Radiometry
Applied Geophysics 2020a

Edited by G. Pethő

Fundamentals of radioactivy

Alpha decay: $${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + E_{kin}$$

Beta decays:

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^{-} + \bar{\nu}$$ Negative beta decay

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + e^{+} + \nu$$ Positive beta decay

$${}^{A}_{Z}X + e^{-} \rightarrow {}^{A}_{Z-1}Y + \nu$$ Electron capturing

Roentgen discovered X-ray (1895), Becquerel and Pierre &Marie Curie observed natural radioactivity (1896) at first , Thomson discovered electrons (1897), Rutherford and Villard made difference between ionizing radiations on the basis of ionizing power and the three types of radiations were simply named alpha, beta and gamma, for the first three letters of the Greek alphabet. It was only later that the radiation was shown to consist of: helium nuclei (alpha decay), electrons or positrons (beta decay) and high-energy electromagnetic waves (photons, gamma radiation).

Fundamentals of radioactive disintegration

In course of **alpha decay** a new nucleus is formed by emitting a helium nucleus. The new nucleus has an atomic number decrease by two, and a mass number decrease by four.

An alpha decay looks like this : $${}^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He + E_{kin}$$

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + e^{-} + \bar{\nu}$$

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + e^{+} + \nu$$

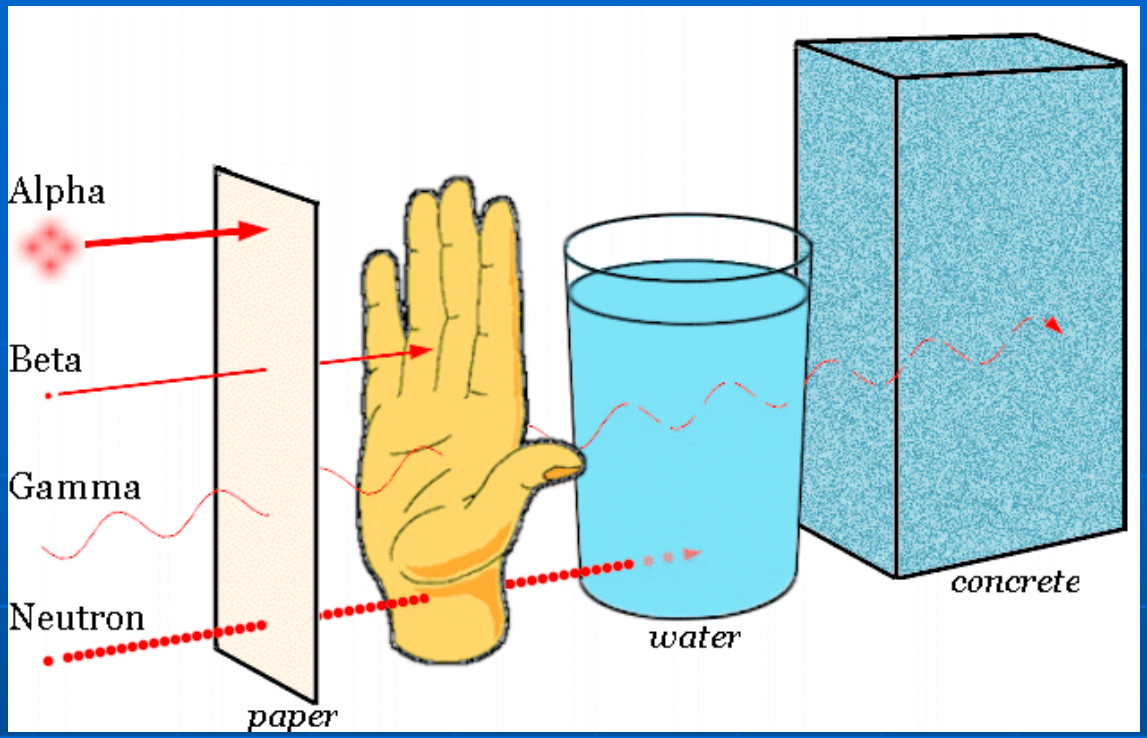
$${}^{A}_{Z}X + e^{-} \rightarrow {}^{A}_{Z-1}Y + \nu$$

In course of **negative beta decay** one neutron of the unstable nucleus converts into a proton and an electron and an antineutrino are emitted (left). The atomic number increases by one, but the mass number does not change. There are two types of **positive beta decays**: in both cases neutron is produced from proton. It can be either by positron emission (middle) or by electron capture (right). In the latter an orbital electron is absorbed by a nucleus, effectively converting a proton into a neutron.

After alpha or beta decay, a nucleus is often left in an excited state, that is, with some extra energy. It then "calms down" by releasing this energy in the form of electromagnetic wave, known as **a gamma ray**. The energy of this gamma ray is typical of the emitting nucleus.

$${}^{40}_{19}K + e^{-} \rightarrow {}^{40}_{18}Ar + \gamma + \nu$$

The energy of gamma ray emitted by the metastable Ar equals 1.46MeV.



Alpha particles can usually be stopped by a sheet of paper. Radioisotopes emitting alpha particles are usually not hazardous outside the body, however, they can cause damage if they are inhaled or ingested.

Beta particles (streams of electrons) can pass through a hand, but are usually stopped by a modest barrier such as a few millimetres of metal, or even a layer of clothing. Just like , beta particles, they are more hazardous if they are inhaled or ingested.

Gamma radiation can be very penetrating and can pass through thick solid materials. Several meters of concrete would be needed to attenuate some of the more energetic gamma radiations. One of the most common natural gamma sources found in the environment (and in the human body) is ^{40}K, an isotope of potassium. Neutrons are also very penetrating. Some elements, like
Chlorine or Hydrogen, capture and scatter neutrons. Water is commonly used as a neutron radiation shield. (SOURCE: WIKIPEDIA)

Fundamentals of radioactive disintegration

The rate of decay of N nuclei is linearly proportional to the number of unstable isotope N.

$$\frac{\partial N}{\partial t} = -\lambda N$$

λ denotes the decay constant, N_0 is the number of nuclei present at t=0.

$$\int_{N_0}^{N} \frac{dN}{N} = \int_{t=0}^{t} -\lambda dt$$

$$\left[\ln N\right]_{N_0}^{N} = -\lambda t$$

$$\ln\left(\frac{N}{N_0}\right) = -\lambda t$$

$$N = N_0 e^{-\lambda t}$$

The larger the decay constant is, the faster the decay will be.

Fundamentals of radioactive disintegration

Relationship between decay constant and half-life $T_{1/2}$

The half life is the time taken to reduce the number of parent atoms by one-half.

$$N_0 / 2 = N_0 e^{-\lambda T_{1/2}}$$

$$\ln e^{\lambda T_{1/2}} = \ln 2$$

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

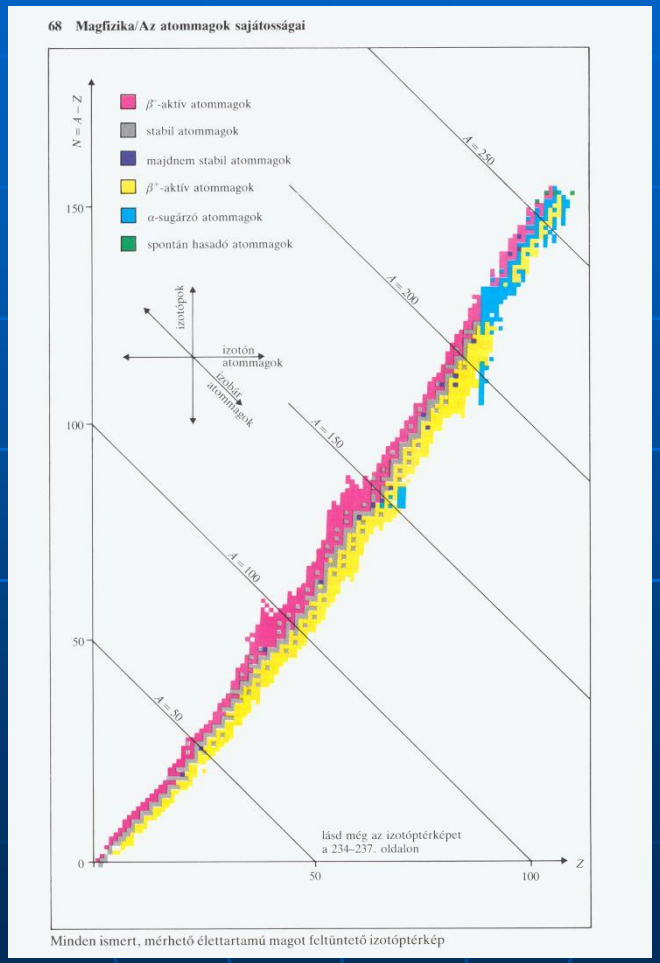
There is an inverse relationship between decay constant and half-life and the factor is ln2.

Most important radioactive decays in nature

Element	Instable isotope	Occurence %	Decay mech.	Stable daughter isotope	λ year^{-1}	$T_{1/2}$ 10^9 year
U	^{238}U	99.274	$8\alpha + 6\beta$	^{206}Pb	$1.55*10^{-10}$	4.47
	^{235}U	0.720	$7\alpha + 4\beta$	^{207}Pb	$9.85*10^{-10}$	0.703
Th	^{232}Th	100.	$6\alpha + 4\beta$	^{208}Pb	$4.95*10^{-11}$	14.0
Rb	^{87}Rb	27.85	β	^{87}Sr	$1.42*10^{-11}$	48.8
K	^{40}K	0.01167	$K\,EC$ (11%)	^{40}Ar	$5.81*10^{-11}$	} 1.25
			β (89%)	^{40}Ca	$4.962*10^{-10}$	
C	^{14}C	$1.6*10^{-10}$ (air CO_2)	β	^{14}N	$1.209*10^{-4}$	$5.73*10^{-6}$

Sharma: Geophysical methods in Geology (1986)

Instability of the nucleus



KSH ATLASZ

Units used in radiometry

Radiation measurement units and conversion factors.

Unit	Definition	Conversion
R (roentgen)	Radiation required to produce 1 electrostatic unit (e.s.u.) of charge	1 e.s.u. charge $=2.083\times10^{15}$ ions/m^3
Bq (becquerel)	1 disintegration/s	1 Bq=27 pCi
Ci (curie)	Activity of 1 g of Ra	1Ci=3.7×10^{10} Bq
pCi/l	Activity measured in fluids	1 pCi/l=37 Bq/m^3
Gy (gray)	Absorbed dose corresponding to 1 joule (J) of radiation per kg of body tissue	1 Gy=100 rad
Sv (sievert)	Equivalent dose representing damage to tissue	1 Sv=1 J/kg
WL (working level)	Potential α-radiation concentration in air at a working place	1 WL=3740 Bq/m^3 (or 3.7 Bq/l)
WLM (working level month)	Exposure at a working place in 1 month (173 hours)	1 WLM=1 WL×173

The **gray** (Gy), with units J/kg, is the SI unit of **absorbed dose**, which represents the amount of radiation required to deposit 1 joule of energy in 1 kilogram of any kind of matter. The **sievert** (Sv) is the SI unit of **equivalent dose**. Although it has the same units as the gray, J/kg, it measures something different. It is the dose of a given type of radiation in Gy that has the same biological effect on a human as 1 Gy of x-rays or gamma radiation.

Eisenbud, Gesell: Environmental Radioactivity,1997

SOURCE:WIKIPEDIA

Average effective dose in USA

Annual estimated average effective dose equivalent received by a member of the population of the United States.

Source	Average annual effective dose equivalent	
	(μSv)	(mrem)
Inhaled (Radon and Decay Products)	2000	200
Other Internally Deposited Radionuclides	390	39
Terrestrial Radiation	280	28
Cosmic Radiation	270	27
Cosmogenic Radioactivity	10	1
Rounded total from natural source	3000	300
Rounded total from artificial Sources	600	60
Total	3600	360

Shown in the table above, 82% of the total average annual effective dose is from natural sources of radiation, and of that, most is from radon. Of the other 18%, the majority is from medical diagnosis and treatments, with <1% from nuclear power and fallout.

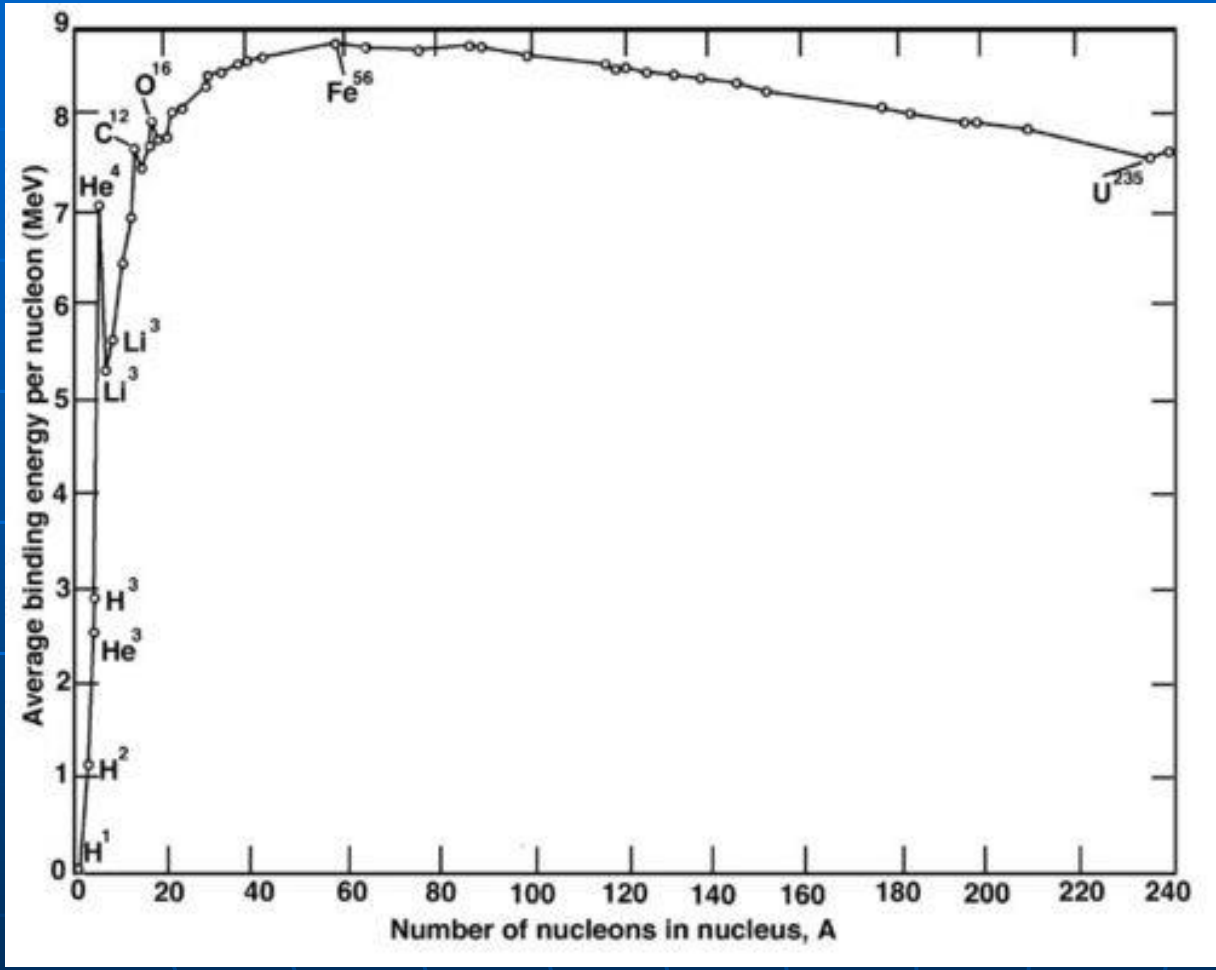
Eisenbud, Gesell: Environmental Radioactivity,1997

Units used in radiometry

The **equivalent dose** was defined to give an approximate measure of the biological effect of radiation. It is calculated by multiplying the absorbed dose by a weighting factor W_R which is different for each type of radiation.

