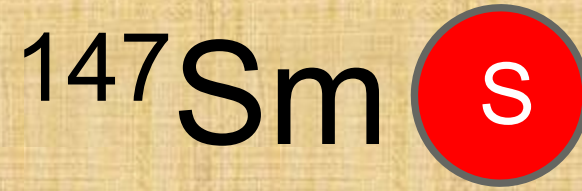


# RARE EARTHS & SKITTLES

SAMARIUM/NEODYMIUM DATING  
SIMULATION



# Periodic Table of the Elements

© www.elementsdatabase.com

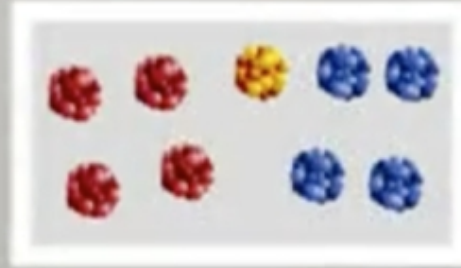
1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57-71	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89-103	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

- hydrogen
- alkali metals
- alkali earth metals
- transition metals
- post-transition metals
- nonmetals
- noble gases
- halogens
- metalloids

lanthanoids	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
actinoids	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

# ROCK WHEN FIRST FORMED

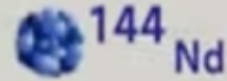
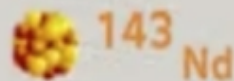
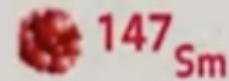
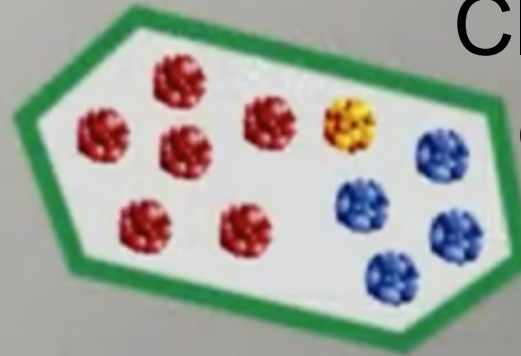
Plagioclase

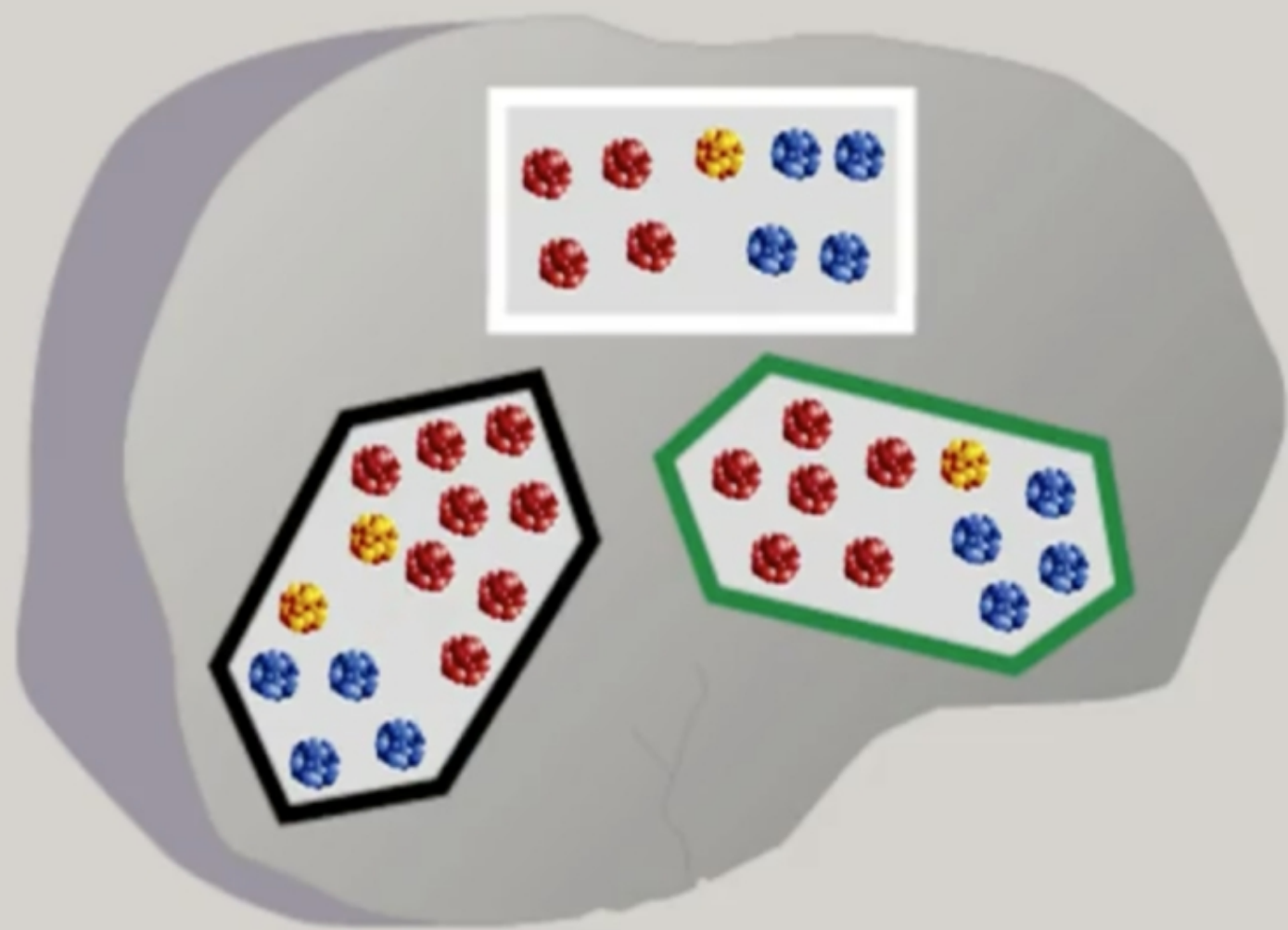



Orthopyroxene





Clinopyroxene (Augite)

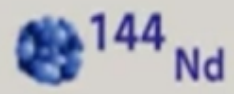
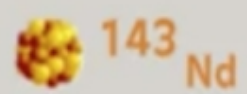
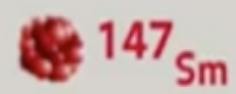
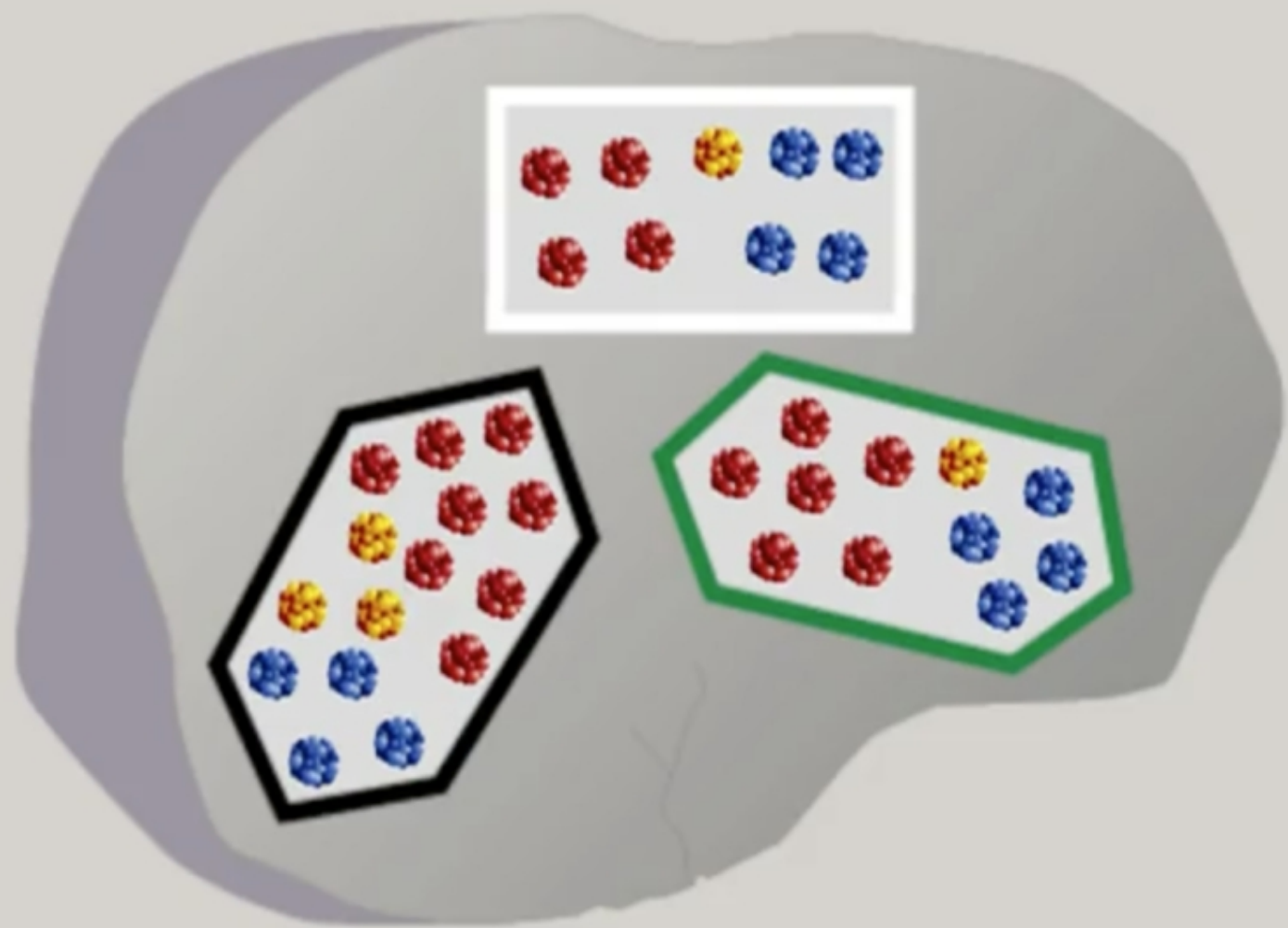


