Acta Mineralogica-Petrographica, Szeged, XL, 121–138, 1999

NATURAL RADIOACTIVE ELEMENT CONTENT OF THE OLD CRYSTALLINE ROCKS IN SOUTHERN TRANSDANUBIA (SW HUNGARY)

E. PÁL MOLNÁR*, I. VADOS**, I. GERZSON**, B. KÓBOR*

*Department of Mineralogy, Geochemistry and Petrology, Attila József University
**Mecsekérc Environment Protection Co.

ABSTRACT

On the basis of systematisation of several thousand radioactive element content analyses made in laboratories since the 50's, U and Th content of old granitoid rocks of Southern Transdanubia proved to be much higher than the average U and Th content of granitoids in the world. This value of rocks from areas west of Mecsek Mountains as well as near Szalatnak village and Pécs city is twice higher than the world average. Areas west of the Mecsek Mountains show higher U and lower Th contents than areas east of these mountains. Uranium accumulation is higher in aplites and hydrothermal formations than in granites.

The western and eastern granites are less and highly sensitive to leaching, respectively. The intensive U migration resulted in significant U accumulation in young sediments in some places.

INTRODUCTION

Study of natural radioactive element (U /Ra/, Th, K) content of the rocks in Hungary was performed by the Mecseki Ércbányászati Vállalat (Mecsek Ore Mining Company) until 1990, when uranium exploration was stopped in Hungary. Aim of the analyses was to research U sources, therefore, rocks supposed to contain perspective U accumulation were mainly studied.

The aim of this paper is to elaborate many thousands radiological data of granitoid rocks, gneisses and amphibolite-like metamorphic rocks coming from Southern Transdanubia (south of the Szekszárd-Kaposvár-Kutas line to the state boundary, and east of the Kutas-Csokonyavisonta-Barcs line to the Danube).

Data bank of the late Mecseki Ércbányászati Vállalat Kutató Mélyfúró Üzem (Mecsek Ore Mining Company, Research and Drilling Branch) was used as a basis of our study. Now, this data bank is owned by the Magyar Geológiai Szolgálat (Hungarian Geological Survey) and managed by the Mecsekérc Környezetvédelmi Rt. (Mecsekérc Environment Protection Co.).

SUMMARY OF THE APPLIED METHODS AND HISTORY OF RADIOLOGICAL STUDIES ON OLD CRYSTALLINE ROCKS IN SOUTHERN TRANSDANUBIA

Because of the veins containing U ore, radiological research were begun in granite areas all over the world. Similarly, granite was the first rock which was studied by

* H-6701 Szeged, P.O.Box 651, Hungary
** H-7633 Pécs, Esztergár út 19., Hungary

radiological methods in Hungary. Scientific and industrial research began in 1948 and 1953, respectively.

In Southern Transdanubia the first radiometric measurements were performed in the granite area near Mórágy village as the greatest surficial granite occurrence in Hungary. Research of the environment of two small granite outcrops near Nyugotszenterzsébet and Nagyváty village situated in the westernmost part of the Mecsek Mountains was begun as late as the early 60's. Granite outcropping in the city of Pécs town, although it has been known for a long time, can be studied only in a very limited area, and the rock is quite weathered.

Granite is slightly explored even in the Mórágy Mountain, however, aerial and field (by car and on foot) gamma-radiation measurements were performed since the middle of the 50's. Since the significant covering, soil gas-radon method was also used in the beginning of the industrial research work. Detailed study of the radioactive anomalies and areas of higher radioactivity was made by removal of the soil cover (trench or pit) or by drilling. Of course, granite and other crystalline rocks of the basement were also exposed by drilling that were made to expose the Permian sedimentary U accumulations. Moreover, crystalline formations of the basement were also found during coal, petroleum, drinking- and thermal water prospecting. Structure wells, which were deepened for exposure of the basement, provided important information on this topic, too. Outcrops, trenches and wells made direct study, sampling and radiological analysis of the rocks belonging to the crystalline basement possible.

Although, gamma-radiation measurements characterise radiological conditions (e.g. in the case of borehole logging or surficial measurements), but these are characteristic for only sum total of radioactive elements; influence and ratio of the three most important natural radioactive elements (U, Th, K) can not be determined. Gamma spectrometry enables the distinction between them on the basis of the difference between energy spectra of gamma radiation of the given radioactive elements. This kind of measures were also used during the aerial and the field measurements. Aerial measurement can be regarded as a review, the obtained results can hardly be correlated with rock outcrops because of the bad exposure conditions.

As it will be presented, aerial measurements are followed by field controls where radioactive element content of the rock outcrops were also determined by using gamma spectroscopy. That time however, these determination required long time because of the simple apparatus. Moreover, error of the measures was significant because of the low energy resolving power of the detector, thermal sensitivity of the instrument, and variation of geometrical conditions of the measure. Radioactive equilibrium radon exhalation difference resulted in further decrease in accuracy of the measurements.

Taking these facts into consideration, only laboratory analyses of the collected rock samples were regarded suitable for an exact characterisation of radiological condition of the studied formations.

