NATURAL CAPITAL RECOVERY IN THE FORMER URANIFEROUS MINING AREA SITUATED IN THE ROMANIAN CARPATHIANS. CASE STUDY: THE NATURAL PARK OF GRADISTEA DE MUNTE – CIOCLOVINA

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Abstract. The objective of the present study case is to demonstrate that the geographical landscape affected by the uraniferous mining activities can be recovered in the benefit of the touristic activity, of the biodiversity conservation, as well as historical and cultural patrimony preservation. In order to re-organize the post-mining geographical space by enhancing the balance between economic activities and environmental protection a solution with positive long-term effects is suggested and discussed in the paper.

Key words: Natural capital recovery, Uraniferous mining arera, Natural Park of Gradistea de Munte-Cioclovina. Romanian Carpathians.

INTRODUCTION

The investigation is focused on the mining area of Gradistea de Munte situated in the Sureanu Mountain which belongs to the central part of the Southern Carpathian Mountains. This area includes Gradistea de Munte and Costesti villages both placed in the district of Hunedoara. Nowadays, this territory represents an important part of Gradistea de Munte – Cioclovina Natural Park (GMCNP) established in 2003.

Despite the archaeological, anthropological, ethnographical, geological, speleological, flora and fauna complexities, all attractions which are harmoniously divided into exceptional landscape, the consequences of mining activities that were developed in two stages between 1958 and 1988 can be felt. These mining activities investigated a rare earth mineralization with noticeable thorium content ±uranium. The map of the region illustrates the existence of 14 galleries and 4 waste rock dumps derived from mining processes. The mining wastes are disposed into a perimeter of 8 - 9 km^2 and they have a total approximate volume of 120,000 m^3.

The environmental problems are visible in the proximity of the mine galleries where the natural landscape and runoff water are affected; the sterile rocks contain different types of low radioactive rare earth minerals with thorium and uranium. Because of this radioactive potential, the local population and potential investors in tourism are afraid and distrustful of the future development of the area. The further recovery of natural capital depends on the environment quality and for this reason an assessment of the environmental impact in this abandoned mine site and its surrounding areas is required. The purpose of this study is to initiate a suitable environment restoration program to allow for the returning of the land use to the same status which existed prior to mining.

STUDY AREA LOCATION

The mine perimeter is situated in a mountainous area that is crossed over from South to North by the Gradistea

River which drains the affluents of the Northern slopes that form the Sureanu Mountain. The altitude reaches over 2,000 m in the mountain peaks and it gradually descends while approaching the Mures River valley, the slope heights in the studied area ranging between 700m and 1,279m.

The surface runoff waters are gathered by Gradistea River, which is an affluent of the Mures River; the rivers meet near Orastie town.

The mountain slopes are covered with deciduous forests and, rarely, coniferous trees. The main road starts from Orastie and goes across Ludesti, Orastioara, Costesti and Gradistea de Munte villages, along the Valley of Gradistea River.

The local inhabitants get their income from forest exploitation and animal farming.

GEOLOGICAL SETTING AND MINERALIZATION

The Sureanu Mountain Massif belongs to a metamorphic unit known as the Getic Nappe, Upper Proterozoic Sebes–Lotru Series which comprises of mesometamorphic rocks, such as: mica-schists, gneisses, quartzite-schists, amphyblites, paragneisses affected by migmatized processes.

The metamorphic rocks are divided into four petrographical assamblages according to the dominant rock types, forming a large synclinorim structure. The tectonic evolution generated a major system of NE-SW regional faults, which are also affected by a number of cross local faults striking from NW to SE and from NE to SW. The regional faults have enhanced the penetration of magmatic rocks and the development of hydro-metasomatic processes.

The main mineralization is associated with quarzo-feldspar migmatized gneiss lenses and it consists in yttrium and cerium rare earth associated with thorium and uranium oxides and silicates. The radioactive minerals have a high content of Th and U and they disseminate into the host rock without forming important accumulations. The following useful minerals were identified: monazite, orthite, uranothorianite, thorite, xenotime, zircon, apatite, rutile, sphene, rare earth with niobium, yttrium and tantalum as well as thorium ± U,Ca,Fe,Ti.; small quantities of cassiterite, magnetite, hematite, pyrite,chalcopyrite, galene and ilmenite were also identified.

