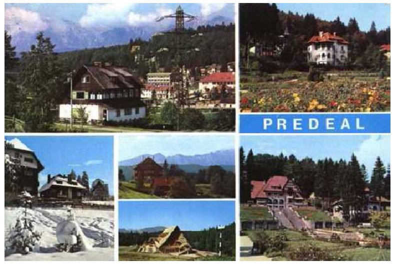
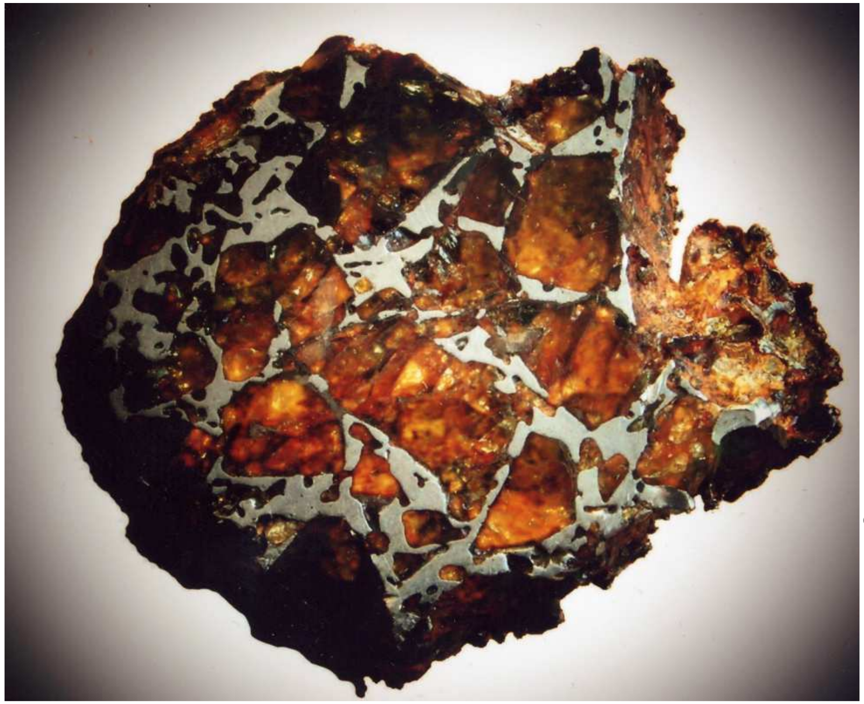
Workshop on Nuclear Track Emulsions



Search for Superheavy Elements in Galactic Cosmic Rays

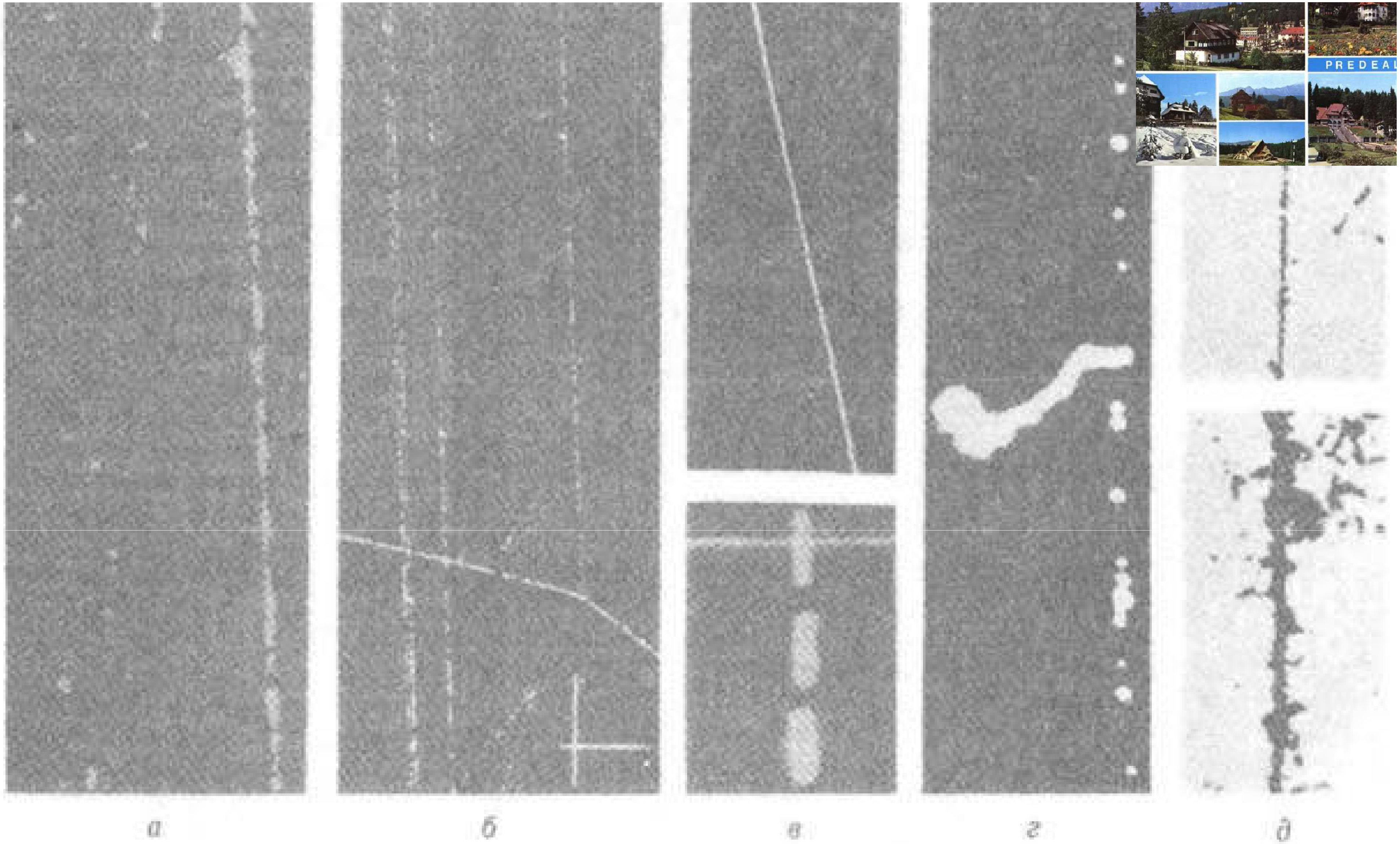


Lebedev Physical Institute of RAS

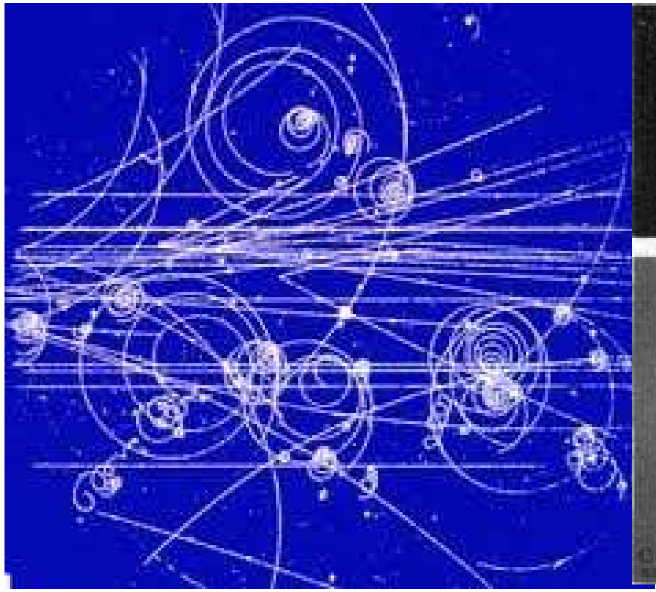
Vernadsky Institute of Geochemistry and Analytical Chemistry of RAS

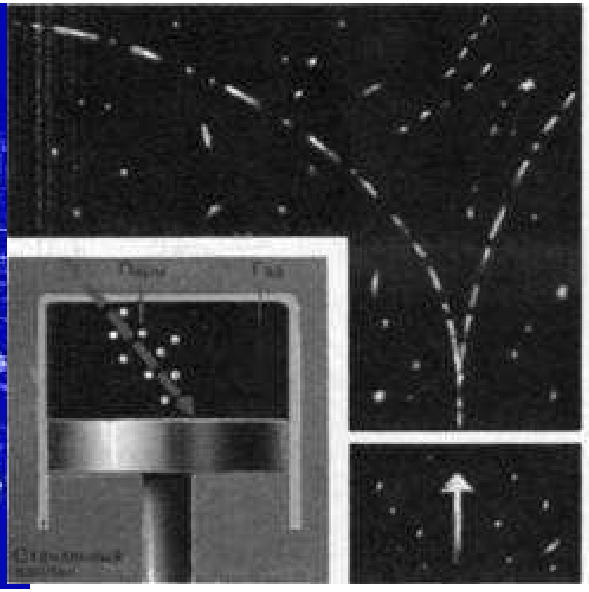
N.Polukhina

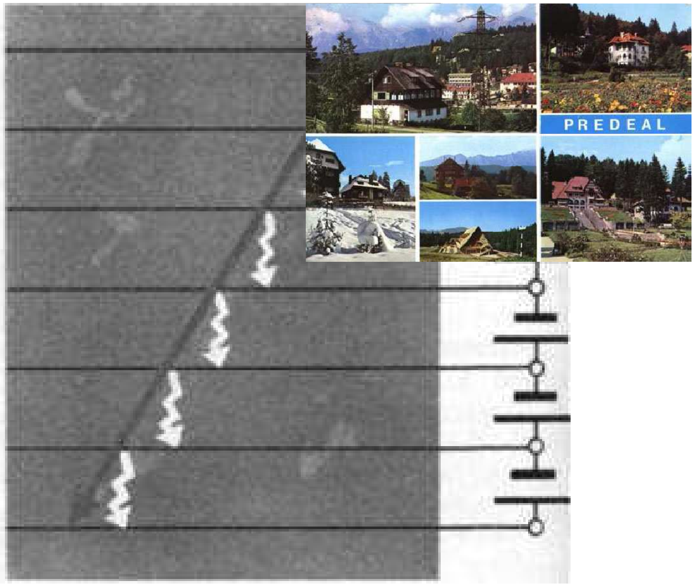
October, 2013



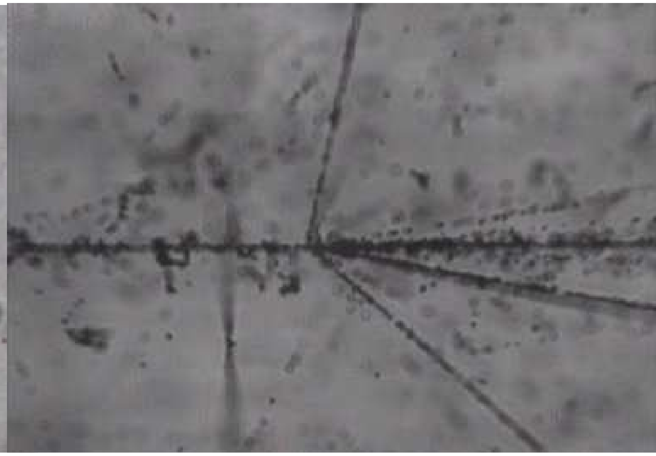
In track detectors registration of elementary particles is accompanied by the emergence of observable traces (tracks) repeating the trajectory of an elementary particle. These are bubble and spark chambers, nuclear emulsions, silver chloride crystals and etchable solid state track detectors

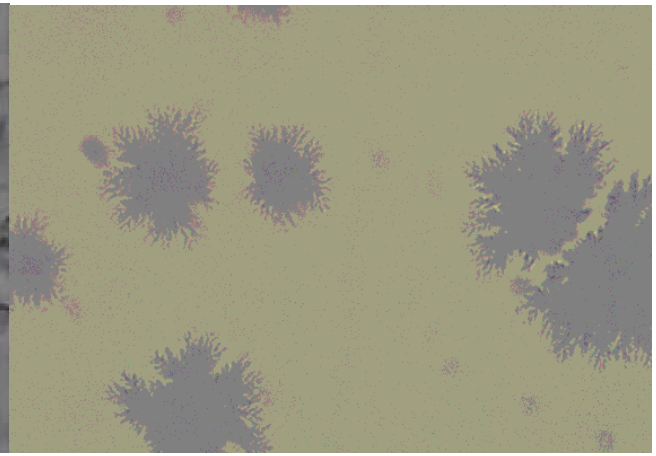




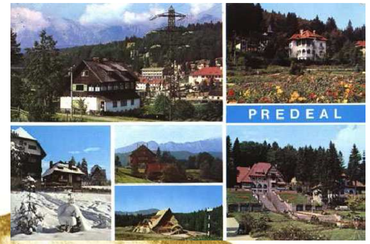


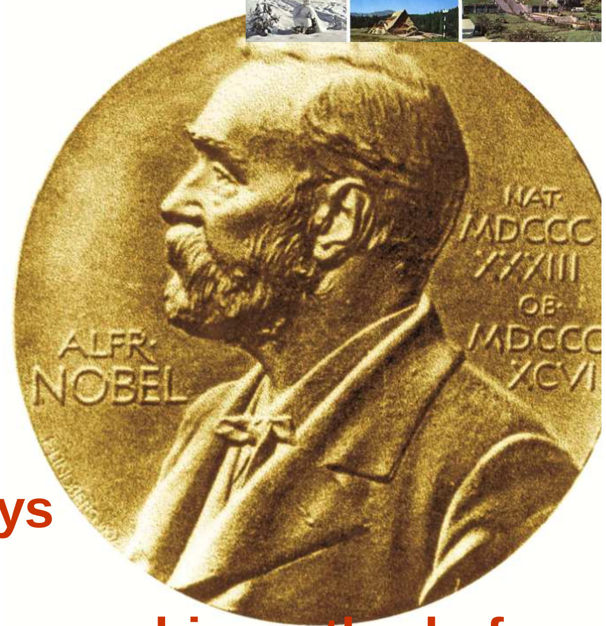
The popularity and long life of the track detection technique are not by chance and are due to a range of detectors' merits: unique spatial resolution, obviousness of the reconstructed spatial pattern of particles' interaction, relative simplicity and low cost, capability of accumulating information over long periods of time and other advantages.





Great meaning of track detectors for nuclear physics.





Nobel prizes:

1903 – H. Becquerel , natural radioactivity .

1927 – C.T.R. Wilson, Wilson cloud chamber

1936 – V.Hess, photolayers, discovery of cosmic rays

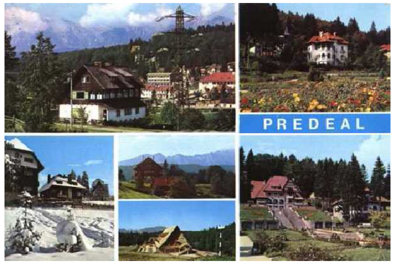
1950 – C. F. Powell, for the development of the photographic method of studying nuclear processes and the discovery of mesons;

1960 – D. A. Glaser, for the invention and improvement of the bubble chamber;

1968 – L. Alvarez for the discovery of a large number of resonance states, made possible through the use of hydrogen bubble chambers;

1992 – G. Charpak, for the multiwire proportional chamber.

Great meaning of track detectors for nuclear physics.



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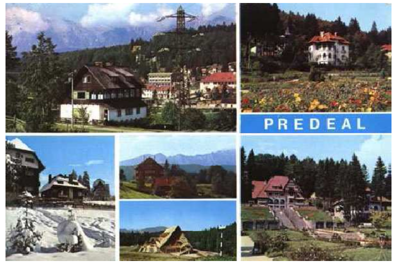

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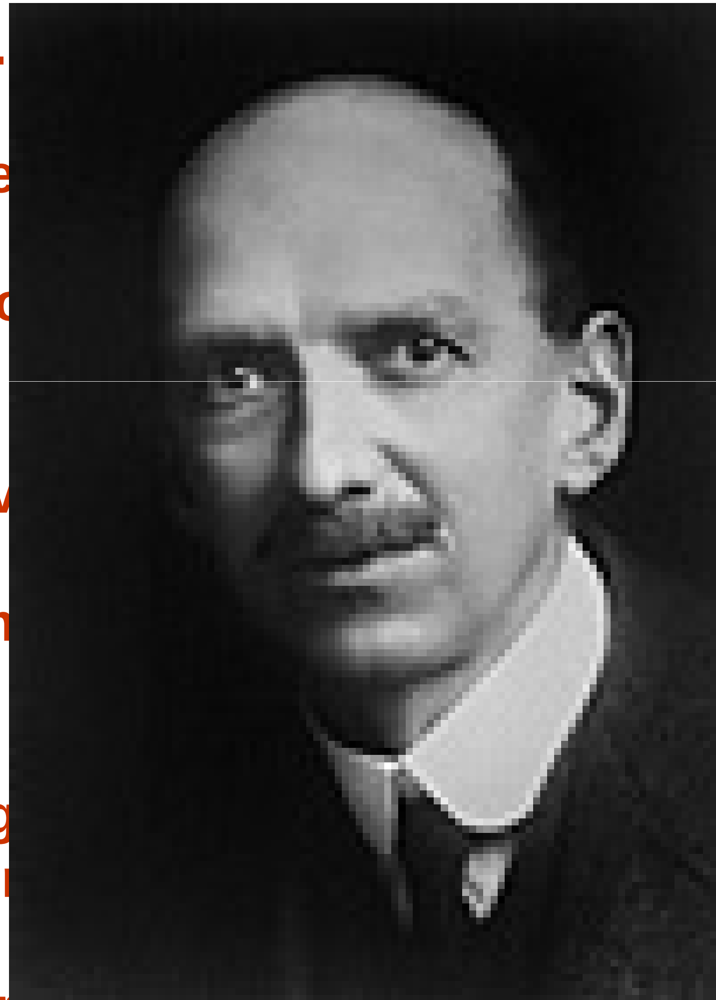

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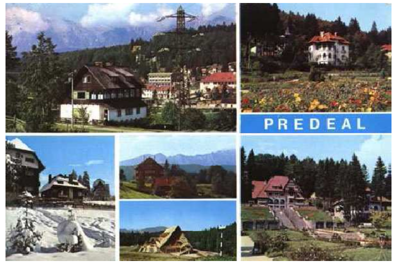

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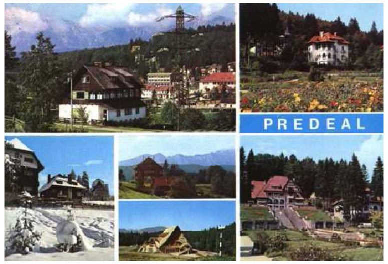

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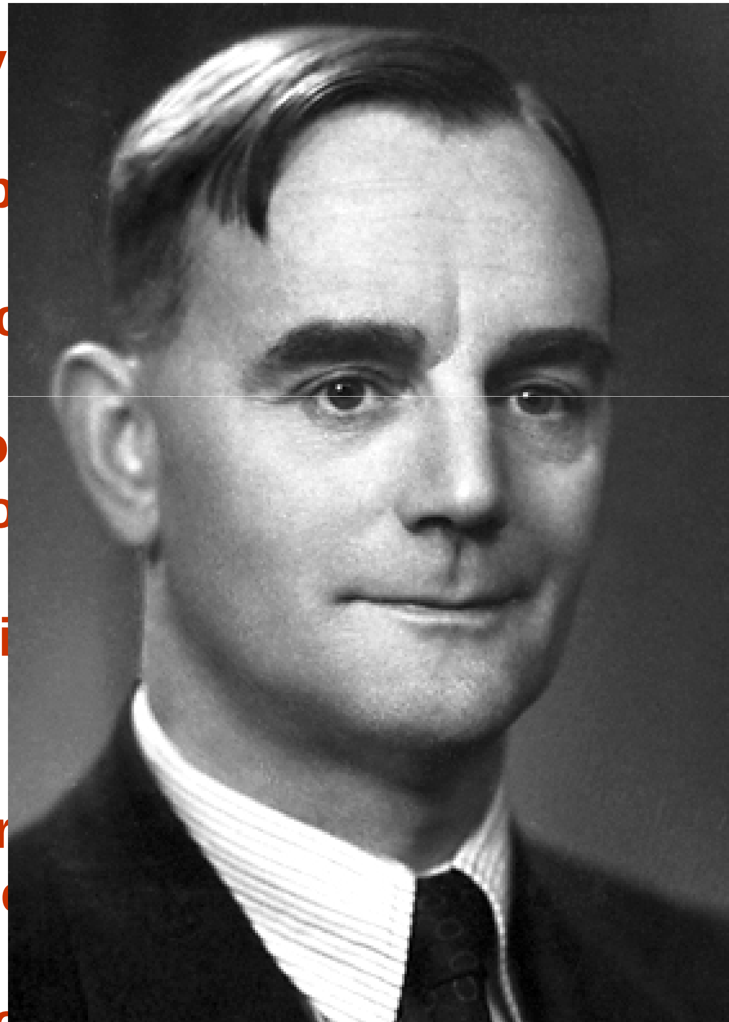

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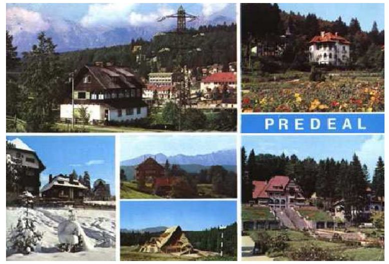

