ORIBATIDA DIVERSITY ON LIMESTONE AND CLAY QUARRIES

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Abstract. Oribatid mite diversity was investigated in Gardabani clay and Kavtiskhevi limestone quarries. Soil samples were collected on quarries of different ages and adjacent natural ecosystems that were referred as control sites.39 species of oribatid mites were identified in six locations of Gardabani clay quarry, among them *Phyllozetes tauricus* Gordeeva, 1978 is new for the Caucasian fauna.40 species were found in four locations of Kavtiskhevi quarry, *Simkiniaschachthachtinskoi* (Kulijev, 1961) and *Laisobelba* sp. being new for the Georgian fauna. Abundance and species richness of oribatid mites was low in active quarries, and increased in older quarries. Increase of species richness of soil fauna in the reclaimed sites of Gardabani quarries indicatesthat soil formation process is going onat these sites. Similarly, high diversity and abundance of oribatid mites in oldest quarry in Kavtiskhevi indicate that active soil formation process is supporting formation of soil fauna. However, oribatid fauna of old and reclaimed sites in both Gardabani and Kavtiskhevi quarries still differs from those, found on natural sites.

Introduction

Presented paper discusses results of the researchon Gardabani clay and Kavtiskhevi limestone quarries of "Heidelbergcement Georgia" which was conducted in the framework of "Quarry life Award"project.

Kavtiskhevi limestone quarry is located near Kaspi city (5 km away from Kaspi cement Plant). The climate is moderate dry continental with average annual temperature 11.50°C and average annual precipitation – 500 mm. The Quarry is located on undulating terrain. Mining in Kavtiskhevi has been started in 1936 and continues till today. Total area of the quarry is 182.98 ha and 80% of whole territory is opened (http://www.quarrylifeaward.com).

The Gardabani quarry is located to the east of Rustavi city. The climate is dry continental with average annual temperature 12°C and average annual precipitation – 400-420 mm. The Quarry is located on the flat ground. Gardabani quarry was opened in 1954 and it's still operating. Total area of the quarry is 44.06 ha, 75% is opened (http://www.quarrylifeaward.com).

Soil zoocenoses, microarthopods in particular, by their complex structure and species composition are widely reported as bioindicators of the regeneration degree of the productive soil layer [1, 2]. Oribatid mitesare the most numerous soil arthropods with about 10 000 described species [3] and are found in the majority ofterrestrial ecosystems [4, 5]. Oribatid mites can't easily escape from stress conditions due to their low dispersal ability [6]. Consequently population of oribatid mites decline rapidly when their habitat is disturbed. This allows detection of environmental degradation. Appearance and dominance of oribatid mites in the microarthropod complex indicates the beginning of soil and humus formation [2, 7]. Soil regeneration processes can be evaluated based on the soil faunal composition and community structure.

We investigated (1) the biodiversity of oribatid mites on clay and limestone quarries of different age as well as on reclaimed and natural sites (2) the patterns of colonization of disturbed sites by oribatid mites in the process of soil recovery and (3) the influence of oribatid mites on soil formation processes.

Material and Methods

Site description

Field sampling was performed in May, June and October of 2014.

List of visited sites is as follows (Tables 1-2):

Table 1.List of sampling sites in the Gardabani clay quarry

Abbreviation	Site description	GPS coordinates
G1	Active quarry	41°30.640 45°05.695
G2	15 years old quarry	41°30.438 45°05.709
G3	40 years old quarry	41°30.235 45°05.700
G4	Two years ago reclaimed site	41°30.135 45°05.866
G5	One year ago reclaimed site	
G6	Control. Natural meadow	

Note: sites G5 and G6 are located close to each other, so, the GPS coordinates are the same.

Table 2. List of sampling sites in the Kavtiskhevi limestone quarry

Abbreviation	Site description	GPS coordinates
K1	Active quarry	41°53.702 44°26.739
K2	20 years old quarry	41°53.718 44°26.533
K3	Oldest quarry of 1923	41°53.999 44°26.568
K4	Control. Natural meadow	41°53.277 44°27.681

Sampling strategy

From each site six soil samples were taken of 10 cm^3 volume for each. Soil samples were appropriately labeled, delivered in the laboratory and invertebrates were extracted from soil using Berlese-Tullgren apparatus. The functioning of this apparatus is based on the negative reaction of soil invertebrates on high temperature, lack of humidity and light. Duration of the extraction was one week and extracted soil arthropods were stored in 70% alcohol with drop of glycerol. In order to perform species identification, temporary slides were made for oribatid mites using cavity slides and drop of lactic acid. Such slides allow to turn the specimen and to observe the characters needed from all the sides.

