Trinitite

Radioactivity of trinitite after 62 years

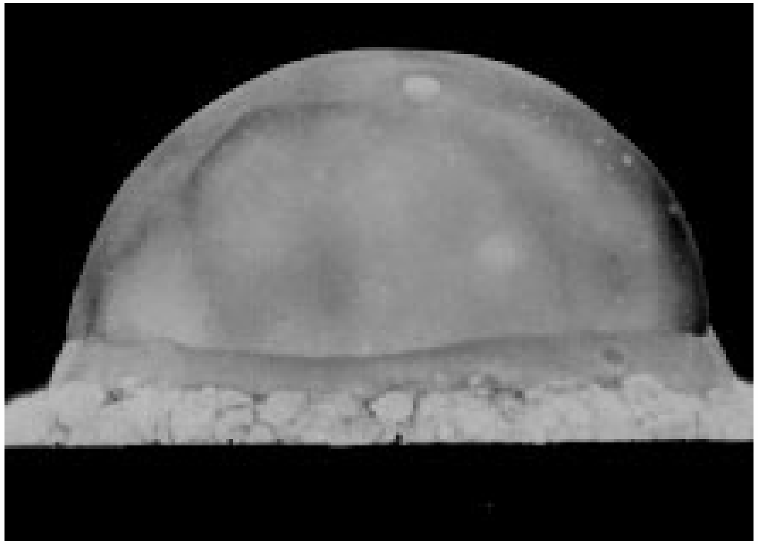
Daniela Pittauerova

Universität Bremen

Contents

We waited until the blast had passed, walked out of the shelter and then it was extremely calm. We knew the world would not be the same. A few people laughed; a few people cried. Most people were silent. I remembered the line from the Hindu scripture,

"Now I become Death,
the destroyer of worlds
I suppose we all thought that,
one way or another"



Robert Oppenheimer, Director, Los Alamos Laboratory

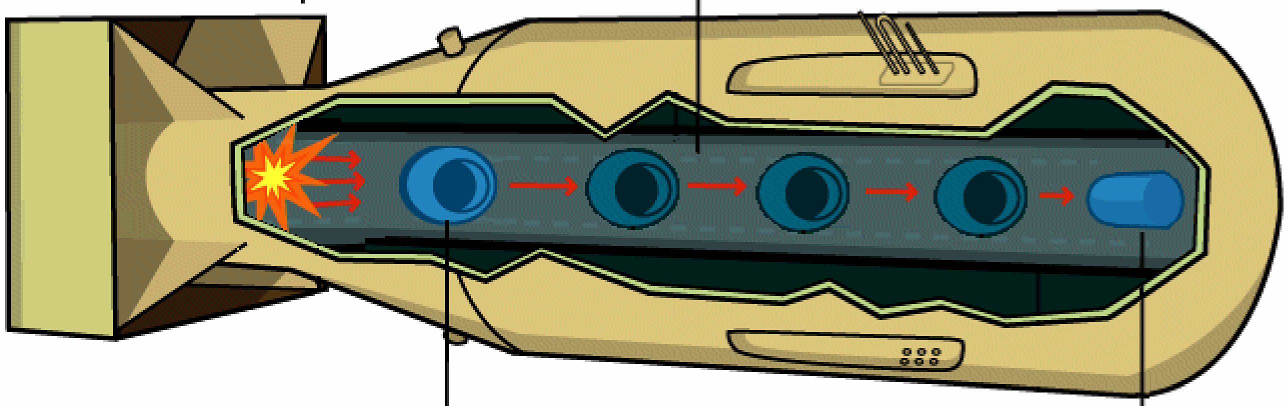
Photo: White Sands Missile Range web page: www.wsmr.army.mil

Los Alamos Laboratory

- organized in 1943 to design a nuclear weapon
- 2 basic bomb designes:
  - in the first 2 years: gun type designed
  - later: solving problem of implosion design
- lots of uncertainties about the implosion weapon – it must be tested

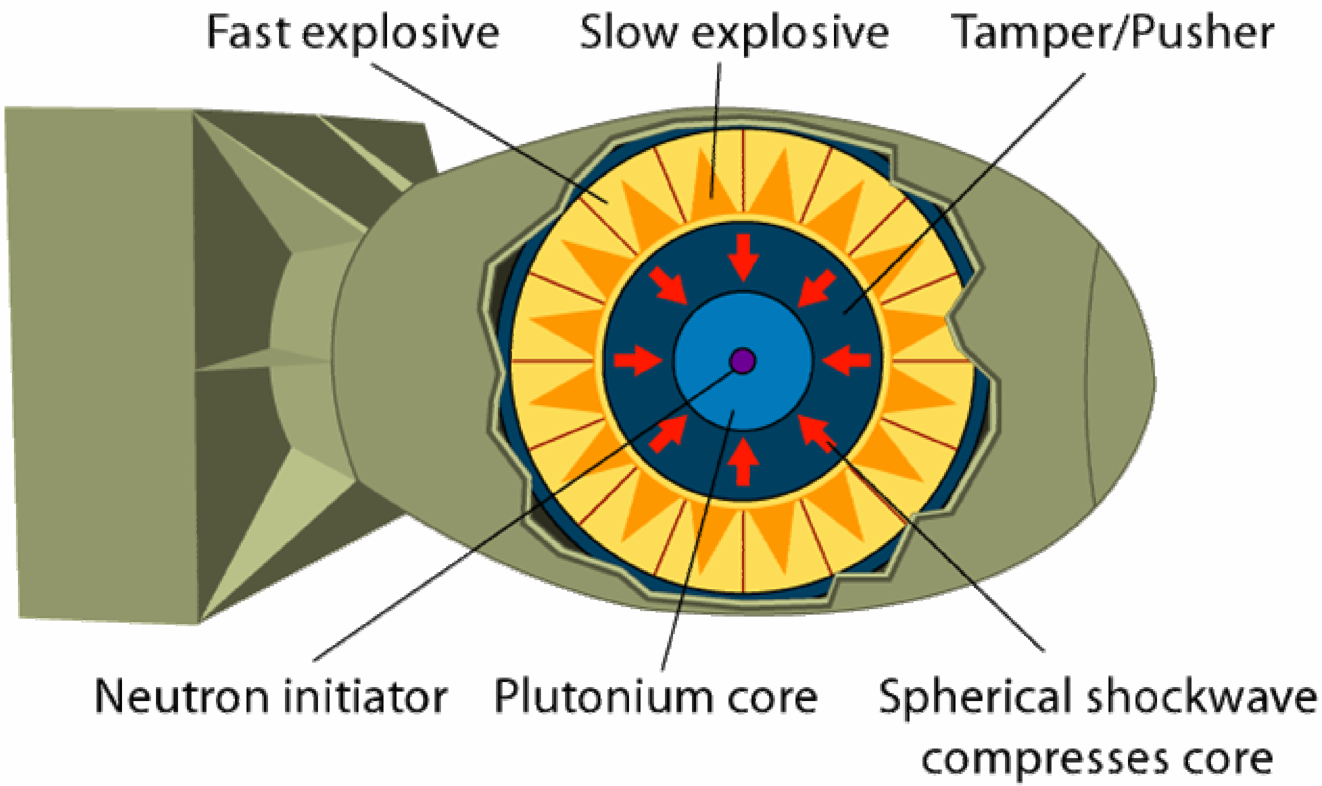
Photo: American Physical Society web page: www.aps.org

