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Present Landscapes and Their Ecological States in the Ore Mining Region of Chiatura

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Abstract: Comprehensive studies have been carried out in the manganese deposit areas in Chiatura. The studies showed changes in separate components of the nature – relief, air, water, soil, which have taken place due to anthropogenic, namely, technogenic influence and peculiarities of ecological states of the components. Using literary sources, expedition materials, aerospace images and topographic maps we have compiled a large scale map (1:50 000) of the landscapes of the mining region of Chiatura; The scheme depicting ecological condition; We have also revealed ecologically hazardous foci.

Keywords: Landscapes, Ecological States, Manganese Mines, Chiatura

1. Introduction

Mining complexes, which include excavation and exploitation of ores, make geodynamic, geochemical, physical, technogeneous and other kinds of influences on the environment. Such activities cause considerable changes in the medium of ore mining areas. One of such examples is the ore mining region of Chiatura (ar. 272 km^2) (Fig. 1), which is situated in Imereti (Zemo Imereti) in the gorge of the river Kvirila, 400-800 m above sea level, in the north-western part of Zemo Imereti Upland, in Chiatura Municipality (ar. 542km), on the structural plateau of Chiatura, which reaches its maximum height at the Goradziri Mountain (1100 m). The surface of the Zemo Imereti Upland is segmented by the gorges of the rivers Kvirila, Dzirula, Dumala, Sadzalikhevi and Khelmosmula. At some places it is cut by deep, canyon-like valleys. There are many landslides and rockslides observed on the Chiatura Plateau. A karst relief has developed in the Cretaceous limestones. Here more than 100 caves have been observed.

Exploitation of the Chiatura Ore began in 1879 and till 1990 (before Declaration of Independence of Georgia) 203 million tons of raw materials were extracted and 108 million tons of commodity products were sold [1]. Nowadays the Chiatura Ore is exploited by *GEORGIAN MANGANESE, LLC.*

The Oligocene deposits, including manganese, are almost horizontally situated on the Cretaceous limestones on the ore territory. The limestones are cut by deep canyon-like valleys of the river Kvirila and its tributaries, which separate out certain plateaus. The most part of the manganese minerals is laid out on these plateaus. On the right bank of the river Kvirila there are the plateaus of Rgani, Bunikauri, Tabagrebi, Mgvimevi, Darkveti and Sareki, while the plateaus of Perevisa, Shukruti, Itkhvisi, Merevi and Pasieti are situated on its left bank. The manganese is extracted by deep method (mining of ore by boring or explosion) and surface method, i.e. open cast mining.

All the components and especially the relief of the landscape have significantly changed. The manganese area is criss-crossed by numerous tunnels. The lengths of some of them exceed 2 km. The total length of all the tunnels is approximately 200 km [2]. Here numerous relief forms created as a result of mining works can be observed: caves, technogeneous surface collapses, piles of broods – slag heaps and etc. Therefore, there is quite appalling ecological state in the Chiatura areas. 1100 ha fertile lands have become useless, the soil has eroded, sources have disappeared, the natural balance has been disturbed. Open mining of the manganese ore was resulted in deserting the territory of villages and the

neighboring settlements. The inhabitants have to leave their native homes and settle at new places. The excavated soils are not recultivated that leads to full erosion of the agricultural lands.

