SALT-RELATED GEOLOGICAL AND CULTURAL HERITAGE IN ROMANIA

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Abstract. In the intra- and extra-Carpathian areas of Romania, 8 salt-related nature monuments and Natura 2000 sites were declared by law, most of them in areas with ancient or active salt mines (Turda, Ocna Sibiului, Praid, Slănic Prahova), or salt springs (Sărățel, Sarea lui Buzău). Two other geological reserves represent areas with saline exo- and endokarst (Algheanu, Meledic) in the Subcarpathian Nappe of the East Carpathians. A large number of remarkable salt-related archeological sites occur both in the East Carpathians, as well as in the Transylvanian basin, accompanied by brine wells and salt springs. Archaeological research in areas with salt springs and fountains recovered various remains from the Neo-Eneolithic (Lunca-Poiana Slatinei), Bronze Age and the second Iron Age (Băile Figa), along with elements from post-Roman, medieval and premodern times. All these natural and cultural sites are briefly presented here.

Key words: nature reserve, salt diapir, salt spring, salt mining, archaeological site, wooden artefacts

1. INTRODUCTION

Romania can be considered a salt-rich country, with reserves estimated at 4,390 million tons, according to data from the Mining Strategy of Romania 2017 - 2035 (Romanian Government, 2016), the salt deposits occupying an area of 30,000 km^2 (Monah, 2007). Salt formations have been found at several stratigraphic levels in Romania, but those with economic value are included exclusively in the Miocene. Important accumulations occur in the East Carpathians – Subcarpathian area (87 deposits) and in the Transylvanian basin (107 investigated deposits), frequently, the salt being visible on the surface, in outcrops (Stoica and Gherasie, 1981). In the East Carpathians there are two Miocene salt formations: a lower one, attributed to the Lower Burdigalian (previously considered Aquitanian), and another upper one, of middle Badenian age; in the Transylvanian Depression and in the Maramures Basin, the salt deposits are exclusively mid-Badenian in age. Numerous salt outcrops appear in the Outer Carpathians, and especially in the area of diapir folds, in the Eastern Carpathian Bend Zone. In Transylvania, outcrops occur more frequently in diapir folds which follow both the eastern and western margins of the basin.

Due to the complicated tectonics of the Outer Carpathian Domain in the East and South Carpathians and to the overlapping of the two salt levels in space (lower Burdigalian and middle Badenian), it is sometimes difficult to estimate the age of the salt brought to the surface by very intense diapir processes. Clay mineralogy studies have shown distinct clay mineral assemblages for the pelitic material present in salt: illite + chlorite in Burdigalian salt and illite + chlorite + smectite in Badenian salt. The differences are explained by the different origin of the source areas of detrital material during the Miocene: Foreland during the Burdigalian and the emerging Carpathian area in the Badenian. The peculiar evolution of the clay mineral assemblages within the Lower and Middle Miocene suggests the possibility to determine the age of the salt deposits involved in the complex nappe and/or diapir fold tectonics of the Carpathians (Rădan, 1978; Rădan and Vanghelie, 1993).

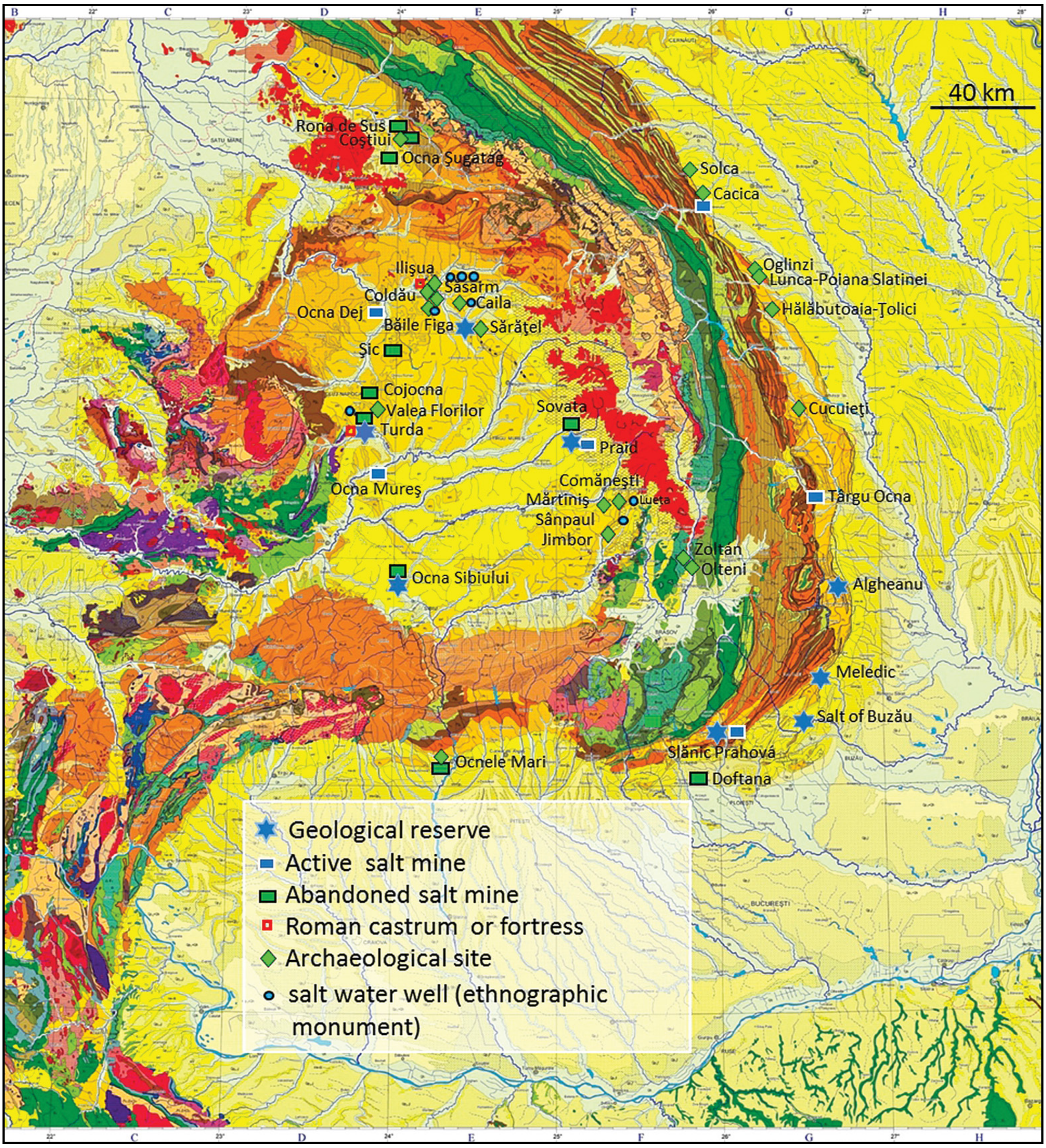

Fig. 1. The main salt-related nature reserves, archaeological and cultural sites and active and closed mines in 2019, featured on the geological map of Romania sc. 1:1,000,000 (simplified after Săndulescu *et al.*, 1978).

In the Carpathian-Danubian space, mostly Miocene salt was exploited through time, starting with the Neolithic. Whether exposed or concealed by younger sediments, the salt reveals its presence through saline areas with halophile plants, salt springs, salt ponds, salty muds and salt water fountains, saline crusts and efflorescences. Due to the large number of salt deposits, as well as of salt water sources, exploited since prehistory, toponyms based on salt-derived terms are abundant (Sărăţel, Slănic, Slatina, Valea Sării, Sărata, Sările etc.).

More than 40 salt mines were active in this area (Fig. 1), with largest salt reserves estimated in the Transylvanian basin. Through time, ancient mine galleries have collapsed and the salt lakes formed in their places often becoming modern spas. According to Salrom (National Society of Salt, on Wikipedia) currently there are still 6 active salt mining areas in Romania, while a number of abandoned mines are open to the public for tourism and halotherapy.

Despite the rich geoheritage related to salt and salt mining in Romania, the salt sites are protected only in 8 nature reserves from the Carpathians and the Transylvanian basin (according to law 5/2000, with subsequent modifications) (Fig. 1). However, there is a large number of remarkable salt-related archeological sites both in the East Carpathians (Alexianu *et al.*, 2015a; Alexianu, 2020), as well as in the Transylvanian basin, along with brine wells and springs (Chintăuan and Rusu, 1988; Alexianu *et al.*, 2008) (Fig. 1).

The rich archaeological heritage related to salt includes fortresses and castra (built in the vicinity of salt exposures, salt springs, or on salt roads), records of ancient mining techniques, of salt mines management and of salt trade routes, as well as stone, metal and wood artefacts.

Recent ethnoarchaeological studies have shown that salt had been exploited since prehistory in the form of natural brine coming from salt water springs (Dumitroaia, 1987). A thorough investigation of over 200 salt springs along the PeriCarpathian Fault in the East Carpathians revealed 15 archaeological sites related to salt exploitation since the early Neolithic until the end of the Chalcolithic (c.6000-3500 BCE) (Weller *et al.*, 2008a; Weller and Brigand, 2017). Such salt springs have been proposed for the World Heritage List, due to their age, uniqueness, rarity and conservation state (Alexianu *et al.*, 2015a). It is also inferred that in these areas, salt and salt waters were used as traditional halotherapeutic practices since prehistory (Sandu *et al*, 2010).

The main objective of this paper is twofold: to present the salt-related geological reserves, assess their values and state of preservation since their establishment according to law 5/2000; to give a brief overview of our cultural heritage on salt, as results from recent archaeological, ethnoarchaeological and paleoenvironmental studies in national and international projects.

2. GEOLOGY OF SALT IN ROMANIA

Part of the Alpine orogen in Romania, the East Carpathians were issued from the Tethys, with a geological history spanning the Early Jurassic-Miocene interval (Săndulescu, 1984, 1988; Maţenco and Bertotti, 2000; Csontos and Vörös, 2004; Schmid *et al.*, 2008). During the Lower and Middle Miocene, evaporitic deposits of the Central and Eastern Paratethys realm were precipitated in the Carpathian foreland as two horizons: the early Burdigalian lower salt formation and the middle Badenian upper salt formation (Mrazec, 1905; Popescu *et al.*, 1973). Subsequent deformation incorporated the evaporites in the outer Carpathian nappes and thrusts. From late Miocene to recent, the younger deformational event of the Wallachian phase (Hippolyte and Săndulescu, 1996) had an essential role in salt tectonics (Schléder *et al.*, 2019).

Surrounded by the Apuseni Mountains, East Carpathians and the South Carpathians, the Transylvanian basin is a Neogene depression superimposed on the thick-skinned nappes of the Alpine belt stacked by mid-Cretaceous. As such, the Transylvanian basin is interpreted lately as a post-Cenomanian sag basin (Krézsek and Filipescu, 2005; Krézsek and Bally, 2006). The basin fill attains in places over 5000m of sedimentary successions, that include salt deposited in the Badenian.