Both radiometric and chemical methods were used for laboratory analyses. Radiometric analyses have been performed by using multichannel analyzer since the middle of the 70's, which made U, Ra (uranium equivalent value), Th detection of some ppm sensitivity and detection of total potassium content (by means of K-40 isotope) of some % sensitivity. U and uranium equivalent of Ra are almost corresponding to each other. In the cases of the surficial samples, there is little difference for Ra. For a comparison of chemical U analyses, uranium values are listed in the tables. Of course, this accuracy can be reached in case of suitable sample quantity and optimal measuring

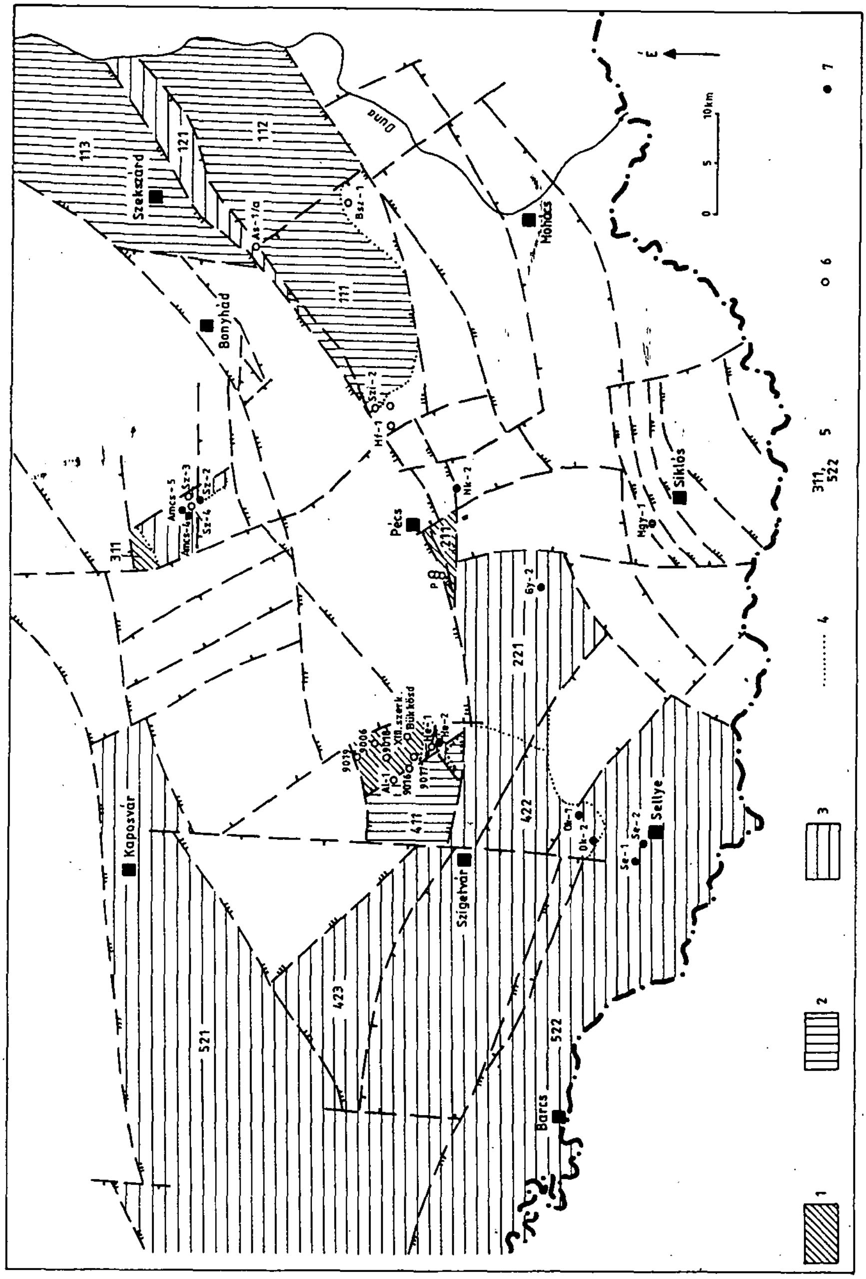

Fig. 1: Uncovered tectonic map of the Southern Transdanubian granitoid and metamorphic basement
1. Granitoid area covered by sedimentary basement formation; 2. Granitoid formations on the surface of the basement; 3. Metamorphic formation on the surface of the basement; 4. Arbitrary division of a crystalline basement block along topographic line; 5. Area code; 6. Borehole reaching granitoid formation under another basement element; 7. Borehole reaching metamorphic formation under another basement element.

time. Unfortunately, the quantity of the samples was often low, and measuring time was also limited because of economic considerations. Hence, detection limit of uranium was as high as 5 ppm in one case.

Theoretically, chemical analyses provide a sensitivity of some ppm, however, uncertainty of chemical digestion could make problem in some cases. Particularly, if major element content of the samples had unexpectedly changed for which chemists were not prepared. In these cases, even high differences occured between chemical and radiometric analyses.

In the beginning, chemical method of Th determination was not suitable, therefore, these results are not listed together with the old chemical analyses.

By developing the methods and the instruments, both chemical and radiometric methods are suitable to product analytical results of the expected accuracy (some ppm and some tenths %). Available data were used by considering the above mentioned facts.

Tectonic units of the rocks of the crystalline basement indicated in the geological map on the scale of 1:200000 are discussed according to figure 1.

It must be noted that, in some cases, great continuous crystalline basement areas were divided (mainly along tectonic lines) because of practical reasons (e.g. 1.1.1., 1.1.2. areas), but some parts were geographically separated from each other (e.g. 2.2.1. and 4.2.2. areas).

RADIOLOGICAL CONDITIONS OF CRYSTALLINE FORMATIONS OF THE MÓRÁGY MOUNTAIN

The crystalline basement is studied the most here, since this is the greatest surficial occurrence of granitoid formation in the Southern Transdanubia.

Radiometric survey were performed three times (1956, 1965, 1986) which were followed by control measures in the field using by gamma and radon methods. During the field measures, samples were also collected; radiological condition of the area are revealed by their U and Th analyses.

Because of the above mentioned facts, only chemical U analyses (table 1) can be considered from samples collected after the report J-0053 of the gamma survey performed by car in 1961 (VINCZE, 1961).