Radiation type	Rad. weighting factor, W_R
Photons	1
Electrons and muons	1
Protons > 2 MeV	5
Alpha particles, fission fragments, heavy nuclei	20
Neutron energy < 10 keV	5
Neutron energy 10 to 100 keV	10
Neutron energy > 100 keV to 2 MeV	20
Neutron energy >2 to 20 MeV	10
Neutron energy > 20 MeV	5

Binding energy in the function of nucleons number



The greater the average binding energy per nucleon is, the less the probability of disintegration for the nucleus will be.

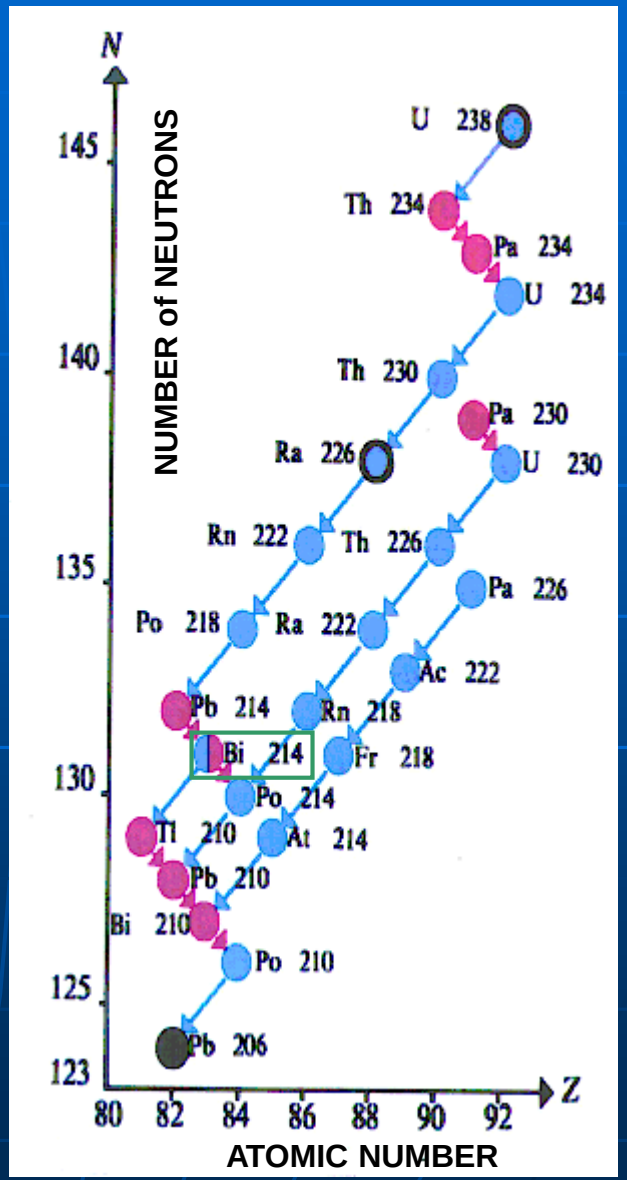
The situation for large mass number:

With increasing proton (and mass) number the electrostatic repelling force will be greater resulting in decreasing binding energy.

At relatively small mass number the nucleons are situated on the surface of the nucleus, the binding is less between them and nucleons in the interior. The exception is ^{4}He.

Decay series of ^{238}U (8 alpha, 6 beta disintegration)

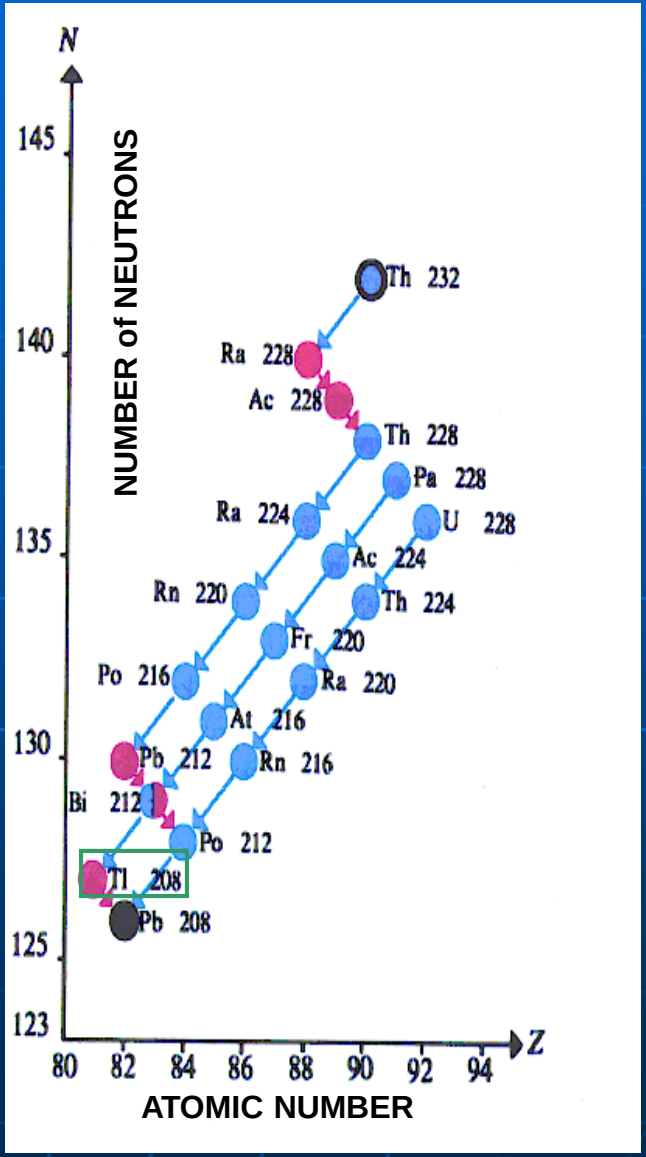
ISOTOPE	HALF-TIME	DECAY
^{238}U	4.49×10^9 year	α
^{234}Th	24.1 day	β–
^{234}Pa	1.17 min	β–
^{234}U	2.48×10^5 year	α
^{230}Th	7.7×10^4 year	α
^{226}Ra	1600 year	α
^{222}Rn	3.82 day	α
^{218}Po	3.05 min	α
^{214}Pb	26.8 min	β–
^{214}Bi	19.8 min	β–
^{214}Po	162 μsec	α
^{210}Pb	22.3 year	β–
^{210}Bi	5.01 day	β–
^{210}Po	138.4 day	α
^{206}Pb	STABLE	



The beta decay of ^{214}Bi is accompanied by a gamma radiation of 1.76 MeV.

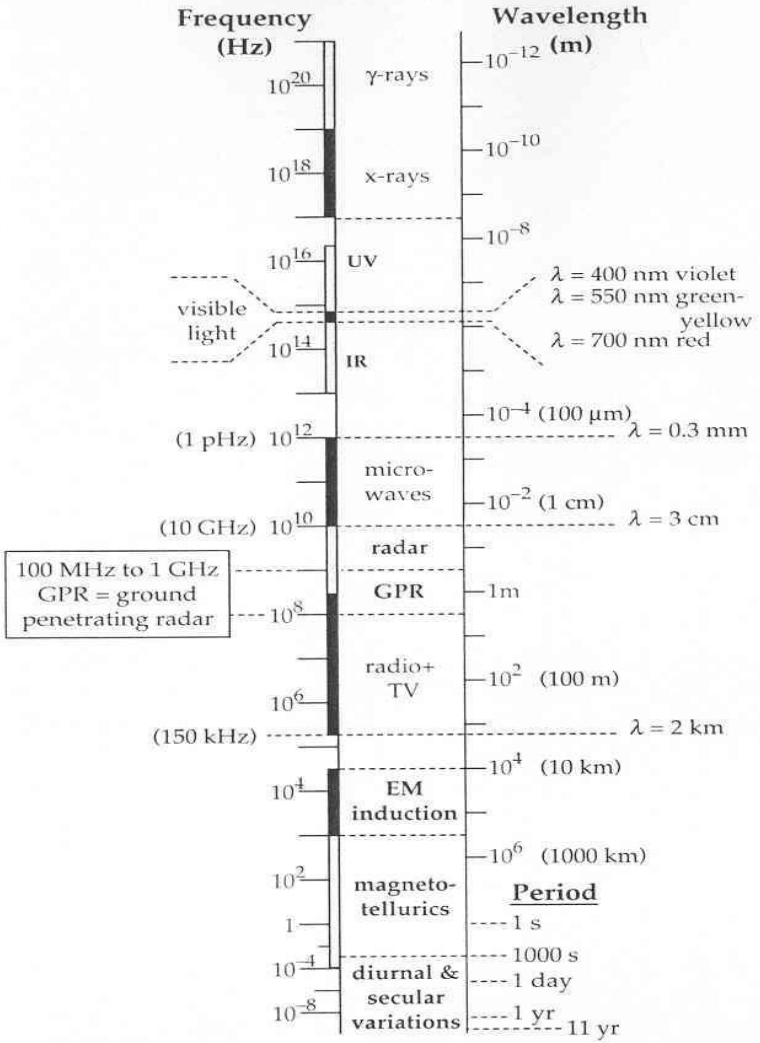
Decay series of ^{232}Th (6 alpha, 4 beta disintegration)

ISOTOPE	HALF TIME	DECAY
^{232}Th	1.41×10^{10} YEAR	α
^{228}Ra	5.8 YEAR	β–
^{228}Ac	6.13 HOUR	β–
^{228}Th	1.91 YEAR	α
^{224}Ra	3.66 DAY	α
^{220}Rn	55.6 SEC	α
^{216}Po	0.15 SEC	α
^{212}Pb	10.64 HOUR	β–
^{212}Bi	60.6 HOUR	β–
^{212}Po	2.05×10^{-7} SEC	α
^{208}Pb	STABLE	



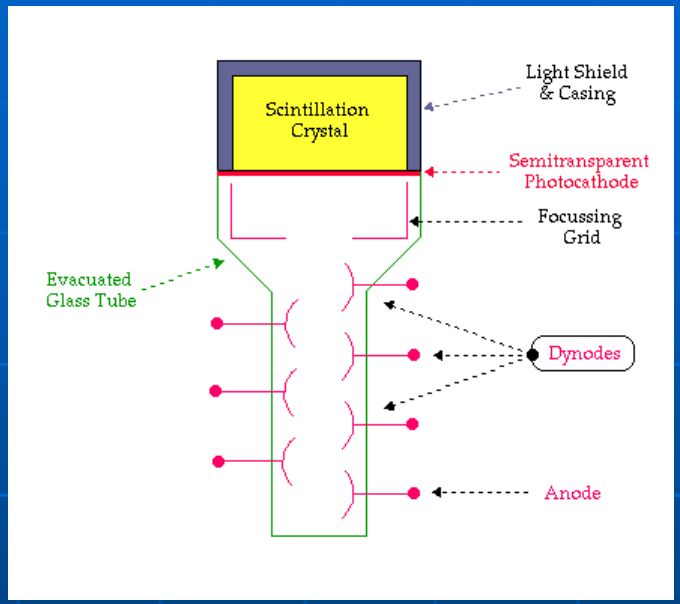
The beta decay of ^{208}Tl is accompanied by a gamma radiation of 2.62 MeV.

