DETERMINATION OF THE ELEMENTAL COMPOSITION AND THE AGE OF GEOLOGICAL SAMPLES BY NUCLEAR ANALYTICAL METHODS

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Purposes of this work

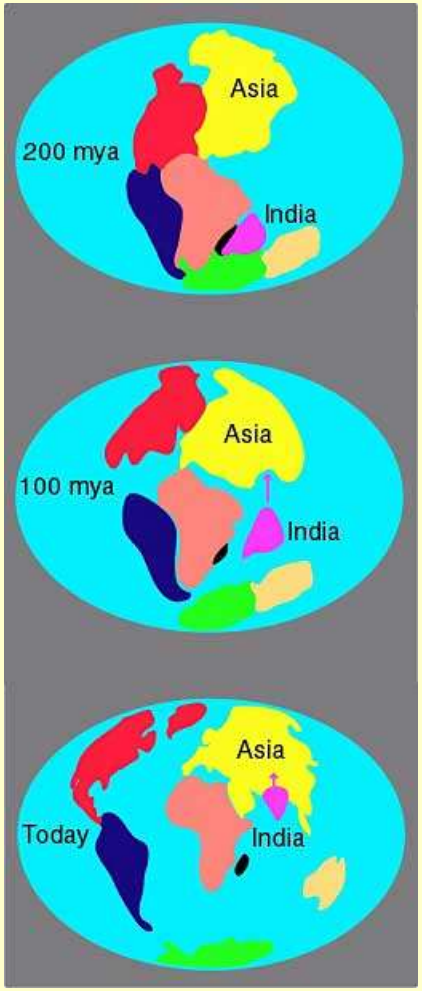
- To get more geological information about the Mount Kailash - one of the most mysterious places in the world,
- The **rubidium-strontium dating** method has usually carried out using Mass Spectrometry, this work shows that the method could be realized using nuclear analytical techniques

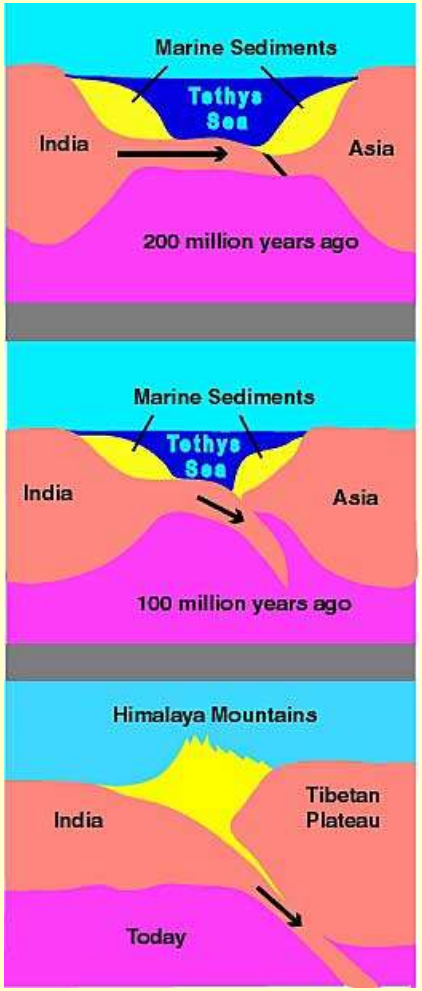
About the Kailash Mount

Location of the Mount Kailash

- Mount Kailash included in the Trans-Himalaya system is located in western part of Tibet – China.
- Mount Kailash is the sacred site of four religions: Hinduism, Jainism, Bon and Buddhism which attracts many spiritual seekers and researchers.

