NUCLEAR PHYSICS TECHNIQUES FOR DETERMINATION OF ROCKS AGE

N.P. Dikiy, A.N. Dovbnya, Yu.V. Lyashko, E.P. Medvedeva, D.V. Medvedev, V.L. Uvarov, [1)]I.D. Fedorets, [2)]A.A. Valter, [2)]V.E. Storishko

NSC Kharkov Institute of Physics and Technology,
[1)]Kharkov National University,
[2)]Institute of Applied Physics NAS, Ukraine

The low background nuclear physics techniques were used for measure age geologic samples of micas (biotite, lepidolite, muscovite, phlogopite) by means of detection a gamma radiation from radioisotopes. The nuclear reactions $^{87}Sr(\gamma,\gamma`)^{87m}Sr$, $^{87}Rb(\gamma,n)^{86}Rb$ and $^{85}Rb(\gamma,n)^{84}Rb$ was used. Application of a braking radiation of the powerful accelerator of electrons has allowed simultaneously to measure an element composition of samples. The age of biotite from the deposit Stankovatskoe (Ukraine) was measured that corresponds an inhering lithium pegmatites of the Kirovograd block of the Ukrainian Shield to relevant global paleoproterozoic metallogenic episode by age $2.4\cdot 10^9$ years.

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INTRODUCTION

The many radioisotopes of different genesis of Earth are known: the first natural radionuclides and their products of decay, cosmogony radionuclides, radionuclides of an anthropogenous genesis. The special properties of radionuclides allow to use it as tracer and geochronometers of different processes, from a nucleosynthesis, evolution of system a crust-mantle and ending modern processes in biosphere, atmosphere, hydrosphere and surface of lithosphere. The geologic history of the Earth and space bodies in modern time is object of intensive investigation. Such investigation assist, in particular, making of the consistent concepts of formation of minerals, explaining a genesis of a variety of rocks and minerals, allow to forecast evolution of Earth, to design policy of use non-repairable minerals and burial of harmful waste metals, in particular radioactive.

The age of geologic sample and meteorites up to 30 thousands years as rule determinate by measuring of decay ^{14}C. Recently unique methods of content determination ^{14}C by accelerator mass spectrometry (AMS) resolve to make more precise of formation time of carbonates in archeology, to learn environmental by atomic power stations etc. [1].

The determination of rocks age by analysis of ratio of isotopes content of products decay ^{238}U, ^{235}U, ratio content of isotopes Rb/Sr, Re/Os, K/Ar was elaborated and widely was used for geology.

These methods do not destroy by determination the most valuable witnesses of a history of an early Solar system - rare meteorites and valuable ores.

Wide use of a U-Pb method for determination of rocks age up to 10^{10} years is known. The nuclear physics techniques of determination of the content pair ^{87}Sr and ^{87}Rb allow to carry out measuring of such age interval without destruction rare of rocks.

RESULTS AND DISCUSSION

The radioactivity methods of measuring of age of geologic rocks and meteorites with the help of determination of parent/daughter ratios of nuclides: ^{238}U-^{206}Pb, ^{235}U-^{207}Pb, ^{232}Th-^{208}Pb, ^{40}K-^{40}Ar, ^{87}Rb-^{87}Sr, ^{187}Re-^{187}Os, ^{147}Sm-^{143}Nd, ^{176}Lu-^{176}Hf are used [2-7]. As a rule, such ratios are measured with the help of mass spectrometers. But mass spectrometer method has some problems for measuring concentration of rubidium-87 and strontium-87. The large difference of ionisation as rubidium both strontium and difference in chemical properties these elements frequently lead to systematic mistakes. Besides mass spectrometer method is destructive. Use of nuclear physics techniques allow to determinate the $^{87}Rb/^{87}Sr$ ratio without destruction of samples. The indestructibility of these samples is especially important at examination of meteorites and rare geologic rocks [8-11].

The principle of a method is irradiation of sample with considerable quantity of rubidium-87 on an electron accelerator for excitation reactions $^{87}Sr(\gamma,\gamma`)^{87m}Sr$ и $^{87}Rb(\gamma,n)^{86}Rb$.

Calculate of rocks age by $^{87}Rb/^{87}Sr$ carried out on expression

$$t=(-1/\lambda)\ln(1+(^{87}Sr/^{87}Rb))$$

where λ-decay constant ^{87}Rb, $^{87}Rb/^{87}Sr$ – ratio of the content of isotopes in mica [2].

The content of rubidium and strontium is 0,5…2,5 % and 50…200 μg/g, accordingly. Therefore the low background detection of a gamma radiation from rocks and meteorites was necessary for determination of its age.

