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# Mining-induced land use and landscape changes in Roşia Montană metallogenetic field during the last 90 years

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**Abstract.** The paper analyses the changes in landscape induced by the occurrence of mining wastes structures and exploitation voids, as a result of the mining activities in the last 90 years in Rosia Montana metallogenetic field. This is performed by comparing the land use distribution in the investigated area in the years 1913 and 2006. The impact of mining on landscape reflects itself in the large areas no longer used as agricultural or forestry lands and in the visual footprint. The results of the comparison show that the practice of surface mining after the year 1971 has increased the scale and amplitude of landscape changes along the time. The landscape changes are significant and should be carefully analyzed when considering the post-mining planning.
**Key Words:** Mining landscape, land use, Roşia Montană, metallogenetic field.

**Résumé.** L'article propose une analyse des modifications du paysage et de l'utilisation du terrain provoquées par l'occurrence des dépôts de déchets miniers et des vides d'exploitation, résultants des activités minières déployées les dernières 90 années dans le site métalogenique de Roşia Montana. On l'avait accompli par une analyse comparative de la distribution des différentes catégories spécifiques à l'utilisation du terrain pendant les années 1913 et 2006. L'impact des activités minières sur le paysage est visiblement réfléchi par les surfaces du terrain exclues de l'agriculture et de forêts, l'impact visuel ayant lui-même la même importance. Les résultats montrent le fait que les pratiques minières de surface issues après l'année 1971 ont augmenté l'ampleur et l'envergure des modifications du paysage le long du temps. Ces changements sont très importants et ils doivent être analysées très attentivement si on envisage l'aménagement post-minier du territoire.
**Mots clés:** paysage minier, l'aménagement du territoire, Roşia Montană, site métalogenique.

**Rezumat.** Lucrarea analizează modificările la nivelul modului de utilizare a terenului şi la nivelul peisajului induse de apariţia structurilor de depozitare a deşeurilor miniere şi a carierelor de exploatare în urma activităţilor miniere desfăşurate în ultimii 90 ani în câmpul metalogenetic Roşia Montană. Aceasta se realizează prin compararea distribuţiei categoriilor de folosinţă a terenului din anii 1913 şi 2006. Impactul mineritului asupra peisajului se reflectă în suprafeţele scoase din circuitul agricol şi forestier şi în amprenta vizuală. Rezultatele comparaţiei indică faptul că practicile de exploatare la suprafaţă aplicate după 1971 au sporit scara şi amplitudinea schimbărilor la nivelul peisajului de-a lungul timpului. Modificările modului de utilizare a terenului şi ale componentei peisagistice sunt deosebit de importante şi trebuie atent analizate atunci când se face planificarea teritorială post-minerit.
**Cuvinte cheie:** Peisaj minier, utilizarea terenurilor, Roşia Montană, câmp metalogenetic.

**Introduction**. Landscape bears the marks of the antropic activities and provides detailed information on the antropization degree of a region. The landscape features reflect human priorities, choices and interventions of the past, just like actual interventions will be reflected in the landscape of the future (Bockemuhl 1992; van Mansvelt & van der Lubbe 1999).

Mining induced landscape is a very distinctive one, introducing new features such as: tailings dams, waste heaps and open pits. These landscape features specific to mining activities have been included into four types of topographic features (Francaviglia 2004):

1) Primary extractive features (pits, shafts, slopes);
2) Secondary mining features (waste dumps and overburden piles);

3) Tertiary mining features (tailings dams);
4) Quaternary mining features (slag piles resulting from the smelting facilities).

All these introduce highly disruptive visual elements into the natural landscape of an area, creating a specific environment.

Roşia Montană is a metallogenetic field in the Metalliferous Mountains, the most complex mountainous unit of the Apuseni Mountains, central-western part of Romania. The Roşia Montană metallogenetic field is part of the Roşia Montană - Bucium district, and corresponds to the metallogenesis associated to late subsequent magmatism (Neogene). The structural - evolutionary complications of the Romanian Carpathians have created favourable conditions to the genesis of precious metals, thus making the Roşia Montană deposit the most significant hotbed of gold concentrations in our country and in Europe (Vlad 2005).

The surface of the investigated area is 21.45 square kilometres and it lies between 23°02'52'' –23°08'33'' longitudes and 46°18'57''–46°17'24'' latitudes. It partially overlaps Roşia Valley drainage basin and its confluence with the Abrud River. Figure 1 presents the location of the investigated area within the administrative territory of the Roşia Montană commune.

