching the runout zones in the lower valleys at lower altitudes (Fig. 10). Along the path areas, boulder tongues consisting of debris deposits transported by snow avalanches are present. Dendrogeomorphic studies carried out in two distinct avalanche paths located on the eastward slopes allowed for the reconstruction of a minimum of past 10 major snow-avalanche events spanning the period 1950-2016 (Pop et al, 2017) (Fig. 12).

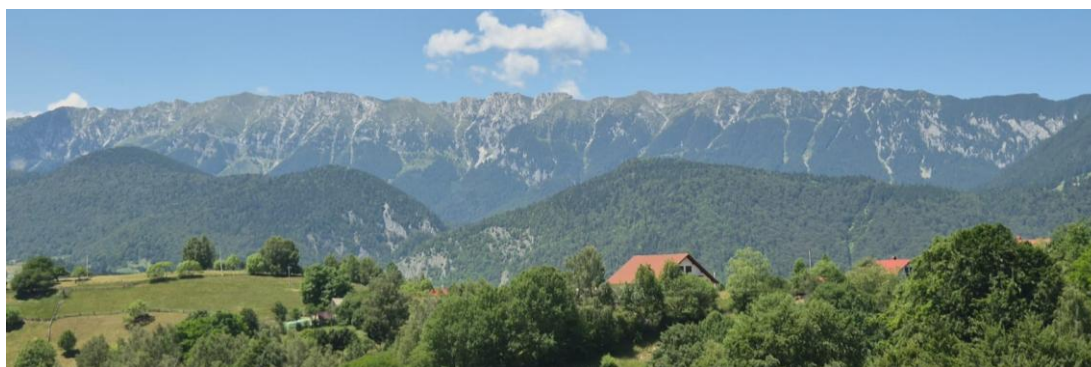


Fig. 11: Avalanche paths on the eastern slope of the Piatra Craiului Massif

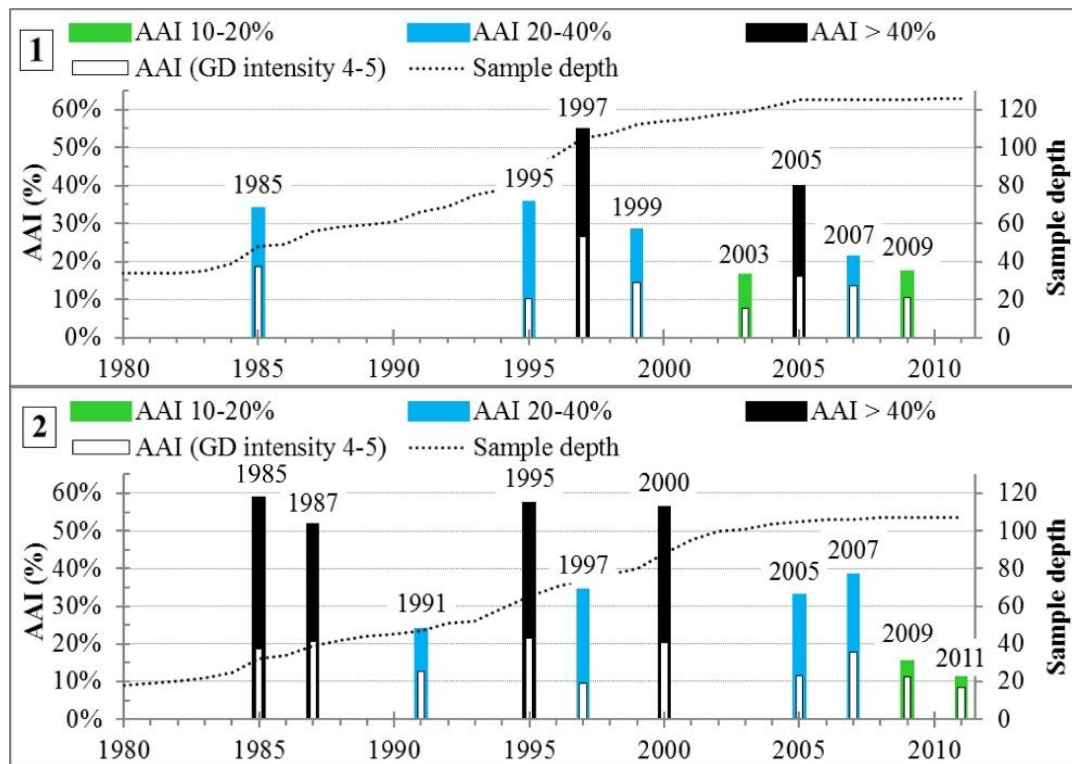


Fig. 12 (1 and 2) Snow-avalanche activity reconstructed from tree rings in two avalanche paths from Padinile Frumoase, Piatra Craiului. With black, blue, and green bars, indicate confirmed snow avalanche events.

The landscape variety and the uniqueness of landforms, to which are added the presence of several rare plant species, allowed the declaration of Piatra Craiului massif as a Natural Reserve Area (since 1938) and a National Park (since 1990), covering a surface of 14,766 ha. The Piatra Craiului Massif has great potential for recreational activities and is a notable national and international destination for mountain tourism, attracting about 90,000 visitors each year.

References

- Constantinescu T., 2009. Masivul Piatra Craiului. Studiul geomorfologic, Ed. Universitară, București, 164 p.
- Cruceru N., Pop O.T., Perșoiu A., Vlaicu M., 2025. Piatra Craiului Mountains. In Micu M., Tatui F. (eds.) Landscapes and Landforms of Romania, Springer, Berlin (in press).
- Mircescu C.V., Bucur I.I., Săsăran E., Pleș G., Ungureanu R., Oprea A., 2019. Facies evolution of the Jurassic-Cretaceous transition in the Eastern Getic Carbonate Platform, Romania: Integration of sequence stratigraphy, biostratigraphy and isotope stratigraphy. *Cretaceous Research* 99: 71–95.
<https://doi.org/10.1016/j.cretres.2019.01.015>
- Onac B P, Goran C (2019) Karst and Caves of Romania: A Brief Overview, in *Cave and Karst Systems of Romania*, Springer International Publishing AG, part of Springer Nature, https://doi.org/10.1007/978-3-319-90747-5_10.
- Panaiotu C. E., 2000. Platforma carbonatică din zona masivelor Bucegi și Piatra Craiului. Analiza comparativă a sistemelor depoziționale și a proceselor postdepoziționale. Teză de doctorat
- Patruș D., Dimitrescu R., Dessila-Codarcea M., 1968. Carte geologique, echelle au 1/200.000, L-35-XX, 28. Brasov, Comitet d'état pour la géologie. Institut géologique.
- Pop O.T., Munteanu A., Meseșan F., Gavrilă I.G., Timofte C., Holobacă I.H., 2017. Tree-ring-based reconstruction of high-magnitude snow avalanches in Piatra Craiului Mountains (Southern Carpathians, Romania), *Geografiska Annaler: Series A, Physical Geography*, DOI: 10.1080/04353676.2017.1405715.
- Săndulescu M., 1984. Geotectonica României. Editura Tehnică, București, 336 pp

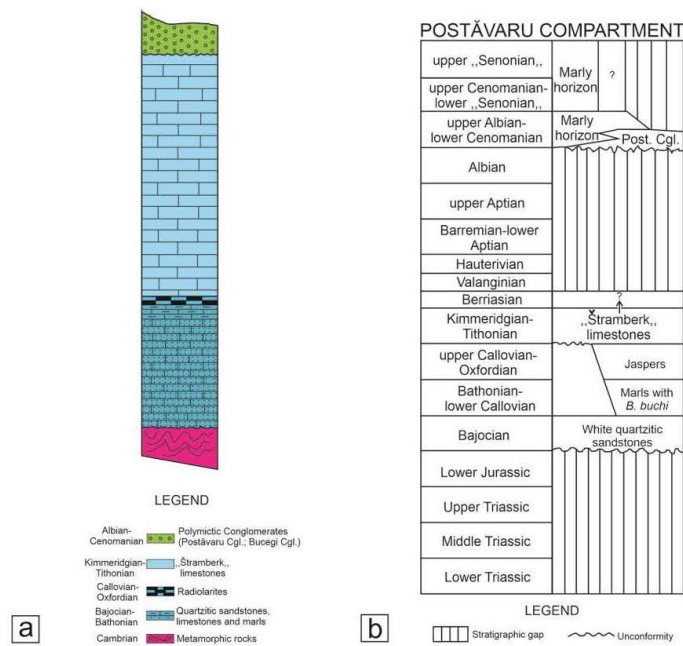


Fig. 14: Sedimentary succession from the Postăvaru Compartment (Șerban et al., 2021): a) Synthetic lithological column of the Mesozoic deposits from the vicinity of Postăvaru peak; b) Vertical distribution and lithology of the sedimentary succession from the Postăvaru Compartment.

The ski area comprises approximately 25 km of slopes with varying levels of difficulty. The longest slope in the resort is *Drumul Roșu* ("Red Way"), which measures 3,829 m, while the most difficult slope in the country is considered to be the *Kanzel* slope, with a length of 350 m. In Romania, a total of 90 ski slopes has been officially homologated across 15 counties, with Poiana Brașov hosting the highest number (10 of them).

The resort's lift system is designed to provide efficient access to the ski slopes, comprising a total of 11 installations, including a high-capacity gondola, a cable car, several chairlifts, and multiple drag lifts. Together, these facilities can transport over 7,000 skiers per hour. Additionally, the resort is equipped with a modern artificial snowmaking system that covers the majority of slopes, ensuring consistent skiing conditions throughout the winter season. Snow grooming operations are carried out regularly to maintain slope quality (Fig. 5).

These features have contributed to the establishment of the Poiana Brașov resort, which spans approximately 150 hectares. The resort is situated on a surface-levelled area at an altitude of 1,030 m, characterized by low relief fragmentation (1–2 km/km²), low relief energy (less than 100 meters), and gentle slopes (generally below 5°) (Alixandroae et al., 2014).

The first chalet was built in 1907, in the northern part of the resort, known as Poiana de Jos. In 1909, the first ski competition took place, following a route that today coincides with the modern road leading to Brașov. Between the two world wars, several chalets and villas were constructed in Poiana de Sus. The resort reached a significant milestone in 1951, when it hosted the World Winter University Games (referred to at the time as the "International Championship of Ski Descent"). For this event, ski jumping hills, a ski lift, a chair lift, a bobsledding course (later decommissioned), and a hotel were built (Ielenicz and Comănescu, 2006). Today, Poiana Brașov is recognized as the mountain resort with the highest level of infrastructure in the Carpathians, supporting both recreational and professional winter sports activities.

Accommodation options in Poiana Brașov are diverse, ranging from budget lodgings to luxury hotels, with many establishments located in the proximity of the ski area. The resort also offers comprehensive services including ski rentals, professional ski schools, equipment repair, and après-ski facilities such as restaurants, cafes, and wellness centers.