In the Middle Miocene a worldwide cooling event was recorded, triggering a sea level fall that restricted the narrow straits between the Paratethys basin and the Mediterranean, blocking the deep saline outflow (De Leeuw *et al.* 2010). This eventually led to brine formation and started the Badenian salinity crisis that affected the Central Paratethys (Peryt 2006; De Leeuw *et al.* 2010), precipitating a salt succession with an initial thickness of about 300 m in a deep marine dessicated setting (Krézsek and Bally 2006). In the central part of the Trasylvanian basin, the thick, plastic salt layer was deformed as salt pillows (Krézsek and Bally, 2006), supposedly due to differential loading by local basin depocenters (Tiliță *et al.* 2015). In this area, salt attains depths of 4000 m (Drăgănescu, 2006a). The salt forms two major diapir lineaments along the basin margins. According to Krézsek and Bally (2006), diapirs along the eastern lineament were initially related to extension produced by gravitational gliding; a subsequent compression of the diapirs occured later in relation with the additional load produced by the Pliocene volcanism. In contrast, toe trusting occured along the western lineament. The near-surface presence or exposure of salt also reflects a different kinematic history of the two diapir lineaments: a subsequenlty shortened, initially reactive and then passive diapir at Praid, as compared to the gravitational toe-thrust diapir at Turda.

3. SALT-RELATED GEOLOGICAL RESERVES IN THE EAST CARPATHIANS

The largest part of geological reserves in Romania were confirmed or established according to the Law 5/2000, and many of them were included in the Natura 2000 network of SCIs and SPAs. However, many nature reserves on salt were declared much earlier, by decisions of local or county councils.

In the outer area of the Carpathians, the salt is protected in four reserves situated in the East Carpathians Bend Zone. *Algheanu* is a nature reserve (IV IUCN category) of geologic and landscape type in the Vrancea County. *Sarea lui Buzău*, first declared in 1955, is a nature monument of geologic and botanic interest (III IUCN category). The *Meledic Plateau,* a mixed type of natural reserve (IV IUCN category) (geological, speleological, botanical and zoological), is also included in the ROSCI0199 Meledic Plateau site of community interest, protecting species and habitats. Sarea lui Buzău and Meledic Plateau are both situated in the Buzău Land Aspiring Geopark (Melinte-Dobrinescu *et al.*, 2017). The *Slănic Prahova Salt Mountain* is a nature monument (III IUCN category) in Prahova County, declared a geological and geomorphological nature reserve since 1954. Despite its great scientific, educational, aestethic and economic value, the salt mountain has been significantly destroyed in recent years due to natural causes, with the disappearance of the very object of protection.

3.1. Algheanu

Algheanu is a reserve of 41,4 ha (according to the ANANP website) situated in the central part of the Vrancea Depression, in the hydrographic basin of Putna river and accessible on the local road through Vrâncioaia village. The reserve was established in 1990 in order to protect the salt karst landforms and other erosional features created by Algheanu (or Zmeu) stream in the Lower Miocene soft rocks of the Subcarpathian Nappe East of the Vrancea half-window (Fig. 2).

The geological succesion consists of lower Burdigalian salt-rich deposits, with a lithology of grey clays interbedded with gypsum and gypsum-rich sandstones, overlain by the Salt Breccia and forming several scales. On top of the Early Miocene deposits there are terrigenous Holocene terrace sediments (sands, clayey sands, gravels) of the 6-th terrace of Putna river (Dumitrescu *et al.*, 1968). A salt massiv is exposed on the right bank of the reserve, belonging to the Valea Sării – Algheanu salt alignments from the Vrancea county. The saline soils formed on such a bedrock are highly vulnerable to precipitations that result in deep erosion of rocks and the formation of mud flows. The Algheanu valley is U shaped and shows features typical for salt landforms (halokarst) (Fig. 3). The salt from Algheanu is used either pounded, for pig fodder or human consumption, as natural brine for pickles, or cheese and meat preservation, as well as artificial brine for human and animal halotherapy (Alexianu *et al.*, 2015b).

The main threats to the reserve are represented by natural erosional processes, like rock falls and landslides, a typical phenomenon in areas rich in salt or salty clays. Therefore, according to the National Agency of Natural Protected Areas (ANANP in Romanian) slope enforcing works have been done, especially along the communal road to Vrâncioaia, by terracing and planting the slopes with salt resistent species (ananp.gov.ro/rezervatia-algheanu).

3.2. The Meledic Plateau

Situated between Lopătari and Mânzăleşti in the Buzău County, the Meledic Plateau is an area of 156,7 ha located on the left side of Slănic River (Fig. 4), in the Diapir Folds Zone of the East Carpathians Bend Zone. The plateau forms the apex of a salt diapir, where the salt of the Lopătari salt deposit (Stoica and Gherasie, 1981), ascribed to the early Burdigalian and overlying a terrigenous clastic succession (brackish molasse), occurs at the contact between the Tarcău and Subcarpathian Nappes (Săndulescu, 1984; Melinte-Dobrinescu *et al.*, 2017).

The structure of the salt was investigated by wells and detailed outcrop and microscopic observations were performed (Tămaş *et al.*, 2021b). The typical structural feature of Meledic salt is the recumbent isoclinal folding, accompanied by a sub-horizontal foliation. The original coarse-grained halite fabric is strongly overprinted by a superimposed deformation, which resulted in subgranulation and dynamic recrystallization around large porphyroclasts. Such microstructures were interpreted by the cited authors as the result of sub-horizontal shear produced by the overriding Tarcău Nappe thus decapitating the salt body.

The Meledic plateau is not only the largest rock salt exposure in Europe, but also represents the most important saline karst in Romania, as the salt-rich bedrock of the plateau controls an iconic landscape and a large variety of habitats in a temperate continental climate. The salt is exposed in amphitheaters and canyons formed along the valleys and on the steep sides of the plateau. The salt dissolution contributes to special landforms and landscapes like the saline pseudokarst, with undeniable scientific value, characterized by exokarst features (dolines and uvalas) at the surface and saline endokarst at depth, and also by lakes (Móga *et al.*, 2018).

Dolines are the most widespread karst features in the Meledic Plateau, occuring in areas where salt is exposed in outcrops or is covered only by a thin layer of soil. They develop in places where water can percolate easily into the salt substrate, on joints and fractures. Two types of dolines are dominant, differing in shape and attaining up to 50 m in diameter, with maximum depths of 10 m (Ponta, 2018). Collapse dolines show circular or oval shape and steep, almost vertical walls, while solution dolines form bowl-shaped depressions. Adjoining dolines are separated by steep, sinuous ridges, which results in a chaotic landscape morphology. Karstic lakes occur in dolines on top of the plateau, but also a freshwater lake has formed on clays deposited atop the salt layer (Móga *et al.*, 2018; Ponta, 2018).

The plateau hosts about 50 caves with a cumulated length of about 4500 m and a total vertical development of 300 m, as mapped by members of Emil Racoviţă Speleological Club in Bucharest. In time, many caves have collapsed and were filled with debris (Giurgiu *et al.*, 1980a). 6S Cave discovered here is over 3300 m long, being the longest salt cave in Europe and one of the longest salt caves in the world (Giurgiu, 1985, 1995) (Fig. 5a). The entrance of 6S Cave repeatedly collapsed in time, and the total length of the cave changes due to high solubility of the salt rock and ephemerity of underground features.

Some caves are adorned with salt stalactites, corallites and anemolites (deflected stalactites) (40-100 cm long), tubular or conical in shape and formed of crystallized salt, with yellow, red, brown and grey colors due to impurities (Giurgiu *et al.*, 1980b) (Fig. 5b). Stalagmites are rarely seen, attaining only few tens of centimeters in height and 10 cm in width. Salt draperies frequently form at cave entrances. However, due to the high risk of collapse and breakdown, as well as of potential damage to delicate salt formations by visitors, no show salt caves exist in the Meledic Plateau, contributing to a long-term natural conservation of caves (Tîrlă, 2018).

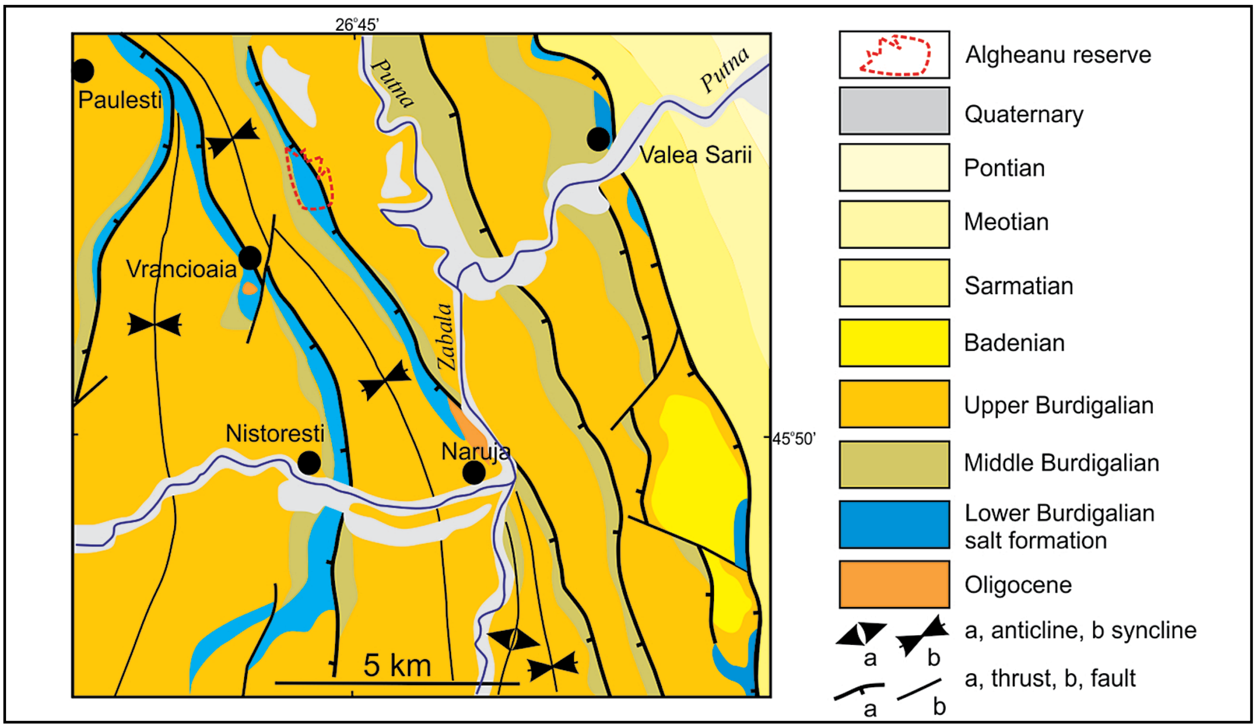

Fig. 2. Geological map of the Subcarpathian Nappe in the area of Algheanu reserve, showing several scales involving salt diapirs of the Lower Salt Formation. Simplified after Dumitrescu *et al.* (1968).

Fig. 3. Algheanu reserve. *Photo copyright of Association for Conservation of Biological Diversity* (ACDB in Romanian).