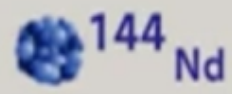
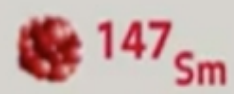
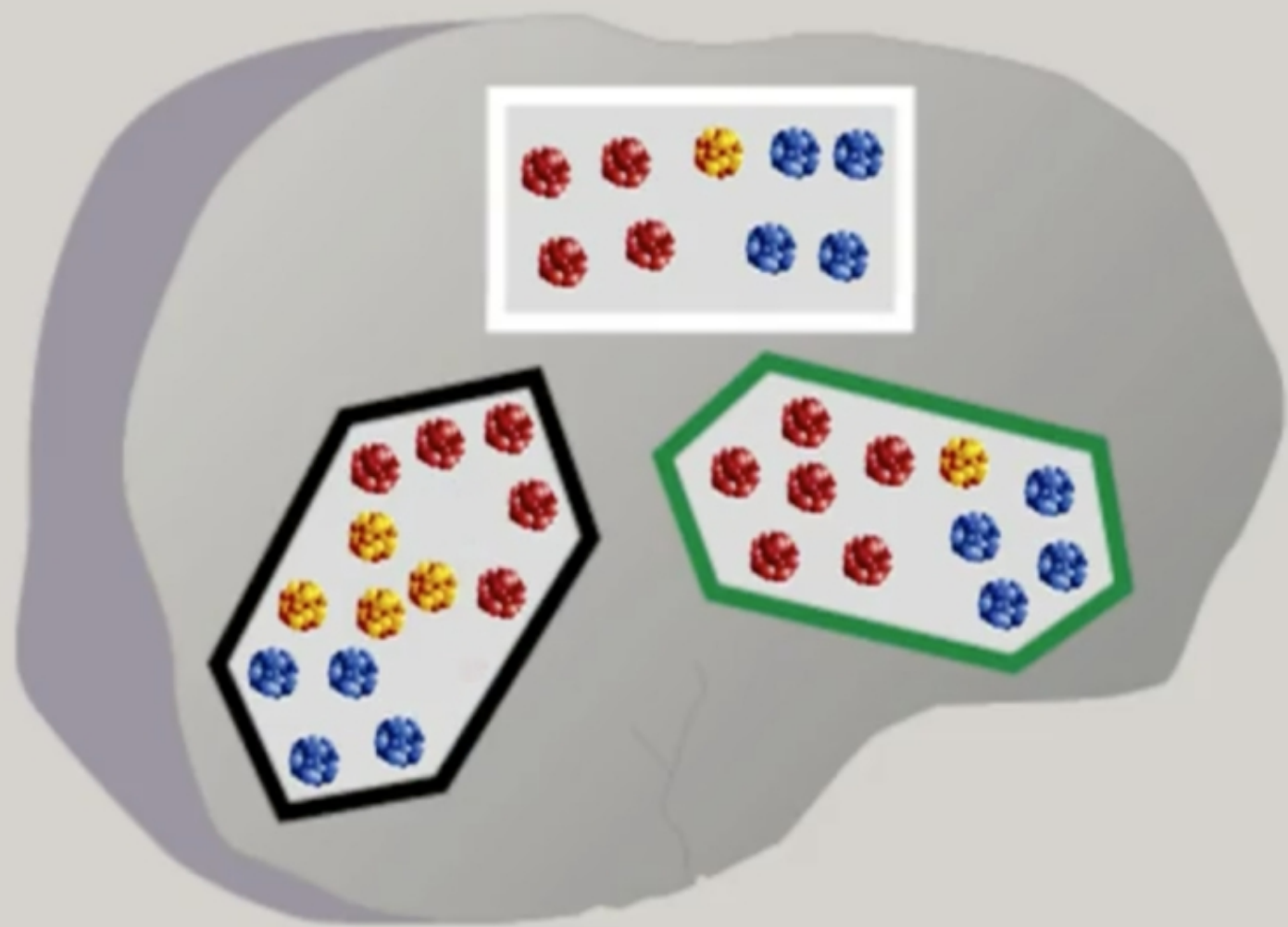


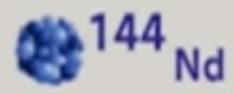
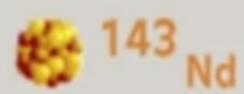
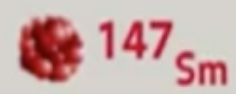
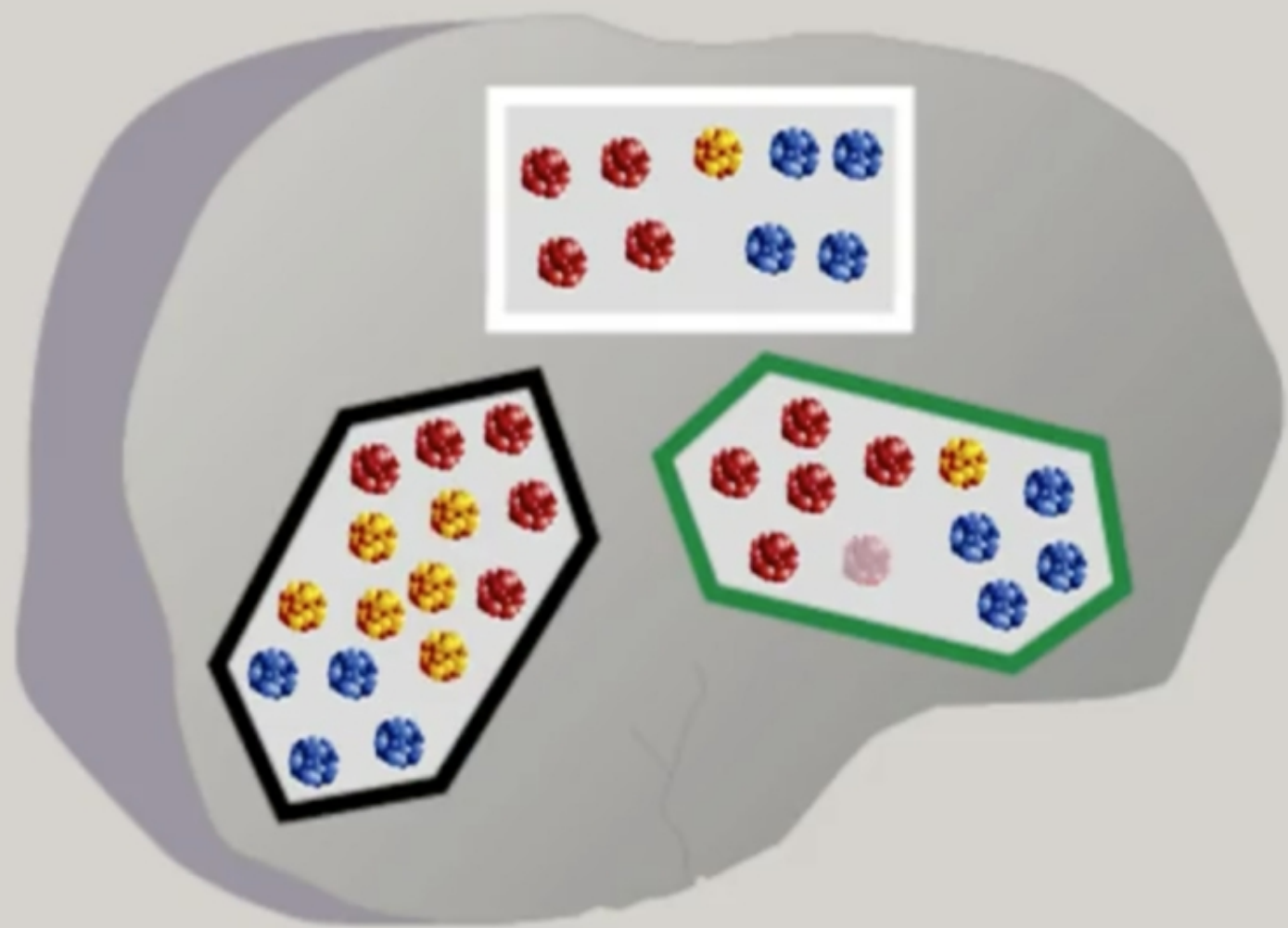
  $^{147}\text{Sm}$