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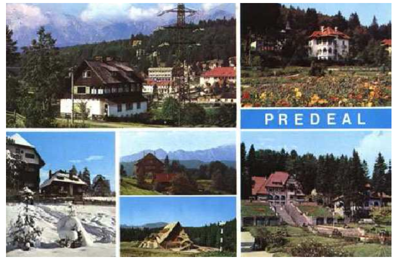

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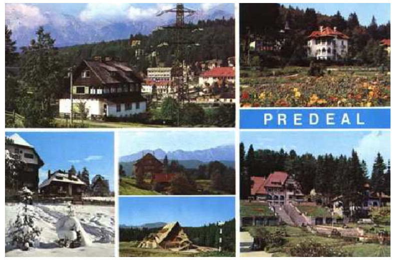

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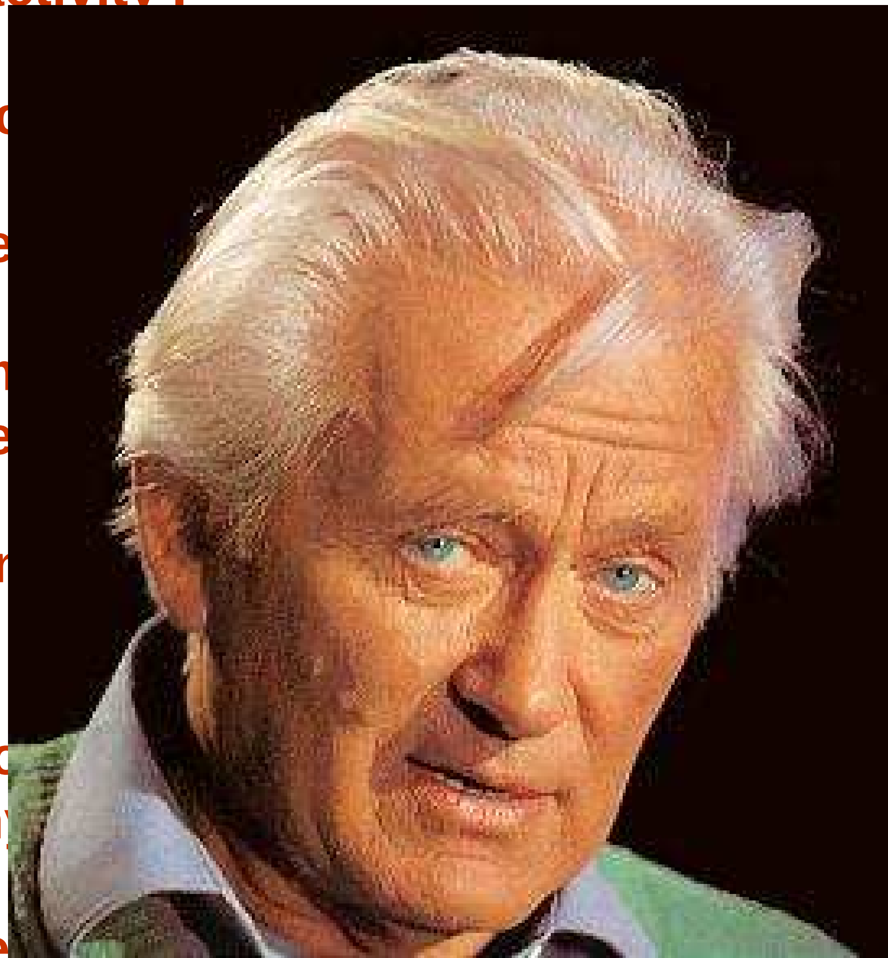

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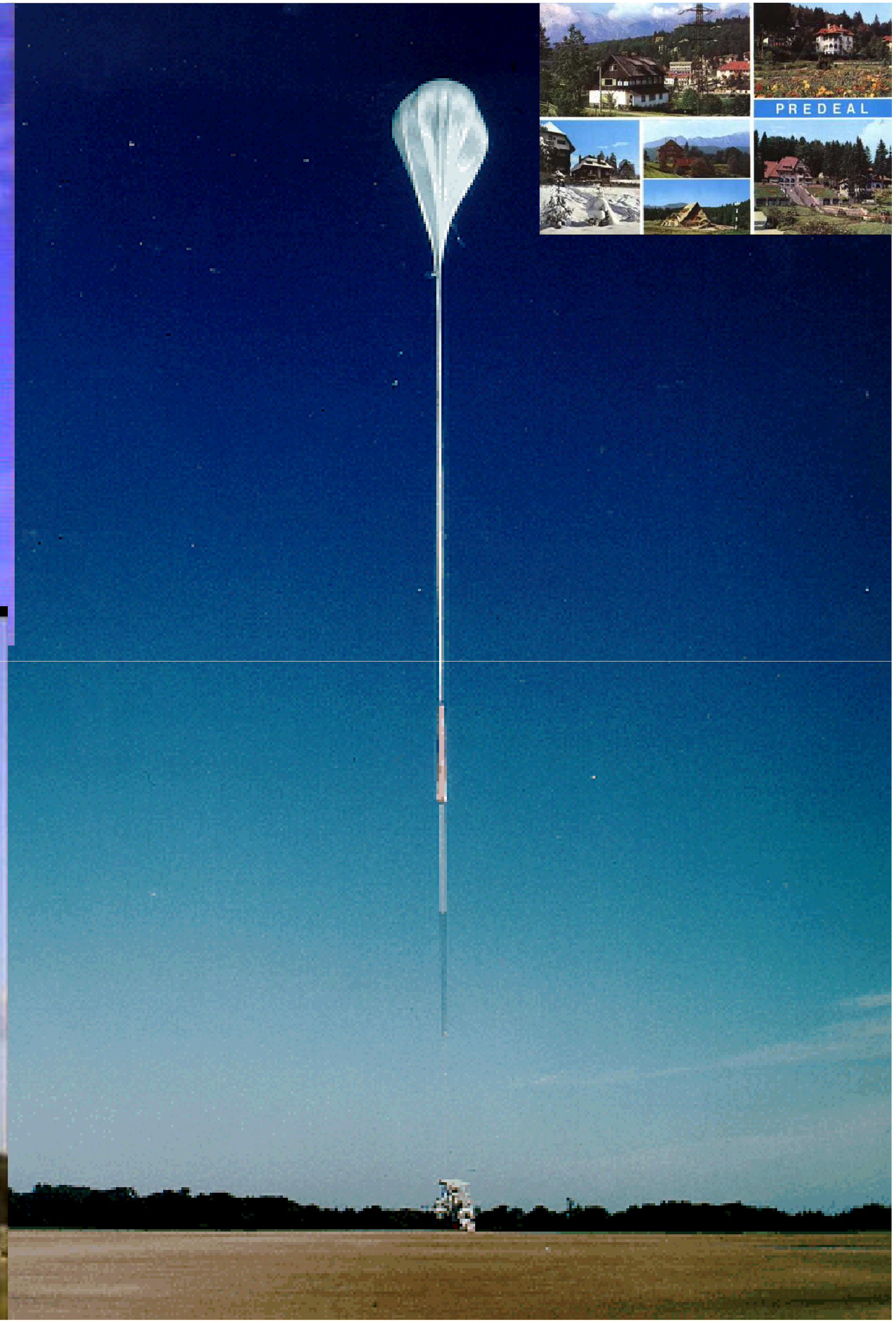
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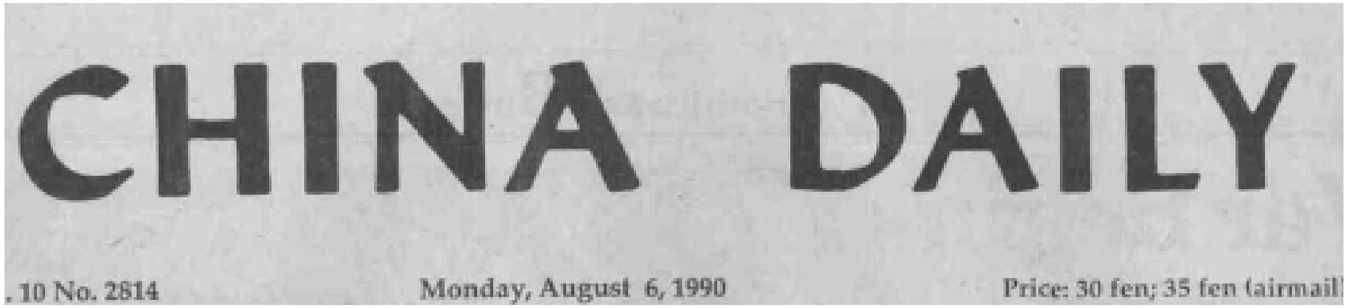
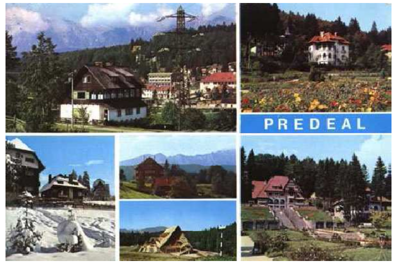


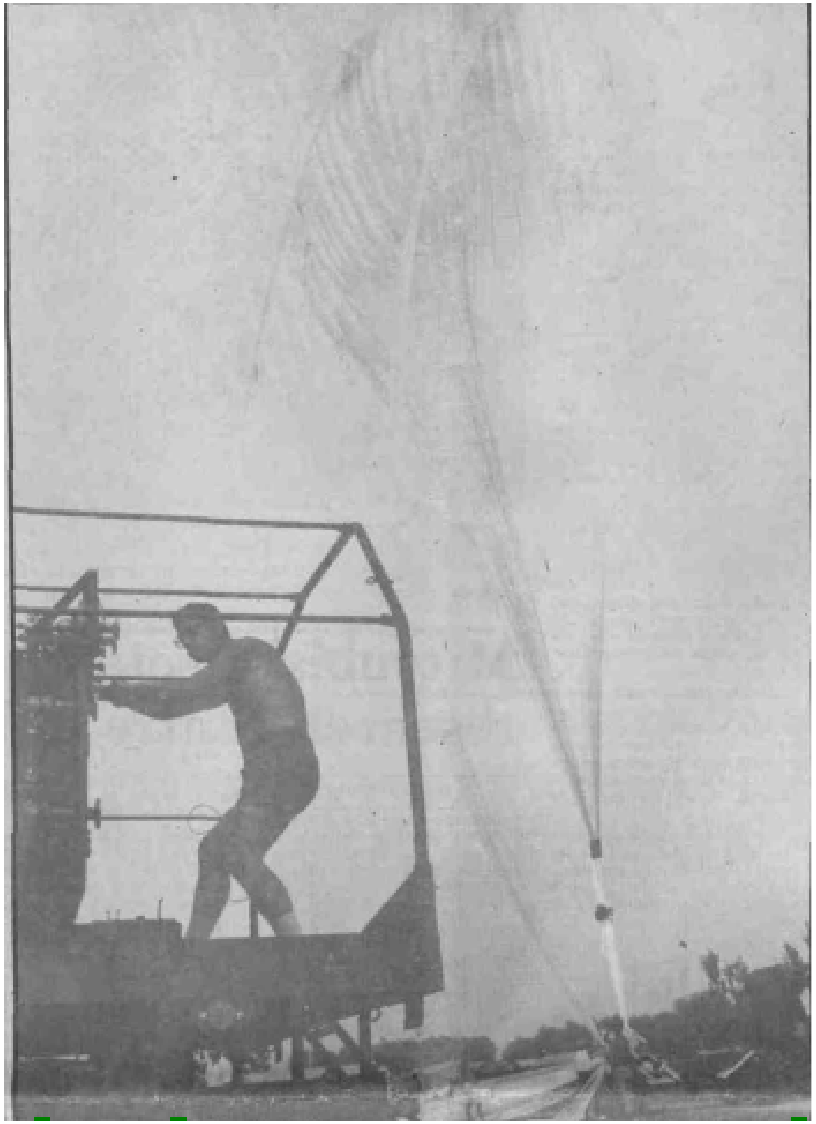
CHINA DAILY

. 10 No. 2814 Monday, August 6, 1990 Price: 30 fen; 35 fen (airmail)



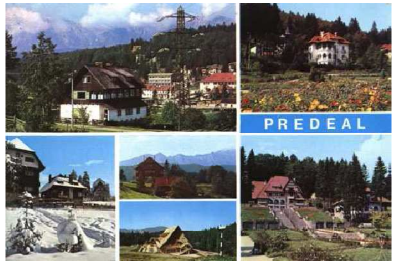
Chinese and Soviet scientists send an experimental balloon skyward yesterday after a year's preparation. A Soviet expert is filling the balloon with hydrogen at a station in Hebei Province. The balloon will fly over 33 kilometres high out of China from Kashi in the Northwest and is scheduled to be retrieved near the Caspian Sea in the Soviet Union, covering 5,000 kilometres in three days.

China Daily photo by Wu Zhiyi



SCIENCE AND TECHNOLOGY DAILY

1990. 8. 6.　　CN 11-0078　1-97



中苏高空科学观测气球升空

预计飞行四天行程万里

本报北京8月5日讯　记者孙明河、董志翔报道　今后4天，我国北方7省区北纬40°左右广大地区的天文爱好者，可能看到一只白色气球，以每小时约70公里的速度，自东往西飞过。

今天19点30分，中苏联合高空科学观测气球，在河北省香河县中国科学院气球发放场，克服近地层湍急气流的干扰，以每分钟约400米的速度徐徐升高。它的目的地是苏联里海东岸。

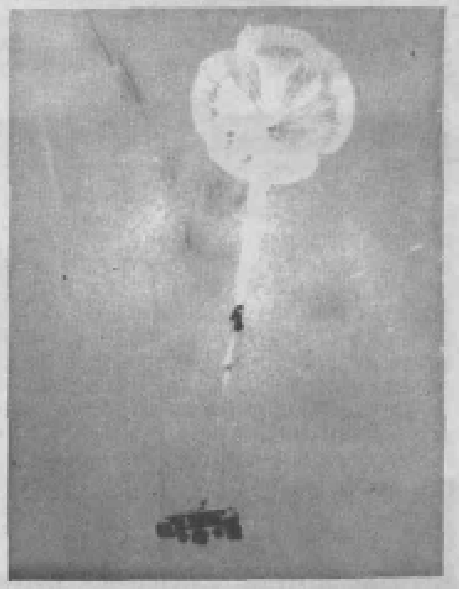
这只容积18万立方米的气球，虽然在地面只充进约1／100体积的氦气，但负载1.4吨重的观测仪器，升空时仍显得轻松自如。

科学家们说，随着高度上升，空气越来越稀薄，气球会逐步膨胀，达到预定的33公里高度时，升力和重力平衡。而后，沿着平流层大气由东向西飘移。据悉，这次飞行携载了接受高能宇宙射线的乳胶室和生物样品。

在预期4天的飞行途中，中苏双方将通过国际救援卫星对它密切关注。如果成功，将是迄今北半球距离最长的一次国际空间气球飞行。

这个堪称亚洲大陆高空的探险者将受到强烈的太阳辐射和摄氏零下50度低温的考验。除了有限地自动调整高度外，它将得不到人们的其他帮助。为此，筹备工作进行了1年半之久。

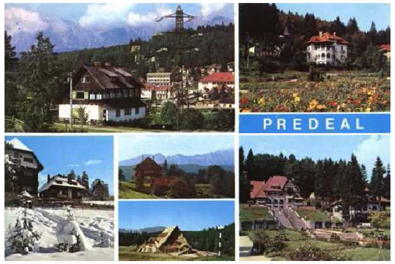
今天，发放场天气异常潮湿闷热。中苏16位科学工作者大汗淋漓，紧张工作了5个小时。21点30分，气球已顺利达到预定高度，进入正常飞行状态。