In 1974, during the following research of the area, samples listed in the former table and other samples collected in 1961 were re-analysed by using the more modern radiometric method. The results are listed in table 2 (VINCZE, 1975 - J-0667). There are Th and K analyses too since spectral analysis made them possible.

In 1974 field study followed the aerial measurements, its aim was to check the detected radiometric anomalies on the field. Most of the anomalies can be detected in the cases of crystalline rocks cropping out from loess of lower radioactivity. The analyses are summarised by table 3 (VINCZE, 1975).

On the basis of all samples collected from the area, the author stated that areas north and south of the Pécs-Bátaszék railway line have significantly different radiological mean values (table 4).

Another phase of field control of the aerial radiometric survey in 1965 was limited only to some important points of anomaly, and it had rather focused on petrographic identification. Author of the report J-0130 (SZEDERKÉNYI) studied the rocks by several

TABLE 1

Chemical U analysis of rock-samples in the year 1961 (Vincze, 1961)

Rock type	Chemical U average value 10^{-4}% (ppm)	Min - Max (ppm)	Sample (pcs)
Granite	12	1 - 138	74
Acidic dyke rocks (pegmatite, aplite), clay gouge	16	5 - 69	25
Basic dyke rocks (lamprophyre, biotitite)	7	3 - 17	13
Metamorphic granite and hydrothermal dyke	25	5 - 41	9

TABLE 2

Results of complex radiological study on analyses in the 1961 (Vincze, 1975)

Rock type	U (ppm)	Th (ppm)	K (%)	Sample (pcs)
Amphibolite	1,4	5,8	0,9	10
Granite	5,8	41,3	4,3	101
Metasomatic granite	10,0	35,0	2,3	7
Pegmatite	5,0	17,5	2,5	10
Kersantite	2,6	29,0	4,0	5
Aplite	7,7	41,0	3,8	24
Bostonite	4,9	42,0	5,0	12
Alkaline basalte (diabase)	6,1	35,0	5,7	7

TABLE 3

Results of radiological studies in the year 1974 (Vincze, 1975)

Rock type	U average (ppm)	Th average (ppm)	K average (%)	Samples (db)
Aplogranit, aplite	4,8	59	4,7	31
Microgranite	4,0	56	4,8	11
Medium-grained granite	5,0	52	4,6	25
Coarse-grained granite	5,5	77	4,5	34
Migmatite	5,7	54	5,2	16
Kersantite	4,5	34	5,0	2
Alkaline basalte (diabase)	2,6	19	2,7	5

TABLE 4

Radiological mean values south and north of Pécs-Bátaszék railway line (Vincze, 1975)

Area	U (ppm)	Ra (U equ.) (ppm)	Th (ppm)	K (%)	Samples (pcs)
North of Pécs-Bátaszék railway line	3,8	4,7	34	4,0	250
South of Pécs-Bátaszék railway line	6,0	6,5	55	4,8	144
Whole area	4,6	5,6	42	4,3	394

classifications according to phases of the granitization process. The following rock types were distinguished on the aerial anomaly no. 90 which is situated in 5-700 km from Geresdlak village in NNE direction: a. Agmatites; b. Granite; c. Arterites, venites (monomineralic differentiated melt between the crystals); d. Aplogranite (light red granite without mafic mineral constituents); e. Alkaline basalt ("alkaline diabase").

Mean values were not calculated for the given rock types, only the list of samples are published.

• In the case of anomaly no. 89 belonging to the quarry near the railway station of Kismórágy village, mean values (based on estimation) and maximum values were given for rock types listed in table 5.

In his studies no. J-0401 and J-0491, L. KÓSA (1977) studied U-Th content in fresh and weathered granites from the Mórágy Mountains. His results are listed in table 6. Unfortunately, sample number serving as a base for calculation was not published, but his manuscripts no. F-1612 and F-1611 contain several radiometric analyses. Undoubtedly, these analyses refer to this area, therefore, the values were calculated from numerous samples, this way, his results can be regarded as reliable.

The latest aerial (helicopter) survey was made in 1986, and field identification of several detected anomalies was performed by KARDOS et al. (1987 - J-1239).

On the basis of aerial spectrometry measurements they published mean values of the element concentration given in the "content channel" of the aerial apparatus; these values refer to the whole area:

U mean value = 2,18 ppm; Th mean value = 10,00 ppm; K mean value = 1,53 %.

Of course, it must be considered that these otherwise correct mean values refer to the cover areas, too.

During the field control work, rock samples were collected from the studied anomalies that might be correlated with real geological formations. Unfortunately, these samples were analysed by using rapid radiometric method (i.e., method of lower accuracy), and U concentration could generally be detected over 5 ppm.

A relative comprehensive study on samples from outcrops in the Mórágy Mountains were performed in 1974 (NAGY, 1974 - J-0656). Granitoids and metamorphites were divided in a detailed way. Faciology and phases of granitization was also applied for classification.

Elaboration of rock samples from the surface is represented in table 7. Uranium contents of the western and the eastern areas are different, therefore, separated U mean values were calculated. Z. Nagy stated that U content of granites (first phase) is less than that of microaplites (second phase). At the same time, Th an K tends to decrease. From the east to the west U content increases in both granites and microgranites. U and Th content of basic dyke rock is relatively high which is attributed by the author to lateral transportation along the faults.

On the basis of analysis of all surficial samples (including sedimentary rocks, metamorphic schists, limestones, Triassic, Miocene and Pleistocene formations), the author suggested the following mean values for the area:

U: 8,6 pp Th: 30,5 ppm K: 3,7 %

Report J-0656 (NAGY, 1974) deals with granitoid formation found in boreholes out of the strictly speaking Mórágy Mountain but in its vicinity. This author evaluates boreholes Martonfa-1, Szilágy-1 and 2 as well as Báta-1, Bátaszék-1 and Alsónána-1.

