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Instrumental Neutron Activation Analysis (INAA) – Practice and Potential Forensic Applications

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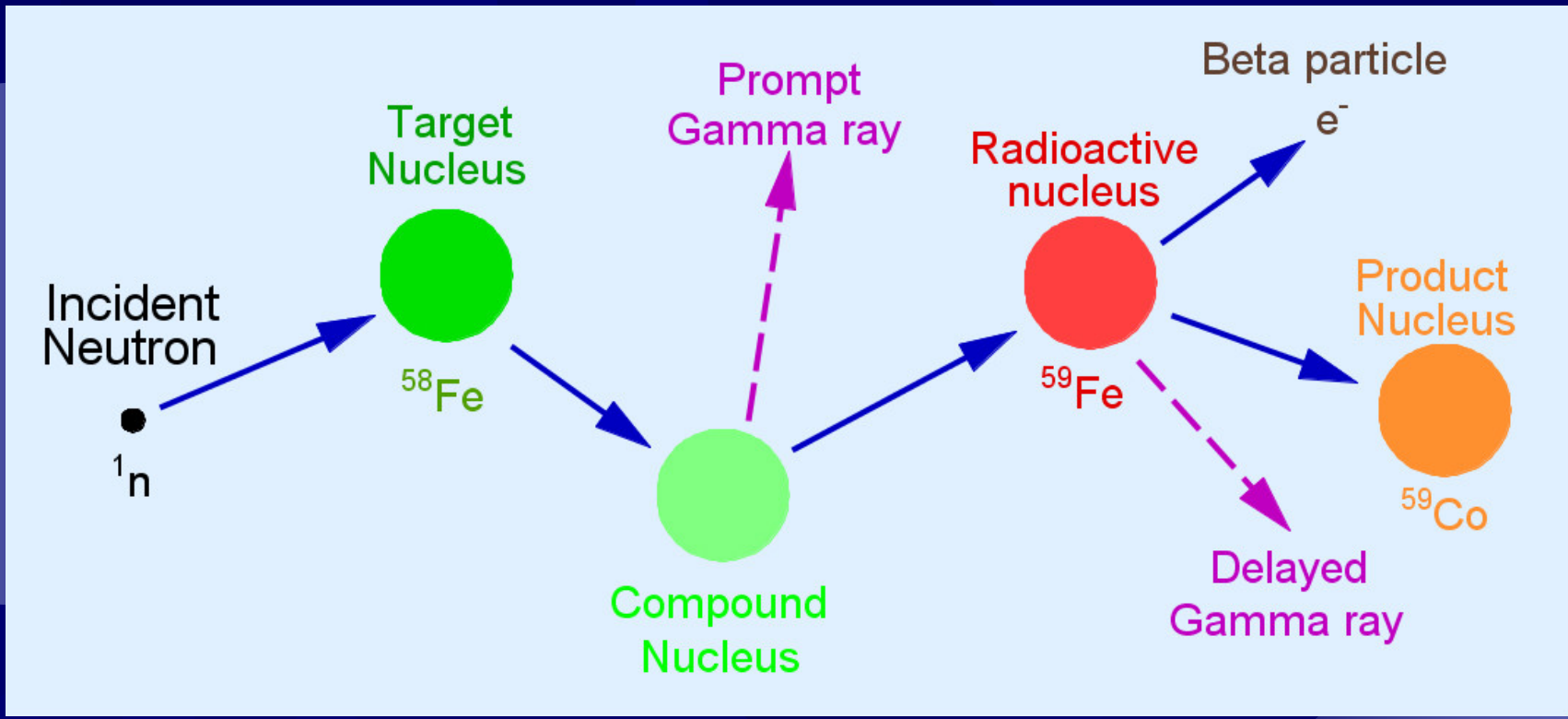
The n–gamma Reaction