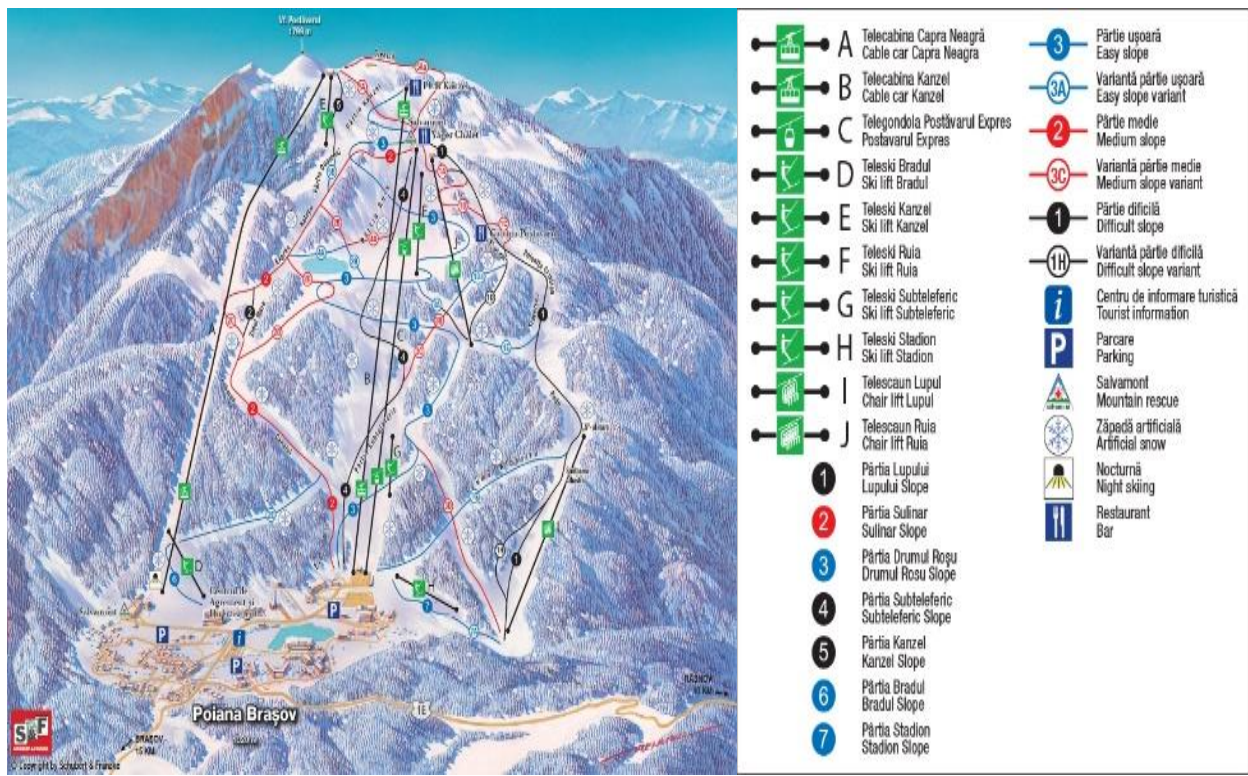


Fig. 15: Poiana Brașov ski infrastructure developed on the northwestern slope of Postăvaru Massif (<https://starepartii.brasovcity.ro/harta-domeniul-schiabil/>)

In addition to downhill skiing, Poiana Brașov supports a range of winter and off-season activities, including snowboarding, sledding, cross-country skiing, hiking, mountain biking, and paragliding. The infrastructure also meets the standards required to host international competitions and training camps. These features position Poiana Brașov as a leading destination in Romania's mountain tourism sector and a regional hub for alpine sports development.

References

- Alixandroae I., Dobre R., Comănescu L., Nedelea Al., 2014. Evaluating the landscape accessibility for tourism activities in Postăvaru Mountains, *Studia UBB Geographia*, LIX, 2, 2014, pp. 157 – 166.
- Ielenicz M., Comănescu L., 2006. *România-potențial turistic*, Edit. Universitară, București.
- Patruluius D., 1969. *Geologia Masivului Bucegi și a Culoarului Dâmbovicioara*. Editura Academiei RSR, București, 321 p.
- Săndulescu M., 1964. Geological structure of the Postăvarul-Runcu Massif (Brașov Mountains). *Anuarul Comitetului Geologic*, 34 (2): 382–422.
- Șerban S., Mircescu C.V., Ungureanu R., Bucur I.I., 2021. Carbonate clasts from Cretaceous conglomerate deposits of the Postăvaru Massif (Southern Carpathians, Romania) - depositional environments and biostratigraphic remarks. *Acta Palaeontologica Romaniae*, 17 (1): 27-39, <https://doi.org/10.35463/j.apr.2021.01.03>.

Racoșul de Jos Geological Complex

The three most recent eruptions in the Carpathian Pannonian Region occurred during the Upper Pleistocene, and represent two different types of volcanism located in two different areas of the region: in the Central Slovakian Volcanic Field, and at the south-easternmost end of the East Carpathian volcanic arc (Harghita Mts. – Ciomadul and Perșani Mts).

Neogene to Quaternary volcanism in the Carpathian Pannonian Region is closely related to the evolution of the Carpathian thrust-and-fold system and of the Pannonian Basin. The primary driving mechanism for the Inner Carpathian Volcanic Arc is the subduction of the European Plate beneath the advancing Alcapa and Tisia blocks. Related to the subduction three types of volcanism can be distinguished (1) large-volume felsic calc-alkaline, mostly explosive volcanism, (2) large-volume intermediate calc-alkaline magmatism, mostly represented by composite volcanoes, and (3) small-

volume alkaline volcanism, mostly represented by monogenetic volcanic fields (Szakács et al, 2002).

The youngest eruption at Ciomadul will be presented later, the second youngest eruption occurred at the Putikov Vrsok volcano in the alkali-basaltic Central Slovakian Volcanic Field and the third youngest volcanic activity took place in the Perșani Mts, at the southeastern terminus of the Carpathian volcanic arc, some 40 km to the west from the South Harghita Mts. (Szakács et al, 2002). This volcanism followed an extended period of subduction-related mostly andesitic and dacitic magmatism in the Eastern Carpathian arc (see also Ciomadul volcano tectonic setting). The Perșani Mts. alkaline activity coincided with the last phase of subduction-related activity (Downes et al., 1995, Szakács et al, 2002). Volcanism in the Perșani Mts. developed as a small (22x8 km) alkali-basaltic monogenetic field (Fig. 16), consisting of a number of maar structures, scoria cones and surrounding lava fields.

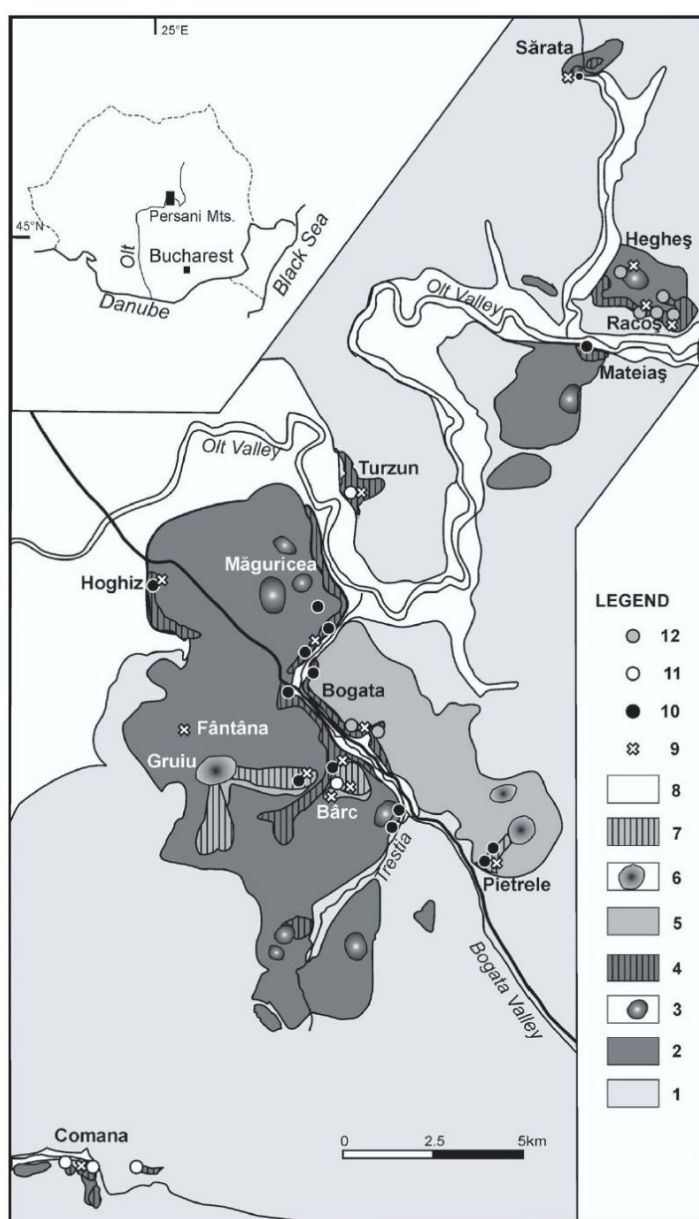


Fig. 16: Volcanological sketch-map of the Perșani Mountains — Quaternary basaltic province. 1 — Prevolcanic basement (Mesozoic and Cenozoic). First phase: 2 — Initial pyroclastics (phreatomagmatic deposits); 3 — Scoria cones; 4 — Lava flows. Second phase: 5 — Pyroclastics (phreatomagmatic deposits); 6 — Scoria cones; 7 — Lava flows; 8 — Holocene alluvia (Panaiotu et al., 2004)

Volcanological investigations have delineated successive eruptive stages, each typically commencing with phreatic or phreatomagmatic activity, subsequently transitioning to less energetic strombolian or effusive phases (Seghedi & Szakács 1994). According to Panaiotu et al. (2004) this volcanism developed in two main stages with a time gap of ca. 0.6 Ma: between 1.5-1.2 Ma and 0.67-0.52 Ma.

The Perșani Mountains exhibit well-preserved volcanic structures, manifesting as spectacular topographic features. These include variably eroded conical hills and relict scoria cones situated atop a “volcanic plateau” (Panaiotu et al., 2004). The most unique formations of high scientific and touristic values became part of a nature reserve under the name of Racoșul de Jos Geological Complex, including the Hegheș scoria cone, the Brazi quarry (lake) and basalt columns from Racoș.

The **Hegheș basaltic scoria cone** (Fig. 17, Fig. 18), located approximately 1.3 km north of Racoș village, represents one of seventeen identified scoria cones within the Perșani Volcanic Field (Seghedi et al., 2016). It is an inactive quarry that was excavated in spiral form in the past preserving the neck (Fig. 17) area as well as the distal parts of the volcano.

As the only basaltic scoria occurrence within Romania and the surroundings, it provides a unique window into eruptive processes. The well-exposed stratigraphy reveals distinct pyroclastic layers with granulometric variations inversely correlated with distance from the vent. Proximal deposits exhibit welded



Fig. 17: Neck of the Hegheș scoria cone

spatter, rich in agglutinated lapilli, blocks, and bombs of various morphologies, and lava tongues, attesting the Hawaiian-type effusions within the predominantly Strombolian explosive regime. Distal facies are characterized by non-welded, variably colored lapilli-tuff, alongside fresh black scoria. Beyond its geological significance, the site represents importance in the everyday life of the nearby village, as the locals still use the scoria for thermal insulation in residential attics and ground floors. Its distinctive landscape has made it a location for various film and commercial productions, summer festivals open-air concerts and public science communication events (Soós et al., 2025).



Fig. 18: Hegheș scoria cone quarry, drone image (www.dronestagr.am).

The **Brazi quarry** (Fig. 19) known by the tourists as “Emerald Lake” is located next to the Hegheş scoria cone. This locality provides an exceptional opportunity to observe the contact zones between lava flows, basaltic magma intrusions and pyroclastic sediments.



Fig. 19: Brazi quarry and quarry lake known as “Emerald Lake”.

The volcanic activity started with recurrent magmatic and phreatomagmatic explosive phases, which generated diverse pyroclastic materials. These materials were deposited in parallel layers around the vent, forming either a maar volcano or a tuff ring. When the groundwater was depleted, the volcanic activity continued with shallow, horizontal magma intrusion into the maar deposits and possibly also filled the former crater. The solidified basaltic lava at this site exhibits various patterns, including columnar, platy, and curvilinear platy jointing. A globally rare and remarkable feature of this locality is the presence of millimeter- to centimeter-sized, rust-colored, columnar-jointed “baked sediments” (Fig. 20) situated at the contact between the basalt sill and the overlying volcanoclastic deposit (Soós et al., 2025).



Fig. 20: Baked sediments at Brazi quarry (Soós et al., 2025).