TABLE 5

Mean and maximum U and Th values of rocks of the aerial anomaly 89 (Szederkényi, 1965)

Rock type	U average (ppm)	Th max (ppm)	Samples (pcs)
Granite	2-4 (max. 10)	36	19
Aplogranite	10	17	4
Venite	10	24	1
Bostonite dykes	10	56	3
Alkaline basalte („diabase") dyke	2-4	43	7
Dyke (friction breccia, cementated by carbonates)	10	40	5

TABLE 6

Mean U-Th contents of fresh and weathered granites of Mórágy (Kósa, 1977)

Rock type	U (ppm)	Th (ppm)	K (%)
Granite (fresh)	7	33	4,3
Granite (weathered)	5	33	4,1

TABLE 7

Radiometric study on rocks of the Mórágy Mountain in the year 1974 (Nagy, 1974)

Rock type	U (ppm)		Th (ppm)		K (%)		Samples (pcs)
	aver.	max.	aver.	max.	aver.	max.	
Agmatite	10,2	27	27,5	56	2,5	4,4	21
Migmatite	3,5	9	26,6	60	3,9	7,5	13
Pseudopegmatite	6,7	11	20,5	67	2,6	6,4	8
Granite, E	5,3	33	32,0	60	4,3	6,8	69
Granite, W	9,1	70	43,4	320	3,6	7,0	198
Microgranite, E	8,7	15	25,7	45	5,0	6,5	3
Microgranite, W	15,0	21	29,0	60	2,4	5,7	4
Aplogranite	5,5	25	47,8	100	3,9	7,2	33
Aplite	16,8	65	33,3	85	3,8	7,5	51
Bostonite	14,5	32	35,1	75	2,6	4,5	10
Lamprophyre	6,8	18	25,4	42	4,1	7,0	13
Mafic dyke rocks	12,3	31	20,2	21	2,3	2,8	4
Granite (carbonated)	3,0	5	21,4	40	3,1	5,2	5
Hydrothermalithe	18,1	130	18,1	45	2,1	3,7	15
Hornblende-schists	1,4	3	7,8	13	1,9	3,7	18

bored in the western and the eastern margin, respectively (1.1.2. and 1.2.1. areas - figure 1). Mean values of the radioactive elements according to different types of the samples collected from these boreholes are listed in table 8. As it was found in the cases of samples collected from the surface, U contents of these samples tend to increase from the east to the west. (The author noted that borehole Bátaszék-1 does not show this tendency, possibly, because the two samples were obtained from a place of maximum gamma intensity.)

TABLE 8

Mean radioactive element content of granitoid formations from the boreholes in the immediate vicinity of the Mórágy Mountain (Nagy, 1974)

Rock type	Borehole	U (ppm)		Th (ppm)		K (%)		Sample
		aver.	max.	aver.	max.	aver.	max.	(pcs.)
Pseudopegmatite	Bátaszék-1	4,5	5	40,0	42	3,1	3,3	2
	Szilágy-1	5,5	6	42,0	45	4,5	5,1	2
Granite	Bátaszék-1	7,5	11	47,7	72	3,4	5,2	39
	Alsónána-1	4,5	9	25,3	37	4,2	5,2	22
	Báta-1	16,0	16	15,5	16	5,7	5,8	2
	Szilágy-1	5,4	15	26,9	40	4,3	4,9	7
	Martonfa-1	12,1	32	25,8	37	4,7	7,2	25
Aplogranite	Bátaszék-1	21,0	21	24,0	24	5,9	5,9	1
Bostonite	Alsónána-1	4,8	10	22,3	40	4,4	5,2	12
Granite	Alsónána-1	6,7	9	25,0	36	3,8	4,6	13
(cataclastic)	Báta-1	7,5	9	42,5	44	3,3	4,0	4
Granite	Báta-1	6,9	14	49,0	63	3,3	4,4	26
(carbonated)	Alsónána-1	4,0	4	22,0	22	4,1	4,1	1

TABLE 9

Radioactive element conditions of formations in the Mórágy Mountain (Nagy, 1974)

Rock type	U	Th	K	Samples
	accumulation factor			(pcs)
Agmatite	1,2	0,9	1,2	21
Migmatite	0,4	0,9	1,1	13
Granite, E	0,6	1,0	1,2	69
Granite, W	1,1	1,4	1,0	198
Aplogranite	0,6	1,6	1,1	33
Aplite	2,0	1,1	1,1	51
Bostonite	1,7	1,2	0,7	10
Lamprophyre	0,8	0,8	1,1	13
Alkalinebasalt (diabase)	0,5	0,9	1,4	11
Granite (carbonated)	0,3	0,7	0,8	5
Hydrothermalite	2,1	0,6	0,6	15
Hornblende-schists	0,2	0,3	0,5	18
Helvetian sand	0,8	0,4	1,1	75
Cainozoic clay	1,6	0,5	0,9	17

In this report, Z. Nagy attempted to calculate radioactive element factors of the given rock types, i.e. to demonstrate how the formations of the Mórágy Mountains relate to each other according to their radioactive element contents (table 9) (accumulation factor = mean value for the formation/mean value for the area). Here, there is also an obvious tendency of increasing accumulation from the east to the west: 0,6→1,1. Higher U accumulation of hydrothermal formation is evident. Aplite and bostonite are relatively more accumulated. The well-known fact that young formations may fix U in higher quantity can also be observed. There is a characteristic difference between distribution diagram of U contents of the western and eastern granites.

