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ENVIRONMENTAL RADIOACTIVITY OF THE KARADAG GEOTOURISTIC SITE (UKRAINE)

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The results of the radioecological mapping in the Karadag Nature Reserve, Crimea are presented. The results indicate on the low content of the natural nuclides. Described nuclides are typical for the oceanic bottom volcanisms. Laboratory investigations also indicate on the relatively low content of the natural radionuclides. This anomaly is connected with local accumulation of soil.

Key words: Karadag, radioactivity, spectrometric mapping.

Karadag Nature Reserve of the National Academy of Sciences of Ukraine situated at the southern coast of Crime is the number one geotouristic attraction of the region and its Golden (or Devil's) Gate is the most popular post card motive of the area. Its is unique not only from the geological point of view, but due to location at the contact of Mediterranean with the Great Steppe is a treasure chest of biodiversity. 2874,2 hectares of protected area forms habitat for 2 800 flora and 5 300 fauna species.

Radiometric study described below is a part of environmental monitoring program of the Environmental Station of the Karadag Nature Reserve. It is continuation of preliminary study performed by Tyshenko in 2007 [1] who found slightly increased gamma radiation dose at the Chronyj Yar site.

Karadag Volcanic Massif (KVM) is a remnant of the Middle Jurassic island arc volcanism which took place at the southern margin of Laurasia. It was here where, already in the Late Paleozoic and Early Mesozoic north-dipping subduction system developed within Thetys Ocean along the southernmost part of Laurasia [2, 3]. Although in the centre of the Laurasian continent the core of the East-European Craton (with Ukrainian and Fennoscandian parts) existed (fig. 1), their southern prolongation was covered by the sediments of the Scythian– Platform. Back-arc rifting dominated here since Triassic and the Tauric Flysh Basin

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in nowadays Crimea was formed. The gradual consumption of Paleotethys was accompanied by simultaneous opening of the Neotethys Ocean.

The Paleotethys Ocean was finally closed in the western part of the Tethyan realm already in the Early Jurassic. After a phase of Late Triassic–Early Jurassic compression, a rifting regime was re-established locally within the southern edge of Laurasia and continued through Middle to Late Jurassic times. However, in the Early - Middle Jurassic subduction of the Neotethys under the western part of the Scythian–Turan Platform dominated [3] and subduction related igneous activity developed in the Mountainous Crimea.

Finally, in the Middle Jurassic, the Pontides plates collided with the southern margin of Laurasia, closing remnants of the Triassic rift and back-arc system of basins and causing deformations in the Mountainous Crimea and adjacent areas. Later on, the period of relative geotectonic stability resulted in the Upper Jurassic-Lower Cretaceous carbonate platform development on the southern margin of the Laurasia [4].

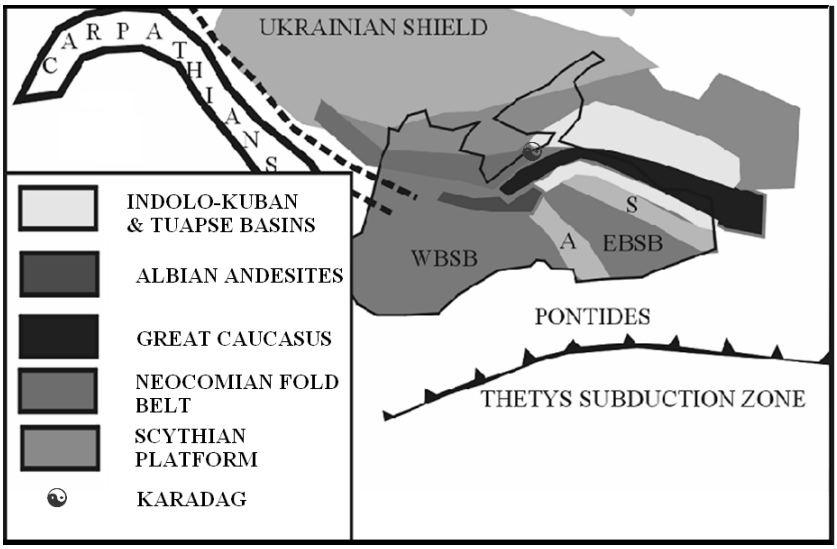

Fig. 1. Geological position of the Karadag Nature Reserve, WBSB – Western Black Sea Basin, EBSB-Eastern Black Sea Basin, A – Andrusov Ridge, S – Shatsky Ridge