Tectonic evolution pattern of Himalayas





- The pattern explained by the continental collision of Indian and Asian plates gains world-wide acceptance.
- The pictures show position of two continents by the time from 200 million years ago until now.
- The impinging of the two landmasses has yet to end. The Himalayas continue rising more than 1 cm a year
- The last earthquake in Nepal shows the continuation of the collision tectonic pattern

Rubidium-Strontium dating method

- The radiometric dating technique used to determine the age of rocks and minerals from their quantities of specific isotopes of rubidium (^{87}Rb) and strontium (^{87}Sr, ^{86}Sr)
- The method was suggested by German chemist Fritz Strassmann
- This method is useful in the case of
  - ✓ correctly measuring all related data
  - ✓ The samples are co-genetic and old aged.
  - ✓ The rock must not have undergone any re-formation which could have disturbed the Rb-Sr system

Rubidium-Strontium system

^{87}**Rb=27.83%**
^{85}Rb=72.17%

^{87}Rb decays to ^{87}Sr by β^- with the half-life = 48.8 billion years

^{88}Sr=82.53%
^{87}**Sr=7.04%**
^{86}Sr=9.87%
^{84}Sr=0.56%

} all stable

- Therefore, relative isotopic abundances of Sr isotopes vary by the time
- And the isotopic composition of Sr in a rock or mineral depends on
  - its age
  - and its Rb-Sr ratio

Rb-Sr dating method

- The Rb/Sr dating method based on the decay equation

$$^{87}Sr = {}^{87}Sr_{i} + {}^{87}Rb(e^{\lambda t} - 1) \qquad \text{i: initial} \qquad (1)$$

- In practice, the ratio of Sr and Rb isotopes in sample is considered. Therefore the above equation is divided through by the number of ^{86}Sr atoms which is constant during the time. This gives us the equation

$$^{87}Sr/^{86}Sr = (^{87}Sr/^{86}Sr)_{i} + {}^{87}Rb/^{86}Sr(e^{\lambda t} - 1) \qquad (2)$$

- The half-life of ^{87}Rb is $T_{1/2}$ = 48.8 billion years, and $\lambda = \ln 2/T_{1/2}$ so that λ is very small, then the equation reduces to the equation

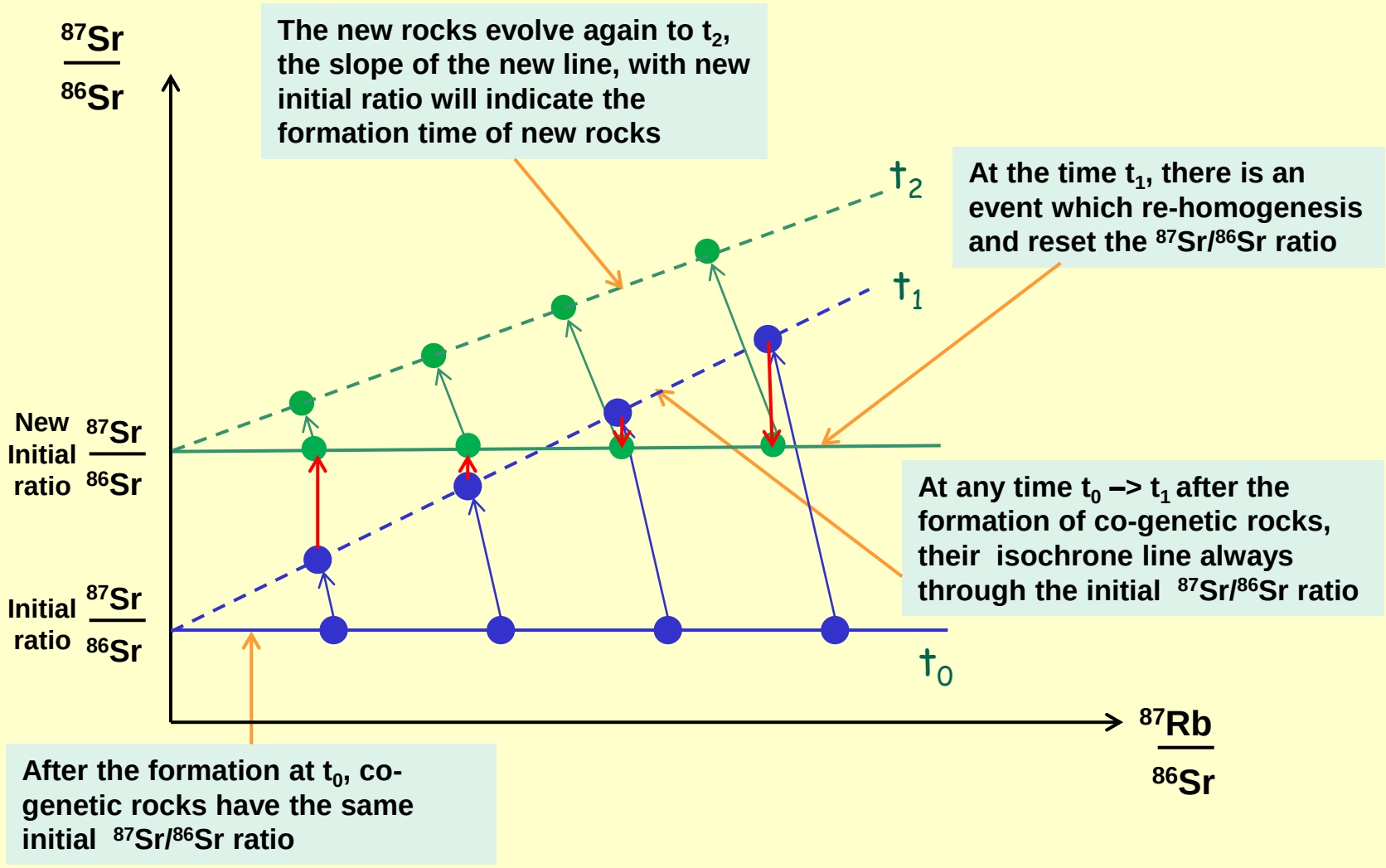
$$^{87}Sr/^{86}Sr = (^{87}Sr/^{86}Sr)_{i} + (^{87}Rb/^{86}Sr)\,\lambda t \qquad (3)$$