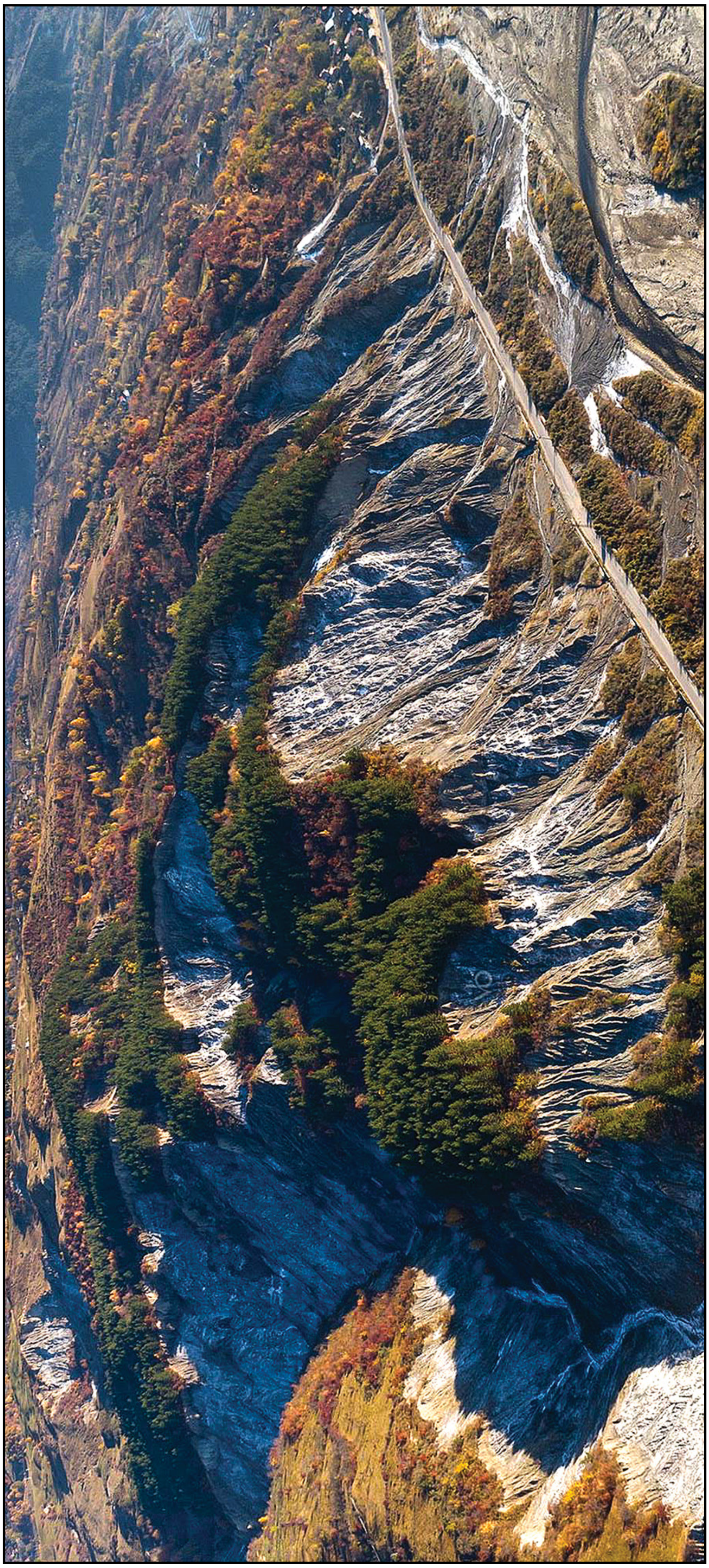

Fig. 4. Aerial view of the Meledic Plateau, showing the salt walls and canyons exposed along Slănic and Izvorul Sărat valleys in the southern part of the plateau, and dolines and lakes on the flat top of the site, where forests and meadows are supported by a thin soil layer. *Photo courtesy of Alin Barbu*, https://meledic.com/.

Fig. 5. (**a**) One of the entrances in cave 6S, situated at the base of a sinkhole in the Meledic Plateau, showing salt drapes at the entrance. *Photo courtesy of Alin Barbu*, https://meledic.com/; (**b**) Anemoliths, stalactites of crystallized salt at a cave entrance, Izvorul Sărat. *Photo copyright BogdanGoim*, wikimapia.org.

A remarkable biodiversity develops above the salt layer, with terrestrial, lacustrine and Natura 2000 habitats with meadows and forests (Ponto-Sarmatian shrubs habitat), while cave ecosystems occur underground.

According to the management plan of the site, the most important threats to this reserve are represented by landslides and salt dissolution, while main anthropic threats are garbage disposal and agricultural practices.

3.3. Sarea lui Buzău

Situated on the left bank of Buzău river in the vicinity of Bădila village, Sarea lui Buzău (the Salt of Buzău) is an area of 1,77 ha with salt springs, saline efflorescences and halophile vegetation (Fig. 6), all indicating the presence of a salt massif at depth (which forms the Ruşavăţ salt deposit). The salt spring is sourced by an Aquitanian (currently attributed to Burdigalian) faulted salt diapir (Bădila-Lapoş anticline) (Stoica

Fig. 6. Sarea lui Buzău nature monument. *Photo Antoneta Seghedi*.

and Gherasie, 1981) from the Subcarpathian Nappe. Borehole and gravity data indicate that this asymmetric anticline, with a Paleogene-early Miocene core and Sarmatian-Pliocene successions on its limbs, represents a mature, uprooted teardrop diapir uplifted along the Bădila Fault (Stoica and Gherasie 1981). For generations, the highly saline springs of this reserve are used by locals to preserve food (Toma *et al.*, in print).

3.4. The Slănic Prahova Salt Mountain

The geological reserve from the western part of Slănic town is a nature monument of national interest, protecting an area of 2 ha related to an important salt deposit of Badenian age. When designated, the reserve included the Salt Mountain and the Bride's Grotto.

The Salt Formation, showing a cryptodiapir structure, is located in the axis of the Slănic Syncline, included in the inner zone of the Tarcău Nappe. The average thickness of the Slănic salt massif is 400 m. A detailed study of its internal structure and the degree of salt folding led to the conclusion that the initial thickness of the salt lens was around 200 m, a value comparable to the thicknesses of 100 -200 m appreciated for salt in the less diapirized areas of the Transylvanian Basin. This would suggest the existence of similar concentration conditions and the same duration of deposition for the Badenian salt, both inside and outside the Carpathian arc (Lăzărescu *et al.*, 1969).

The history of salt exploitation in Slănic begins in 1685, when the boyar Mihai Cantacuzino bought half of the Slănic estate to open salt mines. Following a series of successful exploratory works, carried out between 1685 and 1689, Mihai Cantacuzino opened the first bell-shaped mine in 1891. After 1894, when he bought the second part of the Slănic estate, it expanded with other exploitations. Later, in 1713, the mining area was donated to the Colțea Monastery in Bucharest, and in 1862, it became part of the patrimony of the *Eforia Spitalelor Civile* (Board of Civil Hospitals) (Stamatiu, 1942). Salt mining in Slănic continues to this day, but the mining system has evolved from the bell-shaped mine to large galleries or chambers with a trapezoidal profile, and further to the room and pillar method.

The lake inside the salt mountain was formed in 1914, after the collapse of the ceiling followed by flooding of a bell-shaped salt mine, active until 1852. The name of the Bride's Cave appeared in 1920, related to a real event, when an unhappy bride committed suicide by throwing herself into this lake four days after the wedding.

Over time, the mountain has suffered a process of slow erosion / dissolution, due to rainwater and groundwater runoff, which have permanently acted on it, their effects being visible only at long intervals (Fig. 7 a, d). Unfortunately, the effects have built up in time and in recent years this site became almost completely destroyed by landslides and collapse of the cave walls. The progressive destruction of the site is shown in Fig. 7 e-m. Thus, after the earthquake on March 4, 1977, quite large and deep cracks appeared, especially on the eastern side of the mountain. The placement of an anchor system with steel cables and adjusting screws did not work due to subsequent dissolutions. On May 28, 1993, the first major collapse occurred when the southwestern side wall fell into the inner lake. A few years later, on June 20, 1999, due to heavy rainfall, a new massive collapse of the southern and eastern side of the Salt Mountain occurred. In September 2005, landslides were reported north of the mountain, affecting several nearby houses, then, on March 27, 2006, other houses were affected by landslides (Fig. 7g). In the same time, another part of the mountain collapsed into the Bride's Grotto, and the northwest slope, trees included, slipped all the way to the lake, partly covering it (Fig. 7g, h). By 2012, the Bride's Cave vanished due to combined action of dissolution, collapse, and landslides (Fig. 7i, j). In the following years, the landslides continued, completely covering the site of the former Bride's Lake with earth and huge blocks of salt (Fig. 7k-m).

The Slănic-Prahova Salt Mountain, once a landmark in the area (Fig. 7c), is nowadays practically destroyed by salt dissolution and landslides. A recent Google Earth image (Fig. 8) illustrates the uneven relief resulted from multiple landslides largely covered by vegetation.

It should also be noted that in the northeastern part of the town of Slănic, in the point called Piatra Verde, a series of vestiges (pottery) dating from the Iron Age (La Tène) have been found, attesting the traces of a fortified Getic settlement. The site is included in the National Archaeological Repertory (RAN).

4. SALT-RELATED GEOLOGICAL RESERVES IN TRANSYLVANIA

An area with the most consistent saline manifestations accessible for pre-industrial exploitations, Transylvania is rich in salt landscapes, where nature reserves are outnumbered by archaeological, historical and ethnographic cultural sites. As previously mentioned, salt in Transylvania is exclusively middle Badenian in age.

The salt is protected in four geological reserves, two as nature monuments and two as Natura 2000 sites. Two of the geological reserves (Praid and Sărățel) are situated on the eastern diapir alignment. The other two (Turda and Ocna Sibiului) are located along the western tectonic alignment of the basin. *The Praid Salt Mountain* nature monument, established in 1980, is part of the most important salt deposit in Transylvania (and one of the largest in Europe). The *Sărățel Salt Massif*, established in 1976, a geologic and floristic nature reserve in Bistrița-Năsăud county, is a salt diapir largely concealed by alluvial deposits. *Turda salt marshes and the Old Salt Mine* (superimposed to the Natura 2000 site ROSCI0223 Sărăturile Ocna Veche), established in 1984 in Cluj County, is a wetland including lakes, salt marshes, pastures and meadows, formed as result of salt exploitation at surface and underground.