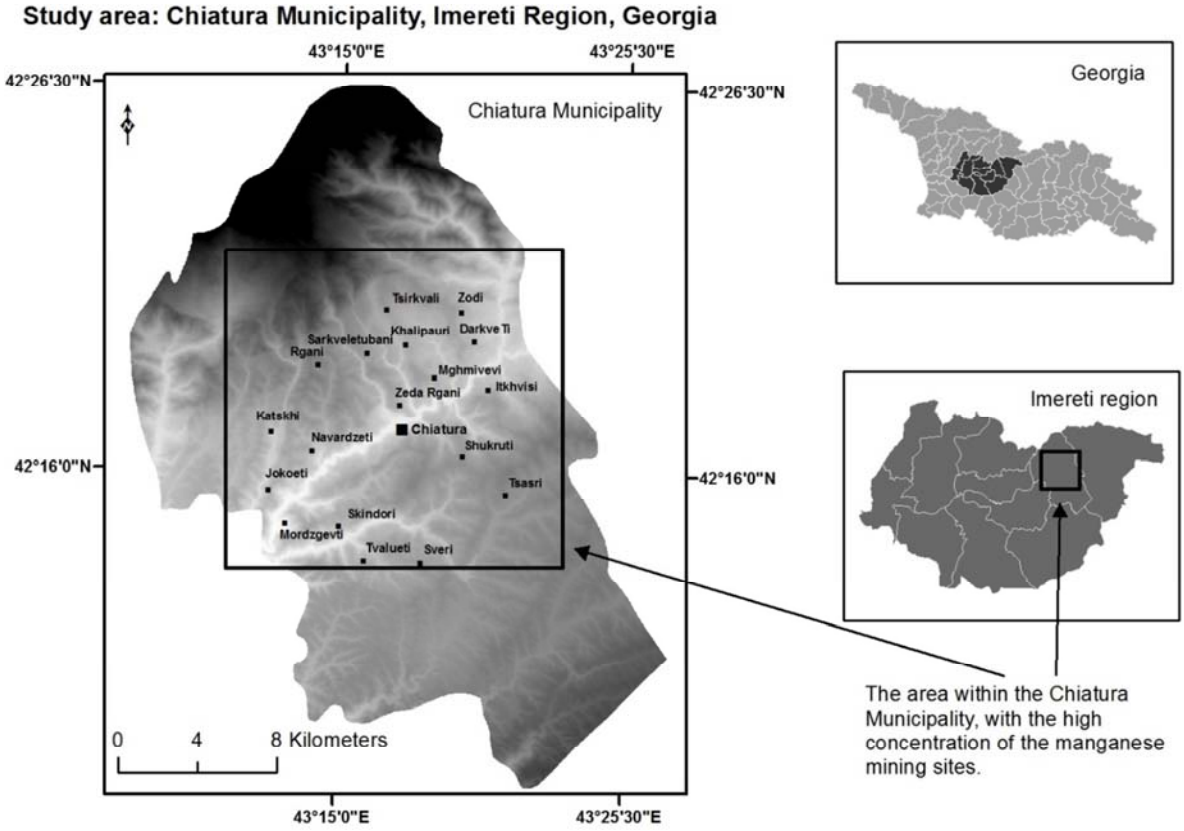

Figure 1. *Location of Study area.*

2. Main Part

Nowadays in Georgia the most contaminating among industrial enterprises is manganese mining. In 2013 the damage to the environment in Georgia was 2 million, GEL, 80% of which was caused due to the mining industry in the region of Chiatura [3]. Nowadays in Chiatura 16 480 ha area is exploited by both deep and surface mining methods. Manganese excavation and exploitation, later exploitation of red marble and other building materials, among them quartz sand, have been the main factors of anthropogenic influence on the environment during decades in Chiatura and its adjacent villages. At present in Chiatura there are 20 ores, 11 open casts and 9 mines [1]. Among them 16 mining plants are located immediately in the basin of the river Kvirila, in its northern part covered by its tributaries, whereas the rest 4 of them are located to the south of the river basin.

In order to reveal the ecological state here it was necessary to study the current state of the environment. This required revealing the modern landscapes of Chiatura and their mapping – compiling a large scale map of landscapes of Chiatura.

Formation of ecological states of natural complexes is negatively affected by the results of technogenic activities – pollution of air, water and soil by production wastes.

The meteorological conditions, direction and velocities of the winds significantly determine the degree of emission influence in Chiatura and its adjacent areas. In the recent years observations on the atmospheric air quality has become difficult. Therefore, data on the concentration of harmful substances are not available. Assessment of all the parameters of the air quality was last carried out only by the end of 80-s of the XX century, when industrial activity was much higher in this region. The exhausts consisted of the following harmful substances: suspension particles, sulphur anhydride, carbon dioxide, nitrogen oxides, manganese dioxide and etc. The dust concentration here 3.26 times exceeds the maximum permissible concentration (0.5 mg/m^3) established by the Georgian legislation [4].

The main polluter of the air by radioactive aerosols is radon. Mines are polluted due to extraction of outcropped rocks from the surface. In the manganese mining industry of Chiatura the symptom of intoxication by manganese is significant changes in the central nervous system that mainly causes acute symptoms of manganese Parkinsonism, chronic bronchitis and pulmonary diseases in the staff of the Chiatura manganese industry. In spring the concentrations of Ra^{226} and Rn^{222} decrease in the waters of the river Kvirila due to increase in the atmospheric precipitations – as a huge amount of atmospheric precipitations are mixed with radium and radon in to the river Kvirila [5].