TABLE 10

Radiometric analyses of weathered granite samples from boreholes in the Mórágy Mountain and its environment (Kósa, 1985)

Borehole	Depth (m)	Sample 12-K-	U (ppm)	Th (ppm)	K (%)
Martonfa-1	780,0	1218	30	27	2,8
	784,0	978	2	37	5,8
	784,7	978	5	28	6,3
Szilágy-1	498,7	970	3	19	4,5
	501,6	971	4	28	3,7
Szilágy-2	630,0	999	15	23	3,6
Fazekasboda-1	54,3	557	12	10	3,0
	55,0	558	5	29	6,1
	61,1	563	12	10	1,0
	62,9	566	11	10	1,1
	69,0	1000	8	25	4,6
Fazekasboda-2	78,0	653	12	11	4,7
	87,4	1017	5	28	4,1
	93,4	1018	5	24	2,7
Alsónána-1	156,2	938	3	21	4,3

TABLE 11

Radiometric analyses of rocks from the borehole Szalatnak 3 (Várszegi, 1971)

Sample	Rock type	Radiometric			Chemical	
		U (ppm)	Th (ppm)	K (%)	U (ppm)	Th (ppm)
8563	Diorite-syienite, (quartzic)	12	45	5,8	5	35
8562	Diorite-syienite (quartzic)	16	46	6,1	12	43
8561	Pyroclastics (carbonated)				9	44
8560	Granodiorite (carbonated)	3	20	3,8	3	15
8559	Diorite	12	39	5,0	8	42
8558	Diorite	9	33	5,3	4	36
8534	Dyke rock (essexit typ)	3	11		2	7
8533	Andesite				4	14
8532	Syenite	4	37	5,4	3	32
8530/a	Syenite				2	25

It must be noted that T. Szederkényi made a summary report on boreholes in Szilágy and Bátaszék area (SZEDERKÉNYI, 1962 - J-0062). Unfortunately, sensitivity of analytical methods of that time did not allow the correlation of the detailed petrographic evaluation with radiological data.

Radiometric analyses of weathered granites exposed by boreholes in the Mórágy Mountains and its vicinity were collected by L. KÓSA (F-1602). These are listed in table 10. Moreover, KÓSA send 14 samples for chemical U and Th analysis. These samples coming from the boreholes Feked-1, -2, -4, -5, -6, and are described in manuscript no. F-1504 (KÓSA, 1985). The analyses were surely done, however, results have not been available. It is expected to come to light during the further arrangement of the data bank.

RADIOLOGICAL CONDITIONS OF CRYSTALLINE FORMATIONS IN THE MÁGOCS-ALSÓMOCSOLÁD-SZALATNAK AREA

There have been some boreholes in the area, however, only few analytical data have been found. Research work performed in this area was reported by K. VÁRSZEGI (1971 - J-0142).

Beside a detailed petrographic and tectonic study, only the samples from crystalline basement exposed by borehole Szalatnak-3 from 510-580 m were published. Even analyses of these samples are not complete. Description of the rocks and the analytical result are listed in table 11.

On the basis of the chemical analyses, mean concentrations of the samples listed in this table are 5,2 and 29,3 ppm for U and Th, respectively. Disregarding essexite-type (basic) dyke rocks, mean concentrations increase: U = 5,6 ppm, Th = 31,8 ppm. Mean values of the radiometric analyses (U = 8,4ppm; Th = 33 ppm) are similar to those of samples from boreholes of the Mórágy Mountain (U = 8,1; Th =35,1).

RADIOLOGICAL CONDITIONS OF CRYSTALLINE BASEMENT ROCKS IN PÉCS AND ITS ENVIRONMENT

As it is mentioned above, granitoid rocks in Pécs are weathered and difficult to get at. Granitoid formations were exposed by the U exploration well no. 4716. Luckily, it was continued to clear tectonic conditions, and exposed formations of the crystalline basement. More than 300 samples were petrographically studied by L. Kósa, and these samples were analysed for determination of U and Th content (KÓSA, 1980 -J-0917).

Tables 12 and 13 show radioactive element content of the rocks grouped in detailed and comprehensive ways.

It must be noted that three samples qualified as metaarkose coming from the point of maximum radiation intensity in the section 1110-1113 m had much higher mean values than the mean value above:

U = 17,5 - 20 ppm Th = 32 - 53 ppm.

Comparing layered migmatites to diatexites, there is remarkable difference between their Th contents. While Th/U = 6 for layered migmatites, this value is 11 for diatexites.

The crystalline basement (mainly metamorphic rocks) was found by several boreholes south of Pécs. A petrographic evaluation of three of them was made by K. TÖRÖK Jr. (TÖRÖK, 1986 - J-1140 in his diploma work). Two-mica gneiss ranging from 1124,8 to 1172 m was intersected by structure well XII near Szentlőrinc village. Chlorite gneiss, muscovite gneiss and two-mica gneiss ranging from 1533,6 to 1701 m was intersected by borehole Máriagyűd-1. Borehole Nagykozár-2 exposed two-mica schist and milonite between 1953,1 and 1964,2 m as well as pink gneiss and cataclasite originated from orthoclase gneiss was intersected between 1964,2 and 1992,4 m. Unfortunately, the petrographically evaluated cores were not radiologically analysed in the frame of this work, and analytical results concerning these samples have not been found.