Identification keys of Weigmann [8], Ghilarov & Krivolutsky [9] were applied for identification. All identified individuals were counted. Systematic arrangement is according to Schatz *et al.* [10].

Data analyses

For statistical analyses PAST, Biodiversity Pro Software and Microsoft Excel were used. Simpson's index of biodiversity (1-D) was calculated [11](Simpson, 1949) in order to reveal oribatid diversity.

Sampling completeness was revealed by Chao1 index and rarefaction curve analyses. Cluster analyses based on the Jaccard's formula was performed in order to show faunal likeness between the sites

Results

In total 58 species of oribatid mites are registered on both investigated quarries that belong to 25 superfamilies and 30 families (Table 3). Most species rich superfamily is Oripodoidea with two families and nine species.30 species were found in six locations of Gardabani clay quarry, one of them -*Phyllozetes tauricus* Gordeeva, 1978 is new for the Caucasian fauna. 32 species are registered in four locations of Kavtiskhevi limestone quarry with *Simkinia schachthachtinskoi* (Kulijev, 1961) and *Lasiobelba* sp. being new for the Georgian fauna. *Punctoribates punctum* (Oribatida) is a pioneer species of disturbed habitats. This species is abundant on quarries of different age in Kavtiskhevi and is less numerous on control sites. As for new species for Georgia, *P. tauricus* was found on 15 years old quarry and*S.schachthachtinskoi* – on the oldest limestone quarry in Kavtiskhevi. *Laisobelba* sp. was registered on natural meadow.

Table 3. List of Oribatid mites found on Gardabani and Kavtiskhevi quarries with numbers of individuals for each site

Species	G1	G2	G3	G4	G5	G6	K1	K2	K3	K4
Liochthonius sp.	0	5	0	0	0	0	0	0	0	0
Papillacarus aciculatus(Berlese, 1905)	0	0	32	5	1	1	0	0	0	0
Phyllozetes tauricus Gordeeva, 1978	0	2	0	1	0	0	0	0	0	0
Sphaerochthonius splendidus (Berlese, 1904)	0	6	0	3	6	0	0	1	10	0
Epilohmannia cylindrica (Berleze,1904)	0	0	3	1	0	0	3	4	8	2
Acrotritia ardua (C. L. Koch, 1841)	0	0	0	4	4	0	0	3	3	1
Phthiracarus laevigatus (C.L. Koch, 1844)	0	0	0	0	0	0	0	0	1	0
Steganacarus (Steganacarus) magnus (Sellnik,1920)	0	0	0	0	0	0	0	0	1	0
Trhypochthhonius tectorum (Berlese, 1896)	0	0	0	0	0	0	0	2	1	0
Hermanniella granulata (Nicolet, 1855)	2	0	0	0	0	0	0	0	0	0
H. punctulata Berlese, 1910	0	1	0	0	0	5	0	0	0	0
Plateremaus mirabilis Csiszar, 1962	0	0	0	0	0	0	1	0	0	0
Belba dubinini Bulanova-Zachvatkina, 1962	0	0	0	2	2	3	0	0	2	0
Microzetes auxiliaris Grandjean, 1936	0	0	0	8	6	1	0	0	0	0
Damaeolus ornatissimus Csiszár, 1962	0	0	0	0	0	0	0	0	1	0
Xenillus tegeocranus (Hermann, 1804)	0	0	0	0	1	0	0	0	2	0
Austrocarabodes foliaceisetus georgiensis Murvanidze & Weigmann, 2007	0	0	0	0	0	0	0	0	0	1
Carabodes kintrishiana Murvanidze 2008	1	0	0	0	0	0	0	0	0	0
Graptoppia foveolata (Paoli, 1908)	0	0	0	0	0	76	0	10	0	0
Microppia minus (Paoli, 1908)	2	1	4	4	1	0	0	0	6	8
Oppia nitens C.L.Koch 1836	0	0	0	0	0	0	0	0	1	0
Oppiella fallax (paoli, 1908)	0	0	0	0	0	0	0	8	1	0
Lasiobelba sp.	0	0	0	0	0	0	0	0	0	3
Quadroppia quardridentata (Michael, 1885)	0	0	0	5	0	0	0	0	0	0
Suctobelbella duplex (Strenzke, 1950)	0	0	0	0	0	0	0	1	0	0
Tectocepheus velatus velatus (Michael,1880)	0	0	0	0	2	0	1	25	16	33