Nuclear weapon – gun type



From: Wikipedia

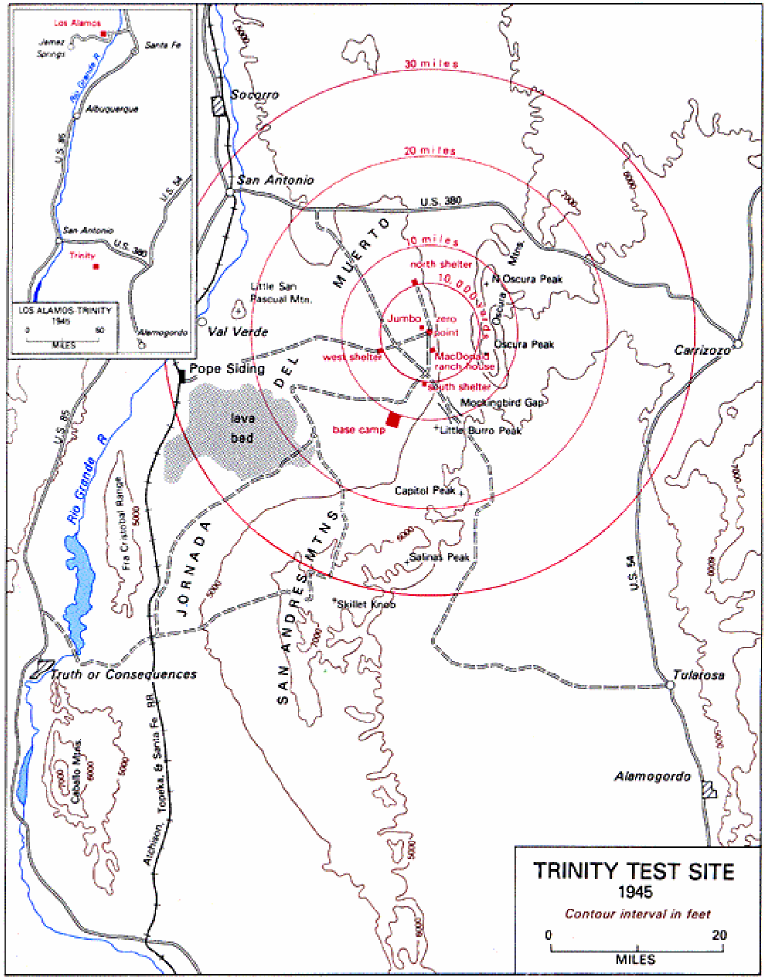
Nuclear weapon – implosion type



From: Wikipedia

Selection of site

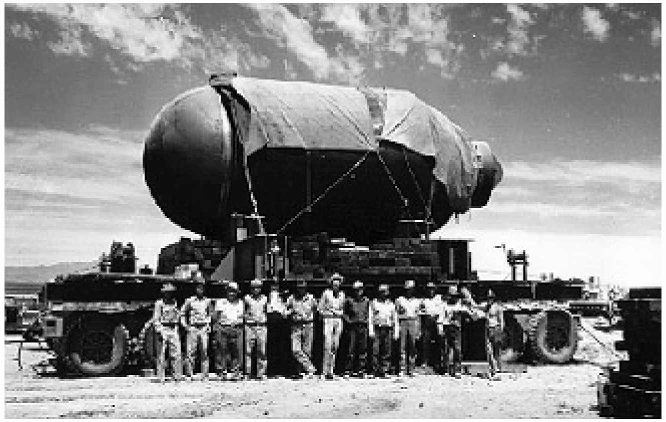
- Trinity site selected of 8 possible sites
- Flat site: to minimize extraneous effect of the blast
- Good weather: large amount of optical information desired
- Minimum 20 km from the nearest settlement: to prevent the radiation hazards of people from fission products
- Minimum time loss in travel of personel and material (mainly from Los Alamos)
- Question of security and complete isolation of the activities of the test site from activities at Manhattan project



From: U.S. DOE site: www.doe.org


Google
Sichthöhe 19.79 km

The Jumbo test



- Jumbo: 7,6 m x 3 m, 214 t container
- it could contain the TNT explosion if the chain reaction failed
- Prevention of the Pu from being lost
- If the nuclear explosion occurred as theorized, Jumbo would be vaporized
- Growing confidence in the plutonium bomb design, concern about adding tons of radioactive steel vapour - decision not to use Jumbo.

Photo: White Sands Missile Range web page: www.wsmr.army.mil

The Jumbo test

Jumbo prior to the test...

and after...

Photos: White Sands Missile Range web page: www.wsmr.army.mil

The Instrument test

- a simulated blast on 7 May 1945
- 100 tons of TNT: calibration of the instruments which would be measuring the atomic explosion and to practice a countdown
- small amount of radioactive material from Hanford

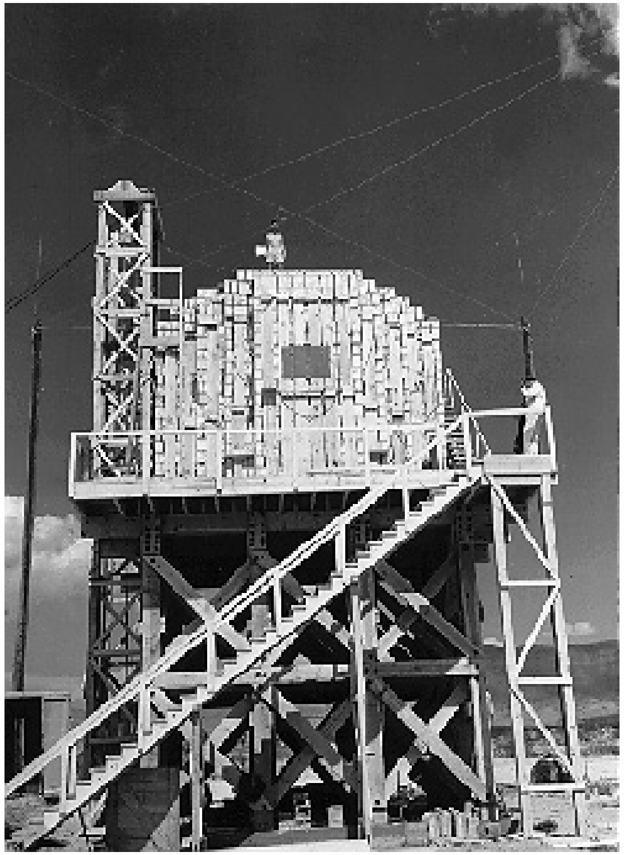


Photo: White Sands Missile Range web page: www.wsmr.army.mil

Trinity test

- July 16th 1945 5:29 a.m. Mountain War Time: world‘s first nuclear explosion
- Place: Jornada del Muerto, near Alamogordo, New Mexico desert, 33,675 °N, 106,475 °W
- named by Los Alamos director R. Oppenheimer after a poem by John Donne
- yield: 21 kt TNT