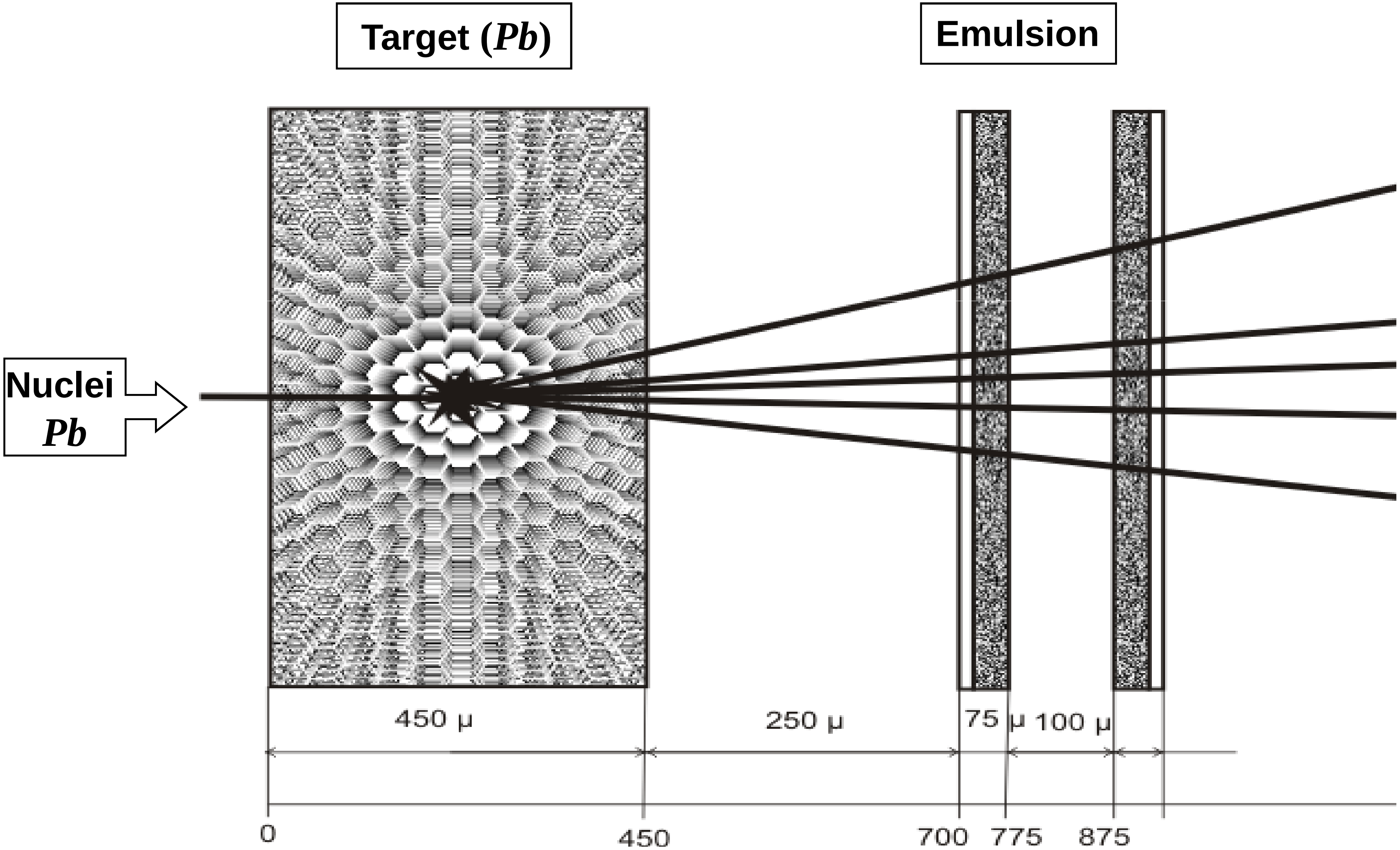
（上图）气球升空时的情景。

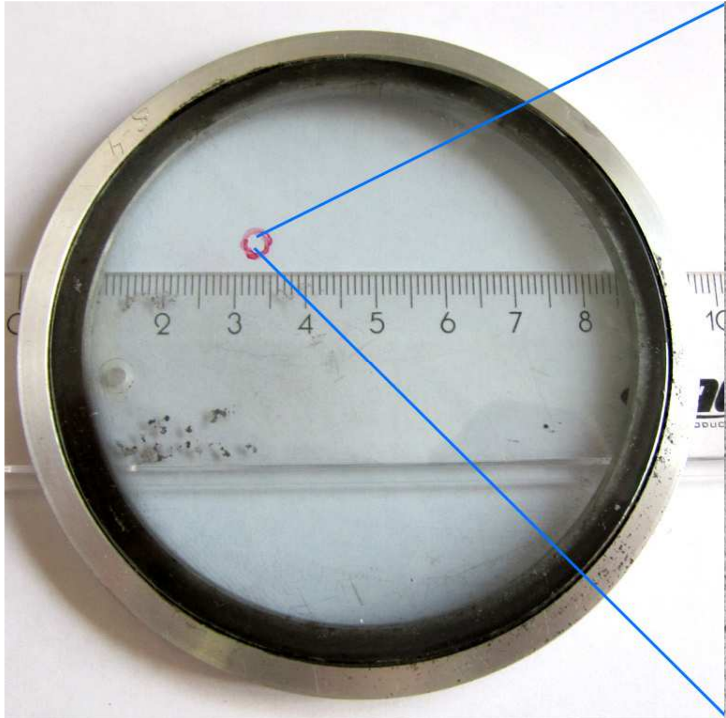
（中图）中苏双方专家在现场进行升空前的最后检查。

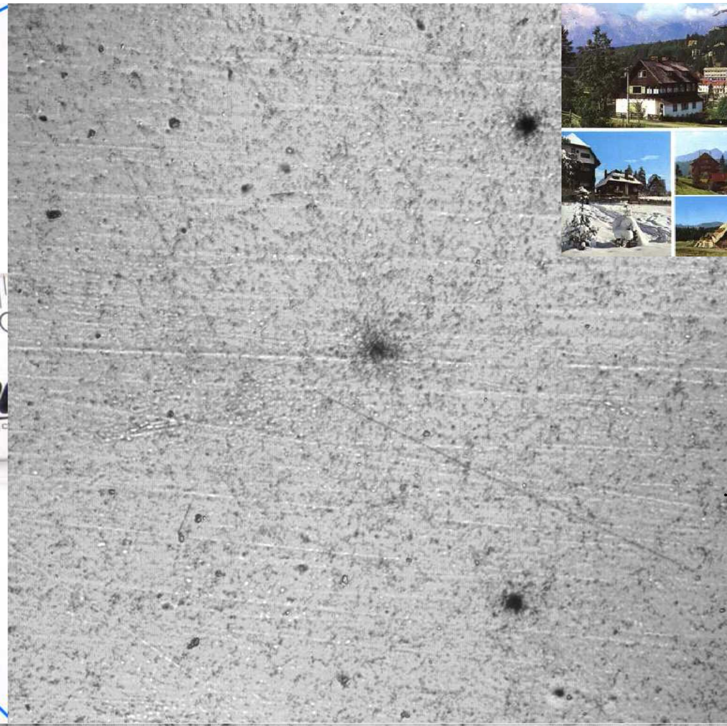
（下图）科学工作者们正紧张地摆弄气球准备充气。

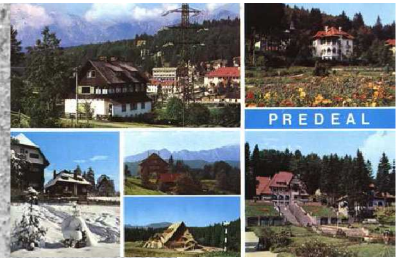


CERN experiment EMU-15

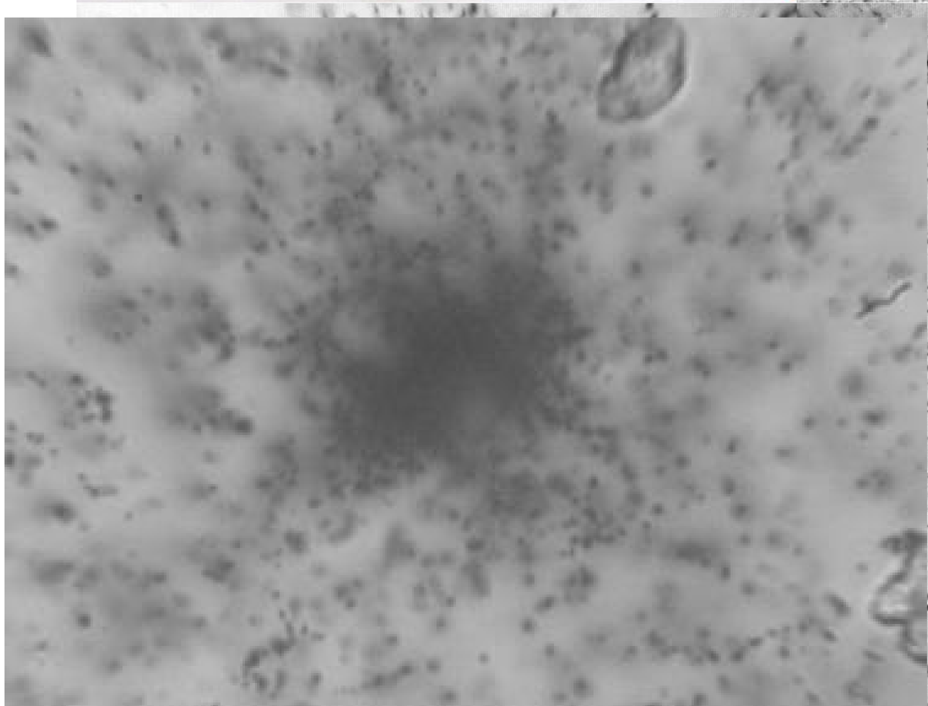




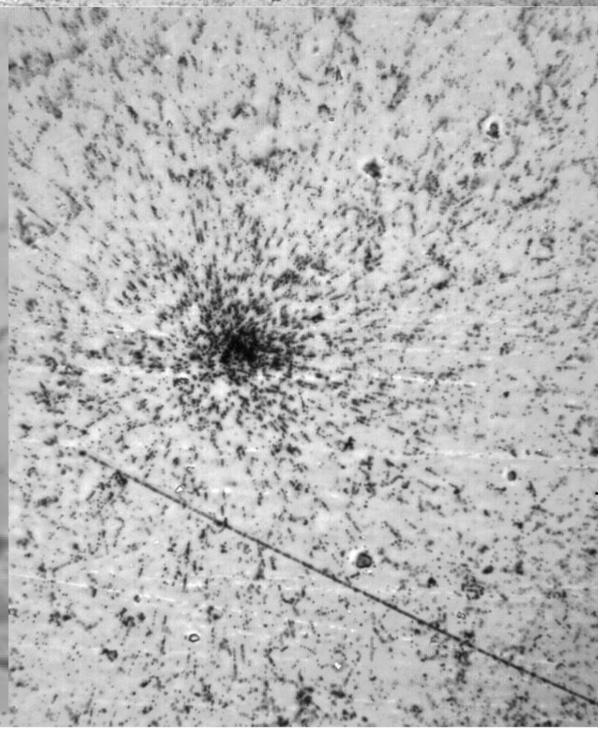




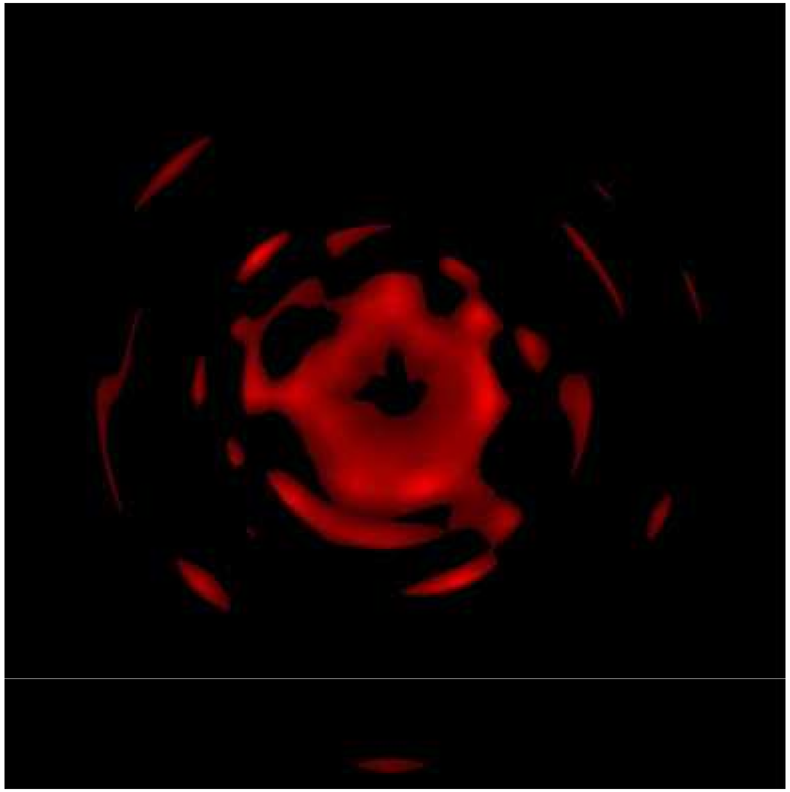
8×
820 × 820
мкм^2

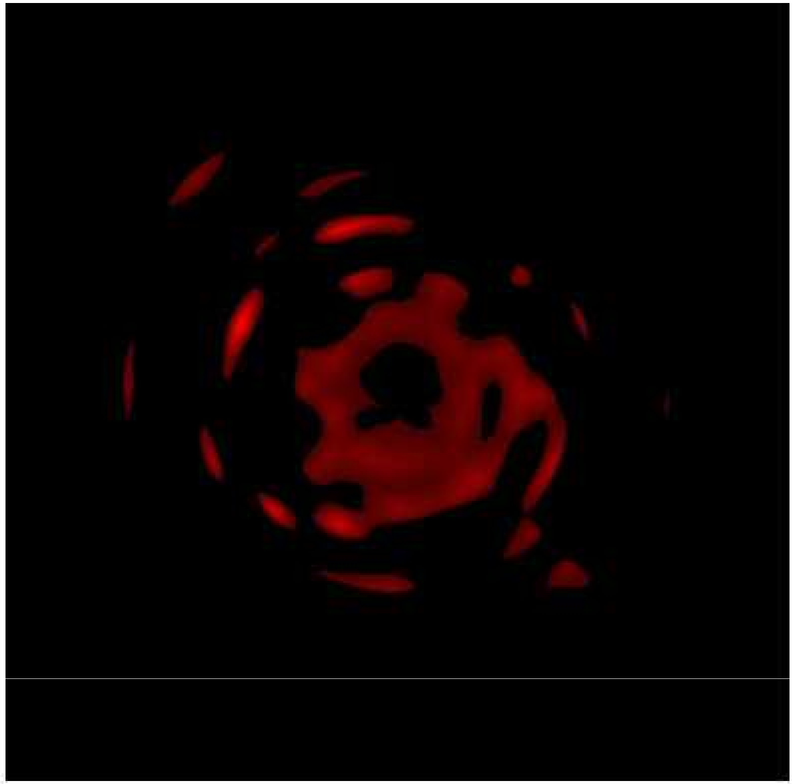


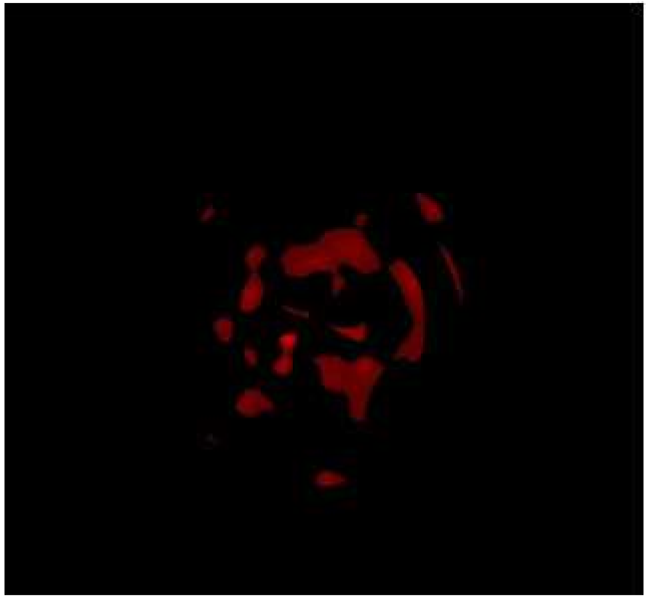
60×
115 × 115
мкм^2



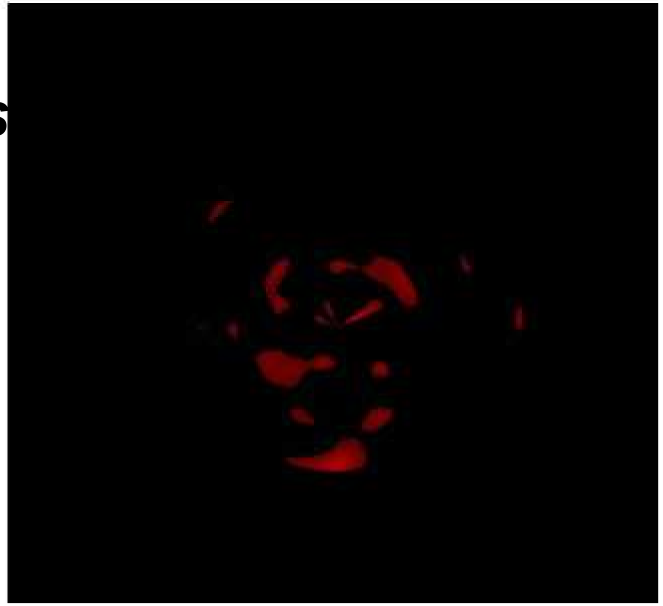
20×
330 × 330
мкм^2

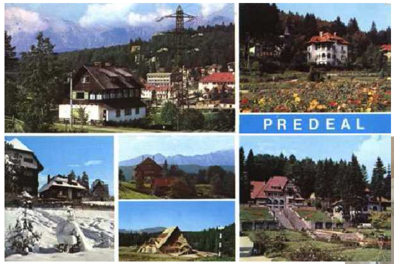




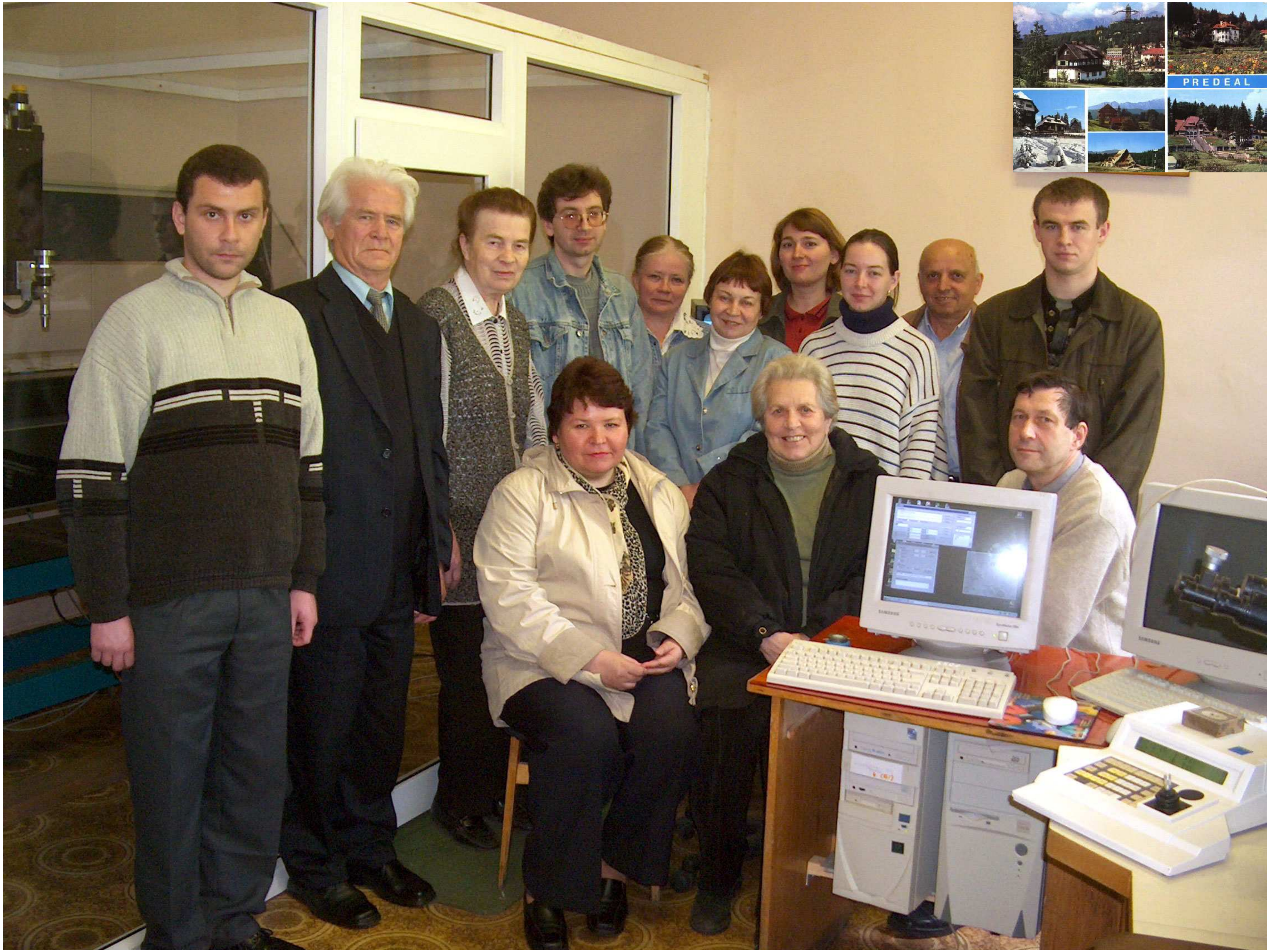


The target diagrams of experimental events (experimental – top fig., calculation – bottom)





Completely Automated Measuring Facility PAVICOM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PREDEAL
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09.09.2008 11:00


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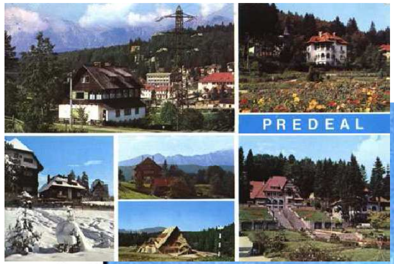
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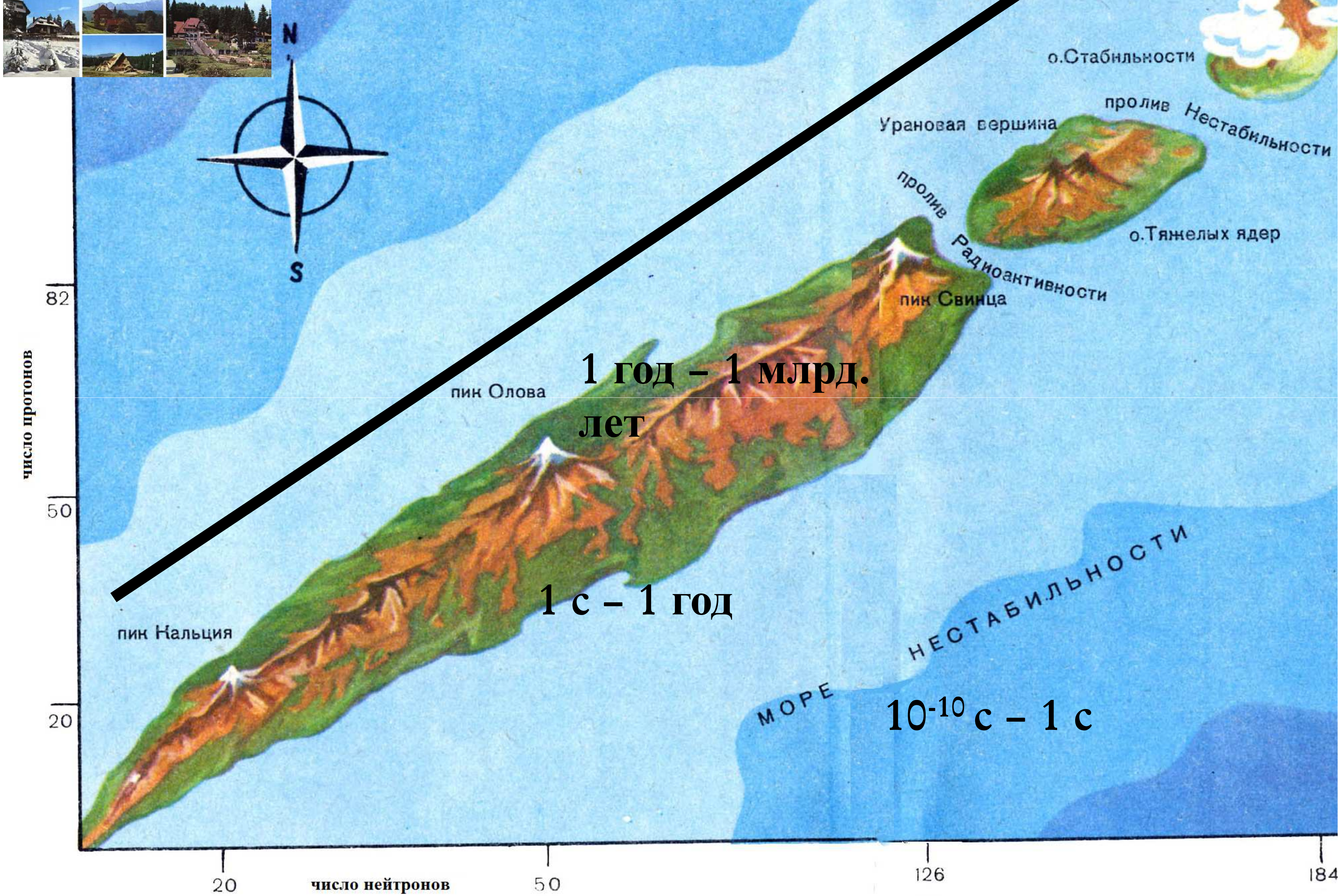
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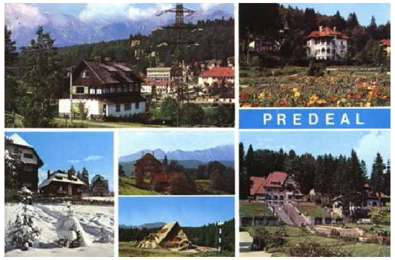
о.Стабильности
пролив Нестабильности
Урановая вершина
пролив Радиоактивности
о.Тяжелых ядер
пик Свинца
пик Олова
пик Кальция
1 год – 1 млрд. лет
1 с – 1 год
МОРЕ НЕСТАБИЛЬНОСТИ
10^{-10} с – 1 с
число протонов
82
50
20
число нейтронов
20
50
126
184



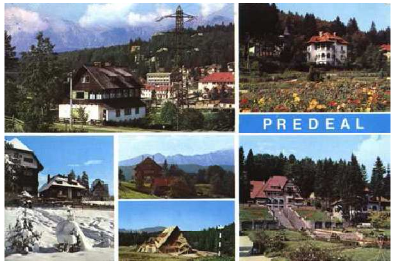
In 1869 г. – 63 elements, in 2012 - 118

(238)	92 U	$5f^3 6d^1 7s^2$	1132	3818	~1.2/1.2	Uranium	Уран
(239)	93 Np	$5f^4 6d^1 7s^2$	639	3902	1.22/1.2	Neptunium	Нептуний
(239)	94 Pu	$5f^6 7s^2$	641	3340	1.2/1.2	Plutonium	Плутоний
(243)	95 Am	$5f^7 7s^2$	996	2607	~1.1/1.2	Americium	Америций
(247)	96 Cm	$5f^7 6d^1 7s^2$	1340	3110	1.2/1.2	Curium	Кюрий
(247)	97 Bk	$5f^9 7s^2$	1050	2630	~1.1/1.2	Berkelium	Берклий
(252)	98 Cf	$5f^{10} 7s^2$	900	1227	1.2/1.2	Californium	Калифорний
(251)	99 Es	$5f^{11} 7s^2$	860	-	1.3/-	Einsteinium	Эйнштейний
(257)	100 Fm	$5f^{12} 7s^2$	-	-	1.3/1.2	Fermium	Фермий
(258)	101 Md	$5f^{13} 7s^2$	-	-	1.2/1.2	Mendelevium	Менделевий
(259)	102 No	$5f^{14} 7s^2$	-	-	1.3/-	Nobelium	Нобелий
(260)	103 Lr	$5f^{14} 6d^1 7s^2$	-	-	1.3/-	Lawrencium	Лоуренсий
(261)	104 Rf	$5f^{14} 6d^2 7s^2$				Rutherfordium	Резерфордий
(262)	105 Db	$5f^{14} 6d^3 7s^2$				Dubnium	Дубний
(263)	106 Sg	$5f^{14} 6d^4 7s^2$				Seaborgium	Сиборгий
(264)	107 Bh	$5f^{14} 6d^5 7s^2$				Bohrium	Борий
(265)	108 Hs	$5f^{14} 6d^6 7s^2$				Hassium	Хассий
(268)	109 Mt	$5f^{14} 6d^7 7s^2$				Meitnerium	Мейтнерий
(269)	110 Uun	$5f^{14} 6d^8 7s^2$				Ununnilium	Унуннилий
( )	111 Uuu	$5f^{14} 6d^9 7s^2$				Unununium	Унунуний
(277)	112 Uub	$5f^{14} 6d^{10} 7s^2$				Ununbium	Унунбий
( )	113 Unt	$5f^{14} 6d^{10} 7s^2 7p^1$				Ununtrium	Унунтрий
(289)	114 Uuq	$5f^{14} 6d^{10} 7s^2 7p^2$				Ununquadiun	Унунквади

JINR synthetic elements production:
Flerov:
102, 103, 104, 105 (dubnii), 106
Oganessyan:
112, 113, 114 (flerovii), 115,
116 (livermorii), 117, 118.