Fig. 7. The Slănic Prahova Salt Mountain nature monument in various stages of degradation: (**a**) **1933**, view from the north. The dark rectangular shape in the center of the image is the entrance to the visiting gallery of the Bride's Grotto (Grota Miresii). *Illustrated postcard;* (**b**) **1970s**, view from the West, with Baia Baciului Lake in the background. The Bride's Grotto is visible in the foreground. *Illustrated postcard;* (**c**) **1983**, the position of the Salt Mountain on the western slope of the Slănic Valley – general view. *Photo Silviu Rădan*; (**d) 1985**, view from the southeast. The only visible change is a diminished volume of the rising salt mass. *Photo for Wikipedia by Romeo Iugovoiu* https://ro.wikipedia.org/wiki/Muntele_de_Sare_Sl%C4%83nic_Prahova; (**e**) **2005, May 3**, view from the west of the remains of the Salt Mountain and of the lake in the Bride's Grotto, after the collapse of the southwestern, southern and southeastern walls in 1993 and 1999. View taken from a position comparable to that in Fig. 7b. *Photo Silviu Rădan.*

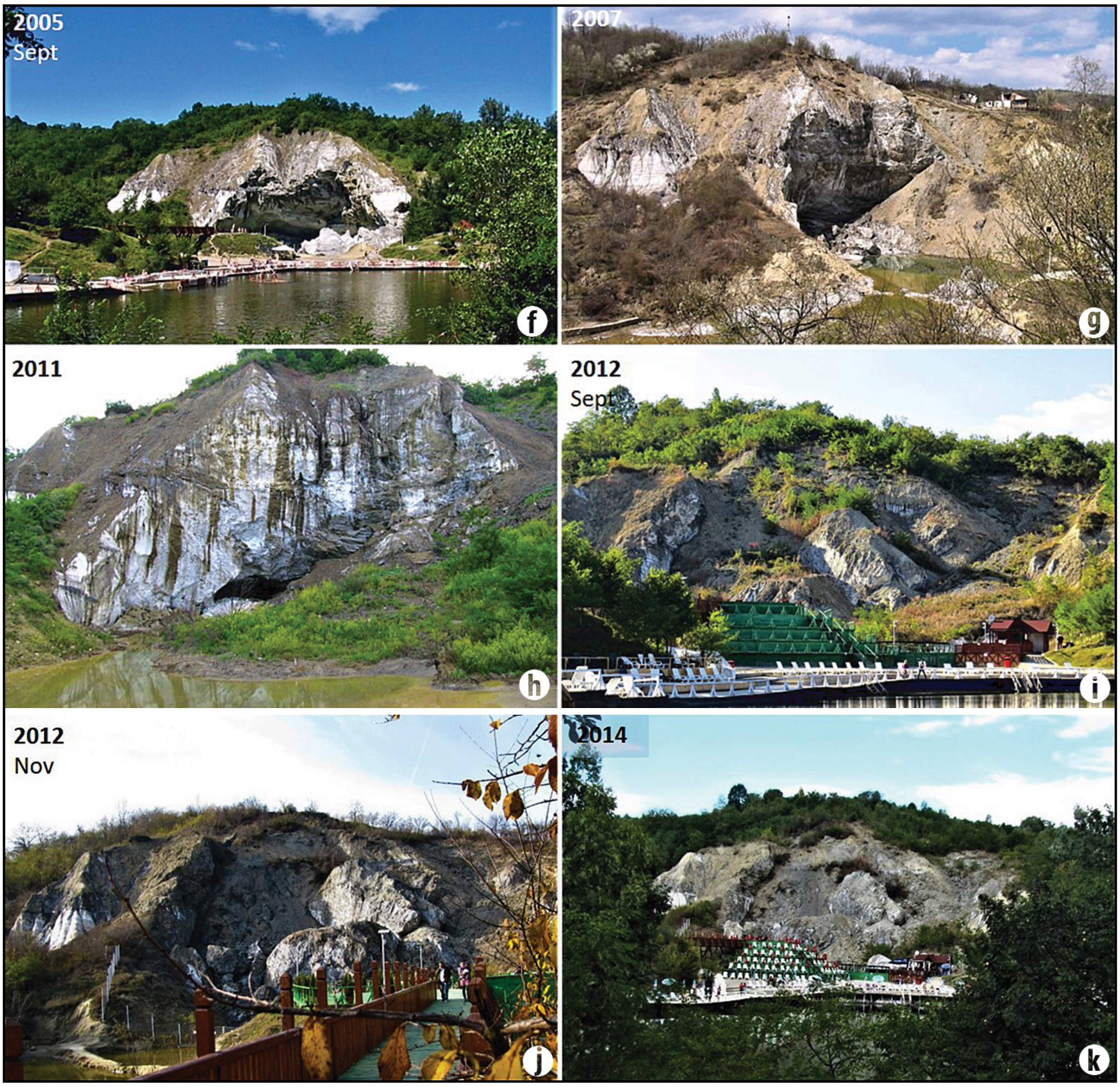

Fig. 7. (*continued*) (**f**) **2005, September 8**, view from the east. Baia Baciului and the Salt Mountain, after the salt rock collapses of 1993 and 1999 and few month before the landslides in autumn 2005 and spring 2006. *Photo Silviu Rădan*; (**g**) **2007, April 10**, view from the southeast (position similar to that in Fig. 7d) of the Salt Mountain and Baia Neagră (Porcilor). The great 2006 landslide and mudflows, which partially covered the Bride's Lake, are clearly visible. *Photo Sorin-Corneliu Rădan*; (**h**) **2011, June 25**, view from the southeast (position similar to that in Fig. 7d and 7g) with Baia Neagră (Porcilor) in the foreground. It is obvious that the 2006 landslide has almost completely obliterated the Bride's Lake. The growth of vegetation on the earthflow area indicates landslide stabilization. *Photo Sorin-Corneliu Rădan;* (**i**) **2012, September 9**, view from the east of the Salt Mountain and Baia Baciului after the landslides from the spring of 2012. The Bride's Lake was completely covered. *Photo Sorin-Corneliu Rădan;* (**j**) **2012, November 11**, view from the southeast. New destructions are observed 2 months after taking the previous photo (7d, 7g and 7h). *Photo Sorin-Corneliu Rădan;* (**k**) **2014, September 28**, view from the east. The remnants of the Salt Mountain show a relative stablility. *Photo Silviu Rădan*.

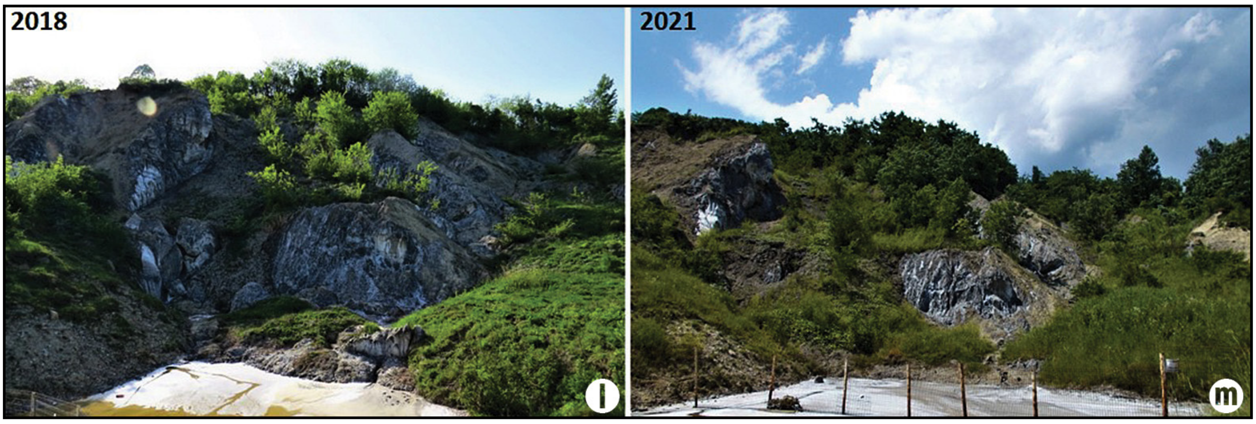

Fig. 7. (*continued*) (**l**) **2018, May 1**, the ruins of of the Salt Mountain viewed from the southeast (similar position to those from Fig. 7d, 7g, 7h and 7j). The vegetation overgrows not only the 2006 landslide, but also the more recent mudflows (visible in the center of the image). The Bride's Lake does not exist anymore. *Photo Silviu Rădan;* (**m**) **2021, June 6**, view from the southeast (position similar to those in Fig. 7d, 7g, 7h, 7j and 7l). The remnants of the Salt Mountain appear as isolated salt cliffs that pierce the cover formed by landslides in the last 30 years (now overgrown by vegetation). *Photo Silviu Rădan*.

Fig. 8. Google Earth image of the Salt Mountain area (**August 5, 2020**, 47 years after the general view of 1983 – photo 7c – was taken). The outlines of the 1987 Salt Mountain outcrop (in yellow), the inner lake formed by the collapse of the bell-shaped salt mine (in blue) and of the upper aperture of the Bride's Cave (in yellow) are superimposed on the background provided by the GE image. A gallery to the inner lake (visible in Fig. 7a), dug in the salt wall, is shown with brown lines. The contour lines are taken over and modified from Bulgăreanu *et al.* (1987) and Bulgăreanu and Cehlarov (1993). For orientation and comparison, on both images (Photo 7c and GE image) it is easy to identify the street that borders the reserve to the north-east and north.

It includes two habitats of halophile plants (*Salicornia* comunities and other annual species that colonize wetlands and sandy areas, and Pannonian and Ponto-Sarmatian salty meadows and swamps), as well as plants from the IUCN Red List. The Old Salt Mine is on the list of Cluj County cultural monuments since 2015. The *Ocna Sibiului Bottomless Lake* reserve in Sibiu County, established in 1968, has formed through the collapse of the former Francisc salt mine. This is one of the 14 heliothermal salt lakes at Ocna Sibiului, formed by inundation of collapsed saltworks, 13 of them belonging to an important resort and spa based on the healing properties of water and mud.

4.1. The Praid Salt Mountain

The Praid Salt Mountain (Sóhát in Hungarian) is a geological reserve of 66 ha established on Corund stream in Praid village, Harghita County. The salt is part of a 25 km long anticline extending between Săcădat and Corund, which is pierced by the diapir salt at Sovata and Praid. Salt diapirism, which also affects the Quaternary deposits of Corund and Târnava Mică valleys, resulted in a dome geomorphology (Stoica and Gherasie, 1981). The Corund Gorges, formed in the last 5000 years, deeply cut the salt dome during its formation (Fig. 9), but the current relief is the result of both natural erosion and human activities (Toma, 2012). The Praid diapir is the most representative recent salt flow in Romania, which is also degrading quickly, as about 30.000 tons of salt are leached each year from the massif (Stoica and Gherasie, 1981). Various forms of saline karst are present in the spectacular, steep, white salt cliffs of this nature monument: karren (Fig. 10), sinkholes, salt springs, various types of salt crusts, etc.

A brief history of salt exploitation at Praid is given on the Pride salt mine website (salinapraid.ro). The Praid salt was excavated since Roman times in open mines. After the Aurelian withdrawal from Roman Dacia in 271 AD, during Barbarian invasions, the Avars and Bulgarians extracted the salt from the old, abandoned "salt-cuts", but, after that, there were also periods when salt exploitation was halted. According to the first written mention, which is a letter of privileges that King Andrew the 2nd granted to German knights, salt mining resumed in 1222. The letter enabled each knight to use six vessels on rivers Mureş and Olt to transport salt and other merchandise. Underground mining started in 1762, when the Josef mine was opened as a bell-type exploitation. The systematic exploitation of salt started in 1787, when Praid salt mine became the property of Vienna Treasury. The *Paralela* mine, with trapezoidal chambers, was opened in 1864, while *Elisabeta* gallery was started in 1898 on the north-eastern part of the salt massif.

Fig. 9. Aerial view of the Praid salt canyon and tourist trail, along the Corund valley. The roofs visible on the left bank of the stream are the old mud baths. *Printscreen from SaltLand.*

Fig. 10. The Praid Salt Mountain nature monument, showing karren at the surface of salt. *Photo copyright Rodica B.*, ro.wikipedia.org

The geological reserve is a good example of exploitation and capitalization of salt and salt waters. Currently, the Salt Canyon Trail, organized by the Sóvidék Hegyalja Tourism Association in partnership with Harghita County Council, has a length of about 2 km and 9 stops with explanatory pannels in three languages (Hungarian, Romanian and English) (Fig. 11). Various forms of salt exposures, saline karst, salt springs and creeks, old salty mud baths can be seen along the educational trail. The remains of the Elisabeta gallery, opened in 1898, where the salt was extracted at the surface, are still visible on the trail as small caves, with salt and mudflows formed along the trace of this former gallery.