The basic reaction for INAA



Example: $^{58}Fe + {}^{1}n \longrightarrow {}^{59}Fe + Beta^- + gamma\ rays$

Gamma ray energies = 142.4, 1099.2, 1291.6 KeV

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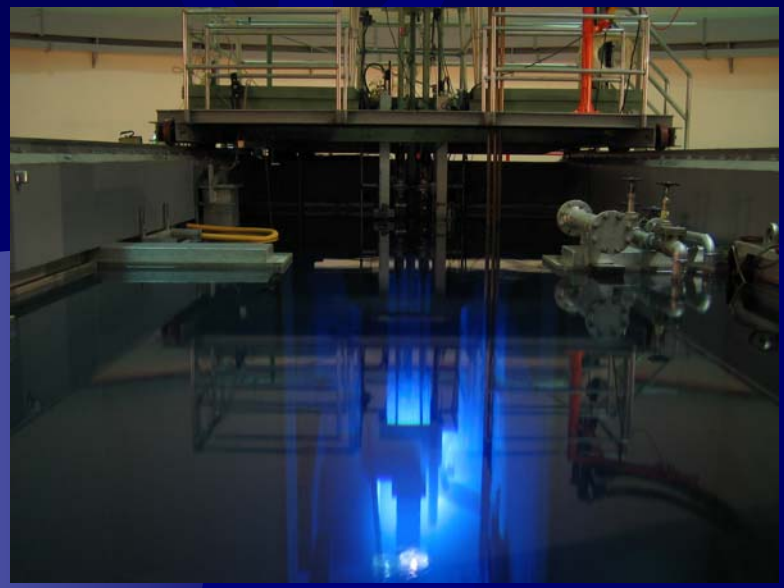
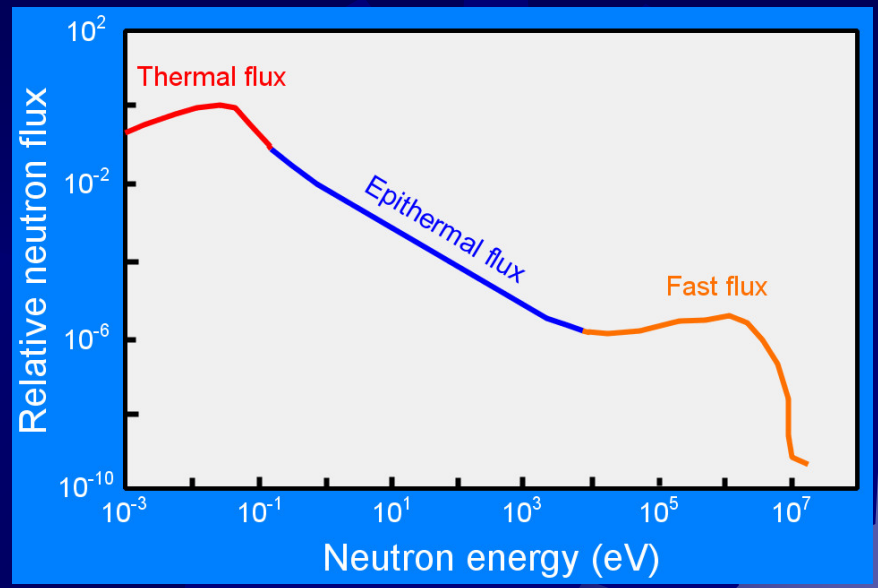


UML 1 Mw Research Reactor

The Neutron Source

Different neutron energies are used for different types of experiments.