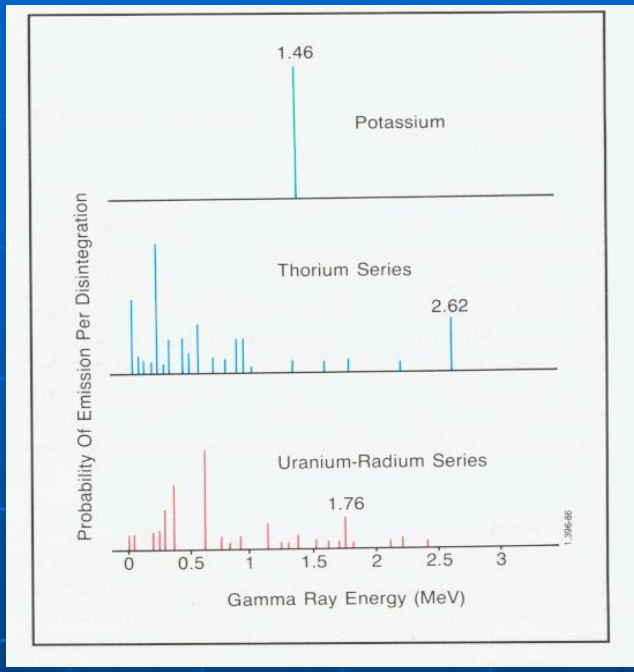
EM spectrum



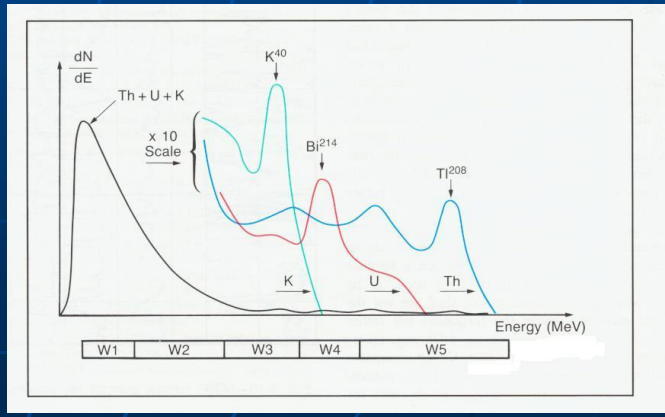
The electromagnetic spectrum, showing the frequency and wavelength ranges of some common phenomena and the frequencies and periods used in electromagnetic surveying

Radioactive potassium isotope with atomic weight of 40 and the radioactive elements of uranium and thorium series emit nearly all the natural gamma radiation. We can measure either the **total natural gamma intensity** or we can determine the content of them on the basis of **selective natural gamma measurement**.

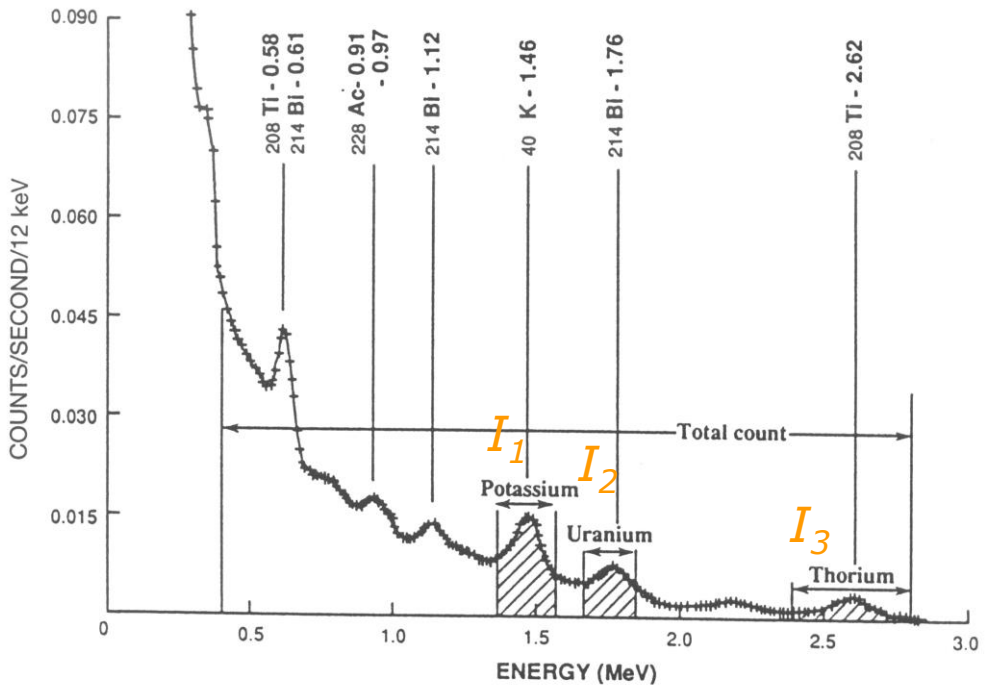




Sodium iodide scintillation detector (or "crystal"), which emits a pulse of light when it is struck by a gamma ray. The crystal is optically coupled to a photomultiplier tube that amplifies the pulse of light and outputs a current pulse. The energy of the pulse is proportional to the energy of the gamma radiation that caused the pulse. The spectral gamma tool records both the number of pulses and the energy level of each pulse.



The determination of K, U and Th content



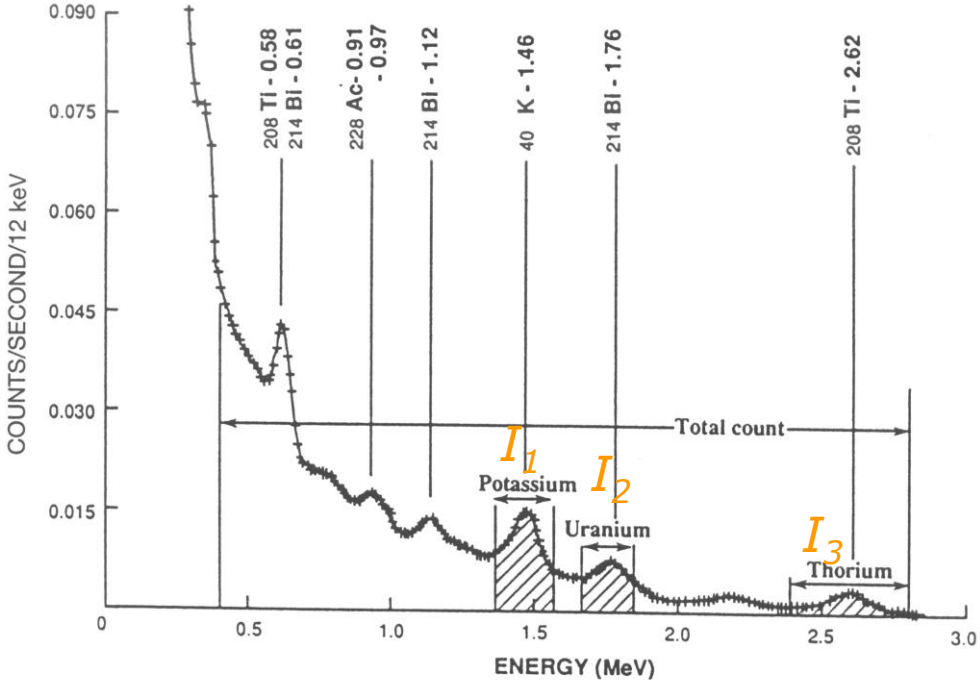
A typical airborne gamma-ray spectrum showing the customary four windows: total count, 0.4–2.81 MeV; ^{40}K, 1.37–1.57 MeV; ^{238}U, 1.66–1.86 MeV; and ^{232}Th, 2.42–2.81 MeV. (After Grasty, 1987.)

$$I_1 = A_1K + B_1U + C_1Th + r_1$$
$$I_2 = A_2K + B_2U + C_2Th + r_2$$
$$I_3 = A_3K + B_3U + C_3Th + r_3$$

$$\sum_{i=1}^{3} r_i^2 = \sum_{i=1}^{3} \left[I_i - (A_iK + B_iU + C_iTh) \right]^2$$

The sum of the deviation square has to be minimized.

The determination of K, U and Th content



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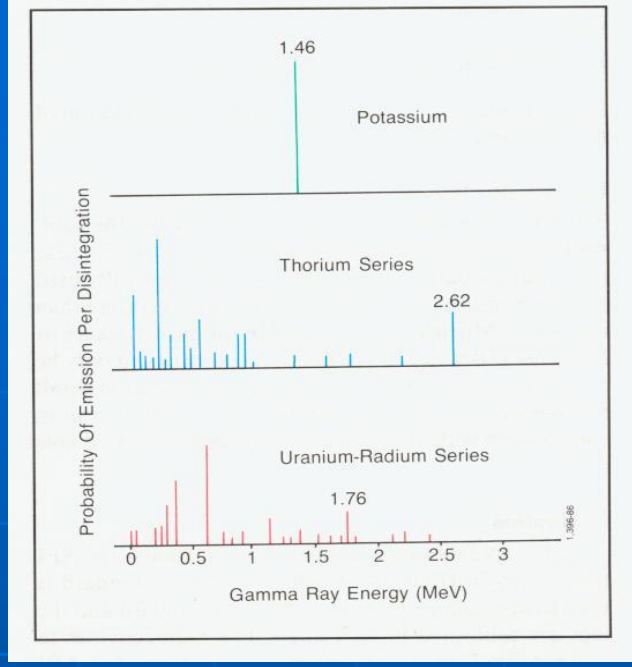


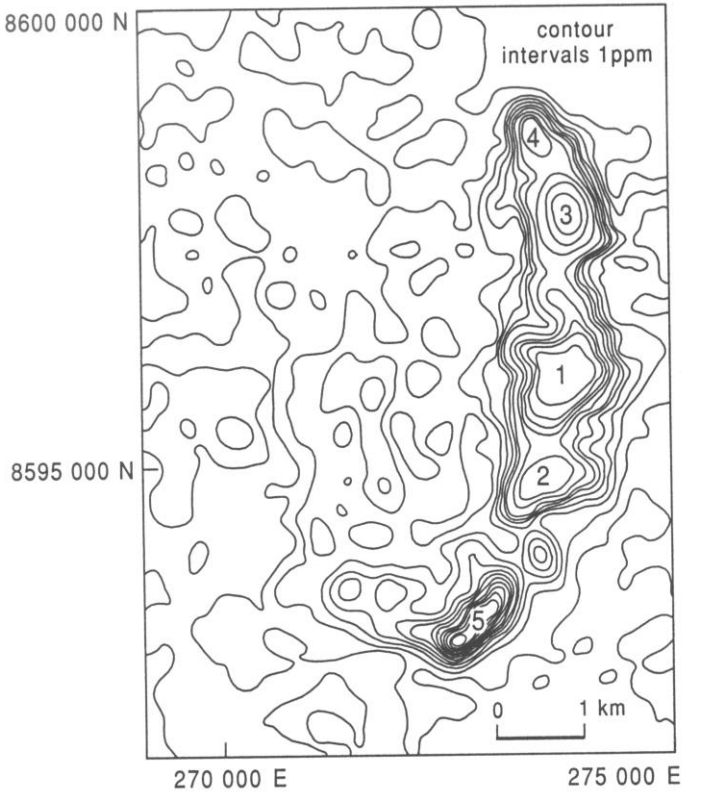
$$Th = k_3 I_3$$

$$U = k_2 (I_2 - S_3 I_3)$$

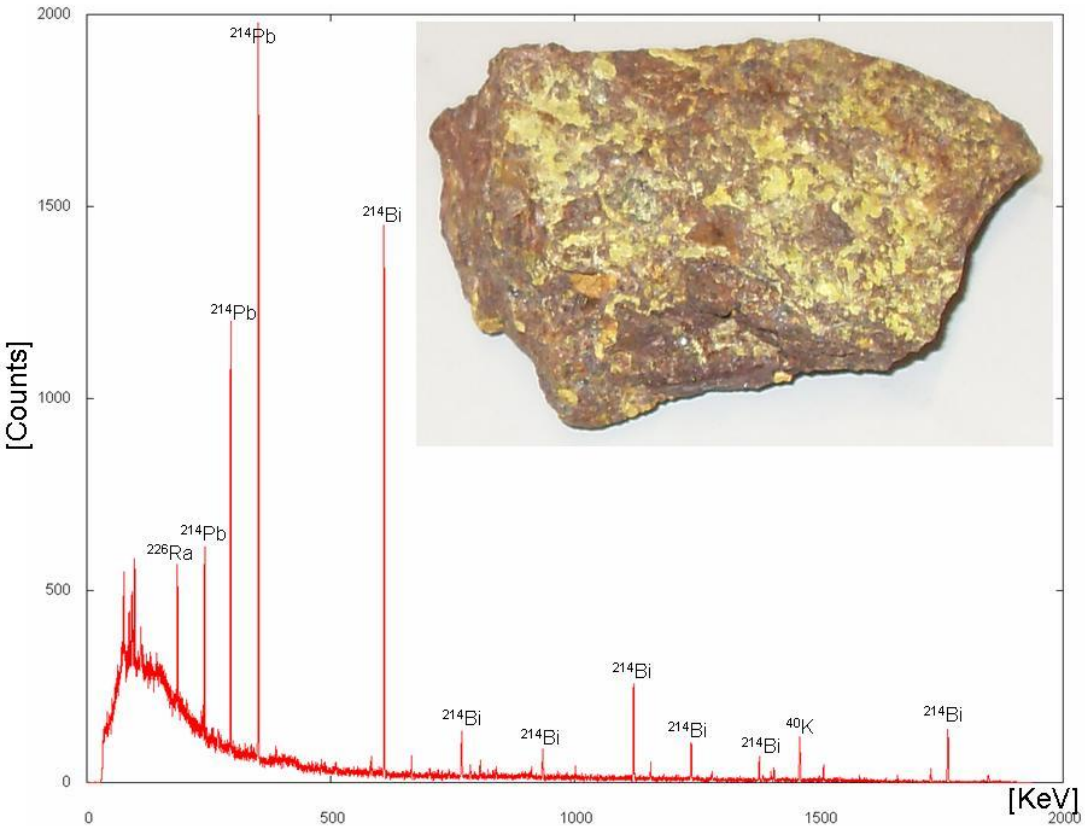
$$K = k_1 \left[I_1 - S_2 (I_2 - S_3 I_3) - S_1 I_3 \right]$$

None of the gamma rays from U and K has sufficient energy to be recorded in the Th channel (upper equation). The U channel records gamma rays from U and Th, but none from K. It is the K channel which records gamma rays from K,U,Th. The k_i are channel constants, S_3 is the stripping constant for Th gamma radiation in the U channel (middle equation). S_2 and S_1 are the stripping constants for U and Th gamma radiations in the K channel (bottom equation).