4.2. The Sărățel Salt Massif

This is a nature reserve of 6 ha in Bistrița-Năsăud County, located in the vicinity of the national road DN15A, between Reghin and Sărățel. The protected area is a salt diapir situated in the core of the Bârla-Uila anticline (Rusu *et al.*, 2012), largely concealed beneath the alluvial sediments of Șieu and Budac valleys, with only local salt exposures. The diapir is oval in shape, with its long axis situated along the Șieu valley, and prolongations on the three valleys (Bistrița Ardeleană, Budac, Șieu), towards localities Sărata, Simionești and Domnești (Chintăuan *et al.*, 2004). The presence of salt is indicated by local salt exposures, saline efflorescences, salt springs and ponds, salty mud, as well as by halophile plants (Fig. 12). Plant associations typical of saline soils are represented by *Salicornia herbacea*, *Atriplex patula*, *Limonium gmelinii*, *Puccinellia distans*, *Phragmites communis* (Svoboda, 2006), *Aster tripolium, Artriplex hastate* (Rusu *et al.*, 2012).

In the alluvial plain of Şieu valley, along the Sărățel-Domneşti country road, numerous saline crusts, halophile plants and low discharge salt springs are present in an abandoned meander. The water from some of the salt springs accumulates as small ponds. At lowstands, when water level is low and the alluvium overlying the salt is washed away, salt is exposed in the Şieu riverbed (Rusu *et al.*, 2012). In the vicinity of the junction with Budacului valley, the Şieu valley flows directly on salt, which is periodically covered with fine-grained alluvial sediments. In several areas within the river bed, massive salt rock occurs at the surface. In the area, ponds also occur on the places of former clogged lakes; where landslide-related clays occur in the bedrock, a salt water basin, a salt spring and a freshwater lake (variously named Dani, Făget or Bobeica lake) develop (Chintăuan, 1997; Chintăuan *et al.*, 2004).

Fig. 11. Pannel at the entrance in the Praid Salt Mountain geological reserve, showing the educational trail proposed to visitors. *Photo Silviu Rădan*.

Fig. 12. Aerial view of the Sărățel Salt Massif geologic and floristic nature monument. Note the mud holes in the salt crusts within the abandoned meander; locals use the salty mud for therapy, as visible from the cars parked next to the meander. *Photo copyright Darius Cîrmaci* (https://timp-online.ro/cum-arata-aria-protejata-masivul-de-sare-de-la-saratel/).

A Roman votive altar (2nd century AD), discovered at Sărăţel and hosted by the Bistriţa County Museum, is the first epigraphic monument attesting salt extraction here in Roman times (Chintăuan *et al.*, 2004).

The economic potential of this reserve is obvious, as 13 salt water wells in the area were exploited until 1945, their brine being sold according to a certain schedule to locals from nearby villages (Chintăuan, 1997). The wells are not used anymore.

The geological reserve shows an advanced state of degradation, due to former and current tourist development works in the neighborhood, which are threatening to destroy it (Chintăuan *et al.*, 2004). Currently, only locals use the salt water and mud for treatment, the real therapeutic potential of the area not being exploited. There are also areas in the reserve where some firms are throwing their garbage. And although the TORA Association from Bistriţa ecologized the area in 2012 (according to their blog), the waste continues to accumulate.

4.3. Turda salt marshes and the Old Salt Mine

The nature reserve is situated in the northern part of Turda city, in a depression with altitudes around 370 m. This area was a well known center for salt exploitation from the 11th century to the middle of 20th century, but archaeological evidence shows that the salt was mined in Durgău-Turda area both in the pre-Roman period (50 BC-106 AD) and during the Roman occupation (106-274 AD) (Chintăuan *et al.*, 2019). The first written mention of the Customs of salt mines at Turda dates from the year 1075, in a document of the Hungarian Chancellery, and the Durgău mine is found in a document from 1271. Roman exploitations of salt are first reported by Fridwaldszky (1756), then by Fichtel (1780), who found Roman works covered with water.

The Turda-Valea Sărată and Turda Băi salt deposits are situated on the Ocna Mureş-Turda and Măhăceni – Ploscoş anticlines, on Valea Sărată, north of Dealul Ocnei (Mera, 2008). The salt belongs to the Ocna Dejului Formation (Mészáros, 1991), and represents salt deposited during the middle Badenian salinity crisis. The age of the Turda salt was established as Wielician=middle Badenian, based on the calcareous nannofossil association from the clay interbeds, with *Triquetrorhabdulus rugosus* and *Cyclicargolithus floridanus,* indicating the upper part of NN5 and the lower part of NN6 subzones in Central Paratethys (Chira, 2001).

From mineralogical point of view, the Turda salt is more than 99% halite, the impurities attaining 0.7% (clay minerals, iron oxides or gypsum). The bedding is centimetric, marked by darker or lighter layers, with various content of impurities. The structure of the salt rock visible in the old mine consists of tight isoclinal folds, with axial planes from subhorizontal to steeply dipping or vertical (Tămaş *et al.*, 2021a).

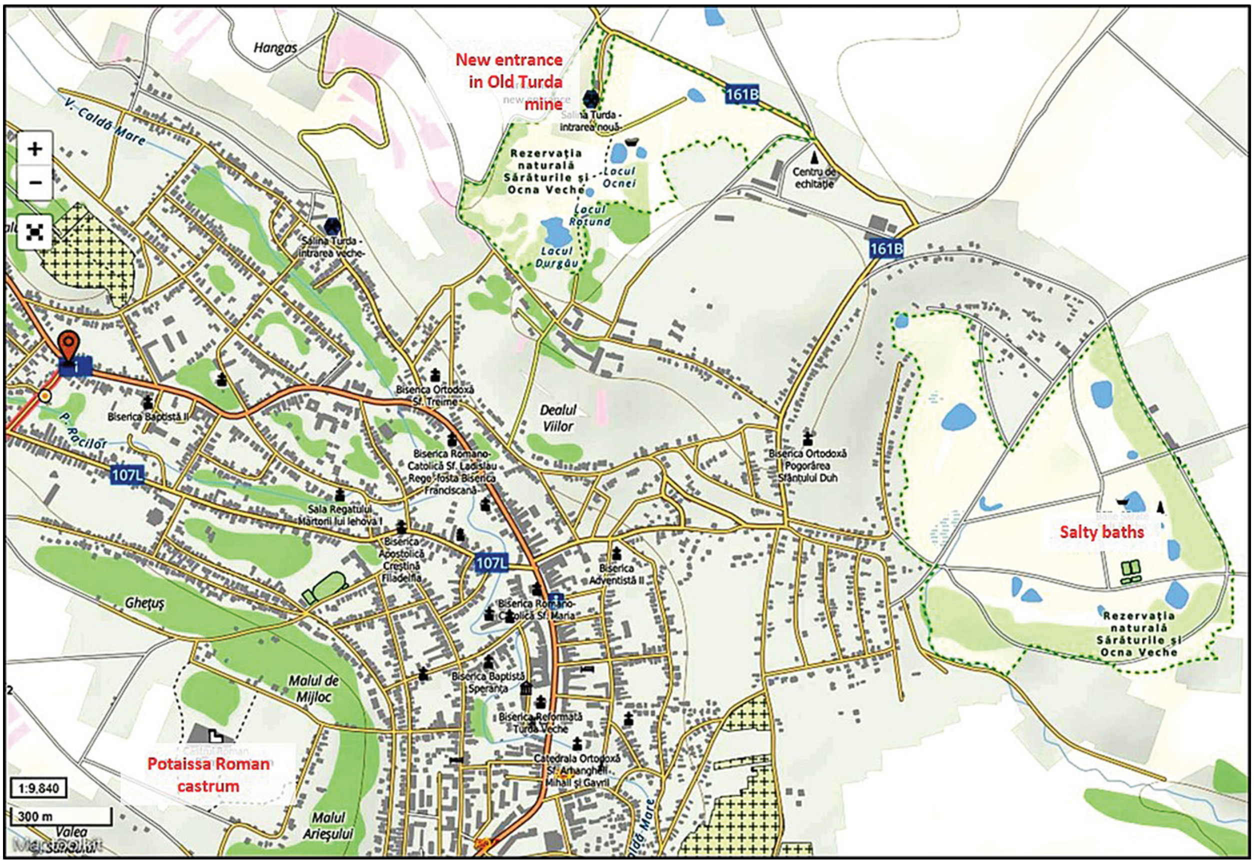

Fig. 13. Topographic map showing the *Turda Salt Marshes and the Old Mine* nature reserve (dashed green outline) with the lakes (in blue) formed in ancient collapsed mine works, the entrance in the modernized old mine and the Potaissa Roman fortress. Modified from www.muntii-nostri.ro

Sheath folds are also visible, especially on the ceiling of Rudolf mine. Salt mylonites are visible near the diapir edge. Stalactites form by brine seepage on ceilings.

Along with two salt related habitats, the natural reserve includes 10 saline lakes in various evolutionary stages, formed through the collapse of the old, Roman and medieval salt exploitations. The reserve includes two separate geographic areas (Fig. 13). The eastern area, where the Salt Baths are located, is situated east of the road descending from Turda and used to host 12 anthroposaline lakes of various sizes and various degrees of salt concentration (Lacul Fără Fund, Privighetorii, Roman, Csiki, Kimpel, etc.) (Petrescu *et al.*, 2006). The western area, which also includes the old Turda salt mine (new entrance) includes 5 lakes (Durgău, Lacul Dulce, Lacul Ocnei, Lacul Sulfuros and Lacul Rotund) (Fig. 14). The areas with lakes and pond vegetation are partly covered with *Salicornia* type plants, while reed develops in the area of clogged lakes. Currently, the two areas of the reserve are delimited by modern wire fences. Pannels were emplaced and parking places were built. The acces in the reserve is permitted only upon approval.

The extraction of salt from the last two mines active at Turda (Rudolf and Ghizela) in the XIX-th century was definitively stopped in 1932, due to the low yield compared to other salt mines. Sixty years after the cessation of mining activity, the Turda Salt Mine was opened for tourism in 1992. In 2010, a large scale modernization of the mine was funded by a European project of the Turda city hall. A new treatment base was organized, while the former exploitation chambers got a new look and extended functionality. Rudolf mine now houses a concert amphitheatre, sports fields (handball, football, tennis, and badminton), bowling and minigolf fields, billiards, as well as a huge panoramic wheel. A wharf was built in Terezia mine, for boat trips on the saline lake. Apart from being one of the top touristic objectives in Romania, the Turda mine is extremely valuable for the salt mining heritage in Transylvania, as it preserves several types of superimposed mining works (Fig. 15).

4.4. Ocna Sibiului Bottomless Lake

The Bottomless Lake (Lacul fără Fund) in Ocna Sibiului is a nature monument established on an area of 0,20 ha north-west of Sibiu, in the Ocna Sibiului resort. The access is on the County Road DJ 106b, then on Gării Street until the fence of the reserve. The so-called Bottomless Lake is, in fact, 34 m deep (Fig. 16) and was formed by the collapse of the ceiling of the former Francisc salt mine, abandoned in 1755. This is one of the 14 heliothermal salt lakes at Ocna Sibiului, resulted through flooding of collapsed saltworks and dolines. Currently, the other 13 lakes belong to an important resort and spa. The difference in salt concentration between the surface (96 g/l) and bottom waters (max. 318 g/l) causes warming of salt particles by the sun beams penetrating to depth and producing the phenomenon of heliothermy (Maxim, 1931).

Fig. 14. Turda, general view of the western part of the reserve, with the fence, red colored halophile plants and the new entrance to the old mine opened to tourism. *Photo Antoneta Seghedi*.