The region of Chiatura is quite rich in internal waters. The average frequency of the river network is 1.45 km/m^2. The

main river is the Kvirila and its main tributaries are: Jruchula, Sadzalikhevi, Katskhura, Itkhvisistskali, Shouletisghele, Shukrutistskali, etc. The gorge of the relatively long river Ghurghumela is used for precipitating the manganese. There is a reservoir (Fig. 2) built in the gorge. The industrial waste water left after the process of ore washing contains a huge amount of suspension particles and manganese compounds. In the past the silt flew from the central flotation plants through the silt ducts (pipes), the manganese concentrate was separated out and the remaining silt was run to the so called Ghurhgumela Reservoir. There the silt was precipitated and the purified water was used again. Nowadays none of the ore-dressing plants have any treatment facilities, whereas the old ones are out of order. The Ghurghumela Silt Reservoir is inactive at present and it can cause a big hazard as its embankments may collapse in this seismically active, landslide and complicated relief zone.

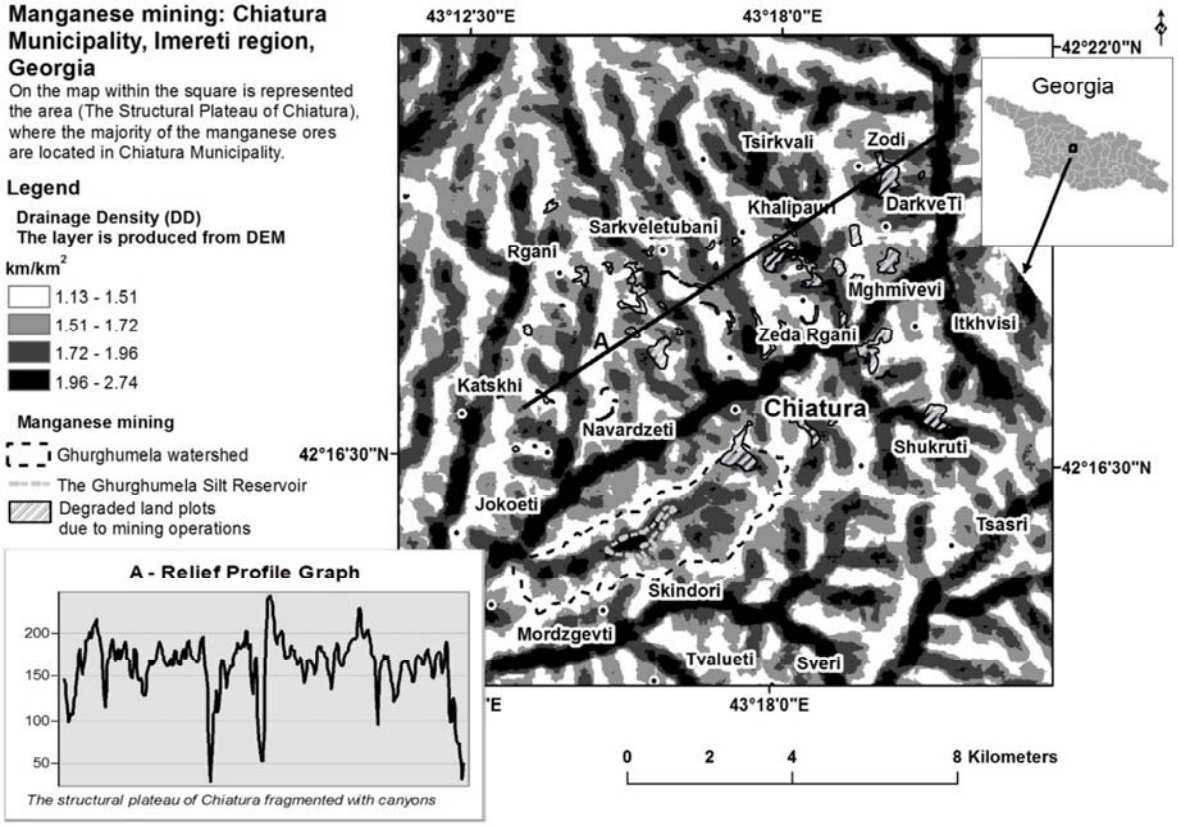

Figure 2. *Internal waters and environmental degradation.*

Within the boundaries of Chiatura Municipality the river Kvirila is highly polluted (Fig. 3, Fig. 4). For dressing the most of the manganese is run to the river Kvirila and permanently gets polluted with manganese ore admixtures. The content of manganese ore in the river Kvirila is 10-12%. [6]. The river Kvirila is contaminated by the manganese ions. In 2009 at the entrance of Chiatura the recorded concentration of the manganese ions in the river Kvirila was 3.9 mg/l (maximum permissible concentration of manganese ions in water is 0.1 mg/l). According to the 2013 data in the waters of the river Kvirila the manganese concentration (6 folds) exceeded the maximum permissible concentration [7].

The water from the brood ("leaked water") and mines ("mine water") is contaminated by metals and other kinds of chemical substances. Using the contaminated water for irrigation purposes is harmful for human health. The underground waters are often polluted. The main arteries, karst sources of the potable water of Chiatura town – the Ghrudo, Lezhubani, Monastery and the Sakurdgliis Tskali have been contaminated due to manganese mining. It is necessary to take drastic remedies against contamination of karst waters in order to avoid epidemic breakout among the population [8]. Besides the manganese, the river Kvirila is contaminated by domestic wastes, sanitary sewage and industrial water as they are not filtered properly.

Figure 3. *The river Kvirila permanently gets polluted with manganese.*