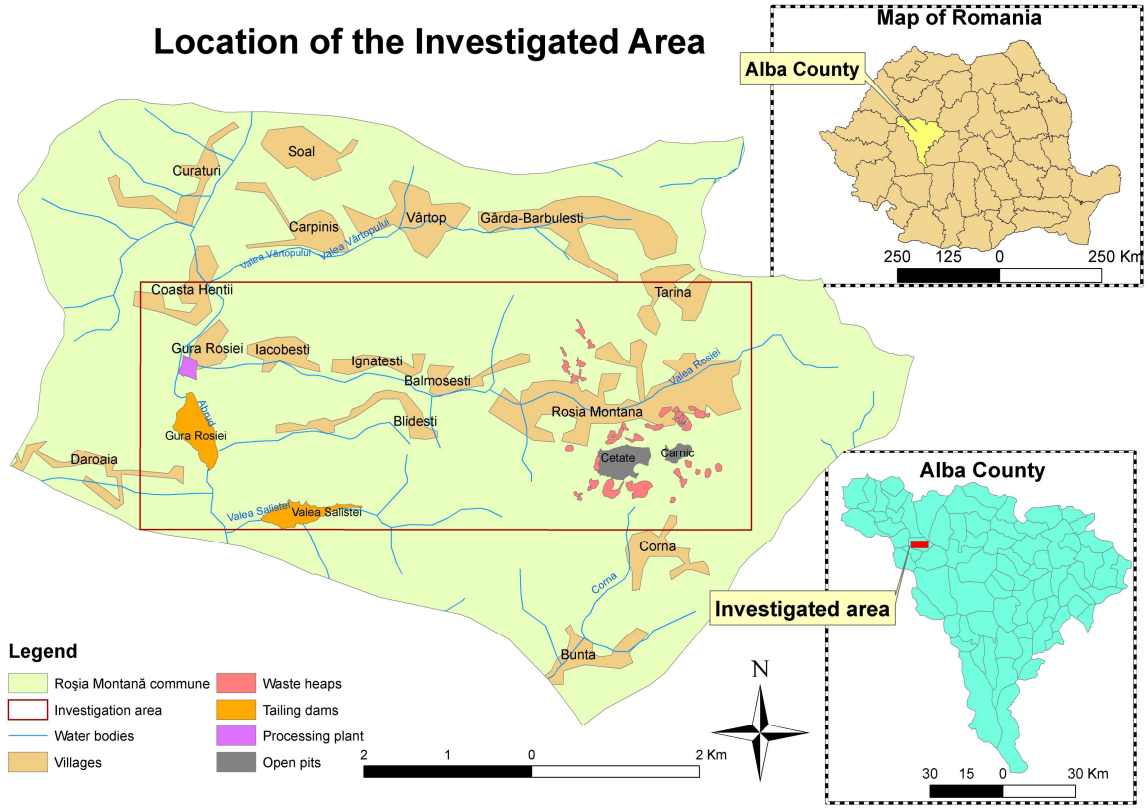


Figure 1. The location of the mining objectives within the investigated area

This perimeter was chosen to include all the mining objectives of the MinVest mining company – RoşiaMin branch, whose activity was ceased in 2006. The same investigated area was overlapped with an older map, dating back from 1913.

The objectives covered by the perimeter are:

- the two tailings dams: Gura Roşiei and Valea Sălişte,
- Gura Roşiei processing plant unit,
- Cetate and Cârnic open pits,
- the waste heaps.

The history of the region is inseparable from mining, which dates back since Roman times and left its imprint both on the landscape and on the region's development.

During the period considered in this study, the landscape associated with mining has evolved at an increasingly rapid pace and on larger scale, manifesting a series of changes. These changes have resulted in loss of biodiversity, loss of agricultural lands, and land degradation, creating threats to environmental security as relative stability of earth's natural ecosystems against human activity (Nurlu et al 2008).

**Material and Method**. The materials used in this study consisted mainly in standard topographic maps and recent orthophotographs. The analysis was performed by means of ArcGis 9.1 software. The topographic materials used was composed of 1:25,000 scaled maps, Military Topographic Division, 1913 edition, scanned and georeferenced into the STEREO 1970 coordinates system and then transposed by digital format. For the present situation an orthophotograph from 2006 was used. One should take into account that digitization has certain limitations and conditions which might lead to either the incomplete or incorrect production of their digital replicas (Tsioukas & Daniil 2009).

