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PALEOCRYOGENESIS AND SOIL FORMATION

TRACE ELEMENTS IN THE RESIDUAL SOIL OF OASIS BEDROCKS, GALINDEZ ISLAND, WEST ANTARCTICA

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The results of studying the content of heavy metals, rare earth elements and strontium in the surface formations of Galindez Island, western Antarctica, have been presented. Identification of the content of mobile forms of these chemical elements makes it possible to determine the characteristics of their migration and accumulation in environmental objects. Based on these results, conclusions have been made that the maximum number of mobile forms of Cu, Pb, Zn and of the most part of the rare earth elements are supplied into the clay fraction of residual soil as a result of bedrock destruction. The clay-silt fraction with admixture of organic matter is characterized by the maximum content of Sr. Moss contains the maximum number of the mobile forms of Fe. The content of the mobile forms of strontium in moss is much higher than in the surface deposits. This allows one to suggest that the possible supply and accumulation of Sr occurs from the atmosphere.

Galindez Island, chemical composition, environmental objects, metals, rare earth elements

INTRODUCTION

Due to continuous environmental and geochemical monitoring of environmental objects of western Antarctica planned by the National Antarctic Scientific Center of Ukraine to be conducted in 2014, it seems especially important to investigate the conditions of migration of chemical elements in different chains of the natural landscape: bedrock–sediments–water–biota.

The first phase of our study is to investigate individual microelements in the basic objects of the surface deposits of an oasis on Galindez Island. Antarctic oases are small for their size and free from glaciation parts of the littoral zone of Antarctica. Geochemical studies of environmental objects located in the oases allow answers to be found for the questions regarding the sources of supply of chemical elements, as well as a whole series of environmental problems to be solved.

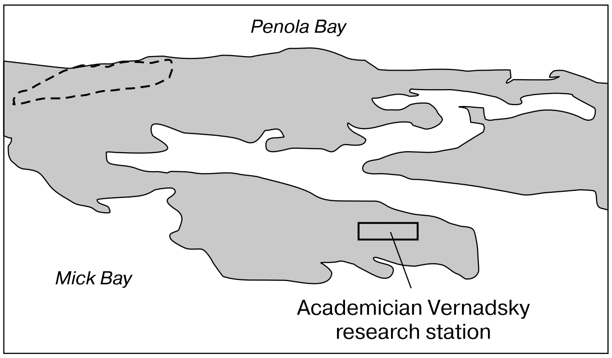

Fig. 1. A layout of Galindez Island (the dashed line designates the oasis territory).

Although the Antarctic oasis territory is unique for its properties, geochemical works to determine microelements in the environmental objects have not been conducted there yet. Therefore the data on the content of microelements are provided herein for the first time.

THE GENERAL CHARACTERISTIC OF THE OASIS

The oasis in question is located on the northern slope of Galindez Island (Fig. 1), the largest one in the Argentinian Islands archipelago, consisting of about 15 comparatively small islands with the total area of about 10 km^2. The Ukrainian Antarctic station *Academician Vernadsky* is located on Galindez Island. The area of Galindez Island is 0.43 km^2, and that of the oasis is 0.016 km^2.

The oasis altitude varies from 51 m (the absolute height of the top of Woozle Hill) to the foot of the slope at the level of 10 m above sea landwash in the Mick Bay. The oasis width varies from 30 to 70 m, its average steepness in the upper part is 12–15°, in the lower part it is 50–90°.

The bedrocks of the oasis are represented by rhyolite and its changed variations. Residual soil unevenly spread across the bedrocks consists of detritus, granitic subsoil, and a clay fraction, the latter often containing part of organic remains.

Vegetation is represented by mosses, lichens, cyanobacteriae, and bacterial communities.

Moss (Marchantiophyta) fills depressions in rock clefts; forms moss cover on wet slopes and escarpments, building up significant accumulations of necrotized mass. It is likely that moss accounts for the largest contribution to the formation of humus substrates on the oasis.

Among the symbioses formed by algae, their symbiosis with fungi is of greatest interest, known as a lichen symbiosis, as a result of which there arose a specific group of plant organisms called lichens. In the oasis territory, several varieties of lichens were found: crustose, fruticose, and foliose lichens.

Algae are widely found within the oasis and suggest their significant influence on the formation of landscapes both as their immediate component and as a powerful source of organic matter. On the surface of bare rocks, diatomic and some (mostly one-celled) green algae grow; yet, representatives of cyanobacteria are most common in these habitats.

Algae and the accompanying bacteria form the so-called "rock film" on crystalline rocks of different mountain ranges. Loose rock, which gets accumulated in depressions on rocks subject to weathering, is normally a habitat for one-celled green algae and cyanobacteria.

Especially rich are the algae living on the surface of wet rocks, where they form films and crust of different colors. As a rule, species with thick slimy covers live there. Depending on the intensity of illumination, slime may be more or less intensely colored, thus determining the color of the vegetation. It may be bright-green, golden, dirt brown, ochre, purple or dark blue and green, brown, and nearly black, depending on the species constituting it.

Primitive soils (humus substrates) are formed in the territories devoid of vegetation for different reasons, to the formation of which algae make an essential contribution.