Building of a silt reservoir on the territory of the new ore-dressing plant near so called Dakhlaura Gorge is planned (approximately within 500-600 m distance of the mining site). In case the reservoir is built the risks regarding environmental contamination linked to transportation will decrease significantly. By 2016 a new ore-dressing plant must have been put in function, though *GEORGIAN MANGANESE, LLC* could not obtain the relevant license.

Ore excavation works cause degradation of soil. In case of open cast mining the adjacent landscapes are damaged as a result of cutting down the plants and removing the upper layer of the soil on the industrial territory. This causes soil erosion and reduces potential for agriculture development in the region.

Figure 4. *Canyon of River Kvirilaand Ore Mining Rregion of Chiatura.*

The Company Georgian Manganese was charged with 158 832 GEL fine for "the damage caused to the environment as a result of the mining activities in the village of Rgani of Chiatura region" (Fig. 5). The damage was represented in the following: The trees and plants dug out during the activities on the processed territory were fully buried in the earth fill [9]. In the ore excavation and open cast mining areas any recultivation works are not carried out, the newly formed reliefs are neither leveled nor covered with soil layer, nor grass, trees and bushed are planted.

Figure 5. *Rgani mining plateau.*

Various concentrations of toxic elements have been observed on the irrigate lands near the manganese ore-dressing plant. Heavy metals manganese, cadmium, copper, cobalt, aluminium and nickel have active negative influence on soil formation processes; Manganese naturally prevails over other elements. Concentration in different areas reaches 127338 mg/kg, 1465 mg/kg, while its maximum permissible concentration is 1500 mg/kg, under EU standards and 700 mg/kg under the Georgian national standards. The concentration limit is violated in the grassland areas near the Thiri water canal the village of Itkhvisi [10]. They reduce the hydrophysical potential of the soil. The balance among solid, liquid and gas phases is upset and the soil becomes degraded. The ore material appears on the soil surface and spreads over the ore explosion area. The particles of sulphide compounds are dispersed by the wind and are oxidized by air and water. Consequently, sulfuric acid and soluble metal salts leak into the soil, change the composition of the ground waters and the pH of the soil and contaminate them by metals. When appeared in the soil, these metals are absorbed by clay minerals. Besides, the carbonate system of the soil is a barrier for them. Therefore, the metals accumulate on the surface during technogenesis. High concentrations of chemical elements are observed in the ore deposit zone, within 100-200 meters around the ore. The geochemical activity of elements is reduced in the next zone. The composition of ingredients is poor [11].