$$y = b + x\,a$$

This equation has the form of a straight line with the slope

$$a = \lambda t$$

Rb-Sr Isochron

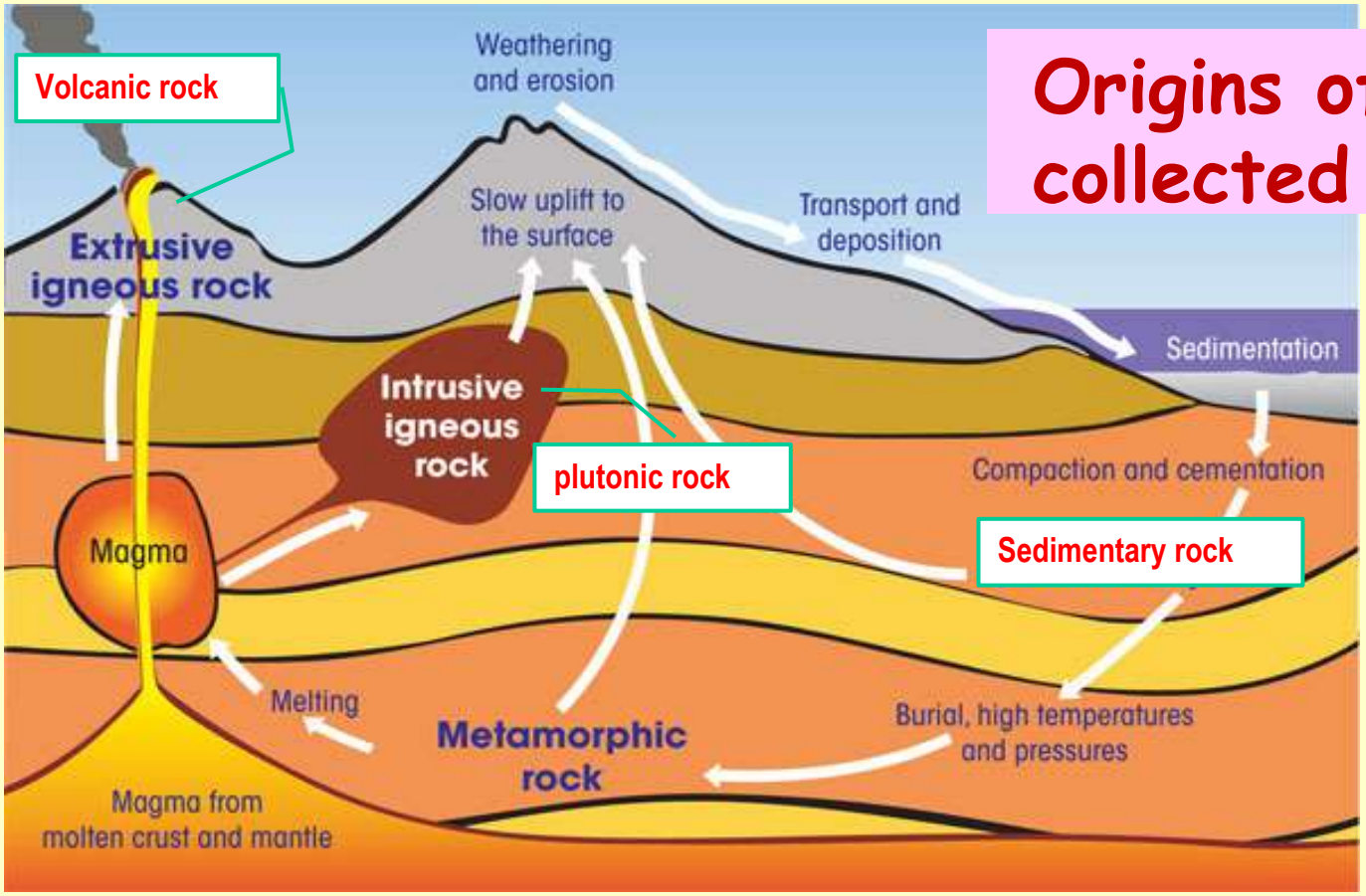


Sample collection

- 13 samples of 6 rock types collected during the expedition in 2013-2014 at many sites on different faces of the Kailash mountain and at the height of 5390 to 5800 meters over the sea level

Name	Samp. number	Rock origin	Collecting site
K1	2	volcanic	on the left of the east face base , at 5570 м
K2	2	plutonic	on the left of the top stage of the western face, at 5390 м
K3	2	Volcanic debris	in the middle of the northern face base, at 5555 м
K4	2	Sedimentary	inner crust on the western ridge, at 5670 м
K5	3	Sedimentary	inner layer under the conglomerate layer of 13 feet of the southern face, at 5800 м
K6	2	plutonic	outer layer, on the right of eastern face, at 5590 м

Origins of the collected rock



plutonic rock forms when magma cools and solidifies below earth;
volcanic rock forms when magma cools and solidifies on earth;
sedimentary rock forms through the deposition and solidification of sediment