Pu-239

Production of synthetic elements in the world growed from billion part of gramme up to many kilograms, even tonnes.



The meteorites are natural “detectors” which have many millions years of exposition time.

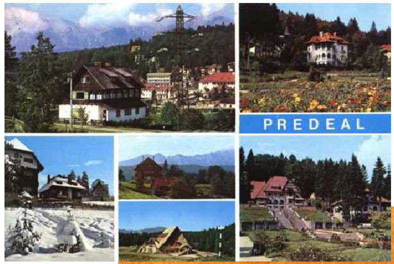
The use of the factor of long-time exposure of meteorites in space leads to a great advantage of the method for the search of superheavy elements in crystals of olivine from meteorites as compared with methods based on the use of various satellite and aerostat detectors.

G.Flerov evaluated that in consideration of great meteorite ages ivestigation of 1 cubic centimetre olivine from meteorites is equal results of space experiment with 1 tonne of emulsion during 1 year.

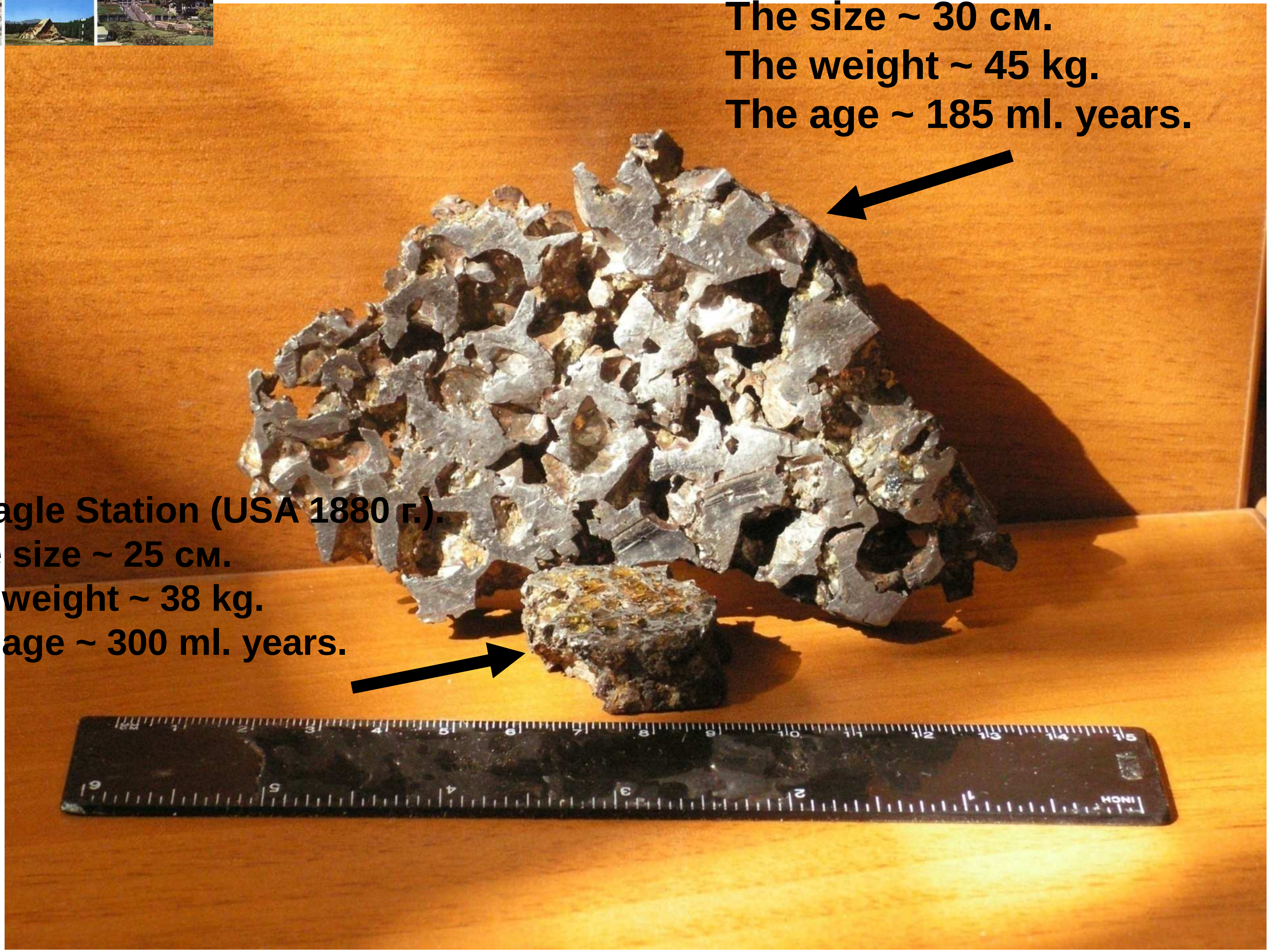
First investigation of very heavy nuclei (Z~26) were carried out by Maurette et al. (1964)

More heavy: Fleischer et al. (1967)

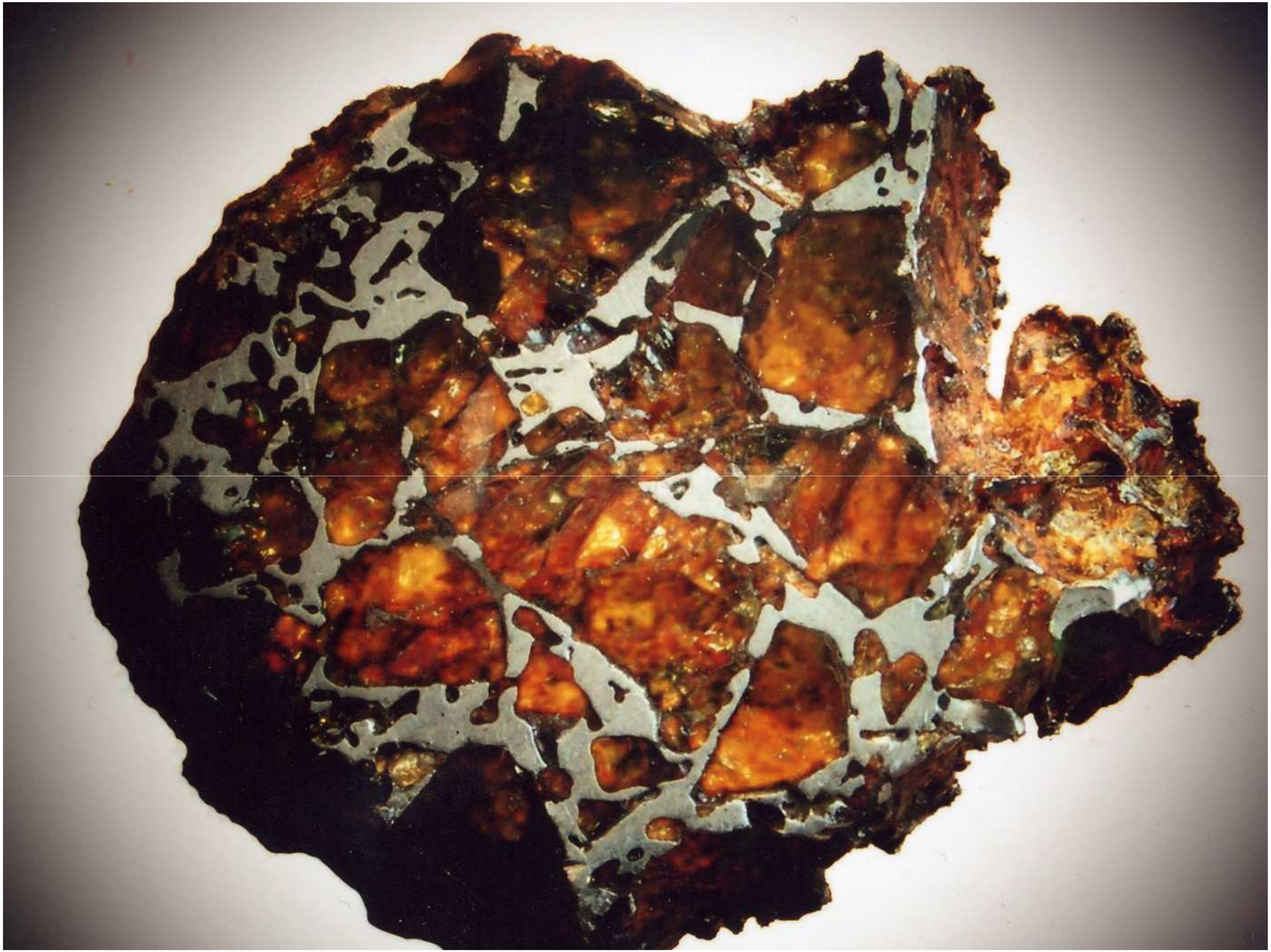
The most detailed – Perelygin V. et al.(1975-2003, Dubna)



1. Marjalahty (Finland, 1902 г.).
The size ~ 30 см.
The weight ~ 45 kg.
The age ~ 185 ml. years.

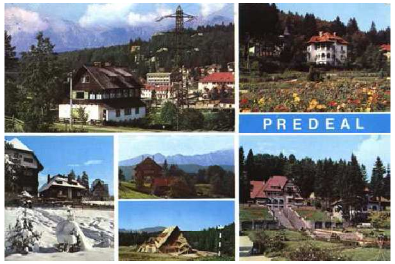


2. Eagle Station (USA 1880 г.).
The size ~ 25 см.
The weight ~ 38 kg.
The age ~ 300 ml. years.



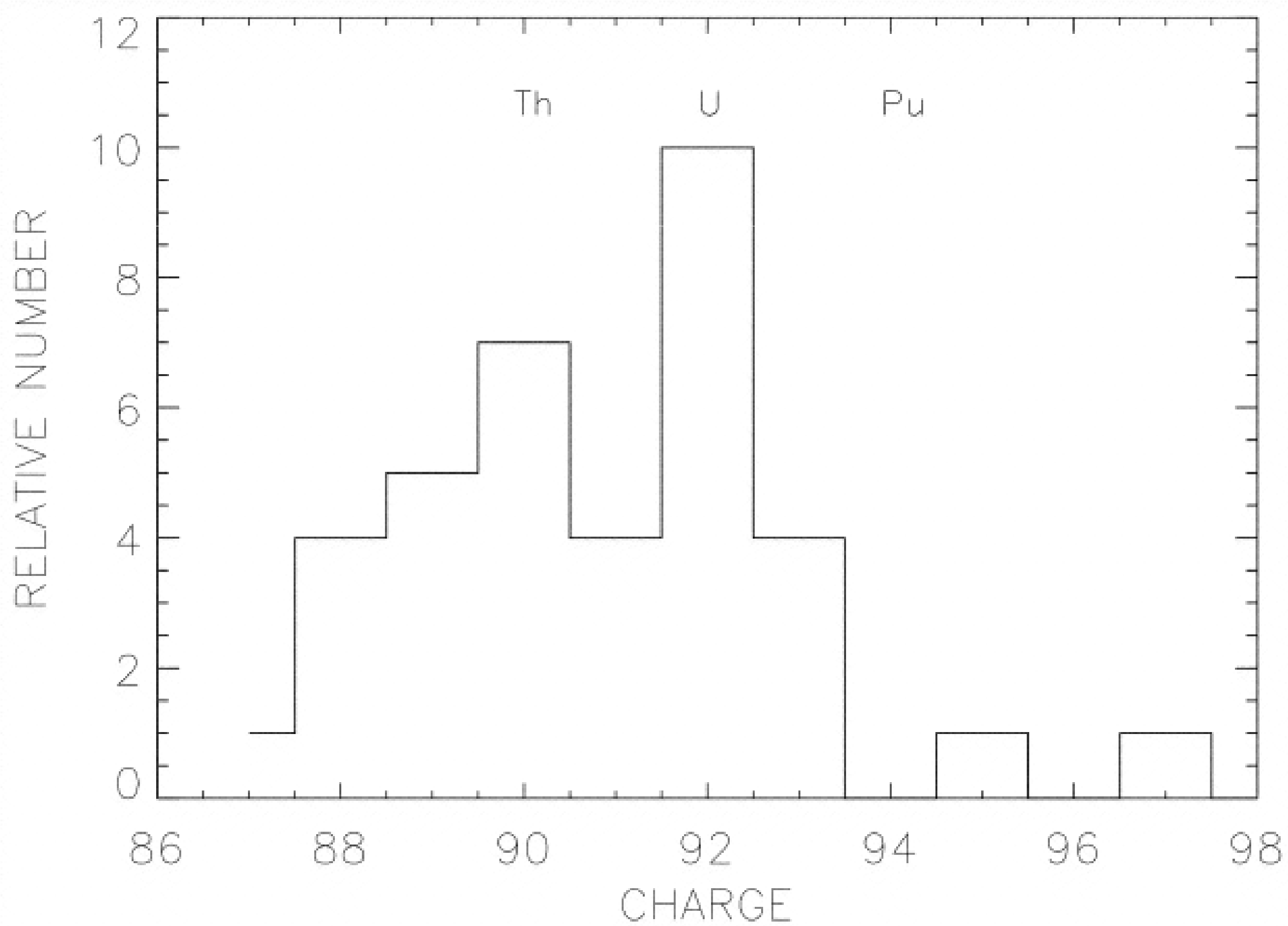

PREDEAL

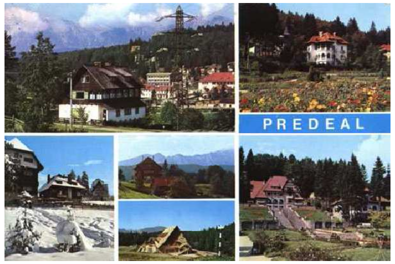
L.L.Kashkarov died September 27, 2013.



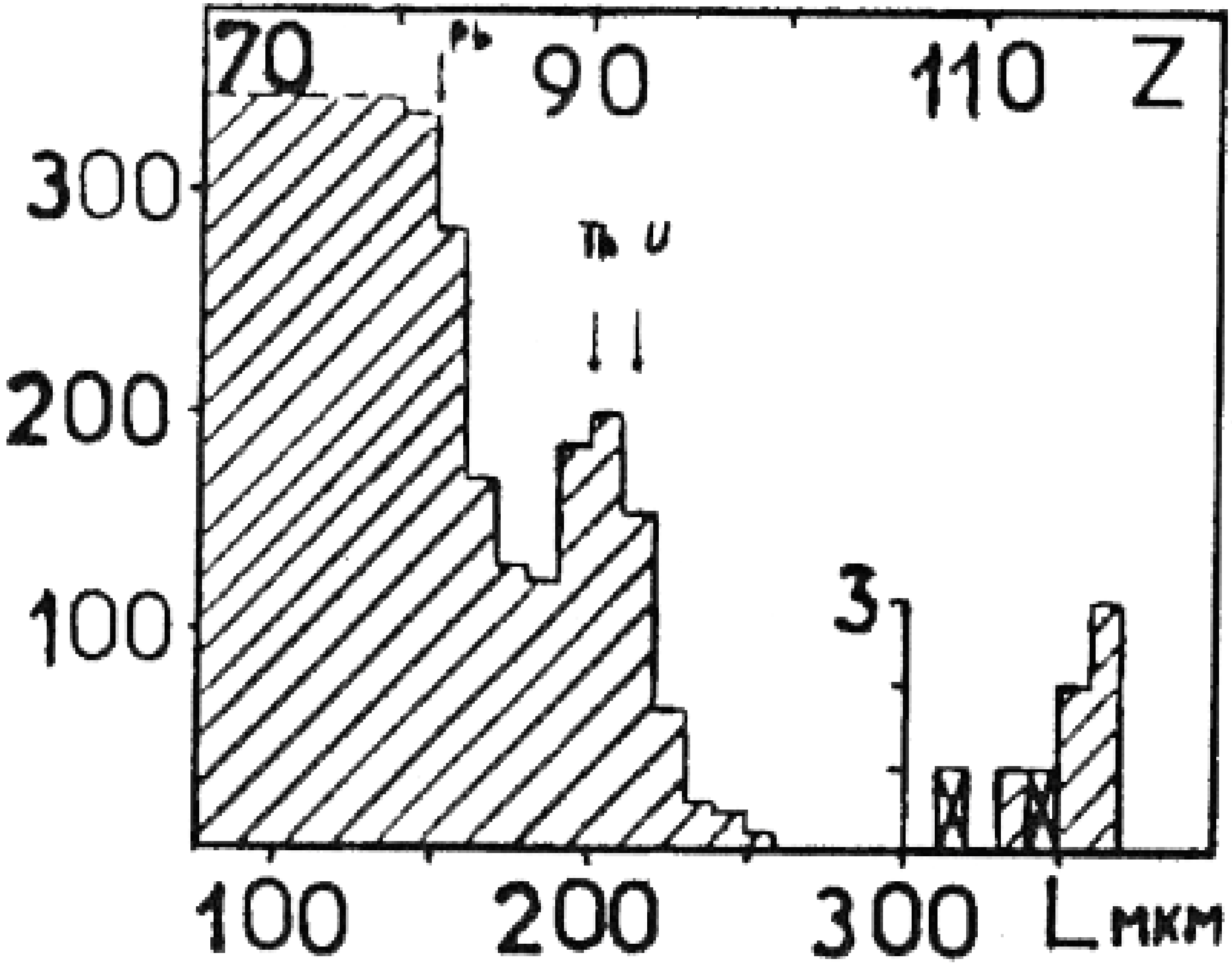
H. Tsao, et al., Astrophysical Journal, 549, 320-324, 2001

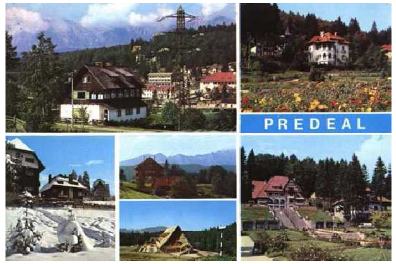
Domingo et al. (1995), Westphal et al. (1998), Donelli et al. (1999)