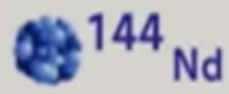
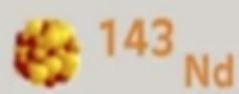
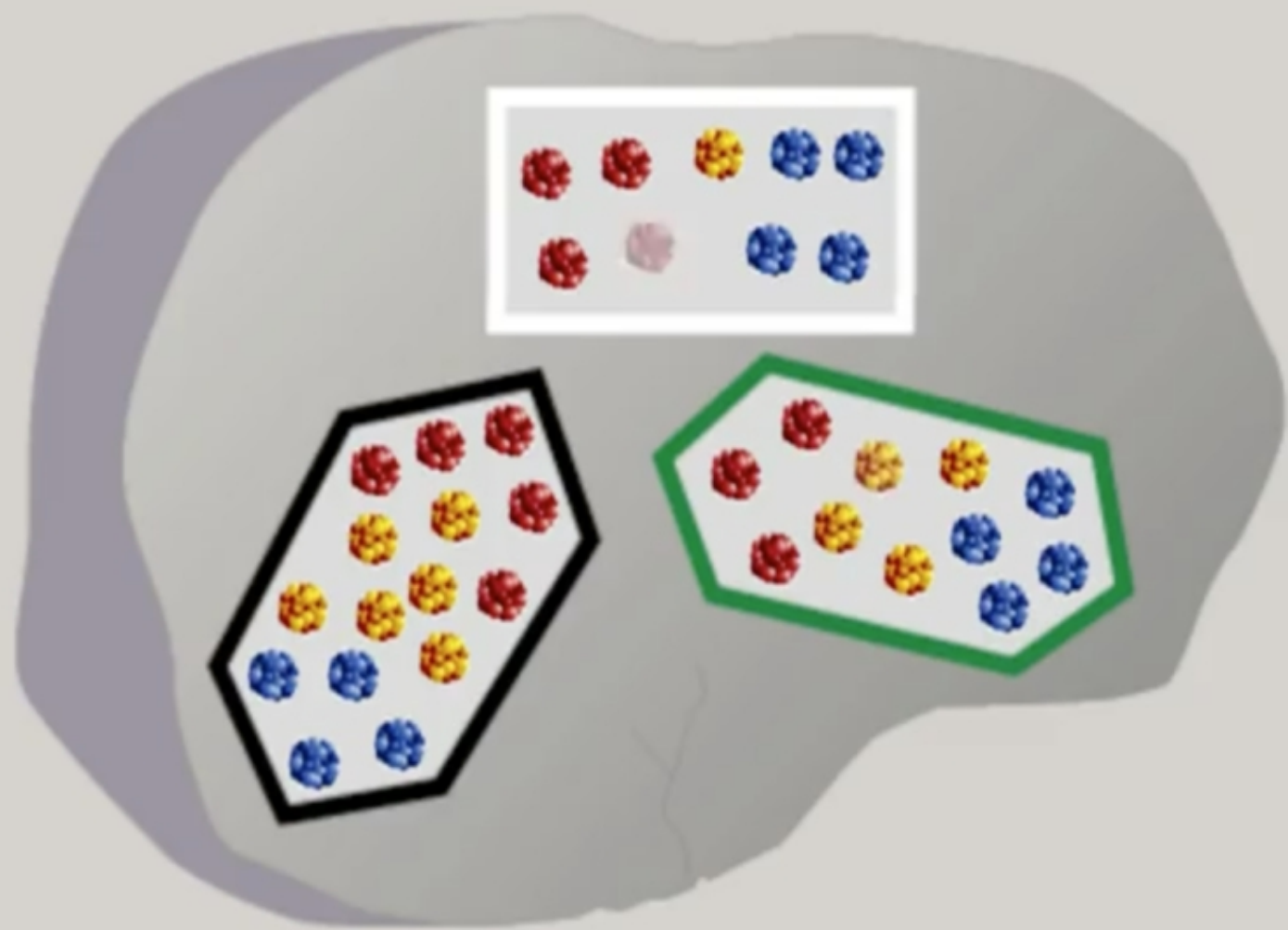
  $^{143}\text{Nd}$

  $^{144}\text{Nd}$

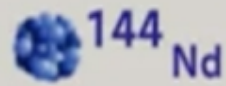
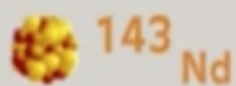
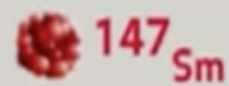
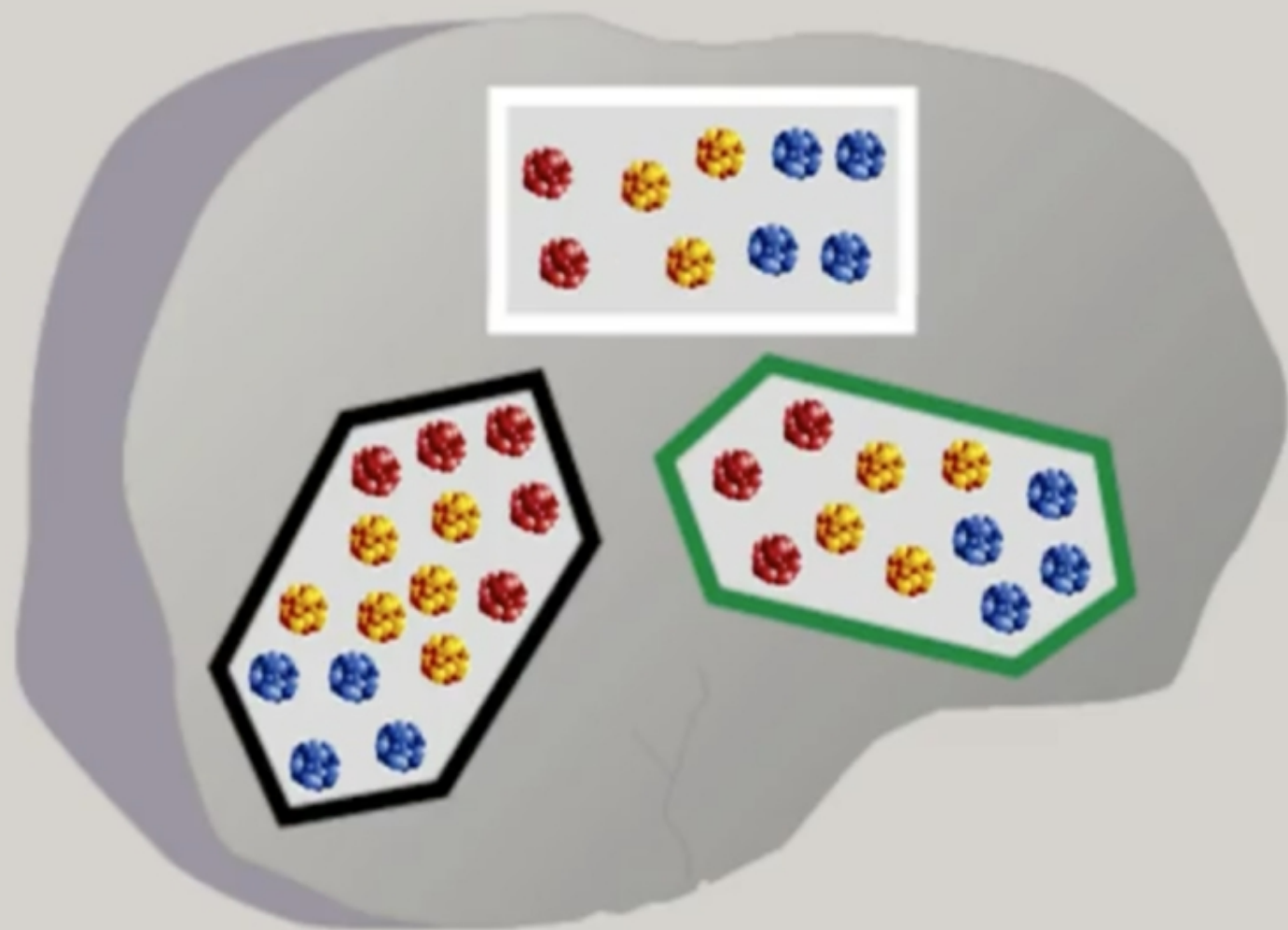