Fig. 15. The modernized Turda salt mine, showing the older, bell-shaped Terezia mine, with its access wells on top and a newer trapezoidal gallery cut in one of its walls. Tight, isoclinal or sheath folds are seen in the walls, as well as stalactites and salt crusts, formed in areas of water circulation on fractures and access wells. *Photo courtesy Călin-Andrei Stan*.

Fig. 16. Ocna Sibiului Bottomless Lake. The nature monument is surrounded by a wire fence, on which panels are mounted with basic information about the reserve. *Photo Silviu Rădan*.

The presence of density stratification explains the heliothermal energy capture by maintaining heat in the deeper and denser layer of salt water, which is thus protected from the temperature variations in the atmosphere. A fauna specific to saline environments populated the lake waters, and halophyte flora is developed on the lake shores.

Located along the western diapir lineament from Transylvania, the Ocna Sibiului salt deposit lies in the southern part of the Păuca – Alămor – Ocna Sibiului anticline (Stoica and Gherasie, 1981) with a NNE-SSW trend. The age of both the salt massif and its cover of clays and marls is Badenian. The salt deposits form a NE-SW oriented diapir, which pierces the overlying sediments reaching the land surface. The salt rock is formed by tiny cubic crystals of NaCl, very brittle due to clayey impurities. The salt massif contains strongly deformed, discontinuous clay layers, which often host gypsum nodules with anhydrite cores (Pošepný, 1871). Salt pseudomorphs after fibrous gypsum were also recovered (Ciuntu *et al.,* 2006).

Ocna Sibiului is one of the oldest salt deposits mined in Transylvania. The presence and accesibility of salt deposits determined the concentration of successive habitations beginning in the early Neolithic and practically extending until the end of the first Christian millennium (Popa, 2006). Salt exploitation in Roman times was confirmed since the XVIII-th century, based on field observations of Fichtel (1870), who reported here 15 collapsed mines, showing all the features of ancient exploitations. Moreover, two iron hammers used for splitting the salt rock and found in one of the ancient mines are dating since Roman times (Popa, 2006). The Romans used to dig at depth between 20-40 m, and then abandoned the mine, which explains the large number of lakes, which represent low-depth, water-filled, abandoned salt mines (Wollmann, 1996). The first written mention of salt exploitation here dates from 1263. According to the unpublished monograph of Andrei Bakk (1888), based on a thorough research of the local Salt Office archives, the Saint Francisc mine was recorded as active in documents from 1765; however, salt extraction ceased relatively soon, as the mine was filled with water (Şerbănescu, 2006). The monograph specifies that the only mine which remained still active after 1867 was Saint Ignatius mine. The exploitation activities at Ocna Sibiului were stopped at the beginning of the 20th century (1931).

The salt massif was eroded by the right tributaries of the Visa stream, producing a microdepression with steep margins, subject to gully erosion and landslides (Balteş and Nistor, 1986). 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. The karstosaline lakes formed by the collapse of sinkholes have formed following the subsidence of the salt roof or the collapse of some caverns, generated by the processes of karstification of the surface of the salt massif by groundwater and infiltration (Pânzaru, 1982). Costea (2010, in Chintăoan *et al.*, 2019) specifies that only two lakes at Ocna Sibiului are karstosaline and the other 12 are anthroposaline. The lakes formed on the place of abandoned salt mines were the starting point for the development of the locality as an important balneo-climatic resort. The resort was officially inaugurated in 1845 (Şerbănescu, 2006).

Currently, the Bottomless Lake nature reserve is separated throug a wire fence from the other lakes, which are used for therapeutic purposes. The fence holds a pannel with the name of the reserve. Access of visitors is forbidden.

5. QUANTITATIVE ASSESSMENT OF SALT-RELATED GEOLOGICAL RESERVES

For geoconservation purposes, a quantitative assessment may help to distinguish between various geological reserves. From the methods proposed, the approach of Brilha (2016) was already applied to other geological reserves from Romania (Seghedi *et al.*, 2020). This type of assessment requires calculating four parameters: scientific value (SV), potential educational use (PEU), potential touristic use (PTU) and degradation risk (DR). Each of these parameters are calculated using 7 to 12 criteria (Brilha, 2016), some of them common in estimating distinct values, but assigned different weight. The three main values and the degradation risk calculated for the salt-related reserves are presented in Table 1.

The Turda salt marshes and Old Salt Mine nature reserve, a top tourist destination in Romania, shows the highest scientific, educational and touristic values (Table 1). The Turda salt was researched since the XVIIth century, when the first mineralogical data were published (Fichtel, 1780). Various aspects of the Turda salt (mineralogy, structure and tectonics, micropaleontology, mining history, archaeology, etc.) were investigated and are still studied. The educational potential is high (3.95), as the wealth of geological, archaeological and historical information can be capitalized upon. Current guided tours of the mine provide information about the history of mining, the technologies and equipment used. The high touristic value (4.2) is related to the top tourist facilities in the old mine catering for all tastes, as well as to location in a city with many cultural objectives, including the archaeological remains of a Roman castrum.

The Praid Salt Mountain reserve also scores high as scientific appeal (3.22) as well as its educational and touristic values (3.75 and 3.40 respectively). Praid salt was also studied since the XVIII-th century. In 1837, in his study of halophile flora around Praid, Fridrich Fronius also described the salt mine and technologies used, the salt springs and even the composition of salt used for cattle (Horváth, 1998). The nature reserve is also a good example of exploitation and capitalization of salt and salt waters.

The Slănic Salt Mountain still scores high in educational and touristic potential (3.45 for both), although the features which were meant to be protected in this nature monument are destroyed. This can be explained by location in a city with all the logistic facilities and the proximity of other natural and cultural objectives, including the Unirea salt mine (the largest in Europe) opened for tourism and treatment, and the mud and salt bath at Baia Baciului complex next to the reserve.

The Meledic Plateau is considered the most important salt geosite in the country for its exo- and endokarst features (Tîrlă, 2018). The special exokarst landforms like salt canyons, amphitheaters, dolines and uvalas and lakes can be easily seen and visited, only the salt caves are closed for visitors for reasons of visitor security and heritage protection. This reserve scores highest for its scientific value (3.22), but high enough for educational and tourist potential (2.9 and 2.95 respectively). Despite being an unusual and highly picturesque landscape, it has a lower score then Praid, because the access road to Meledic is an unpaved road and the reserve is located in the countryside, not in a town with all the logistic facilities.

Table 1. Main values calculated for the salt-related geological reserves

Geological reserve	Scientific value	Educational value	Touristic value	Degradation risk
Algheanu	1.80	2.5	2.0	1.55
Meledic	3.22	3.3	3.1	1.55
Sarea lui Buzău	2.30	3.15	2.95	1.50
Slănic	2.25	3.45	3.45	2.7
Ocna Sibiului	2.80	3.25	3.30	1.30
Praid	3.22	3.75	3.40	2.25
Sărățel	2.95	2.6	2.50	1.85
Turda	3.22	3.95	4.2	1.65

A new, 7 km long geotourist trail, entitled "Ups and downs in Salt", was recently proposed to highlight the geological, karst and biodiversity features of the salt massif, possible to cover by hiking, cycling or by car (Toma *et al.*, in print). The Meledic diapir can complete the story of salt tectonics which starts in the Geopark with Sarea lui Buzău, illustrating a phase of diapirism which the latter site can attain in the distant future.

The Ocna Sibiului Bottomless Lake also shows high educational and touristic potential, because it is situated in a well known tourist resort. Similar with the Slănic Salt Mountain, people visit this place mainly for health treatment, and the town has a range of other cultural objectives close to the reserve, which contribute to enhance the scores. However, Ocna Sibiului has an interesting story to tell, not only about the salt diapir, but also about the history of mining.

The Salt of Buzău scores high in educational and touristic potential, although the landscape of the site itself is a flat surface with white salt crusts, nothing like the Meledic Plateau or even a salt lake formed in the place which once was a salt mine. According to Popa *et al.* (2017), Sarea lui Buzău represents a non-attractor site, but with a compelling story to interpret. As a cryptic diapir yet unexposed, this reserve can be used to tell the combined story of salt tectonics and the traditional use of brines. The story of salt diapirism, a phenomenon first described in the Romanian Subcarpathians (Mrazec, 1907, 1927), is intended to be told in The Buzău Land Geopark within a set of new geotourist trails through natural and cultural heritage, and the Salt of Buzău is one of them (Toma *et al.*, in print).

Sărățel reserve scores higher for scientific appeal (2.95), as there is interest in its geological, geomorphological and archaeological heritage, as well as in the biodiversity and curative properties of the salty mud. The landscape, although flat, is very picturesque, as the reserve is situated on a meandering river with salt outcrops, salt crusts and halophile vegetation. The educational potential is related to both natural and cultural heritage: salt diapirism and the use of salt water wells which now are abandoned, and the organization of salt trade in ancient, Roman times. Locals are also visiting the reserve for bathing in salty mud, which they use to treat various health conditions. However, there are no facilities of any kind yet, and the real potential for tourism and education is wasted.

Algheanu reserve scores the lowest for scientific appeal (1.80), educational (2.55) and touristic potential (2.0). Despite the beauty of the landscape, a stream cutting a salt-rich hill, the site presents several drawbacks, like its location in the countryside with difficult access on unpaved roads, large distance from a city, and difficulty of the relief in the reserve. There are no scientific papers specifically dedicated to the area of the reserve, but more general. However, the reserve became interesting lately for etnoarchaeological studies (Alexianu *et al.*, 2015b).

Overall, the values of individual salt-related nature reserves in Romania are dominated by either their scientific interest (Turda, Praid, Meledic), educational potential (Turda, Praid, Slănic, Meledic, Ocna Sibiului and Sarea lui Buzău, all scoring over 3.00) and tourist potential (Turda, Slănic, Praid, Ocna Sibiului, Meledic, with Turda scoring 4.2 and the rest between 3.45-3.1). Sărățel and Algheanu reserves score the lowest educational and touristic values.

The degradation risk assessment indicates which reserve needs management measures before any other capitalization. The Slănic Prahova Salt Mountain shows highest values for degradation risk (2.7), followed by Praid (2.25). The rest of the geological reserves show values below 2.0, most of them between 1.3-1.55. As salt is an easily soluble rock, degradation of natural causes is much higher in areas where the salt is exposed in outcrops, or in areas prone to landslides. As already shown, the Slănic Salt Mountain was destroyed by natural causes, a combined action of dissolution, collapse and eventually landslides. The salt mountain was slightly dissolved for more than 50 years, showing only a diminished volume in 1985 compared to 1933, but the degradation accelerated once the three walls of the former salt exploitation collapsed in the 1990's. Then landslides contributed rapidly to the complete destruction of the Bride's Grotto and Lake over a short period of time (only six years, from 2005 to 2012). Thus the entire salt mountain was reduced to several salt exposures surrounded by clastic rocks of the landslides, which are now largely overgrown by vegetation. The Slănic Salt Mountain does not fulfill anymore the criteria for which it was declared a nature reserve. Even so, it is a good example of what reserves on soluble rocks may become if they are lacking a protective cover.