TABLE 12

Radiometric analyses of granitoid formations of the borehole 4716 (Kósa, 1980)

	Rock type	U (ppm)	Th (ppm)	Mintasz.(db)
Migmatite	Biotite migmatite	4,0	23	30
	Migmatite (layered)	3,4	23	32
	Migmatite (porphyroblastic)	4,1	25	28
	Migmatite (leucosome)	5,0	23	20
Diatexite	Diatexite (biotitic)	2,7	36	49
	Diatexite	3,0	34	41
	Aplitoid	4,0	40	14
	Microgranite	3,8	38	5
	Skialith	3,4	32	12

TABLE 13

Radiometric analyses of formations of the borehole 4716 (Kósa, 1980)

Rock type	U (ppm)	Th (ppm)	Samles (pcs)
Phyllite, metasandstone, metaarkose, sericiteschist	2,2	15	99
Layered migmatite	4,1	23	110
Diatexites	3,0	34	121
Fault zone (clay minerals)	2,8	20	21
Gneiss	2,2	22	3

TABLE 14

Radioactive element content of granitoids in the Mórágy Mountain and the W Mecsek Mountains (Kósa, 1977)

Area	Rock type	U (ppm)	Th (ppm)	K (%)
Mórágy Mountain	Granite (fresh)	7	33	4,3
	Granite (leached)	5	33	4,1
W Mecsek	Granite (fresh)	23	26	3,3
	Granite (leached)	8	24	2,9

TABLE 15

Uranium and thorium content of granitoid rocks in the W Mecsek Mountains (Buda, 1984)

Rock type	U		Th		Abundance (%)
	ppm	σ	ppm	σ	
I. Diorite, tonalite	2,6	± 1,3	28,3		11
II. Granodiorite, quartzmonzonite	15,5	± 13,5	40,8	± 25,2	32
III. Monzogranite	5,5	± 3,5	22,4	± 15,4	53

Note: uranium concentration of type II ranges from 3,5 to 4,5, variation of thorium is lower than that of uranium.

ENVIRONMENT OF GRANITE OUTCROPS NEAR NYUGOTSZENTERZSÉBET-NAGYVÁTY, RADIOLOGICAL CONDITIONS OF CRYSTALLINE BASEMENT IN THE AREA WEST OF THE MECSEK MOUNTAINS

Metarhyolite near Gyűrűfű village (west margin of the Mecsek Mountains) was begun to study as early as the first decade of the uranium exploration; later, research of the granite outcrops near Nyugotszenterzsébet and Nagyváty villages started. Possibility of a study on the surface is very limited because of the small extension of the exposed rocks. During the drilling research of U accumulation near Kővágószőlős in the area west of the village some boreholes exposed granitic rocks under Permian beds in the environment of Korpád village.

Development in analytical sensitivity made correct detection of low concentration differences of radioactive elements possible. This way, it could correctly be stated that U content of granite from western part of the Mecsek Mountains is higher than that of granite from the eastern part of the mountains as well as weathering resulted in a significant decrease in U concentration of the western granite. It was interesting, since it was questionable whether origin of U ore in Mecsek Mountains can be explained by dissolved uranium of significant quantity, and whether usable U accumulation is possible in other younger sediments.

L. KÓSA dealt with this problem in his report J-0491 and J-0401 (KÓSA, 1977). He compared radioactive element contents of the western and the eastern granites, and studied their fresh or weathered state (table 14).

In a later report, GY. BUDA (BUDA, 1984 - J-1088) studied granitoid rocks of the W Mecsek mountains from a mineralogical-petrological point of view, and published chemical U and Th analyses, too. He distinguished three types of rock (table 15).

Examples for these types together with the sampling places is listed in table 16. Variety of rocks belonging to type II is obvious.

Samples from crystalline basement situated in the western margin of the Mecsek Mountains, west of Bükkösd fault line, were analysed by L. KÓSA (KÓSA, 1985 - F-1533).

Mean values of the analyses of formations from boreholes exposed granitoids are listed in table 17. Besides the mean values, σ-values (standard deviation) are also given.

Data published in report F-1533 suggest that analyses of samples from several boreholes in the western granite area were preliminary elaborated. It is supposed that L. KÓSA used these data for his reports J-0401 (1977) and J-0491 (1977). Since these are direct connection with given boreholes, these data are listed in table 18.

There are several hundreds analytical results in reports F-1603 and 1606. However, these data can not be identified, only the fact that these come from samples collected from the Western Mecsek Mountains, and that most of them are in connection with the crystalline basement. Probably, these data were used for calculation of mean values published in other reports.

TABLE 16

Uranium, thorium and potassium content of the W Mecsek Mountains (Buda, 1984)

	Borehole	Depth (m)	U (ppm)	Th (ppm)	K (%)
I.	Dinnyeberki-19	77	1,7	4,0	-
	Nyugotszenterzsébet-6	52	3,3	58,3	4,3
	XIII. struct. (Bükkösd)	761	6,4	6,2	-
	Nagyváty-101	77	4,1	38,2	4,5
	Nagyváty-101	70	1,3	12,5	5,3
II.	9016 (Dinnyeberki)	261	7,9	9,4	4,2
	9016 (Dinnyeberki)	265	3,6	4,4	-
	9017 (Dinnyeberki)	452	11,5	77,0	-
	9017 (Dinnyeberki)	495	16,9	60,5	3,2
	Dinnyeberki-203	53	6,5	24,0	3,0
	Almáskeresztúr-5	283	18,6	28,3	-
	Nagyváty 2/1	131	43,5	61,4	5,6
	Nagyváty-104	67	3,5	24,8	-
III.	Nyugotszenterzsébet-5	35	6,5	8,7	-
	Nyugotszenterzsébet-5	38	4,0	17,5	-
	Nyugotszenterzsébet-6	29	2,8	13,6	3,5
	Nyugotszenterzsébet-6	61	3,6	52,8	3,9
	Almáskeresztúr-5	239	7,3	22,5	-
	XIII. struct. (Bükkösd)	703	13,1	40,7	-
	Nagyváty-104	66	3,0	17,4	-

TABLE 17

Means of analysed samples of boreholes exposing granitoids of the W Mecsek Mountains for the every formation (Kósa, 1985)