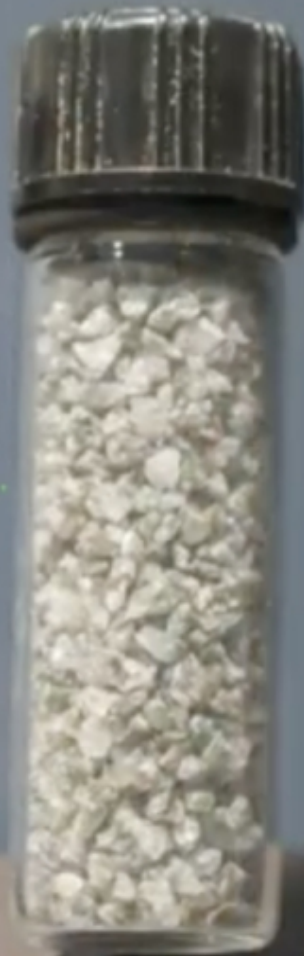
# ROCK AFTER ONE HALF-LIFE (106 BILLION YEARS LATER)



Plagioclase



Whole rock



Clinopyroxene



Orthopyroxene



$^{143}\text{Nd}$   

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 $^{144}\text{Nd}$

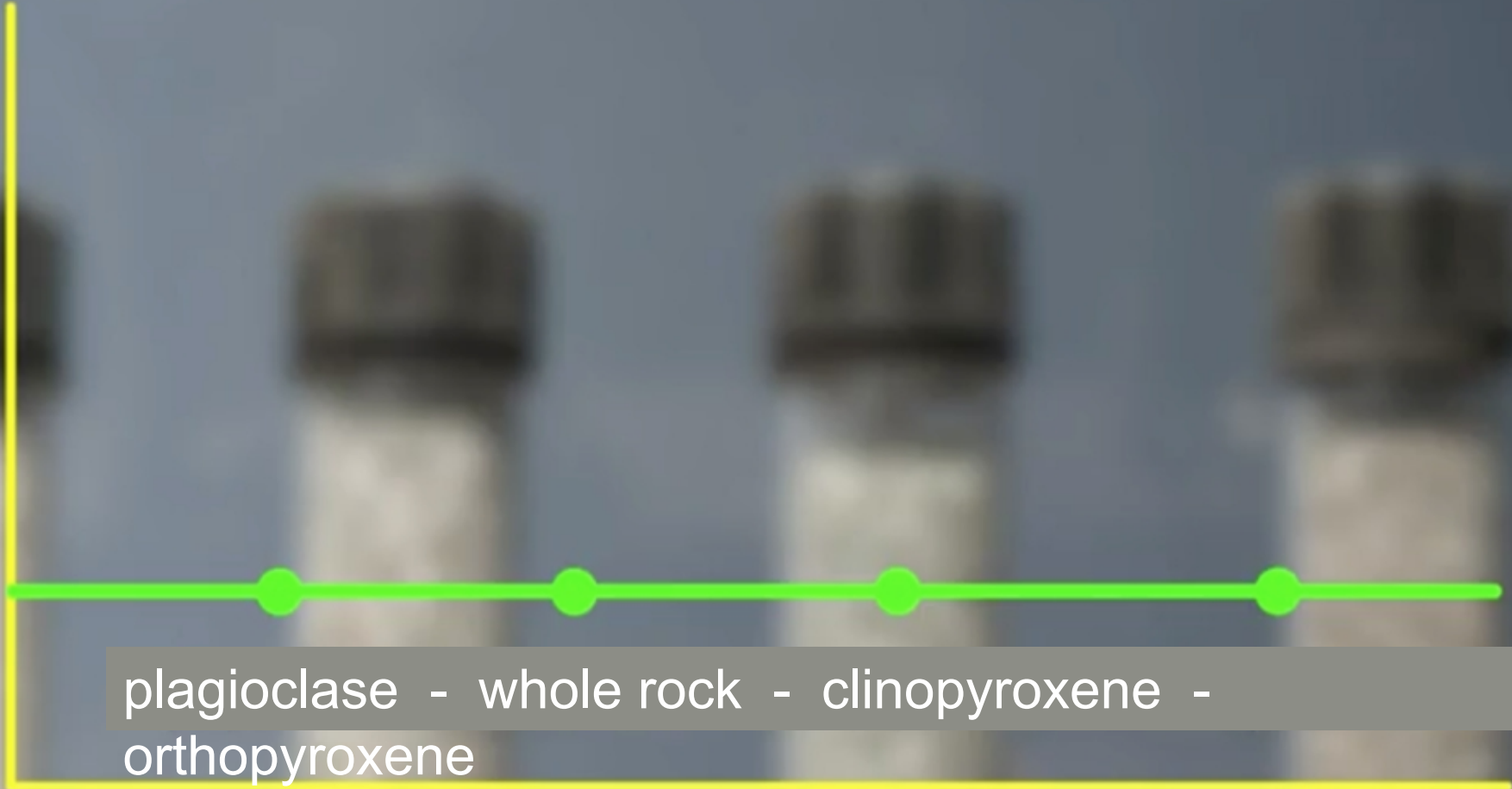
Nd (Neodymium)  
Sm (Samarium)

$^{147}\text{Sm}$   

---

 $^{144}\text{Nd}$

$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$



plagioclase - whole rock - clinopyroxene -

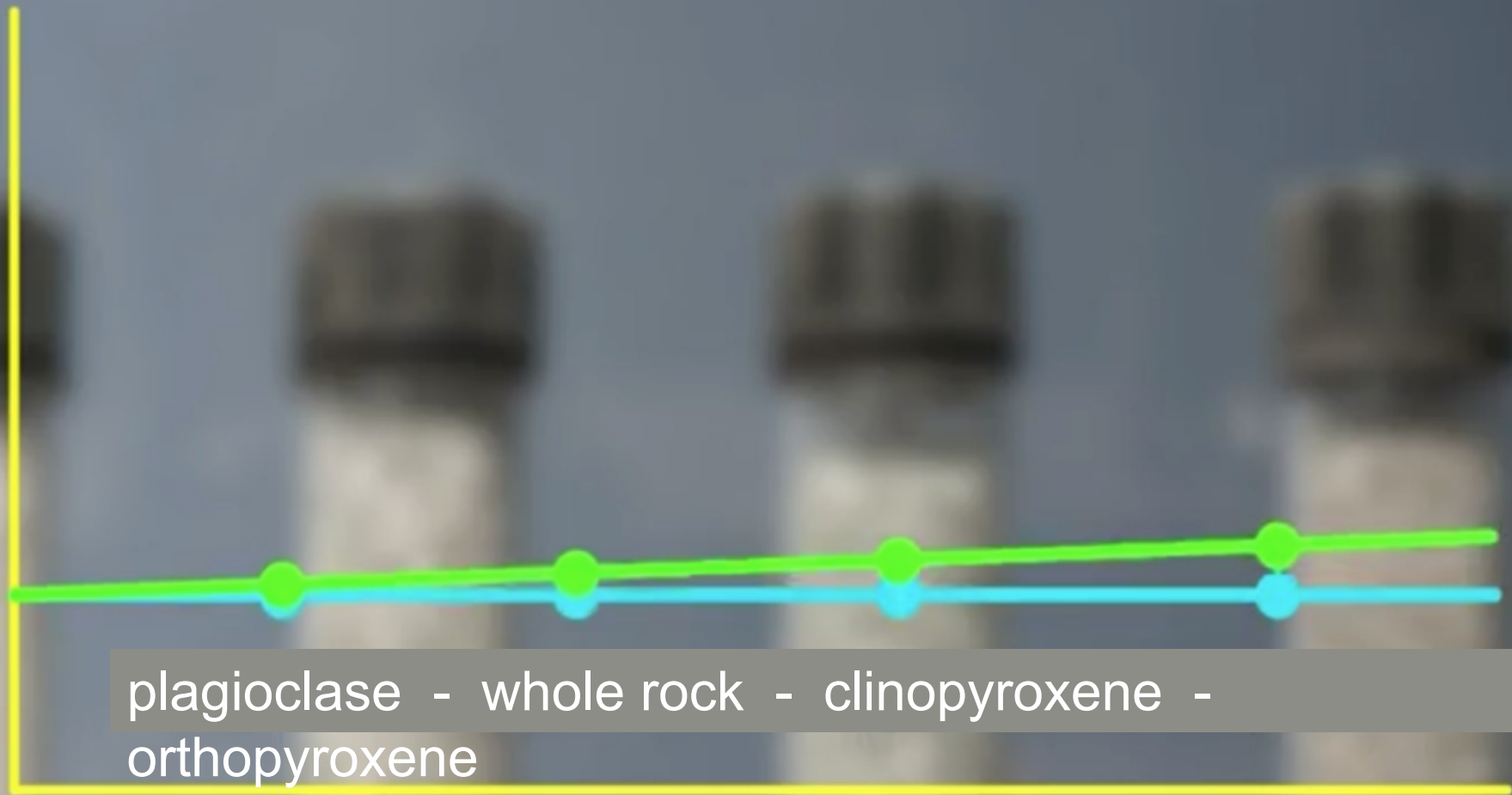
orthopyroxene

Nd (Neodymium)