6. SALT-RELATED CULTURAL HERITAGE

A large number of remarkable salt-related archeological sites occur both in the East Carpathians (Cucuieți, Cacica, Oglinzi, Solca, Lunca-Poiana Slatinei, Țolici) (Weller *et al.*, 2007; Alexianu *et al.*, 2015b), as well as in the Transylvanian basin (Băile Figa, Caila, Coldău, Comăneşti, Ilişua, Jimbor, Mărtiniş, Săsarm, Valea Florilor) (Cavruc *et al*, 2006a, b). They are accompanied by brine wells and springs (Chintăuan and Rusu, 1988; Chintăuan, 2006; Alexianu *et al., 2008*; Chintăuan *et al.*, 2019) (Fig. 17), some protected by wooden or brick houses (Fig. 18), others in various stages of degradation. Archaeological research in areas with salt springs and fountains recovered various remains from the Neo-Eneolithic (6050-5050 BC) (Cavruc and Dumitroaia, 2006; Weller and Dumitroaia, 2005; Weller *et al.*, 2008a; Weller, 2015), Bronze Age (about 2500 – 800 BC) (Cavruc *et al.*, 2006a, b), the second Iron Age (400 – 200 BC)(Cavruc *et al.* 2006c), along with elements from post-Roman, medieval and premodern times (500 – 1800 AD) (Ciobanu, 2006; Cavruc and Harding, 2010; Simon, 2006). Wooden, stone and ceramic objects, necessary in the extraction, storage, manipulation and use of salt waters, were found in archaeological sites next to salt water springs, and represent evidence for the continuity in use of this traditional water supply.

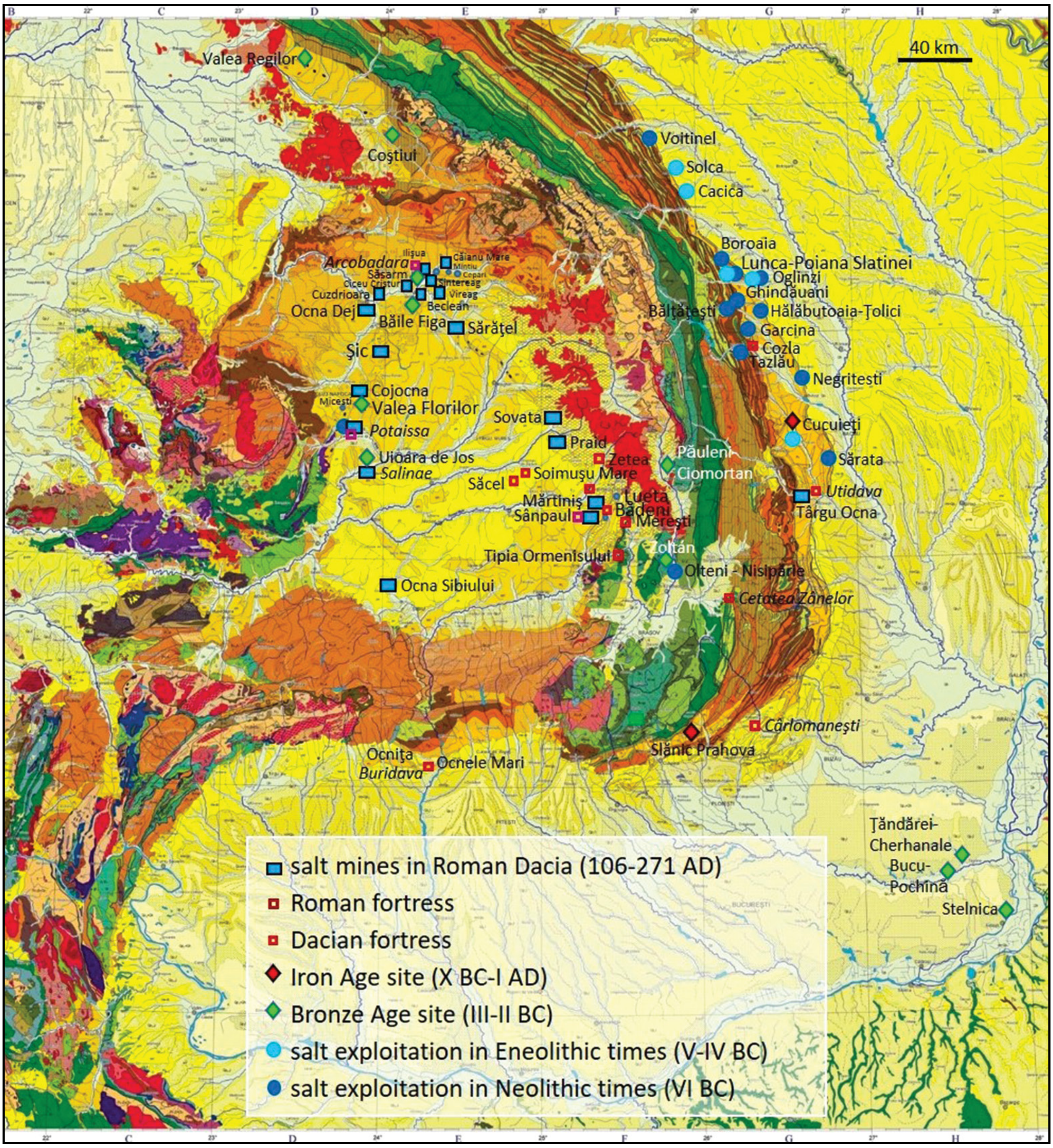

Fig. 17. Main archaeological sites (cultural heritage) shown on the Geological map of Romania scale 1:1,000,000 (Săndulescu *et al.*, 1978), compiled after Andronic *et al.* (2006); Cavruc *et al.* (2006 a, b, c); Drăgănescu (2006b); Alexianu *et al.* (2015).

Archaeological and epigraphic remains, as well as written sources from antiquity, indicate that the most important salt exploitations in Roman Dacia were at Potaissa (Turda), Salinae (Ocna Mureş), Ocna Dejului, Ocna Sibiului, Praid, Sovata, Sânpaul, Mărtiniş (Cavruc *et al.*, 2006c; Cavruc and Harding, 2010), where tools and technologies for salt extraction were also recovered. Currently, areas from three of them are protected as nature reserves of geological type.

Along with various stone objects, metal artefacts (tools, objects and coins) were also recovered during archaeological research. Wodden troughs and tools, dated as Middle-Late Bronze Age and Dacian Iron Age found at Băile Figa in NE Transylvania (Cavruc and Harding, 2010) give insight in ancient salt exploitation technologies. Three epigraphic monuments found in salt-rich areas of Dacia shed light on salt mine management and organization: a Roman votive altar (2nd century AD) found near Sărăţel (Chintăuan *et al.*, 2004); the votive altar from Micia (Veţel)(2nd-3rd centuries AD); the votive altar from Sânpaul (Mărtiniş village) (2nd-3rd centuries AD), found close to the Roman castrum (Cavruc *et al.*, 2006c).

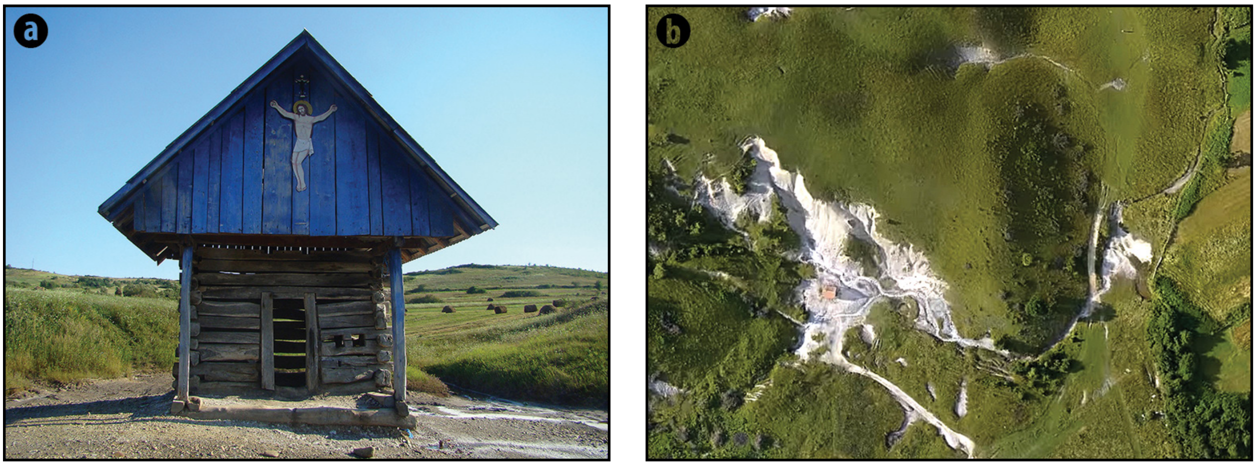

Fig. 18. Salt-water fountains protected by little houses, part of the ethnoarchaeological heritage in Transylvania. (**a**) wooden house protecting a salt water well in the Bronze age site at Mintiu, Nimigea commune; it is on the list of historical monuments of the Bistrița-Năsăud County. *Photo copyright Țetcu Mircea Rareș*, Wikimedia.org; (**b**) house with red tile roof over a salt water well in Orşova, Bistrița-Năsăud County. Note the salt stream, marked by white salt crusts precipitated on the thalveg. *Printscreen from SaltLand*, a video inviting to a virtual trip to salt-related cultural heritage of Transylvania, posted on the website of the National Museum of the East Carpathians in Sfântu Gheorghe.

Archaelogical and epigraphic remains, as well as accounts of ancient authors, indicate that Dacian and Roman fortresses, fortifications and camps were built in strategic locations close to salt resources, enabling to defend the salt exploitations and to control the salt roads, as salt from the Carpathian-Danubian space was used in the trade with Hellenistic states and Rome (Wollmann, 1996; Cavruc *et al.*, 2006b). Examples are: the Getian-Dacian fortresses at Bădeşti, Mereşti "Dâmbul Pipaşilor", Tipia Racoşului, Cârlomăneşti, Târgu-Ocna, Ocnele Mari (Cavruc *et al.*, 2006 b); the Potaissa Roman camp (Fig. 19), which defended the salt exploitations from Turda (Wollmann, 1996); or the Roman fortress of Arcobadara (at Ilişua) (Fodorean, 2010), close to the numerous salt occurrences west, north and north-east of Beclean.

Along the salt roads, salt was transported both on land and water (Marc, 2006). On water, it was transported by rafts and boats both westward, to Hungary (on rivers Mureş, Someş, Tisa and their tributaries), as well as southward, on Olt, towards the Danube (Bassa, 1970; Măluțan, 1984; Cavruc, 2010). About 16 vessels used to salt transportations were uncovered so far on Romanian territory. In Transylvania, 6 wooden boats (monoxyls) (up to 10-13 m long) buried in the river bed sediments of Crişul Alb (at Răpsig and Berindia), Someş (at Berindani, Odorheu commune) and Mureş (at Zădăreni, in the area of Lunca Mureşului Natural Park) (Godea, 2014; Mureşan, 2015) are hosted now in museums from Arad and Constanța (Fig. 20).

Among the salt-related archaeological sites, two sites with European value stand out: Lunca-Poiana Slatinei, the most important Neolithic site in the East Carpathians (Weller and Dumitroaia, 2005; Alexianu *et al.*, 2008, 2015a) and Băile Figa, the most important site in the Transylvanian basin (Cavruc *et al*, 2006a; Cavruc and Harding, 2010).