The backgrounds in our case are formed from building materials: yields of the products decay of ^{238}U, ^{235}U, ^{232}Th, ^{40}K and cosmic radiation. The energy of gamma background is varied from 2,615 MeV up to energy of

X-rays. The intensity reduces of detecting a gamma background is reached by means of making of triplex protection. The protection facing of the Ge(Li) detector are carried out by thickness 5 cm by Pb. The middle stratum consists of Cu with thickness 1,5 cm. An inner ply consists of Al with thickness 0,5 cm. The Ge(Li) detector of volume 40 cm^3 and energy resolution 2,8 keV for a gamma of a line ^{60}Co 1333 keV are used for measuring radiation spectrums. These actions are allowed to lower a background of energy range 100…300 keV in less than 10-12 time. The intensity of a gamma line 1461 keV from kalium-40 decay is decreased in 10…12 times, too.

The productivity of background reduction was tested at determination of effective time of change of uranium ores on a nonequilibrium method from a ratio of yields of decay ^{238}U and ^{235}U. Particular thus effective age of a sample of ore Geltorechenskogo uranium deposit has equalled 120±14 thousands years, that corresponds most to high level terraces in Pleistocene [12].

Examples use of low background facility for determination of micas age (biotite) of Stankovatskoe deposit (Ukraine) and lepidolite from Madagascar is possible to see in Figs. 1-3.

Fig. 1 represents spectrum of a sample $^{87}SrCO_3$ of weight 450 mg enriched of ^{87}Sr up to 75 % after an irradiation by a braking radiation. The gamma line with energy 388,4 keV from reaction $^{87}Sr(\gamma,\gamma')^{87m}Sr$ in this case is reliable detect. Fig. 2 represents spectrum of lepidolite from Madagascar. In this case the gamma line with energy 388,4 keV do not detect.

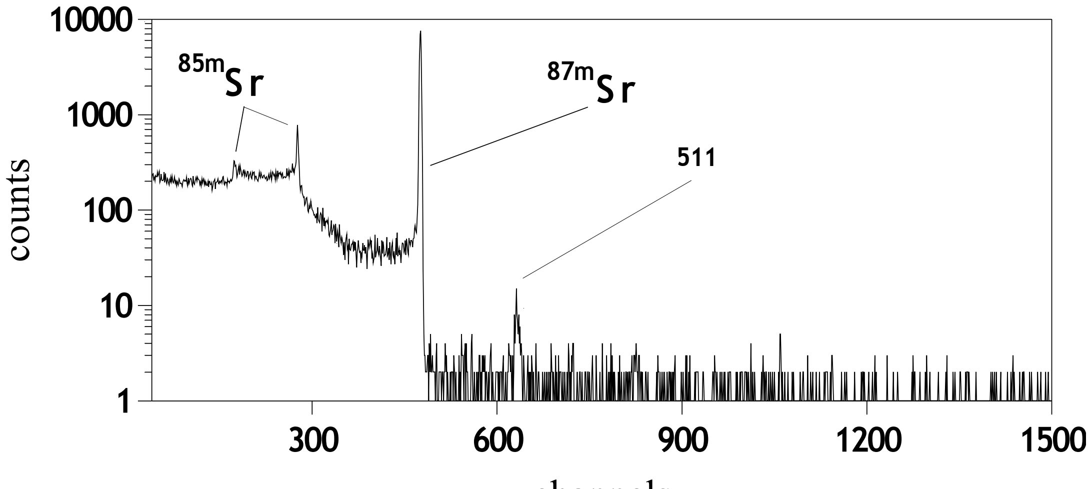

Fig. 1. *A radiation spectrum of $^{87}SrCO_3$ after an irradiation during 6 hours by bremsstrahlung with maximal energy 11 MeV*