The Spatial Analyst extension was used to create the digital elevation models of the area and the slope maps for the two periods taken into consideration: 1913 and 2006. Land use maps were elaborated and compared.

GIS maps are a very useful tool in identifying the changes in how land surfaces have been occupied along the time. This also provides an overall image of the impact that mining has had on the landscape component since 1913. Furthermore, the prediction of future land-use changes can form input for GIS-based impact assessment, which is a very important input of decision-making process.

**Results and Discussion**. From the analysis of the two land use maps and the resulting calculated areas, the following results could be emphasized:

- 1.19 $km^2$ of the investigated area were removed from the agricultural and forestry use, for the location of the waste heaps, tailings dams and open pit;
- the perimeter occupied by forests has decreased from 42.84 % in 1913 to 31.09 % in 2006 of the total investigated area;
- 8.34 % of the total investigated area is covered nowadays by mining-related terrains (mining fabric: industrial sites, waste heaps, tailings dams, mineral extraction sites, damaged adjacent areas) as compared to only 0.37 % 90 years ago. This is mainly the result of the open-cast mining practices, which take up large surfaces of land.

In 2006, due to the format of the cartographic support which was used as basis for the land use map, the fruit trees plantations were included in the rural fabric. Also, the light-felling surfaces were not represented in 2006, as the orto-rectified imagery photograph did not allow us to identify such land use categories.

The land use changes occurred from 1913 until nowadays are numerically presented in Table 1 and graphically in Figure 2.

The maps elaborated for the land use categories in 1913 and 2006 are presented in Figures 3 and 4.

**Present landscape features induced by mining in Roşia Montană metallogenetic field.** Since Roman times, Roşia Montană (Alburnus Maior) has been an El Dorado of the territory defined by the Carpathians, the Danube and the Black Sea. One can notice along the time the characteristic phenomenon of merging between the history of the village and the history of the basic productive sector, which imprinted the economic peculiarity.

The impact on the landscape component has become major with the practice of open-cast mining. The large open pit in the Cetate hill started in the year 1971. As production increased, the scale of the pit and especially the waste deposits increased too, as did their cumulative impact. 120 m were cut off from the top of the Cetate hill, which was 1,040 m initially. Nowadays the exploitation elevation of the open pit is 873 m and the upper diameter of the pit is approximately 400 m (see Figure 5).

Table 1

Results of the land use comparison between the 1913 and present situation

| Land cover classes | Surface 1913 ($km^2$) | Surface 2006 ($km^2$) |
|---|---|---|
| Water surfaces | 0.23 | 0.09 |
| Fruit trees plantations | 1.63 | 0 |
| Forest light-felling | 2.62 | 0 |
| Coniferous forests | 1.1 | 0.68 |
| Broad-leaved forests | 4.5 | 5.99 |
| Grasslands | 8.22 | 10.21 |
| Transport network | 0.29 | 0.21 |
| Shrubs and herbaceous vegetation | 0.54 | 0.51 |
| Industrial sites | 0.04 | 0.07 |
| Rural fabric | 2.24 | 1.9 |
| Waste heaps | 0.04 | 0.48 |
| Tailings dams | 0 | 0.42 |
| Mineral extraction sites | 0 | 0.29 |
| Archaeological discharge areas | 0 | 0.07 |
| Damaged adjacent areas | 0 | 0.53 |
| Total | 21.45 | 21.45 |