T. velatus sarekensis Tragardh,1910	0	0	0	5	0	0	0	0	3	0
Cymbaeremaeus cymba (Nicolet, 1855)	1	0	0	0	0	0	0	0	0	0
Passalozetes africanus Grandjean, 1932	0	18	0	0	0	0	1	0	0	2
Scutovertex minutus (C. L. Koch, 1835)	0	0	0	0	0	0	0	1	0	3
Eupelops acromios (Hermann, 1804)	0	0	0	0	0	1	0	0	0	0
Peloptulus phaenotus (C.L.Koch, 1844)	0	0	0	0	0	0	0	6	4	3
Parachipteria georgica Murvanidze & Weigmann, 2003	6	3	0	11	0	0	0	0	0	0
Tectoribates ornatus (Schuster, 1958)	0	0	0	0	0	1	0	0	0	0
Haplozetes elegans Kunst, 1977	0	2	0	0	0	0	0	0	0	0
Peloribates longipilosus Csiszar & Jeleva, 1962	0	0	0	0	0	0	0	5	0	0
Protoribates capucinus Berlese, 1908	15	2	0	0	1	1	0	35	82	0
Lucoppia burowsi (Michael, 1890)	0	0	0	0	0	0	0	0	0	2
Oribatula tibialis (Nicolet, 1855)	1	0	0	0	0	0	0	0	17	0
Simkinia schachthachtinokoi Kulijev, 1961	0	1	0	0	0	0	1	0	0	0
S. tianschanica Krivolutsky, 1967	0	1	0	0	0	0	0	1	11	0
Zygoribatula frisiae (Oudemans, 1916)	2	25	0	14	3	0	3	8	11	27
Liebstadia longior (Berlese, 1908)	0	0	0	0	0	0	0	3	3	0
Liebstadia similis (Michael, 1888)	0	0	0	0	4	0	0	3	1	0
Scheloribates laevigatus (C.L. Koch, 1835)	2	0	0	0	1	0	0	3	23	0
S. latipes (C. L. Koch, 1844)	0	0	0	0	0	0	0	2	16	0
S. longus Kulijev, 1968	0	0	0	0	0	0	0	0	0	4
Ceratozetes gracilis (Michael, 1884)	0	0	0	3	0	0	0	0	0	0
C. minutissmus Willmann, 1951	0	0	0	0	0	0	0	0	0	18
Trichoribates naltschiki (Shaldybina, 1971)	0	0	0	2	2	0	0	0	4	0
Minunthozetes pseudofusiger (Schweizer, 1922)	0	0	0	0	2	0	0	2	1	3
Punctoribates punctum (C. L. Koch, 1839)	0	5	0	0	0	2	8	73	20	36
Galumna tarsipennata Oudemans, 1914	0	0	0	32	6	33	0	0	2	16
*Galumna s*p.	1	0	0	0	0	0	0	0	0	0
Pergalumna nervosa (Berlese, 1914)	0	0	0	3	2	0	0	3	3	1

Number of oribatid mite species in Gardabani was higher on 15 years old quarry and reclaimed sites (13-17) and four species were found at 20 years old quarry (G3). In Kavtiskhevi, high number of species (28) was registered in 80 years old quarries and seven species were found on active quarry. Calculation of Chao1 index revealed about 80-95% of sampling completeness for Gardabani sites. As for Kavtiskhevi, sampling completeness was 80-95% for all sites except active quarry, where sampling completeness was about 70%. Simpson's index of diversity (1-D) was about 0.80 for all sites in Gardabani except 20 years old quarry and natural meadow. As for Kavtiskhevi quarry, the diversity index was higher in oldest (80 years old) quarry and natural meadow compared to active and 20 years old sites (Table 4).