Case history

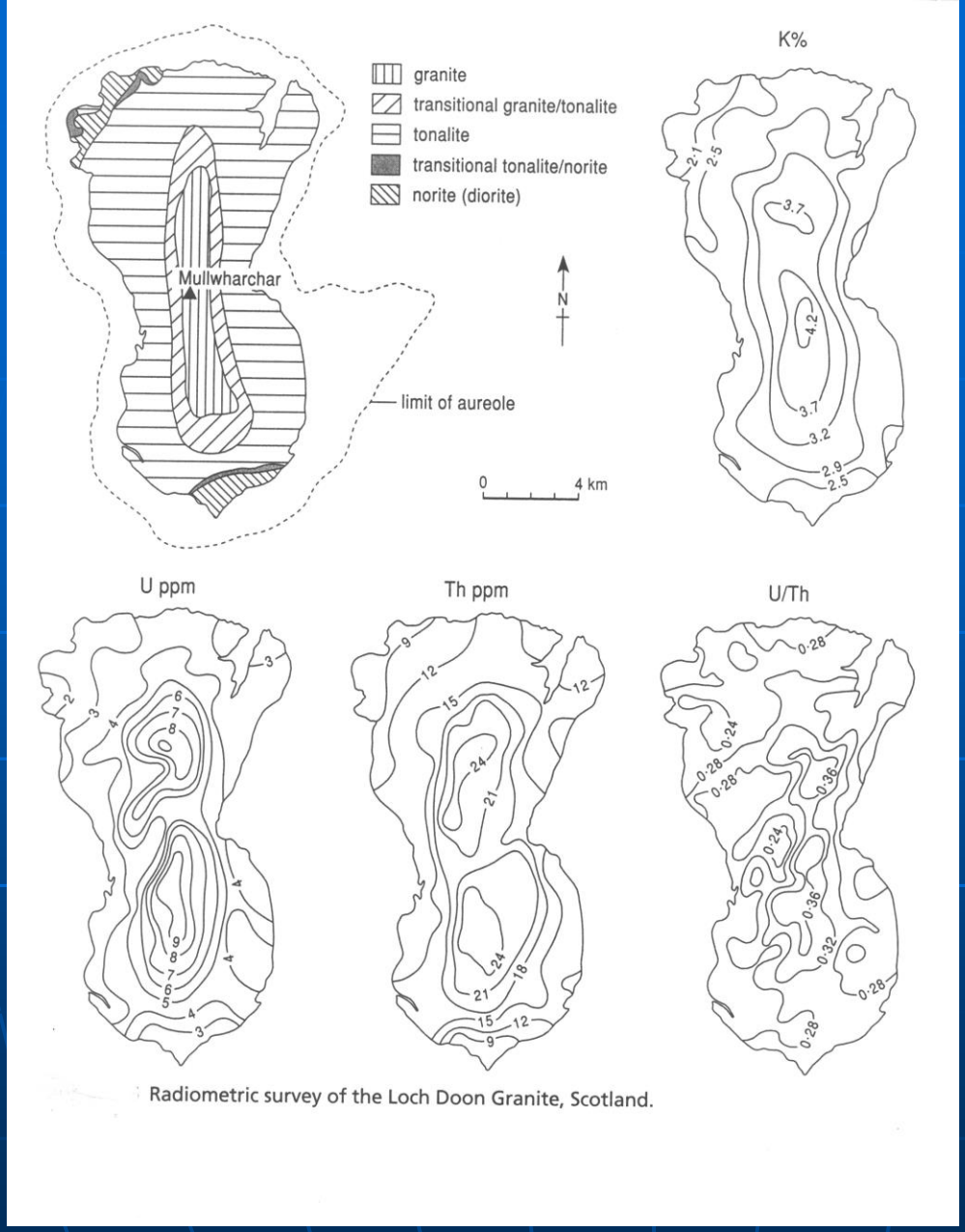


Airborne survey of uranium orebodies
Ranger, Australia.



Sharma: Geophysical methods in Geology (1986)

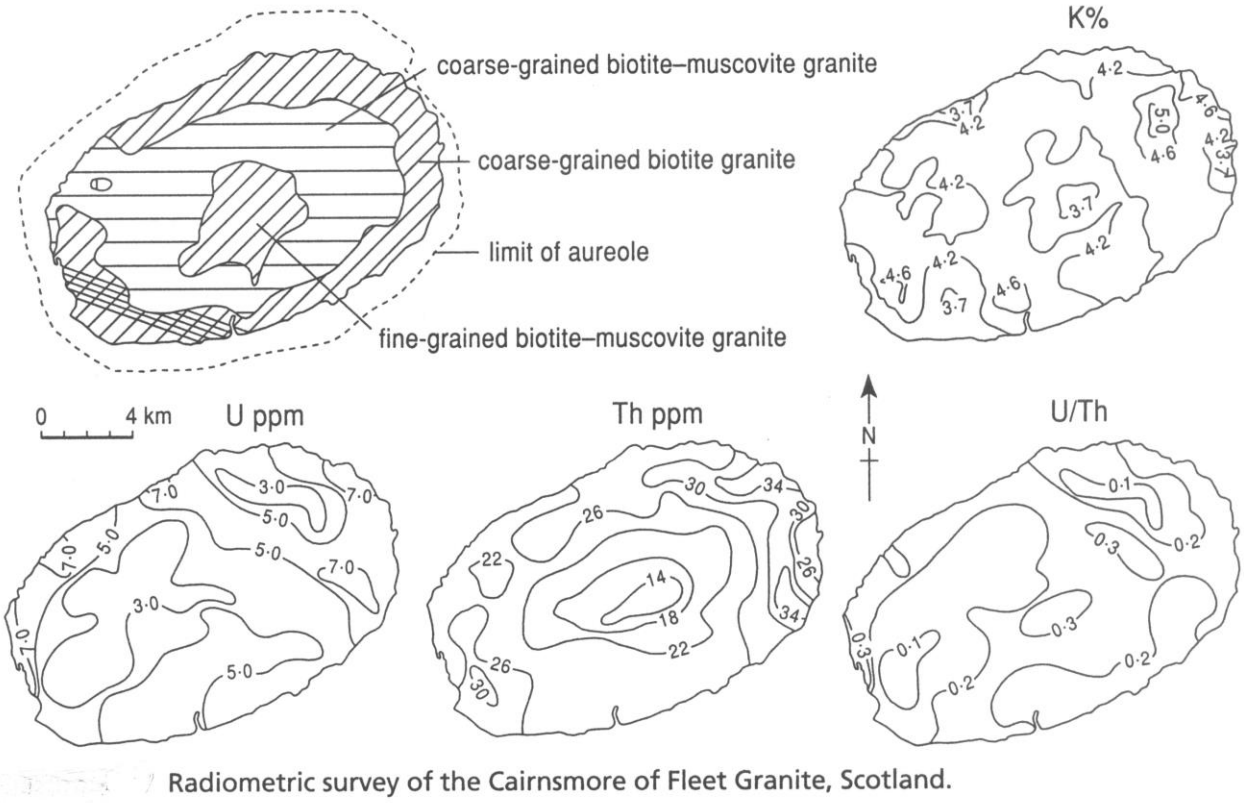
Case history



Radiometric survey of the Loch Doon Granite, Scotland.

Sharma: Geophysical methods in Geology (1986)

Case history



Radiometric survey of the Cairnsmore of Fleet Granite, Scotland.

Sharma: Geophysical methods in Geology (1986)

Most imortant radioactive elements, minerals and their occurence

Potassium	Mineral	(i) Orthoclase and microline feldspars [$KAlSi_3O_8$]
		(ii) Muscovite [$H_2KAl(SiO_4)_3$]
		(iii) Alunite [$K_2Al_6(OH)_{12}SO_4$]
		(iv) Sylvite, carnallite [KCl, $MgCl_2 . 6H_2O$]
	Occurrence	(i) Main constituents in acid igneous rocks and pegmatites
		(ii) Same
		(iii) Alteration in acid volcanics
		(iv) Saline deposits in sediments
Thorium	Mineral	(i) Monazite [ThO_2 + rare earth phosphate]
		(ii) Thorianite [$(Th, U)O_2$]
		(iii) Thorite, uranothorite [$ThSiO_4$ + U]
	Occurrence	(i) Granites, pegmatites, gneiss
		(ii) Granites, pegmatites, placers
		(iii) Same
Uranium	Mineral	(i) Uraninite [oxide of U, Pb, Ra + Th, rare earths]
		(ii) Carnotite [$K_2O.2UO_3.V_2O_5.2H_2O$]
		(iii) Gummite [uraninite alterations]
	Occurrence	(i) Granites, pegmatites, and with vein deposits of Ag, Pb, Cu, etc.
		(ii) Sandstones
		(iii) Associated with uraninite

Telford,Geldart, Sheriff: Applied Geophysics,1993

Probably the most imortant relationship between radiometry and geology

Acid magmatic rocks are usually more radioactive than intermediate and basic magmatic rocks. Ultrabasic rocks are characterized by the least natural radioactivity. It can be stated, that the natural radioactivity of magmatic rocks is in a good correlation with the SiO_2 content.

The radioactivity of sedimentary rocks mainly depends on the radioactivity of the deposited sediments and the radioactivity of metamorphic rocks can be correlated to the radioactivity of the primary rocks.

Thorium, uranium and potassium contents of some igneous rocks

Igneous Rocks	Th (ppm)	U (ppm)	K (%)
Acid intrusive			
Granite	19–20	3.6–4.7	2.75–4.26
Rhode Island [1]	21.5–26.6 (25.2)	1.32–3.4 (1.99)	3.92–4.8 (4.51)
Rhode Island [1]	6.5–80 (52)	1.3–4.7 (4)	5.06–7.4 (5.48)
New Hampshire	50–62	12–16	3.5–5
Precambrian	14–27	3.2–4.6	2–6
Average for granitic rocks	15.2	4.35	4.11
Syenite [1]	1338	2500	2.63
Acid extrusive			
Rhyolite	6–15	2.5–5	2–4
Trachyte	9–25	2–7	5.7
Basic intrusive			
Gabbro	27–3.85	0.84–0.9	0.46–0.58
Granodiorite	9.3–11	2.6	2–2.5
Colorado [a]	99–125 (110.6)	0.19–2.68 (1.98)	2.62–5.6 (5.48)
Diorite	8.5	2.0	1.1
Basic extrusive			
Basalt			
Alkali basalt	4.6	0.99	0.61
Plateau basalt	1.96	0.53	0.61
Alkali olivine basalt	3.9	1.4	1.4
in Oregon [1]	5.5–15 (6.81)	1.2–2.2 (1.73)	1.4–3.23 (1.68)
Andesite	1.9	0.8	1.7
in Oregon [1]	5–10 (6.96)	1.4–2.6 (1.94)	2.4–4.28 (2.89)
UltraBasic			
Dunite	0.01	0.01	0.02
Peridotite	0.05	0.01	0.2
in California [1]	0.0108	0.0048	0.019

[1] From U.S.G.S. Geochemical standards, in Adams & Gasparini, 1970.

Case history (Telkibánya, Hungary)

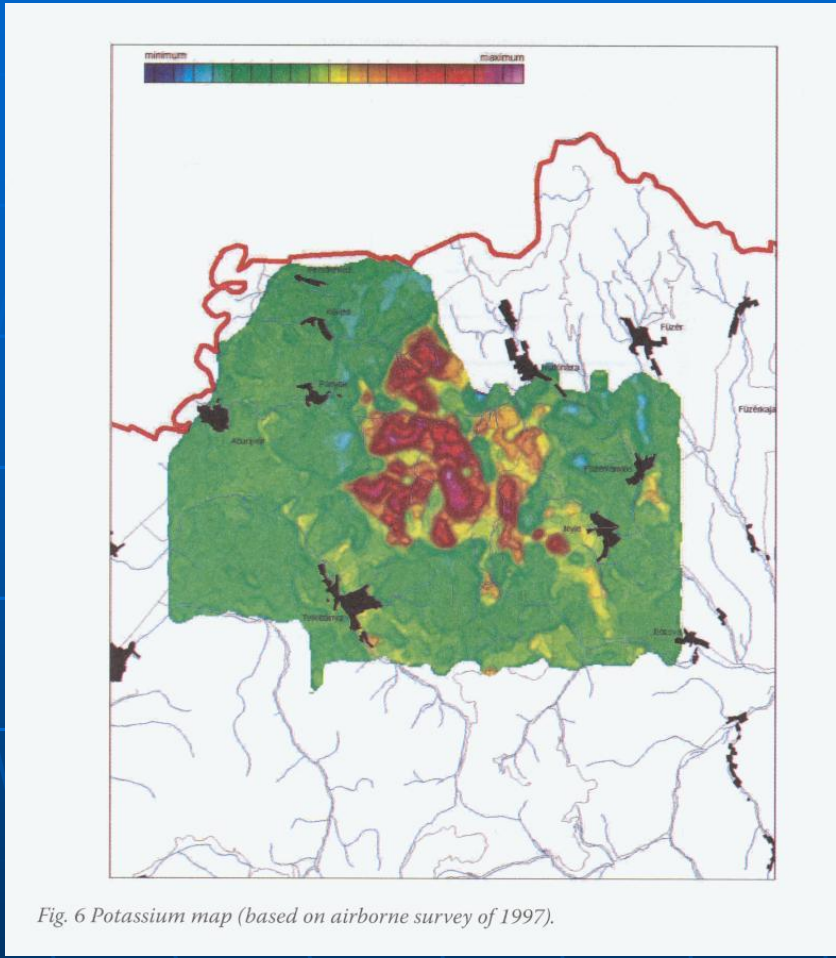


Fig. 6 Potassium map (based on airborne survey of 1997).