The **basalt columns from Racoş** (fig. 21) present the most spectacular columnar structures of the Perşani volcanic field. This is also an abandoned quarry where mining started in 1872 (Schafarzik 1904), the earliest of all in Racoş area.

Volcanic activity in the Perşani Mountains began at this site, which is the oldest and dates back to approximately 1.21 Ma. The basalt columns, which typically form through the slow cooling of homogenous lava, are usually exposed at the surface by erosion. However, at this site, exposure occurred due to mining, thereby converting the entire area into an anthropogenic landscape. The basalt columns, reaching heights of approximately 10–12 meters, exhibit well-developed hexagonal and pentagonal geometries. A distinct contact with the underlying pyroclastic deposits is clearly visible. The columns turn upwards into platy-jointed layers, which are overlain by less well-defined vesicular basalt columns at the top (Soós et al., 2025).

All three sites having high scientific, educational and scenic value would be included in the proposed Carpaterra UNESCO Global Geopark.



Fig. 21: The basalt columns from Racoş.

References

- Downes, H., Seghedi, I., Szakács A., Dobosi G., James, D.E., Vaselli, O., Rigby, I.J., Ingram, G.A., Rex, D., Pécskay Z., 1995, Petrology and geochemistry of the late Tertiary/ Quaternary mafic alkaline volcanism in Romania, *Lithos* 35, pp. 65-81.
- Panaiotu C. G., Pécskay Z., Hambach U., Seghedi I., Panaiotu C. E., Tetsumaru Itaya., Orleanu M., Szakács A., 2004, Short-lived quaternary volcanism in the Perşani Mountains (Romania) revealed by combined K-Ar and paleomagnetic data, *Geologica Carpathica*, 55/4, pp.333-339
- Schafarzik, F (1904) A magyar korona országai területén létező kőbányák részletes ismertetése. A Magyar Királyi Földtani Intézet kiadványa, Budapest, 487 p.
- Seghedi I, Szakács A (1994) The Upper Pliocene-Pleistocene effusive and explosive basaltic volcanism from the Perşani Mountains, *Rom. J. Petrology*, 76, pp. 101–107
- Soós I., Szepesi J., Harangi Sz., 2025, Volcanic Geosite Inventory and Assessment in the Perşani Monogenetic Basalt Volcanic Field (Romania): Geoheritage Framework of the Proposed Carpaterra Geopark, *Geoheritage*, 17, 64, 22 p.
- Szakács A, Seghedi I, Pécskay Z, 2002, The most recent volcanism in the Carpathian Pannonian Region. Is there any volcanic hazard? *Geol. Carpath* 53 Special Issue, Proceedings of the XVIIth Congress of Carpathian-Balkan Geological Association, pp 193–194
- ***Racoş scoria cone drone image, <https://www.dronestagr.am/the-racos-volcano/>

Ciomadul volcano and Sf. Ana Lake

The Ciomadul volcano terminates the 700 km-long Inner Carpathian Volcanic Arc (Fig. 22), along which a calc-alkaline andesitic–rhyolitic volcanism took place during the past 20 Ma.

The volcanic activity was not simultaneous across the arc. It showed a migration over time, generally from the west and north to the east and south. Its southern segment – the Călimani –Gurghiu –Harghita chain – displays a regular time-space migration of volcanic activity, together with a gradual decrease in magma output extending the volcanic activity of the Carpathian Volcanic Arc to the last glacial stage.

The youngest volcanic activity of the whole Carpathian-Pannonian region occurred at Ciomadul volcano. Located at the southernmost part of the volcanic region of the Călimani-Gurghiu-Harghita mountain range, is separated from the 1500–1800 m high main volcanic range by the river Olt at Tuşnad Gorge. It is bordered by the Quaternary Ciuc, Bixad and Târgu Secuiesc basins from where it rises 600-700 m. The elevation of Ciomadul is slightly lower than the adjacent volcanic and Cretaceous flysch mountains (Bodoc and Ciuc Mountains situated to its east), the highest point being 1301 m in Ciomadul Mare, but this is not what makes it distinctive. While the neighbouring mountains have relatively flat, N-S oriented ridges, the Ciomadul shows a more rugged relief. Whereas the andesitic Pilişca volcano (to the west of Olt River) resembles other edifices of the Harghita Mountains, Ciomadul has conical or truncated conical geometries.

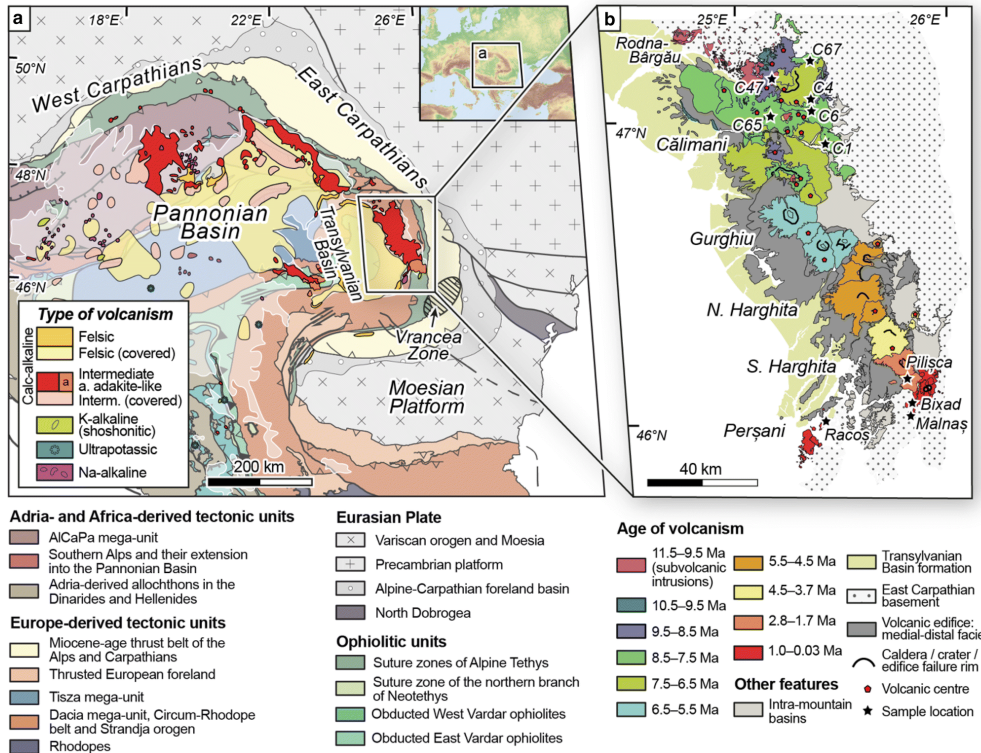


Fig. 22: a) Tectonic map of the Carpathian-Pannonian region b) Temporal and spatial evolution of volcanism, Bracco Gartner et al., 2020.

This is because Ciomadul is a dacitic lava dome complex (Fig. 23) consisting of a central edifice

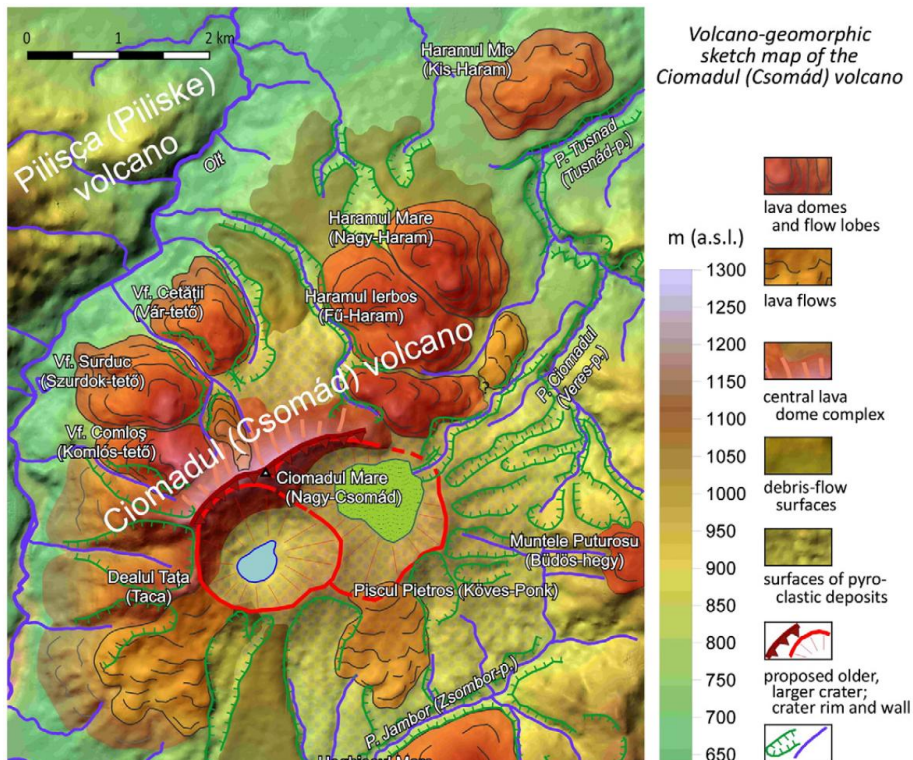


Fig. 23: Volcano-geomorphic sketch map of the Ciomadul (Karátson, 2013).

truncated by the twin craters of Lake Sfânta Ana and Mohoş peat bog surrounded by a number of individual lava domes as well as a narrow volcanoclastic ring plain (Karátson et al., 2013).

It is formed in the north by the distinct Haramul Mic, going southward by Haramul Mare, Haramul Ierbos, Scaunul Vârghisului, the long ridge of the Ciomadul Mare and the truncated cones of Vârful Surduc and Vârful Cetății. The southern border is marked by the separate eruption centre of Heghieșul Mare, on the east it terminates in the solitary cones of the Muntele Puturosu and Bălványos which are sometimes grouped together with Ciomadul, under the name of Ciomadul-Puturosu. Some of the domes overlap each other and the small-scale features have been eroded, still the large-scale primary morphology is relatively well-preserved (Fig. 24).

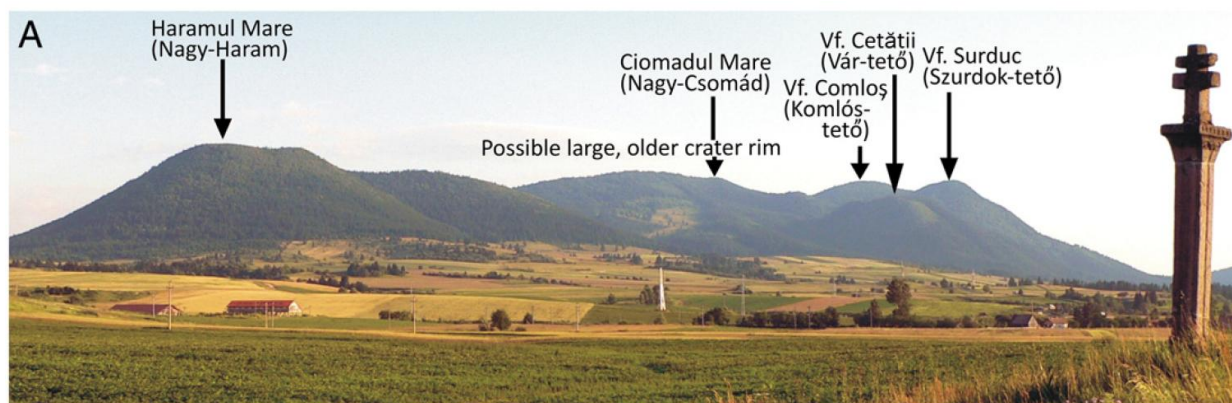


Fig. 24: Panoramic view of the Ciomadul (Csomád) massif from the NW. B (Karátson et al., 2013).