Table 4. Diversity indexes of oribatid mites on Gardabani and Kavtiskhevi quarries

	G1	G2	G3	G4	G5	G6	K1	K2	K3	K4
Taxa_S	10	13	4	17	16	10	7	21	28	18
abundance	183 ±109	400 ±404	233 ±683	650 ±356	244 ±167	689 ±445	100 ±159	1106 ±975	1322 ±703	917 ±917
Chao1	11	14.2	4	17.25	17.43	13.33	10	22.2	35.2	19.2
Dominance D	0.258	0.2045	0.5975	0.1275	0.0898	0.4493	0.2654	0.1905	0.1535	0.1409
Simpson 1-D	0.742	0.7955	0.4025	0.8725	0.9101	0.5507	0.7346	0.8095	0.8465	0.8591

Abundance (inds/m^2) of oribatid mites in Gardabani was low on active quarry, increased on older quarries and reclaimed sites and was highest on the natural meadow. Similarly, in Kavtiskhevi abundance was lowest on active quarry, increased along the quarry age and was highest in natural meadow (K4) (Table 4. Fig. 1).

Sample based rarefaction curveshows sampling completeness for natural meadow, 15 years old quarry (G2) and site (G4) reclaimed two years ago in Gardabani and for all the sites except of the active quarry in Kavtiskhevi (Figs. 2-3).

Oribatid mitesfound in natural meadow and open quarry are well separated from those found in older quarries and reclaimed sites in both, Gardabani and Kavtiskhevi territories (Figs. 4-5).

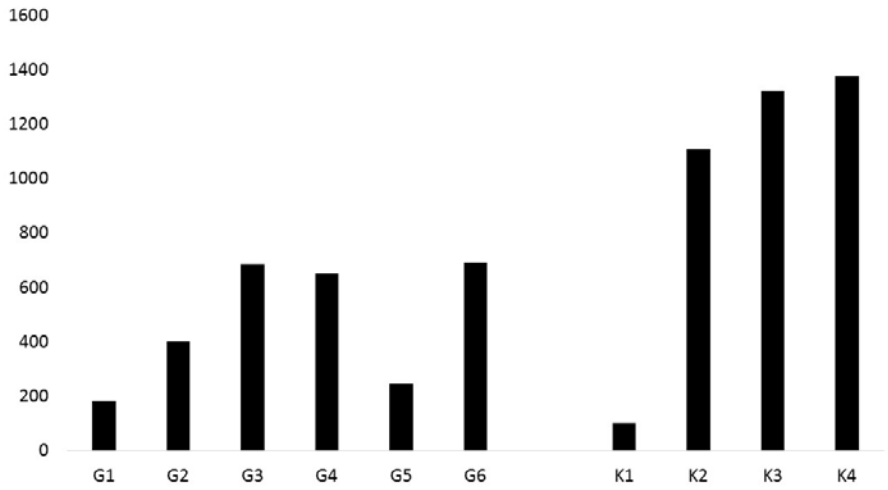

Fig. 1. Abundance of oribatid mites (inds/m^2) in Gardabani and Kavtiskhevi quarries