Sm (Samarium)

$\frac{^{147}\text{Sm}}{^{144}\text{Nd}}$

$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$

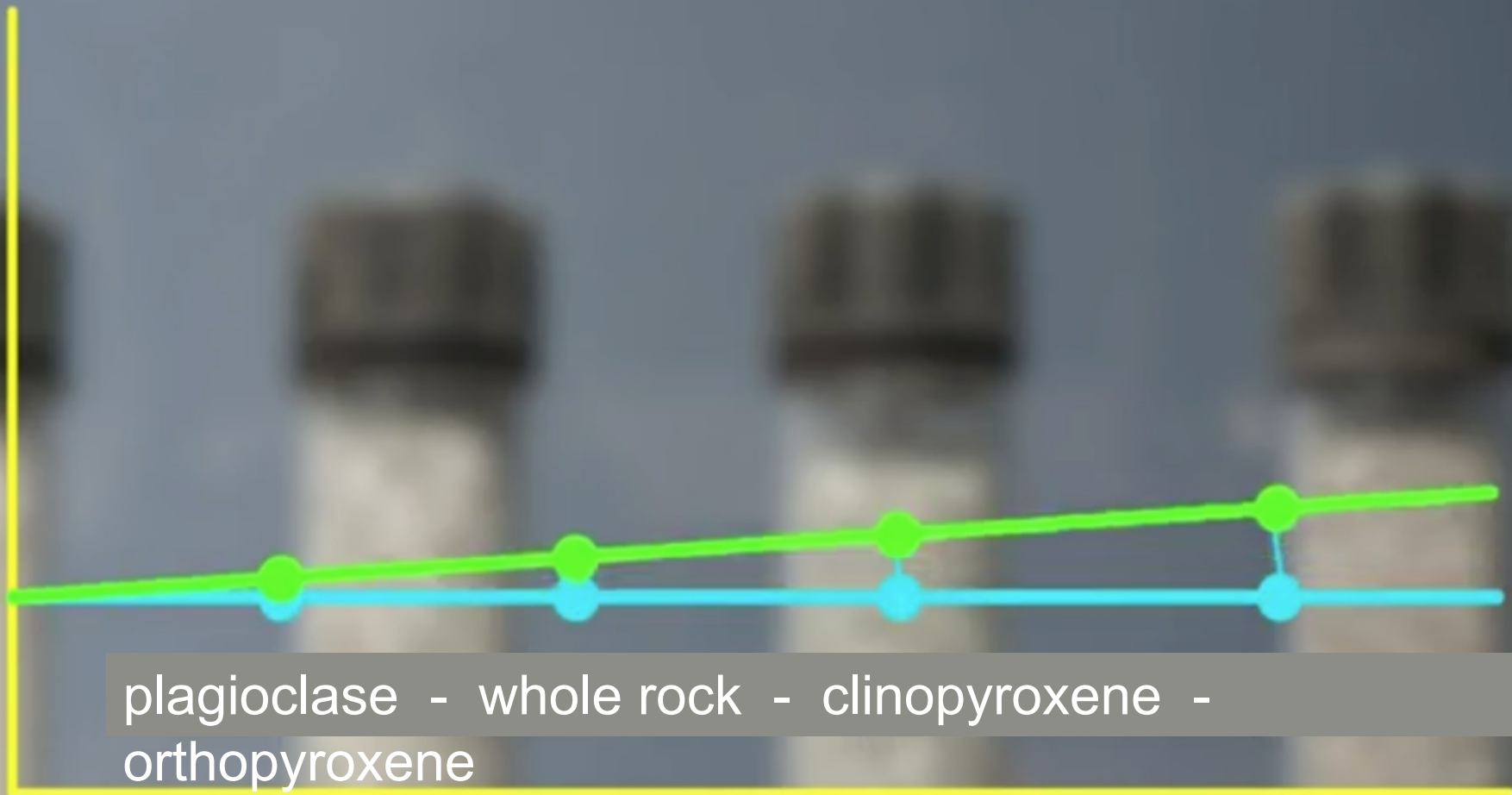


Nd (Neodymium)

Sm (Samarium)

$\frac{^{147}\text{Sm}}{^{144}\text{Nd}}$

$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$

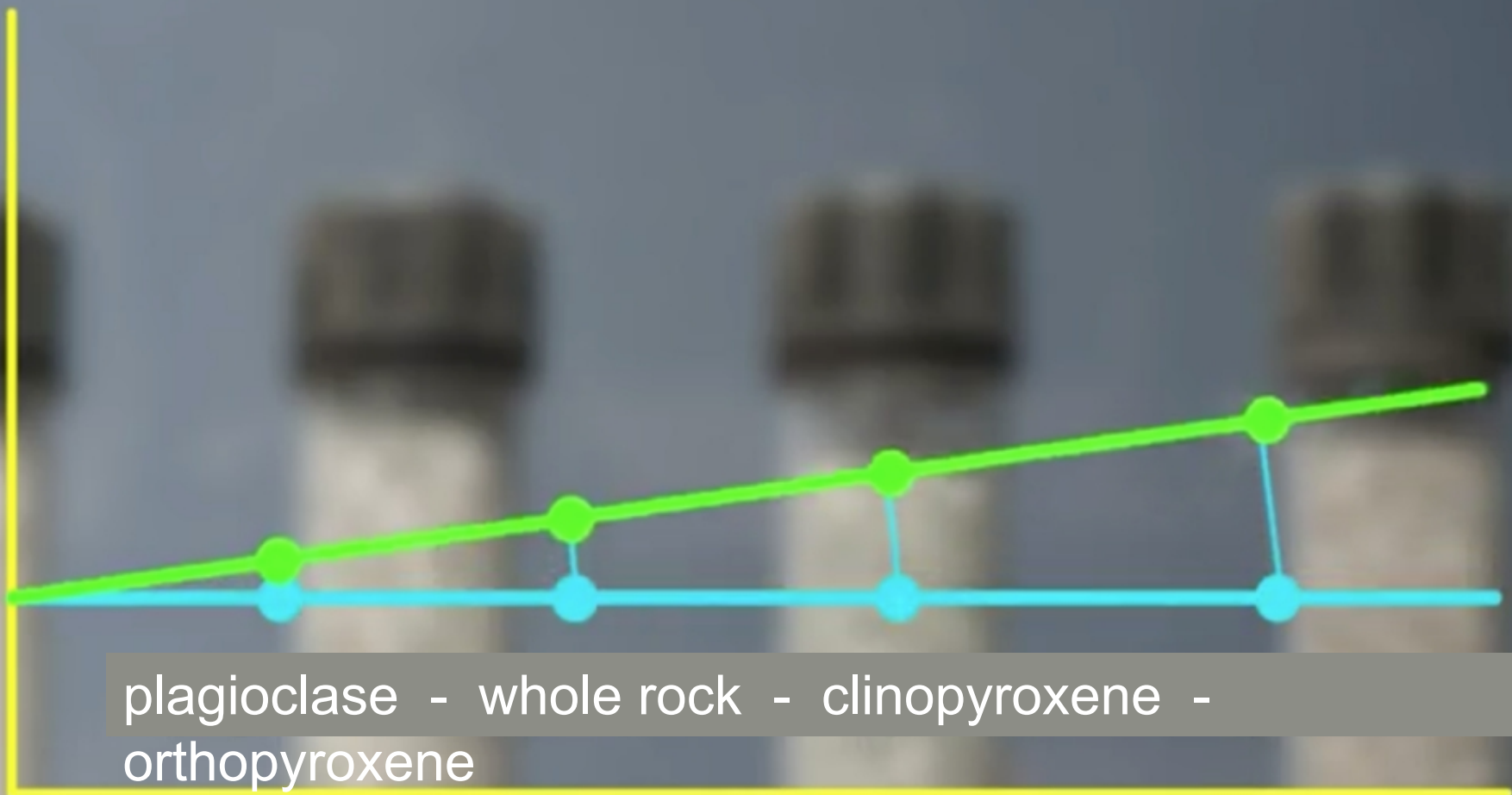


plagioclase - whole rock - clinopyroxene - orthopyroxene

Nd (Neodymium)  
Sm (Samarium)