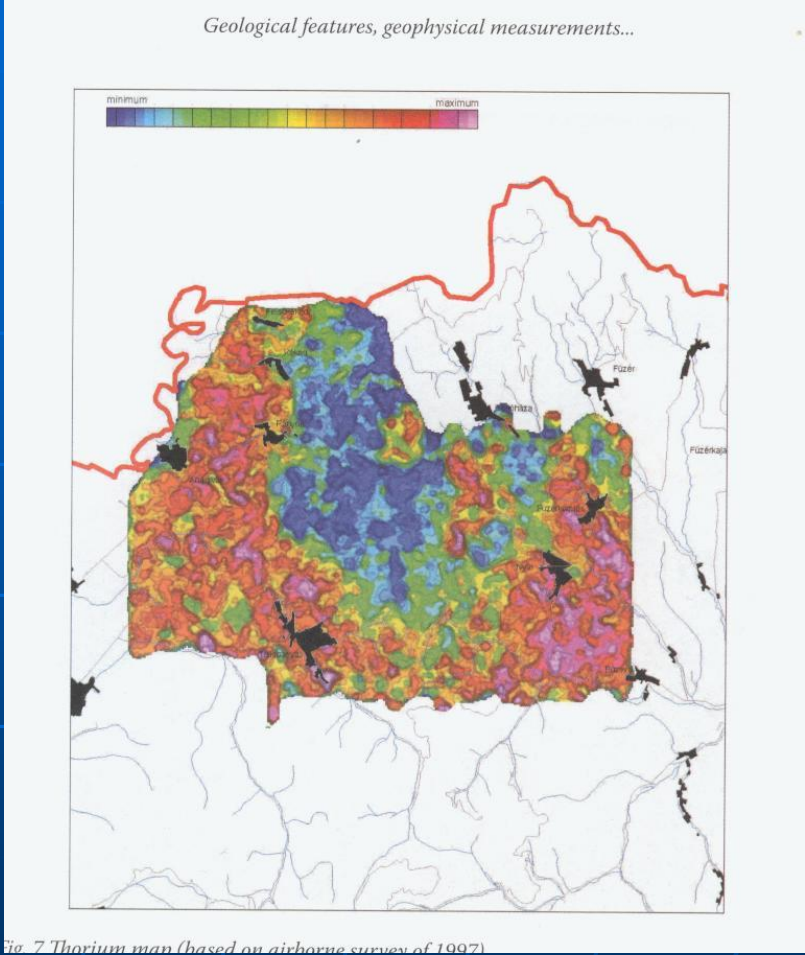


Fig. 7 Thorium map (based on airborne survey of 1997)

Silver ore can be found in K trachyte. This rock can be characterized with high K and low Th content.

Kiss, Zelenka (2009)

Case history (Telkibánya, Hungary)

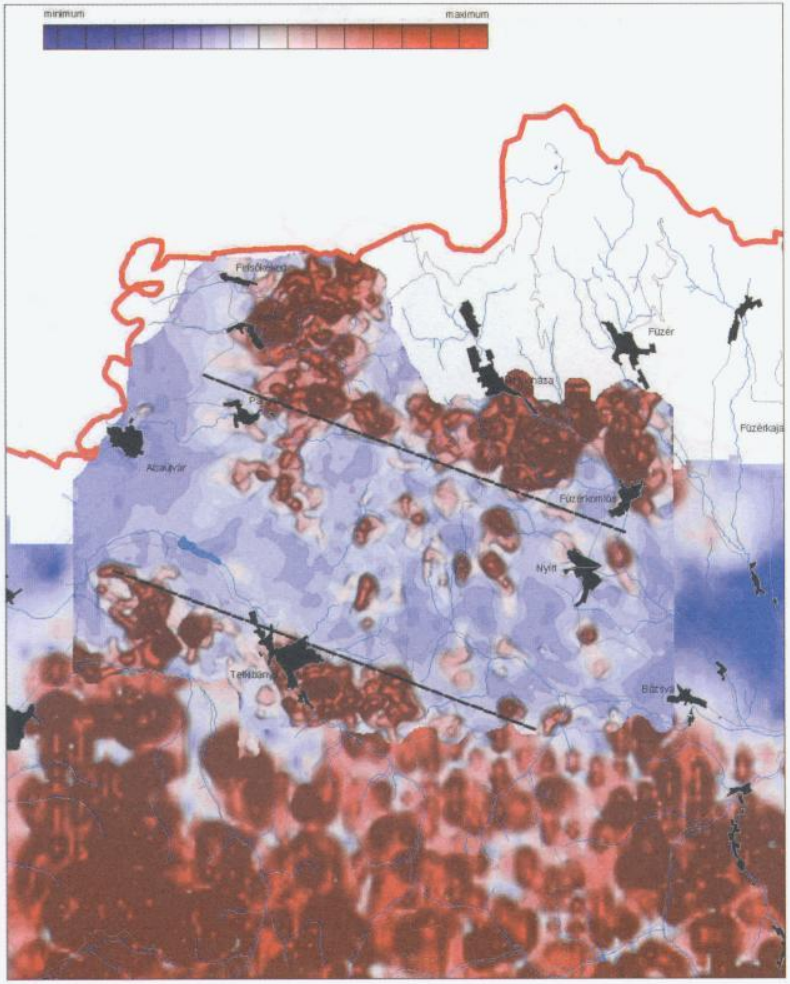


Fig. 8 Magnetic analytical signal map (based on airborne survey of 1967 and 1997).

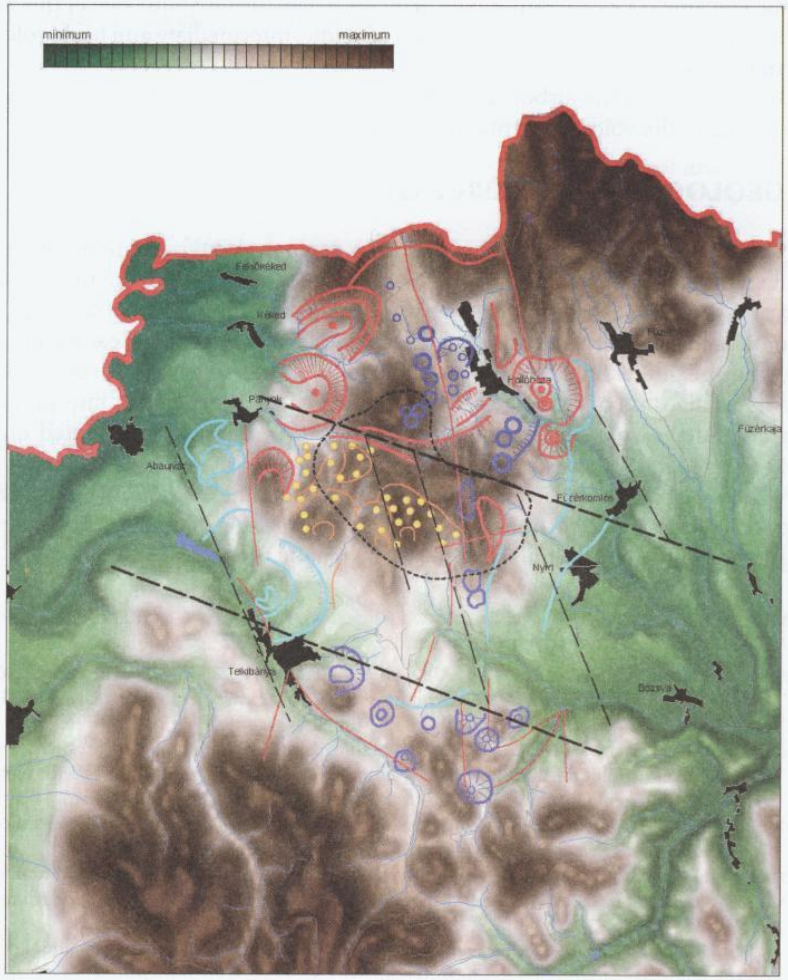
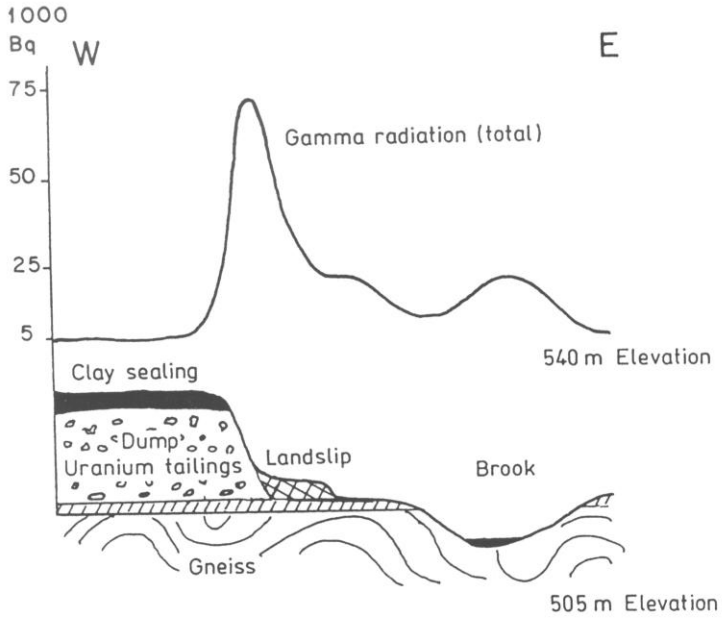


Fig. 9 Volcano-geological interpretation at Telkibánya (red curves: andesites, deep blue curves: rhyolites, light blue curves: tuffs of rhyolites, yellow dots and curves: K-metasomatic formations, red lines: tectonic lines, black lines: volcano-tectonic lines from airborne geophysics).

Kiss, Zelenka (2009)

Case history



Radiometric survey over a dump of uranium tailings partly covered by a 3-m thick clay sealing. (After Vogelsang, 1995.)

EGEC European Geotechnical and Environmental Course

Education and Culture DG
ERASMUS MUNDUS

Radiometric dating

Radiometric dating is a technique used to date materials such as rocks or minerals usually based on a comparison between the observed abundance of a naturally occurring radioactive isotope and its decay products, using their ratio and known decay rates.

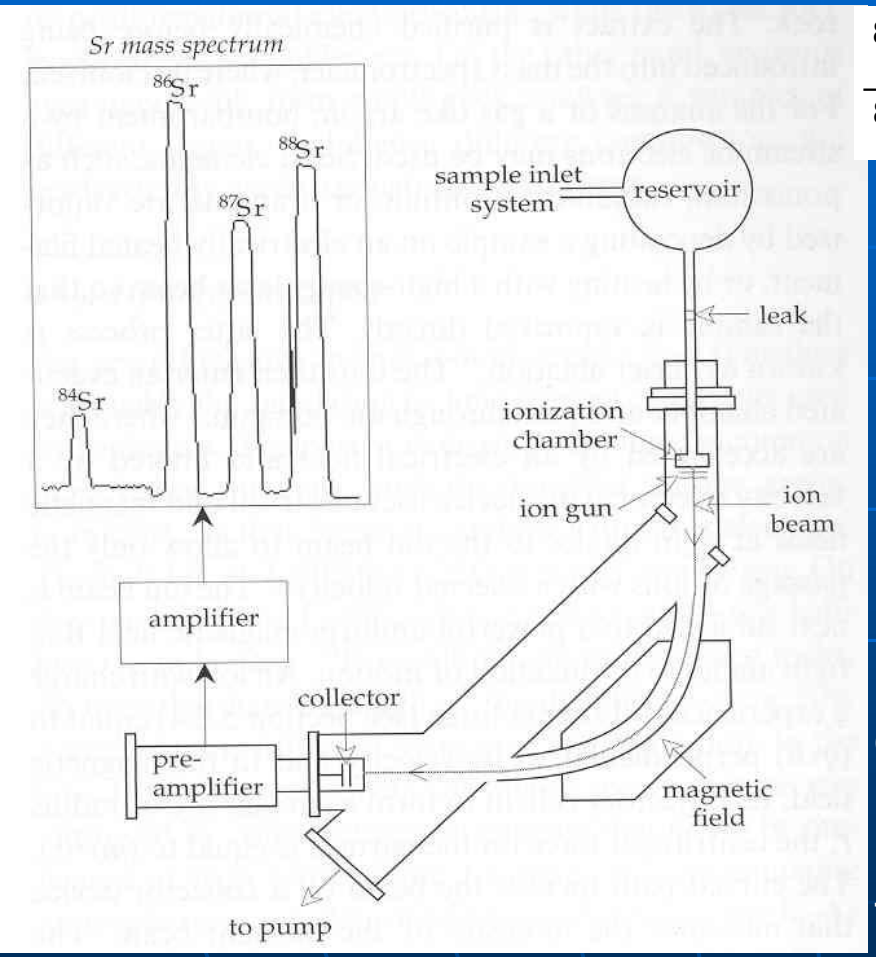
$$D(t) = N_0 - N(t) + D_0$$

$$D(t) = N(t)e^{\lambda t} - N(t) + D_0 = D_0 + N(t)(e^{\lambda t} - 1)$$

$$t = \frac{1}{\lambda}\ln\left(\frac{D(t)}{N(t)} + 1 - \frac{D_0}{N(t)}\right)$$

Rubidium-Strontium method

$$^{87}_{37}Rb \rightarrow ^{87}_{38}Sr + e^{-} + \bar{\upsilon}$$



$$\frac{^{87}Sr}{^{86}Sr} = \frac{^{87}Sr_0}{^{86}Sr} + \frac{^{87}Rb}{^{86}Sr}(e^{\lambda t} - 1) \approx \frac{^{87}Sr_0}{^{86}Sr} + \frac{^{87}Rb}{^{86}Sr}\lambda t$$

$$mv^2 / r \qquad qx\vec{v}x\vec{B}$$

$$r = \frac{m}{B}\frac{v}{q}$$

Rubidium is vaporized, the ions enter an evacuated chamber and then accelerated by an electrical field (in ion gun); the ion beam is subjected to an uniform magnetic field. Its trajectory bent to form a circular arc of radius ***r.***

Additional rad. dating method: U-Pb, Th-Pb, Ar-Ar, K-Ar.