METHODOLOGY

Geochemical testing of surface deposits and moss was conducted in December, which is one of the warmest months in Antarctica. 10 samples were taken from residual soil, the clay fraction and the clay-silt fractions with significant admixture of organic remains (parts of moss, bird excrements, etc.), as well as mosses.

As the character and the specific migration features of chemical elements constitute one of the criteria of geochemical monitoring, the content of microelements and their mobile forms were studied in the environmental objects in question.

The analytical works were performed in the Semenenko Institute of Geochemistry, Mineralogy and Ore Formation, National Academy of Sciences of Ukraine (IGMOF, NANU), with different methods employed: potentiometric analysis – pH, Eh, F; nuclear absorption – heavy metals and their mobile forms (Zn, Cu, Co, Pb, Ni, Fe) [*Zhovinsky and Kurayeva, 2002*]. Surface deposits and moss are characterized by a weakly acidic reaction with insignificant pH variations (5.1–5.6). Such physical and chemical conditions of the environment are most favorable for migration of the majority of heavy metals. This is corroborated by the results of identifying their mobile forms in the sedimentary formations overlapping bedrocks.

A mass-spectrometer with inductively coupled plasma was used to identify rare earth metals (*ISP-MS Element-2* mass spectrometer manufactured by Thermo Finnigan, Germany).

The methodology of identifying the mobile forms of rare earth elements consisted in the following: 0.2 g of the sample (sifted and ground) was placed in a cup, and 10 ml of the normal solution of HNO_3 (very pure) was added to it, and the mixture was mixed in a magnetic mixer during 30 minutes, H_2O_2 was added to the mixture (3–5 drops to remove organic matter), then it was filtered with a white band filter and finally an aliquot was taken to be analyzed with the ISP-MS.

RESULTS

Rhyolites and their changed varieties are the main rocks of the oasis bed [*Artemenko et al., 2012*], characterized by medium content of heavy metals (mg/kg): Zn – 60; Cu – 10; Co – 5; Pb – 20; Ni – 8, Fe – 2700.

Migration from the bedrock and the specific features of accumulation of heavy metals in landscape bodies are shown in 3D diagrams (Fig. 2). It has been found that the maximum content of the mobile forms of Zn, Cu, Pb is typical of the clay fraction of the residual soil. Accumulation of the mobile forms of Co and Ni is more uniform. Mosses are characterized by maximum accumulation of the mobile forms of Fe. In the case of the increase in the share of iron sulfate compounds, moss turns brown and dies.

The specific feature of the migration of heavy metals into weathering products is quantified by a calculated conditional rate of weathering (%), i.e., the ratio between the content of the mobile forms of a chemical element in a body under study and its total content in the bedrock, multiplied by 100 (Table 1). Due to the high sorption ability of the clay fraction, the maximum amount of the mobile forms of Cu, Pb, Zn (22, 20 and 11.7 %, accordingly) gets there. Accumulation of Co, Ni, Fe and formation of organic-metallic compounds are characteristic of the clay-silt fraction with organic admixture – 14, 8.8 and 31.5 %,