The Ciomadul domes reach 300–400 m height and 1–2 km width and have generally steep flanks excepting the northernmost Haramul Mic low dome with more gentle slopes. In the case of Haramul Mare, Haramul Ierbos and Vf. Cetății, the symmetric shape is characteristic of a Peléan dome, whereas the other domes facing the Olt (Vf. Comloș and Vf. Surduc) are asymmetric domes/coulées superimposed on the westward-dipping slope of the central dome complex. Some domes like Haramul Mare or Vf. Cetății are simple domes having one (typically broad) summit; others like Haramul Ierbos are lobate. However, even simple domes may have been fed by more than one eruptive event (Karátson et al, 2013).

Ciomadul experienced an extended eruptive history from ≈ 850 ka, with predominantly effusive activity during the first stage (≈ 850 to ≈ 440 ka) that also produced the isolated, peripheral domes such as Puturosu and Balványos. Subsequently, after possibly a long repose interval, a voluminous central dome cluster developed in the second stage of lava dome building from about ≈ 200 ka. This occurred with explosive activity that resulted in the formation of the twin craters Mohoș and Sf. Ana during the youngest phase of volcanic evolution between ≈ 60 to <30 ka (Szakács et al., 2002, Karátson et al., 2016). In the past c. 60 ka four major eruptive successions can be distinguished that define the dominantly explosive activity at Ciomadul: eruptions older than 51 ka, likely from the Mohoș crater and c. 40–42 ka from the Sf. Ana crater interpreted as the early phreatomagmatic and plinian activity; followed by ≈ 31.5 ka middle plinian activity; and the final dominantly phreatomagmatic eruptions in particular the “St. Ana” eruption at c. 28–29 ka (Karátson et al., 2022). The older age of the Mohoș crater relative to the still existing crater lake of Sf. Ana is evidenced by the facts that it is almost completely filled in by sediments and a 10 m-thick peat bog (Juvigné et al., 1994; Tantau et al., 2003 in Karátson et al., 2022). The older age of the Mohos crater relative to the still existing crater lake of Sf. Ana is evidenced), and that its western rim is cut by the Sf. Ana crater (Karátson et al., 2016).

Although, the youngest eruption of Ciomadul volcano is dated at ca. 30 ka, the fact that the area hosts the highest density of thermal and mineral water springs as well as dry CO₂ emanations in the whole Carpathian volcanic arc and different studies regarding the composition and flux of the emitted gases at mofettas, seismic tomography as well as combined petrologic and magnetotelluric studies indicate that there is still melt-bearing magma body beneath the volcanic complex and therefore, there is still a potential for further volcanic activity at Ciomadul (Szakács et al., 2002; Karátson et al., 2022).

The unbreached crater hosting the Sf. Ana Lake has been left behind by the most recent eruption of Ciomadul volcano and of the whole Carpathian Pannonian Region. The highly symmetric shape, the dimensions of the intact crater (~1600 m diameter, ~200 m depth and the very steep inner crater slopes (up to 38° on the northern wall) also demonstrate the explosive origin. The St. Ana explosive eruption produced a characteristic stratigraphic sequence, beginning with phreatomagmatic and subplinian pumice fall deposits overlain by pumice-and-ash-flow deposits and subsequently by debris flows. These eruptive products are observed to outcrop on the flanks of the Ciomadul volcano and within its proximal surroundings (Szakács et al., 2002).

Sf. Ana Lake (Fig. 25) is the only primary open-water crater lake in East-Central Europe, having an area of 0.2 km². The presence of a persistent water body within the Sf. Ana crater is directly attributed to the relatively young age of the eruptions that formed the structure. This contrasts with older crater lakes that are subject to infilling or drainage via erosional processes over longer timescales.



Fig. 25: Sf. Ana Lake (coltisorderomania.ro).

The lake is a closed hydrological system, with no drainage and fed mainly by rainwater. Meteorological data indicate an average annual precipitation input of 600–700 mm/yr. When considering additional contributions from slope runoff, the total annual water inflow to the lake is estimated to be two to three times greater than direct precipitation. Despite this substantial input, which theoretically suggests a rising water level (given an approximate evaporation rate of 500 mm/yr), historical water level measurements spanning more than 100 years contradict this expectation, showing a decline or fluctuations rather than increase. The maximal depth measured in 1909 was 8,3 m that varied along the years between 4,85 m and 7,2 m (latest reading in 2018) (Karátson et al., 2022). The negative annual water balance might be explained by subsurface leakage, the precise magnitude of which remains unquantified. This lost water re-emerges as springs on the external slopes of the crater. Additionally, periods of drought or extreme aridity, alongside elevated summer water temperatures leading to increased evaporation, are recognized as significant contributing factors to the observed water deficit (Karátson et al., 2022).

The lake's water was historically known for its exceptional purity, described in the early 20th century as approaching the quality of distilled water. However, the human impact, including the influx of organic matter from bathing, picnicking and lack of proper infrastructure (leading to improper waste disposal), contributed to a decline in water quality. In order to protect this valuable natural heritage and prevent further degradation of its ecosystem in 2018 conservation measures banned swimming in the lake.

References

- Bracco Gartner, A. J. J., Seghedi, I., Nikogosian, I. K., Mason, P. R. D., 2020, Asthenosphere-induced melting of diverse source regions for East Carpathian post-collisional volcanism. *Contributions to Mineralogy and Petrology*, 175(5), 54, 24 p.
- Karátson D, Telbisz T, Sz H, Magyar E, Dunkl I, Kiss B, Cs J, Veres D, Braun M, Fodor E, Biró T, Sz K, von Eynatten H, Lin D, 2013, Morphometrical and geochronological constraints on the youngest eruptive activity in East-Central Europe at the Ciomadul (Csomád) lava dome complex, East Carpathians., *J Volcanol Geotherm Res.*, pp. 43-56
- Karátson D, Wulf S, Magyar EK, Gertisser R, Timar-Gabor A, Novothny Á, Telbisz T, Szalai Z, Anechitei-Deacu V, Appelt O, Bormann M, Jánosi Cs, Hubay K, Schäbitz F, VD, 2016, The latest explosive eruptions of Ciomadul (Csomád) volcano, East Carpathians—a tephrostratigraphic approach for the 51–29 ka BP time interval, *J Volcanol Geotherm Res.*, pp. 29–51.
- Karátson, D., Veres, D., Gertisser, R., Magyar, E.K., Jánosi, C., Hambach, U. (eds), 2022, A Kárpátok legfiatalabb tűzhányója, a Csomád. *Vulkánosság, öskörnyezet, ember és táj*. Tortoma könykiadó, Barót, ISBN 978-606-9716-47-2, 287 p.
- Seghedi I, Downes H, Szakács A, Mason PRD, Thirlwall MF, Roşu E, Pécskay Z, Márton E, Panaiotu C, 2004, Neogene-Quaternary magmatism and geodynamics in the Carpathian-Pannonian region: a synthesis., *Lithos* 72, pp. 117–146
- Szakács A, Seghedi I, Pécskay Z, 2002, The most recent volcanism in the Carpathian Pannonian Region. Is there any volcanic hazard? *Geol. Carpath* 53 Special Issue, Proceedings of the XVIIth Congress of Carpathian-Balkan Geological Association, pp 193–194
- ***Lake Sf. Ana, drone photo, <https://coltisorderomania.ro/2020/08/22/o-minunatie-a-naturii-lacul-sfanta-ana-impresii-de-calatorie/>

Mohoş Peat Bog (Ciomadu Massif, Harghita Mountains)

The Mohoş peat bog is located in the Ciomadu volcanic complex, near Lake Saint Ana. It lies at an altitude of 1050–1060 m within the Ciomadu Mare crater, part of the southernmost Harghita volcanic range of the Eastern Carpathians. The site is included within the Mohoş Nature Reserve and is also part of the Natura 2000 network (ROSCI0027 Tinovul Mohoş), designated for its rare habitats and species. Tourist access is regulated and restricted to wooden walkways accompanied by local guides.

Mohoş peat bog formed in a phreatomagmatic crater created by explosive volcanic activity during the Late Pleistocene (~60-30 ka BP), when magma interacted with groundwater in the Ciomadu volcano (Karátson et al., 2022). The crater floor subsequently hosted a lake, like nearby Lake Saint Ana. Over time, sedimentation, water stagnation, and organic matter accumulation led to the infilling of the lake basin (Fig. 26) resulting in peat formation. Today, the bog occupies an area of ~80 ha, of which ~80% is covered by peat up to 10 m thick and a volume of ~ 3 million m³ of peat (Tanţău et al., 2003) representing ~10,000 years of continuous accumulation (Longman et al., 2022). The site represents a classic transition from a volcanic crater lake to a raised bog, making it an important location for studying post-volcanic geomorphology and long-term ecological succession.

The peat bog is sustained by precipitation-fed water input (ombrotrophic conditions). The impermeable volcanic substratum, coupled with poor drainage, allowed waterlogging and accumulation of partially decomposed organic matter. The peat mass forms a self-contained hydrological unit, with limited lateral runoff. Water balance is maintained primarily by precipitation, making the landform highly sensitive to climate variability. Hydrological isolation has made Mohoş a sensitive archive of past environmental and climatic conditions.



Fig. 26 Pond in the Mohoș peat bog

Mohoș is characterized by boreal-type vegetation, relict from postglacial colonization. Dominant species include Sphagnum mosses, forming the main peat matrix, bog rosemary (*Andromeda polifolia*), cotton grasses (*Eriophorum vaginatum*), bog cranberry (*Vaccinium oxycoccos*), round-leaved sundew (*Drosera rotundifolia*), a carnivorous plant adapted to nutrient-poor conditions (Fig.27). Scattered stands of dwarf pines (*Pinus mugo*), birch (*Betula pubescens*), and Scots pine (*Pinus sylvestris*) occur on drier peat surfaces.



Fig. 27 Round-leaved sundew (*Drosera rotundifolia*)

The ecological mosaic is highly sensitive to hydrological changes and climate variability.

the peat bog is one of the most important paleoclimatic archives in Romania. Cores extracted from the peat provide high-resolution records of Holocene vegetation history (forest dynamics and the spread of spruce, fir, and beech, climate variability (through analysis of peat stratigraphy, macrofossils, pollen, testate amoebae, and stable isotopes, fire history (charcoal remains, showing human impact and natural disturbance regimes, and carbon accumulation, the peatlands being an important carbon sink (Tanțău et al., 2022). Lowering of the water table (by climate change or anthropogenic impact) could halt peat accumulation, initiate decomposition, favour wildfires, and transform the landform into a forested wetland.

The Mohoș peat bog, is one of the most representative raised bogs of volcanic origin in Central–Eastern Europe. As an organogenic landform whose primary development results from the accumulation of organic matter, usually under permanently waterlogged conditions, Mohoș peat bog displays several characteristic microrelief forms:

- a. The raised dome structure has a slightly convex bog surface relative to the surrounding crater floor, a result of peat accumulation outpacing lateral drainage. This morphology is typical of ombrotrophic raised bogs, sustained only by precipitation and snowmelt.

- b. The bog surface shows a pattern of hummocks (raised Sphagnum-covered mounds, 20–50 cm high) and hollows (wet depressions with standing water or grass-like plant cover). This microrelief reflects differential growth of mosses and localized waterlogging.
- c. The pools and small ponds are shallow water bodies, remnants of the former lake surface or areas of slower peat accumulation. Wetter depressions host *Sphagnum cuspidatum* and *Eriophorum vaginatum*, while slightly raised sectors carry dwarf pines (*Pinus mugo*), birch (*Betula pubescens*), or Scots pine (*Pinus sylvestris*). Carnivorous plants (*Drosera rotundifolia*) are restricted to wet hollows.

Mohoş peat bog has a significance as unique geomorphosite in Romania, the only raised bog developed in a volcanic maar. It illustrates the transition from geogenic landform (volcanic crater) to organogenic landform (peat bog). Its morphology integrates hydrology, vegetation, and microrelief, making it an exceptional site for geomorphological and ecological education (Tables 1 and 2).