6.1. Lunca – Poiana Slatinei archaeological site

Next to some of the salt springs in Moldavian Subcarpathians, at Lunca and Hălăbutoaia (Fig. 17) (north-west and south of Târgu Neamț locality), the oldest evidence for salt production in the extra-Carpathian area was discovered (Weller *et al.*, 2008b, 2015; Danu *et al.*, 2010; Weller, 2015). The method used was the evaporation of brine in flat bottomed fired-clay vessels (briquetage) (Cavruc and Dumitroaia, 2006). The site is situated in the Vânători-Neamț Natural Park and was proposed to be included on the list of cultural sites with European value (Alexianu *et al.* 2015a).

The Lunca-Poiana Slatinei site is situated in Culmea Pleşului, where the salt lies in the hinge of the Pleşu anticline, which forms the most external scale of the Subcarpathian nappe along the Pericarpathian Fault. The anticline is formed by the Gura Şoimului Formation, dated on microfauna, calcareous nannoplankton and even ichnofauna as Lower Miocene, Aquitanian-Burdigalian (Ionesi and Gheța, 1978; Ionesi and Mészáros, 1995; Melinte-Dobrinescu and Brustur, 2008; Brustur and Briceag, 2018). Borehole data, distribution of salt springs and gravimetric investigation indicate that the salt forms a 130 m thick, 4 km long body, elongated NW from Târgu Neamț.

The archaeological site, dated on ^{14}C as Early Neolithic (between 6050-5500 BC), is the oldest salt exploitation known so far in Europe, and probably worldwide, according to Weller and Dumitroaia (2005), Weller *et al.* (2015) and Sordoillet *et al.* (2017). The Lunca site (Fig. 21) contains numerous lens-shaped layers of clay, ash and charcoal, forming a 3m-high mound of archaeological sedimentary accumulations. The earliest stratigraphic layers yielded painted ceramic fragments of the Starčevo-Criş culture, which indicate an Early Neolithic age, consistent with radiocarbon ages (Sordoillet *et al.*, 2017).

Fig. 19. Google Earth image showing the Potaissa Roman castrum in Turda. Archaeological work uncovered two gates (Porta Decumana and Porta Praetoria), the Praetorium, the Termae (associated with a basilica and palestra), a corner bastion and an angle tower. Although the fortress was built for the Legion V Macedonica, relocated to Potaissa from Troesmis (Scythia, North Dobrogea) in order to defend the borders of the Roman Empire, it was emplaced in a strategic location close to the salt mines to ensure protection of the mines and control the salt trade.

Fig. 20. A 10 m long wooden monoxyl found at Răpsig, in the riverbed of Crişul Alb, now hosted at the National Museum of Romanian Navy in Constanța. *Photo Antoneta Seghedi*.

Fig. 21. Lunca – Poiana Slatinei archaeological site. Note salt crusts formed around the brine well and along the stream bed. The tell is situated on the left side of the stream, hidden by the canopy of the trees. Slightly modified from the website of the Târgu Neamț Information and Tourism Promotion Centre.

The Lunca tell represents one of the most important archaeological sites in the eastern Subcarpathians, due to the superposition of several archaeological layers (Starčevo-Criş, Pre-Cucuteni, Cucuteni, Costişa-Komarovo, Noua, Corlăţeni, Canlia, etc.). According to the cited authors, the superimposed cultural remnants continue up to the Middle Ages, thus showing the constant interest of local communities for the most abundant salt water spring. It is also remarkable that traditional practices related to salt springs exploitation continue to be used in the area, to a large extent, up to the present time.

6.2. Băile Figa archaeological site

Situated 3 km south-east of Beclean, Bistrița-Năsăud County, this site is located on Pârâul Sărat, a salt water stream draining a small, funnel-shape depression, formed on top of a salt massif. The salt massif lies at depth of about 1.5 m and shows a thickness of 1600 m and an area of 1000/1000m (SaltLand). The salt waters and mud are used in a therapeutic complex nearby the site.

The Băile Figa site shows a large number of cavities and mounds of anthropic origin, located both in the river bed, and on its sides (Fig. 22). They represent evidence for salt exploitation at different times (Cavruc and Harding, in Andronic *et al.*, 2006). Here, locals were extracting salt even in the 1970th. In the river bed, there are numerous elements belonging to wooden frameworks and structures, unevenly distributed along the stream and its two tributaries.

Archeological research in the last two decades contributed to the understanding of prehistoric technologies used in salt exploitation. Based on radiocarbon dating, the site shows three main phases of superimposed activity (Middle-Late Bronze Age, Dacian Iron Age, and early medieval). As remains of all these periods were found at the same depth, they indicate the continuity of exploitation of the same parts of the site over several centuries (Cavruc and Harding, 2010; Harding and Kavruk, 2010). According to the cited authors, two types of technologies were used at Băile Figa: in the Middle Bronze Age (1600-850 BC), a system of wooden throughs with holes was suspended above the salt rock, to create holes in it so it could be easily broken (Fig. 23); in the second Iron age (400 BC), salt extraction resumed using a new technology, based on mining, with wooden shafts descending into rectangular galleries dug in the salt bedrock situated at 4 m depth.

Fig. 22. Drone image of Băile Figa archaeological site, located on Pârâul Sărat. Note the excavations in the river bed, as well as the cavities and mounds on the right, resulted from salt exploitation in time. *Printscreen from SaltLand*.

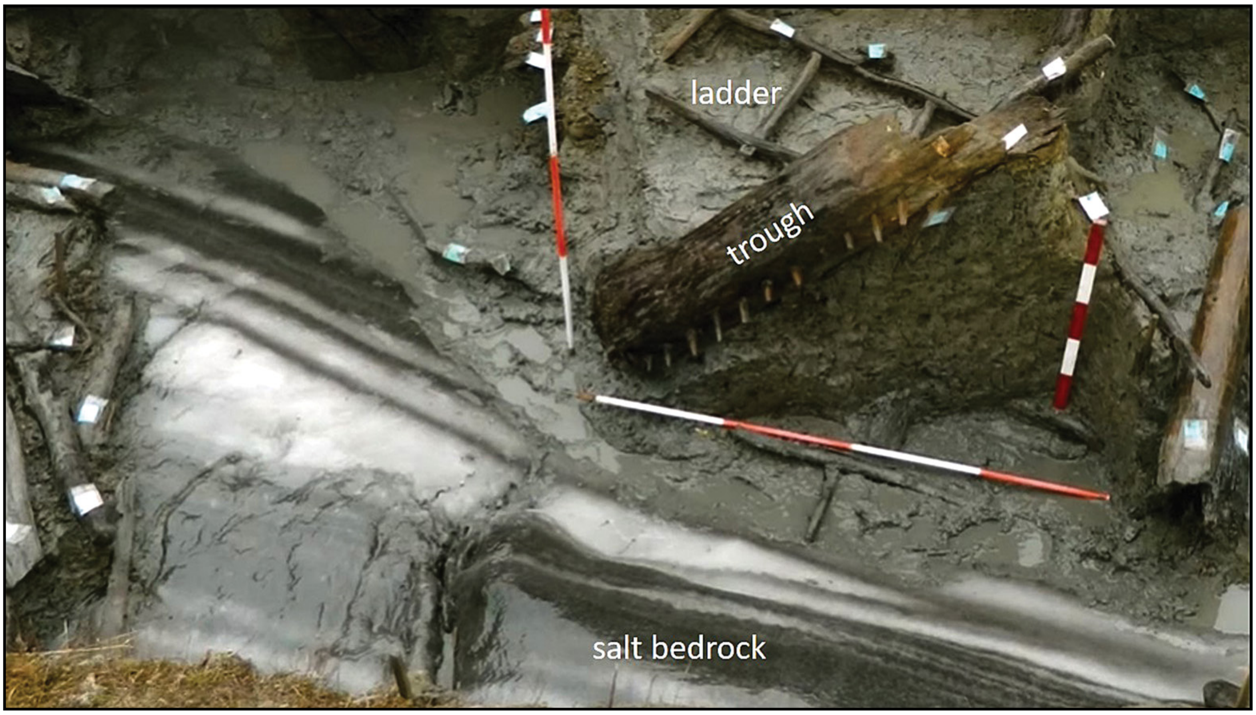

Fig. 23. Băile Figa archaeological site, showing the salt bedrock and wooden artefacts found in the salty mud: a perforated trough with nozzles, a ladder and other wooden parts. *Printscreen from SaltLand*.

These technologies are illustrated in the film "Saltland", posted on the website of the National Museum of the East Carpathians. The list of wooden artefacts found at Figa (dated on dendrochronology and radiocarbon), includes mostly unique and extremely rare finds, like troughs and their nozzles, „hooks", pounders, „stretchers", a spiral log ladder, an incomplete ladder, socketed axe, adze handles, along with props, wedges, bowls and small troughs, all well preserved in salty mud (Harding and Kavruk, 2010; Harding, 2013). Therefore, they represent exceptional evidence of a wide range of tools and procedures used for prehistoric salt production.

7. FINAL REMARKS

Salt, a rock indispensable for mankind, played a great role in shaping history, communities and traditions, while salt extraction by humans greatly changed the landscape. In the Carpathian-Danubian space, former salt mines and lakes formed through collapse of salt mines are now nature reserves.

The salt-related geological reserves presented here reflect various features related to salt tectonics, exposure, erosion and dissolution, as well as to the role of humans in shaping the landscape in salt-rich areas. From the cryptodiapir at Sarea lui Buzău, Sărățel and Slănic Prahova, to the exposed diapirs at Meledic, Praid and Algheanu, these reserves show the formation and various stages of erosion of salt outcrops, going to the extreme situation of destruction of an entire salt mountain. The cause of destruction can be a natural phenomenon, like dissolution and landslides, as is the case of Slănic Prahova nature monument. But human activity can also be a cause of destruction, or at least of pollution, as is the case of Sărățel reserve. Reserves like Turda and Ocna Sibiului, where salt lakes replaced the ancient and medieval salt mines, are good examples of landscape changes triggered by human activity. They also illustrate the numerous uses of salt for human life, health and well being. The cultural significance of reserves in salt mining areas is related to preservation of various objects with archaeological and historical significance, but also to the immaterial heritage.

A brief review of the salt-related archaeological heritage reveals the significance of salt springs and brine wells, some of them catalogued as ethnographic monuments. Traces of the oldest salt exploitation in Europe were found in the East Carpathians, where 15 salt springs, recently proposed to be part of the European cultural heritage, preserve archaeological evidence for salt exploitation as brine, using the technique of briquetage. The best studied is the early Neolithic Lunca-Poiana Slatinei site.

One of the richest salt-bearing areas in the world, Transylvania shows an exceptional saltscape, where natural and cultural values intermingle. Recent archaeological research resulted in the discovery of sites unique in Eastern Europe, where salt was exploited since the Bronze Age. Băile Figa is the best investigated site where prehistoric records of salt exploitation were identified. The salty mud enabled preservation of hundreds of wooden constructions, installations and tools, reliably dated by modern techniques. They attest salt exploitation at industrial scale since the Bronze Age using a system of wooden troughs. Due to their age, degree of preservation, uniqueness and rarity, they can be classified as historical monuments of European importance.

Most objects related to salt extraction are hosted in museums, and some parts of former mining areas with a relevant cultural heritage became nature reserves (Turda, Ocna Sibiului, Praid, Sărățel, Slănic Prahova). To various ceramic, stone and wooden artefacts found next to the salt deposits or salt exploitations, fortified prehistoric fortresses with role in salt trade control were built on navigable rivers or close to major terrestrial communication routes. Such archaeological sites can also be included in the cultural heritage related to salt, as well as a wealth of immaterial heritage.

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