Lowrie: Fundamentals of Geophysics (2007)

K-Ar radiometric dating method

K has three isotopes: two stable ones ^{39}K (93.258%) ^{41}K(6.73%) and it is ^{40}K (0,01167%) , which is instable. There are two kinds of disintegration.

$$^{40}_{19}K \rightarrow ^{40}_{20}Ca + e^{-} + \bar{\nu}$$

$$^{40}_{19}K + e^{-} \rightarrow ^{40}_{18}Ar + \gamma + \nu$$

$$^{40}Ca + ^{40}Ar = ^{40}K(e^{\lambda t} - 1) = \frac{\lambda}{\lambda}\,^{40}K(e^{(\lambda_\beta + \lambda_K)t} - 1) = \frac{\lambda_\beta}{\lambda_\beta + \lambda_K}\,^{40}K(e^{(\lambda_\beta + \lambda_K)t} - 1) + \frac{\lambda_K}{\lambda_\beta + \lambda_K}\,^{40}K(e^{(\lambda_\beta + \lambda_K)t} - 1)$$

$$^{40}Ar = \frac{\lambda_K}{\lambda_\beta + \lambda_K}\,^{40}K(e^{(\lambda_\beta + \lambda_K)t} - 1) = \frac{\lambda_K}{\lambda}\,^{40}K(e^{\lambda t} - 1)$$

$$t = \frac{1}{\lambda}\ln\left(\frac{\lambda}{\lambda_K}\frac{^{40}Ar}{^{40}K} + 1\right)$$

$$^{40}Ar_{radiogen} = ^{40}Ar_{\Sigma} - 295{,}5 * ^{36}Ar$$

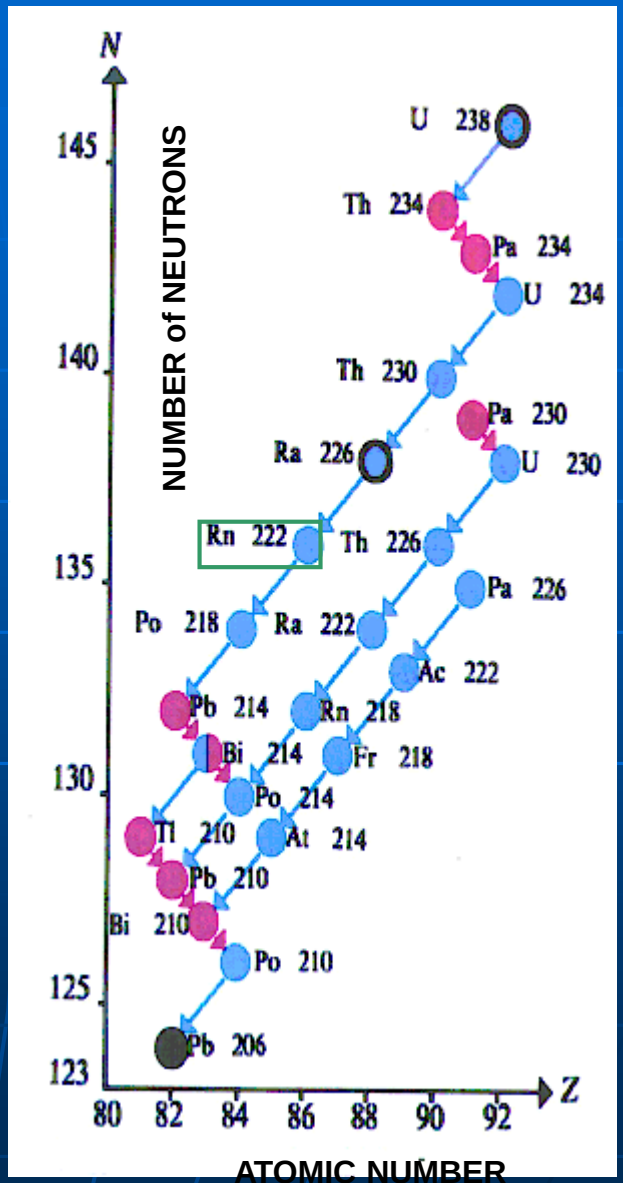
$$t = \frac{1}{\lambda}\ln\left(\frac{\lambda}{\lambda_K}\frac{^{40}Ar_{radiogen}}{^{40}K} + 1\right)$$

Some facts about Rn

Rn has an atomic number of 86. It is a radioactive, colourless, odourless, tasteless noble gas, occurring naturally as the decay product of uranium or thorium.

Decay series of ^{238}U (8 alpha, 6 beta disintegrations)

ISOTOPE	HALF-TIME	DECAY
^{238}U	4.49×10^9 year	α
^{234}Th	24.1 day	β–
^{234}Pa	1.17 min	β–
^{234}U	2.48×10^5 year	α
^{230}Th	7.7×10^4 year	α
^{226}Ra	1600 year	α
^{222}Rn	3.82 day	α
^{218}Po	3.05 min	α
^{214}Pb	26.8 min	β–
^{214}Bi	19.8 min	β–
^{214}Po	162 μsec	α
^{210}Pb	22.3 year	β–
^{210}Bi	5.01 day	β–
^{210}Po	138.4 day	α
^{206}Pb	STABLE	

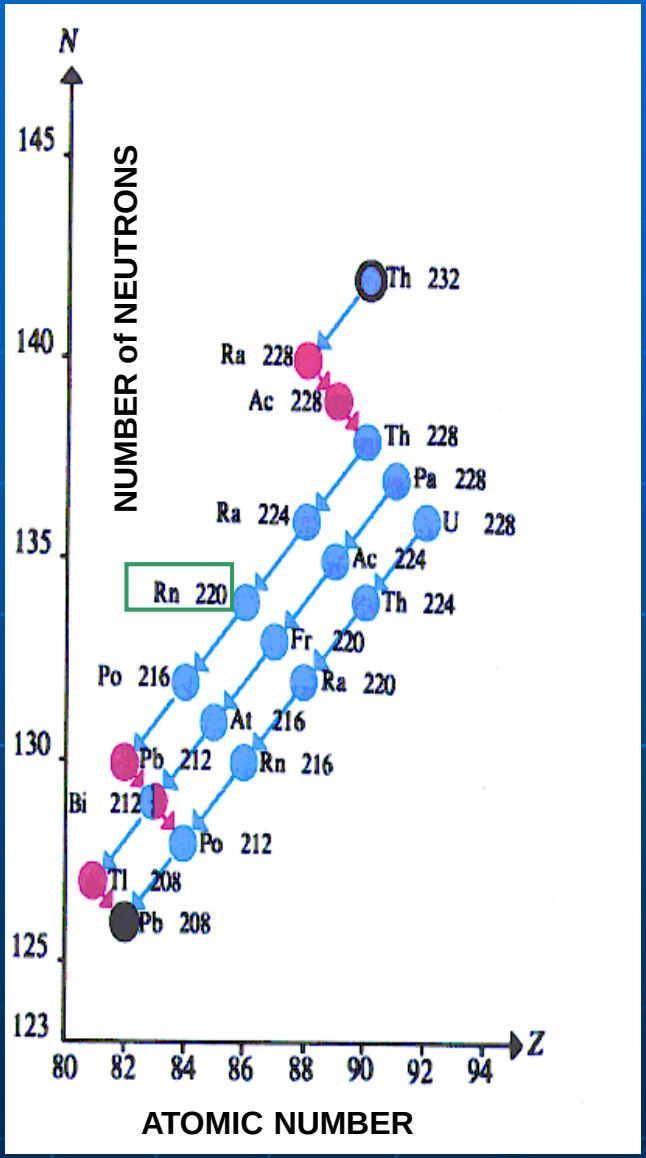


$_{86}Rn$ has a lot of isotopes, among which ^{222}Rn is the most important one.

Decay series of ^{232}Th (6 alpha, 4 beta disintegrations)

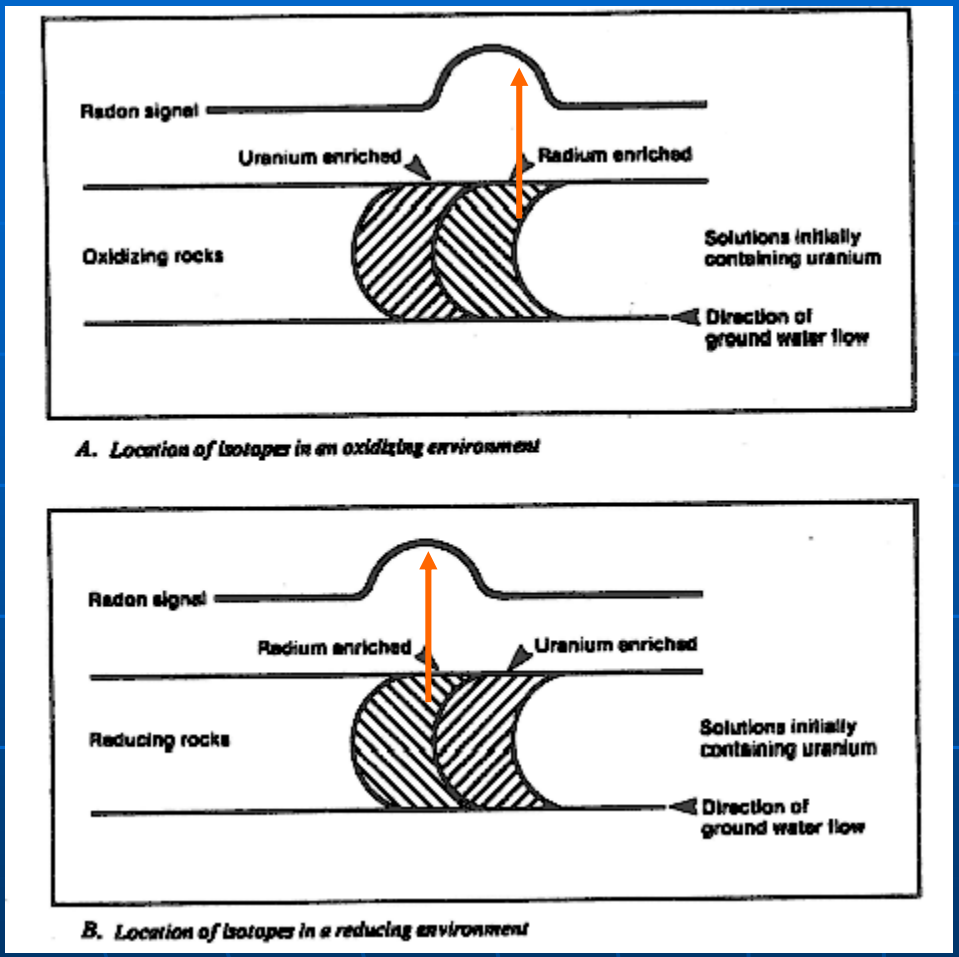
ISOTOPE	HALF TIME	DECAY
^{232}Th	1.41×10^{10} YEAR	α
^{228}Ra	5.8 YEAR	β–
^{228}Ac	6.13 HOUR	β–
^{228}Th	1.91 YEAR	α
^{224}Ra	3.66 DAY	α
^{220}Rn	55.6 SEC	α
^{216}Po	0.15 SEC	α
^{212}Pb	10.64 HOUR	β–
^{212}Bi	60.6 HOUR	β–
^{212}Po	2.05×10^{-7} SEC	α
^{208}Pb	STABLE	

^{220}Rn is produced by alpha decay of radium and decays into polonium. This decay is also alpha desintegration.



SUMMARY about RADON

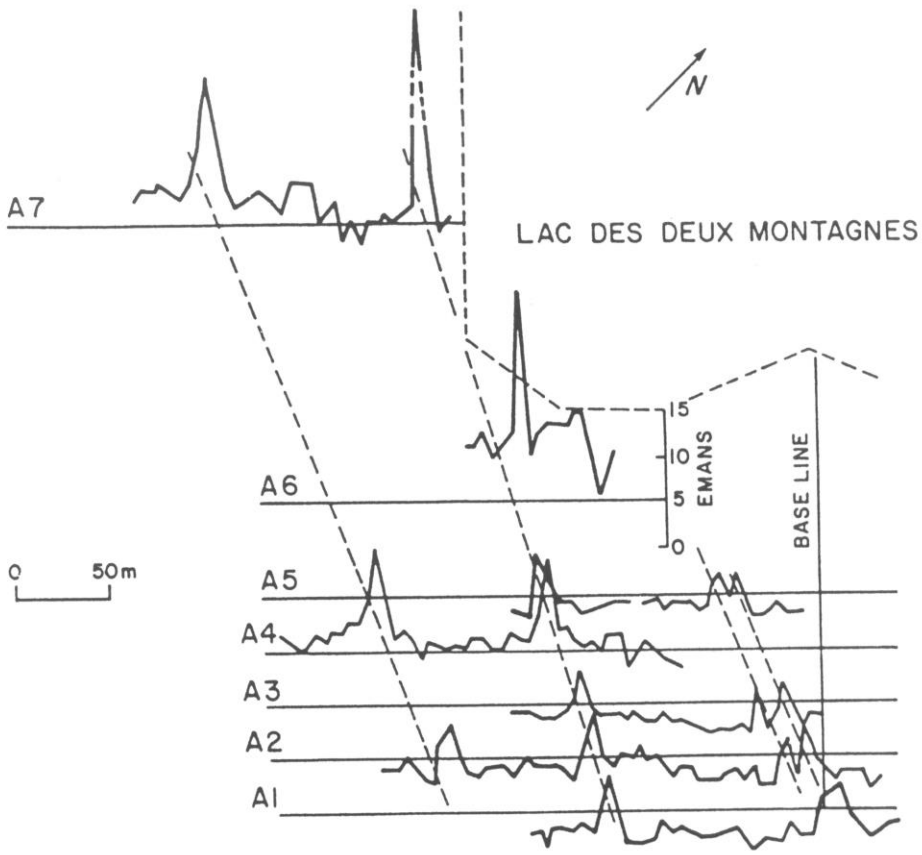
PARENT ISOTOPE	ACTIVITY CONCENTR. Bq/kg	INTER-MEDIATE PARENT ISOTOPE	Rn ISOTOPE	HALF-TIME of RADON ISOTOPE	ENERGY of ALPHA RADIATION MeV	DAUGHTER ISOTOPE of RADON	STABLE DAUGHTER of DECAY SERIES
^{238}U 99.2745%	1.23E+07	^{226}Ra	^{222}Rn	3.82 day	5.59	^{218}Po	^{206}Pb
^{232}Th	4.08E+06	^{224}Ra	^{220}Rn	55.6 sec	6.404	^{216}Po	^{208}Pb
^{235}U 0.72%	5.76E+05	^{223}Ra	^{219}Rn	4 sec	6.946	^{215}Po	^{207}Pb