Sample	Subsurface sampling (m)	Rock type	Means of chem. analisys (ppm)		Sample (pcs.)
			U (±σ)	Th (±σ)	
9-K- -26464- -26480	Db-44 46,7-87,3	GRANITOIDS	2,5 (1,3)	30 (8,7)	36
		granite-gruss	3,5 (0,8)	30 (8,1)	10
		granite	1,6 (0,5)	34 (6,7)	21
		granite (with feldspar)	4,7 (0,9)	17 (1,8)	5
	Db-28 71,0-96,6	GRANITOIDS microgranite (fresh nad weathered)	5,0 (1,9)	23 (3,4)	14
	Db-45 65,6-102,5	granite-gruss	2,6 (0,9)	31 (9,5)	14
	Nyszterzs.-4 96,5-125,3	GRANITOIDS	8,0 (5,5)	23 (8,6)	32
		granite (yellow)	4,6	17	4
		granite (pink, leached)	2,9	27 max. 76	
		granite (pink, fresh)	11,8	27 max. 42	11
		feldspar dyke	18,0	35	3
		granite (green)	10,0	18	9

Sample	Subsurface sampling (m)	Rock type	Means of chem. analisys (ppm)		Sample (pcs.)
			U (±σ)	Th (±σ)	
		granite (weathered)	7.7	20	5
	Nagyváty-103	GRANITOIDS	10,0 (8,0)	27 (9,0)	45
	75,1-120,7	granite-gruss	9,7 (9,9)	27 (10,0)	12
		granite (red)	11,3	30	14
		granite (porphyroblastic)	8,8	26	10
		fault clay	6.6	24	7
	Nagyváty-102	GRANITOIDS	8,3 (5,3)	36 (10,0)	28
	79,3-102,0	granite (weathered)	4,4 (1,9)	27 (4,1)	7
		microgranite	6.9	43 (6,6)	4
		fault clay	4.1	34 (11,0)	4
		microgranite	13,0 (4,1)	40 (9,8)	10
	9018 (Korpád)	GRANITOIDS	10,0 (6,8)	29 (3,6)	52
	425,4-539,4	granite-gruss	2,5 (0,8)	27 (3,5)	16
		granite (green)	13,0 (5,1)	30 (3,3)	31
		granite (red)	17,0 (5,5)	28 (2,1)	5
	Nagyváty-4	GRANITOIDS			
	153,7-471,1	feldspar dyke	16,0 (4,4)	17 (4,5)	23
		granite (red)	12,0 (4,7)	28 (7,3)	69
		granite (grey)	13,0 (2,8)	25 (5,2)	64
		granite (carbonate-bearing)	10,0 (2,5)	23 (3,7)	11
		granite dyke	12,0 (3,1)	33 (6,4)	7
	Almáskeresztúr-5	GRANITOIDS			
	127,6-536,0	granite (pink)	6,5 (1,8)	29 (3,8)	26
		microgranite	8,9 (2,0)	30 (3,8)	11
		granite	13,8 (5,0)	32 (4,7)	20
		granite (grey)	5,4 (1,4)	29 (1,8)	5
		granite (amphibole-bearing)	6,7 (1,3)	28 (2,1)	12
		granite (bright grey)	6,0 (2,0)	27 (4,5)	25
		microgranite (pink)	8,5 (2,1)	32 (2,6)	22
		microgranite, anomalistic tract	16,5 (4,7)	64 (29,0)	5
		microgranite (carbonate-bearing)	17,0 (13)	32 (3,5)	1
		microgranite (weathered)	8,6 (3,0)	30 (3,9)	4
		microgranite (grey)	7,1 (1,8)	23 (5,3)	9
	127-159	feldspar dyke	4,7 (2,3)	14 (8,6)	7
	287-300	feldspar dyke (pink)	13,5 (3,7)	16 (3,2)	18

TABLE 18

Analytical data connecting to some boreholes in the W Mecsek Mountains (Kósa, 1985)

Sample	Rock type	Means of chemical analisys					
		U (ppm)	pcs.	Th (ppin)	pcs.	K (%)	pcs.
9006 (Korpád)	Granite (fresh)	24,8	10	25,0	1	1,5	2
	Granite (weathered)	8,8	6	16,5	2	4,4	2
9008 (Korpád)	Granite (fresh)	26,0	1	30,0	1	-	
	Granite (weathered)	6,5	2	-		-	
9010 (Korpád)	Granite (fresh)	-		-		-	
	Granite (weathered)	5,2	5	38,6	5	6,2	5
9011 (Korpád)	Granite (fresh)	-		-		-	
	Granite (weathered)	4,0	6	37,3	6	5,8	6
9012 (Korpád)	Granite (fresh)	25,5	4	31,3	3	-	
	Granite (weathered)	-		-		-	
9013 (Korpád)	Granite (fresh)	-		-		-	
	Granite (weathered)	3,0	1	-		-	
9014 (Korpád)	Granite (fresh)	30,0	1	20,0	1	3,0	1
	Granite (weathered)	6,5	2	-		-	
9015 (Korpád)	Granite (fresh)	20,6	29	27,2	29	3,8	28
	Granite (weathered)	5,5	2	39,0	2	2,8	2
Nyugotszenterzsébet-1	Granite (fresh)	36,0	1	20,0	1	1,0	1
	Granite (weathered)	-		-		-	
Nyugotszenterzsébet-2	Granite (fresh)	31,0	3	19,3	3	2,5	3
	Granite (weathered)	-		-		-	
Nyugotszenterzsébet-3	Granite (fresh)	22,5	2	23,0	2	4,1	2
	Granite (weathered)	6,0	3	17,6	3	3,9	3
Almáskeresztúr-1	Granite (fresh)	34,5	2	33,5	2	4,6	2
	Granite	-		-		-	