Volcanic sequenceof KVM has been strongly tectonically deformed (locally overturned) due to Late Jurassic tectonic movements. As a result, the volcanic massif is encapsulated between underlying Lower Jurassic Tauric Flysh Series and Upper Jurassic sediments. It is composed of 1 500 m thick sequence of volcanic rocks represented: by andesites, basaltic andesites basalts, trachyandesites, dacites, rhyolito-dacites, rhyolites sometimes basanites trachytes in form of lava flows, pyroclastic breccias and welded tuffs. Locally dykes, necks and small subvolcanic bodies occur. Pillow lavas of the lower part of the sequence originated in submarine environment, while welded tuffs must have been deposited on preexisting land surface.

Field survey concentrated on observation of geomorphologic and geological phenomena combined with radiometric mapping and soil sampling has been performed on the slopes of Karagach Mt forming the western end of the KVM.

Concentrations of natural radionuclides (K, U,Th) has been measured by means of the GR-320 gamma spectrometer with internal ^{137}Cs source used for calibration. Because of calibration source this kind of equipment is useless for ^{137}Cs mapping. Preliminary information about ^{137}Cs occurrence was obtained by comparison of natural radionuclides content (and their gamma dose) with total gamma dose measurements obtained by means of the Geiger Mueller type counter RKP-1.

Soil samples have been taken in the Chornyj Yar, the area of eroded material deposition, where discrepancy between measured gamma dose and this produced by natural radionuclides was found. Radionuclides content of the soil samples have been measured by means of the Ge(Li) gamma spectrometer.

Radiometric mapping has been performed using an Exploranium GR-320 gamma radiation spectrometer with the standard NaI(Tl) GPX-21A detector of 0,35 L volume. Calibration of the detector was performed by the producer using traceable test pads. Impulses supplied by the detector probe were classified using channels 70–204 of the 256 channels of the spectrometr covering the energy window 850–2810 keV.

Three bands (Regions of Interests, ROI) corresponding to energy windows of radionuclides peaks ^{40} K, ^{214}Bi and ^{208}Tl have been set up (table 1).

Table 1

Gamma ray spectrometer GR-320 energy windows characteristics

Band	Radionuclide peak	Channells	Energy window (keV)	Sensitvity
RO/2	^{40}K40 1460 keV	109–122	1 370–1 570	0,661 cps/%
RO/3	^{214}Bi 1760 keV	129–142	1 660–1 860	0,067 cps/ppm
RO/4	^{214}Tl 2620 keV	179–204	2 410–2 810	0,025 cps/ppm

The problem of stabilization of energy windows of channels was solved by means of continous measurement of caesium 662 keV photons from internal source in the band RO/1 covering channels 51–60 (600–730 keV). The gain parameter responsible for fitting channels to energy windows was continuously updated using least-squares fit of a Gaussian cesium peak shape every time the 5 000 level of Cs counts was exceeded. This ensured that the system gain was always correct and selected channels corresponded to the desired energy windows.

Measured activities of radon and thoron daughters were recalculated into uranium and thorium concentrations (in ppm) assuming existence of equilibrium in uranium and thorium decay series, what is a common practice in this kind of measurements marked by eU and eTh notation instead of U and Th. For each measurement the detector was deployed in the field using a geometry as close as possible to 2П. Sampling time ranged from 15 to 30 minutes depending on local radionuclides content to reach statistically significant counts in all ROI's. Ambient temperature during measurements was in the range 0 to 5 ^{o}C.

Area under investigation is located on the southern slopes of the Karagach Mt being the westernmost part of the KVM (fig. 2). Top of the mountain and its southern slope is composed of the volcanic series. Tauric Flysh series forms only the northern foothills. Numerous ravines form in predominantly clayely flysh series and the most prominent one called Chornyj Yar borders outcrops of more resistant rocks of the Volcanic Complex. Chornyj Yar forms here the main drainage pattern canalizing debris flow from the main rock wall in the narrow gorge located 2 m a.sl.