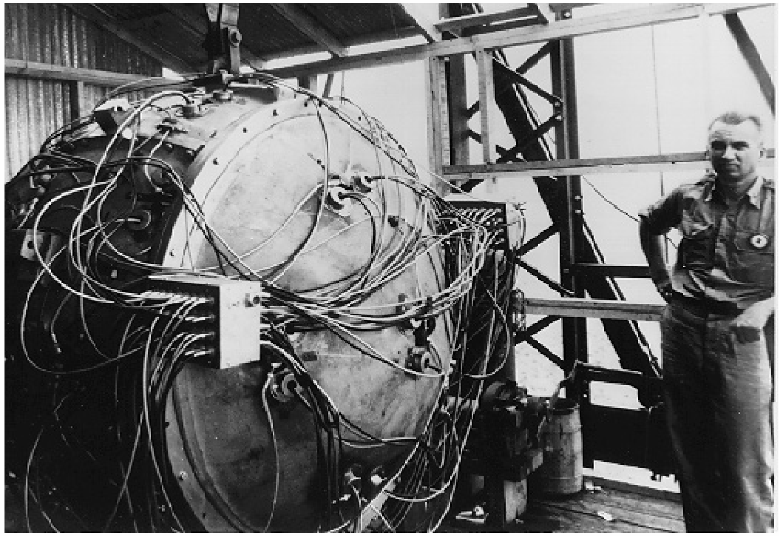
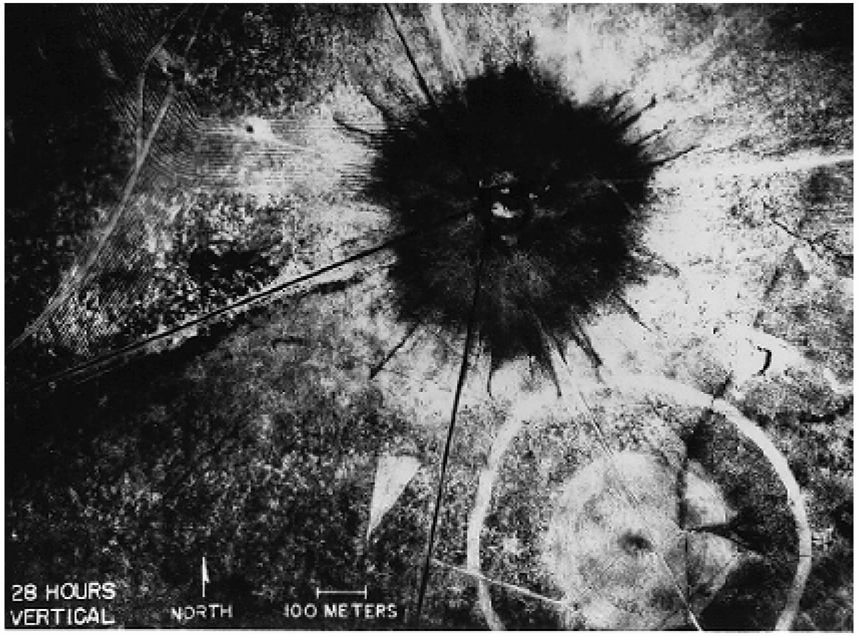


Photo: White Sands Missile Range web page: www.wsmr.army.mil

Ground zero

1945

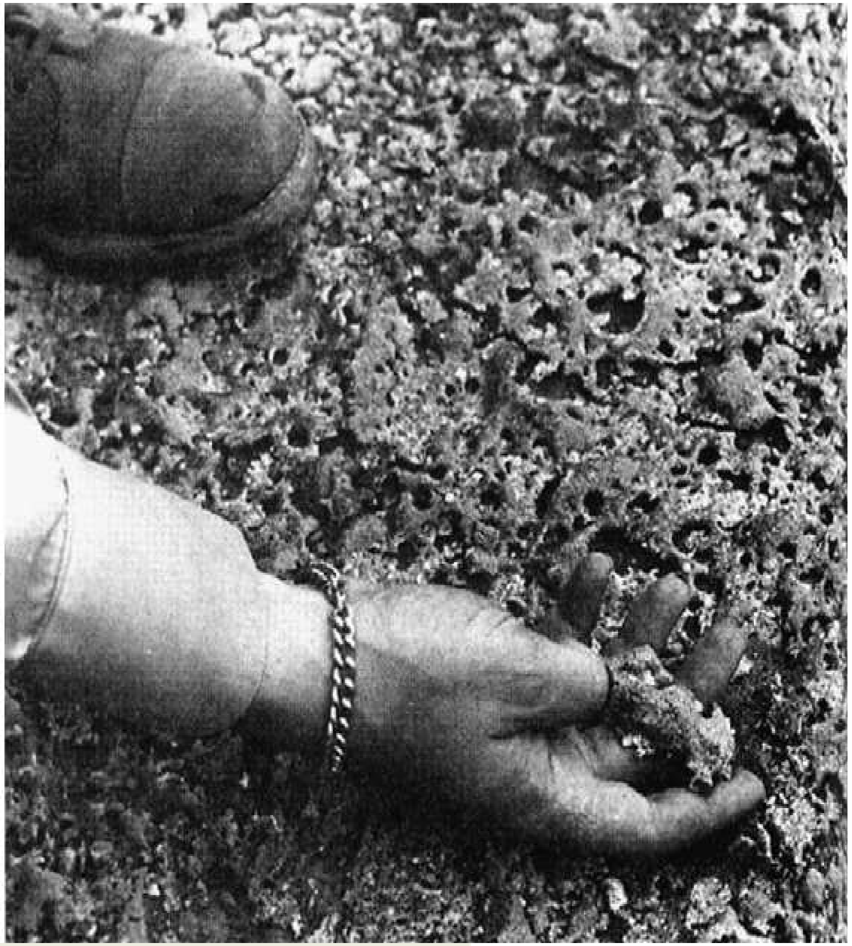


now

From: White Sands Missile Range web page: www.wsmr.army.mil

Trinitite

- „a depressed area 400 yeards in radius glazed with a green, glasslike substance where the sand had melted and solified again“ was found at Ground zero *(physicist Herbert Anderson)*
- Not a real mineral recognized by International Mineralogical Association

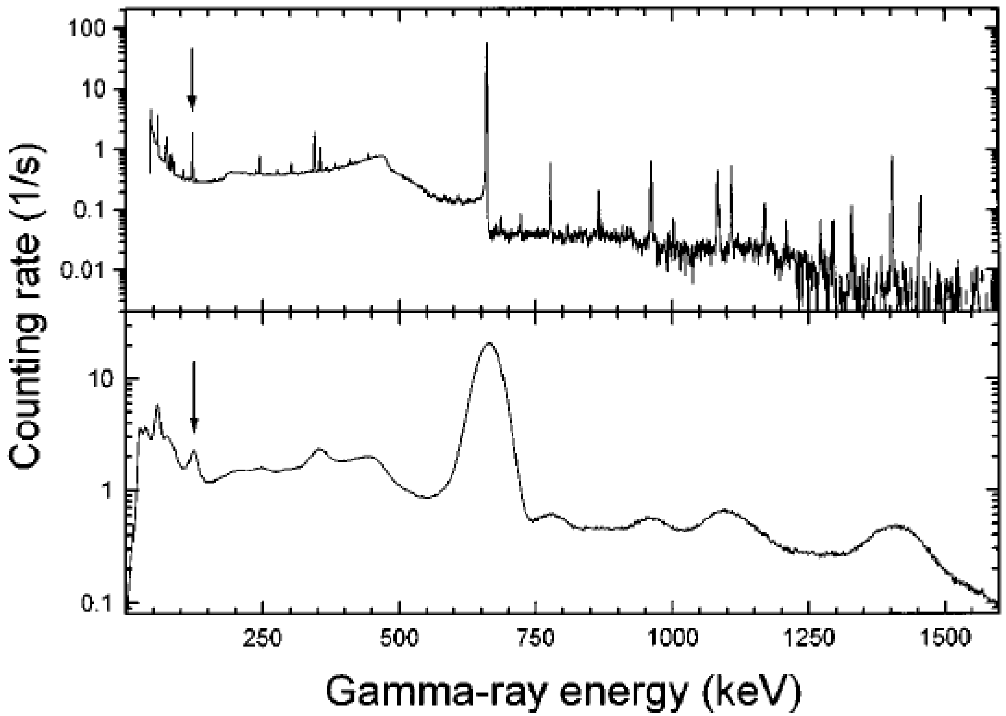


From: White Sands Missile Range web page: www.wsmr.army.mil
Undisturbed surfice of trinitite field