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Sample detector spacing

Activated sample

Detector

Preamplifier

Amplify signal

Amplifier

Shape signal

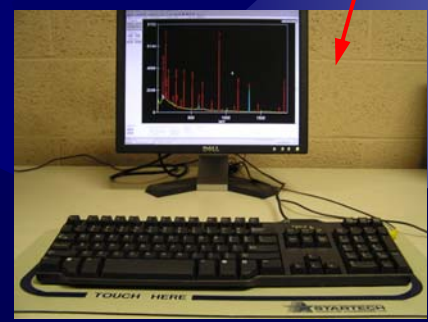
ADC

MCA

Output

ADC = Analog - Digital Converter

MCA = MultiChannel Analyzer



Data acquisition flow sheet

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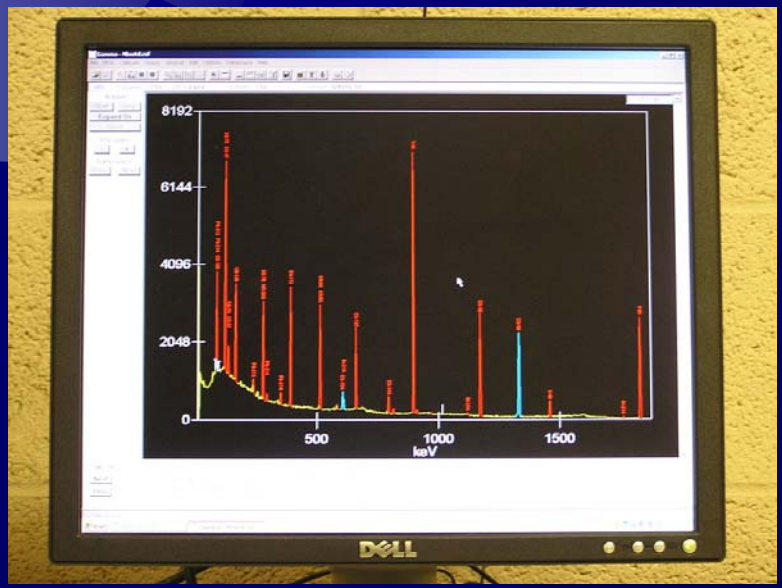
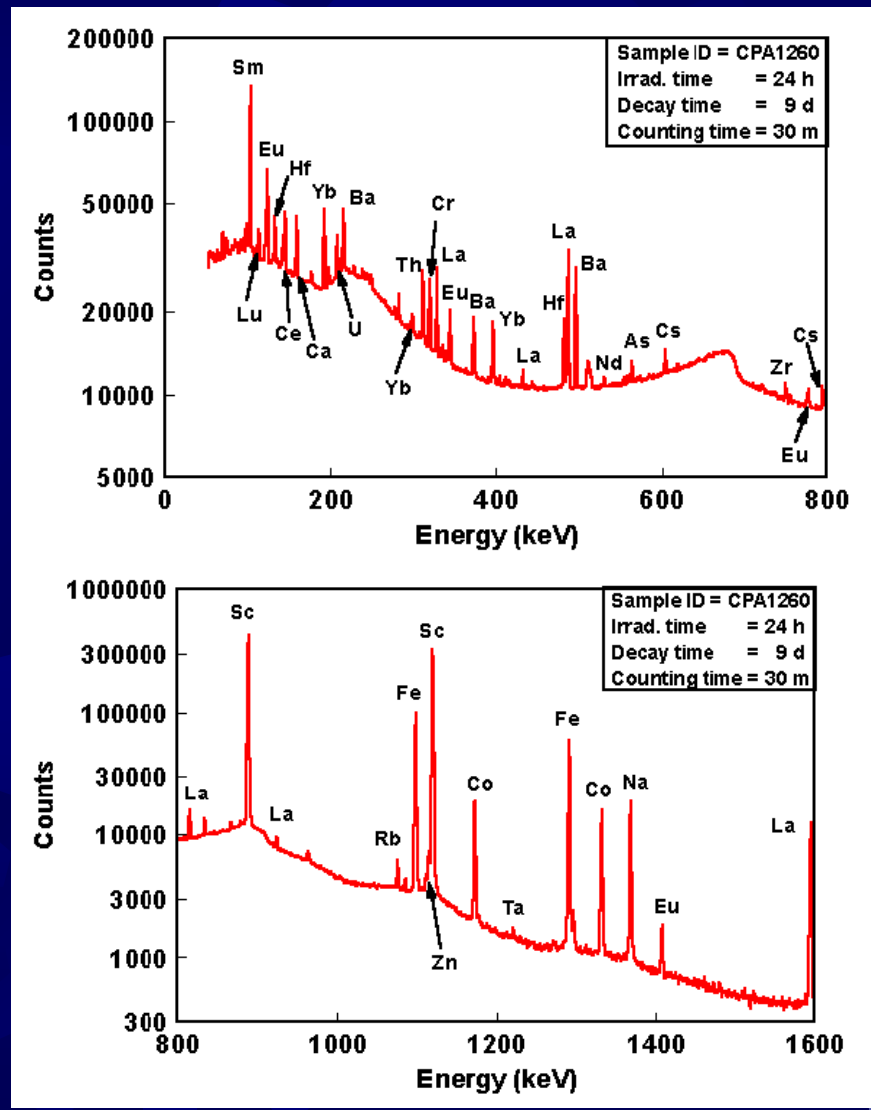
UML INAA Lab



Gamma ray spectrum for a multi element sample



Detection limits (DL) for elements that can be determined by INAA	
DL (nanograms)	**Elements**
0.01-0.1	Au, Eu, Ho, Ir, Sm, Lu
0.1-1	Ag, As, Co, Cs, Hf, La, Sb, Sc, Se, Ta, Tb, Th, Tm, U, W, Yb
1-10	Ba, Br, Ce, Cr, Gd, Mo, Na, Nd, Ni, Rb, Sr, Zn, Zr
10-100	K
100-1000	Fe

Advantages of INAA

- Can analyze a large number of elements simultaneously
- Very low detection limits for many elements
- Small sample sizes (1 – 200 mg)
- No chemical preparation
- Nondestructive. The material is available for other analytical techniques
- Relatively low entry cost (~$60,000) compared to other high sensitivity analytical methods

Forensics – Source of the Maple Syrup

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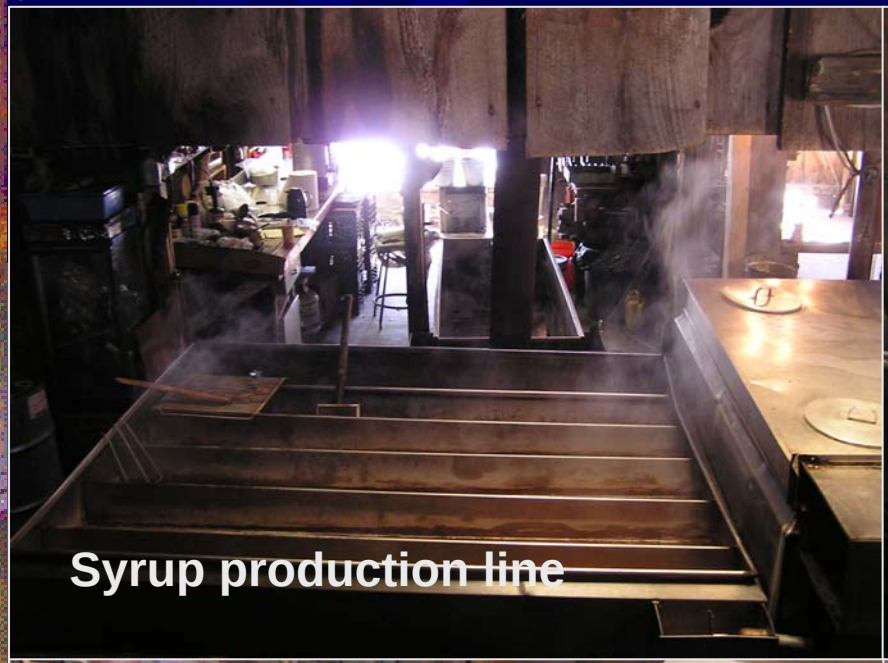
Collecting sap the old fashioned way

Collecting sap the modern way. Plastic barrels and polyethylene tubing.