K1 sample

Meta-andesite

K2 sample

leucogranite with phlogopite

K3 sample

gravel of volcanic debris

K4 sample

arkose sandstone of destructed granite

K5 sample

sandstone

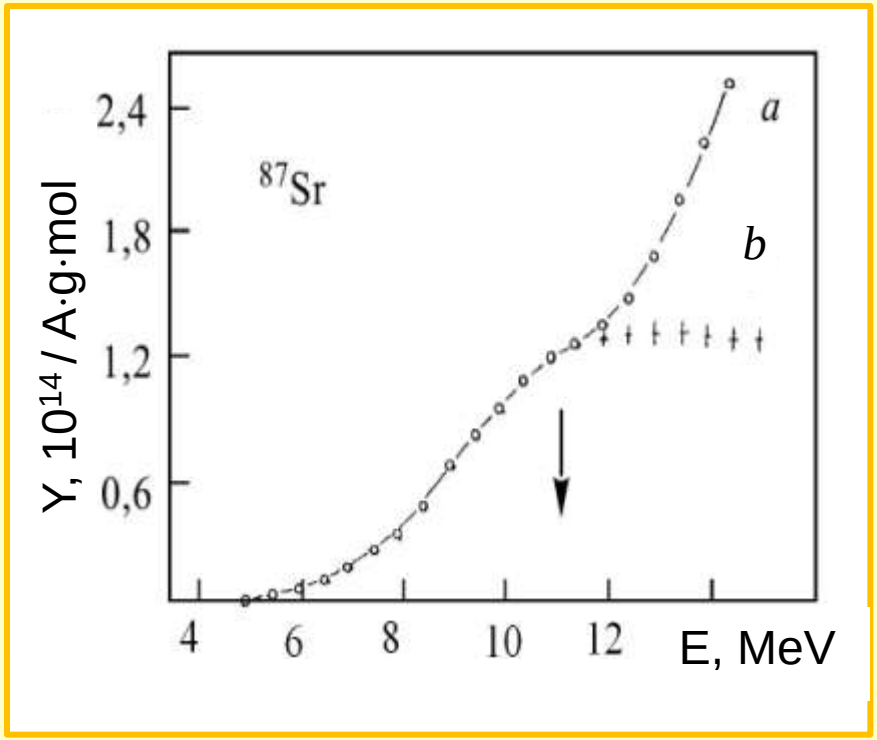
K6 sample

Plagio-granite

Rb-Sr dating method

- To solve the above equation and estimate the age t by nuclear analytical technique, these contents must be known.
  - the total contents of Rb and Sr
  - the content of ^{87}Sr
- In our work
  - The concentrations of 30 elements, including Rb and Sr were determined and inter-comparized by XRFA in the Laboratory of Nuclear Reactions (LNR) and NAA at the IBR-2 pulsed reactor in Laboratory of Neutron Physics, JINR
  - Content of ^{87}Sr obtained by reaction $^{87}Sr(\gamma,\gamma')^{87m}Sr$ using the microtron MT-25 in LNR.
  - The trap-rock CT-1A (an igneous rock) with definite age and composition was used as standard