Sample	Rock type	Means of chemical analisys					
		U (ppm)	pcs.	Th (ppm)	pcs.	K (%)	pcs.
	(weathered)						
Helesfa-2	Granite (fresh)	12,5	2	33,5	2	5,1	2
	Granite (weathered)	3,3	3	30,0	2	4,4	2
Nagyvály-1	Granite (fresh)	46,0	1	21,0	1	1,4	1
	Granite (weathered)	-		-		-	

CONCLUSIONS

1, On the basis of U, Th and K analyses of rock samples from the Mórágy Mountains and the area east of the Mecsek Mountains, the following conclusions can be drawn:

a. Mean values of U = 2,2 ppm and Th = 10,1 ppm are detected by aerial measurements over granitoid rocks covered by loess more than 90 %.

b. Mean values of granitoid samples for the whole area are: U = 8,6 ppm and Th = 30,5 ppm,

c. Mean values of samples qualified as granite are: U = 8,2 ppm and Th = 40,1 ppm.

d. U content ratio for fresh and weathered granites is 7:5 (1,4); Th content ratio for fresh and weathered granites is 33:33 (1,0).

e. U content ratio for western and eastern part of the Mórágy Mountains is 1,5-1,6 (regarding both surface and boreholes). Th content ratio for western and eastern part of these mountains is 1,3 and 0,7 for samples from surface and boreholes, respectively.

f. Accumulation factors (=mean value for formation/mean value for the area) are: Aplite = 2,0; Bostonite = 1,7; Hydrothermal formations = 2,1; Granite = 1,0; "Western" granite = 1,1; "Eastern" granite = 0,6.

g. Granite from the Mórágy Mountain has higher (approximately twice) U and Th content than the world average for granite.

2, Mean values of U and Th content of crystalline basement in the Mágocs-Alsómocsolád-Szalatnak area (U = 8,1 ppm; Th = 35,1 ppm) are similar to those of samples from boreholes in the Mórágy Mountain.

3, Radiological conditions of granitoids of the western area can be summarised as it follows:

a. Granites west of the Mecsek Mountains have higher U and lower Th contents than granites east of these mountains.

b. "Western" granites are highly sensitive to leaching. A fresh granite may loose 60 % of its U content even in covered borehole. Loss of Th is only about 15 %.

c. Dissolved U re-precipitated in young sediments as important accumulation, therefore, an intensive migration of U solution can be regarded to be proved.

d. Uranium content of granodiorite-quartz monzonite type of the granitoid rocks is 3-5 times higher than that of diorite or monzogranite; its Th content is 1,5 times higher. Variety of the U content is the highest in the case of this type (3,5-43,5 ppm).

ACKNOWLEDGEMENT

This work has been supported by the National Science Research Foundation (OTKA) No. F 017369.

REFERENCES

BUDA, GY. (1984): Vizsgálati jelentés a Nyugati-Mecsek területén mélyfúrásokkal feltárt granitoidok ásvány-kőzettani vizsgálatáról. J-1088, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KARDOS, I. et al. (1987): Jelentés az 1986. Évi légi gammaspektrometriai mérések terepi ellenőrzéséről a Mórágyi-hegység területén. J-1239, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KÓSA, L. (1977): Irányelvek a Nyugati-Mecseki terület nyomdetektoros kutatásához. J-0401, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KÓSA, L. (1977): Hazai gránitok urántartalma. J-0491, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KÓSA, L. (1980): Pécs-Báránytető 4716/1 sz. fúrásban feltárt metamorf és granitoid kőzetek radiokémiai vizsgálatának vázlata. J-0917, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KÓSA, L. (1985): A DK-Dunántúli gránitokat feltáró fúrások (főleg Ny-Mecseki) mintaelemzései és azok feldolgozásának mukafüzete. F-1504, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KÓSA, L. (1985): Ny-Mecsek, Mórágyi-hegység és Velencei-hegység gránitmintáinak elemzési adatai. F-1533, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KÓSA, L. (***): A Mórágyi-hegység és környékéről származó fúrások gránitmintáinak U, Th és K tartalma. F-1602, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KÓSA, L. (***): A Mecsek és Villányi hegység közötti terület felszíni magmás kőzetmintáinak U, Th, K tartalma. F-1611, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

KÓSA, L. (***): A Mecsek és Villányi hegység közötti területen mélyült fúrások magmás kőzetmintáinak U, Th, K tartalma. F-1612, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

NAGY, Z. (1974): Mórágyi-hegység kőzeteinek sugárzó anyag eloszlása a négykomponenses elemzések alapján. J-0656, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

SZEDERKÉNYI, T. (1962): A II. sz. kutatócsoport összefoglaló jelentése a Szilágy-Bátaszék kutatási területen 1961. évben végzett kutatásokról. J-0062, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

SZEDERKÉNYI, T. (1965): Földtani jelentés a Mórágyi-hegységi légigamma anomáliák földi ellenőrzéséről. J-0130, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

TÖRÖK, K. (1986): Adatok a Dél-Dunántúl kristályos aljzatának felépítéséhez. J-1140, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

VÁRSZEGI, K. (1971): Összefoglaló jelentés a szalatnaki területen végzett kutatásokról. J-0142, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

VINCZE, V. (1961): A II. sz. kutatócsoport 1960. Évi jelentése a Mórágyi gránitterületen végzett komplex autós-gamma felvételről. J-0053, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

Vincze, V. (1975): Jelentés az 1974-ben végzett komplex radiológiai anomália ellenőrző vizsgálatokról, Mecsek és Mórágyi gránitterület. J-0667, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

*** (***): Ny-Mecseki fúrások és felszíni minták elemzési eredményei. F-1603, Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

***(***): Ny-Mecsek, Zselic és Hegyhát területéről származó felszíni és fúrásbeli minták elemzése. F-1606 Doc. Dept. of Mecsekérc Enviroment Protection Co., Manuscript.

Manuscript received 10. June 1999.