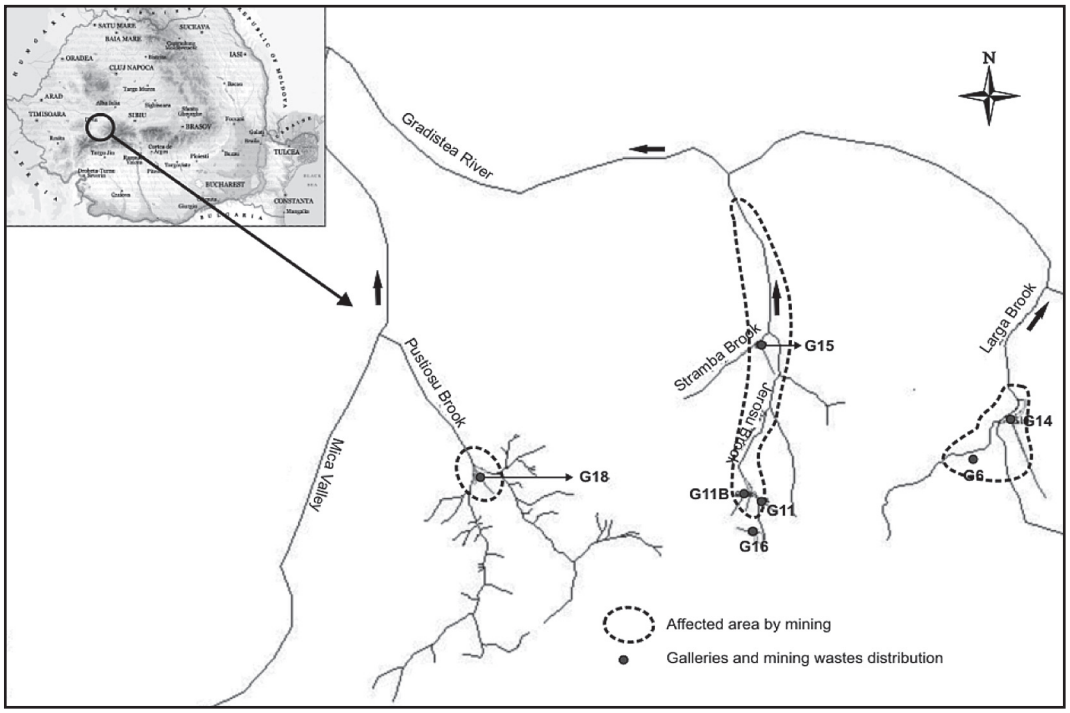

Fig.1. Study area location and hydrographical basin investigated

SITE ASSESSMENT PROCEDURES

In order to observe the impact of mining sources on pollution and to assess the ecological risk and the danger for human health, two procedures were adopted:

- observe and document physical factors (contamination, erosion, instability etc)
- discuss with the community the quality of life, as influenced by radioactivity.

The identified mine galleries and waste rock dumps derived from mining processes are located on the abrupt slopes of the left affluents of Gradistea River named, from East to West, as follows: Larga, Jerosu and Pustiosu brooks (Fig.1); the very old

mine galleries are now collapsing and are difficult to identify. The waste rock dumps and mining water represent the main potential pollution sources and they have not only a physical impact on the environment, but a psychological one on the natives, which associate the incidence of cancer diseases in their communities with the presence of low radioactive waste rocks. In this context it is important to point out that a lot of gneissic lenses outcrop have a natural radioactivity that exceeds the external gamma irradiation level of waste rock dumps.

To describe the mining waste rocks, water, soils and sediments in the northern part of G.M.C.N.P., old mine reports and bibliographical information were reviewed and two field-work campaigns were carried out in order to gather laboratory samples and to run external gamma irradiation measurements.

RESULTS

Characteristics of waste rock dumps

The waste rock dumps impact consists of a lot of disturbance types, but the present study is focused on the radioactive and heavy metals content which could generate surface water contamination due to waste rock dumps drainage and human irradiation. The results of laboratory analysis are presented in Table 1.

The external gamma irradiation measurements were done in a grid that covers the horizontal surface of the dump. The sections exceeding the acceptance level (0.30μSv/h) were outlined as it can be seen in Fig. 2.