Previous studies - radioactivity

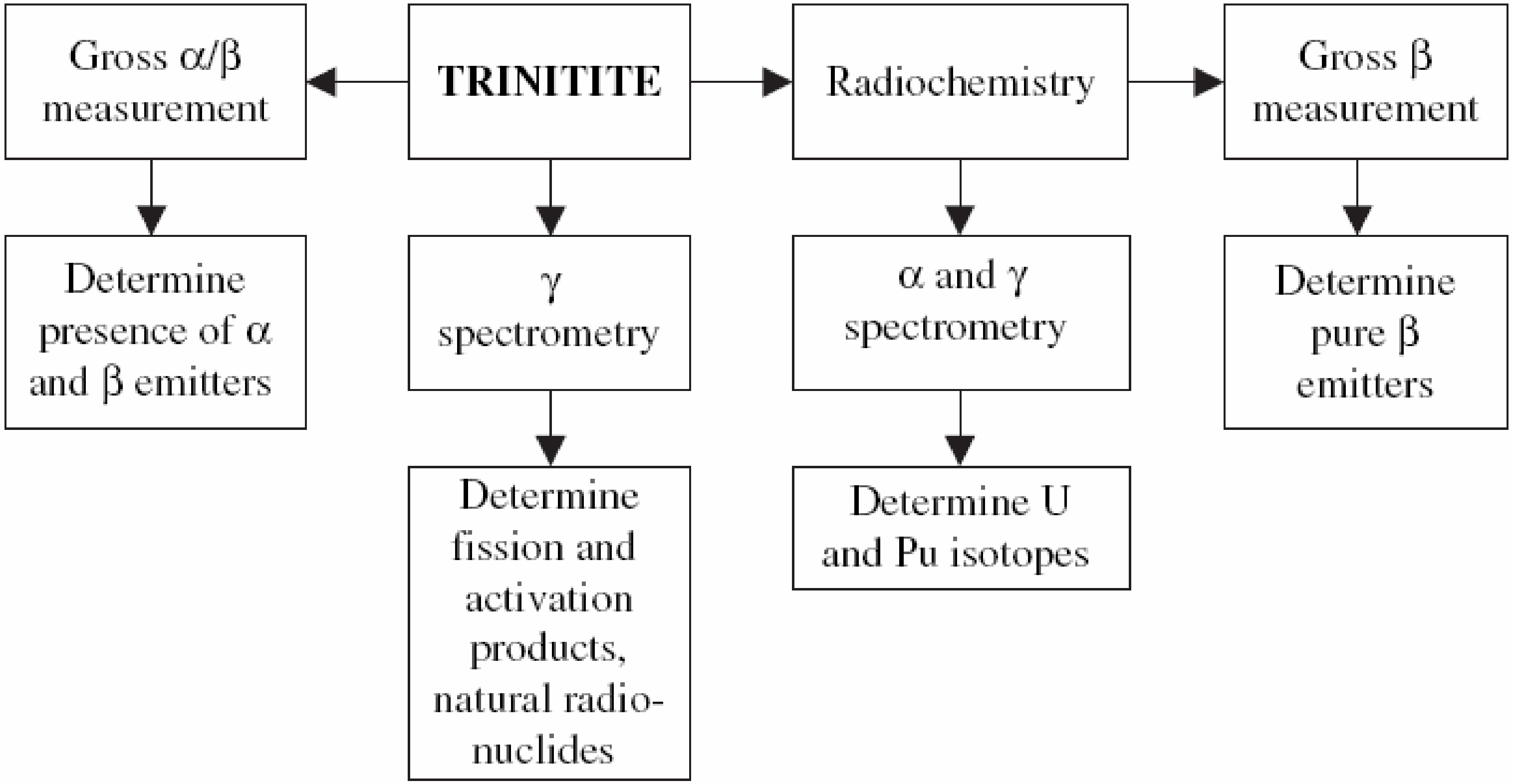
Authors	From	Journal	Year	Methods	Results
TRINITITE					
Atkatz and Bragg	Skidmore College, Saratoga Springs, NY, USA	Am. J. Phys.	1995	NaI(Tl) γ-spectroscopy	• ^{137}Cs and ^{133m}Ba determination • yield calculation
Schlaf et al.	Institut für Kernchemie, Universität Marburg	Am. J. Phys.	1997	NaI(Tl) γ-spectroscopy, HPGe γ-spectroscopy	• ^{60}Co, ^{133}Ba, ^{137}Cs, ^{152}Eu, ^{154}Eu and ^{241}Am determination • yield calculation
Parekh et al.	• New York state department of health, Albany, NY, USA • University at Albany, NY, USA	J. Env. Rad.	2006	γ-spectroscopy, radioachemistry, α-spectroscopy, low bkg betta counting	• ^{60}Co, ^{90}Sr, ^{133}Ba, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu and ^{241}Am determination • ^{40}K, ^{232}Th and ^{238}U determination

Previous studies – Schlaf et al. 1997



From: Schlaf, Siemon, Weber, Esterlund, Molzahn and Patzelt: Trinitite redux: Comment on „Determining the yield of the Trinity nuclear device via gamma-ray spectroscopy," by David Atkatz and Christopher Bragg [Am. J. Phys. 63, 411-413 (1995)]. Am. J. Phys. 65, 1110-1112 (1997).

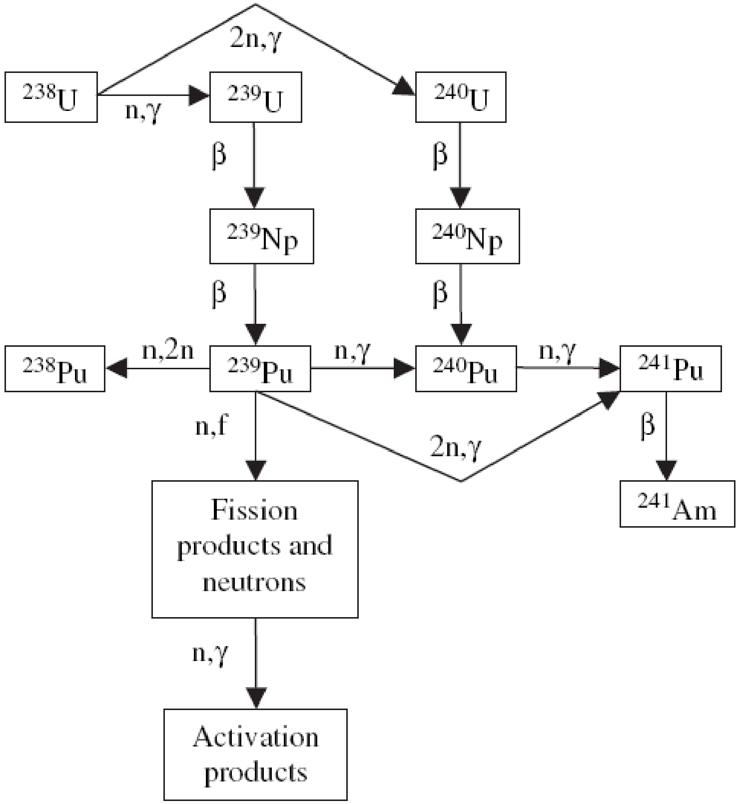
Previous studies – Parekh et al. 2006



From: Parekh, Semkow, Torres, Haines, Cooper, Rosenberg, Kitto: Radioactivity in Trinitite six decades later. Journal of Environmental Radioactivity 85 (2006) 103-120.

Previous studies – Parekh et al. 2006

- Multiple pathways of producing radioactivity in trinitite



From: Parekh, Semkow, Torres, Haines, Cooper, Rosenberg, Kitto: Radioactivity in Trinitite six decades later. Journal of Environmental Radioactivity 85 (2006) 103-120.