Transferring sap to the sugar house

Sap holding vats

Boiling down the sap


Syrup production line

Main boiler

Secondary boiler


Finish boiler

Concentrations (ppm) and ratios of trace metals in Maple Syrup

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	Newton	Winsor	Parker A	Parker B	W MA	VT	Quebec
Sc	0.010	0.009	0.004	0.008	0.006	0.002	0.030
Cr	0.67	0.71	0.83	nd	0.87	0.136	1.67
Co	0.094	0.064	0.073	0.046	0.057	0.078	0.119
Zn	9.3	13.1	50.6	19.4	76.3	5.5	19.4
Rb	7.5	3.1	10.2	5.7	15.7	7.5	9.0
Sr	28.6	13.7	10.7	nd	8.3	10.5	17.5
As	0.029	0.014	0.022	nd	0.010	0.016	0.016
Sb	0.018	0.010	0.034	0.004	0.010	0.002	0.009
Se	ppb	nd	nd	nd	nd	nd	8.72
Zn/Cr	13.9	18.5	61	nd	88	40	11.6
Rb/Cs	642	363	433	nd	175	356	419
Ba/Sr	0.59	0.18	0.76	nd	1.29	2.26	0.37
As/Sb	1.59	1.50	0.64	nd	2.24	8	1.91

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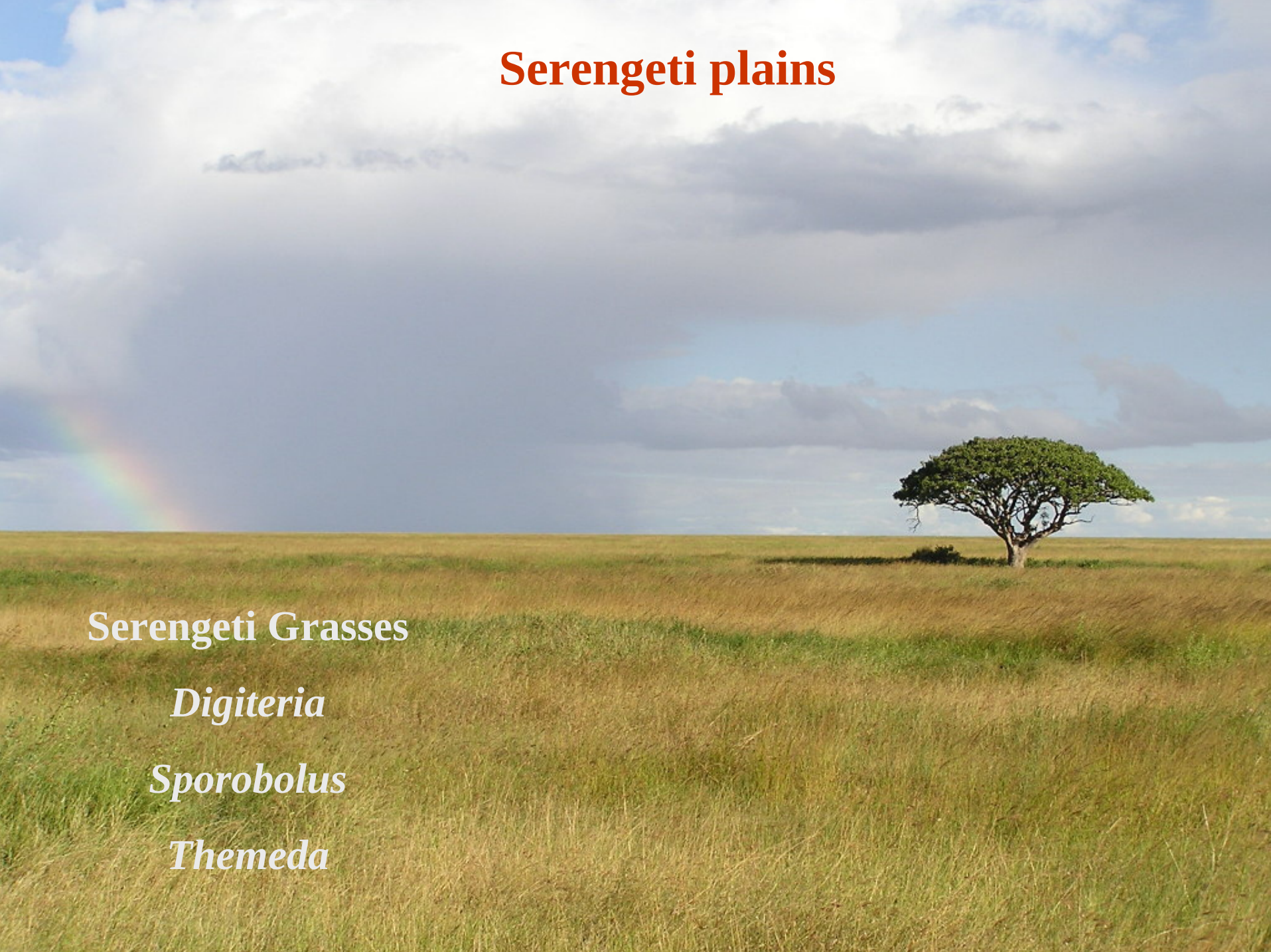
Location map for Tanzania National Parks