$\frac{^{147}\text{Sm}}{^{144}\text{Nd}}$

$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$



plagioclase - whole rock - clinopyroxene -

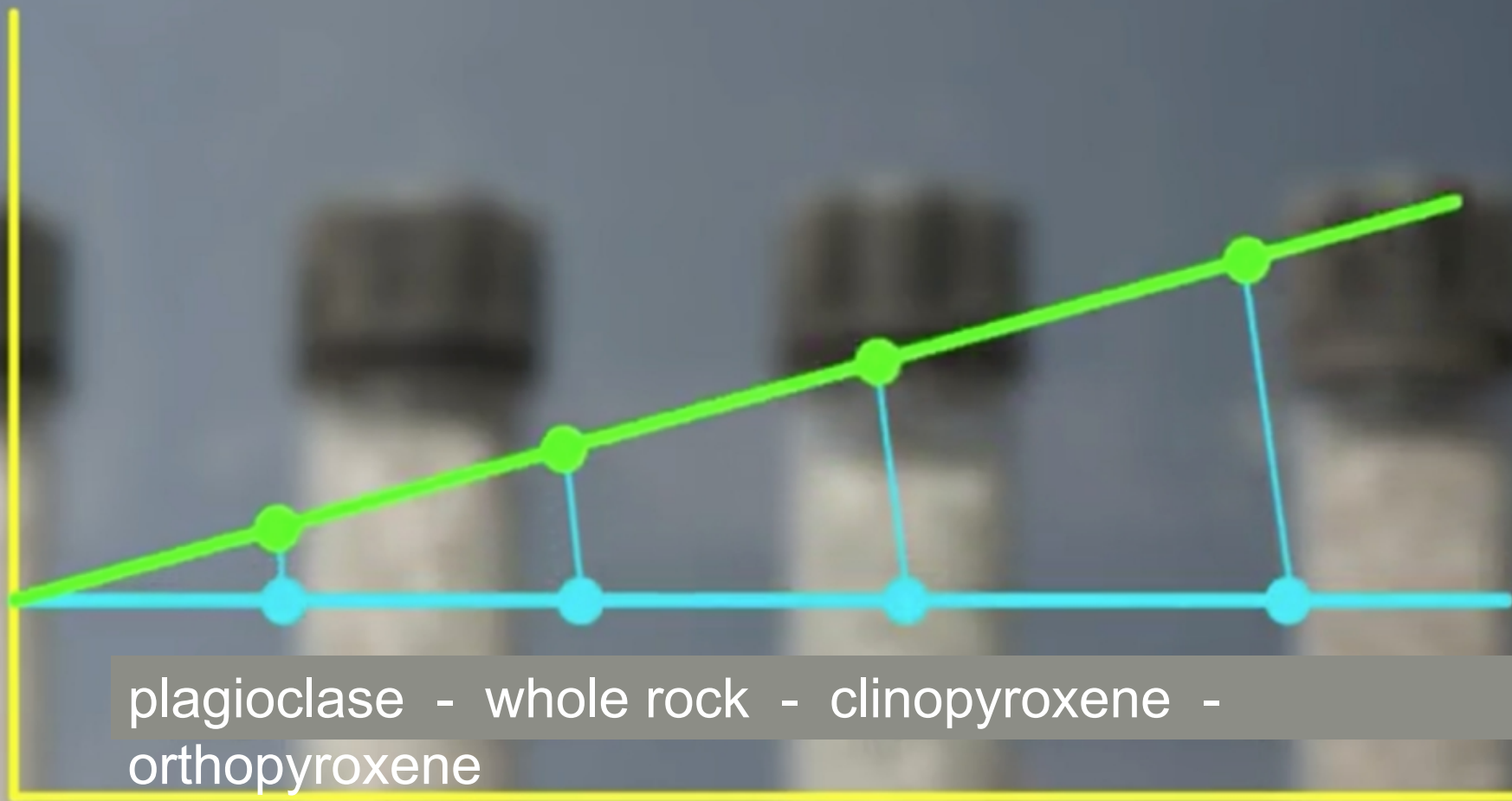
orthopyroxene

Nd (Neodymium)

Sm (Samarium)

$\frac{^{147}\text{Sm}}{^{144}\text{Nd}}$

$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$



plagioclase - whole rock - clinopyroxene -

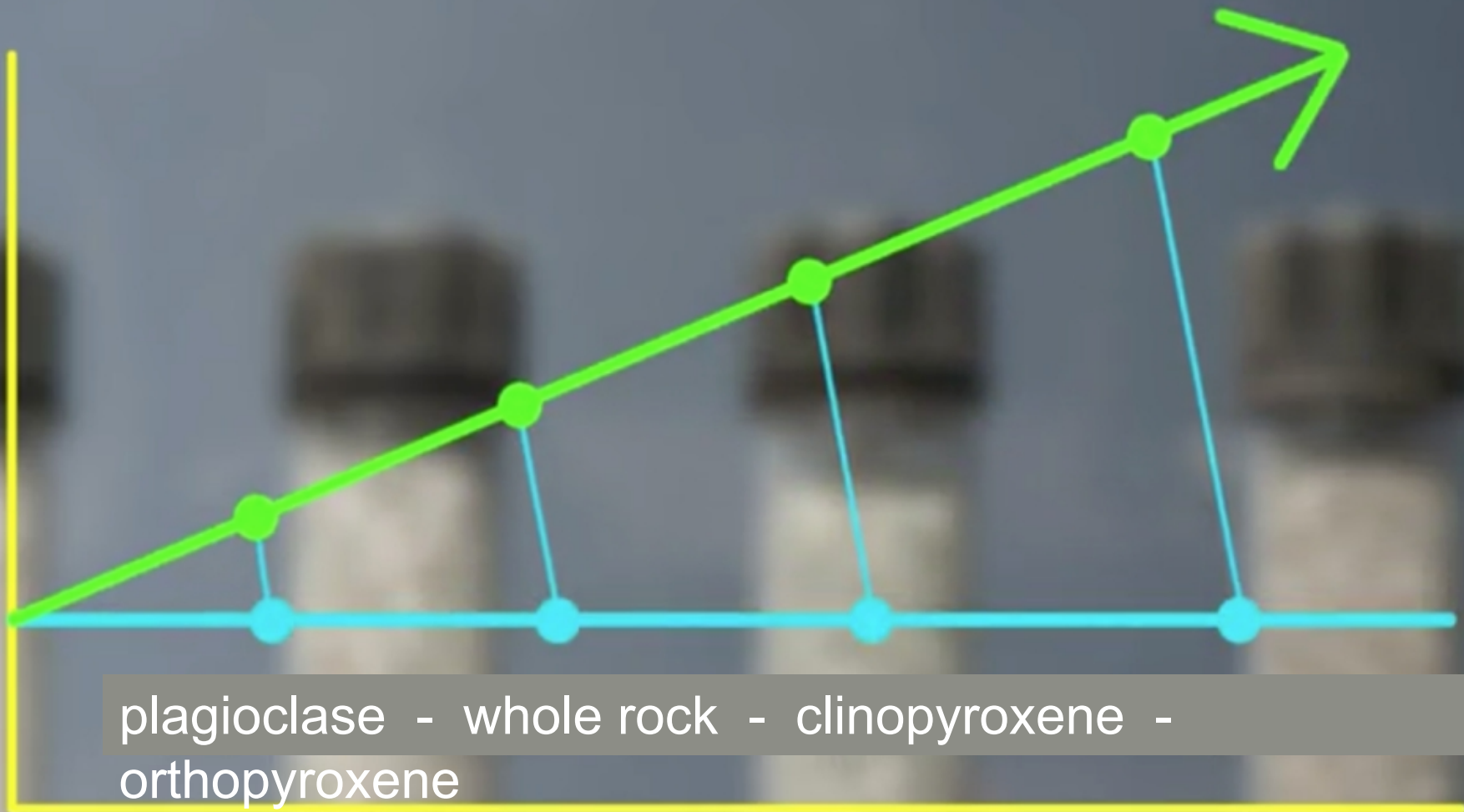
orthopyroxene

Nd (Neodymium)

Sm (Samarium)