Previous studies – Parekh et al. 2006

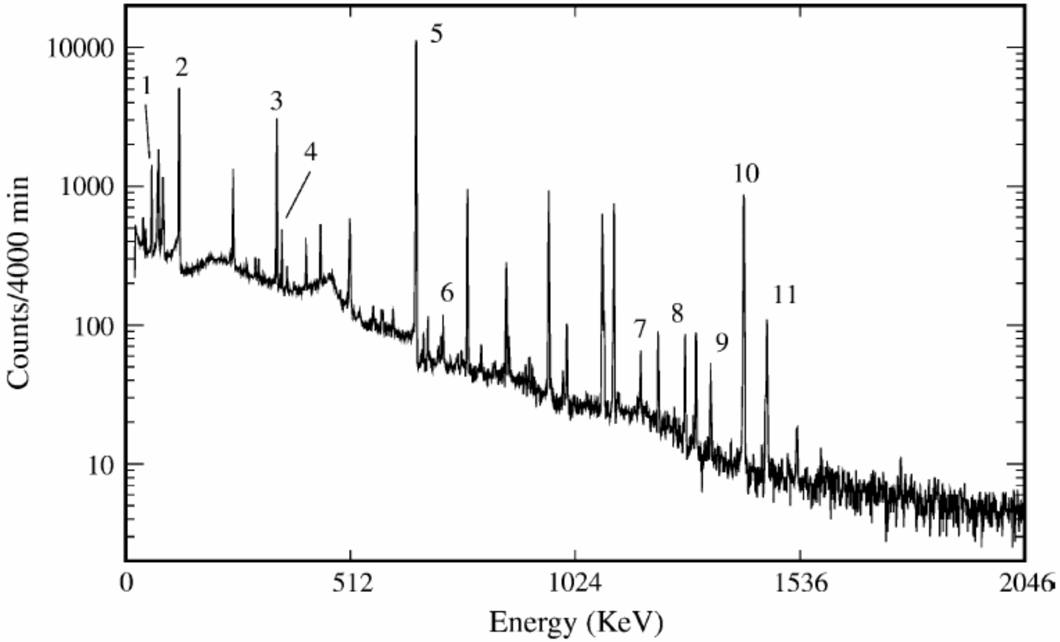


Fig. 9. Gamma-ray spectrum of Trinitite sample A measured on a 131% Ge detector at 10 cm distance. Selected peak assignments are as follows (measured energies are reported): (1) 59.4-keV ^{241}Am; (2) 121.7-keV ^{152}Eu, 122.8-keV ^{154}Eu; (3) 344.2-keV ^{152}Eu; (4) 356.0-keV ^{133}Ba; (5) 661.5-keV ^{137}Cs; (6) 723.0-keV ^{154}Eu; (7) 1173.4-keV ^{60}Co; (8) 1274.3-keV ^{152}Eu; (9) 1332.5-keV ^{60}Co; (10) 1407.8-keV ^{152}Eu; (11) 1460.8-keV ^{40}K.

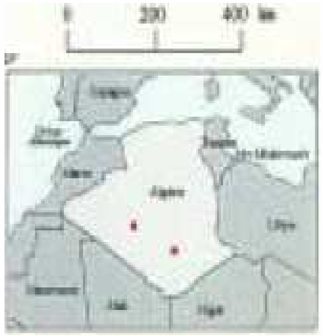
From: Parekh, Semkow, Torres, Haines, Cooper, Rosenberg, Kitto: Radioactivity in Trinitite six decades later. Journal of Environmental Radioactivity 85 (2006) 103-120.

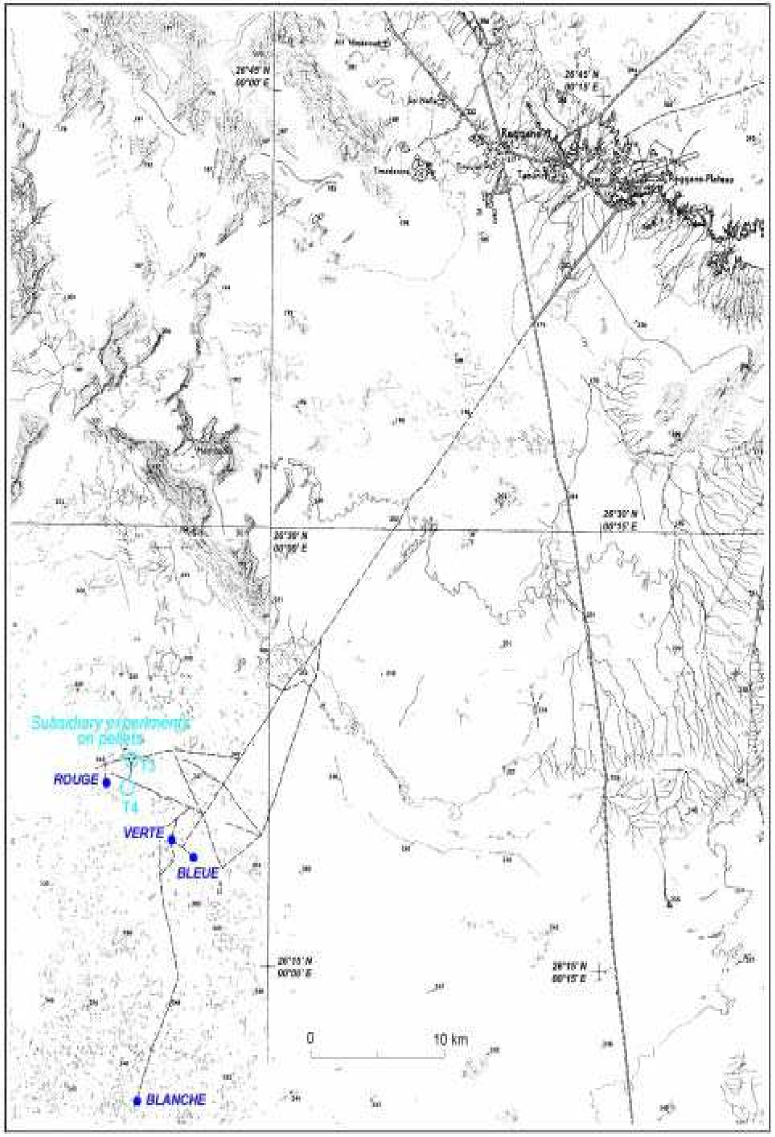
Previous studies - radioactivity

Authors	From	Journal	Year	Methods	Results
ALGERIA					
Danessi et al.	IAEA	Radiological assessment reports series, IAEA	2005	γ-spectroscopy, radioachemistry, α-spectroscopy	• complex radionuclides determination in environmental media •dose calculations
SEMIPALATINSK					
Yamamoto et al.	• Kanazawa University, Ishikawa, Japan • Kyoto University, Japan	Health Physics	1996	γ-spectroscopy, radioachemistry, α-spectroscopy	•γ: ^{60}Co, ^{137}Cs, ^{152}Eu, ^{154}Eu •α: ^{238}Pu, ^{239,240}Pu, ^{237}Np, ^{241}Pu and ^{241}Am in soil

Previous studies – Danessi et al., IAEA 2005

- The Gerboise test zone is a desert area situated 50 km south of Reggane oasis, Algeria
- 1960-61: Three of the atmospheric tests (Gerboise Bleue, Gerboise Rouge and Gerboise Verte) on a tower, one test at Gerboise Blanche on the ground