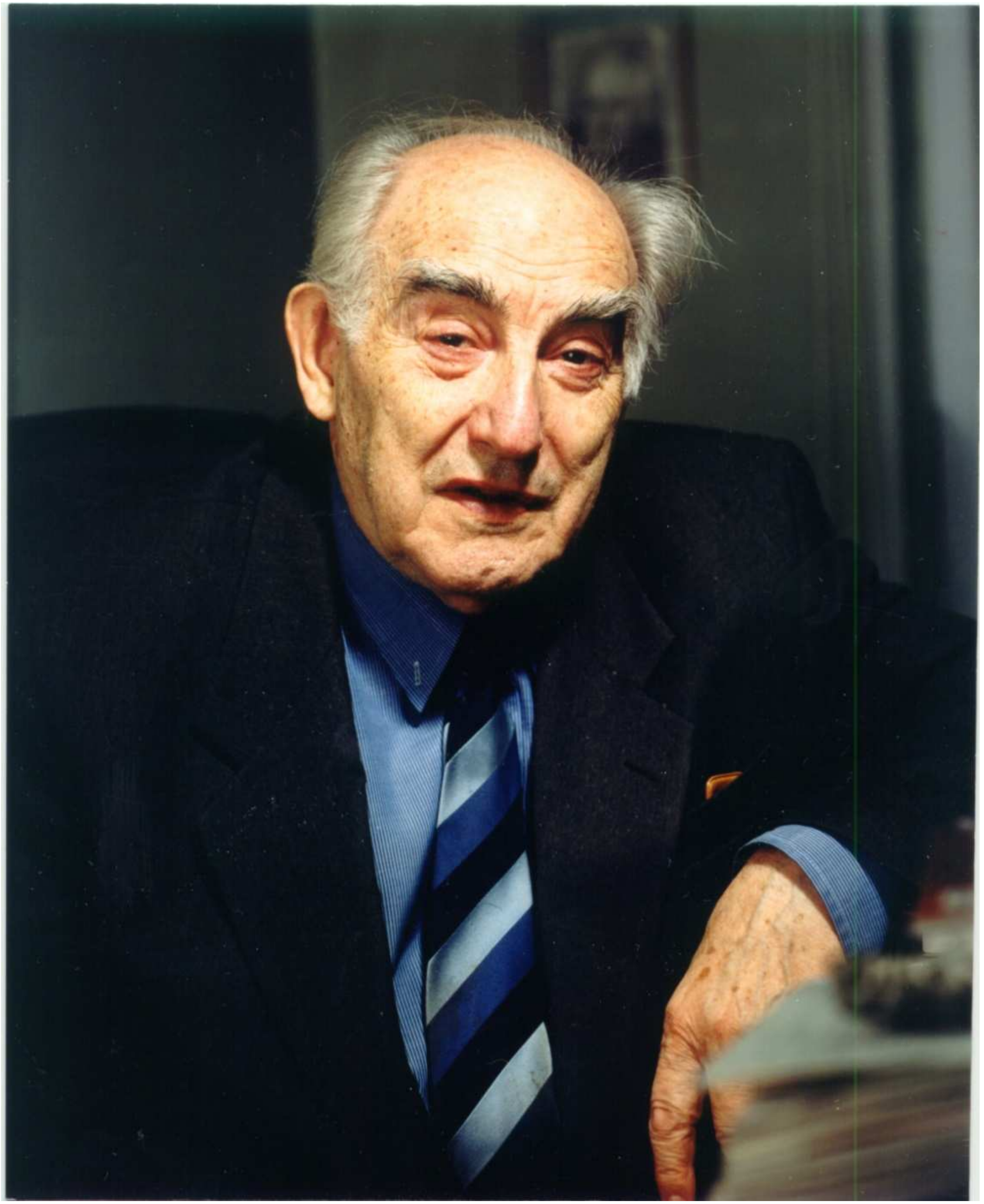




The most detailed – Perelygin V. et al. (1985)

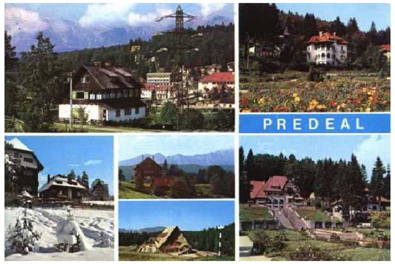






Prof. V.L.Ginzburg (Nobel prize of 2003) considered problem of superheavy nuclei search (investigation of existence of stability element islands) as one of the most important problems in the modern physics.

Prof. V.L.Ginzburg included it to his famous list of first priority physical tasks.



Starting 2005 the investigations of galactic cosmic ray nuclei are carried out at Lebedev Physical Institute of RAS.

Doklady Physics, Vol. 50, No. 6, 2005, pp. 283–285. Translated from Doklady Akademii Nauk, Vol. 402, No. 4, 2005, pp. 472–474.

PHYSICS

Problems and Horizons of the Search for Tracks of Heavy and Superheavy Nuclei in Olivine Crystals from Meteorites (OLIMPIYA Project)

Academician **V. L. Ginzburg**, Academician **E. L. Feĭnberg, N. G. Polukhina, N. I. Starkov, and V. A. Tsarev**

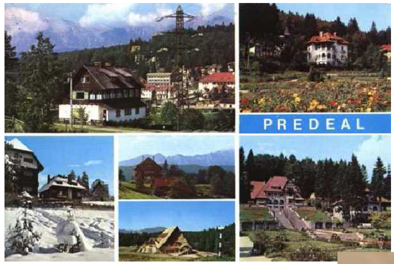
Received February 1, 2005

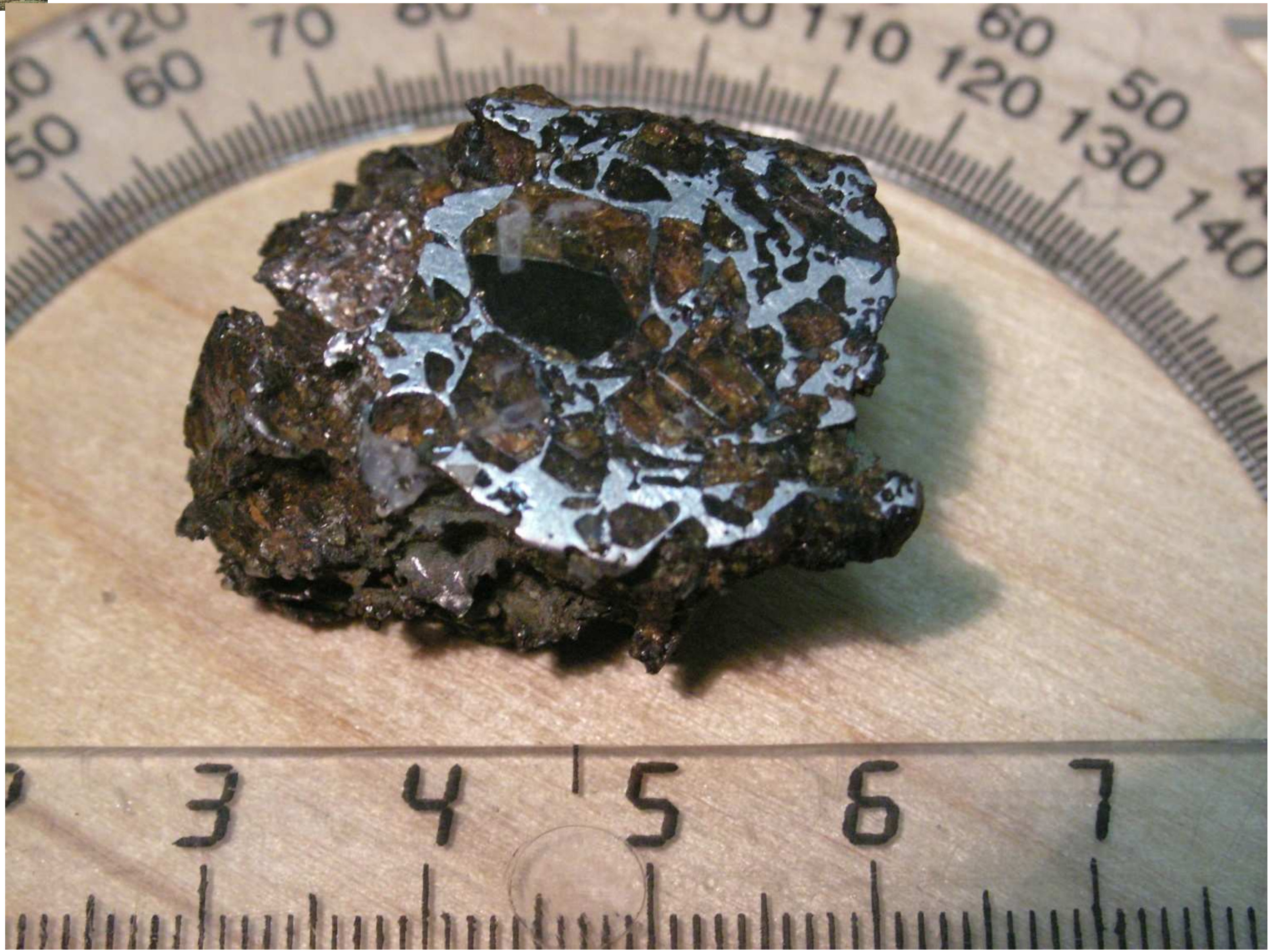
In this paper, we consider the nuclear-physical and astrophysical aspects of investigations associated with the search for heavy and superheavy nuclei in the composition of cosmic rays. We also discuss the potentiality of searching for tracks of these nuclei in the olivine crystals found in meteorites with the use of the completely automated PAVICOM setup, which was designed for the scanning and processing of tracks of particles.

tinue to hold for very large values of N and Z, the existence of stability islands for even heavier nuclei must not be ruled out.

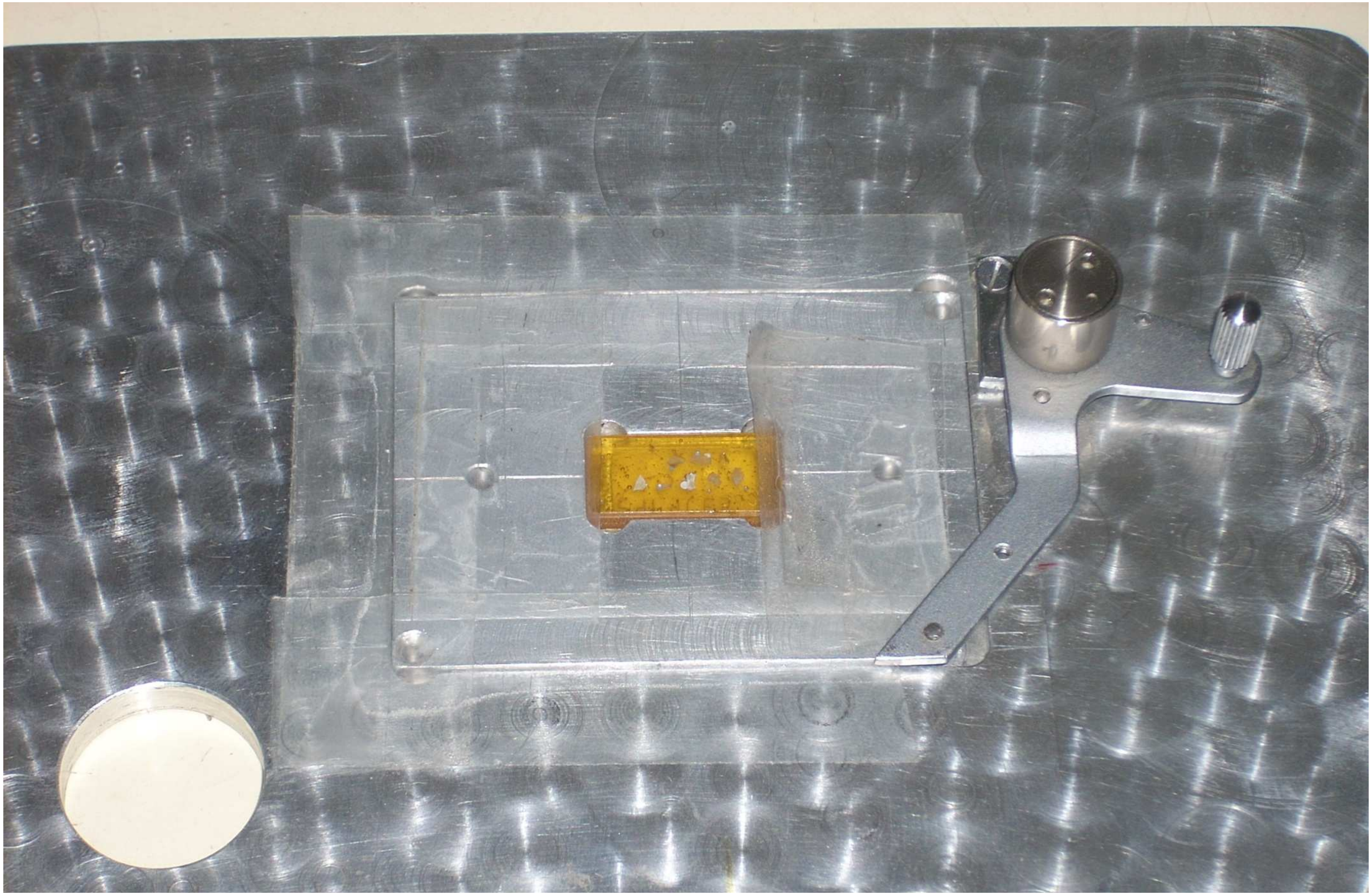
Verification of the existence of unusual stable forms of nuclear matter containing, for example, strange [4] or other even heavier quarks [5] would also be of obvious interest.

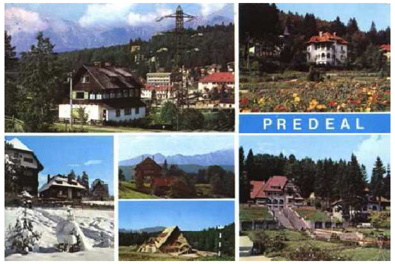
2. The measurement of fluxes and of the spectra of heavy and superheavy nuclei composing cosmic rays is


PREDEAL



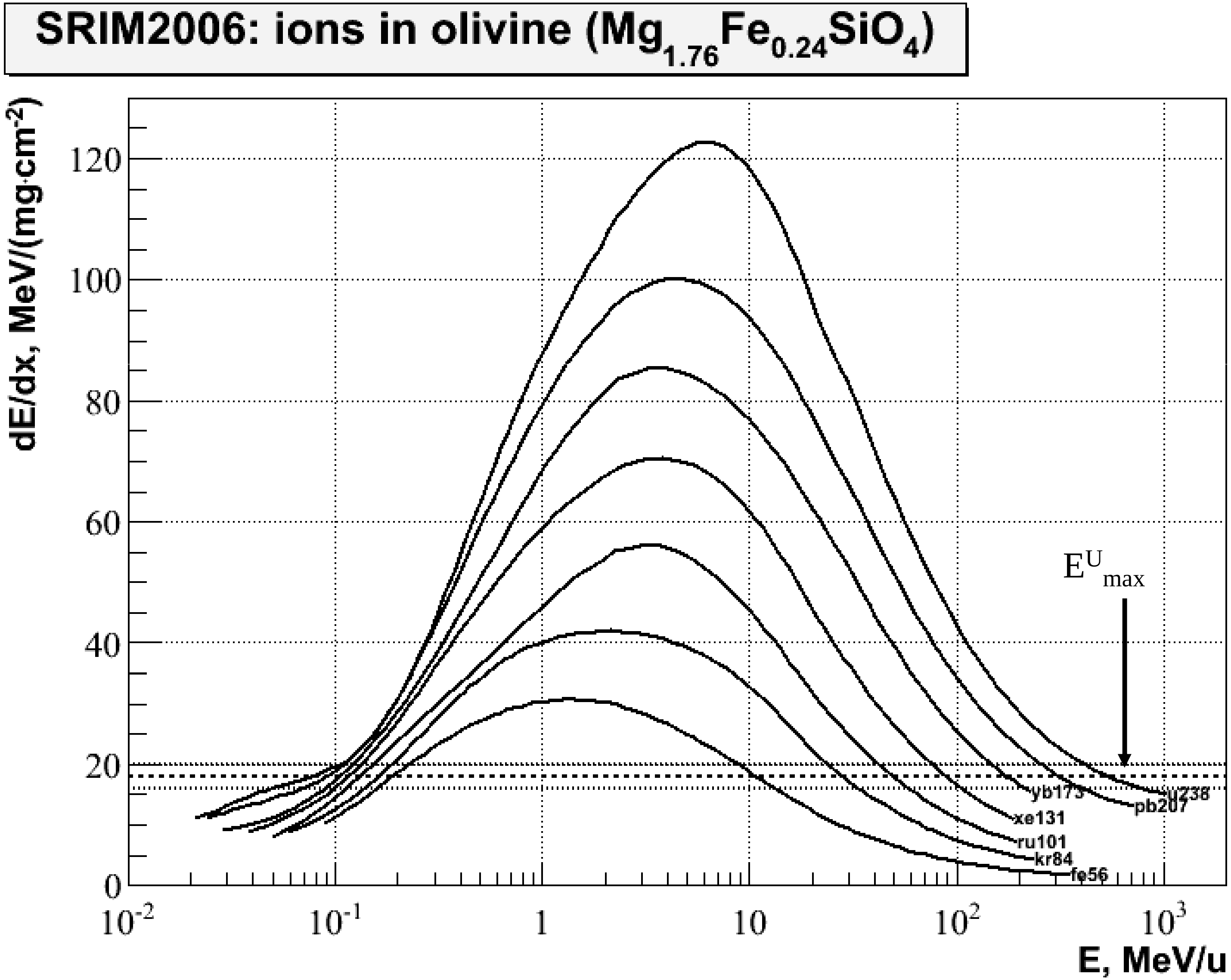
Few crystals mounted in epoxy tablet for investigation on microscope.

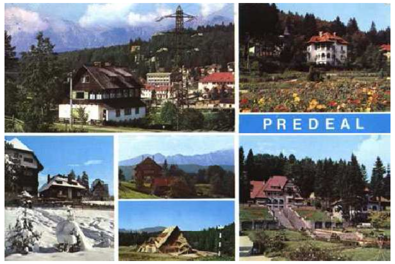




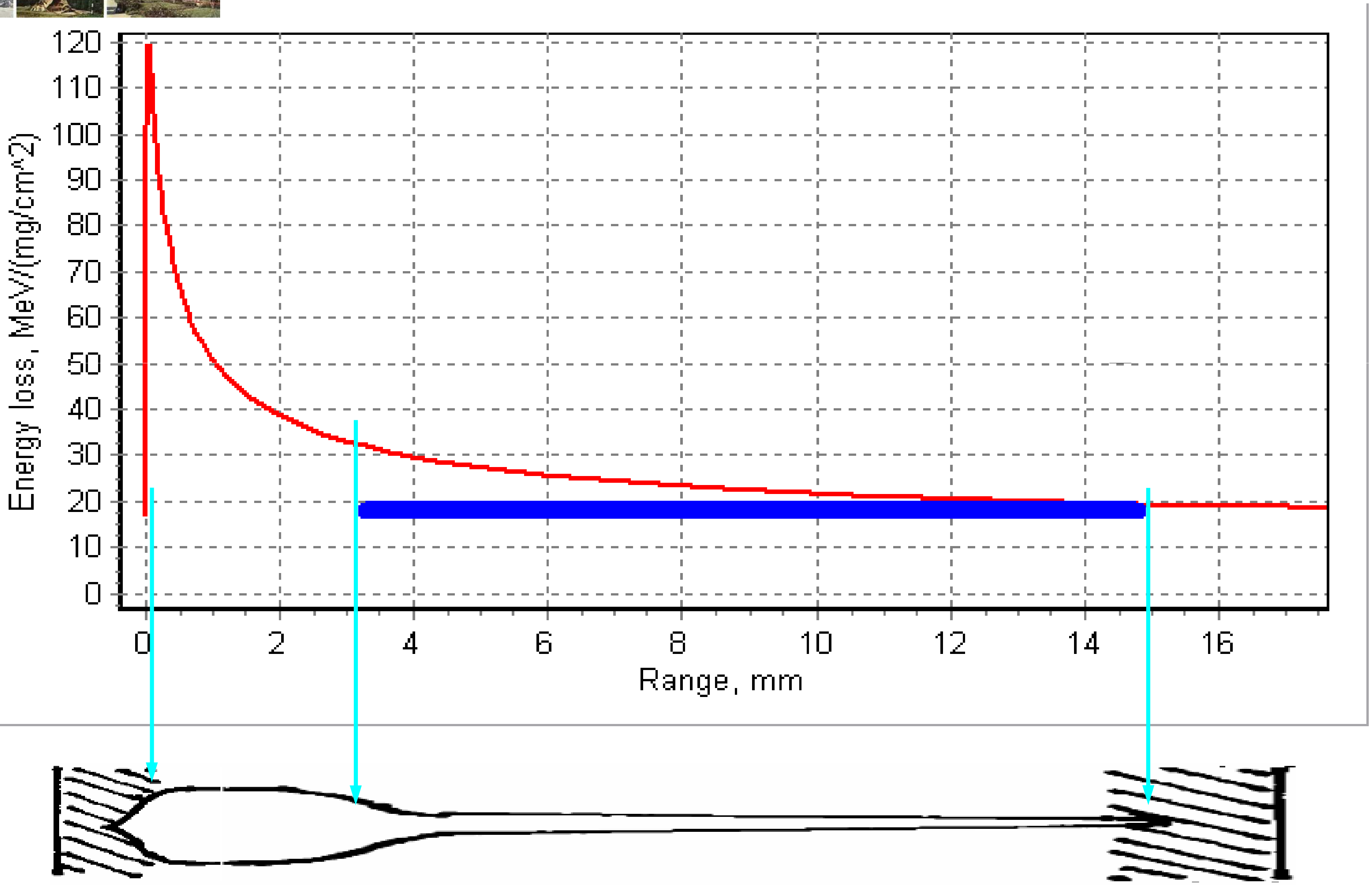
The curves illustrate the method of the full etching track length determination in olivine for a number of nuclei