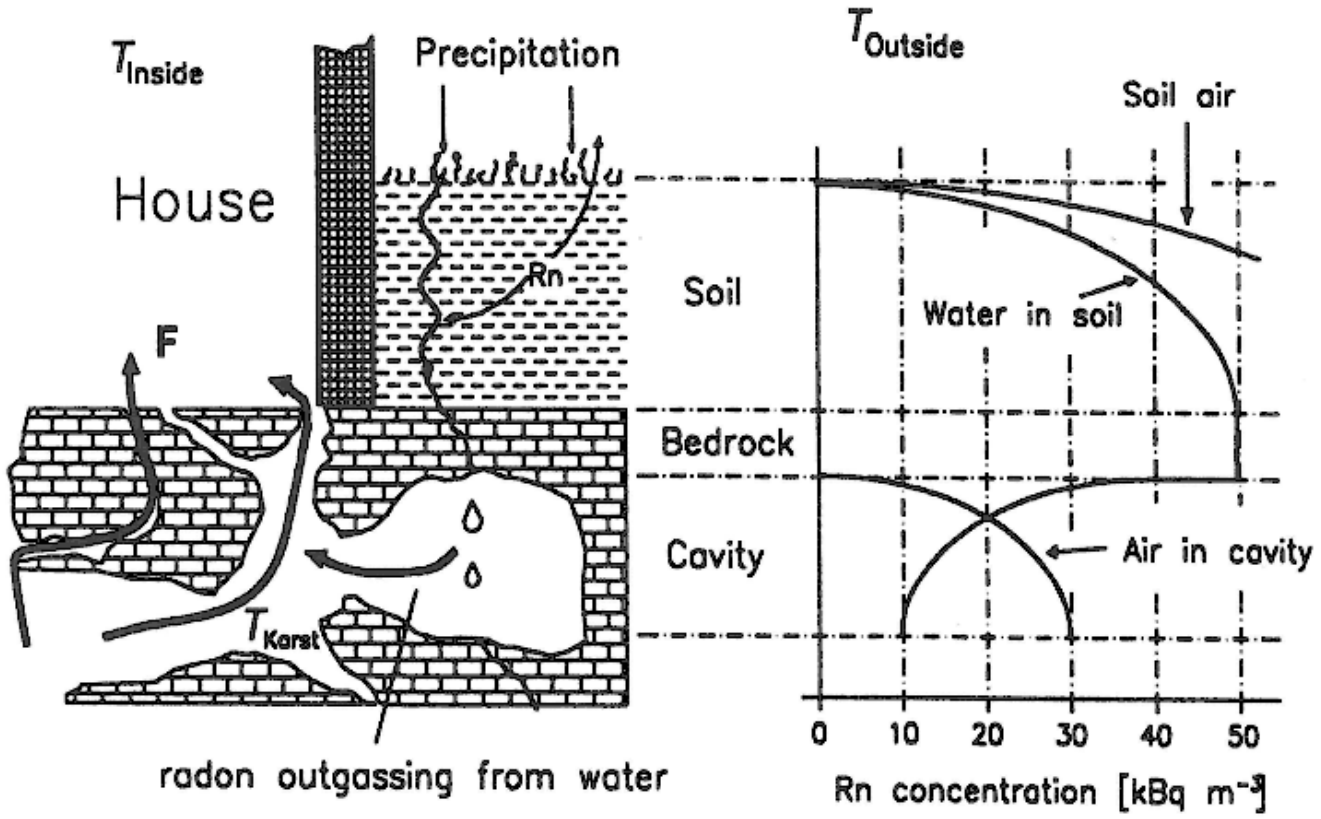
The presence of Rn refers to radium enrichment. Greater Rn signal can be experienced over radium than over uranium.

In reducing environment the precipitation of uranium by the reduction of U^{6+} to U^{4+} forming uranoorganic complexes can be observed. In the case of the same direction of fluid flow and oxidizing environment, the enrichment of uranium occurs in the opposite site of radium.

- Location of U and Ra zones in an oxidizing and in a reducing environment (after Gingrich, 1984)

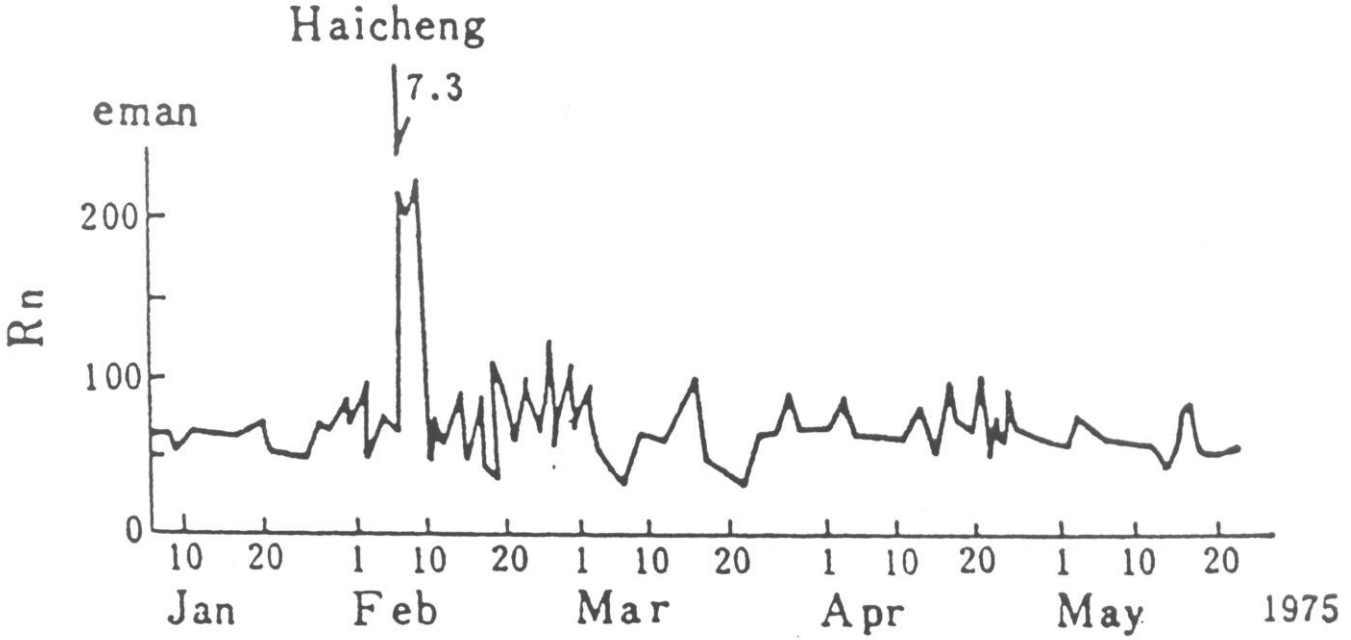


Radon profiles at Point-aux-Carrieres, Montreal Island, Canada. Broken lines indicate inferred positions of fracture zones. 1 eman $=10^{-10}$ Ci/l. (After Abdoh and Pilkington, 1989.)

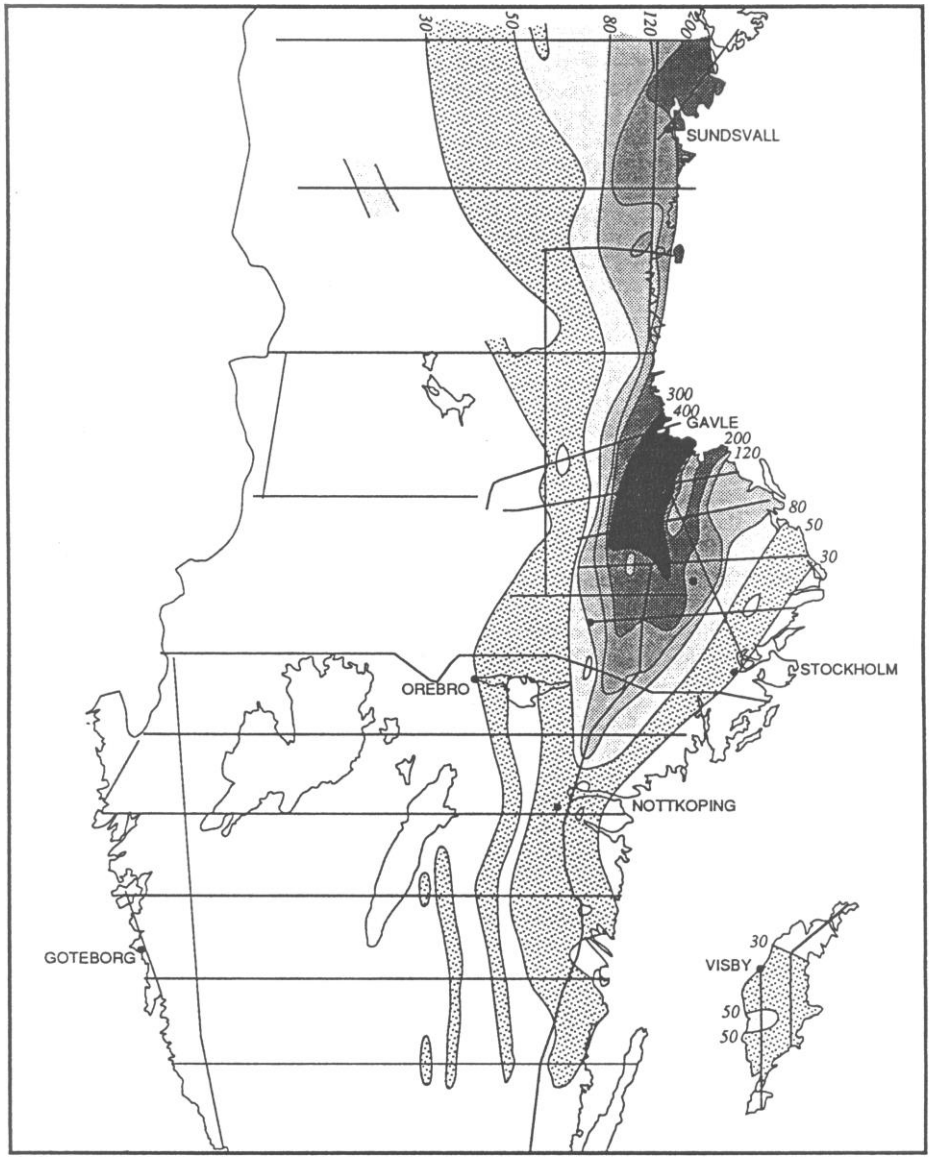


Schematic model describing the radon cycle in karstic areas. The model can explain the elevated Rn concentration in many homes in the Jura region of Switzerland. (After Surbeck and Medici, 1990.)

Percolating water in loose soil takes up Rn. When this Rn-charged water reaches the cave, Rn outgases from it (tending to equilibrium). Rn is in air free to migrate with the subsurface air and eventually is to enter a house.



Variation of radon content in water at the Tange hot spring in Liaoning province, China, before and after the Haicheng earthquake measured at an epicentral distance, $\Delta = 72$ km. 1 eman $= 10^{-10}$ Ci/l. (After Shi and Cai, 1986.)



Airborne γ-radiation map of northern part of Sweden for the interval May 1–6, 1986, after the Chernobyl fallout. The exposure rate values (μR/h) are indicated where the contours cross the coast line or edge of the map. (After Mellander, 1988.)

$^{131}I \longrightarrow {}^{131}Xe \quad T_{1/2} = 8d$

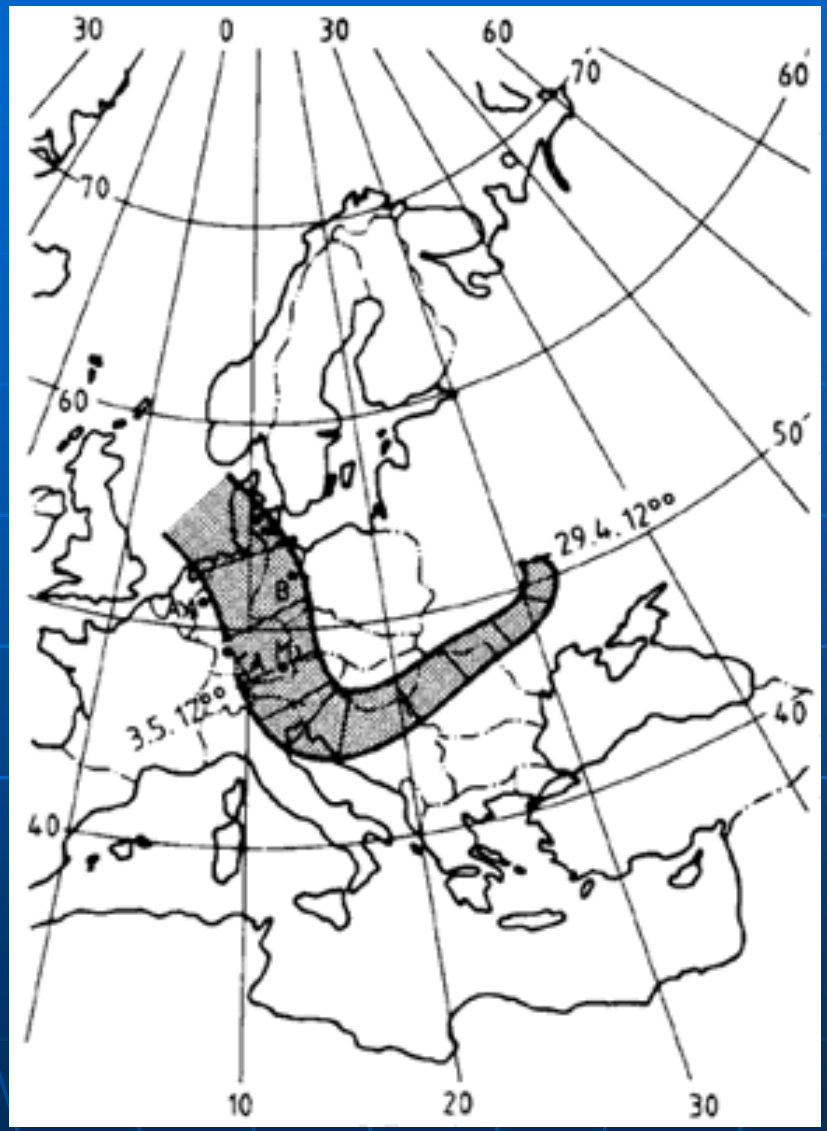
$^{134}Cs \longrightarrow {}^{134}Ba \quad T_{1/2} = 2.1y$