From: Danessi et al., IAEA 2005

Map of Regane area, where atmospheric tests were performed

Previous studies – Danessi et al., IAEA 2005

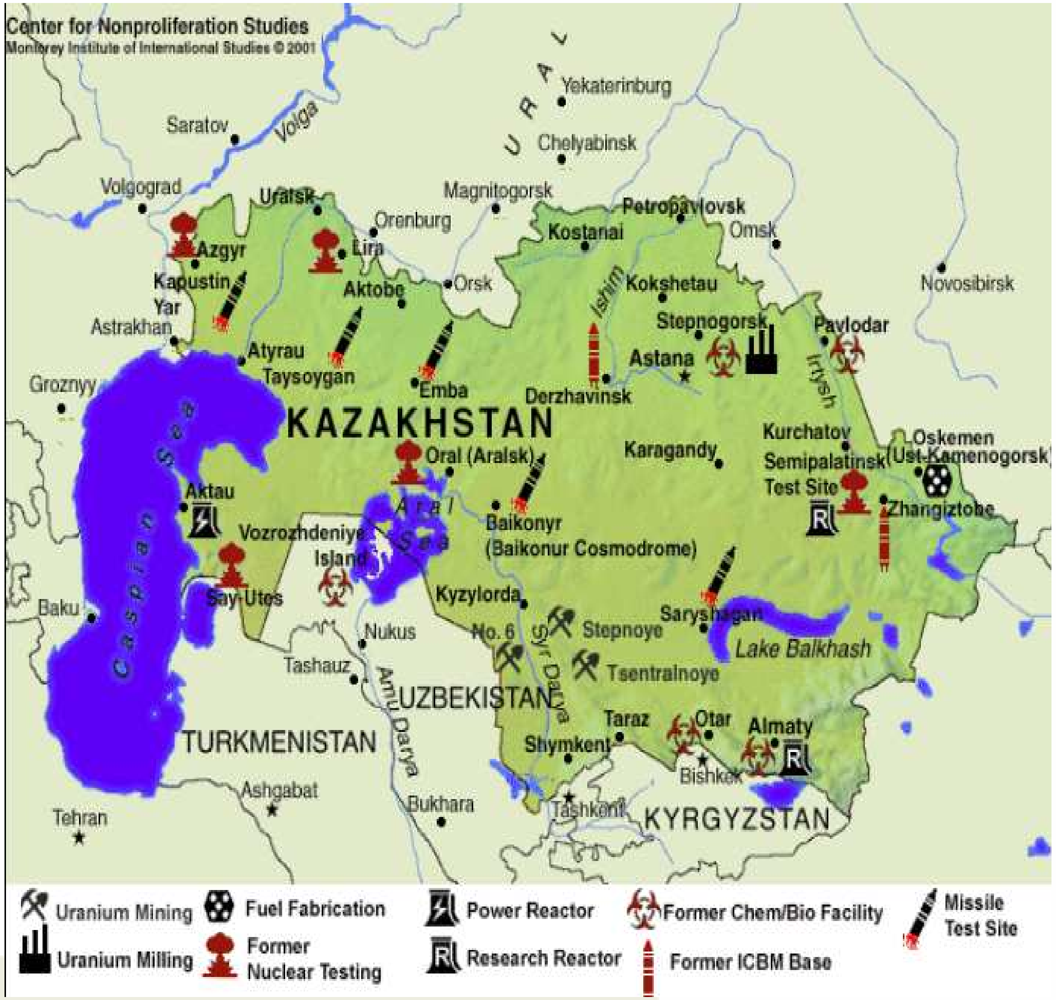
Sample Alg-4:

- 468 g of black fragments of fused sand
- crushed before measurement
- Ground Zero of Gerboise Bleue test ~ 60 kt TNT

From: Danessi et al., IAEA 2005
Black fragments of fused sand

Previous studies – Yamamoto et al. 1996

- Activity of soil (2-3 mm depth) at First experimental site, Semipalatinsk, Kazachstan near hypocenter of the first Soviet nuclear explosion (29.8.1949)



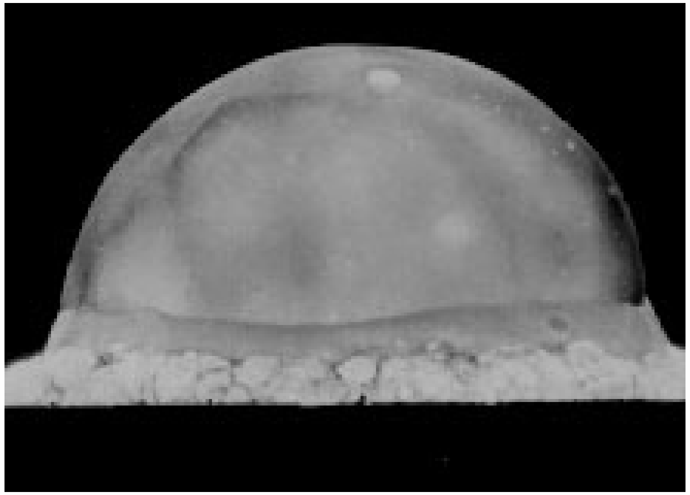
Universität Bremen

Previous studies

Authors	From	Journal	Year	Methods	Results
TRINITY SITE					
Hermes, Strickfaden	Los Alamos National Laboratory	Nuclear Weapon Journal	2005	Non-radiological study	•Yeald calculation •Fireball temperature •Fireball duration •Heat in the rising fireball •Spread of the ejecta
Hermes et al.	Los Alamos National Laboratory	Not published yet		Micro x-ray fluorescence Gamma, beta and alpha spectroscopy	Continuous study on trinitite and beads

Previous studies – Hermes, Strickfaden 2005

- Using (non-radiological) properties of trinitite back-calculated:
  - yield of the bomb: 9-18 kt + 4,2 kt carried away by the mushroom cloud
  - avarage fireball temperature of 8430 K and duration of the fireball: 3,1 s
  - crater depth of: 4 ft – 1,4 m

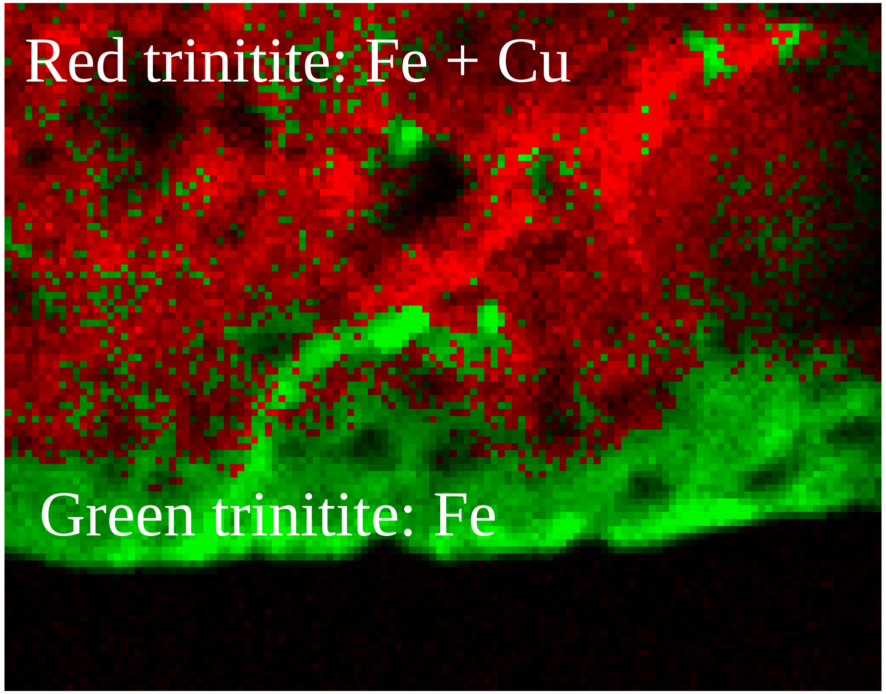


Previous studies – Hermes, Strickfaden 2005

- trinitite was formed not by simple heating and melting the sand
- instead: blasting the material to the air and raining down in the form of little droplets
- ground itself hot – forming a layer of trinitite
- trinitite more radioactive at the top glassy side than at the bottom sandlike side – beads even more radioactive
- study of trinitite and small trinitite beads in anthills