The vegetation cover has been significantly changed. In the past years oak, maple, hornbeam and other trees grew in the uplands of the structural plateau of Chiatura. However, after constructing the manganese plants the most part of the forest was destroyed here. Some parts of the territory are covered by arable areas. Forests are mostly preserved on the slopes of the ridges of Racha and Likhi. Beech, oak, hornbeam, chestnut, maple, ash and lime are dominating and coniferous trees are rarely met in the forests. There are also evergreen (Pontic rhododendron, Ilex colchica, Ruscus aculeatus, etc) and deciduous species. There you can also meet wild fruit: crab apple, wild pear and bilberry. In the river gorges there are narrow rows of alder trees with a small number of willow and aspen. At some places the oak and hornbeam forest have been destroyed and replaced with derivatives – oriental hornbeam, Jerusalem thorn, cornelian cherry, maple, medlar and etc. Oak and hornbeam forests are met at relatively better preserved sites.

40-50% of the region forests are situated at hardly reachable and sometimes unreachable places.

The relief has morphologically obliquely changed as a result of underground mining works. The changes are expressed in collapses of large areas of surfaces that correspond to landslide formations. Such areas are observed on the plateaus of Shukruti, Itkhvisi, Merevi and Darkveti. The intensity of mining works greatly exceeds the intensity of natural processes. Every year on the Chiatura Plateau as an average 5.5 mln/m^3 manganese and 5 mln/m^3 quartz sand are excavated (anthropogenic denudation). Immediately at the ore excavation areas there is 0.1 mln/m^3 brood accumulated (anthropogenic accumulation) [12].

70 million cubic meters mineral mass has been relocated from the ore-bearing area of Chiatura due to natural erosions and denudation in the last 100-120 years. In the same period, 130-140 million cubic meters ground was subject to

technogenic transformations due to mining activities, while extreme anthropogenic transformations affected over 200 square meters land area. These processes resulted in intensive landslides, as well as destruction of villages and agricultural and farming areas [13].

Technogenic influence on the nature changes natural surfaces for a long time and creates new forms of relief (anthropogenic-denudational pits, anthropogenic-accumulative soil piles, holes, slag heaps, embankments, collapsed surfaces and etc.) and new micro-landscapes adjusted to them. Changes in the surfaces and new contrasting forms of the ground are especially observed at the sites of open cast mining.

3. Results

In the past there were various landscapes in Chiatura Municipality: forest, forest-steppe meadow-shrubbery and etc. [14]. This diversity is caused by the complex relief, geologic structure, different kinds of climate, diversity of vegetation and animal world and also by location within three geostructurally different parts: on the one hand between mountainous systems of the Caucasus (Racha Ridge, Likhi Ridge) and on the other hand between the Lesser Caucasus and the intermountain plateau (Imereti Upland).

In the Chiatura region not only separate components of the nature are influenced to some extent by anthropogenic activities but also entire landscapes as well. This process takes place nearly in every natural-territorial complex. In order to determine the behavior and degree of the anthropogenic influence on the natural medium of the study territory we draw a large scale (1:50 000) map of landscapes in the GIS (Geographic Information System) (Fig. 6).