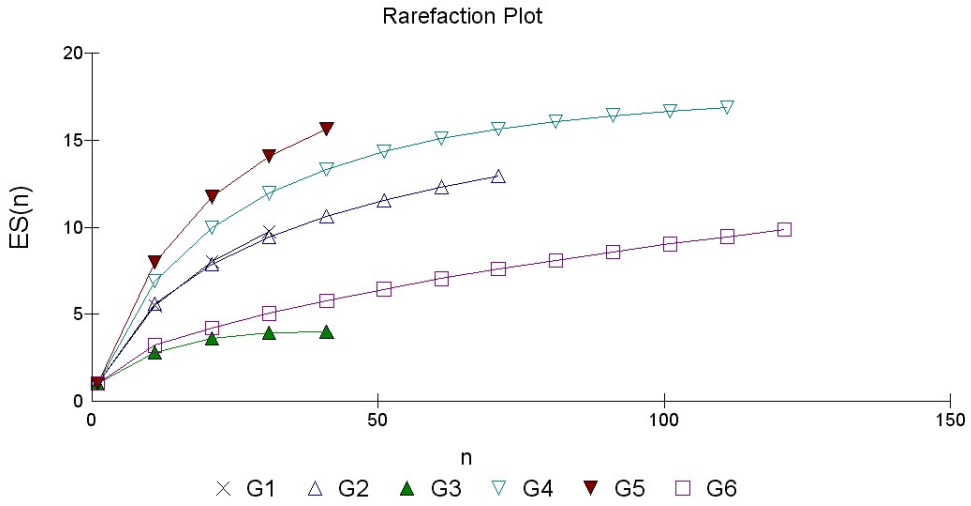

Figure 2. Oribatid mite species richness based on species accumulation curves and rarefaction methods for samples taken in Gardabani

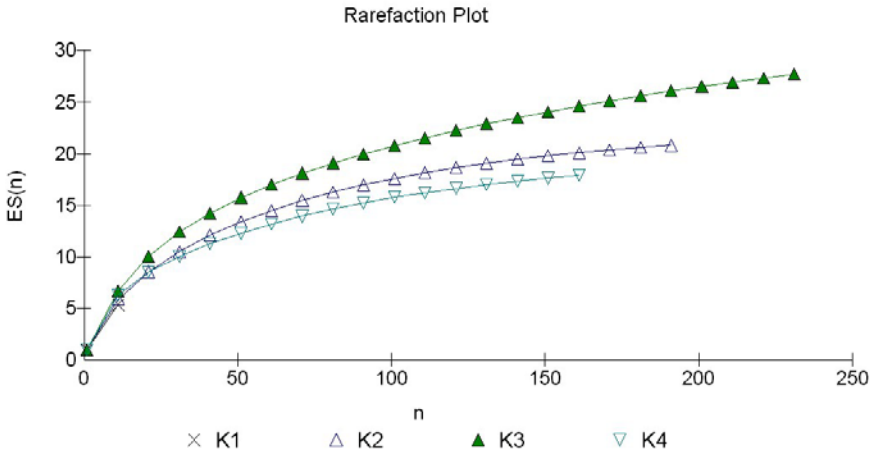

Figure 3. Oribatid mite species richness based on species accumulation curves and rarefaction methods for samples taken in Kavtiskhevi

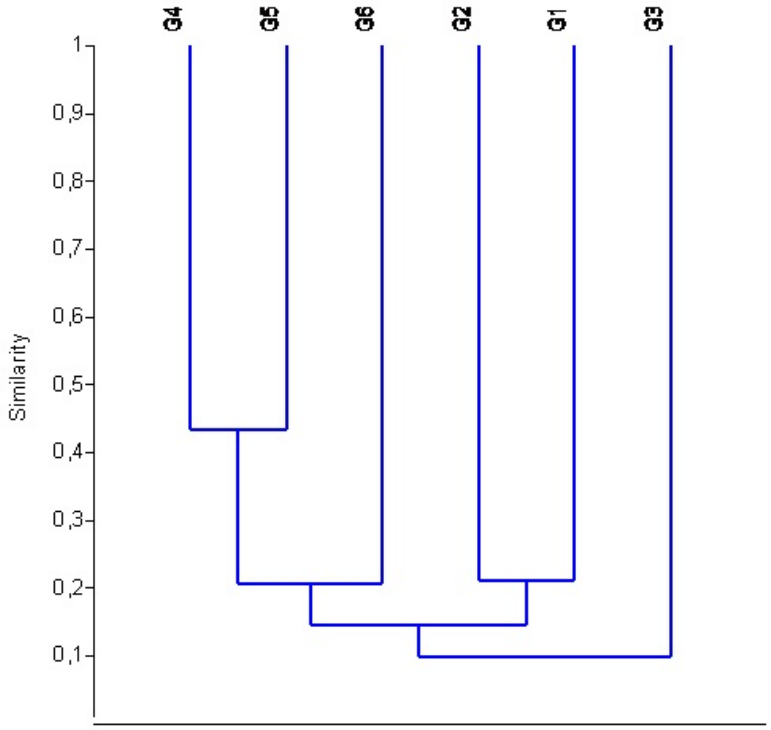

Figure 4. Cluster of faunal similarities of oribatid mites for Gardabani quarries