Table 1. Geomorphosite Evaluation – Mohoş Peat Bog

Criterion	Sub-criteria	Score (1–5)	Remarks
Scientific value	Representativeness (typical of volcanic bog evolution)	5	Excellent example of crater-to-bog succession in the Carpathians.
	Rarity/uniqueness	5	One of the few volcanic peat bogs in Romania and Eastern Europe.
	Integrity/state of preservation	4	Well preserved, but sensitive to hydrological change.
	Scientific knowledge / literature	5	Numerous paleoecological, botanical, and volcanological studies.
Subtotal Scientific		19/20	Outstanding international scientific importance.
Educational value	Didactic potential (clarity of landform–process relationship)	5	Clear succession from volcanic crater → lake → bog.
	Accessibility	4	Easy road access: guided visits required.
	Interpretive infrastructure (panels, guides, trails)	4	Wooden walkways and local guides present.
Subtotal Educational		13/15	Excellent teaching site, especially for volcanism and paleoecology.
Aesthetic value	Landscape diversity and contrast	4	Strong contrast between open bog and forested crater rim.
	Scenic beauty / visual impact	4	High visual appeal, but less dramatic than alpine geomorphosites.
	Seasonal variability	4	Distinct seasonal changes (snow, flowering, autumn colors).
Subtotal Aesthetic		12/15	Attractive and distinctive landscape character.
Protection value	Legal status (reserve, Natura 2000, management)	5	Strict nature reserve; Natura 2000 site (ROSCI0027).
	Vulnerability / fragility	4	Sensitive to hydrological/climate change and tourism.
	Management / monitoring	4	Guided access and controlled infrastructure.

Criterion	Sub-criteria	Score (1–5)	Remarks
Subtotal Protection		13/15	Strongly protected, but still vulnerable to environmental change.

Overall Evaluation

Scientific value: 19/20

Educational value: 13/15

Aesthetic value: 12/15

Protection value: 13/15

Total: 57/65 → Very high geomorphosite value

Table 2: Comparative Geomorphosite Evaluation – Eastern Carpathians Volcanic Sites

Criterion	Sub-criteria	Mohoş Peat Bog	Lake Saint Ana	Racoş Volcanic Complex	Remarks
Scientific value	Representativeness	5	5	5	Each site is exemplary: bog succession (Mohoş), crater lake (Saint Ana), basalt volcanism (Racoş).
	Rarity/uniqueness	5	5	4	Only volcanic bog in Romania; only intact volcanic lake; basalt Prismatic columns are rare in Romania, but not unique worldwide.
	Integrity/preservation	4	4	3	Mohoş and Saint Ana well preserved; Racoş partly degraded by quarrying.
	Scientific knowledge	5	5	4	Mohoş and Saint Ana extensively studied; Racoş less so but still known.
Subtotal Scientific		19/20	19/20	16/20	Mohoş and Saint Ana outstanding; Racoş slightly lower due to quarrying.
Educational value	Didactic potential	5	5	5	Each site clearly demonstrates volcanic processes.
	Accessibility	4	4	4	All easily accessible by road.
	Interpretive infrastructure	4	4	3	Mohoş and Saint Ana have guides and panels; Racoş less developed.
Subtotal Educational		13/15	13/15	12/15	All strong, Racoş slightly less prepared for visitors.
Aesthetic value	Landscape diversity & contrast	4	5	5	Saint Ana and Racoş more visually striking.
	Scenic beauty	4	5	5	Saint Ana crater lake and Racoş basalt cliffs highly scenic.
	Seasonal variability	4	4	3	Mohoş and Saint Ana show clear seasonal changes; Racoş less marked.
Subtotal Aesthetic		12/15	14/15	13/15	Saint Ana highest in scenic impact.

Criterion	Sub-criteria	Mohoş Peat Bog	Lake Saint Ana	Racoş Volcanic Complex	Remarks
Protection value	Legal status	5	5	4	Mohoş and Saint Ana strict reserves; Racoş natural monument but partly quarried.
	Vulnerability fragility	4	4	3	Racoş more impacted by human activity.
	Management monitoring	4	4	3	Stronger at Mohoş and Saint Ana than at Racoş.
Subtotal Protection		13/15	13/15	10/15	Racoş weaker due to quarry scars and limited management.

References

- Karátson, D., Veres, D., Lahitte, P., Telbisz, T., Wulf, S., Gertisser, R., Dibacto, S., Kiss, B., Enikő K. Magyari, E.K., Novothny, A., and Jánosi C., 2022. Evolution of the Ciomadul Volcanic Field—Lava Domes and Explosive Eruptions. In Karátson et al. (eds.), Ciomadul (Csomád), The Youngest Volcano in the Carpathians, Springer, Berlin, pp. 39-63.
- Longman, J., Veres, D., Haliuc, A., Ersek, V., 2022. Hydroclimate Variability and Pollution History of the Mohoş Peatbog. In: Karátson, D., Veres, D., Gertisser, R., Magyari, E.K., Jánosi, C., Hambach, U. (eds) Ciomadul (Csomád), The Youngest Volcano in the Carpathians. Springer, Berlin, pp. 187-195.
- Tanțău I., Reille, M., de Beaulieu, J.L., Farcas, S., Goslar, T., Paterne, M., 2003. Vegetation history in the eastern Romanian Carpathians: pollen analysis of two sequences from the Mohos crater. *Vegetation History and Archaeobotany* 12: 113–125.
- Tanțău I., Grindean R., Magyari E., 2022. Vegetation History and Human Impact in the Ciomadul Area During the Holocene. In: Karátson, D., Veres, D., Gertisser, R., Magyari, E.K., Jánosi, C., Hambach, U. (eds) Ciomadul (Csomád), The Youngest Volcano in the Carpathians. Springer, Cham. https://doi.org/10.1007/978-3-030-89140-4_11

Beaver-related impacts and landforms

The European beaver (*Castor fiber*) was once widespread across Romania, inhabiting virtually all major river valleys of the Carpathians, Transylvania, and the Danube lowlands. In medieval and early modern times, beavers were widespread along the rivers, as confirmed by historical chronicles. However, centuries of intensive hunting, river regulation and deforestation gradually reduced their numbers. By the 18th and 19th centuries beaver populations in Romania declined. The last documented beavers in Romania were recorded in the early 19th century in the Danube floodplain and along the lower Olt River.

The modern return of the beaver to Romania began in the late 20th century, inspired by successful reintroduction projects in Western and Central Europe. In the 1996–2003 period, an official reintroduction program was launched on the Olt River basin. Beavers from Germany and Sweden were released into carefully selected sites, monitored by Romanian wildlife specialists. The species adapted quickly, building dams and lodges and spreading along tributaries, and by the mid-2000s, breeding populations were firmly established along the Olt river and its tributaries. Beavers are present in other major river basins of Romania, e.g., in Mureş and Criş basins (expanding westward into Hungary and Serbia), in Siret and Moldova rivers (more recent natural expansions from Ukraine). Today, beaver populations are spreading along the Olt River headwaters and tributaries, including the streams draining the Ciomadul volcanic complex, near Mohoş Peat Bog.

Beavers are ecosystem engineers whose geomorphic activity transforms fluvial systems. Through tree felling, dam building, canal excavation, and lodge construction, they induce changes in channel morphology, hydrology, sedimentation, and wetland development. Several typical micro-morphologies are the signature of beaver activity:

- a. Dams with heights typically ranging from 0.3 to 1.2 m in Carpathian streams are constructed from branches, mud, and stones, dams impound water and create step-like profiles along small streams. The dams alter river longitudinal profiles, reduce flow velocity, and promote sediment deposition upstream.
- b. Ponds, often 20–100 m long, are accumulated behind the dams, which locally widen floodplains. Ponds act also as sediment traps, accumulating organic-rich silt and dead wood. In the Harghita Mts, near Mohoș peat bog, such ponds might contribute to wetland expansion and enhance habitat heterogeneity.
- c. Canals (0.5–1 m wide, tens of meters long) to access food and transport woody material. These canals increase local drainage density and connect ponds to floodplain depressions. Over time, abandoned canals infill with fine sediment and organic matter, leaving microdepressions visible in the valley floor.
- d. Lodges and Burrows: Lodges are built from branches and mud within ponds or on-stream banks, sometimes exceeding 2 m in diameter. Bank burrows weaken riverbanks, occasionally triggering small collapses or slumps.
- e. Floodplain Microrelief of ponds, levées, collapsed burrows, abandoned dams, and vegetated wetlands. Abandoned structures persist as terracettes or scarps along streams, forming part of the valley-floor geomorphology.

As remarkable biogeomorphic engineers, beavers have significant geomorphic, hydrological and ecological impacts:

- a. Beavers' ponds influence the sediment dynamics trapping the suspended sediment and organic debris. Over time, ponds silt up, converting into marshy meadows or forested wetlands. This sediment trapping reduces downstream sediment loads, altering channel morphology. Beavers modify the river channel morphology due to repeated damming and breaching. They create a multi-thread channel system with side channels cutoffs and widened floodplains.
- b. Hydrological regulation is evident, especially in the case of dams built by beavers that raise the local water tables and create permanent wetlands in otherwise drained valleys. Dams increase water retention capacity, smoothing out floods but extend the periods of local inundation.
- c. Beavers have also an ecological impact by expanding the habitats of riparian wetlands, benefitting amphibians, birds, and aquatic plants.



Fig. 28: Beaver dam (photo Nicusor Chiru, Google Maps)

Fieldtrip day 3, September 14, 2025

Deep-Seated Landslides (*Glimee*) in the Transylvanian Basin

In the Transylvanian Basin, large, ancient to Holocene deep-seated rotational/complex landslides are locally known as *glimee*. The term was promoted in Romanian geomorphology by T. Morariu and V. Gârbacea and has been widely used for massive slides that involve both regolith and bedrock to considerable depths, producing compound headscarps, back-tilted blocks, hummocky terrain, and closed depressions with ponds/lakes (often tens to hundreds of hectares). Typical mapped extents are ~50–150 ha, with some reaching >600–1500 ha at sites such as Șaeș, Movile, and Saschiz. Thickness commonly exceeds ~30 m, reflecting multi-stage movement along clay-rich horizons.

A synthesis of >400 inventoried sites indicate a strong concentration of deep-seated landslides in the Transylvanian Plain (~225 *glimee*), with additional clusters in the Hârtibaciului Plateau, Târnavă Hills, and Someș Plateau (Fig. 30).

Detachment zones occur mostly between 300–500 m a.s.l. (~71% of cases), and there is a marked bias toward sunny (S–SW–W) slope aspects where wet–dry cycling and freeze–thaw promote weathering and strength loss. Individual examples may exceed 700–1600 ha (e.g., Șaeș 1,654 ha; Movile 1,104 ha; Saschiz 786 ha) (Surdeanu et al., 2011).

The deep-seated landslides *glimee* concentrate where Sarmatian and Pannonian marls, clays, sands, and gravels alternate, creating permeable–impermeable couplets that favour perched aquifers, elevated pore pressures, and deep shear zones. A basin-wide inventory shows ~57% of mapped *glimee* on Sarmatian marls/sands/gravels, ~18% on Pannonian argillaceous marls and sands, and ~8% on Badenian lithologies including marls and volcanic tuffs—the latter locally enhancing instability by channelling infiltration and weakening rock fabrics.

Although many *glimee* are presently dormant to marginally active, they are polycyclic landforms that initiated under late Quaternary climates. Stratigraphic and palynological evidence suggests onsets in the Late Glacial–Holocene (Sub-Atlantic). The radiocarbon age obtained from a *glimee* basal layer (Pădureni) is 1820 ± 30 yr BP, confirming Holocene landslide activity.

Regionally, intense humid periods (spring/autumn), torrential rainfall after drought, slope undercutting, deforestation, and local engineering works are the main triggers of reactivations that affects margins, headscarps, and toes. In many sites of the Transylvanian Basin, shallow slides and earth flows preferentially reactivate the escarpments and deposits of older deep-seated *glimee*.