Special condition to obtain ^{87m}Sr

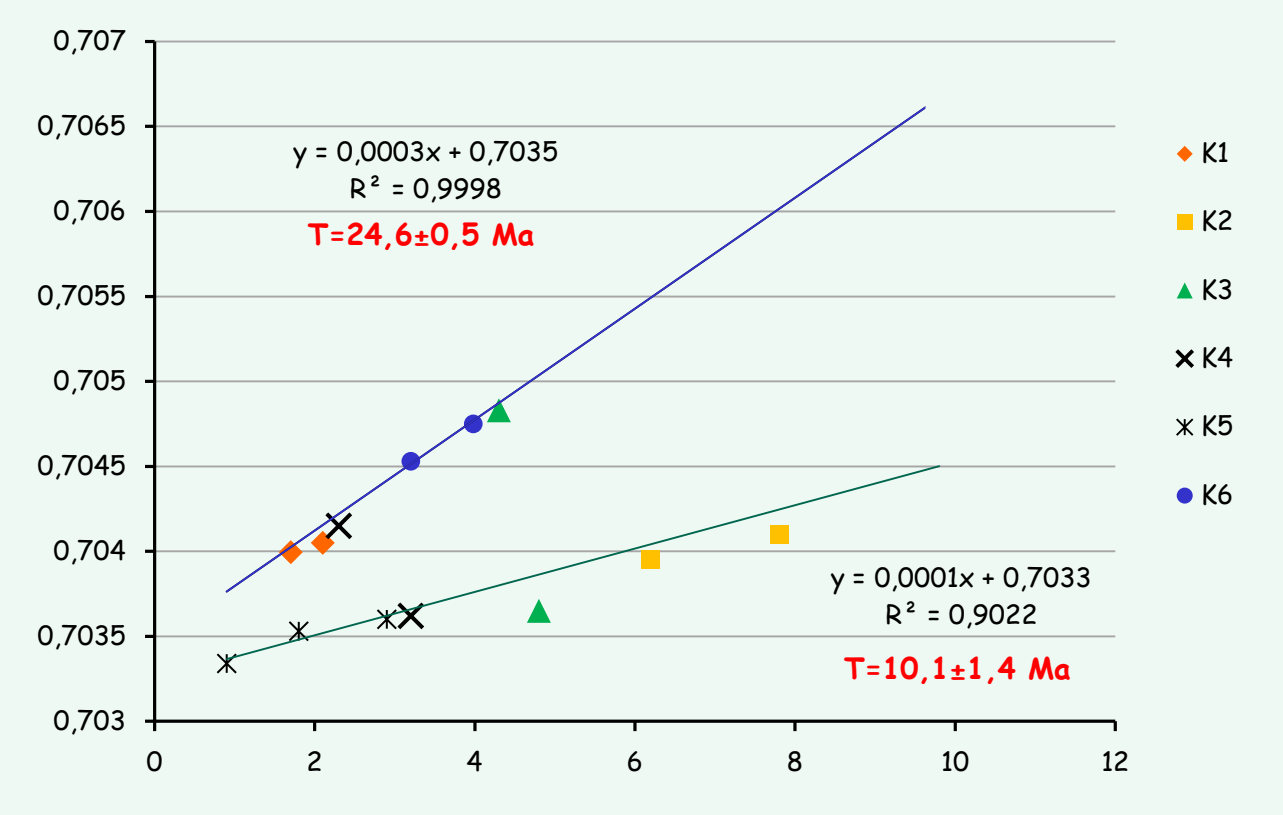


- The isomeric state of ^{87m}Sr can be obtained using gamma irradiation by two reactions
  - $^{87}Sr(\gamma,\gamma')^{87m}Sr$ (a) useful
  - ^{88}Sr (γ, n) ^{87m}Sr (b) unuseful
- In order to obtain only one optimal useful process, energy of irradiating beam is

$E\gamma = 10MeV$

This condition was found out by the study of Gangrskii I.P., Physics of Elementary Particles and Atomic Nuclei, 2002,T33, Vol 1)

Isochrone lines of the Kailash samples



The calculated data are shown in the graphic; they are fitted to two isochrone lines. One line relates to the age of 24.6 Ma; the other to the one of 10.1 Ma

Rock origins and their ages

Name	Rock type	Age (Ma)	Notes
K1	Meta-andesite	22.3 ± 0,1	
K2	Leuco-granite	6.78 ÷ 8.46	
K3	Gravel of volcanic debris	1.93 ÷ 2.65	New rock
		23.3± 0,1	Old rock
K4	Arkose sandstone of destructed granite	8.26± 0,1	New rock
		23.3± 0,1	Old rock
K5	Sandstone,	8.36 ÷ 12.5	
K6	Plagio-granite	25.8± 0,1	

- Tectonic evolution of Tibetan Plateau studied by other method has shown that:
  - Linking between uplift and initiation of the monsoonal weather system in the Tibetan Plateau shows that the uplift dating as far back as 22 Ma
  - Besides, the sedimentation rates deduced from seismic profiles from the South China Sea suggest an active monsoon by the early-mid Miocene (11–16 Ma)
- Our work submits that:
  - Based on the analytical results, this work submitted the age of igneous rocks is from 20 to 25 million years and the age of the younger rock is about 8-12 million years. These results are in agreement with the description of the tectonic evolution of Tibetan Plateau.

Conclusion

- Nuclear analytical techniques were used to determine elemental concentrations and to estimate the ages of geological samples taken in the expeditions in 2013-2014 years, on different sites of Mount Kailash. The dating is well fitted to the estimation of other sources
- Until now Rubidium-Strontium dating traditionally realizes by using Mass Spectrometry
- This work the first time brings out the potentiality of using nuclear analytical technique to the Rubidium-Strontium dating. The work continues to improve

Thanks you!