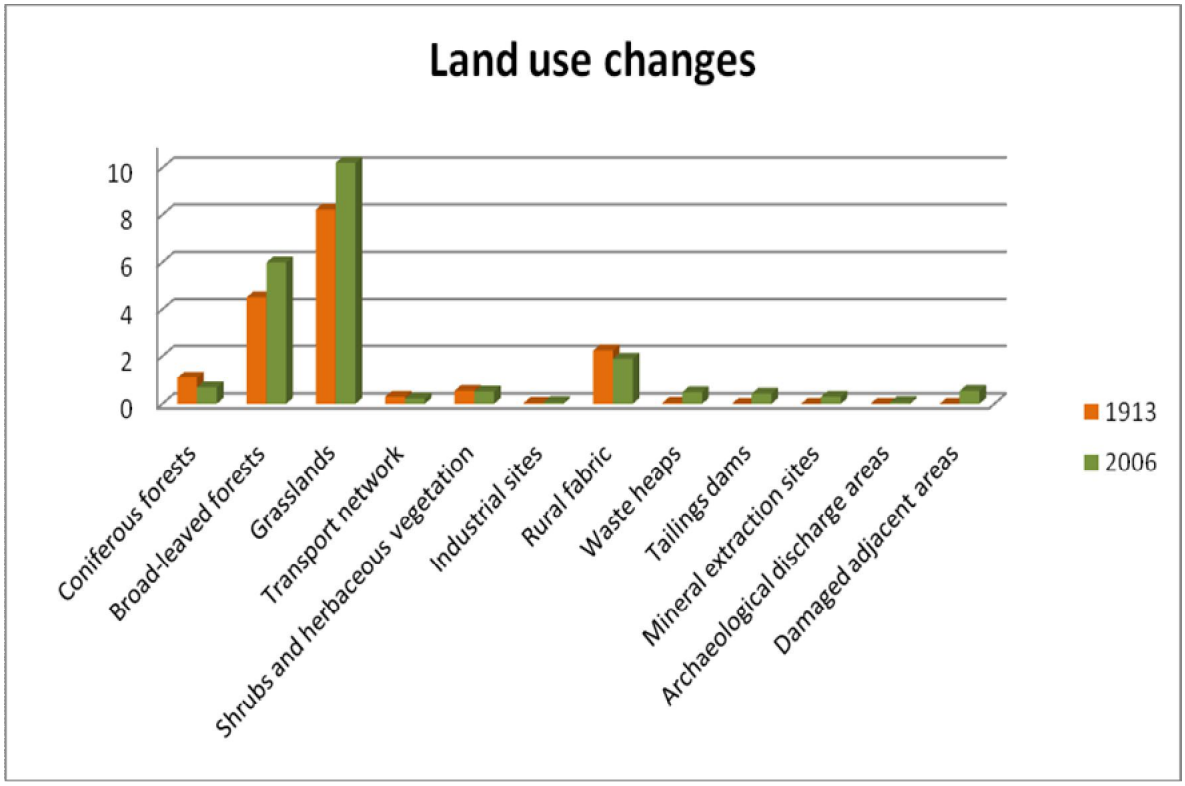


Figure 2. Land use changes in the investigated area

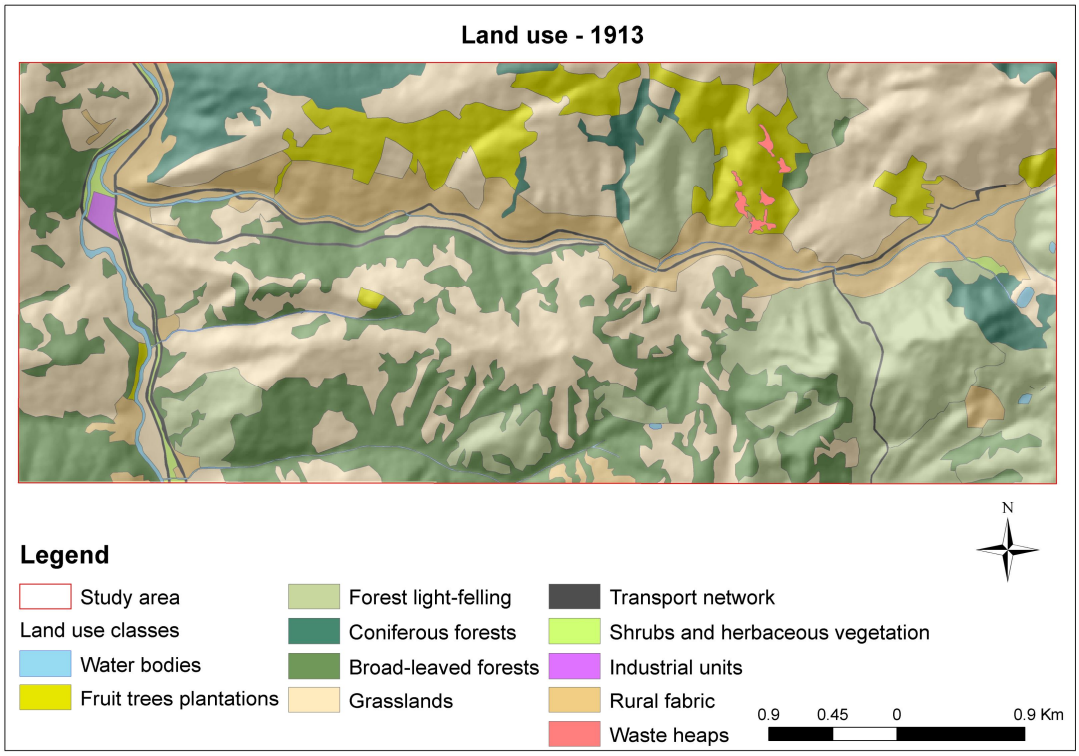


Figure 3. Land use map – year 1913

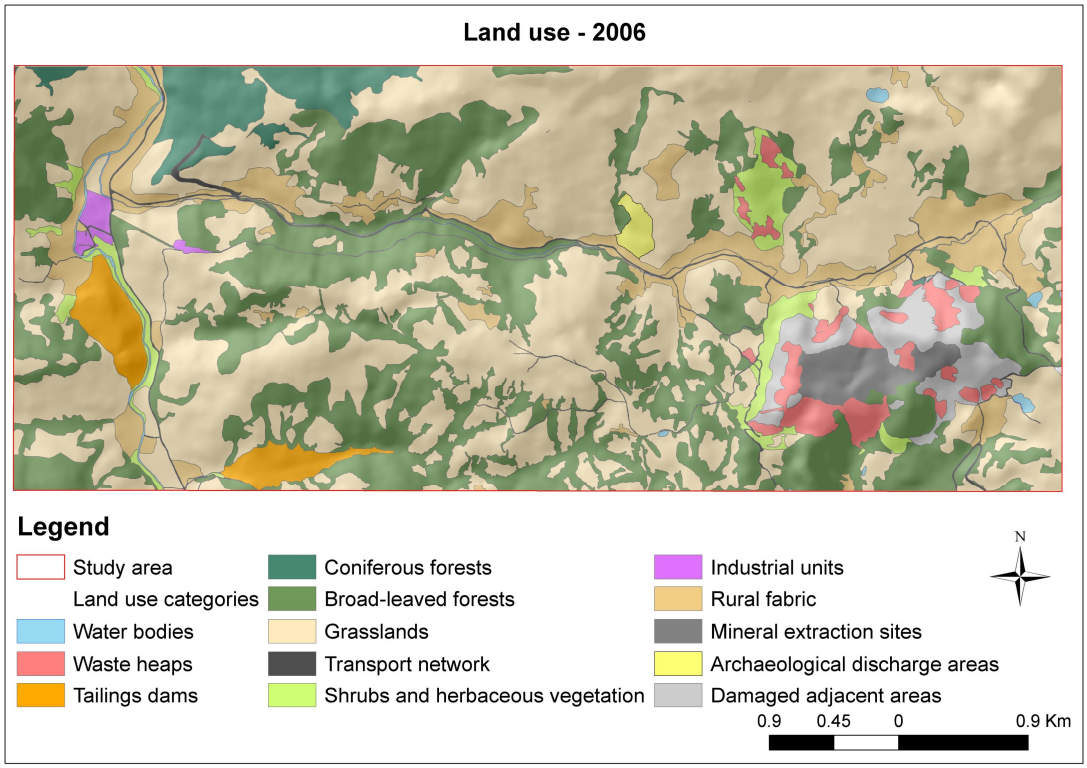


Figure 4. Land use map – year 2006

Figure 5. Cetate pit in 2004 (left) and nowadays (right) (Photo: Lucrina Ştefănescu, October 2004 and August 2009)

In 2001, another open pit was opened in Cârnic hill, but the exploitation lasted only 3 years. Together, the two open pits occupy 0.25 $km^2$. In the land use map of 2006, we included in this area the surface occupied by the open pit auxiliary buildings and yard, thus achieving a surface of 0.29 $km^2$. The antropic modeling of the landscape due to mining activities has disturbed the existing balance between various levels of landscape forms, inducing geomorphologic risks to the surrounding areas (Muntean et al 1998).

Beside the macro-level impact upon landscape, more unpleasant elements are added by the dense exploitation roads network around the exploitation area and the abandoned office buildings within the open pit perimeter.

The two tailings dams represent sources of landscape degradation both by the fact that they occupy vast areas of land and by their selenic aspect, characterized by the lack of vegetation. This leads to serious wind erosion, particles from the tailings dams are airborne at site-specific average speed velocities of 1.4 – 4.1 m/s and lack of vegetation cover.