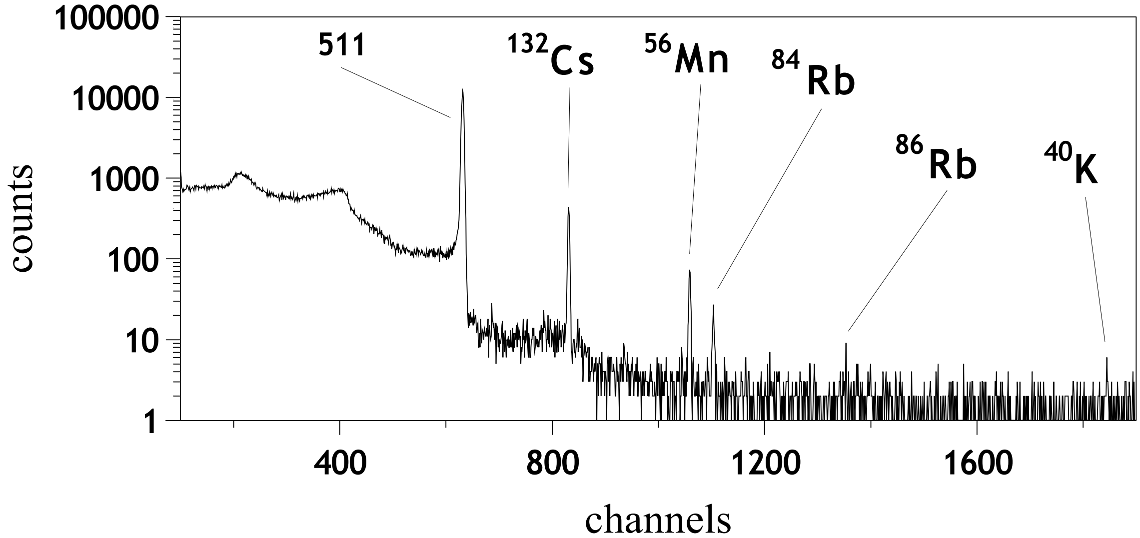

Fig. 2. *A radiation spectrum of lepidolite (Madagascar) after an irradiation during 6 hours by bremsstrahlung with maximal energy 11 MeV*

Fig. 3 represents the part of spectrum with a line 388,4 keV from ^{87}Sr of biotite from Stankovatskoe deposit (Ukraine). Only 1300 γ-quantums are registered. It is shown the complication of determination process of rocks age.

The content ^{87}Sr, ^{87}Rb of biotite from Stankovatskoe deposit (Ukraine) are equalled to 222, 6362 µg/g, accordingly, which determine by nuclear physics techniques. Thus, the tentative estimation of biotite age are equalled to $2,4 \cdot 10^9$ years.

The analysis of an element content of mica from different deposit is held. It is clear that trace elements considerably influence on opportunity of determination of rocks age.

The reaching of optimum ratio $^{87}Rb/^{87}Sr$ appreciably depends on requirements of an irradiation on an electron accelerator. The photoexitation section of ^{87}Sr is approximately 10^{-30} cm^2 for energy 8 MeV. Therefore, the high intensity of gamma radiation is necessary. The content of ^{87}Sr, for example, in mica is only 50-200 µg/g.

More reliable determination of strontium-87 by irradiation a bremsstrahlung from an electron accelerator are obtained with current 700 µA. For reliable determination of the ratio $^{87}Sr/^{87}Rb$ are used enriched etalon to 75 % $^{87}SrCO_3$ and sample $SrCO_3$ with natural abundance of isotopes. Let's mark, the natural composition of strontium isotopes compounds: ^{84}Sr - 0,56 %, ^{86}Sr - 9,86 %, ^{87}Sr - 7,02 %, ^{88}Sr - 82,56 %.