Table 1 Chemical composition of mining waste (maximum values)

Petrografical/mineralogical content	Element %by weight	Larga Brook	Jerosu Brook	Pustiosu Brook
Micaschists, amphybolites, quartzite-schists, migmatized rock , gneisses containing rare earth with Th ± U, magnetite, galene, pyrite, chalcopyrite	U_{nat}	0,0133	0.0197	0.015
	Th	0.043	0.047	0.035
	Ra^{226}*	2.12	2.76	1.98
	Zn	0.0189	0.016	0.014
	Ni	0.0019	0.0015	0.0018
	Cr	0.004	0.0063	0.0065
	V	0.0093	0.0038	0.0031
	Co	0.0006	0.0019	0.0015
	Pb	0.150	0.006	0.0026
	Cu	0.007	0.005	0.005
	Cd	0.0001	0.075	0.0001

* Specific activity (Bq/g)

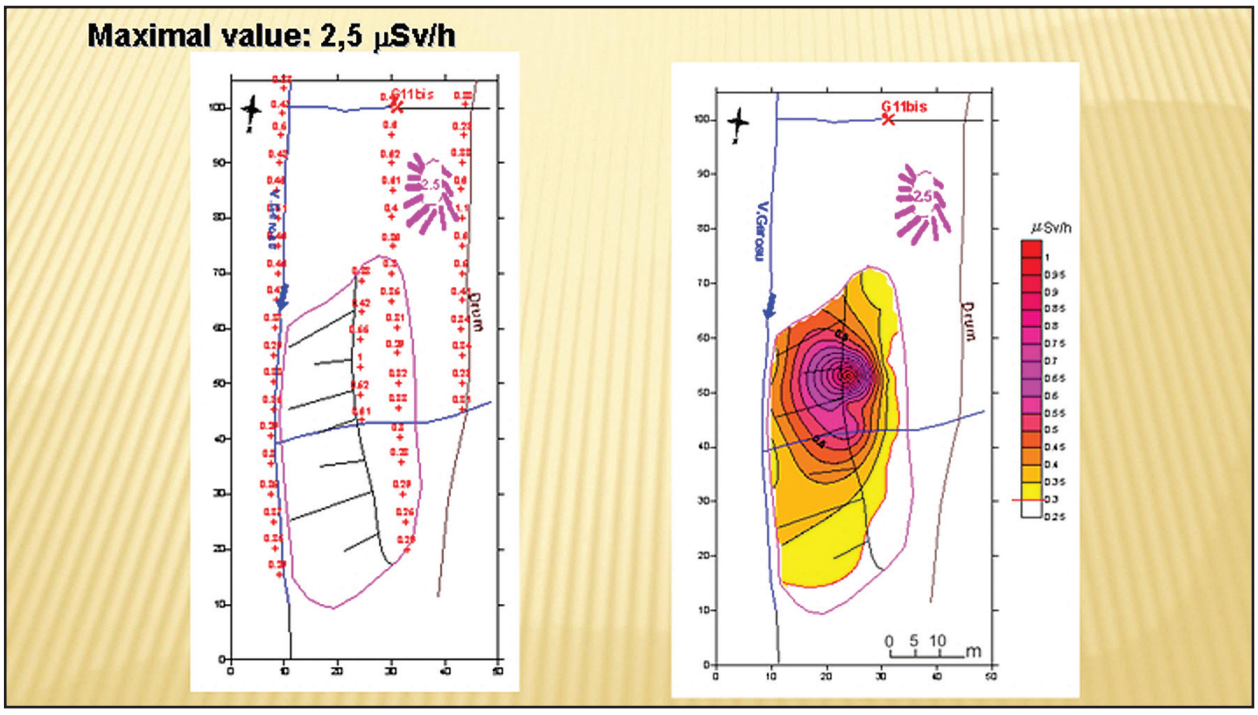

Fig.2 The external gamma irradiation measurements on the surface of a waste rocks dump (Jerosu Brook- G11B)

Table 2 The level of external gamma irradiation and the aproximative size of affected surfaces.