Classic sites with *glimee* include Saschiz, Cornățel (Fig. 29), Șaeș, Movile, (Hârtibaciului Plateau), Suatu, Sălicea, Urmeniș (Transylvanian Plain), as well as Apold, Bozieș, Românești on cuesta margins; these illustrate the variability in lithologic control, altitude bands, aspect, and multi-phase reactivation.



Fig. 29: Cornățel deep-seated (*glimee*) landslide, view from the headscarp toward the hummocky terrain and depressions.

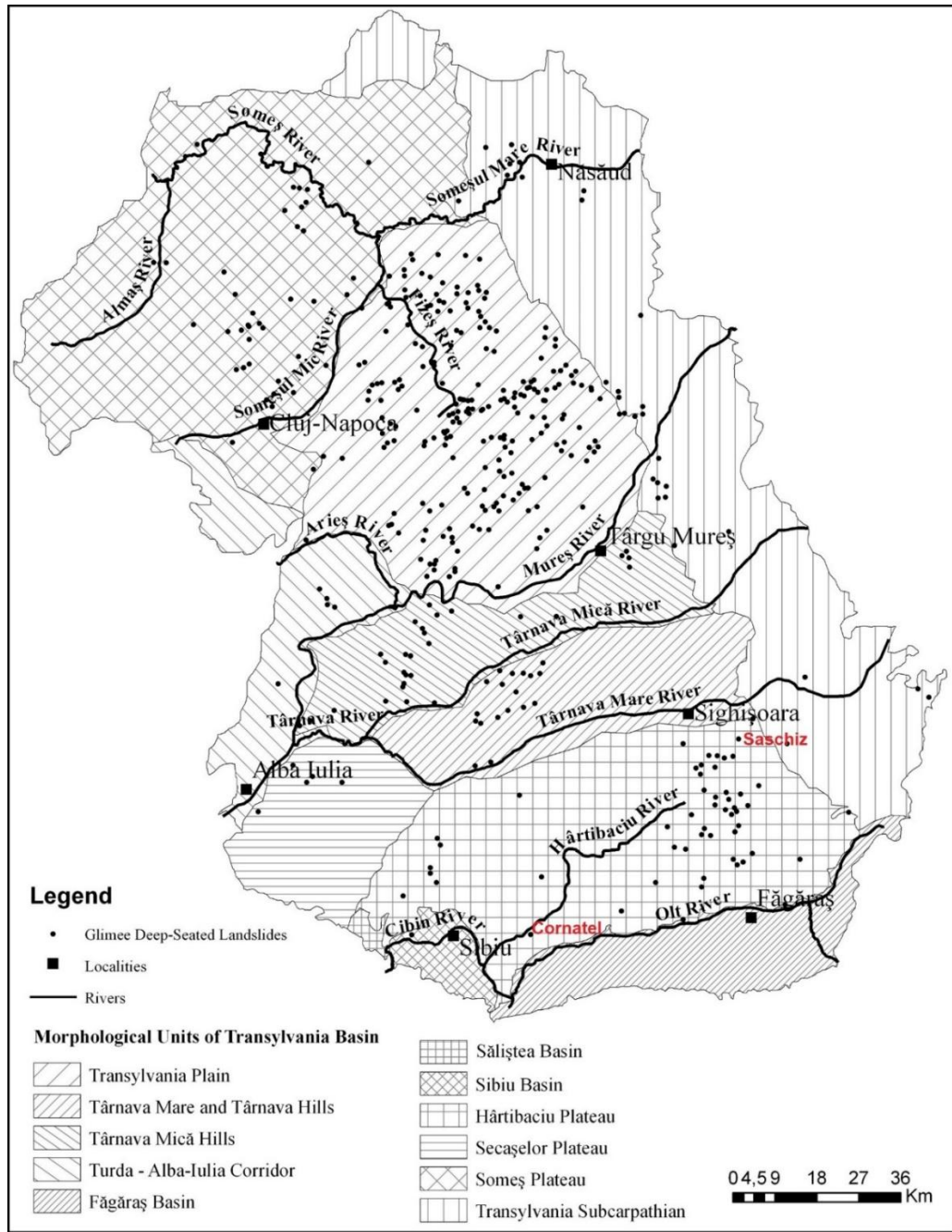


Fig. 30: Spatial distribution map of the deep-seated landslides (*glimee*) within the regional morphologic units of the Transylvanian Basin (Surdeanu et al., 2011).

References

- Gârbacea, V., Țanțău, I., Pop, O., Benea, M. (2015). First radiocarbon dating of landslides (“glimee”) in Romania. *Carpathian Journal of Earth and Environmental Sciences*, 10(3).
- Morariu, T., Gârbacea, V. (1968). Déplacements massifs de terrain de type glimee en Roumanie. *Révue Roumaine de Géologie, Géographie, Géophysique, Série de Géographie*, 12(1–2).
- Surdeanu, V., Moldovan, M., Anghel, T., Buimaga-Iarinca, Șt., Pop, O., & Rus, I. (2011). Spatial distribution of deep-seated landslides (*glimee*) in the Transylvanian Basin. *Studia UBB Geographia*, LVI(2), 3–8.

Ocna Sibiului salt diapir

Romania is a salt-rich country with estimated reserves of 4,390 million tons across 30,000 km². Major salt accumulations are in the East Carpathians–Subcarpathian area (87 deposits) and the Transylvanian Basin (107 deposits), often visible at the surface in outcrops (Seghedi et al., 2021) (Fig. 31).

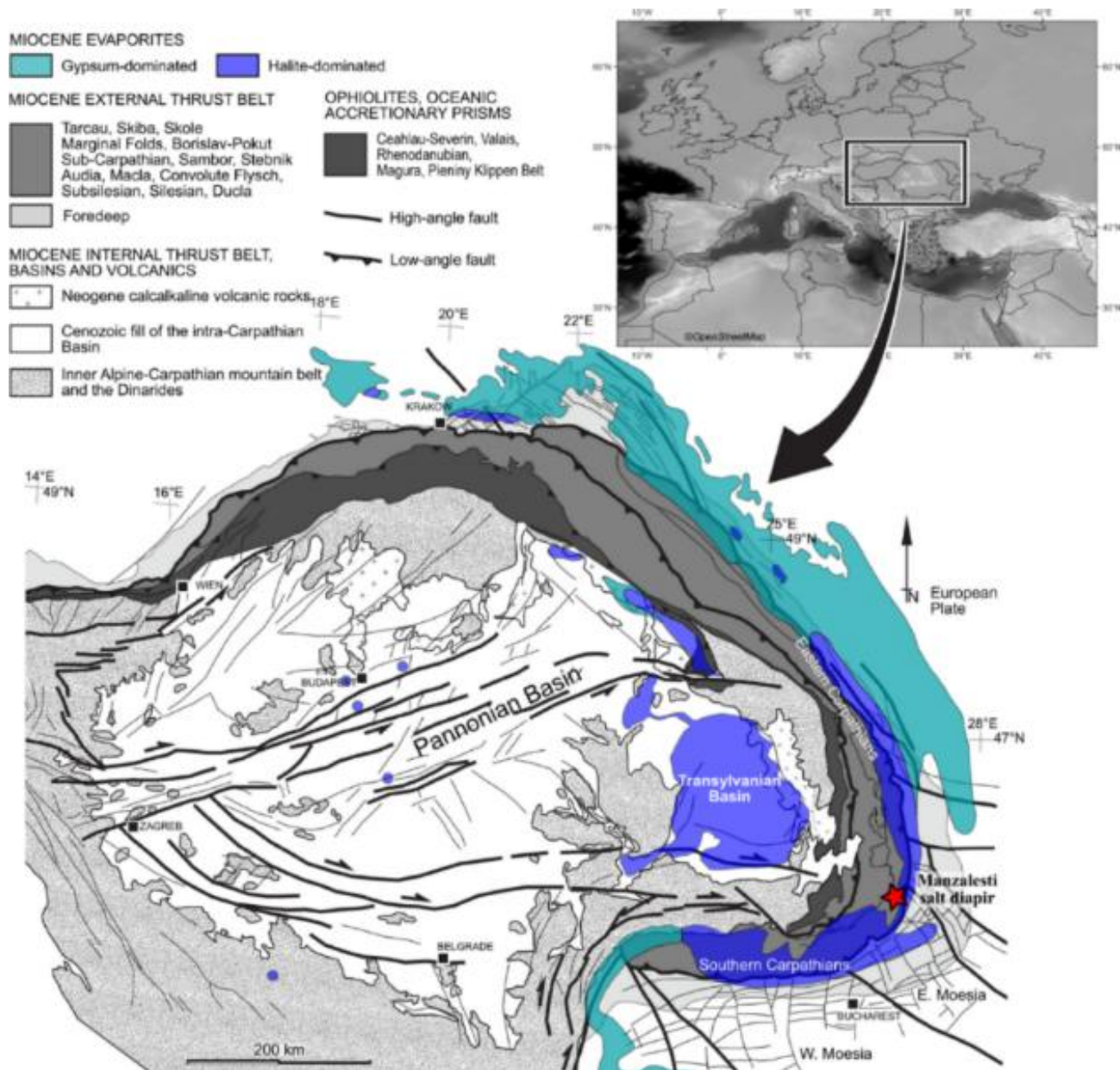


Fig 31. The major Miocene structural lineaments and features of the Pannonian–Carpathian area showing the type and approximate present-day distribution of the Miocene evaporites (Tămaş et al., 2025).

One of the particularities of the salt deposits is the presence of two different horizons: the “lower salt” from the early Burdigalian (lower Miocene) and the “upper salt” from the middle Badenian (mid-Miocene). These evaporites, initially deposited in the foreland area of the Carpathians, were later incorporated within the Carpathian nappes. The Burdigalian salt is limited to the foreland basin, while the Badenian salt also extends into the Transylvanian Basin (Tămaş et al., 2021) (Fig. 32).

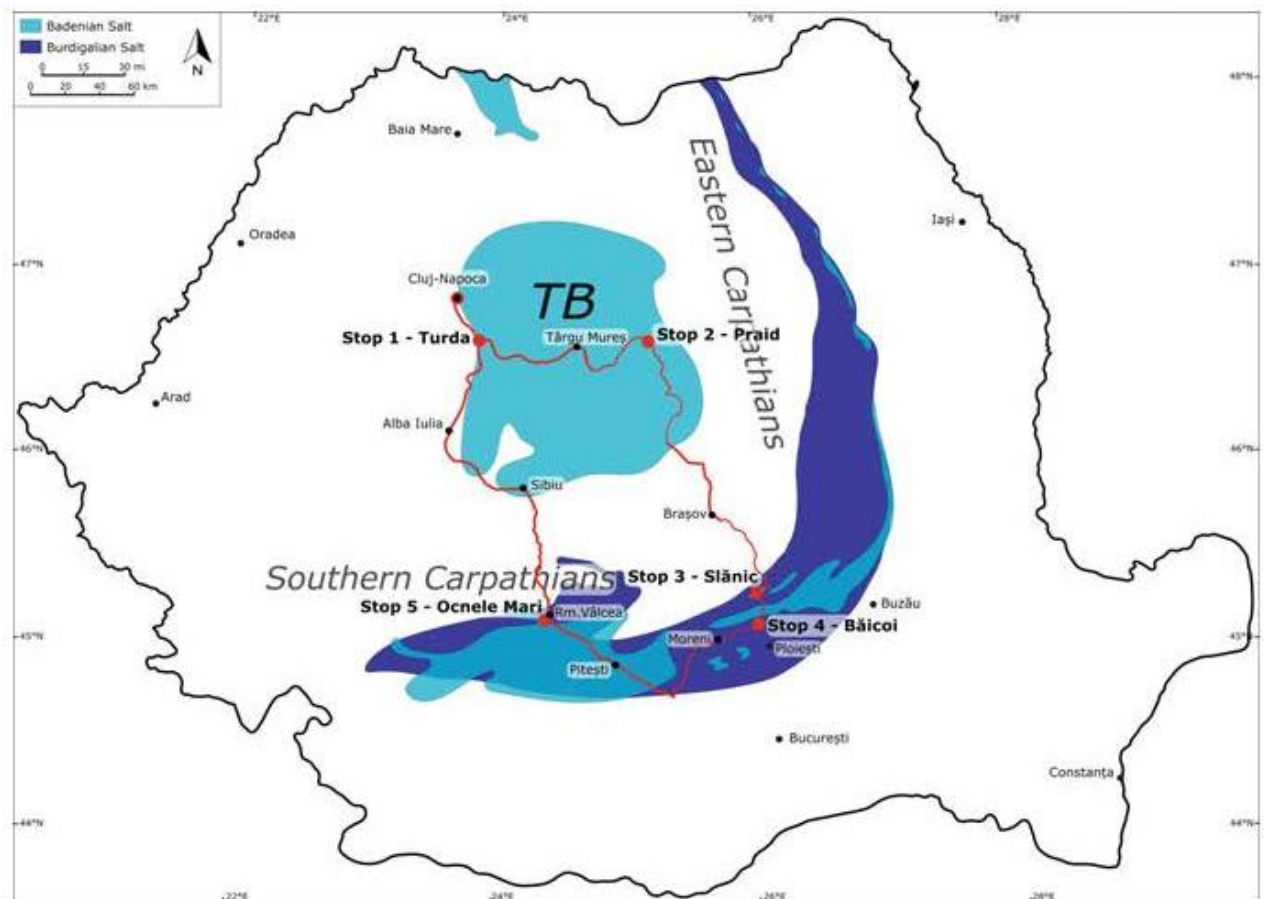


Fig. 32: Simplified map of the distribution of the lower salt formation (lower Burdigalian) and the upper salt formation (mid-Badenian) in Romania (Tămaş et al., 2021)