Serengeti plains



Serengeti Grasses

Digiteria

Sporobolus

Themeda

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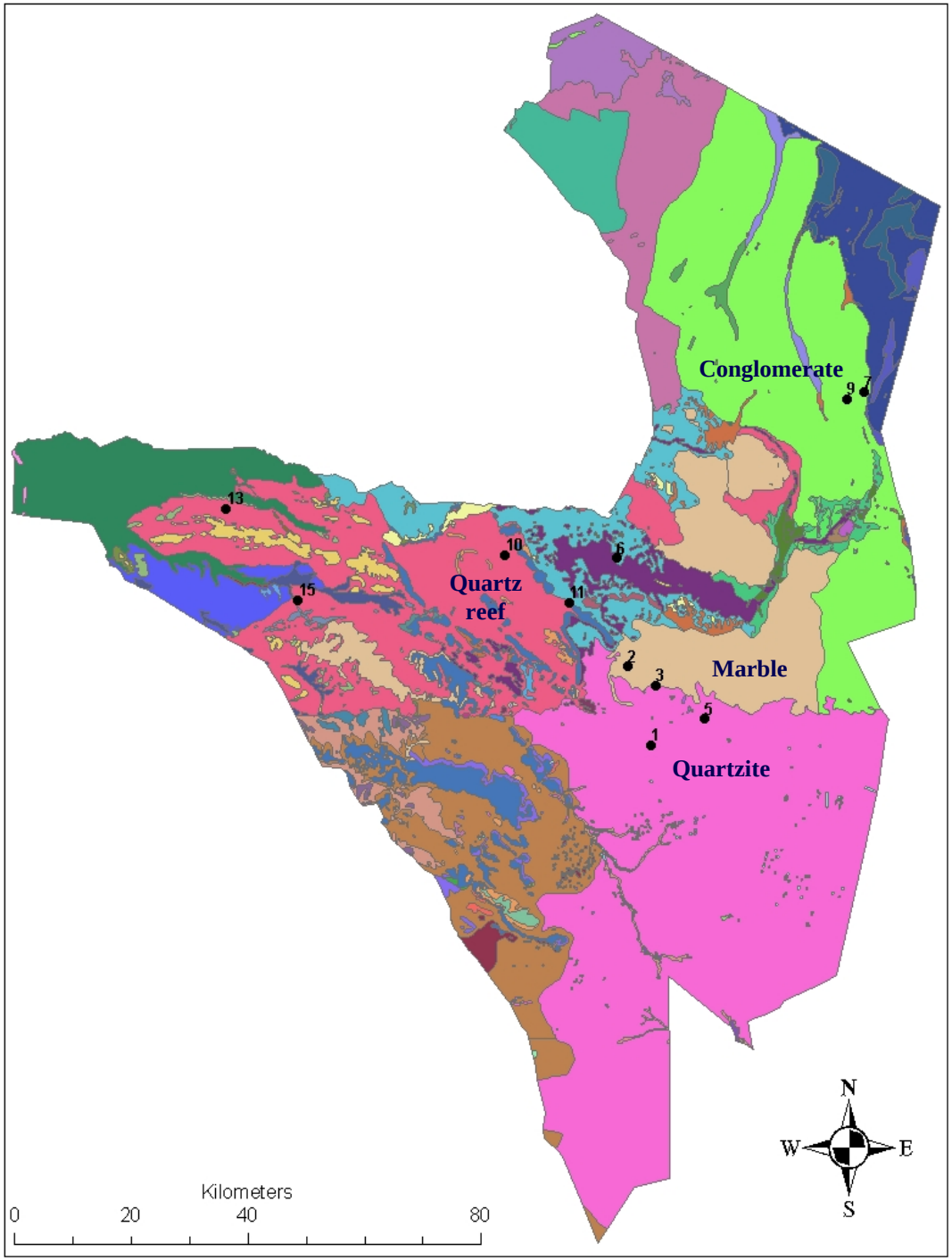
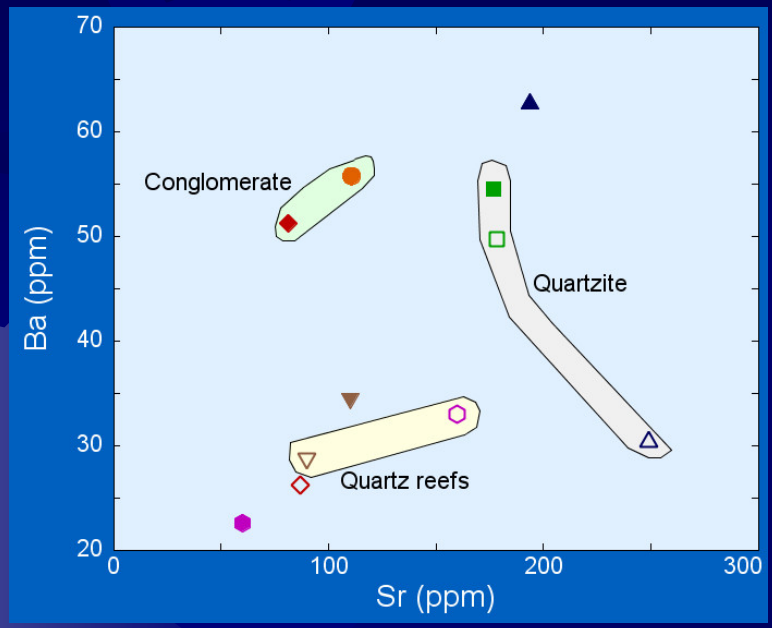
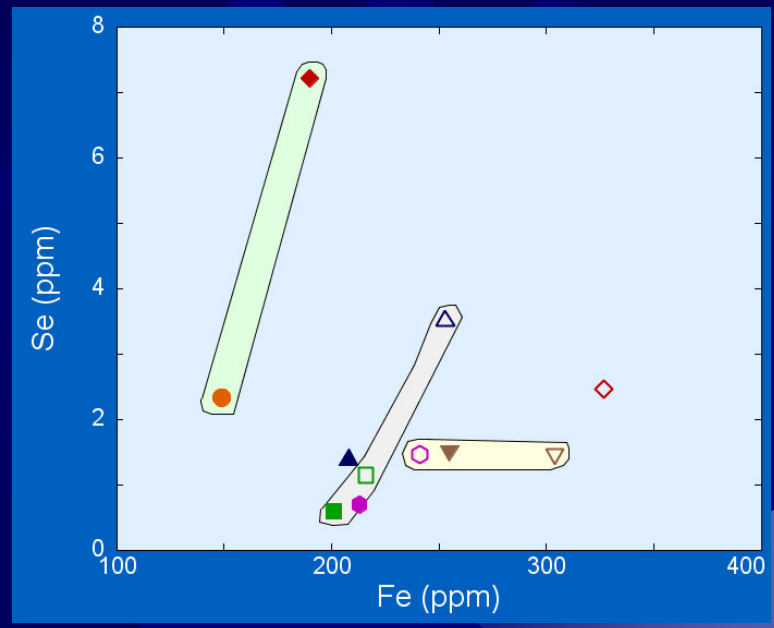
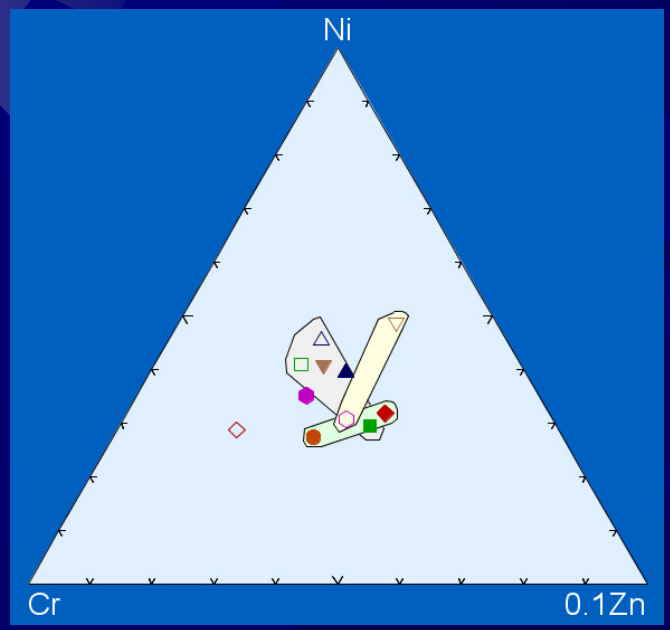
Sample Locations and Geology