Waste rock dump	Total surface of the dump (m^2)	The contaminated surface, m^2		
		Total surface (m^2)	External gamma irradiation level (μSv/h)	
			0.30 – 0 .45	> 0.45
Gal 14 Larga	11,038	3,409	3,159	250
Gal.16 Jerosu	3,342	3,204	1,604	1,600
Gal.11 B. Jerosu	1,465	1,234	684	550
Gal.15 Jerosu	1,596	713	483	230
Gal.18 Pustiosu	2,424	1,405	945	460

Characteristics of mining and surface water

The discharges of out-flowing mining water are not important, oscillating between 1 and 3 l/s. The chemical analysis results are presented in Table 3; in the same table one can be see the chemical composition of runoff water which collects the out-flowing mining and the waste rock dumps drainage water.

Characteristics of soils and sediment samples

The chemical analysis results of the soil and sediments samples collected in the areas near pollution sources are included in Table 4; they are comparable with the results of the analysis of a blank essay which comes from outside the mining wastes influence area, tested for its content in radioactive elements only.

Table 3 Chemical composition of mining and runoff water (maximum values)

Element mg/l	Outflowing mining water			Runoff water		
	Larga Brook	Jerosu Brook	Pustiosu Brook	Larga Valley	Jerosu Valley	Pustiosu Valley
U_{nat}	0.016	0.008	0.009	bdl	0.04	bdl
Th	bdl	bdl	bdl	bdl	bdl	bdl
Cu	0.01	0.04	0.01	0.001	bdl	0.002
Zn	0.03	0.03	0.02	0.01	0.03	0.03
Ni	bdl	0.40	bdl	bdl	bdl	bdl
Sn	bdl	bdl	bdl	bdl	bdl	bdl
Cr	0.02	0.03	0.03	0.03	0.02	0.02
Fe	0.09	4.45	0.06	0.01	0.13	bdl
Co	0.01	0.01	bdl	bdl	0.01	bdl
Pb	bdl	bdl	bdl	bdl	0.018	bdl
pH	6.51	6.87	6.91	6.0/7.0	6.0/7.5	5.5/7.0

* bdl-bellow detection limit

Table 4 Chemical composition of soils and sediments

Element	Larga Valley			Jerosu Valley			Pustiosu Valley		
p.p.m.	max.	min.	blank essay	max.	min.	blank essay	max.	min.	blank essay
$U_{nat.}$	8	4	8	16	3	3	42	7	6
Th	8	-	-	170	7	7	94	5	5
Ra^{226}*	0.1	0.05	0.1	1.063	0.025	0.025	0.525	0.088	0.072
Cu	10	9	-	16	8	-	19	11	-
Pb	7	4	-	22	5	-	14	6	-
Zn	70	56	-	136	70	-	61	52	-
Ni	14	10	-	14	7	-	28	8	-
V	90	75	-	91	65	-	76	63	-
Cr	50	43	-	39	34	-	48	40	-
Cd	1	sld	-	1	0	-	1	sld	-
Co	18	15	-	19	12	-	22	12	-

*Specific activity (Bq/g)

DISCUSSION

Environmental impacts on surface water

The results of chemical analysis demonstrate that the impact of out-flowing mining water and the waste dumps drainage on surface water could be neglected. A single sample from Jerosu Brook, collected at the bottom of a waste rock dump, has an uranium content of 0.04 mg/l. Regarding the heavy metals, their total concentration ranges between 0.06 and 0.20 mg/l; these values are situated bellow acceptable limits indicated for surface water category by the Regulation of Ministry of Environment (NTPA 001/2002). All the brooks crossing over the mining areas are flowing down to Gradistea River; the characteristics of the river water flowing downstream the mining area is similar in composition with the water in the spring beside, which is used for consumption in Gradistea de Munte village (Table 5).

According to the obtained data, the surface water cannot represent an environmental hazard due to the following reasons:

- the high chemical stability of the rare earth forming minerals;
- high and permanent water discharge of the waterflow of brooks and rivers.