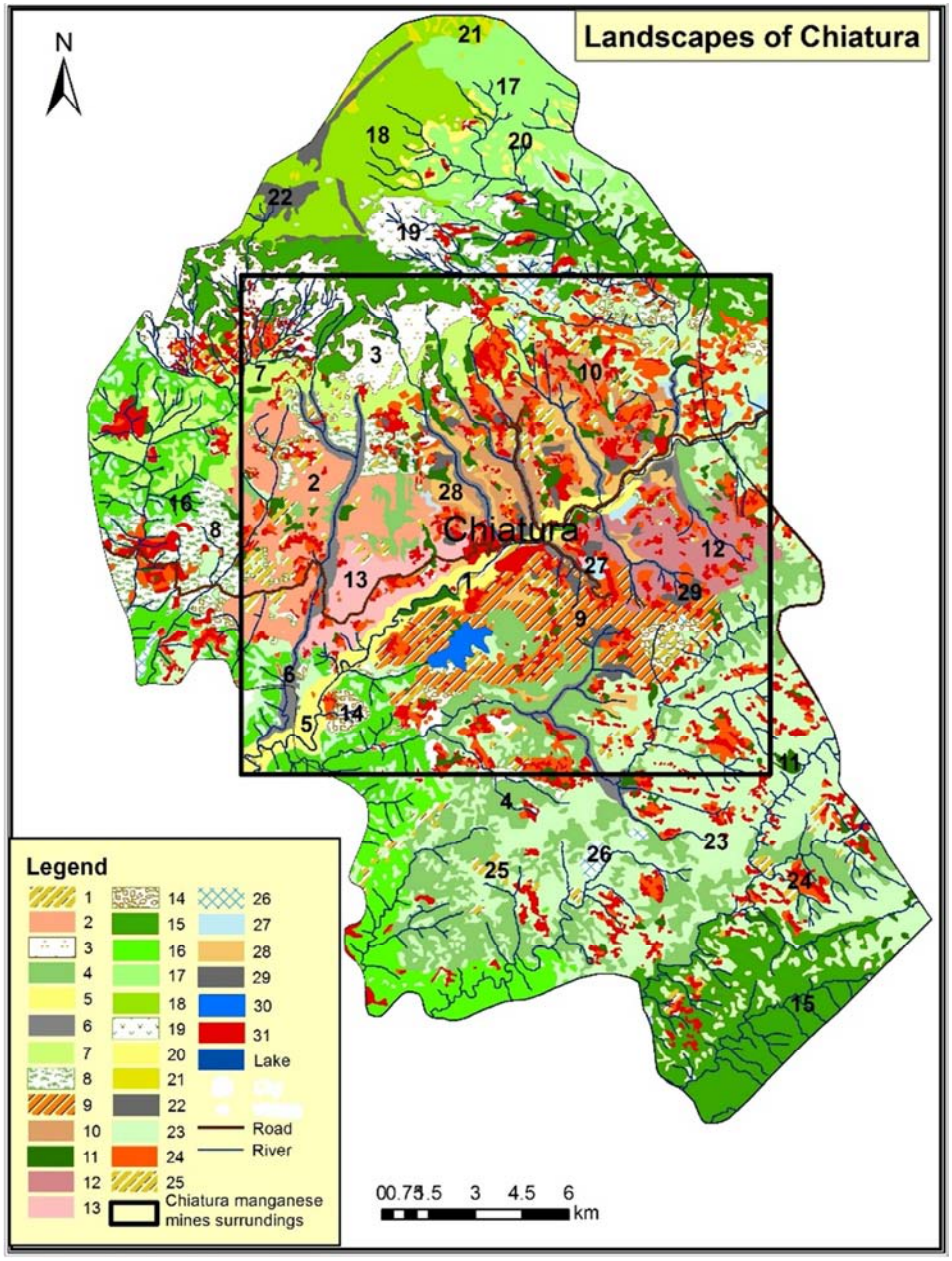

Figure 6. *Landscapes of Chiatura.*

Legend
1. Floodplain landscapes.
2. Hilly landscapes with relict canyons.
3. Hilly landscapes with Colchic vegetation.
4. Oak-hornbeam with brown forest soils.
5. Canyon with erosion terraces.
6. Canyon-like gorges with hornbeam.
7. Karst-erosion plateau.
8. Step by step inclined plateaus with technogenic relief.
9. Plateaus with "anthropobadlands".
10. Plateau with karst formations.
11. Chiatura structural plateau with separate forest stands.
12. Hollow with agricultural land.
13. Low mountainous with agricultural land.
14. Post-forest meadows and shrubs with agro-landscapes
15. Low mountains with deciduous forests
16. Low mountains with beech-hornbeam and chestnut forests.
17. Middle mountains with beech-hornbeam forests.
18. Middle mountains with beech-dark coniferous forests.
19. Middle mountains hollow with karst forms.
20. Subalpine meadows.
21. Alpine meadows with .
22. limestone cliffs.
23. Pastures.
24. Vineyards
25. Arable land
26. Tea
27. Sand pit quarry
28. Open pit
29. Closed quarry
30. Reservoir
31. Residential landscape

In it we distinguished different kinds of landscapes. In the map the role of the anthropogenic factor in the landscape formation is especially well shown as almost every component of the landscape undergoes fundamental changes.

In Chiatura almost every kind of landscapes has undergone changes as a result of technogenic influence. The most changed are the following landscapes: steep slopes of low mountains with oak and hornbeam forests, dark grey soils of washed down forests with low humus content and low mountain plateaus with oak and hornbeam forests, grey and meadow-carbonate soils (Fig. 7).

Figure 7. *Landscapes low mountain plateaus.*

On the territory immediately adjacent to the mining area the following modifications of anthropogenic landscapes are observed: pit and slag heap, slag heap, natural-technogenic (Fig. 8). Formation of technogeneous landscapes was qualitatively newly revealed when the heavy machinery used for the mining works changed the natural landscape as a result of anthropogenic influence (Fig. 9).