The tailing dam from Gura Roşiei was set to work in 1974 and was used until 1986, when the new tailing dam Valea Sălişte was open. The later was built between 1980 and 1986 (see Figure 6). The two tailings dams store together 9 $m^3$ of tailings (Mermezan 2004).

Figure 6. Tailings dams: Gura Roşiei (left) and Valea Sălişte (right) (Photo: Lucrina Ştefănescu, August 2009)

Gura Roşiei processing plant is located at the junction of Roşia and Abrud rivers, occupying 40 $m^2$. It was built in 1852 and was continuously improved in order to recover the precious metals through the amalgamation process. Nowadays, the structures and facilities within the plant are abandoned, leading to unfavorable conditions for all the environmental media (see Figure 7).

Figure 7. The abandoned site of the Gura Roşiei processing plant (Photo: Lucrina Ştefănescu, June 2009)

In 1913 there were the waste heaps in the Orlea massif (dating back since 131 A.D.), as well as the Aurora (1850) and the 23 August (1750) waste heaps. All the other waste heaps were built later, after the year 1962.

Some of the oldest waste heaps are completely covered with natural vegetation and they integrate perfectly into the landscape, as it is almost impossible to identify them. Such examples might be the Orlea waste heaps and Iuliana waste heap (see Figure 8).


Figure 8. Iuliana waste heap (left), *Calluna vulgaris* vegetation in Orlea waste heaps (right) (Photo: Lucrina Ştefănescu, June 2009)

**The post-mining landscape of the area.** For the spatial planning of the post-mining landscape, one should take into consideration the forests and the open areas. The later include the areas intended for agricultural and intensive grazing uses, as well as the water bodies and lakes (the so-called "tăuri"). The economic and ecologic requirements should be integrated whenever possible. The post-mining landscape is subject to development dynamics resulting from a sort of compromise between the natural development potential and the antropic impact. The post-mining landscape may be developed as a variety of results in the context of the site specific factors. The future landscape will be greatly influenced by the economic dimension, which manifests itself as a mosaic of functionally differentiated areas within a territory. Moreover, the degree of correspondence between the geo-ecological and the economic functions of the landscape is a consequence of the cultural and social development of the local community, their

level of knowledge on the environment, and their technological and organizational skills (Petch & Kolejka 1993).

As the surface mining has a much greater effect at the visual level, it is important to act by the immediate revegetation of the area. This would lead to the creation of a natural protection area around the Cetate open pit, absolutely essential in the efficient and rapid repopulation of the post-mining landscape (Häge et al 1996).

A significant aspect regarding the impact on landscape is represented by the maintenance of the land use and spatial planning continuity. This is to say that the post-mining landscape should not eliminate the marks of past activities. The purpose of such approach is to ensure the landscape quality as an expression of time and of the various periods of cultural history. The speed and size of landscape changes should not exceed people's mental capacity of understanding. If landscape changes occur at a very rapid pace and in an abrupt manner, these might alter the specific features and might have disturbing effects upon the population.

At the same time, by understanding and considering sustainability issues, areas not presently valued or recognized as valuable might be saved from further landscape damage (Roe 2007). As landscape is seen to be the product of economic activity over long periods of time and considering the long mining history of the Roşia Montană perimeter, the post-mining landscape cannot and should not eliminate completely the specific mining elements. This would inevitably lead to the loss of place identity. The basic idea is to create a self-sustaining post-mining landscape, which is achievable by careful planning and decision making.

**Conclusions**. The waste heaps and the tailings dams, although they cover only 4.19% of the investigated area, have the greatest impact on landscape. These grounds are often characterized by lack of cohesion, as they are affected by mass displacement processes (landslides), as well as surface and deep erosion. Disposed on the slopes of the valleys, these have contributed to the changing of slope morphology and riverbeds of the Roşia Montană and Valea Săliştei rivulets. Of the 17 waste heaps, in 2006 only two were operational (Hop and Valea Verde), as the others were under preservation, stable and partially covered with spontaneous vegetation. The visual aspect is negatively impacted by the presence of these antropic structures, lack of vegetation and unaesthetic prooves of erosion processes.

All these mining-related structures characterized by large spatial display, render the landscape a highly antropic character. The impact upon the landscape was greatly amplified during the last 90 years.

In conclusion, the impact of mining activities on landscape in the investigated area is one of great amplitude, externalized in open pits, large waste deposits, immense tailings management facilities, abandoned industrial facilities and structures. All these landscape elements should be carefully considered within the future land use planning and decision-making process.

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