$\frac{^{147}\text{Sm}}{^{144}\text{Nd}}$

$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$

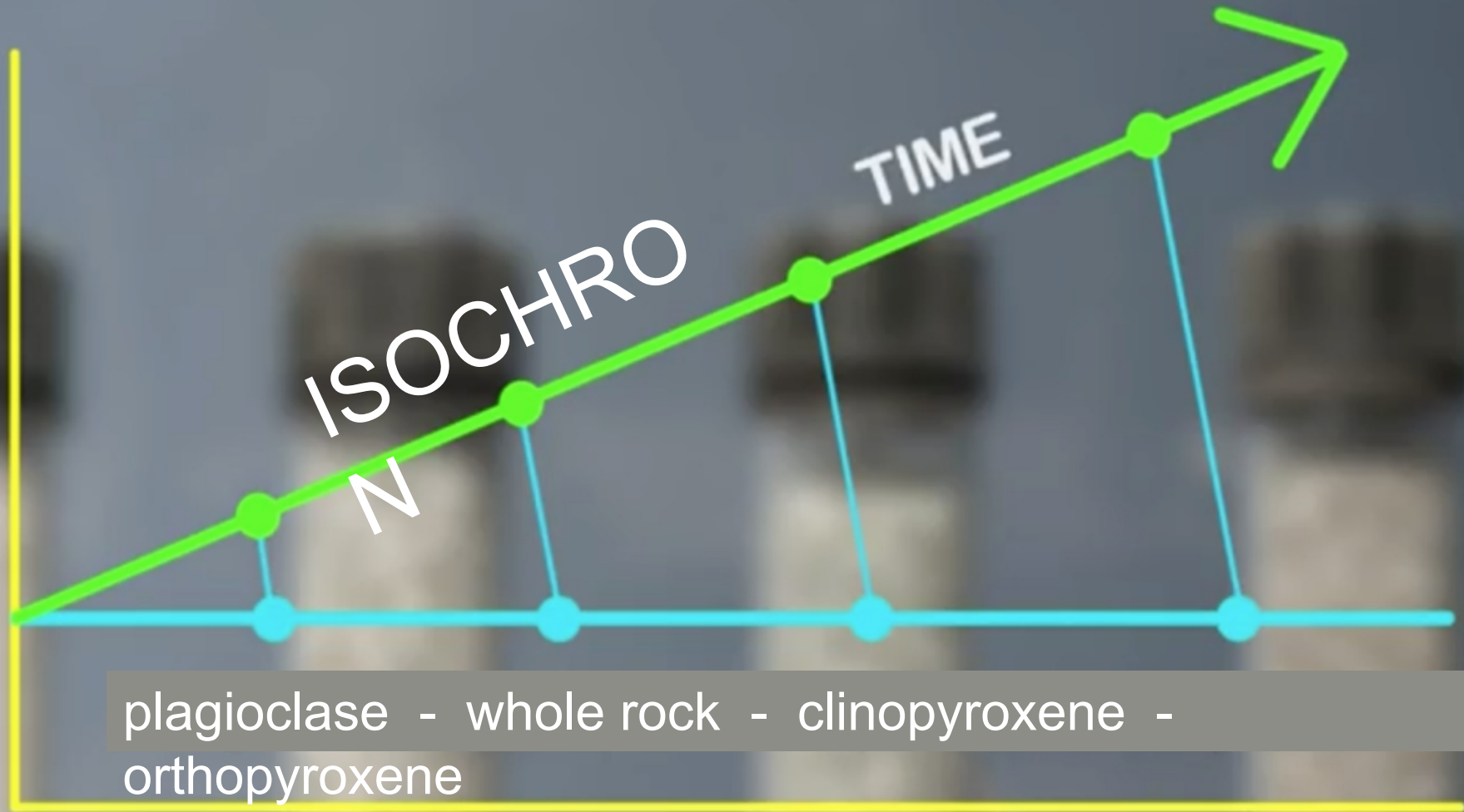


plagioclase - whole rock - clinopyroxene - orthopyroxene

Nd (Neodymium)  
Sm (Samarium)

$\frac{^{147}\text{Sm}}{^{144}\text{Nd}}$

$\frac{^{143}\text{Nd}}{^{144}\text{Nd}}$



plagioclase - whole rock - clinopyroxene - orthopyroxene

Nd (Neodymium)

Sm (Samarium)

$\frac{^{147}\text{Sm}}{^{144}\text{Nd}}$

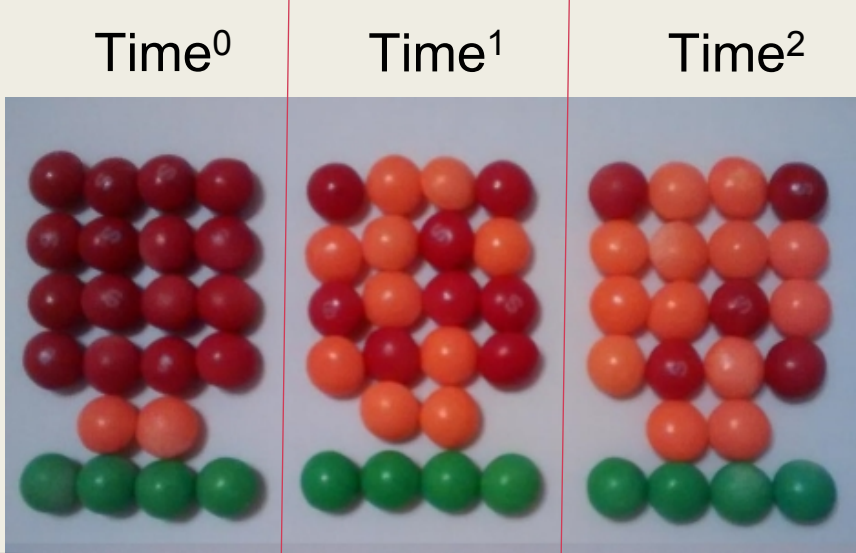
# Advantages

- The ratio  $^{143}\text{Nd}$ :  $^{144}\text{Nd}$  that is measured is highly resistant to secondary processes of alteration and metamorphism.
- Long half life  $1.06 \times 10^{11}$  yrs (106 billion yrs)
- It can be used on terrestrial and extraterrestrial materials
- Common rare earths that are readily measured

# Sm:Nd dating simulation using skittles (or other sweets/coins)

- Make up 3 'minerals' in separate pots with different numbers and colours of sweets to represent  $^{147}\text{Sm}$  (red) but initially the same number of daughter  $^{143}\text{Nd}$  (orange) and stable  $^{144}\text{Nd}$  (green) in each.
- The ratio of  $^{147}\text{Sm}$  to  $^{144}\text{Nd}$  and  $^{143}\text{Nd}$  to  $^{144}\text{Nd}$  are recorded =Time<sup>0</sup>
- Shake the pots individually, tip out sweets and separate into isotopes. Those  $^{147}\text{Sm}$  (red) that show the letter S uppermost have not yet 'decayed' to daughter  $^{143}\text{Nd}$  and remain. Those  $^{147}\text{Sm}$  (red) that do not show the letter S have 'decayed', are removed and replaced by daughter  $^{143}\text{Nd}$  (orange) sweets.
- The new ratios of  $^{147}\text{Sm}$  to  $^{144}\text{Nd}$  AND  $^{143}\text{Nd}$  to  $^{144}\text{Nd}$  are recorded =Time<sup>1</sup>
- Repeat shaking until all the  $^{147}\text{Sm}$  sweets have 'decayed' = Time<sup>2</sup> etc.
- (Whole rock dating can be roughly simulated by summing the isotopes in all the 3 minerals).
- The ratios for 3 minerals (and whole rock) can then be plotted on a graph. Any line drawn from the initial  $^{143}\text{Nd}:^{144}\text{Nd}$  crystallization ratio (on the y axis) represents an isochron. The steeper the gradient the older the sample.

Mineral 1



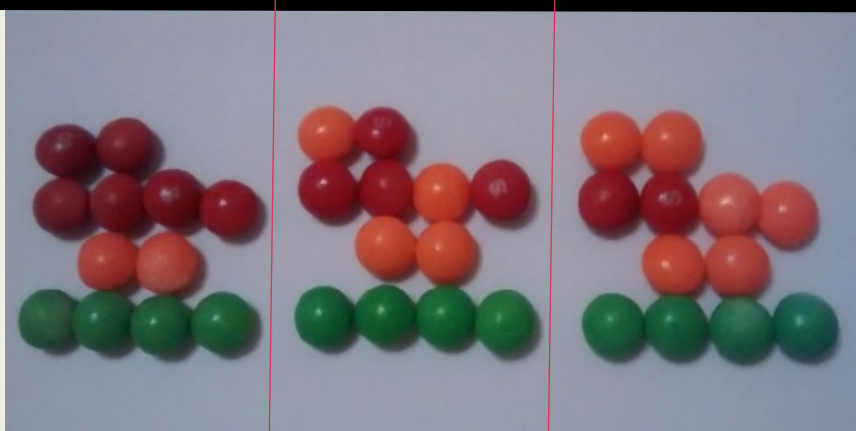
	Time <sup>0</sup>	Time <sup>1</sup>	Time <sup>2</sup>
<sup>147</sup> Sm	16	8	4
<sup>144</sup> Nd	4	4	4
Sm/Nd	4	2	1
<sup>143</sup> Nd	2	10	14
<sup>144</sup> Nd	4	4	4
Nd/Nd	0.5	2.5	3.5

Mineral 2



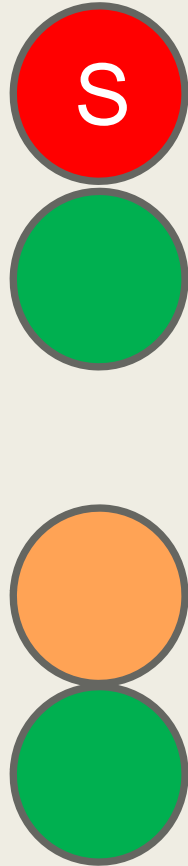
	Time <sup>0</sup>	Time <sup>1</sup>	Time <sup>2</sup>
Sm/Nd	2.5	1.25	0.75
Nd/Nd	0.5	1.75	2.25