Figure 8. *Waste heaps, manganese mines of Darkveti*

Figure 9. *Recultivated landscape of Chiatura.*

In the conditions unsteady for the relief certain ecological problems have been arisen and they are considered the main ecological risk, which is hazardous for the environment. These are: fundamental changes in the relief, activation of geodynamical processes (landslides, mudflows). In such conditions of geodynamical processes the contamination of surface and underground waters is becoming more serious, while the contamination level is increasing in densely populated foothills and gorges. Which was reflected the scheme depicting Ecoligical condition of Chiatura (Fig.10).

Regarding the measures and intensity of landslide hazard the region of Zemo Imereti (where is Chiatura located) is characterized with especially high vulnerability coefficient (0.7-0.9) and is under high risk of landslide development. It belongs to the list of regions under "very high risk" [15-16]. In Chiatura Municipality the most of the landslide deformations are formed due to the manganese mining and tunnel collapses. Average thickness of the collapsed rocks is 500-1000 m. In the areas of village Itkhvisi a three-layer

circus-like landslide is observed. The clays, sandstones and conglomerates are covered with slid material. The Ikhtvisi Landslide has developed in quite "favorable" topographic conditions. The slope is significantly slanting. There are outlets of underground waters, though traces of industrial activities are also seen. Mainly, the landslide processes are activated due to formation of thick layers of the collapsed tunnels. The landslide is especially active now. On the one hand it must be linked to the collapse of the tunnel left after the manganese mining.

The remedies taken against the erosive processes are not effective. The area of the eroded territories is 4.4 thousand ha. The most part of the eroded areas of Imereti region is located exactly in Chiatura. 200 ha area is considered badly eroded that is quite a high value for a complex with such a small area.The ravines are mainly formed on slopes with the inclination of 10-20^{O} and 20-35^{O}. The depth varies from 0,5 to 1,5 metersand occasionally 10-15 meters, and the length varies between 150-200 meters [1]. Soil eroded by water from arable lands totals 10-15 tons per hectare [17].

Erosions and gullying processes are so quick that regional classical badlands have already developed here.

The 1991-1992 Racha-Imereti earthquakes were followed by development of many new landslides and rockslides. A huge amount of solid material transformable into mud torrent was accumulated in the river valleys and gullies. Village Khakhieti was buried under a 70 mln m^3 rockslide and 50 mln m^3 rockslide blocked the gorge of the river Kvirila in the areas of village Perevi (adjacent to Chiatura) [15].

Regarding the damage inflicted by mud torrent processes the region belongs to moderately vulnerable zones (0.1-0.3) [18]

The anthropogenic factor has a great influence on the development of karst processes. It causes formation of new fissures and activation of karst processes.