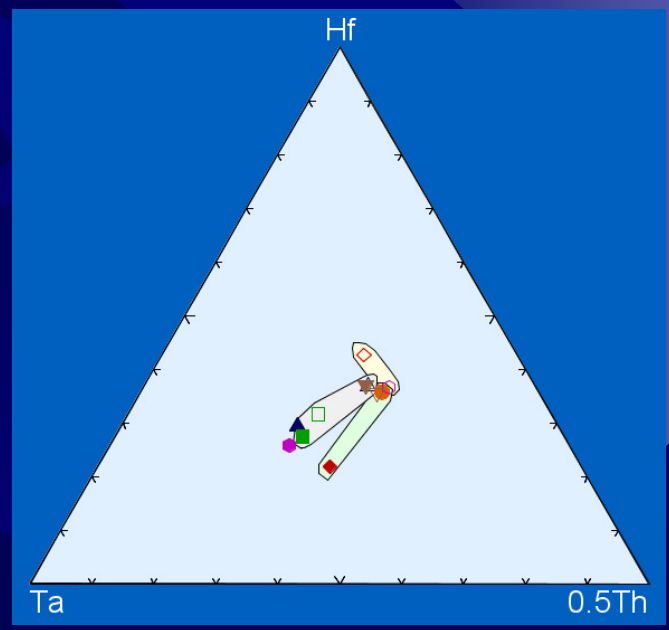


Trace element distributions for grasses from geographic areas with different bedrock geology.