Mineral 3



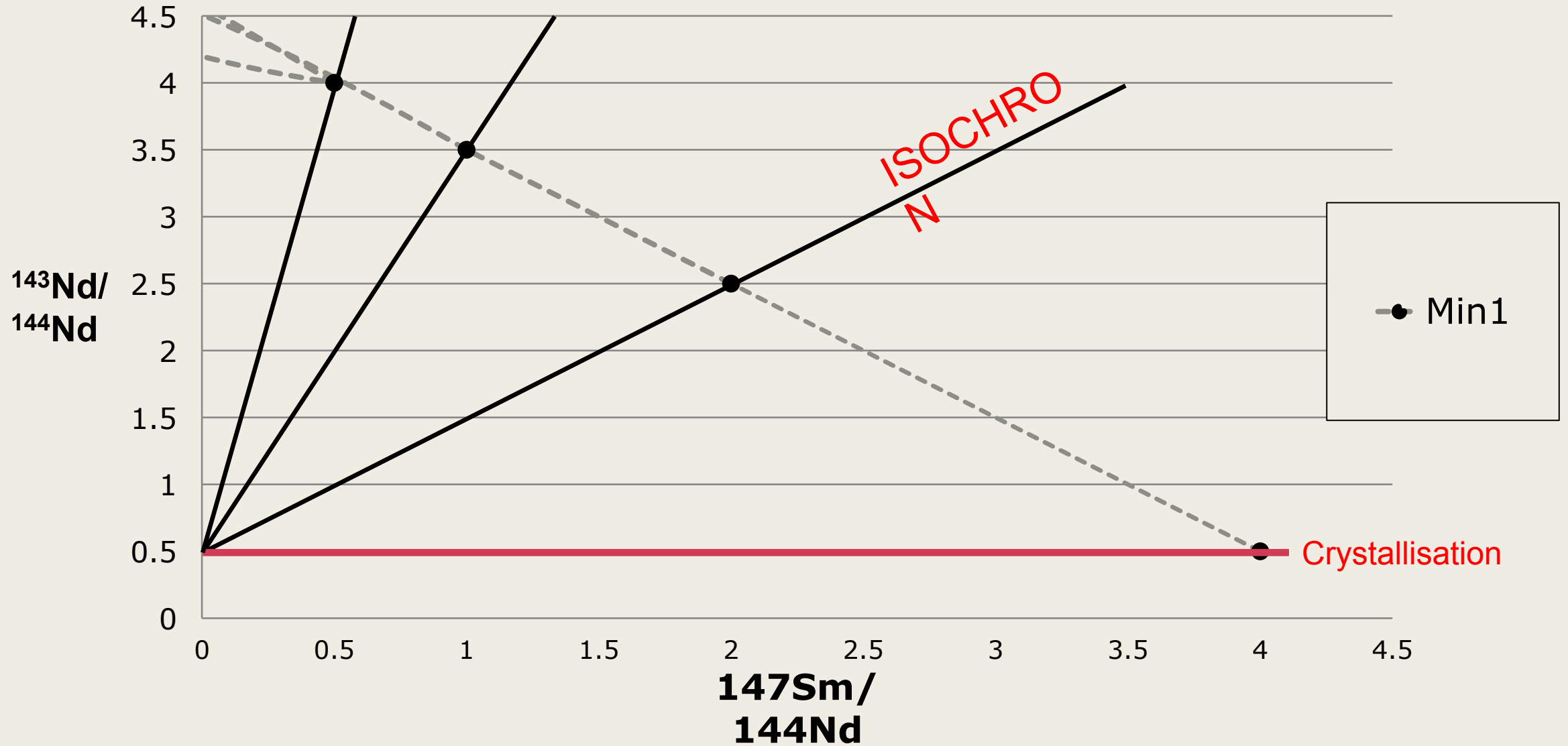
	Time <sup>0</sup>	Time <sup>1</sup>	Time <sup>2</sup>
Sm/Nd	6	4	2
Nd/Nd	0.5	1.0	1.5

# “WHOLE ROCK” dating



	Time <sup>0</sup>	Time <sup>1</sup>	Time <sup>2</sup>
<sup>147</sup> Sm	32	17	8
<sup>144</sup> Nd	12	12	12
<sup>147</sup> Sm/ <sup>144</sup> Nd	2.67	1.42	0.75
<sup>143</sup> Nd	6	21	29
<sup>144</sup> Nd	12	12	12
<sup>143</sup> Nd/ <sup>144</sup> Nd	0.5	1.75	2.42

# Sm/Nd dating simulation

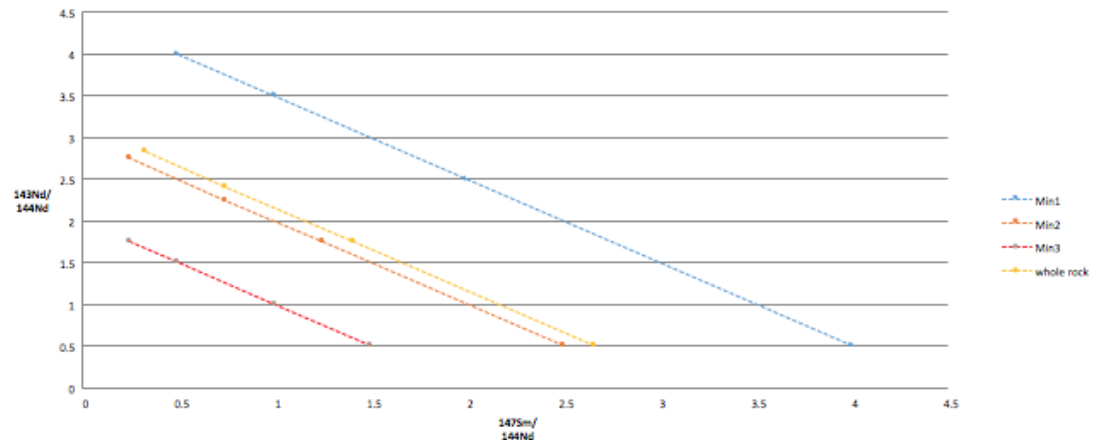


Excel version to record the simulation data collected is available.

### Samarium/Neodymium Simulation

		T initial	T1	T2	T3
Insert the number of initial daughter atoms ( <sup>143</sup> Nd)		2			
Insert the number of initial stable atoms ( <sup>144</sup> Nd)		4			
<b>Mineral 1</b>					
Insert the numbers of remaining parent atoms ( <sup>147</sup> Sm) after each throw		16	8	4	2
<sup>144</sup> Nd		4	4	4	4
<sup>147</sup> Sm/ <sup>144</sup> Nd		4	2	1	0.5
<sup>143</sup> Nd		2	10	14	16
<sup>144</sup> Nd		4	4	4	4
<sup>143</sup> Nd/ <sup>144</sup> Nd		0.5	2.5	3.5	4
<b>Mineral 2</b>					
Insert the numbers of remaining parent atoms ( <sup>147</sup> Sm) after each throw		10	5	3	1
<sup>144</sup> Nd		4	4	4	4
<sup>147</sup> Sm/ <sup>144</sup> Nd		2.5	1.25	0.75	0.25
<sup>143</sup> Nd		2	7	9	11
<sup>144</sup> Nd		4	4	4	4
<sup>143</sup> Nd/ <sup>144</sup> Nd		0.5	1.75	2.25	2.75
<b>Mineral 3</b>					
Insert the numbers of remaining parent atoms ( <sup>147</sup> Sm) after each throw		6	4	2	1
<sup>144</sup> Nd		4	4	4	4
<sup>147</sup> Sm/ <sup>144</sup> Nd		1.5	1	0.5	0.25
<sup>143</sup> Nd		2	4	6	7
<sup>144</sup> Nd		4	4	4	4
<sup>143</sup> Nd/ <sup>144</sup> Nd		0.5	1	1.5	1.75
<b>Whole rock</b>					
<sup>147</sup> Sm		32	17	9	4
<sup>144</sup> Nd		12	12	12	12
<sup>147</sup> Sm/ <sup>144</sup> Nd		2.67	1.42	0.75	0.33
<sup>143</sup> Nd		6	21	29	34
<sup>144</sup> Nd		12	12	12	12
<sup>143</sup> Nd/ <sup>144</sup> Nd		0.5	1.75	2.42	2.83

Sm/Nd simulation



# References and permissions

- “The Dynamic Earth: A Course for Educators” Edmond Mathez, Ph.D. Curator and Professor, Department of Earth and Planetary Sciences American Museum of Natural History
- A level Geology Guidance for Teaching: <http://www.eduqas.co.uk/qualifications/geology/as-a-level/>
- Pete Loader “Samarium-Neodymium dating for A-level students”: Teaching Earth Science Vol 42 No2 2017