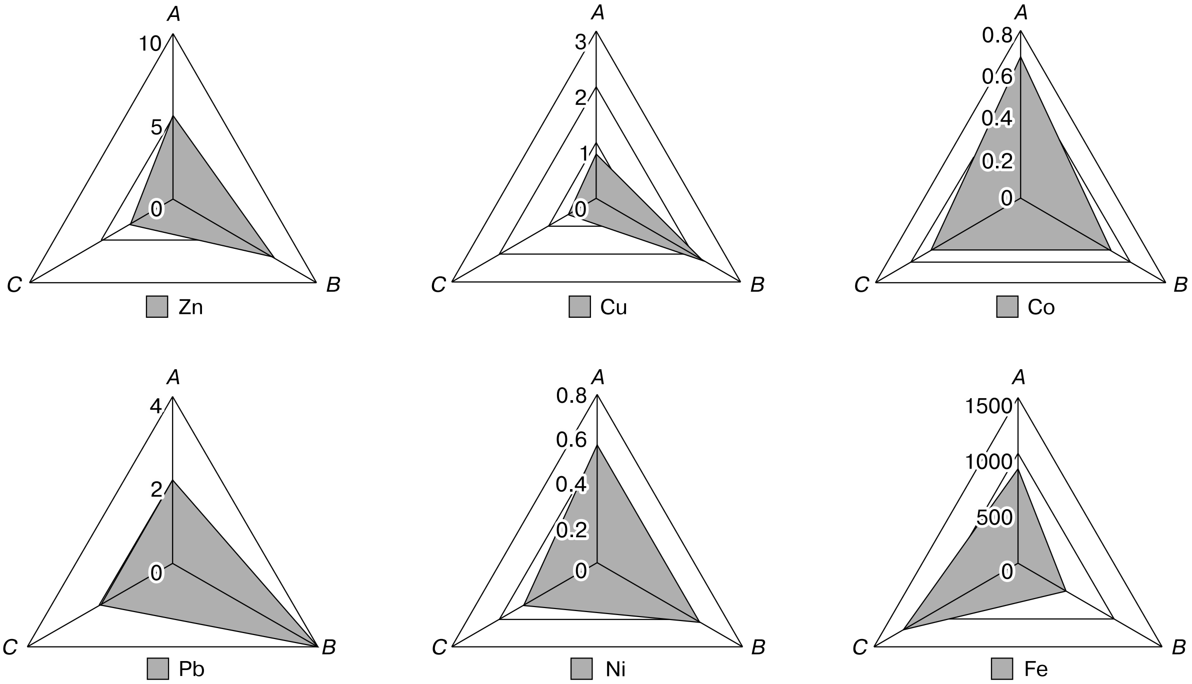

Fig. 2. 3D diagrams of the content (mg/kg) of the mobile forms of heavy metals in environmental objects of the oasis.

A – clay-silt fraction with organic admixture; *B* – clay fraction; *C* – moss.

T a b l e 1. **The weathering factor (%) of bedrock in the oasis of Galindez Island**

Object under study	Metals, %					
	Zn	Cu	Co	Pb	Ni	Fe
Clay-silt fraction with organic admixture	8.3	8.0	14.0	10.0	8.8	31.5
Clay fraction	11.7	22.0	10.0	20.0	8.8	18.5
Moss	5.0	6.0	10.0	10.0	6.3	44.4

N o t e. The tests were conducted in the laboratory of IGMOF, NANU by the method of nuclear absorption.

T a b l e 2. **Content of mobile forms of rare earth elements and strontium on environmental objects of an oasis on Galindez Island**

Chemical element	Clay-silt fraction with organic admixture ($C + \Delta$), ppm	Clay fraction ($C + \Delta$), ppm	Moss ($C + \Delta$), ppm	Detection limit
Sr	131.1 ± 7.0	31.4 ± 0.4	1023.4 ± 50.0	<10–100 ppq
Y	6.3 ± 0.8	6.0 ± 0.8	0.045 ± 0.007	<100 ppq
La	2.3 ± 0.3	5.8 ± 0.5	0.018 ± 0.006	<10 ppq
Ce	5.1 ± 0.6	13.2 ± 1.0	0.040 ± 0.005	<5 ppt
Pr	0.70 ± 0.08	1.7 ± 0.3	0.0050 ± 0.0008	<5 ppt
Nd	3.6 ± 0.5	7.4 ± 0.5	0.020 ± 0.004	<5 ppt
Sm	0.980 ± 0.008	2.1 ± 0.3	0.010 ± 0.003	<5 ppt
Eu	0.18 ± 0.01	0.40 ± 0.05	0.010 ± 0.005	<5 ppt
Gd	1.2 ± 0.2	1.9 ± 0.2	0	<5 ppt
Er	0.60 ± 0.09	0.70 ± 0.08	0.010 ± 0.002	<5 ppt
Yb	0.40 ± 0.08	0.60 ± 0.05	0.0020 ± 0.0004	<5 ppt
Lu	0.060 ± 0.009	0.080 ± 0.009	0.0010 ± 0.0003	<5 ppt
Tm	0.080 ± 0.007	0.10 ± 0.01	0.000 50 ± 0.000 07	<5 ppt
Ho	0.30 ± 0.04	0.2765	0.000 50 ± 0.000 09	<5 ppt
Dy	1.2 ± 0.2	1.5 ± 0.2	0.0090 ± 0.0006	<5 ppt
Tb	0.200 ± 0.001	0.30 ± 0.06	0.0010 ± 0.0003	<5 ppt

N o t e. The tests were conducted in the laboratory of IGMOF, NANU by the method of ISP–MS.

accordingly. Moss is characterized by maximum supply and accumulation of the mobile forms of Fe (44.4 %), the element required for the normal growth of a plant. Worthy of interest was distribution of the mobile forms of rare earth elements and of strontium (Table 2). The clay fraction is characterized by the relatively high content of rare earth elements, their content in the clay-silt fraction with organic admixture is approximately two times less. The content of rare earth elements in moss is tens, hundreds and thousands times less than that in the above mentioned fractions. At the same time, moss is characterized by the maximum content of strontium (1,023.4 mg/kg), which is three times as much as the average content of this element in the bedrock (rhyolites contain Sr in the amount of 300 mg/kg). Based on the results obtained, we can assume that accumulation of the stable isotope ^{88}Sr from the atmosphere takes place in the oasis.

CONCLUSIONS

Results have been reported on the study of the content of heavy metals, rare earth elements and strontium in the surface formations of Galindez Island (western Antarctica). It has been established that the maximum content of the mobile forms of Zn, Cu, Pb is characteristic for the clay fraction of residual soil, while accumulation of the mobile forms of Co and Ni proceeds more uniformly.

Based on the weathering factor calculated, it was found that maximum amount of the mobile forms of Cu, Pb, Zn gets deposited in the clay fraction; the clay-silt fraction with organic admixture is characterized by accumulation of Co, Ni, Fe and formation of organometallic compounds. Moss is characterized by maximum supply and accumulation of the mobile forms of iron and strontium. This allows us to assume that supply and accumulation of Sr originate from the atmosphere.

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