Previous studies – Hermes, Strickfaden unpublished

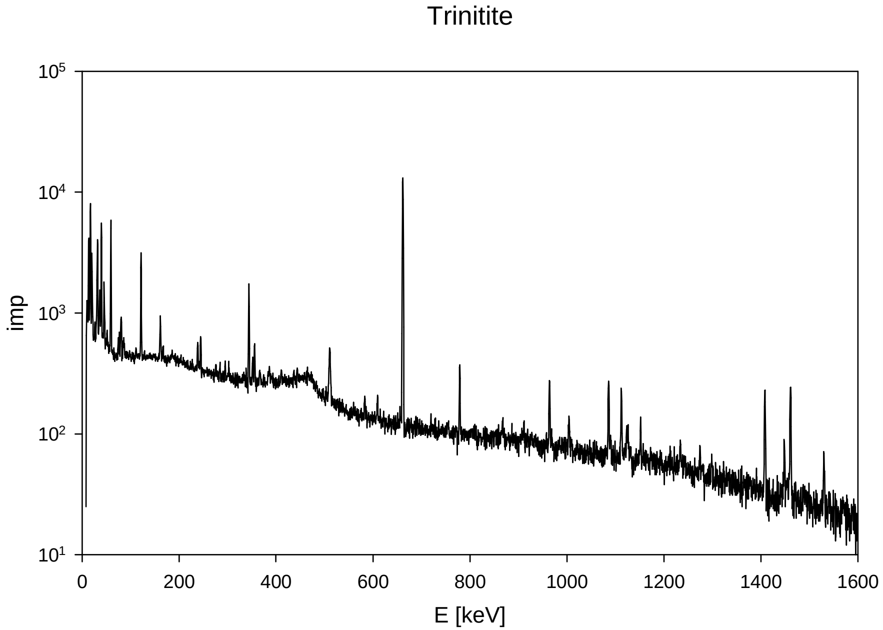
Ants bring up and collect trinitite and beads from the area



Micro x-ray fluorescence image –green coating at the top of red trinitite

Our sample

- mass: 2,2 g
- price: $25 ☺

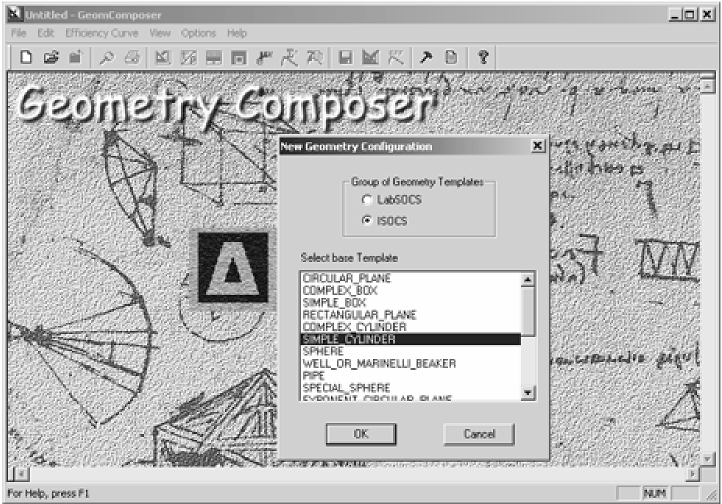


Upper side

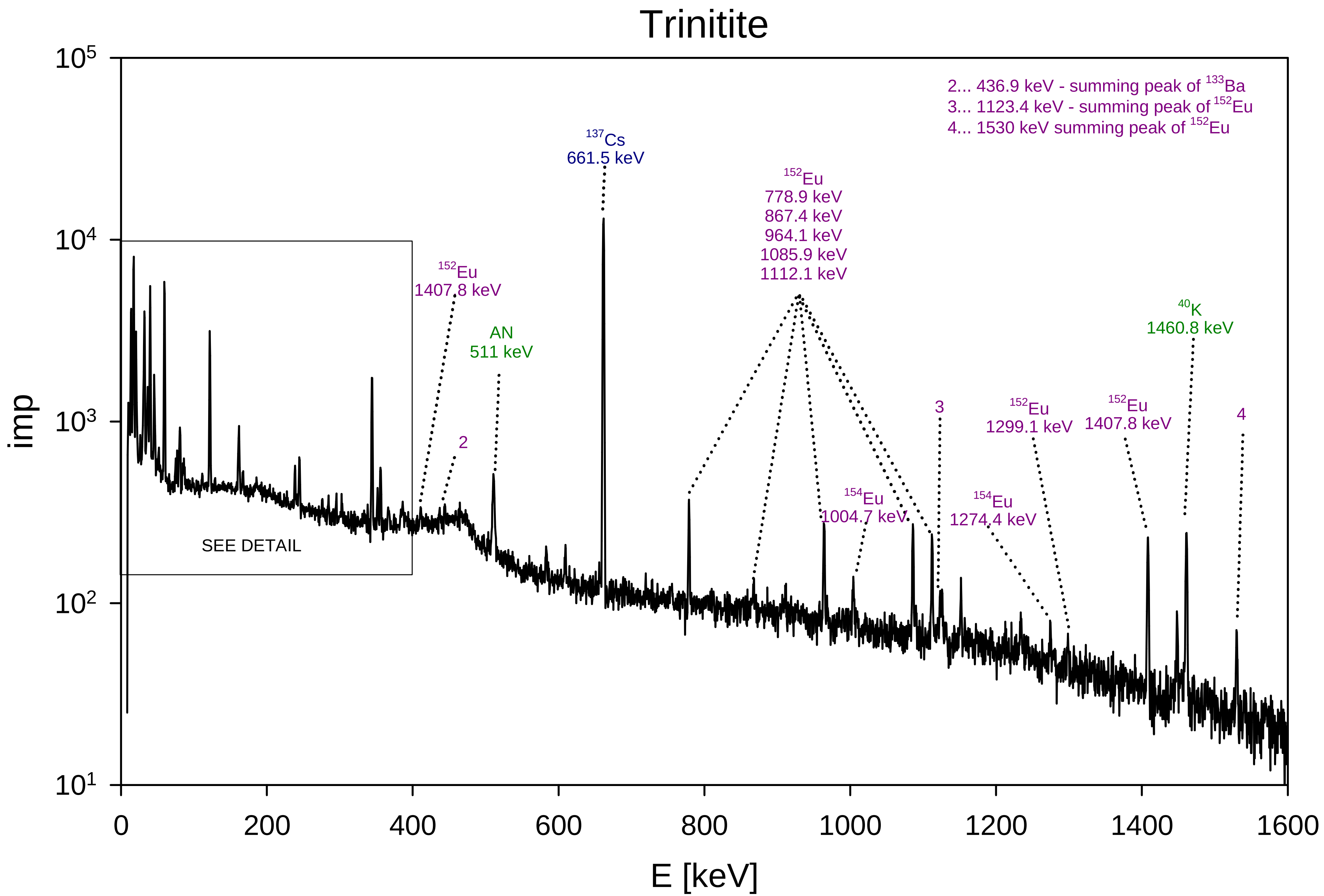
Bottom side

Gamma-analysis

- Using HPGe detector No. 3
- Canberra software Genie2000
- Modelled geometry in ISOCS Geometry Composer:
  - cylinder: diameter 20 mm, hight 5 mm
  - material: glass
  - density: 2,6 g/cm^3