In the Transylvania Basin, salt was deposited in a deep marine desiccated setting, with initial thicknesses of ~300 m (Tămaş et al., 2021). On top of the basement nappes that were stacked by mid-Cretaceous, the basin locally contains a succession of sedimentary rocks (>5 km). In the central part of the basin, the thick, plastic salt layer was deformed as salt pillows, supposedly due to differential loading by local basin depocenters (Krézsek and Bally, 2006). In this area, salt reaches depths of 4000 m (Drăgănescu, 2006).

The salt forms two major diapir lineaments along the basin margins. The eastern lineament is developed initially as reactive diapirs due to extension caused by gravitational gliding. This was later compressed due to the additional loading produced by Pliocene volcanism. The western lineament is characterized by toe thrusting (Krézsek and Bally, 2006). Outcrops occur more frequently in diapir folds, which follow both the eastern and western margins of the basin.

Miocene salt was exploited over time, starting with the Neolithic period. More than 40 salt mines were active in the Carpathian-Danubian region, with the largest salt reserves estimated to be located in the Transylvanian Basin. According to Salrom (National Society of Salt), currently there are still five active salt mining areas in Romania, while several abandoned mines are open to the public for tourism and halotherapy. Ocna Sibiului is one of the abandoned mining areas that ceased activity during the interwar period (Fig. 33). The most recent case is the Praid salt mine, where mining activity was halted in May 2025 due to severe flooding caused by heavy rainfall. Following a dramatic rise of the Corund river, water entered the mine galleries, leading to the suspension of both tourist and mining activity.

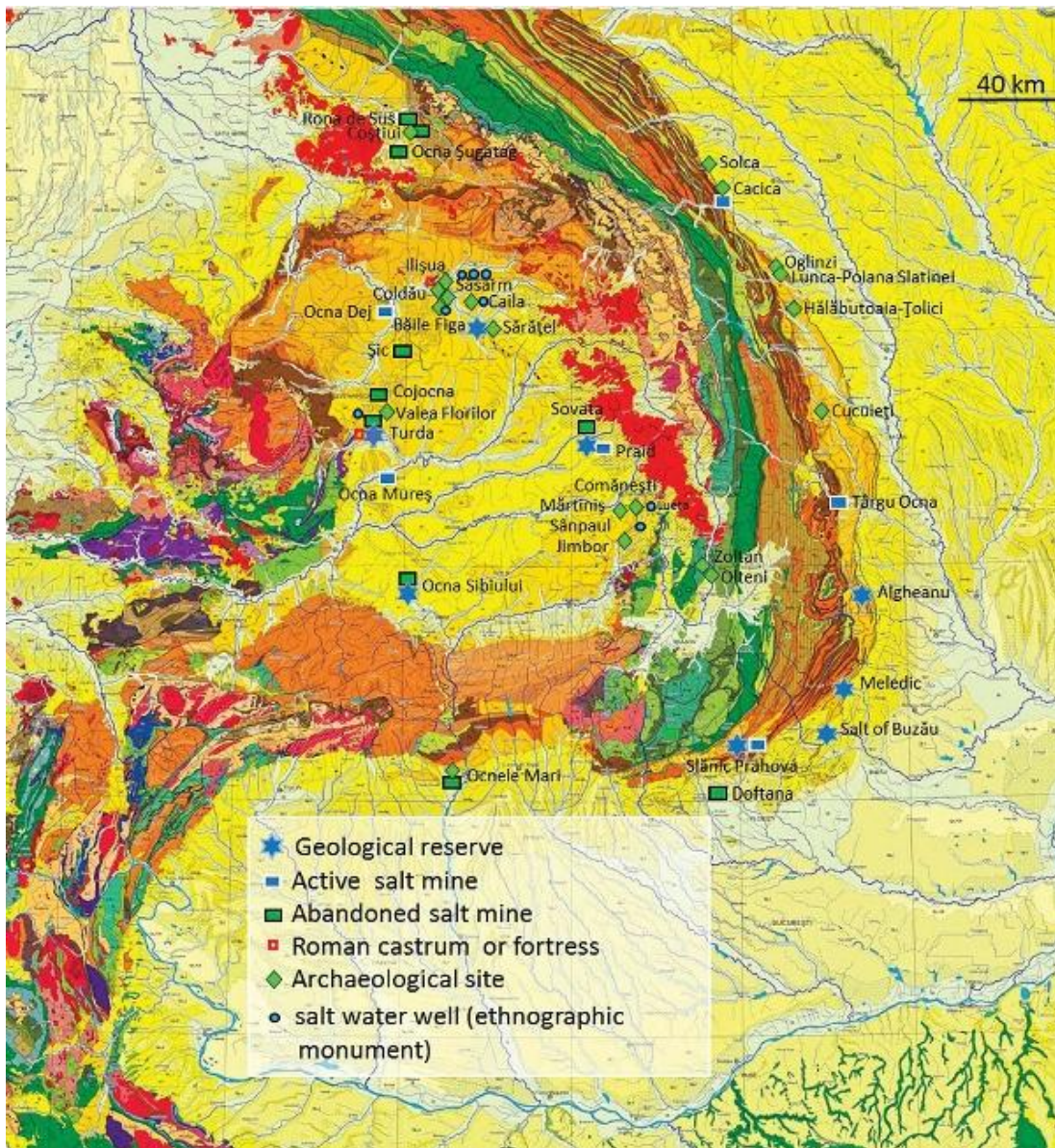


Fig. 33: The main salt-related nature reserves, archaeological and cultural sites, and active and closed mines in 2019, featured on the geological map of Romania 1:1.000.000 (Seghedi et al., 2021, simplified after Săndulescu et al., 1978)

Ocna Sibiului is situated along the western diapir alignment of the Transylvanian Basin, in the southern part of the Păuca – Alămor – Ocna Sibiului anticline (Stoica and Gherasie, 1981). The salt deposits form a NE-SW-oriented diapir, which pierces the overlying sediments, reaching the land surface. The salt massif contains strongly deformed, discontinuous clay layers that often host gypsum nodules with anhydrite cores (Seghedi et al., 2021).

The salt dome has an elliptical shape (1.3 km x 0.6 km) and is estimated to extend to depths of 1.0-1.2 km (Posea, 2005). The salt massif was eroded by the right tributaries of the Visa River, producing a microdepression with steep margins, which are subject to gully erosion and landslides. The chaotic relief inside this depression is controlled by the fault system and karstification processes of the salt massif, which exposed the salt and facilitated its early exploitation (Seghedi et al., 2021).

Salt mining at Ocna Sibiului dates back to prehistoric and Dacian times, expanded under Roman and later Habsburg periods, and ceased in 1931 due to instability and flooding. The collapse and flooding of former galleries led to the formation of numerous salt lakes. Today, Ocna Sibiului hosts Romania's largest salt lake complex, comprising 14 lakes, 12 of which are of anthropogenic origin (Fig. 34).



Fig 34. Ocna Sibiului salt lakes: 1. Horea; 2. Cloșca; 3. Crișan; 4. Pânzelor; 5. Mâțelor; 6. Lacul fără fund; 7. Avram Iancu (Ocnîța); 8. Lacul cu nămol; 9. Negru; 10. Rândunica (Sf. Ion); 11. Gura Minei; 12. Auster; 13. Brâncoveanu; 14. Verde (Google Earth, 2025).

These lakes are typically small (0.1-4 ha), landlocked (i.e., with no permanent water input), circular with steep shores, and variable depths (2 - 127 m), and permanently stratified (Alexe et al., 2018). The Avram Iancu (Ocnîța) lake, with a depth of 127 m, is the deepest man-made salt lake in Romania and probably in Europe.

Salinity increases progressively from the water surface toward the bottom, reaching a maximum concentration of 320 g/l in Brâncoveanu Lake. The high salinity is explained by the position of the water below the salt level, in direct contact with the salt massif on its entire surface.

The vertical salinity profile in most lakes comprises three distinct layers: the upper layer with low and highly variable salinity due to precipitation and runoff; a middle salt jump layer (“halocline”) between 0.5–4 m, where salinity rises sharply to 250–300 g/l; and a lower layer (4–6 m to the bottom), where salinity remains stable around 250–320 g/l year-round. In some lakes, salinity is uniformly distributed from the surface to the bottom due to the direct contact of water with the salt massif (Brâncoveanu Lake) (Alexe et al., 2018).

This stratification enables heliothermy, especially evident in Bottomless Lake (Lacul fără Fund, 34 m) (Fig. 35). There, differences in salt concentration between the surface (96 g/l) and at the bottom (318 g/l) cause warming of salt particles by the sun's beams penetrating to depth and producing the phenomenon of heliothermy. Remarkably, the phenomenon was observed even in winter, under the ice sheet, because of its maintenance from the warm season (Alexe et al., 2018).



Fig. 35: Bottomless Lake (Seghedi et al., 2021).

Conversely, some lakes experience the process of water sweetening due to the loss of contact with the salt massif after the collapse of clastic rocks. Verde Lake is a notable example, with a reduced salinity of 8–9 g/l (Alexe and Șerban, 2008).

The lakes host microorganisms (*Artemia salina*), which play a key role in the formation of a unique sapropelic mud, with renowned healing properties. The therapeutic qualities of water and mud have been exploited over time (since 1845), making Ocna Sibiului an important balneo-climatic resort. Brâncoveanu and the other lakes are exploited as summer spas (Fig. 36); meanwhile, the Bottomless Lake (0.20 ha) is a hydrogeological reserve, protected for its heliothermic properties since 2000.



Fig 36: Exemple of tourism exploitation of the salt lakes from Ocna Sibiului (source: <https://www.lacuriocnasibiului.ro>).

References:

- Alexe M., Șerban Gh., 2008. Considerations regarding the salinity and water temperature of salt lakes of Sovata and Ocna Sibiului, *Studia Universitaris* 18: 305-312.
- Alexe M., Șerban Gh., Baricz A., Andrei A. S., Cristea A., Battes K., Cîmpean M., Momeu L., Muntean V., Porav S., Banciu H., 2018. Limnology and plankton diversity of salt lakes from Transylvanian Basin (Romania): A review. *Journal of Limnology* 77(1): 17-34, DOI: 10.4081/jlimnol.2017.1657.
- Drăgănescu L., 2006. The Neogene salt formation from Romania. *Revista sării*, 2: 3-14.
- Krészek C., Bally, A. W., 2006. The Transylvanian Basin (Romania) and its relation to the Carpathian fold and thrust belt: Insights in gravitational salt tectonics. *Marine and Petroleum Geology*, 23, 405–442.