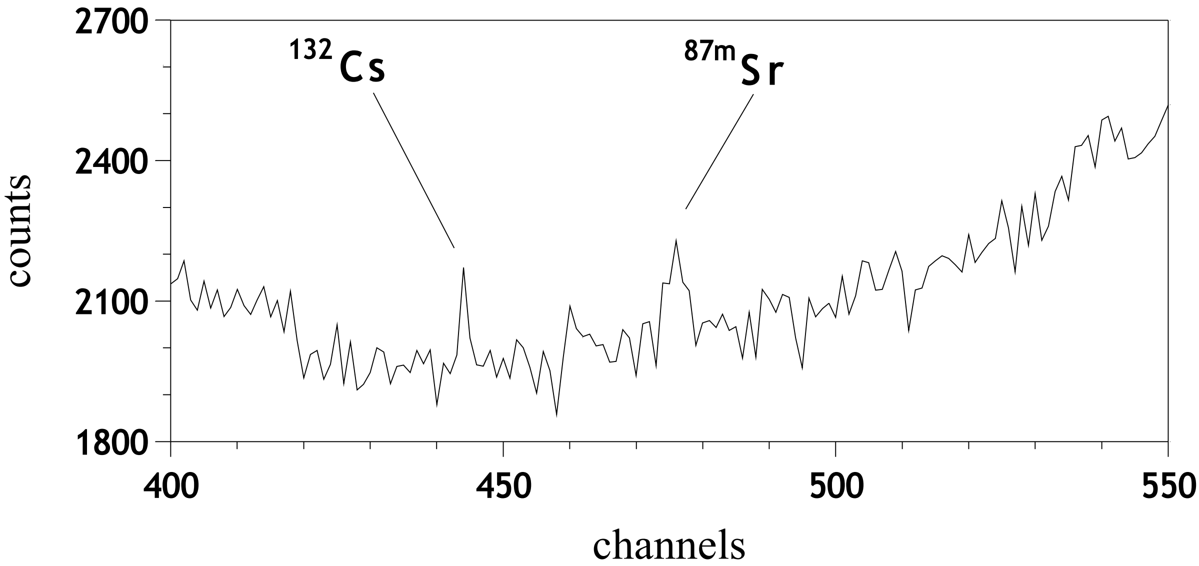

Fig. 3. *A part of radiation spectrum of biotite after an irradiation during 6 hours by bremsstrahlung with maximal energy 11 MeV in region 388,4 keV*

The section of interaction ^{86}Sr with thermal neutrons is 0,8 bn. Therefore the energy accelerated electrons did not exceed 11 MeV with view of the possible contribution from neutrons. The highest inaccuracy of measuring the ratio $^{87}Sr/^{87}Rb$ stipulate by the contribution of reaction $^{88}Sr(\gamma,n)^{87m}Sr$ [13]. The threshold of this reaction is 11.1 MeV. Therefore the electron energy 11 MeV is used.

CONCLUSIONS

The power of nuclear physics techniques for determination of a rocks age and meteorites has been demonstrated the last years. In this article only a few examples of all possible nuclear physics techniques have been mentioned.

The new method of not destructive dating of geologic objects on an interrelation $^{87}Sr/^{87}Rb$ is offered. This method confirms tentative assumptions [14,15] about an inhering lithium pegmatites of the Kirovograd block of the Ukrainian Shield to relevant global paleoproterozoic metallogenic episode by age $2.4 \cdot 10^9$ years [16], earlier within the range of shield to unknown. It is possible therefore to hope that the obtained outcome will be relevant at interpreting a geologic history of a shield and planning of search of new mineral deposits.

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ЯДЕРНО-ФИЗИЧЕСКИЕ МЕТОДЫ ОПРЕДЕЛЕНИЯ ВОЗРАСТА ГОРНЫХ ПОРОД

Н.П. Дикий, А.Н. Довбня, Ю.В. Ляшко, Е.П. Медведева, Д.В. Медведев, В.Л. Уваров, И.Д. Федорец, А.А. Вальтер, В.Е. Сторижко

Приведены результаты разработки низкофоновой ядерно-физической методики измерения возраста геологических образцов слюды (биотит, лепидолит, мусковит, флогопит) с помощью регистрации гамма-излучения от радиоактивных изотопов, которые появляются при облучении тормозным излучением в результате ядерных реакций $^{87}Sr(\gamma,\gamma')^{87m}Sr$, $^{87}Rb(\gamma,n)^{86}Rb$ и $^{85}Rb(\gamma,n)^{84}Rb$. Использование тормозного излучения мощного ускорителя электронов позволило одновременно измерять элементный состав исследуемых образцов. Измерения возраста биотита из месторождения Станковатское (Украина) позволяют предполагать о принадлежности литиевых пегматитов Кировоградского блока Украинского щита к важному глобальному палепротерозойскому металлогеническому эпизоду возрастом $2{,}4\cdot10^9$ лет.

ЯДЕРНО-ФІЗИЧНІ МЕТОДИ ВИЗНАЧЕННЯ ВІКУ ГІРСЬКИХ ПОРІД

М.П. Дикий, А.М. Довбня, Ю.В. Ляшко, О.П. Медведєва, Д.В. Медведєв, В.Л. Уваров, І.Д. Федорець, А.А. Вальтер, В.Ю. Сторіжко

Наведено результати розробки низкофонової ядерно-фізичної методики виміру віку геологічних зразків слюди (біотит, лепідоліт, мусковіт, флогопіт) за допомогою реєстрації гамма-випромінювання від радіоактивних ізотопів, що з'являються при опроміненні гальмовим випромінюванням у результаті ядерних реакцій $^{87}Sr(\gamma,\gamma')^{87m}Sr$, $^{87}Rb(\gamma,n)^{86}Rb$ і $^{85}Rb(\gamma,n)^{84}Rb$. Використання гальмового випромінювання потужного прискорювача електронів дозволило одночасно вимірювати елементний склад досліджуваних зразків. Проведено виміри віку біотиту з родовища Станковатське (Україна), який дозволяє припустити про приналежність літієвих пегматитів Кіровоградського блоку Українського щита до важливого глобального палепротерозойського металогенічного епізоду віком $2{,}4\cdot10^9$ років.