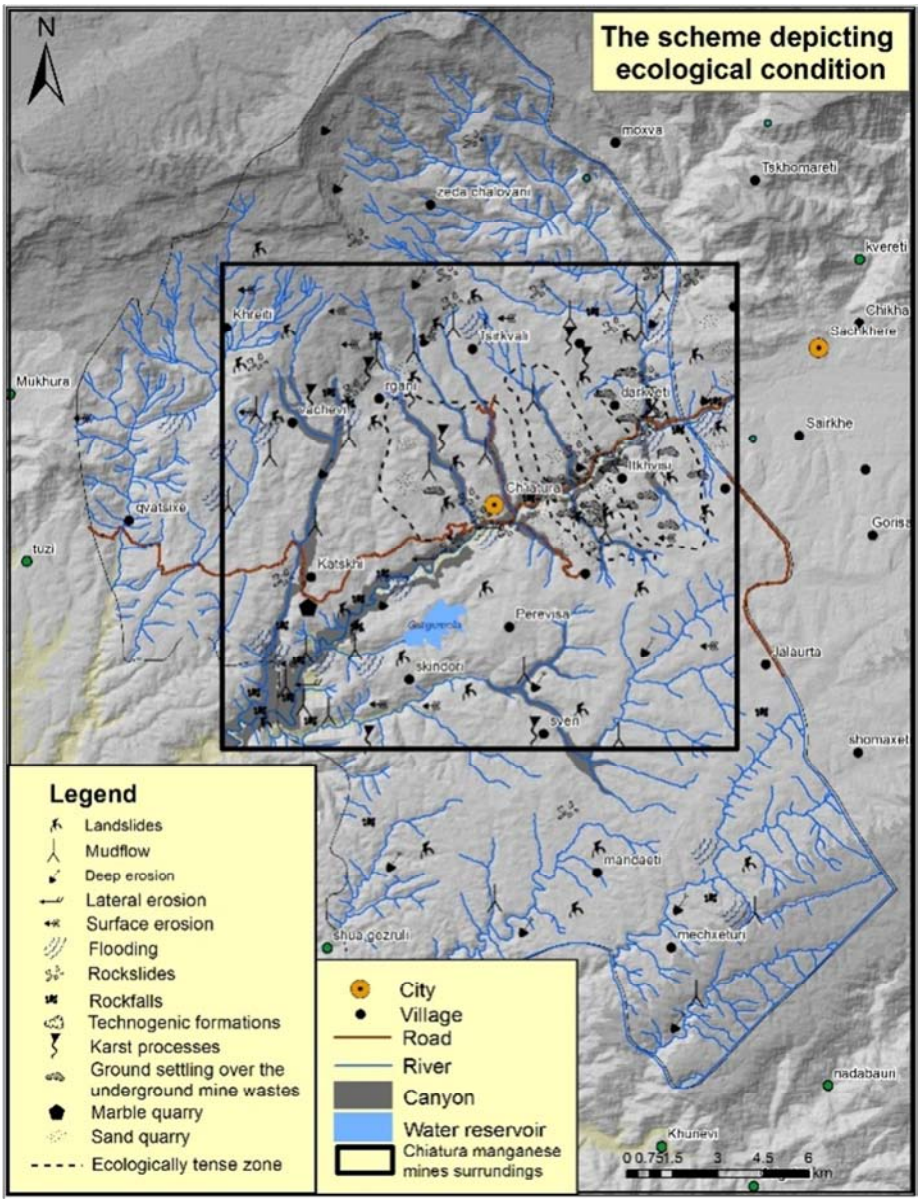

Figure 10. *Chiatura manganese mines surroundings.*

4. Conclusion

The landscape studies carried out by us showed that the changes in natural-territorial complexes are caused by both natural (erosion, landslides, mud torrents) and anthropogenic (ore mining, forest clearing, grazing) factors, duration of human activities on the nature and especially the properties of the landscape itself and its structure. Ecological states of landscapes mainly depend on the intensity of technical-economic activities of the public. The technogeneous results are especially obvious after ore excavating and dressing, agricultural and other kinds of activities. On the one hand the results of anthopogenic influence are not similar everywhere. The landscapes of the manganese-bearing uplands (Rgani, Itkhvisi, Bunikauri, Darkveti and etc.) of Chiatura have undergone the most dramatic anthropogenic transformation. Here the ores are extracted by open cast mining. Consequently, the naturally balanced landscapes formed during centuries have fully destroyed and been replaced with so called "industrial deserts" with loose rocks and activated landslips.

All the components, especially the relief of the landscapes, have changed. Here numerous forms of reliefs formed as a result of mining works are presented: caves, technogeneous collapsed surfaces, piles of brood – slag heaps and etc. 1100 ha fertile land has become degraded. Immediately in the ore mining areas the biological components have completely destroyed.

As a result of the anthropogenic influence the state of the forest vegetation cover has changed and in karst reliefs, where there is lack of water, it has happened faster than in the areas with other geological structures. The main trend in landscape variations is that the ecotopes and the flora are turning xerophytic on the study territory.

Around the mining area of Chiatura the forest flora is either completely destroyed or replaced with derivative vegetation – meadow-shrubbery. Besides, the soils, micro-climate and other components of the landscapes have also changed.

Among the landscapes the most fundamental changes have taken place in the lowland oak-hornbeam forests with dark grey soils, low humus content and the hill plateau oak-hornbeam forests with meadow-carbonate soils.

For the foothill landscapes, besides the high density of population and agricultural lands covering large areas, certain risk is posed by the fact that self-renewing processes in the vegetation cover has delayed due to intense cattle grazing in the area. Overgrazing is also an additional risk-factor for the natural-territorial complexes of the low-mountain forest landscapes, where the vegetation cover has considerably changed and destroyed (mainly due to cutting down of forests). Cattle's grazing has become especially active during the recent years as due to the poor social and economic conditions of the country the population at some places began to use the territories adjacent to populated areas as pastures instead of alpine slopes.

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