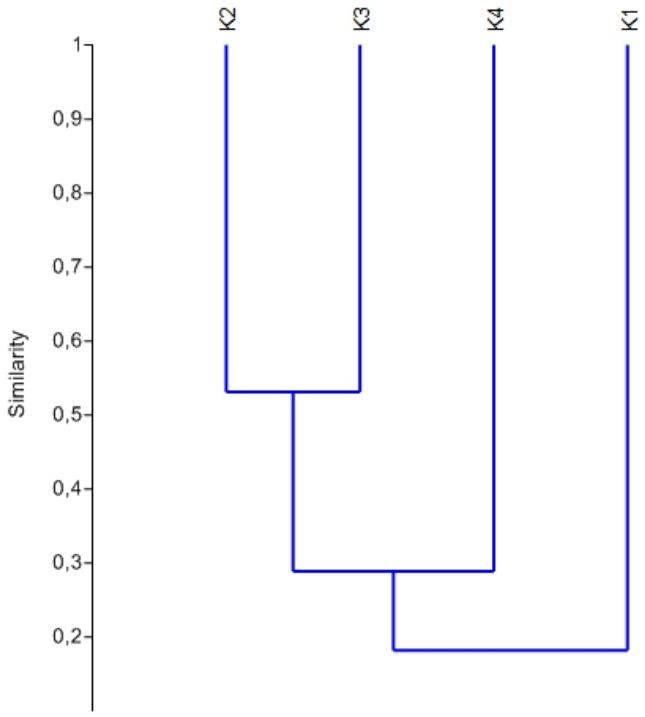

Figure 5.Cluster of faunal similarities of oribatid mites for Kavtiskhevi quarries

Discussion

New species for Georgia (*Phyllozetes tauricus* Gordeeva, 1978 new for Caucasus, *Simkinia schachthachtinskoi* (Kuliev, 1961), *Lasiobelba* sp.) were revealed during the research, thisenrichesthe diversity of the regional soil fauna.

In both locations species characterizing arid ecosystems are frequent, e.g.:*Papillacarus aciculatus* (Berlese, 1905), *P. tauricus* Gordeeva, 1978, *Sphaerochthonius splendidus* (Berlese, 1904), *Epilohmannia cylindrica* (Berleze,1904) and *Passalozetes africanus* Grandjean, 1932. Surprisingly, single individual of *Carabodes kintrishiana* Murvanidze, 2008 was also found, which is described from the humid mixed forest of Kintrishi Reserve [12].

In our study, the faunal composition differed significantly between post-industrial and natural habitats. In quarry sites*Zygoribatula frisiae* (Oudemans, 1916) and *P. puctum* (C.L. Koch, 1839) dominated, whereas in natural sites and old dumps rare and new for the Caucasus and Georgia species were found (see results section). *P. punctum* is considered to be a cosmopolitan species and a good colonizer during early stages of soil regeneration [13, 14]. It is usually frequent and abundant in urban and disturbed habitats [15, 16, 17, 18, 19] compared to the natural ones, where they are outcompeted by more successful species [20]. *Tectocepheus velatus velatus* (Michael, 1880) can also be regarded as a good colonizer. The same species played role of the first colonist on post-industrial dumps of manganese quarries [20].

For both, Gardabani and Kavtiskhevi quarries oribatid community composition found on quarry sites, seems to be still quite isolated from the reclaimed and natural ones (Figs 4-5). Provided reclamation measures in Gardabani successfully supported soil recovery showing faunal composition closer to natural meadow rather than to old quarries. However, natural succession going on the old quarries

(G2, G3, K2, K3) gradually recovers soil structure followed by development of diverse soil fauna and *vice versa*– quarry colonization by soil forming invertebrates improves soils structure making it more favorable for further colonization. Natural succession processes can support even more diverse fauna than artificial reclamation [20, 21] and rehabilitation via natural processes can be regarded as a good ecological restoration. However, artificial reclamation of abandoned dumps and quarries fastens successive processes of soil formation.