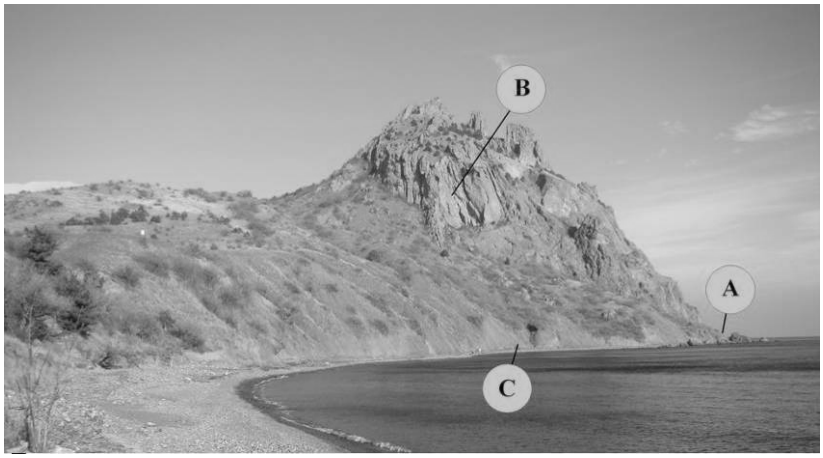

Fig. 2. Western slopes of the Karagach Mt with marked areas of radionulides measurements: A – Basalts, B – Andesites, C – Jurassic shales

Fig. 3. Chornyj Yar

Northern (left on the fig. 3) wall of the gorge is moving south, gradually closing mouth of the ravine. Narrowing of the ravine mouth results in debris accumulation in small grass covered terrace (see fig. 3 where two persons stand). This movement is connected with active slide along slickenside surface (tectonic mirror) visible in low cliff located 10 m north along the coast of the ravine mouth (fig. 4).

Fig. 4. Slip surface of the northern slope of the Chornyj Yar

Summary statistics of K, eU and Th concentration in Tauric Flysh Series and Volcanic Complexes of basaltic and andesitic chemistry has been presented in table 2. Distribution histograms for all measurements have been presented in fig. 5, 6, 7

Table 2

Summary statistics of K, eU and eTh results

	K(%)	eU (ppm)	eTh (ppm)
Tauric Flysh Series			
Mean	2,8	2,8	15,6
Standard deviation	0,3	1,0	1,9
Basalt Volcanic Complex			
Mean	0,8	0,7	2,5
Standard deviation	0,1	0,4	0,5
Andesite Volcanic Complex			
Mean	2,0	0,9	5,6
Standard deviation	0,6	0,8	2,0

Obtained results indicated that generally KVM is of low natural radionuclides content characteristic for the ocean bottom related volcanites [5, 6]. Uranium content is definitely lower than the lithospheric clark (2,5 ppm after Perelman 1971 [7]) Comparison of obtained results with average radionuclides content of various rocks is shown in fig. 8.

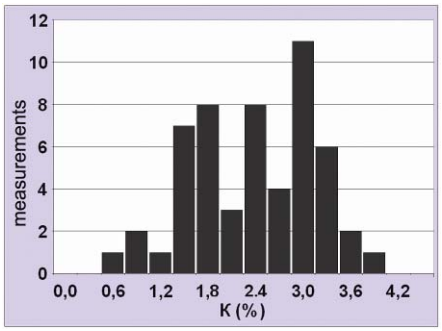

Fig. 5. Frequency distribution of K content on the western slopes of the Karagach Mt

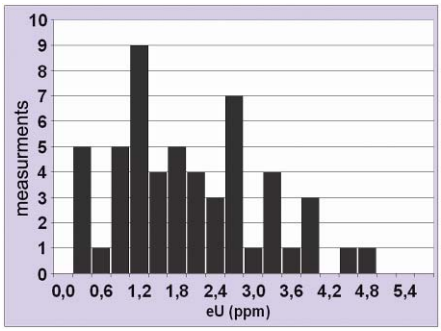

Fig. 6. Frequency distribution of eU content on the western slopes of the Karagach Mt