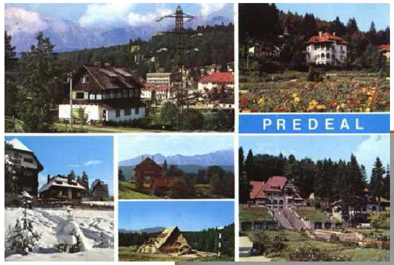
from $^{56}_{26}Fe$ up to $^{238}_{92}U$



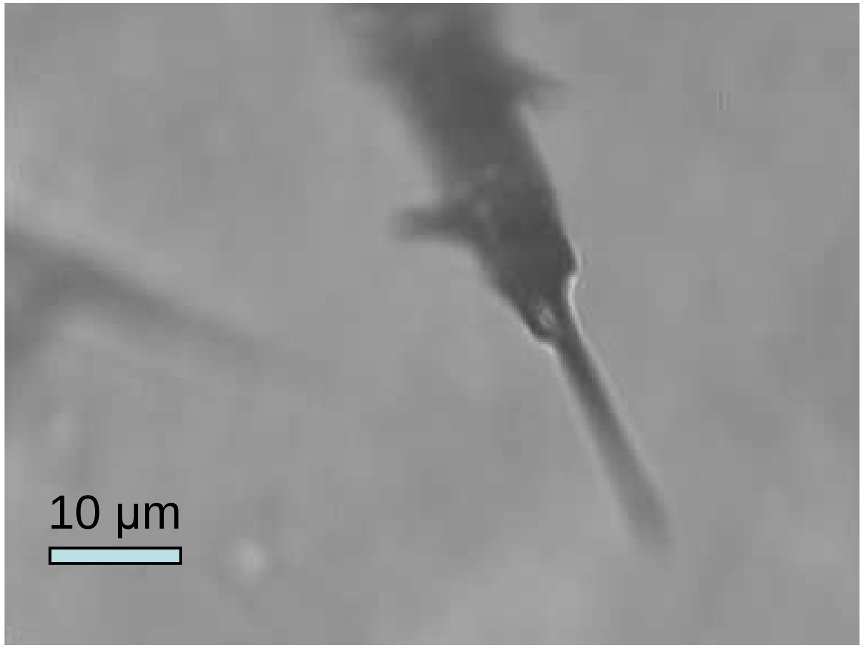


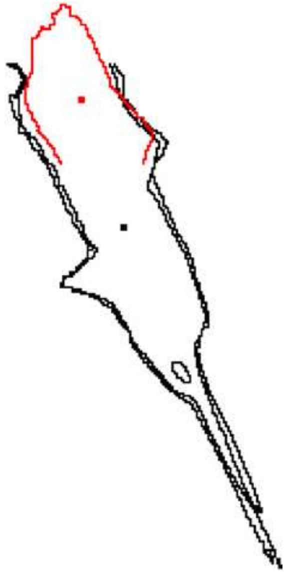
The scheme of etching track formation in olivine

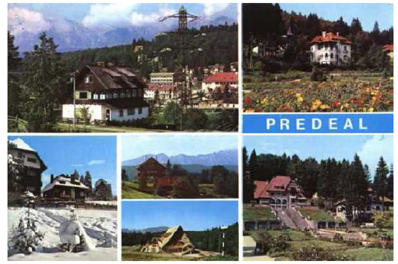


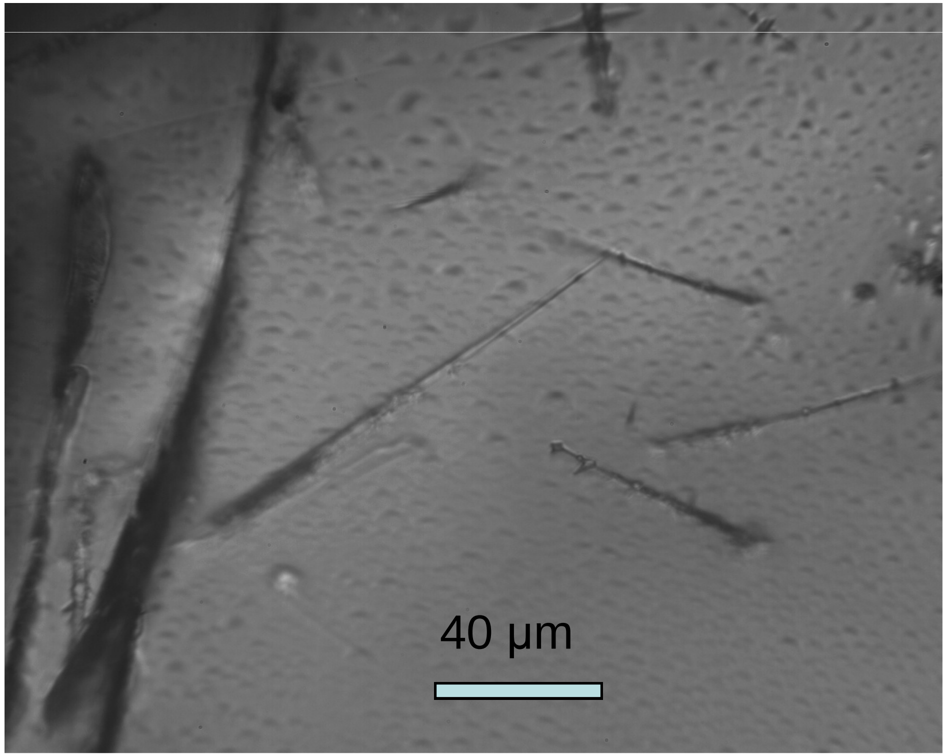

PREDEAL

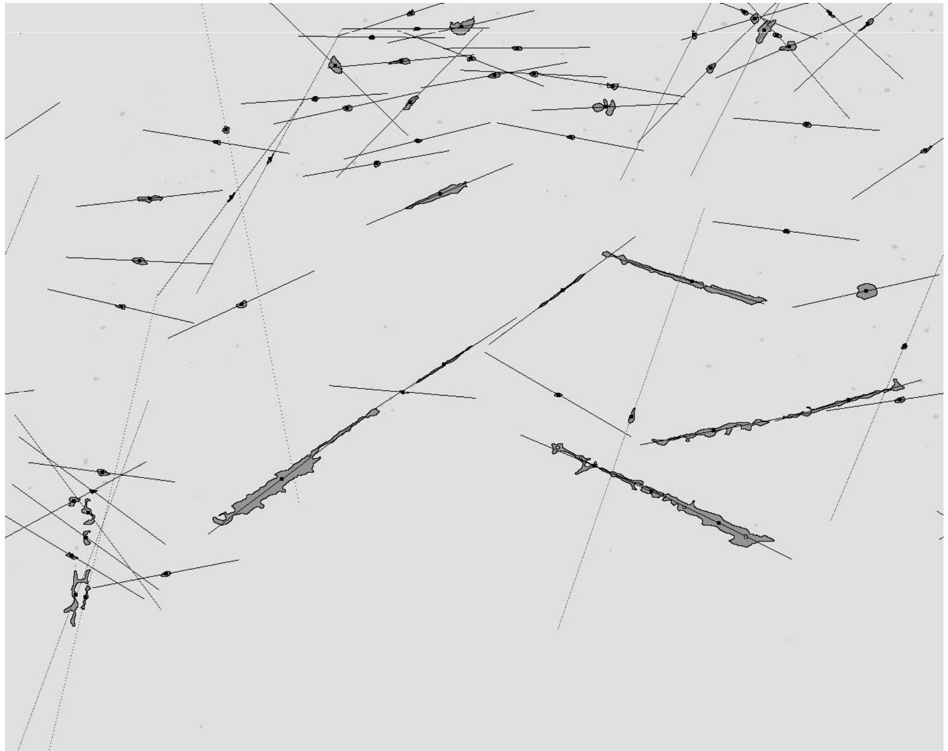

50 μm

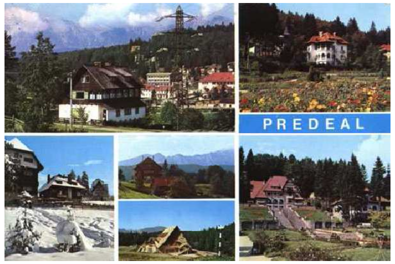

10 µm



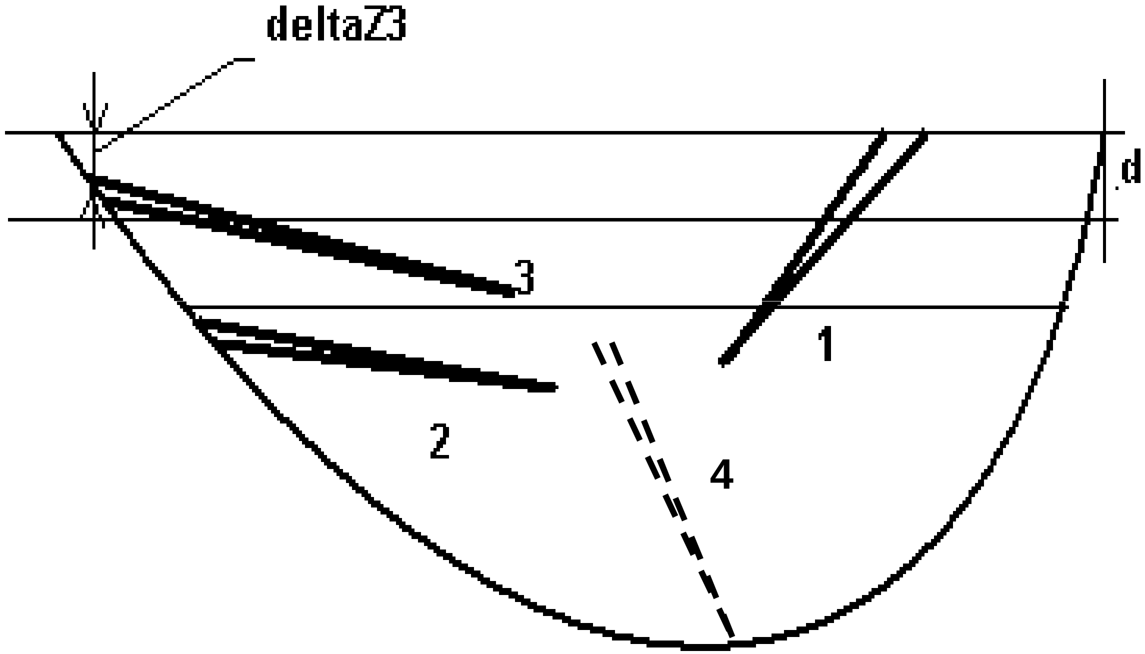

PREDEAL


40 µm

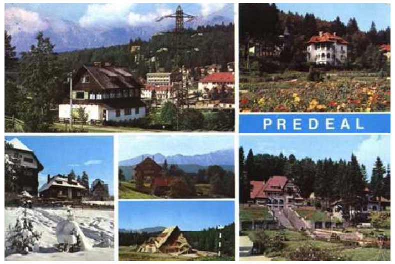




The method of stepwise cut and etching is used



The thickness of cut layer is ***d*** = 30 – 100 μm



The charge identification method

The main problem:

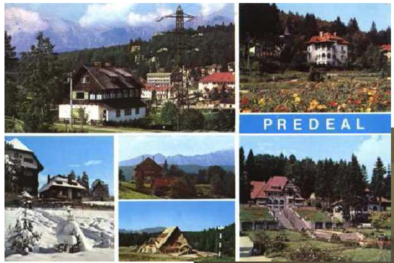
the size of the using olivine pieces is less as compared with total etched length.

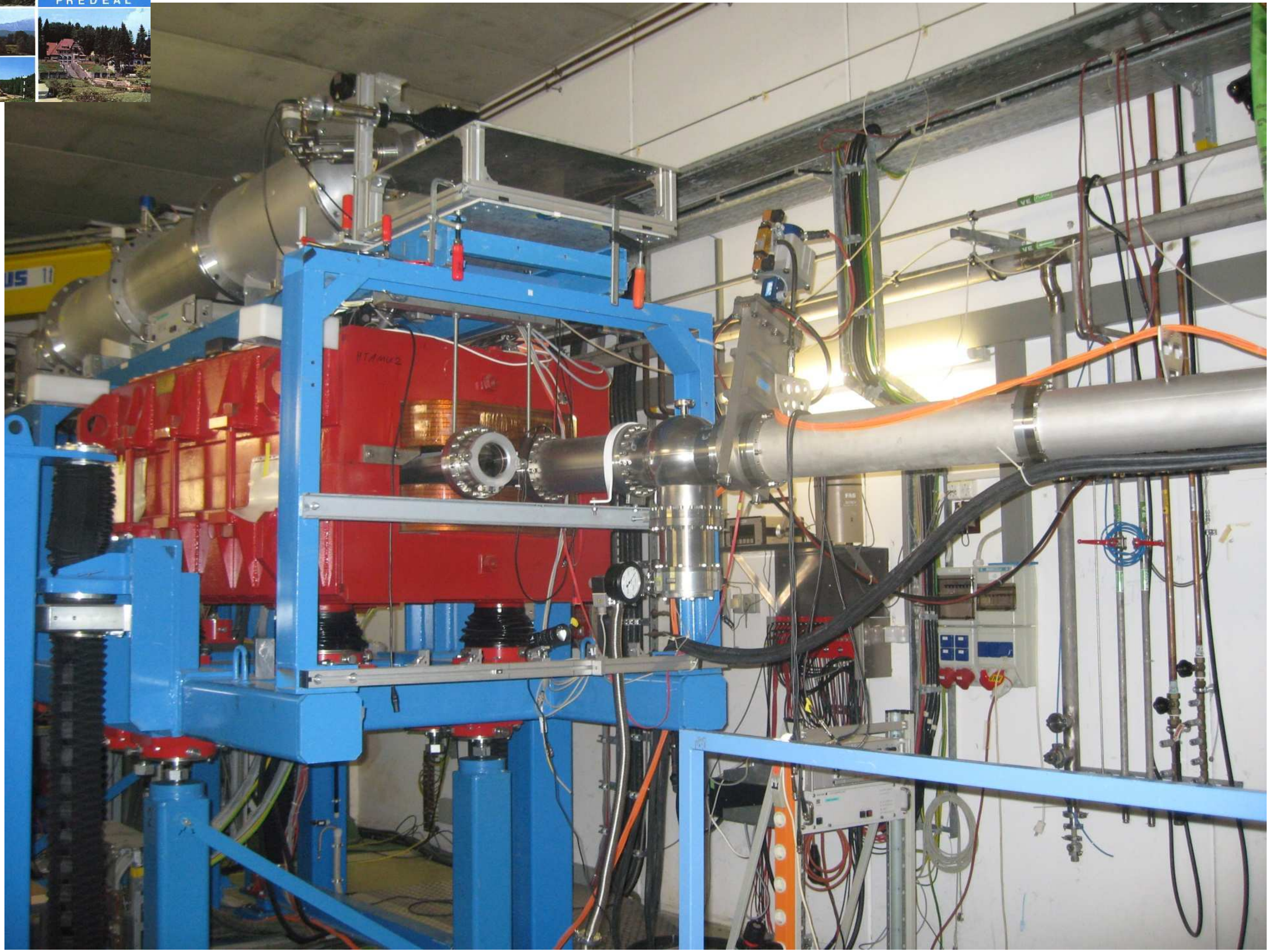
=> The measurement only track length is not enough

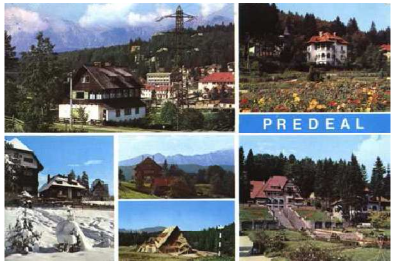
Characteristics :

1. The length of etched track.
2. The etching rate.
3. The etched channel width.

=> It is necessary to have calibration experiments


PREDEAL

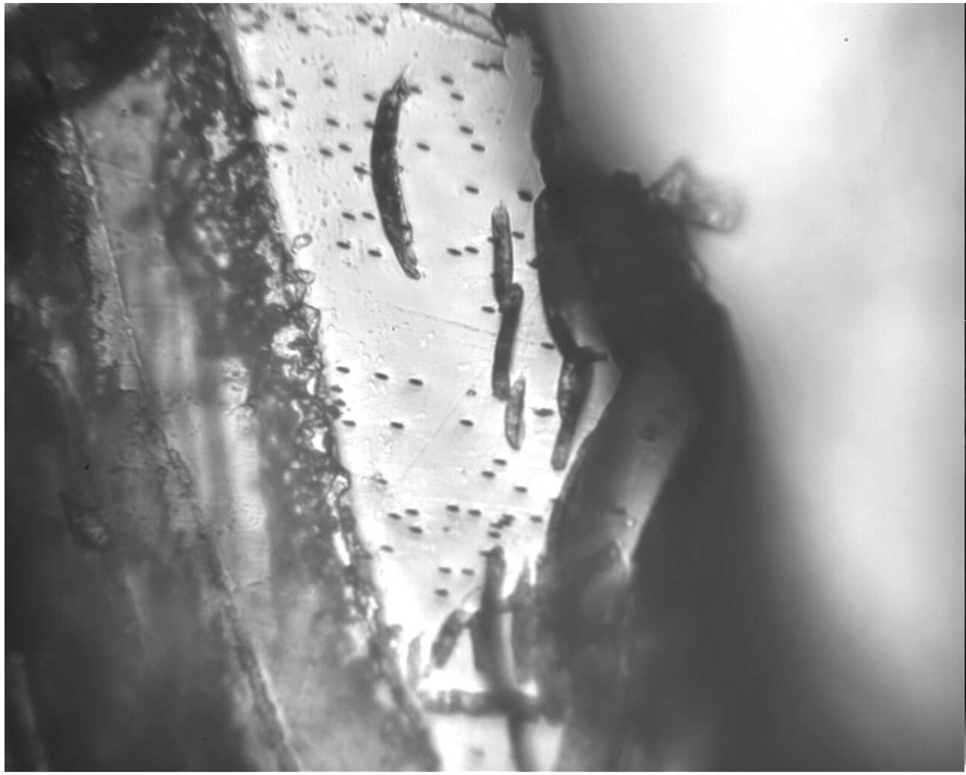




Xe nuclei tracks (E=11,4 MeV/n)

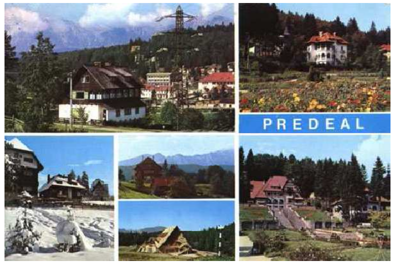
Size field of view ~ 500×700 microns

Flux density (4-10)105 nuclei/cm**2 - 30-80 tracks/crystal**

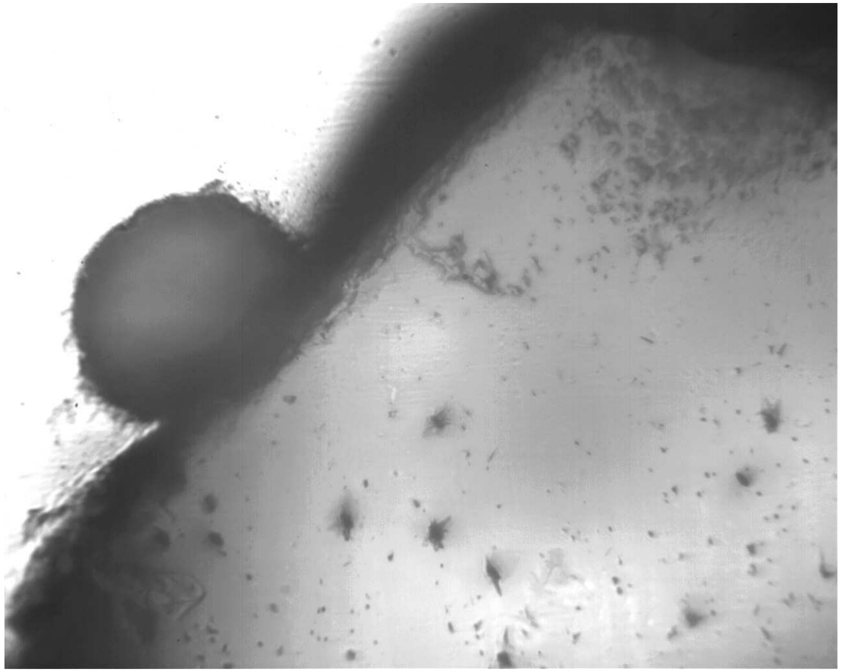


Length of tracks 57±6 мкм (by the calculation ~ 65 мкм)