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References

1. Bielska I. (1996). Oribatida communities of deteriorated coniferous forests of Silesian industrial basin and the Karkonosze National Park.In: Rodger M., Horn D.J., Needham G.R.,W.Welbourn C. (Eds). Acarology IX, Proceedings 1:585-588.
2. Hutson B.R. (1980). The influence on soil development of the invertebrate fauna colonizing industrial reclamation sites. **Journal of Applied Ecology. 17(2):** 277-286.
3. Subías, L. S. (2014). Listado sistematico, sinonimico y biogeografico de los oribatidas (*Acariformes, Oribatida*) del mundo (1758–2002). **Graelsia 60** (numero extraordinario). 2004 Online version accessed in February 2014.577.http: www.ucm.es/info/zoo/Artropodos/Catalogo.pdf
4. Maraun M., Schatz H., Scheu S. (2007). Awesome or ordinary? Global diversity patterns of oribatid mites. **Ecography, 30**: 209-216.
5. Norton R.A., Behan-Pelletier V.M. (2009). Suborder Oribatida. In: Kranz G.W., Walter D.E. (Eds). A Manual of Acarology, 3rd edition. Lubbock: Texas Tech University Press. p. 430-564.
6. Norton R.A. (1994). Evolutionary aspects of Oribatid mite life histories and consequences for the origin of Astigmata. In: Houk M. (Eds). Ecological and evolutionary analyses of life-history patterns. Chapman and Hall. London. p. 99-135.
7. Dunger W., Wanner M., Hauser H., Hohberg K., Schulz H.J., Schwalbe T., Seifert B., Vogel J., Voigtländer K., Zimdars B., Zulka K.P.(2001). Development of soil fauna at mine sites during 46 years after afforestation. **Pedobiologia, 45**: 243-271.
8. Weigmann, G. (2006). Hornmilben (Oribatida). Die Tierwelt Deutschlands. 76 Teil. Goecke and Evers. Keltern.
9. Ghilarov, M. S.,. Krivolutsky, D. A. (1975). Identification keys of soil inhabiting mites.Sarcoptiformes. Moscow,Nauka(in Russian).
10. Schatz H., Behan-Pelletier V.M., Norton R.A. (2011). Suborder Oribatida van der Hammen, 1968. In: Zhang, Z.Q. (Ed.) Animal biodiversity: An outline of higherlevel classification and survey of taxonomic richness**. Zootaxa, 3148:** 141-148.
11. Simpson E.H. Measurement of diversity. (1949). **Nature. 163:** 689.
12. Murvanidze M. (2008). Checklist and key to species of Carabodes (Acari, Oribatida, Carabodidae) of the Caucasus Region, with description of a new species. **Acarina 16 (2):** 177-186.
13. Skubala, P. (1995). Moss mites (Acarina: Oribatida) on industrial dumps of different ages. **Pedobiologia, 39:** 170–184.
14. Skubala P., Gulvik A. (2005). Pioneer Oribatid mite communities (Acari, Oribatida) in newly exposed natural (glacier foreland) and anthropogenic (post-industrial dump) habitats.**Polish Journal of Ecology, 53 (3):** 395-407.

15. Maraun, M., Scheu S. (2000). The structure of oribatid mite communities (Acari, Oribatida): patterns, mechanisms and implications for future research. **Ecography, 23:** 374–382.
16. Maraun M., Salamon J.A., Schneider K. (2003). Oribatid mite and collembolan diversity, density and community structure in a moder beech forest (Fagus silvatica): effects of mechanical perturbances.**Soil Biology and Biochemistry, 35**: 1387-1394.
17. Murvanidze M., Kvavadze Er., Mumladze L., Arabuli T. (2011). Comparison of earthworm (Lumbricidae) and Oribatid mite (Acari, Oribatida) in natural and urban ecosystems. **Vestnik Zoologii. 45:** 233-241.
18. St. John, M. G., Bagatto, G., Behan-pelletier, V., Lindquist, E. E.,Shorthouse,D. Smith, I. M. (2002). Mite (Acari) colonization of vegetated mine tailings near Sudbury, Ontario, Canada. **Plant and Soil, 245:** 295–305.
19. Weigmann G. (1995). Zur Bedeutung von Hemerobie und Habitatstructur für Hornmilben (Acari, Oribatida) in Stadtparks and Ruderalflachen. **Schr. R.f. Vegetationskunde, 27**: 202-210.
20. Murvanidze, M., Mumladze, L., Arabuli,T., Kvavadze, Er. (2013). Oribatid mite colonization of sand and manganese tailing sites.**Acarologia, 53(2):** 127-139.
21. Skubala, P. (2006). Do we really need land reclamation on dumps? (Oribatid fauna case studies). **Advances in Polish Acarology**, 367–374.