- Posea G., 2005. Geomorfologia României, Editura Fundației România de Măine, București.
- Săndulescu M., 1984. Geotectonica României, Ed. Tehnică București, 335 p.
- Săndulescu M., Kräutner H., Borcoș M., Năstăseanu S., Patrușiu D., Ștefănescu M., Ghenea C., Lupu M., Savu H., Bercea I., Marinescu F., 1978. Geological map of Romania sc. 1:1,000,000. Geological Institute of Romania, Bucharest.
- Seghedi A., Rădan S., Briceag A., 2021. Salt-related geological and cultural heritage in Romania. *Geo-Eco-Marina* 27: 153-182, DOI: 10.5281/zenodo. 5795093.
- Stoica C., Gherasie I., 1981. Sarea și sărurile de potasiu și magneziu din România. Editura tehnică, București, 248 p.
- Tămaș D.M., Tămaș, A., Hajdas, I., Quaternary to recent uplift rates of salt diapirs in the Romanian Carpathians determined from radiocarbon dating and PSInSAR data. *Sci Rep* 15, 23379 <https://doi.org/10.1038/s41598-025-08293-8>.
- Tămaș, D.M., Tămaș, A., Jüstel A.M., Passchier M., Chudalla N., Gotzen L., Wagner L.A.P., Tașcu-Stavre T., Schléder Z., Krézsek C., Filipescu S., Urai Y.L., 2021. S. Mukherjee (ed.), *Structural Geology and Tectonics Field Guidebook—Volume 1*, Springer Geology, https://doi.org/10.1007/978-3-030-60143-0_6.
- Tămaș D.M., Tămaș A., Barabasz, J., Rowan, M. G., Schléder, Z., Krézsek, C., & Urai, J.L. 2020. Low-angle shear within the exposed Manzalesti salt diapir, Romania: incipient decapitation in the Eastern Carpathians fold-and-thrust belt, <https://doi.org/10.1002/essoar.10504478.1>.

Râpa Roșie badlands geomorphosite

Râpa Roșie (fig. 37) is a nationally designated geological nature reserve of 25 ha in the Secaș Hills, stretching approximately 800 m in width from east to west on a south facing hill, on right side of the Secaș river.



Fig. 37: Râpa Roșie badlands.

Although no detailed geomorphological research has been conducted on the area, the formation of the badland can be attributed to the regressive erosion of an intermittent watercourse tributary of the Secaș river which, after incising into the loose rock layers, dissected the area, resulting in a rugged

terrain, with 80-100 m steep slopes, intricate, deeply incised gullies, towers, columns, obelisks, and pyramidal structures (Bleahu et al., 1976).

Badland formations of natural origin are typically associated with Mediterranean, semi-arid, or arid climates, still the region's climate is classified as temperate continental, with precipitation ranging from 500 to 600 mm/year, closely influenced by atmospheric circulation patterns. The passage of atmospheric fronts over the mountain ranges induces intense, torrential rainfall events, with peak intensities reaching 10-30 mm/10 min. (ALEA, 2018).

The time of formation is also unknown but the map of the first Military Survey of the Transylvania conducted between 1769-1773 (scale 1:28800) already displays the badland under the name of Rotheberg (red mountain/hill), hence improperly positioned probably at Râpa Lancrăm (fig. 38a. and 38b). On the second Military Survey's map (conducted between 1853-58; 1869-70) we can clearly see the eroded surface (fig.38c)., but the complete extent of the badland is marked on the third Military Survey's map (conducted between 1869-87; 1:25000) with the same name (Rother Berg) as on the first map (fig. 38d).



Fig. 38: Râpa Roșie on old maps. a) First Military Survey's map (improperly positioned), b) same map real position, c) Second Military Survey's map and d) Third Military Survey's map (maps.arcanum.com).

The parent material of the badland, the “red beds” belongs to the Maastrichtian (Upper Cretaceous) Șard Formation (Fig. 39). (Codrea et al., 2010a; Vremir, 2010) which has been interpreted as a braided river depositional system. The sediments were carried by fluvial systems with high discharge, and with deposition controlled by seasonality. The provenance of the sediments suggests a broad source area, likely encompassing the entire extent of the present-day Apuseni Mountains or extending even further (Codrea et al., 2010a). Mariș (2012) has identified four gravelly facies, four sandy facies (ranging from fine- to coarse-grained sandstones), one silt facies, and three paleosol facies associated with the specific architecture of the channels, longitudinal and lateral bars, sheets, prisms, lenses and lobes.

Until lately the red beds sequences were assigned to Sebeș Formation of Cenozoic age primarily based on the presence of Nummulitic limestone pebbles and boulders inside these deposits. These Eocene limestones blocks are, in fact, reworked detritus derived from the transgressing Middle

Miocene (Badenian) marine deposits that overlie the red beds. Their entrapment within the red bed matrix is attributed to either gravitational displacement or erosional processes (Codrea et al., 2010b).

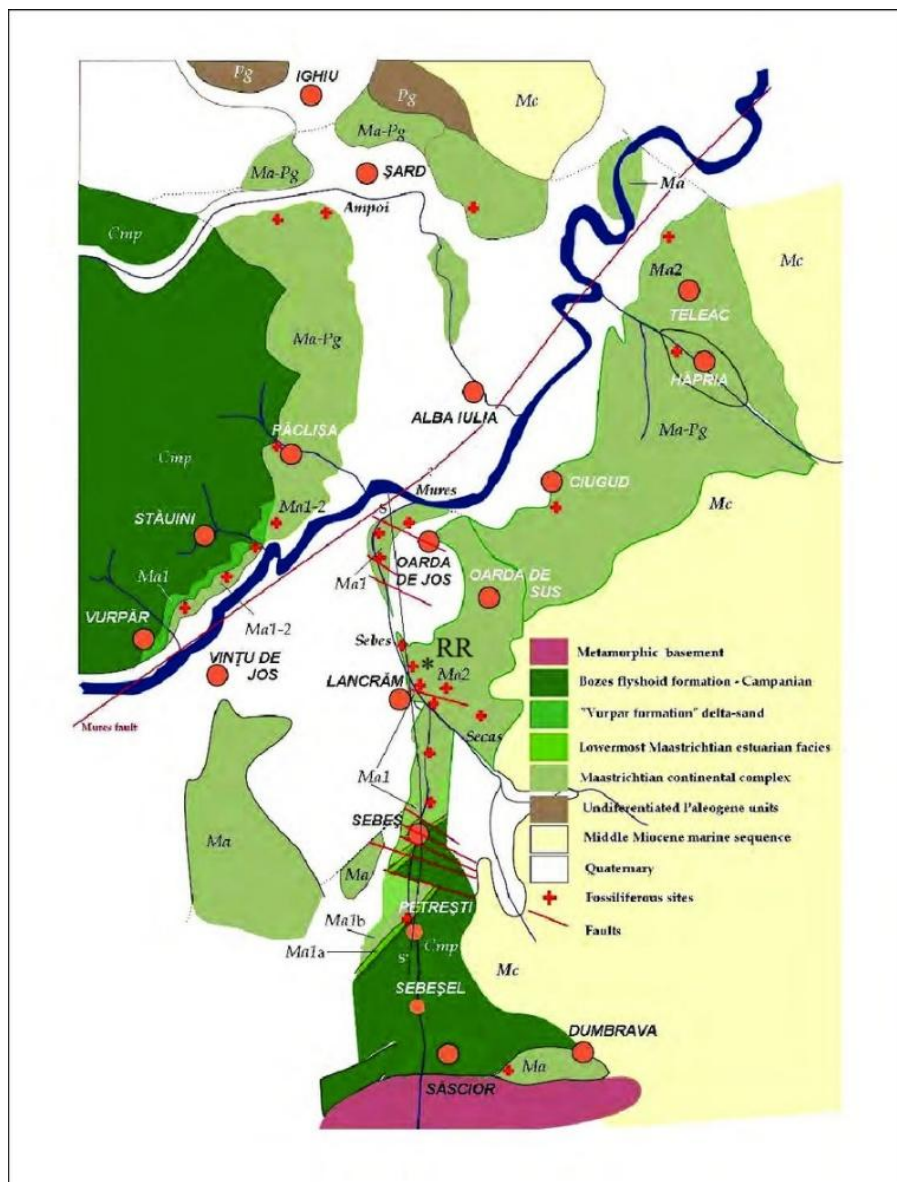


Fig. 39: Geological setting of Râpa Roșie (RR) area.

In this sequence of generally upward fining but alternating and cross-stratified siliciclastic sediments (Fig. 40) came to life the hoodos-like landscape of Râpa Roșie. The lower part is typical of conglomeratic facies while the upper part includes alternating coarser- and finer-grained poorly consolidated sandstones, sandy conglomerates and silty mudstones and clays (Jipa, 2012). The more consolidated rock layers shield the softer rock beneath them and as the hill slope retreats the resistant layer breaches through the surface. Local concentration of runoff around the resistant cap presumably causes the development of the capped-spire hoodoo or earth pyramid landform.

Besides the landscape the site is very important from palaeontological point of view, as the deposits are rich in fossils similar to that of the Maastrichtian deposits of the Hațeg Basin, well-known about the dwarf dinosaurs. The fossil assemblage includes various dinosaurs, mammals, fishes, amphibians, lacertilians, turtles, crocodiles, representing the majority of the taxa already known from

the Hațeg Basin. The only one recorded (up to the present) dinosaur footprint in Romania is also linked to these deposits (Vremir and Codrea, 2002). The fossils are not so well preserved as in Hațeg area, still scientists presume the former Hațeg island that forms today's Hațeg Basin might be extended to the northeast (Codrea et al, 2010a).



Fig. 40: Alternating and cross-stratified deposits at Râpa Roșie

References

- Bleahu, M., Brădescu, V., Marinescu, F., 1976, Rezervații naturale geologice din România, Ed. Tehnică, București, 224 p.
- Codrea, V., Vremir M., Jipa, C., Pascal, G., Csiki-Sava Z., Smith, T. Fărcaș, C., 2010b, More than just Nopcsa's Transylvanian dinosaurs: A look outside the Hațeg Basin, *Palaeogeography Palaeoclimatology Palaeoecology* 293, pp. 391–405
- Codrea, V., Barbu, O., Jipa-Murzea, C., 2010b, Upper Cretaceous (Maastrichtian) terrestrial vertebrate diversity in Alba district (Romania). *Bulletin of the Geological Society of Greece* XLIII(2), pp. 594-601.
- Jipa, C. C., 2012, Upper Cretaceous Continental Vertebrate Assemblages from Metaliferi Sedimentary Area: Systematics, Paleocology and Paleobiogeography, PhD thesis abstract, p. 44
- Maris, I., 2012, The sedimentology of the Upper Cretaceous continental deposits from the southwestern part of the Transylvanian Basin, the Șard Formation, *Geo-Eco-Marina*, 18, pp. 35-44
- Vremir, M. and Codrea, V., 2002, The first Late Cretaceous (Maastrichtian) dinosaur footprints from Transylvania (Romania). *Studia Univ. Babeș-Bolyai, Geologia* 47(2), pp. 93-104
- Vremir, M., 2010. New faunal elements from the Late Cretaceous (Maastrichtian) continental deposits on Sebeș area (Transylvania). *Sebus* 2, p. 635-684
- ***First, Second and Third Military Survey Maps of Transylvania, Arcanum Database, <https://maps.arcanum.com/>
- ***2018, Planul de Acțiune pentru Adaptarea la Schimbările Climatice PAASC al Municipiului Sebeș, Agenția locală a energiei Albe – ALEA, https://www.primariasebes.ro/wp-content/uploads/2023/05/PAASC_SEBES.pdf.