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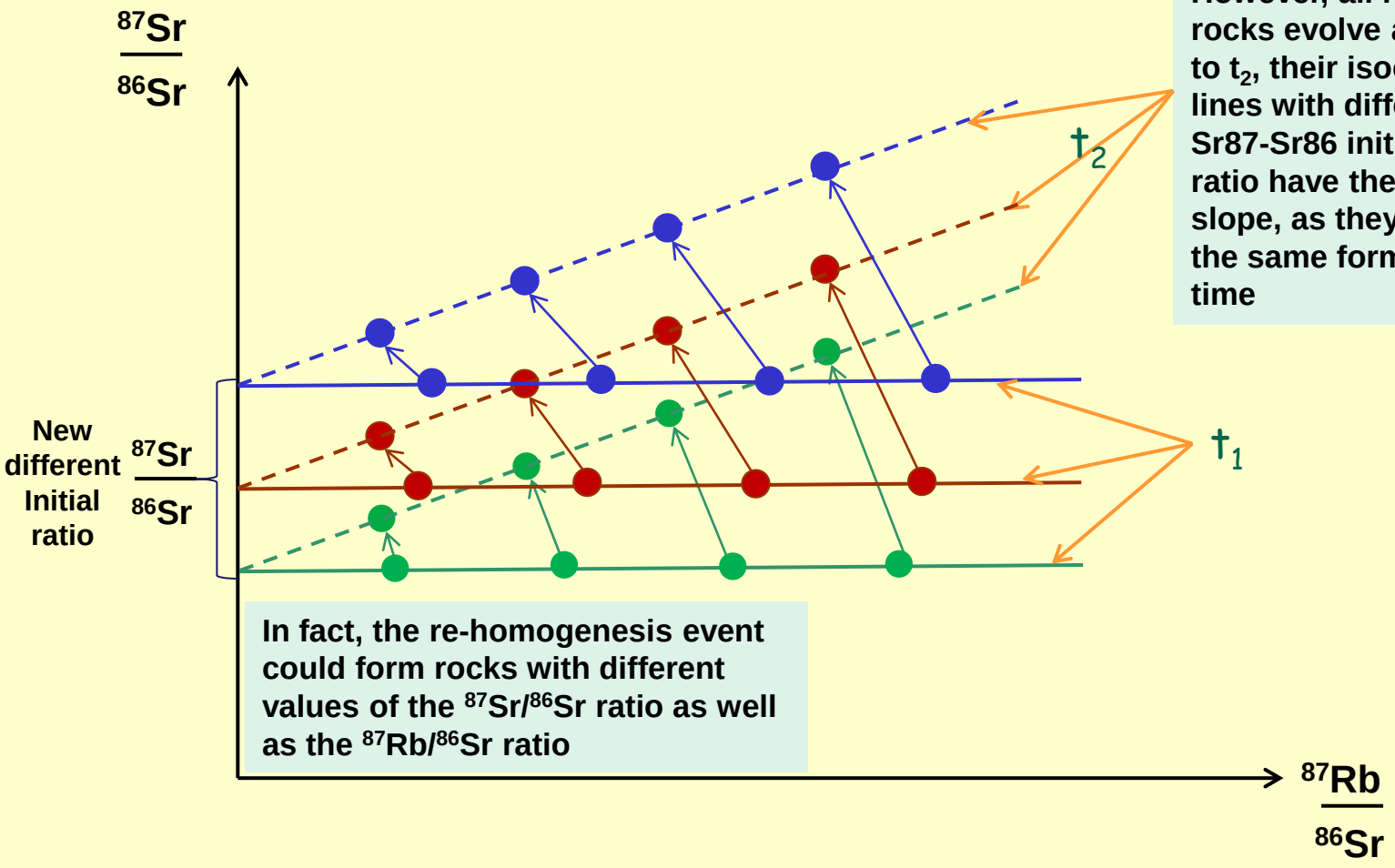
- Khotyleva A.O. Officer, Department of Regional Geology and Earth History, Geological Faculty of Moscow State University Lomonosov for their help in the classification of samples

Rb-Sr Isochron



However, all new rocks evolve again to t_2, their isochrone lines with different Sr87-Sr86 initial ratio have the same slope, as they have the same formation time

In fact, the re-homogenesis event could form rocks with different values of the $^{87}Sr/^{86}Sr$ ratio as well as the $^{87}Rb/^{86}Sr$ ratio

The Fitting of Isochrons

- The fit of data points to a straight line is complicated by the errors that are associated with each of the analyses
- Besides, sample classification helps to choose co-genetic rock samples used to dating
- Work with more samples could give a correct statistic to fit the isochrone line