ჯავშნიანი ტკიპების მრავალფეროვნება კირქვისა და თიხის კარიერებზე

მ. მურვანიძე და ნ. თოდრია

რეზუმე

„ჰაიდელბერგცემენტ ჯორჯიას“ გარდაბნის თიხისა და კავთისხევის კირქვის კარიერებზე შევისწავლეთ ჯავშნიანი ტკიპების მრავალფეროვნება. ნიადაგის სინჯები ავიღეთ კარიერებზე, რომლებიც სხვადასხვა დროს ფუნქციონირებდნენ და ასევე, მიმდებარე ბუნებრივ ეკოსისტემებში, რომლებიც განიხილებიან, როგორც საკონტროლო ტერიტორიები. კერძოდ, გარდაბანში კვლევა ჩატარდა ღია (G1), 15 წლის წინანდელ (G2) და 40 წლის წინანდელ კარიერებზე (G3), ხელოვნურად აღდგენილ ტერიტორიებზე (G4-G5) და ბუნებრივ მდელოზე (G6) (ცხრილი 1), ხოლო კავთისხევში – ღია (K1), 20 (K2) და 80 წლის (K3) წინანდელ კარიერებსა და ბუნებრივ მდელოზე (K4) (ცხრილი 2). გარდაბანის თიხის კარიერის ექვს ნაკვეთზე რეგისტრირებული იქნა ორიბატიდების 39 სახეობა. მათგან *Phyllozetes tauricus* Gordeeva, 1978 ახალია კავკასიის ფაუნისათვის. 40 სახეობა იქნა რეგისტრირებული კავთისხევში, საიდანაც *Simkinia schachthachtinskoi* (Kulijev,1961) და *Laisobelba* sp. ახალია საქართველოს ფაუნისათვის (ცხრილი 3). როგორც გარდაბნის, ისე კავთისხევის კარიერებზე აღინიშნება სახეობათა რაოდენობის და დასახლების სიმჭიდროვის თანდათანობით ზრდა კარიერების ასაკის მატებასთან ერთად (ცხრილი 4. სურ. 1), რაც მიუთითებს ნიადაგის ფორმირების აქტიურ პროცესებზე. ფაუნისტური მსგავსების კლასტერი მიუთითებს როგორც ღია ასევე ძველი კარიერების ორიბატიდების იზოლაციას აღდგენილი ნაკვეთების და ბუნებრივი მდელოს ფაუნისაგან (სურ. 4, 5). როგორც ჩანს, ძველ კარიერებზე (G2, G3, K2, K3) მიმდინარე ბუნებრივი სუქცესიური პროცესების შედეგად წარმატებით მიმდინარეობს ნიადაგის სტრუქტურის აღდგენა,

რასაც მოსდევს ნიადაგის ფაუნის აღდგენა და პირიქით - ნიადაგის ფაუნის აღდგენა განაპირობებს ხელსაყრელ პირობებს უხერხემლოების შემდგომი კოლონიზაციისათვის. ცნობილია აგრეთვე, რომ ბუნებრივი სუქცესიის შედეგად ფორმირდება ზოგჯერ მეტად მრავალფეროვანი ფაუნაც კი, ვიდრე ხელოვნური აღდგენის დროს და ეს პროცესი განიხილება, როგორც კარგი ეკოლოგიური რეაბილიტაცია. მიტოვებული კარიერებისა და ნაყარების ხელოვნური აღდგენა აჩქარებს ნიადაგის ფორმირების სუქსცესიურ პროცესებს.