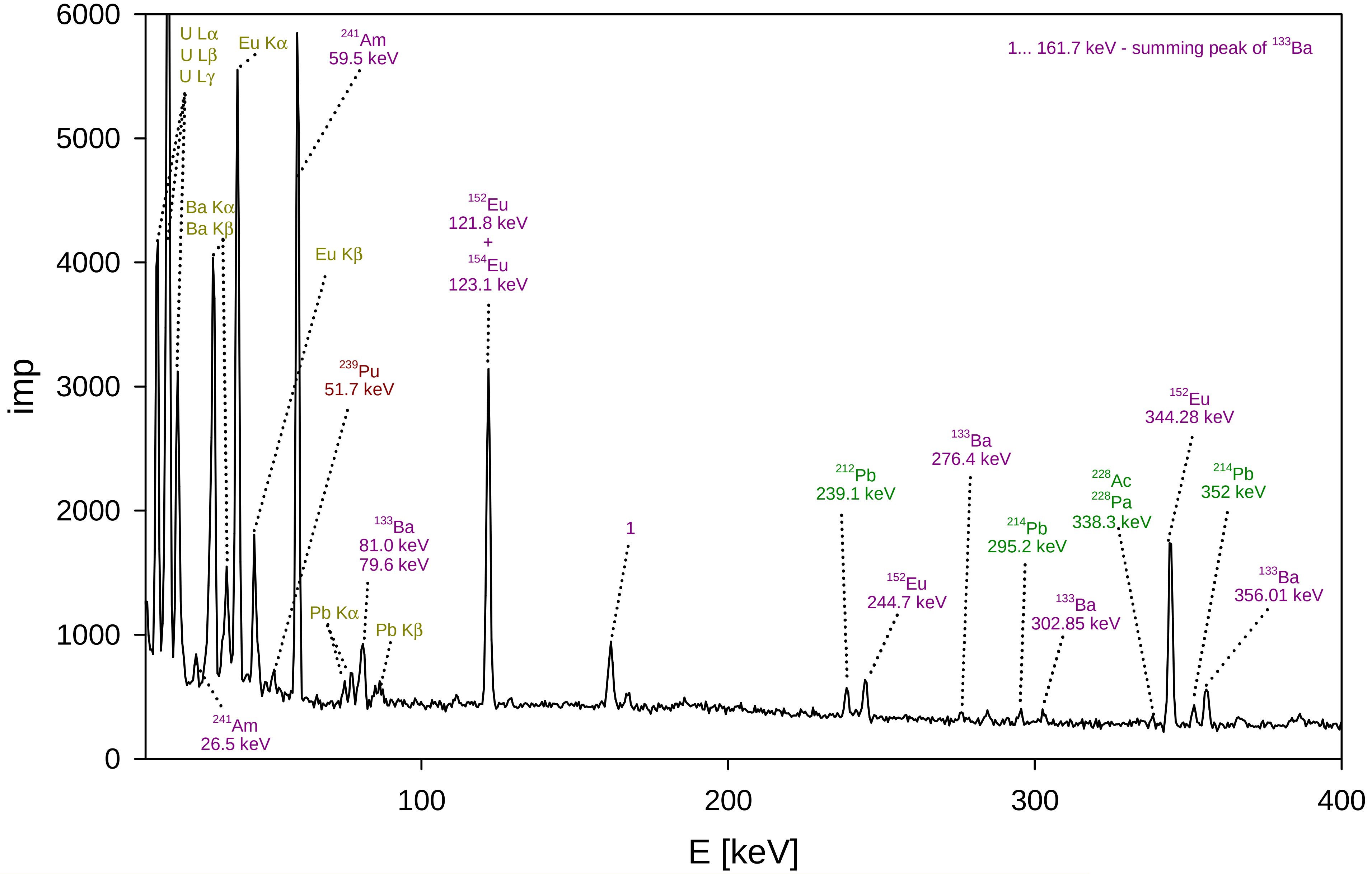


Universität Bremen



Universität Bremen

Trinitite (detail low energies)



Comparing measured activities

(recalculated to 1945)

Isotope	Half-life [yr]	Unit	Atkatz	Schlauf et al.	Pareth et al.	LMS
^{60}Co	5,271	Bq/g	-	44 ± 4	44,4 ± 4,6 62,0 ± 4,9	<37,8 (not present)
^{137}Cs	30,0	Bq/g	83,2	90 ± 9	27,33 ± 0,08 121,8 ± 0,1	16,20 ± 0,86
^{133}Ba	10,54	Bq/g	-	9,9 ± 0,6	7,55 ± 0,45 9,80 ± 0,26	4,40 ± 0,41
^{152}Eu	13,33	Bq/g	-	27 ± 1	22,61 ± 0,38 78,89 ± 0,61	17,22 ± 1,3
^{154}Eu	8,8	Bq/g	-	4,8 ± 0,6	2,45 ± 0,60 16,1 ± 1,3	<3,3 (visible peaks)

Comparing measured activities

(recalculated to 2007 – except ^{241}Am)

Isotope	Half-life [yr]	Unit	Atkatz	Schlauf et al.	Pareth et al.	Yamamoto et al. Semipalatinsk	Danessi et al. Algeria	LMS
^{60}Co	5,271	Bq/kg	-	13,0 ± 1,2	13,1 ± 1,4 18,3 ± 1,4	1040 ± 23	370	<11,5 (not present)
^{137}Cs	30,0	Bq/g	20,0	21,7 ± 2,2	6,58 ± 0,02 29,30 ± 0,02	64,4 ± 0,5	26,5	3,94 ± 0,21
^{133}Ba	10,54	Bq/kg	-	170 ± 10	130 ± 8 168 ± 5	-	2234	75,6 ± 6,3
^{152}Eu	13,33	Bq/kg	-	1085 ± 40	909 ± 15 3172 ± 25	50060 ± 520	4742	748 ± 44
^{154}Eu	8,8	Bq/kg	-	36,9 ± 4,6	18,8 ± 4,6 124 ± 10	1084 ± 48	683	<22,8 (visible peaks)
^{241}Am	432,7	Bq/g	-	2,9 ± 0,5 (1997)	1,841 ± 0,053 4,137 ± 0,058 (2006)	0,52 ± 0,01 (1994)	2,3 (1999)	0,734 ± 0,046 (2007)

Origin of radionuclides

Isotope	Half-life/ yr	Origin
^{137}Cs	30,0	fission product (beta decay of ^{137}Xe and ^{137}I and also independently)
^{60}Co	5,271	activation of ^{59}Co – from test tower steel and from soil
^{133}Ba	10,54	activation of ^{132}Ba – Ba part of explosive lense system (Ba $(NO_3)_2$ - Baratol)
^{152,154}Eu	13,33 / 8,8	activation of stable isotopes ^{151,153}Eu in soil by slow neutrons
^{241}Am	432,2	mostly by beta decay daughter of ^{241}Pu, produced mainly from ^{239}Pu during the explosion via double-neutron capture
^{239}Pu	24100	fuel

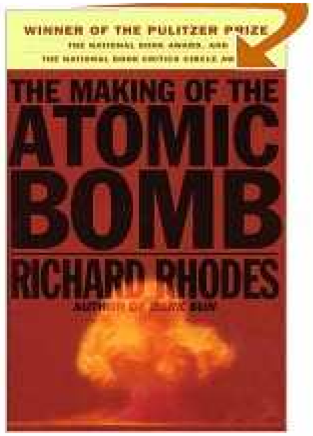
Comparing measured activities

(natural radionuclides)

Isotope	Half-life [yr]	Unit	Pareth et al.	LMS
^{40}K	$1{,}277.10^{9}$	Bq/kg	741 ± 15 846 ± 18	922 ± 77
^{232}Th (^{228}Ac)	$1{,}405.10^{10}$	Bq/kg	27,5 ± 3,5 35,9 ± 5,1	44,5 ± 4,4 (^{212}Pb)
^{238}U (^{214}Pb)	$4{,}468.10^{9}$	Bq/kg	32,3 ± 3,1 40,4 ± 8,3	48,5 ± 5,6

Discussion

- Specific activities of anthropogenic radionuclides in “our” sample generally lower – about ½ - comparing to previously reported values
- not applied summing corrections for ^{133}Ba and ^{152}Eu
- but: natural radionuclides in a very good agreement with previous studies
- unknown distance and position of the sample from GZ – influence of neutron flux, temperature
- not even 100% certain that the sample comes from original Trinity test



Further reading

BOOKS:

- Richard Rhodes: ***The Making of the Atomic Bomb***, Simon and Schuster 1986, New York
- Ferene Szasz: ***The Day the Sun Rose Twice***, University of New Mexico Press 1984, Albuquerque
- Robert Jungk: ***Brighter than a Thousand Suns***, 1958

INTERNET:

- K. T. Bainbridge: ***Trinity***. LANL report, 1976. Download from the Los Alamos National Laboratory website http://www.lanl.gov/history/atomicbomb/trinity.shtml
- Web page of White Sands Missile Range http://www.wsmr.army.mil

Thanks to Nic for the trinitite and books
&
you for your attention!