Etch rate (E=11.4 MeV/nucl) ≈ 10-14 micron/hour



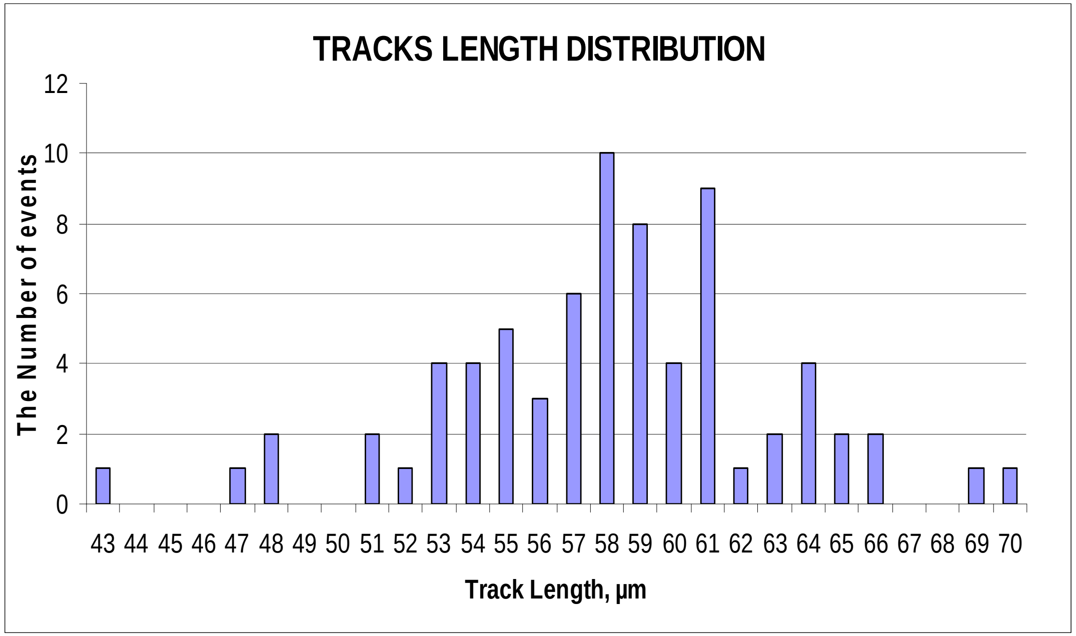
Darmschtadt,
GSI, 2009 г.,
Au, 11.4 MeV/n

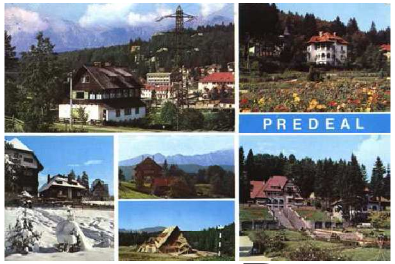


Calculation: (77 ± 5) microns

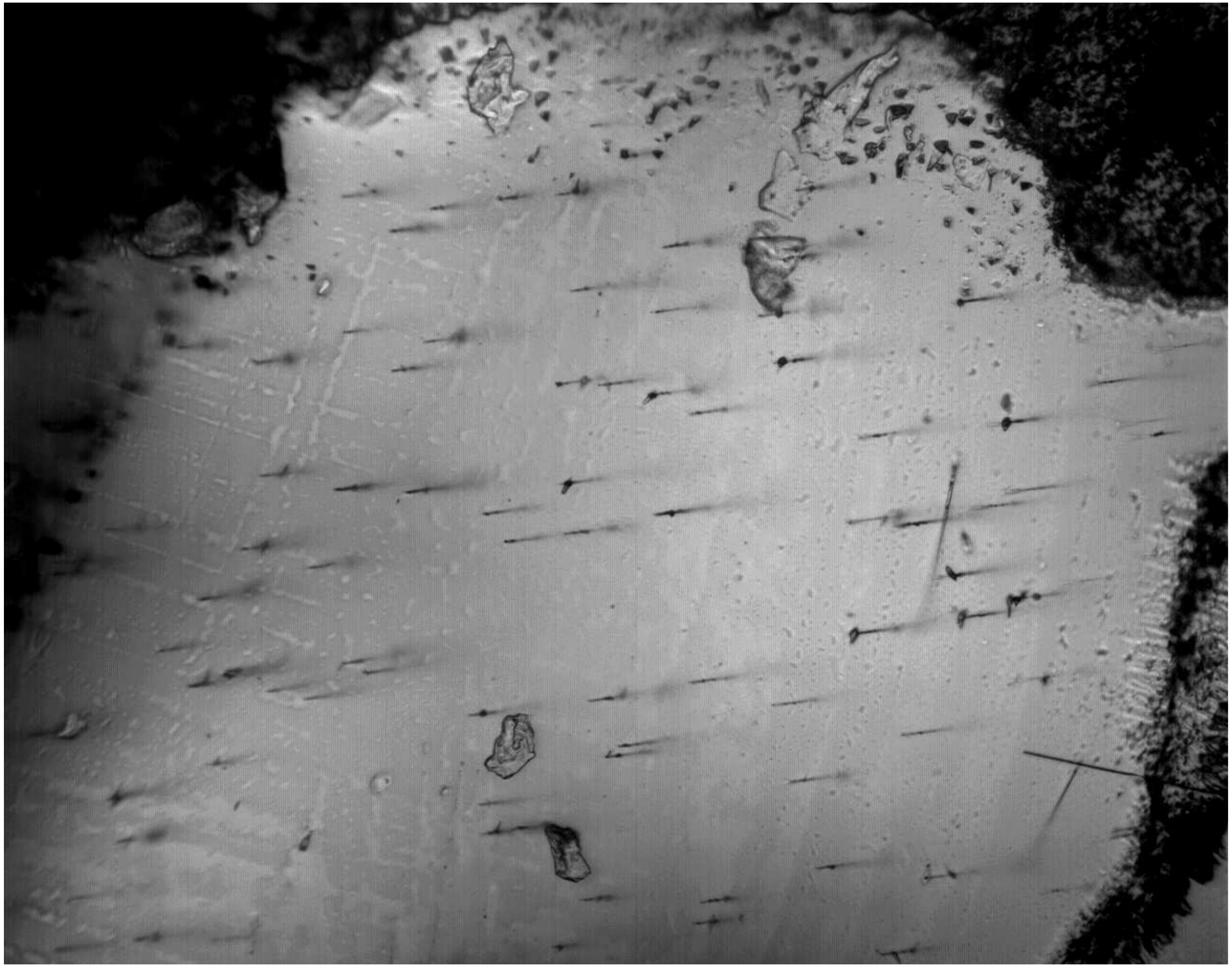
Experiment: (69 ± 6) microns

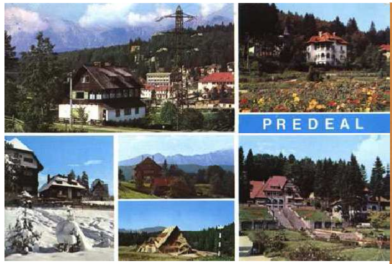
Etch rate 16 micron/hour





Darmschtadt, GSI, 2010 г., U, E= 150 МэВ/н

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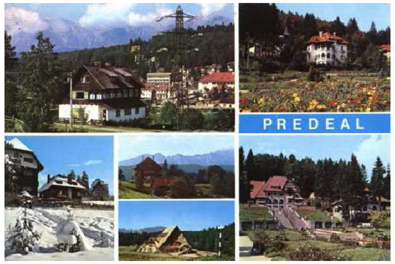
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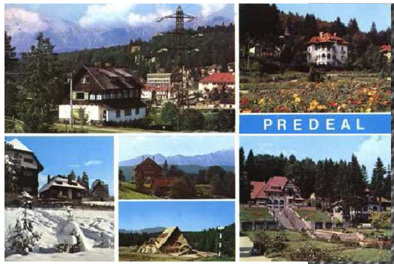
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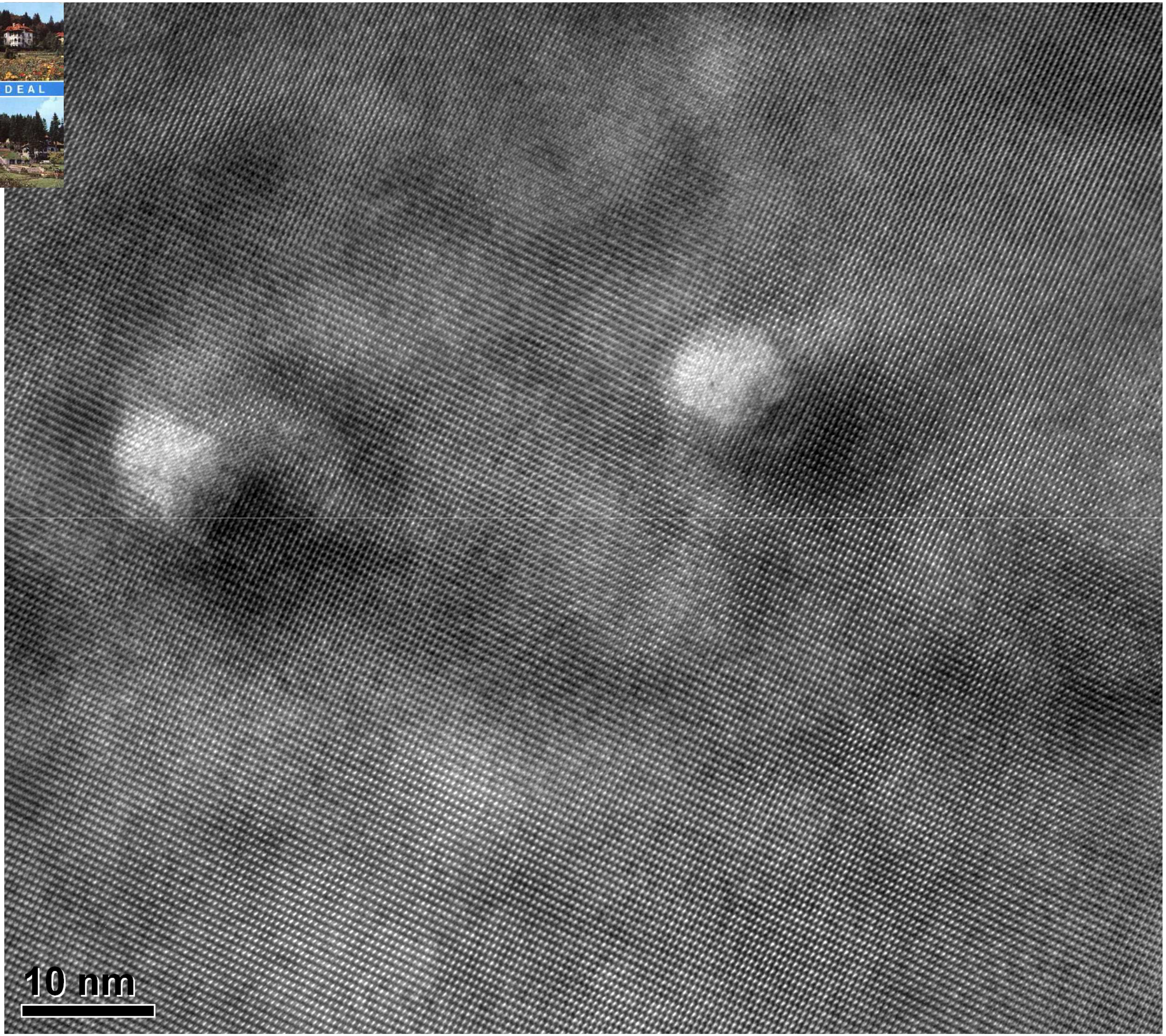
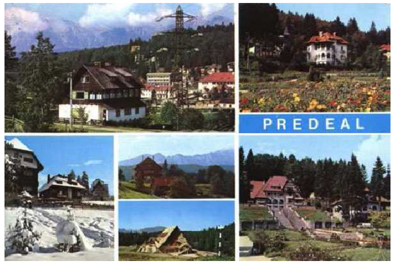
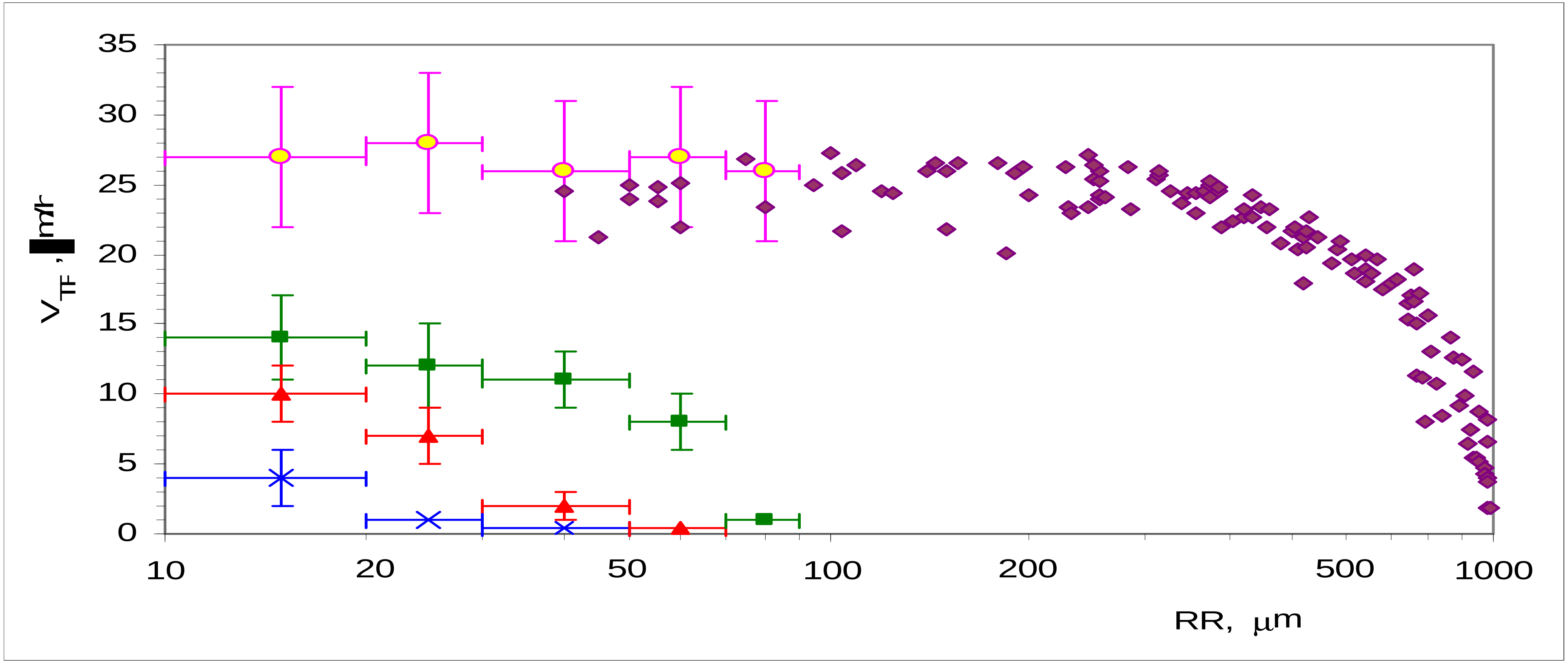
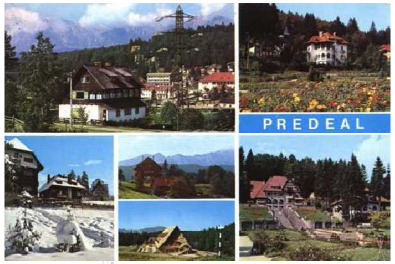

10 nm



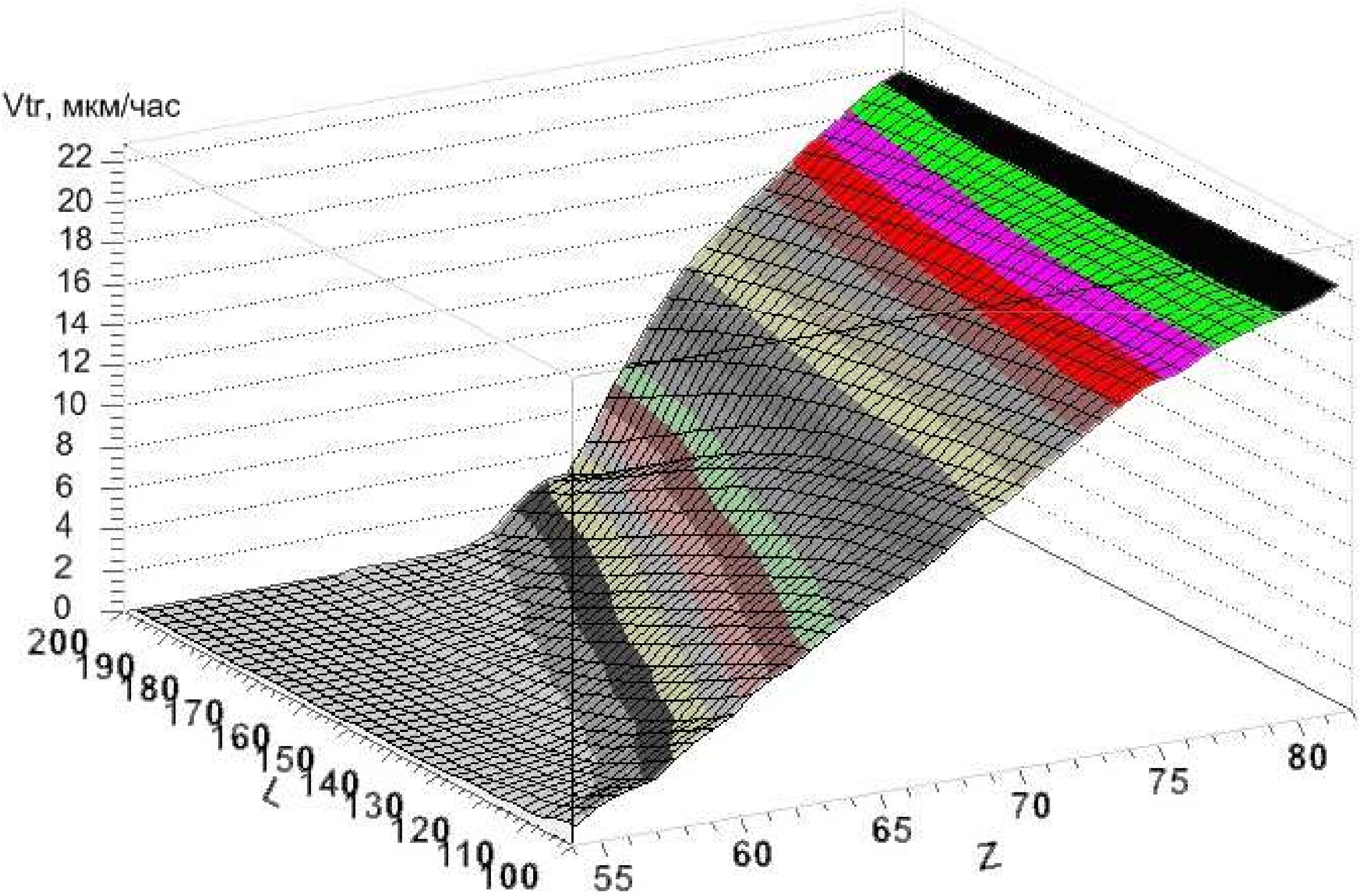


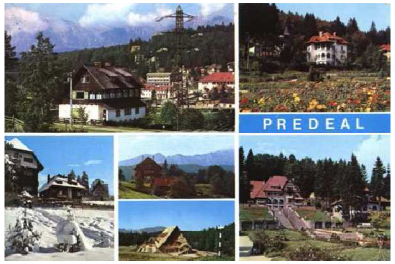
Measured VTR values at the certain residual range (RR) of accelerated Kr, Xe and U ions and Fe nuclei in olivine crystals from the Marjalahti pallasite.