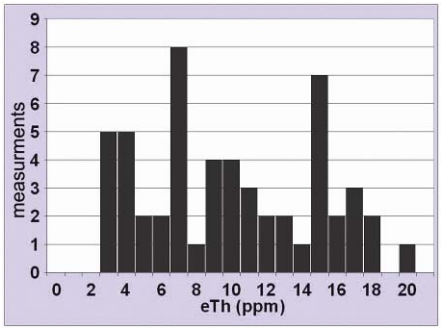

Fig. 7. Frequency distribution of eTh content on the western slopes of the Karagach Mt

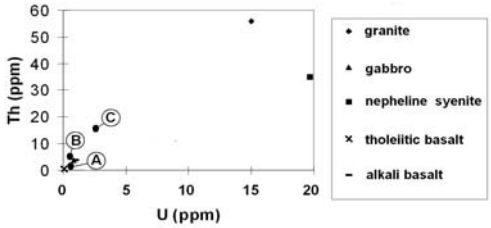

Fig. 8. Comparison of obtained results with average radionuclides content of various rocks: A – Basalt Volcanic Complex, B – Andesite Volcanic Complex, C – Tauric Flysh Series

Results of laboratory soil samples analyses confirmed relatively low natural radionuclides content. Even the highest results for potassium and uranium and thorium decay series marked in bold in table 3 correspond to 2,5% of K, 6 ppm of U and 13,3 ppm of Th what is within the range detected in the field especially in the case of clayely material. Cesium content is comparable with results obtained by Soileau et al. 1990 [8] for areas of accumulation of eroded material in Alabama.

Table 3

Results of HP Ge laboratory analyses of soil samples

	Sample 1 0–0,15 m	Sample 2 0–0,15 m	Sample 3 0,15–0,3 m	Sample 4 0,15–0,3 m
^{137}Cs	70	4,8	3,99	30,3
^{40}K	752	741	750	638
^{226}Ra	63,6	51,3	74,7	44,7
^{214}Bi	29,5	23,8	24,6	20,1
^{214}Pb	30,1	29,9	25	23,9
^{212}Pb	56,5	51,7	49,5	43,9
^{212}Bi	41,9	46,5	46,8	48,5
^{232}Th	54,6	53,1	47,6	42,6
^{228}Ac	52,9	51,1	45,5	41,1
^{208}Tl		17,5	18,1	16,5
^{152}Eu-	7,14			
^{133}Ba		20		

Obtained results indicated that generally KVM is of low natural radionuclides content characteristic for the ocean bottom related volcanites. (K < 3%, U < 3 ppm, Th < 15 ppm) Traces of anthropogenic cesium activity although can be interesting tool for denudation studies are insignificant from the ecological point of view. Performed investigations confirmed the existence of small scale anomaly in the Chrony Yar at the sea coast detected in August 2007 by Tyshenko. This anomaly is connected with local accumulation of soil material and terrain configuration resulting in gamma ray emission both from bottom and walls of the gorge. This kind configuration is definitely different from standard flat surface measurement and may result in doubling of gamma dose obtained.

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ПРИРОДНА РАДІОАКТИВНІСТЬ КАРАДАГЗЬКОГО НАЦІОНАЛЬНОГО ПАРКУ (УКРАЇНА)

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Представлені результати радіоекологічного картування в районі Карадагу, Крим. Результати досліджень свідчать про низький вміст природних нуклідів. Такі нукліди є типовими для вулканітів океанічного дна. Лабораторні дослідження також засвідчують відносно низький вміст природних радіонуклідів. Локальна аномалія в Чорному ярі пов'язана з акумуляцією ґрунтів.

Ключові слова: Карадаг, радіоактивність, радіоекологічне картування.

ЕСТЕСТВЕННАЯ РАДИОАКТИВНОСТЬ КАРАДАЗЬКОГО НАЦИОНАЛЬНОГО ПАРКА (УКРАИНА)

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Представлены результаты радиоэкологического картирования в районе Карадага, Крым. Результаты исследований указывают на низкое содержание естественных нуклидов. Такие нуклиды являются типичными для вулканитов океанического дна. Лабораторные исследования также указывают на относительно низкое содержание естественных радионуклидов. Локальная аномалия в Черном яре связана с аккумуляцией почв.

Ключевые слова: Карадаг, радиоактивность, радиоэкологическое картирование.

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