$^{137}Cs \longrightarrow {}^{137}Ba \quad T_{1/2} = 30y$

30 y

$^{90}Sr \longrightarrow {}^{90}Y \longrightarrow {}^{90}Zr$

28.5y 64hour


30
0
30
60
70
60
70
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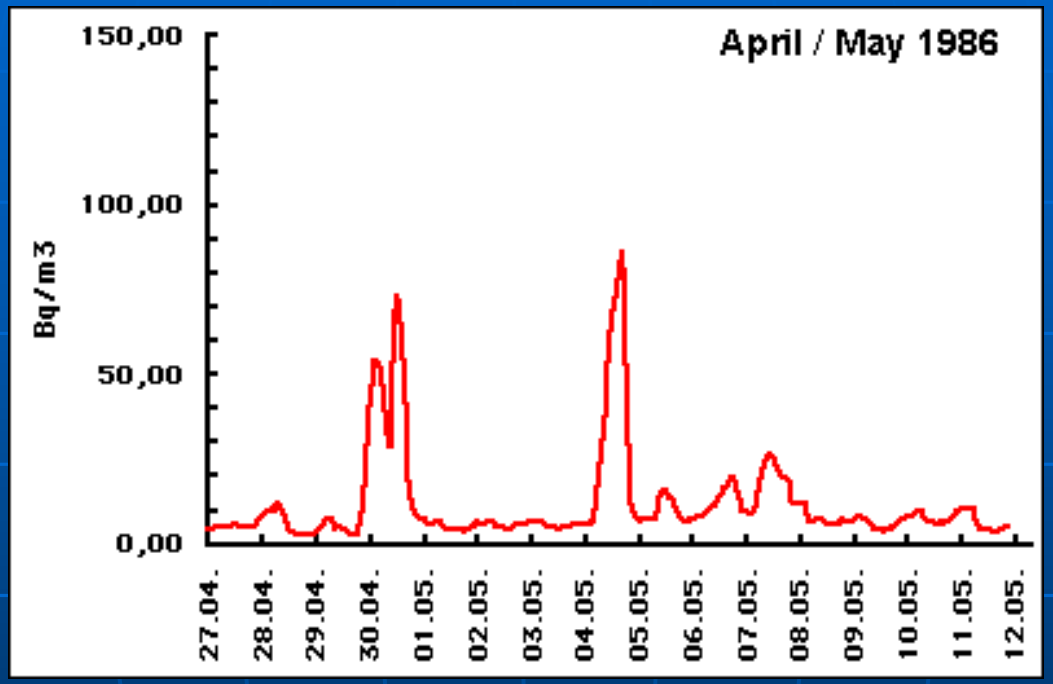
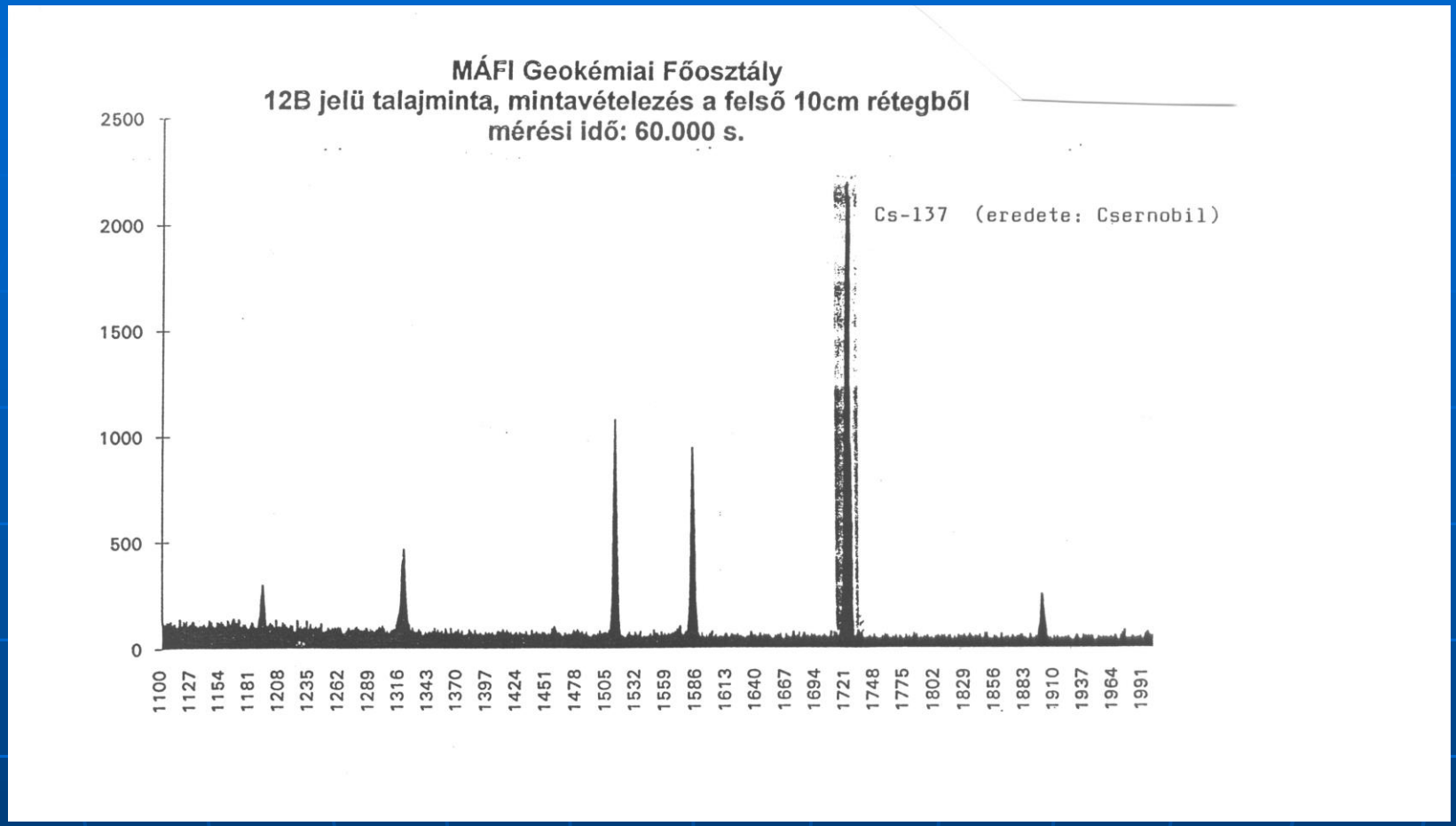
50
40
40
10
20
30
29.4. 12°°
3.5. 12°°
B

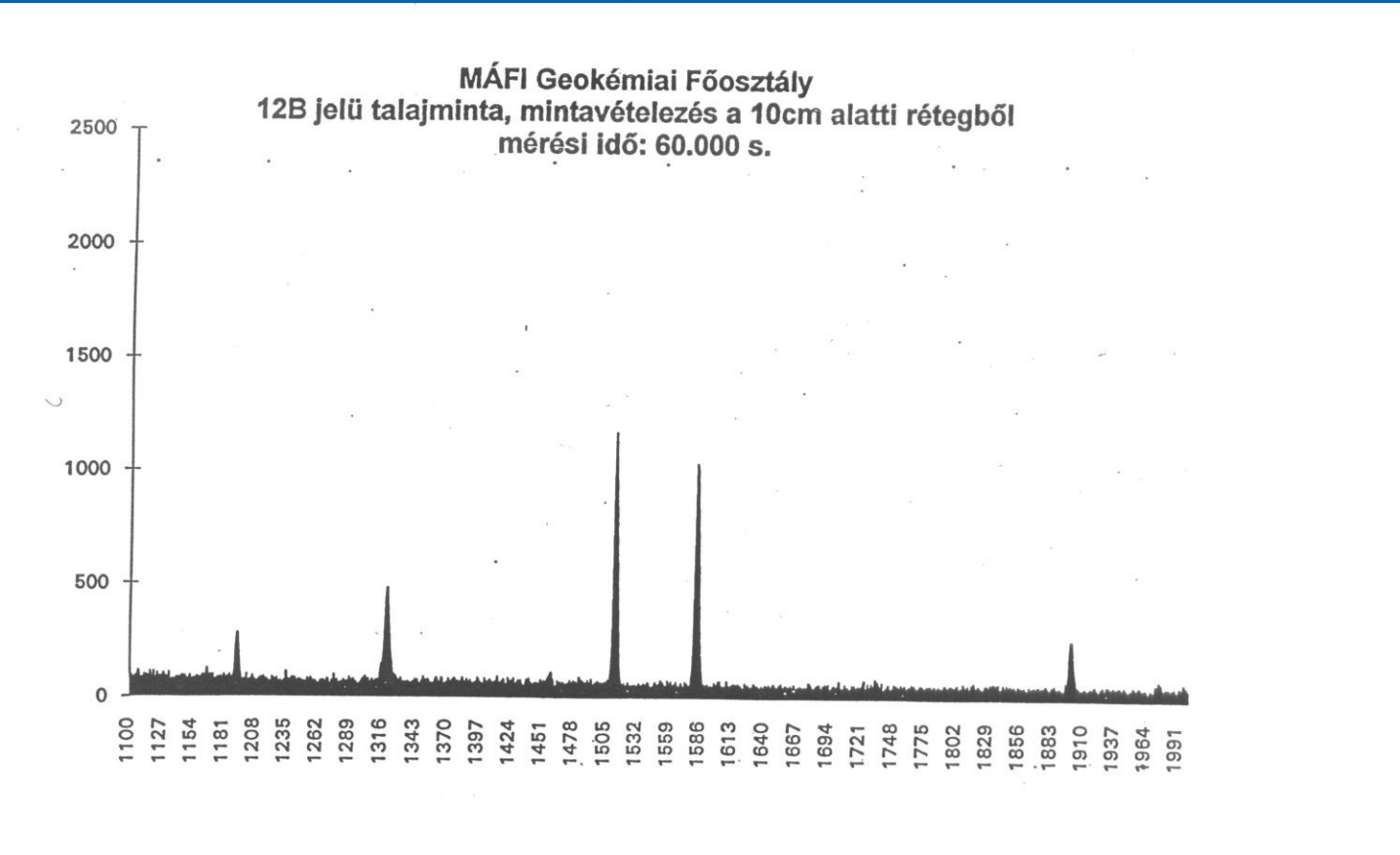


BERLIN : the sum of beta activity concentration



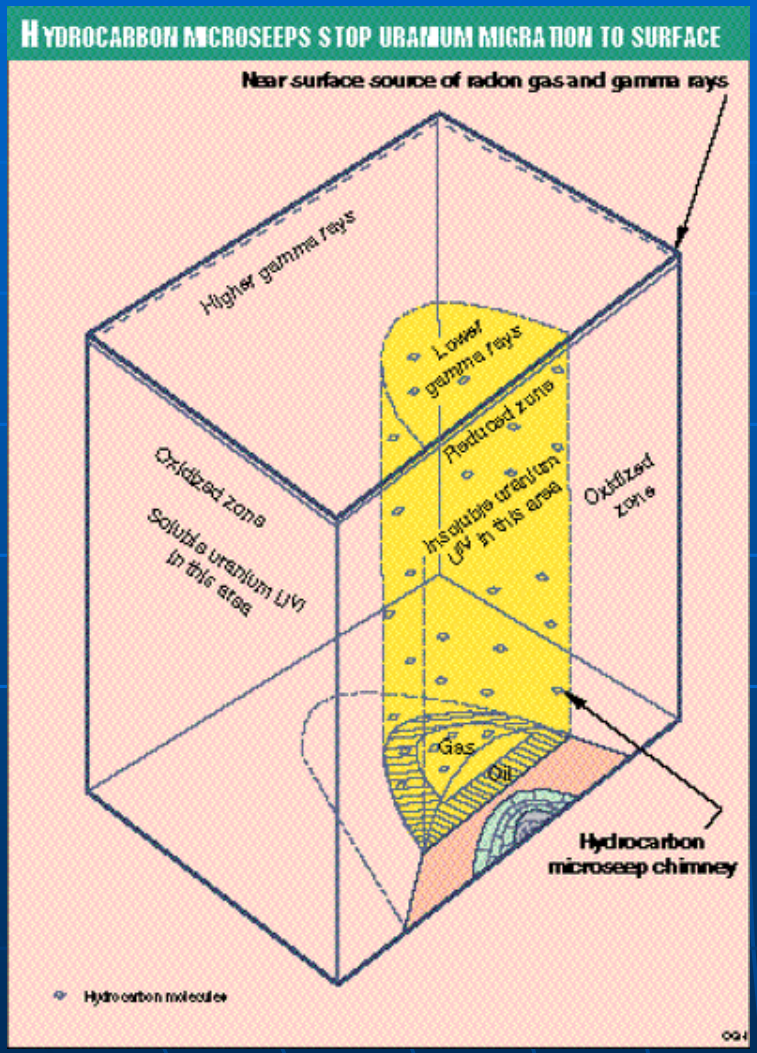
E_{GAMMA}= 662KeV, Ba 137 is in exited state. Soil sample is from the depth of 10cm.

Hungary 1998. The effect of Chernobyl can be presented by the spectrum of gamma ray, in which Cs-137 results in a characteristical peak. Other artificial effect may be observed due to chemical fertilizer.



Sample was taken from a depth greater than 10cm. There is no Cs-137 at all. The upper part of the soil absorbed totally the Cs-137.

RADIOACTIVITY over HYDROCARBON RESERVOIR



Morse & Zinke, *1995*

If hydrocarbons are present geochemical interactions constrain or stop uranium's movement till the surface, resulting in a decrease in natural gamma intensity observed over the hydrocarbon reservoirs in the surface.

The near-surface change of redox and pH conditions, in response to light hydrocarbon microseepage and its microbial oxidation, drives a localized redistribution of trace and radioelements. This localized vertical redistribution of trace and radioelements in the ground over the reservoir is the reason of the low gamma radiation response.

Pirson (1969) discovered that it was a promising tool in HC exploration.

The presence of „halo" with elevated gamma radiation was proved in the 70-s (85%).

QUESTIONS

- What does the basic equation of radioactivity state? What is the relationship between radioactive decay constant and half-life?
- Characterize the natural nuclear disintegrations! Which radiation is mainly applied in geophysical exploration?What is the reason of that?
- What problems can be solved by radiometry?
- What is the basic principle of K, U, Th content determination based on natural gamma radiation? Which has greater radioactivity: basalt or granite?
- What do you know about Rn? What conclusion can you draw from an elevated Rn level?
- What is the principle of radiometric dating? What sorts of radiometric dating methods do you know?
- Can be any correlation between the measured natural gamma intensity (and Rn level) on the surface and the occurence of hydrocarbon reservoir?