Table 5 Comparative chemical data between Gradistea River water and spring potable water

Location	Elements(mg/l)										
	U_{nat}	Th	Cu	Pb	Zn	Ni	Sn	Cr	Fe	Co	pH
Gradistea River	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.03	0.07	0.02	6..32
Gradistea spring	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.02	bdl	bdl	6..38

* bdl – below the detection limit

Impacts on soil and sediments

In soil and sediments samples the radioactive element concentrations range between 4 and 42 ppm for U_{nat} and between 5 and 170 ppm for Th; the soil specific activity ranges between 0.10 and 1,063 Bq/g (Table 3). The Romanian National Commission for Nuclear Activities Inspection recommends the use in forestry of soils having the specific activity between 0.2 and 1.00Bq/g (NMR-03/2003).

Heavy metal concentrations do not exceed the reference levels for forestry soils indicated by the Ministry of Environment and Forestry (ord. 756/1997).

According to the obtained data, the lands surrounding the derelict mine site can be considered weakly polluted.

External Gamma irradiation impact

The external gamma irradiation level exceeds The Romanian National Commission for Nuclear Activities Inspection and European guideline value of 0,3 μSv/h (NMR-03/2003), but the influence of gamma irradiation do not spread over waste rock dump sites. In order to clarify the influence of gamma irradiation on human health, the exposure risk was calculated using a program offered by World Information Service on Energy-Uranium Project, named Radiation Dose to Risk Converter. The guideline for gamma irradiation dose is 1 mSv/year and it is considered to correspond with an excess risk for cancerous diseases of 0.35% (1 in 286 cases), during a life span of 70 years. Five scenarios were taken into account depending on exposure time and maximum value of external gamma irradiation on dump surface. Only in one case the acceptable risk of 0.35% is exceeded: if a person constantly lives or works above the anomalous area; in fact, this is a hypothesis that is not very likely to be fulfilled due to the remoteness of the perimeter, which is located far away from residential centers. A moderate risk, between 0.35% and 0.80 % could be for workers and shepherds if they spend 2,000 hours yearly, for 40 years.Tourists and occasional visitors are unlikely to face any risks and much less so the inhabitants of the villages located downstream of the confluence of Pustiosu Brook and Gradistea River (Fig.1). Therefore, the residents' fear regarding the cancerous diseases is not justified.

RECOMMENDATIONS

The environmental assessment of the mining perimeter Gradistea de Munte proves that human mining intervention has not radically affected the ecologic balance. Therefore, the restoration recommendations will be adapted to the desired end land use in conjunction with the inherent nature and toxicity of the mine site. As known, the designated area will maintain its current use as a natural park. In order to increase the natural capital value some remediation measures are required.

The mine subsidence will be avoided by refilling the abandoned galleries with waste rocks derived from the dumps, followed by sealing with dams.

Waste rock dumps require to be stabilized for stopping material slide and for keeping the natural direction of runoff waters which have been modified by mining activities. Subsequently, they will be covered with local soil and vegetation. Covering the piles is expected to mitigate the external gamma irradiation by 20% which is in the benefit of human health improvement.

Neither mining water nor runoff water need any depollution treatment on the account of their low concentration in radioelements and heavy metals; the natural attenuation processes are expected to bring the water quality to background values.

A special attention should be paid to the instruction of the local population concerning the real situation of the radioactivity levels in the area and the prevention measures that should be taken against accidental contaminations. The local inhabitants and the visitors have to be convinced that the site restoration measures will keep safe their health and will allow the unrestricted use of the land surrounding the radioactive sources derived from mining activities.

FINAL REMARKS

The natural and cultural patrimony value of G.M.C.N.P is reduced by the presence of a derelict mining site which was not yet restored. Though the mining activity does not severely modify the ecosystem, the waste rock dumps are in contrast with the landscape, affect the normal flow direction of surface waters and have a low content of radioactive minerals. This last aspect especially worries the local inhabitants and minimizes the interest of the local community to use tourism as an engine for economic sustainable development.

Risk assessment has demonstrated that specific restoration measurements, which do not require a lot of effort, are needed in order to allow the geographical space reorganization and the development of economic ecologic activities.

Nature conservation, tourism and forestry represent the most appropriate options of land use, capable to utilize and in the same time to protect the natural park ecosystem.

Considering the wealth and variety of touristic attractions inside G.M.N.P.C., it is expected that serious problems in finding interested investors for the land, will not be faced.

AKNOWLEGEMENTS

This study was supported by the Ministry of Research and Education under the contract CEEX 644/2005.

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