Summary of Materials Used in Glazes	
Material	**Chemistry**
Bentonite	$((Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$
Cryolite	Na_3AlF_6
Dolomite	$CaMg(CO_3)_2$
Epsom salts	$MgSO_4 \cdot 7H_2O$
Fluorspar	CaF_2
Gerstley borate	$2CaO.3B_2O_3.5H_2O$
Kaolin (Kaolinite)	$Al_2Si_2O_5(OH)_4$
Lepidolite	$K(Li,Al)_3(Al,Si)_4O_{10}(F,OH)_2$
Lithium carbonate	$LiCO_3$
Nepheline syenite	Various Na-K-Al silicate minerals
Potash feldspar (K-spar)	$KAlSi_3O_8$
Silica (Quartz)	SiO_2
Soda feldspar (Albite)	$NaAlSi_3O_4$
Whiting (Calcite)	$CaCO_3$
Wollastonite	$CaSiO_3$
Zircopax (Zircon)	$ZrSiO_4$
Colorant Oxides	
Cobalt	Co
Copper carbonate	$CuCO_3$
Hematite	Fe_2O_3
Rutile	TiO_2

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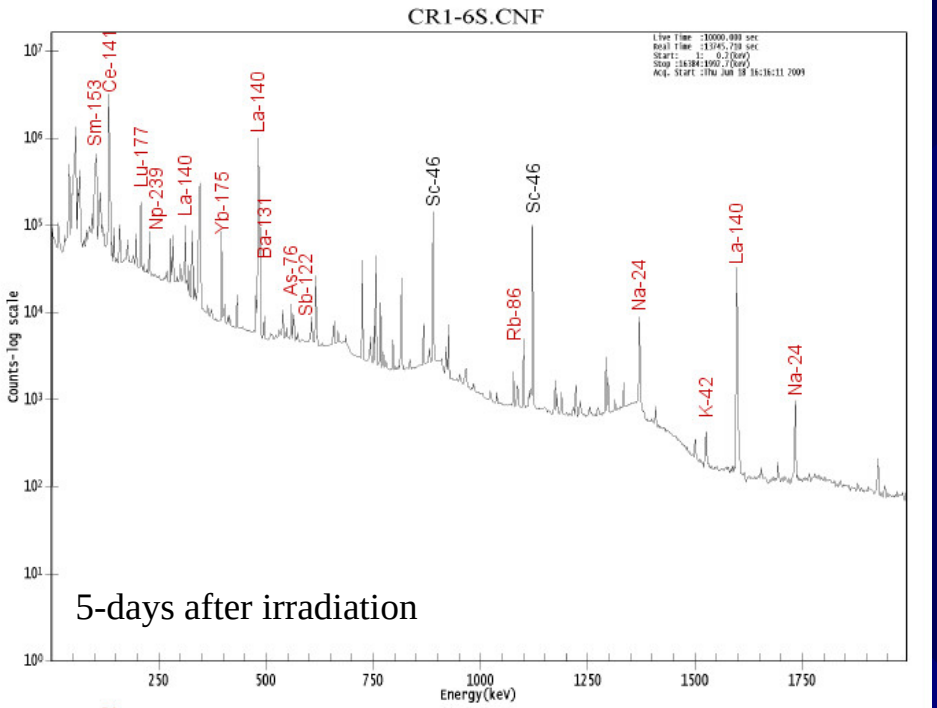
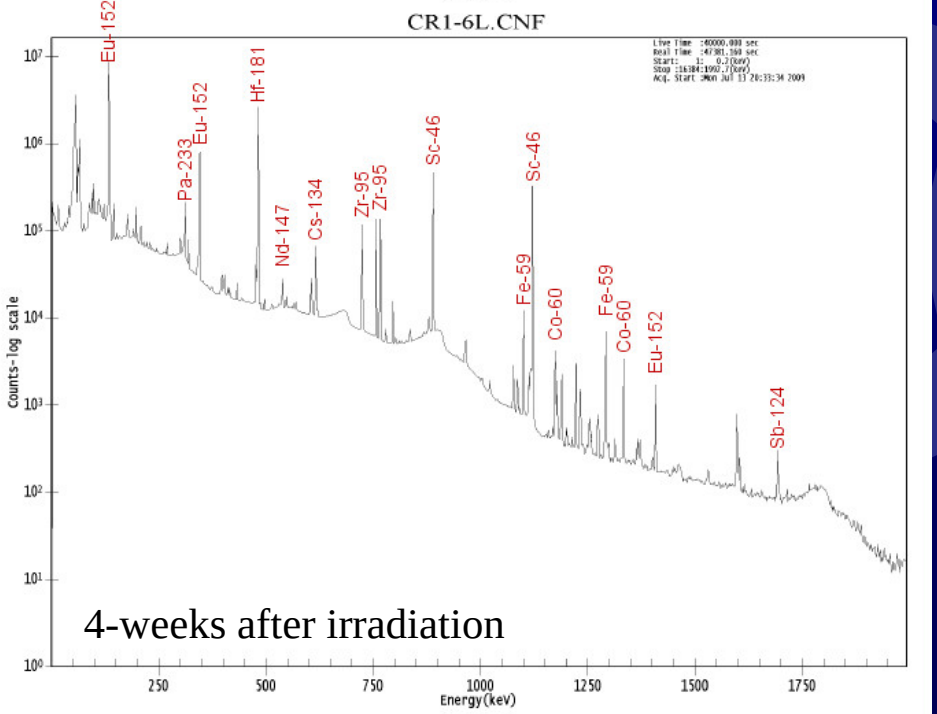
Gamma ray spectrum for Ceramic 6