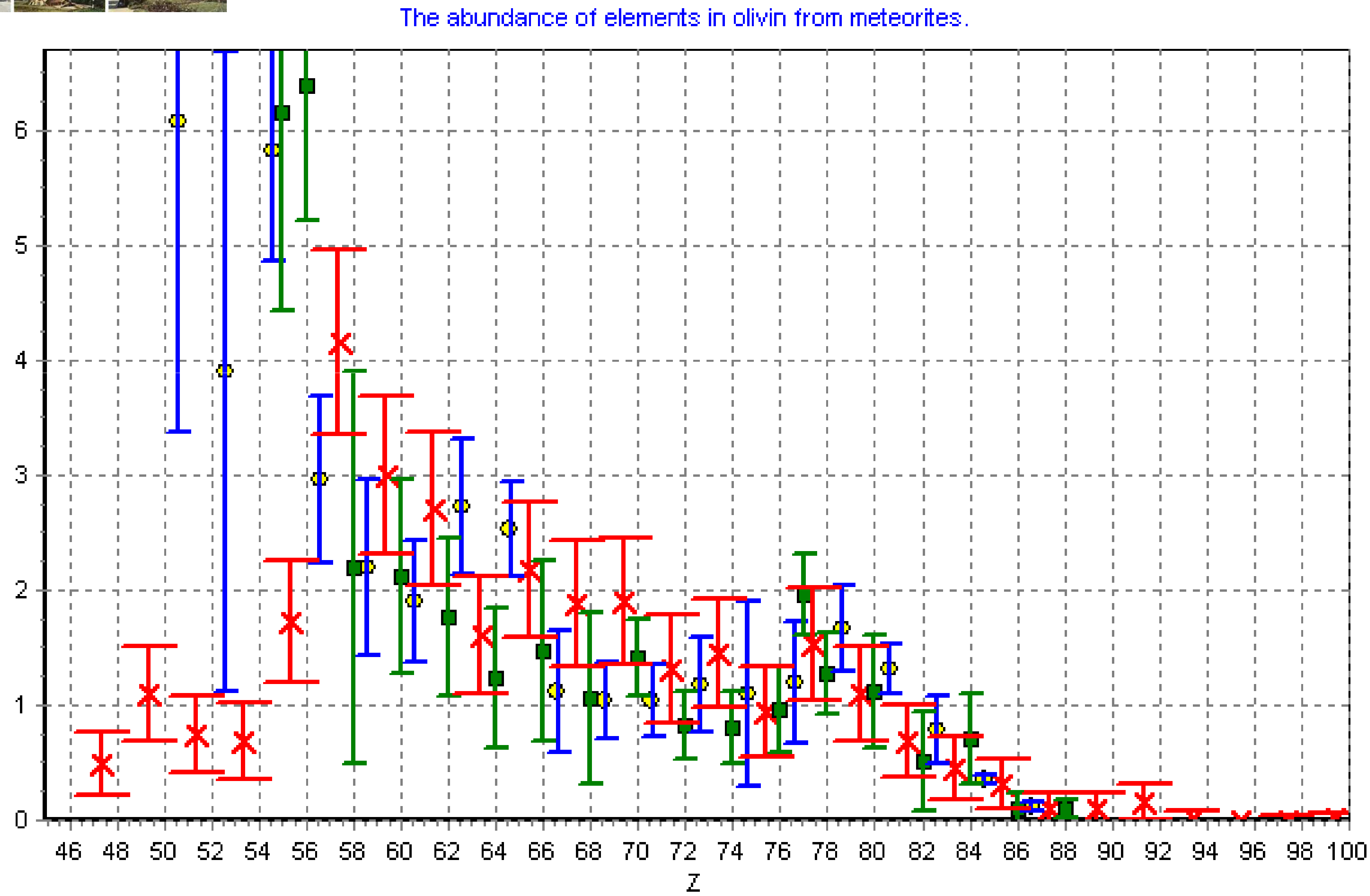
Charge – Length – Etching Rate dependence (UFN, v. 180, № 8, p.839-842, 2010).

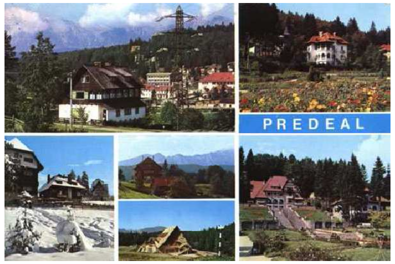
The surface Z-L-V





The galactic nuclei abundance A (A_{Fe}= 10^6)
(■ - HEAO; o – Ariel; x – our results)



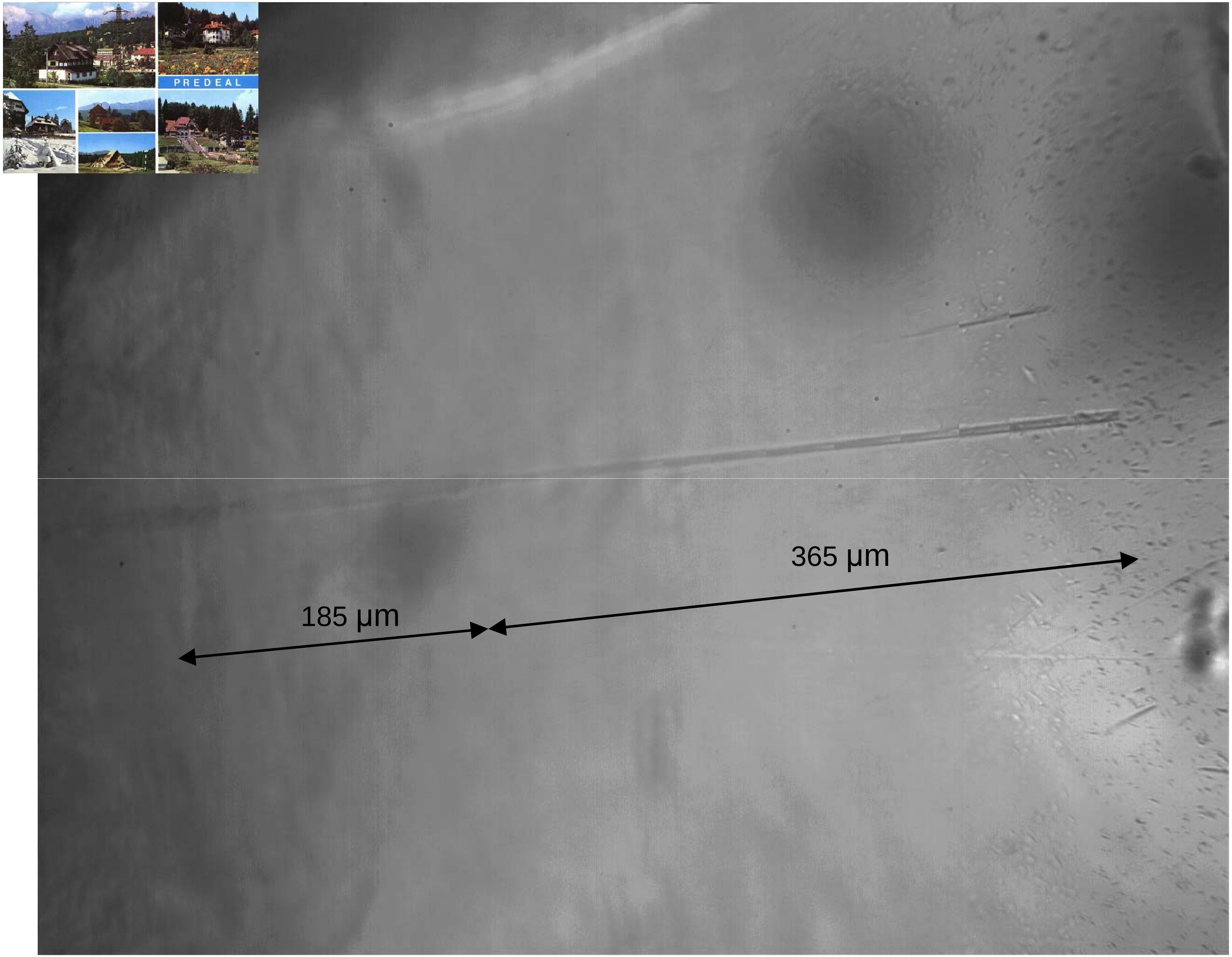


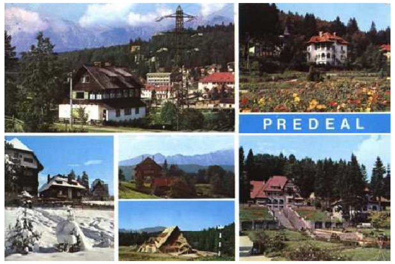
Superheavy nuclei

Besides the distributions of galactic nuclei we observed three events having very large charges (our estimations are Z>105).

Their lengths are large (700-900 μm) but their minimal etching rates are more then 35 μm/h.

It is very large as compared with the uranium maximum etching rate (25 μm/h).

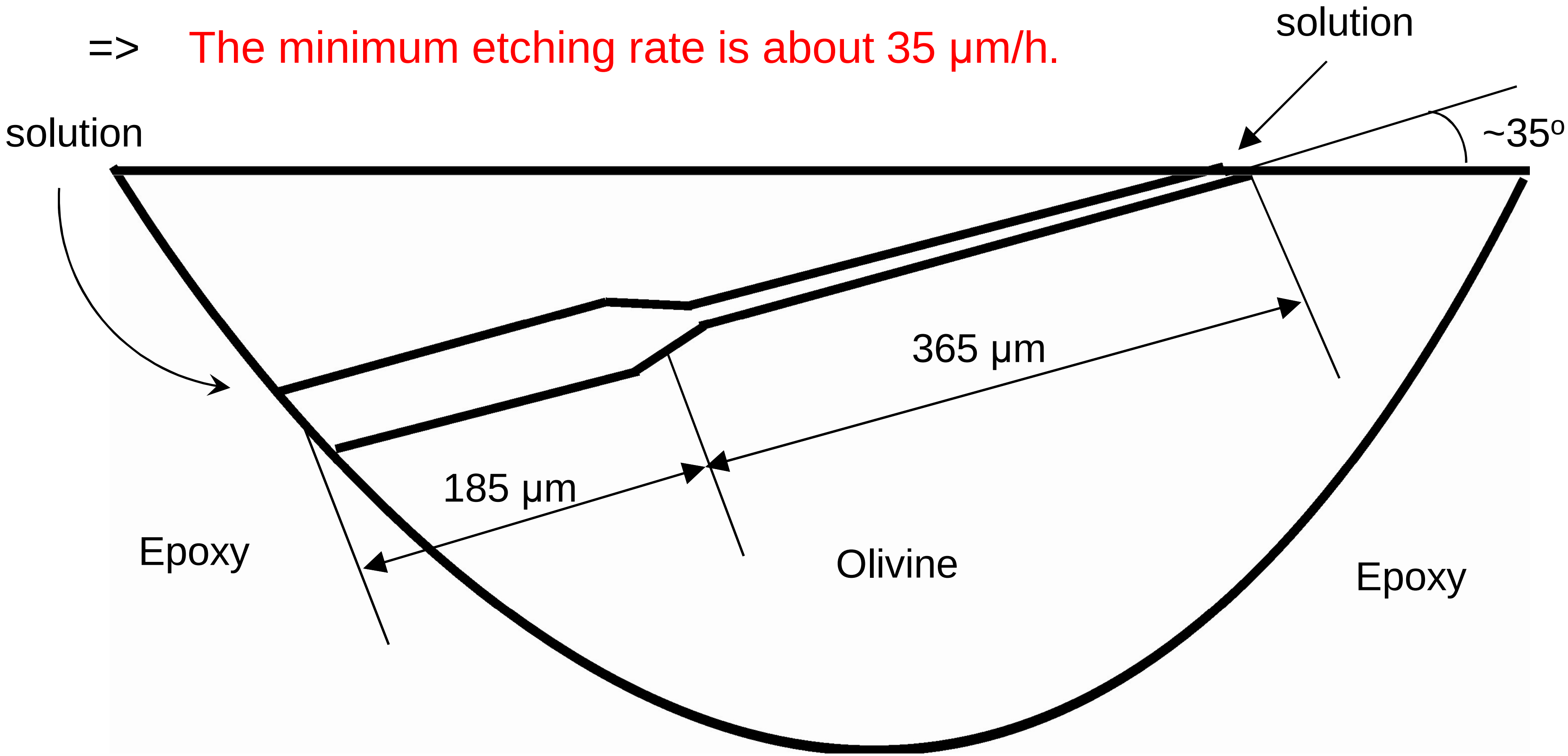

PREDEAL
365 µm
185 µm

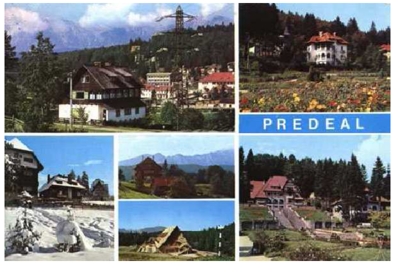


The total track length in olivine is ~550 µm.   The etching time is 8 hours.

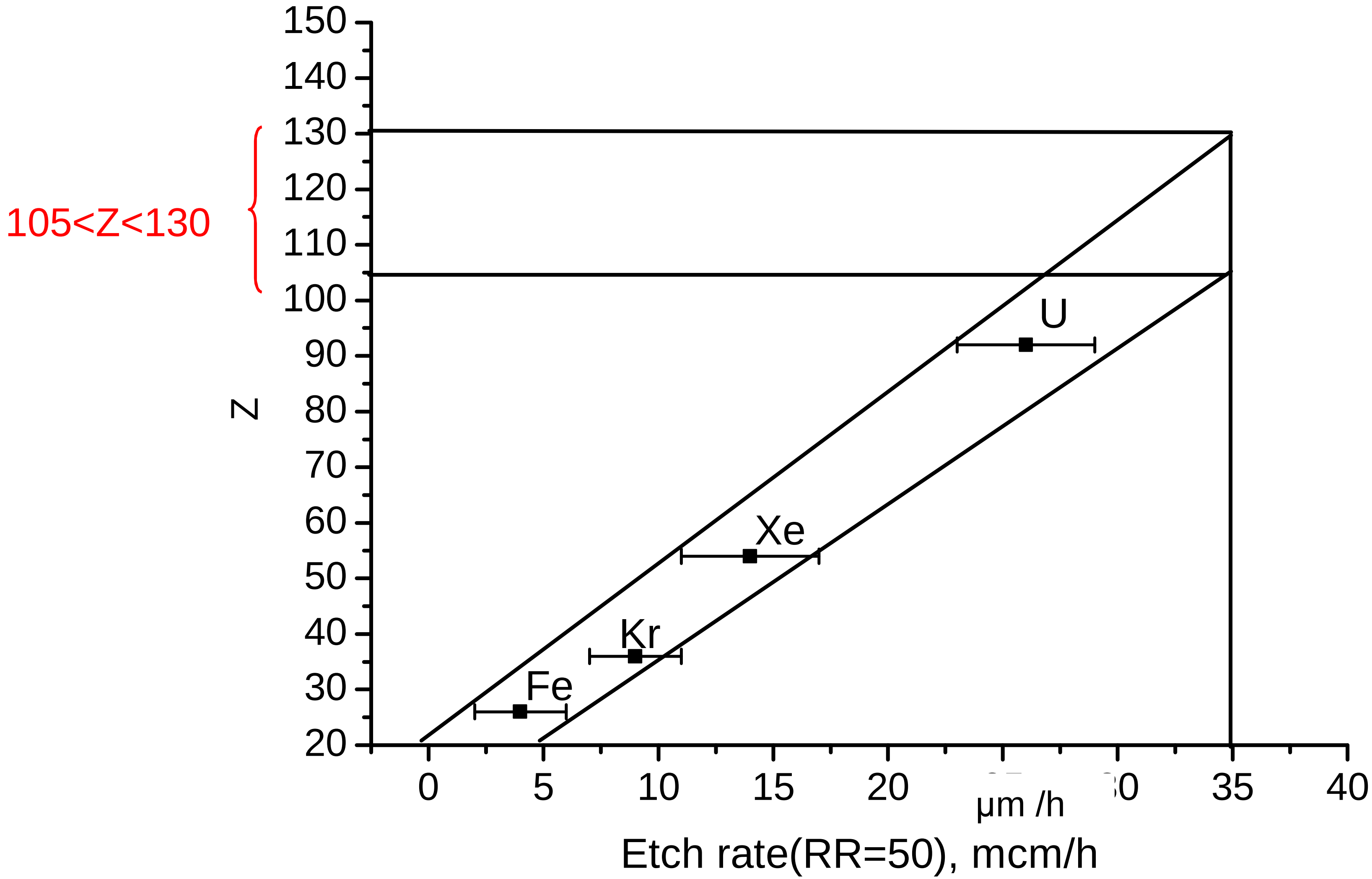
but the etch solution can reach to track from both sides.

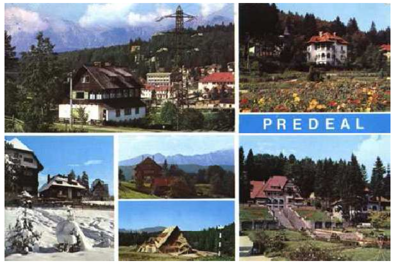
=>   The minimum etching rate is about 35 µm/h.

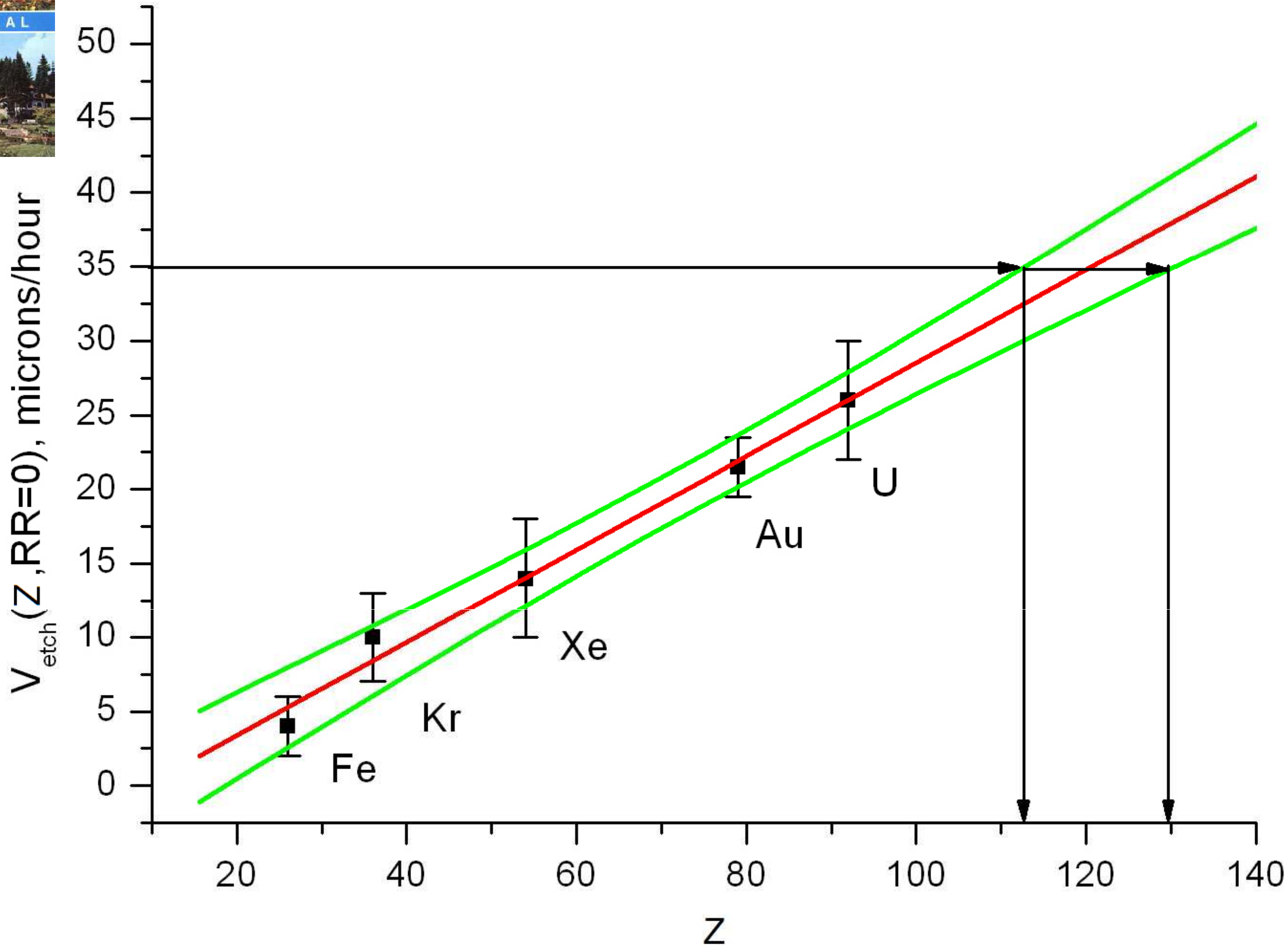




The extrapolation of the residual range dependence $Z(RR,V_{etch})$ to superheavy nuclei.

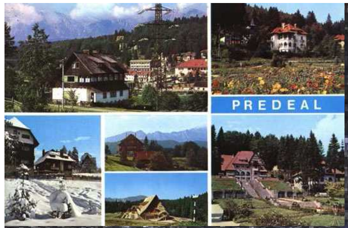






Regression analysis: at the confidence level 95% nucleus charge with etching rate about 35 micron/hour is **Z=119(+10,-6).**

On the plot: red line – approximation for experimental data by straight line, green lines – error corridor at the confidence level 95%. Vertical lines mark out possible charge interval at the confidence level 95% at etching rate near stopping point 35 micron/hour.



The superheavy nuclei in olivine crystals evidently lived long enough to fly from the place of their origin to the meteorite. At present, it is believed that the main source of the nuclear component of GCRs are supernovae, in which the nuclei of superheavy and transuranium elements are generated and accelerated.

To reach the solar system and form the tracks registered in our meteorites, the average lifetime of these nuclei must be equal to at least the time of their propagation from the source to our solar system’s asteroid belt.

In estimating the lifetime of superheavy nuclei, we must consider that

(a) in order to form tracks in olivine crystal the nuclei must have an input energy in the meteorite of several gigaelectron volts per nucleon, and

(b) supernovae in our Galaxy can occur at distances of ~1–8 kiloparsecs from the solar system.

A rough estimate of the minimum lifetime of such GCR nuclei thus yields a value of 3000 to 25000 years.

Conclusions.

1. **We derived the charge distribution more then of 7000 galactic nuclei whose charges are more 55.**

2. **We observed three events whose charges are estimated 105<Z<130; one of them Z=119(+10,-6).**

3. **Our evaluation of minimum lifetime of GCR nuclei is equal about 3000 up to 25000 years.**

4. **So we derived additional indication of existence in nature (galactic cosmic ray) of the stability island elements.**

THANK YOU!