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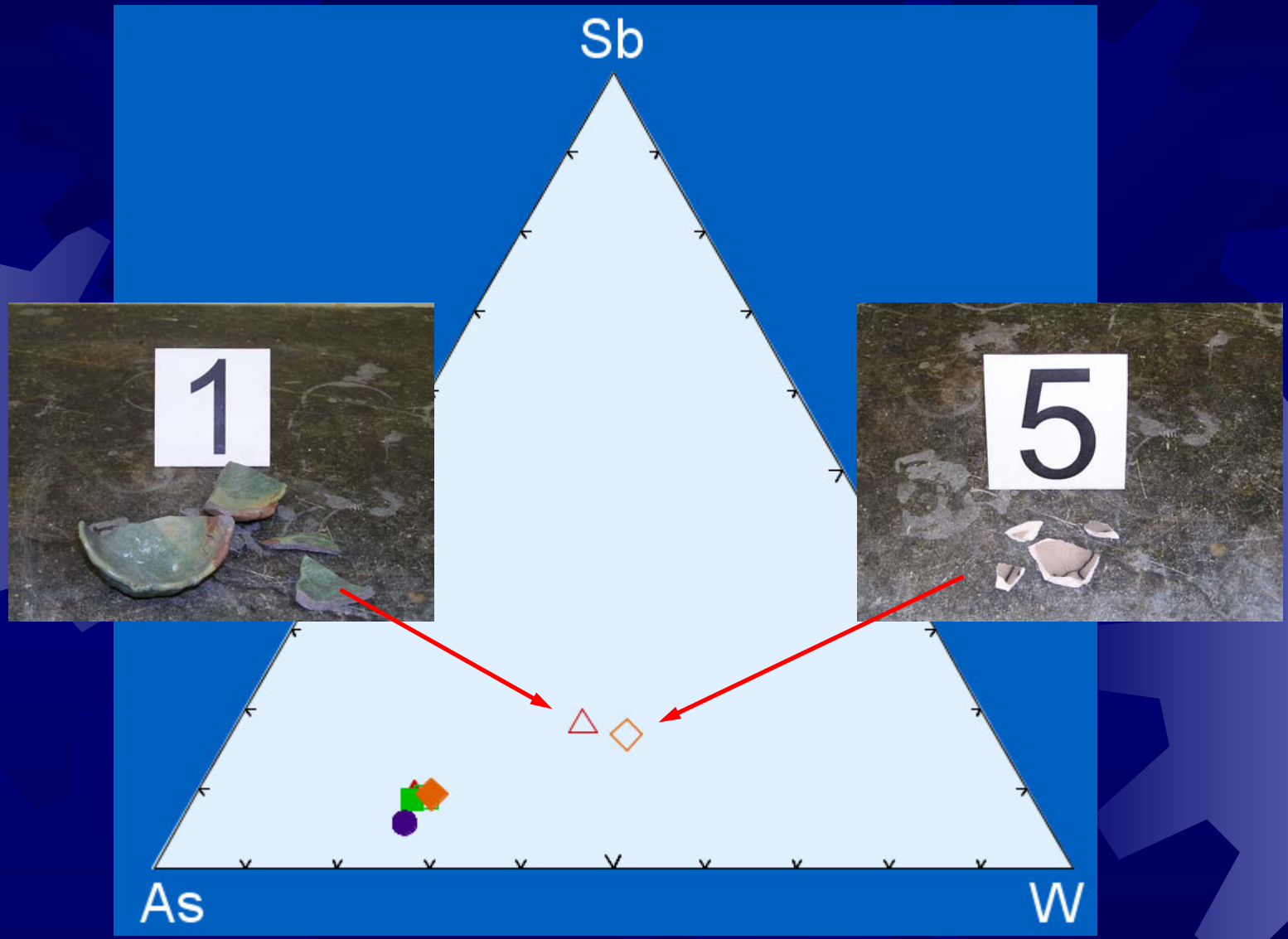

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