Trinitite – the Atomic Rock

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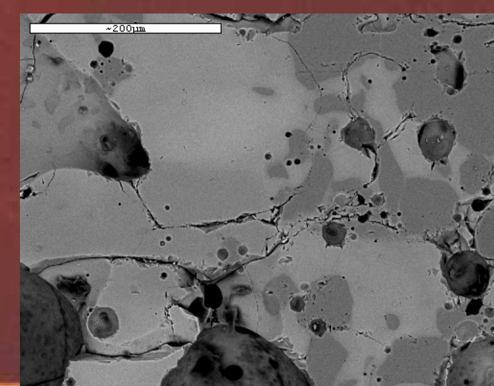


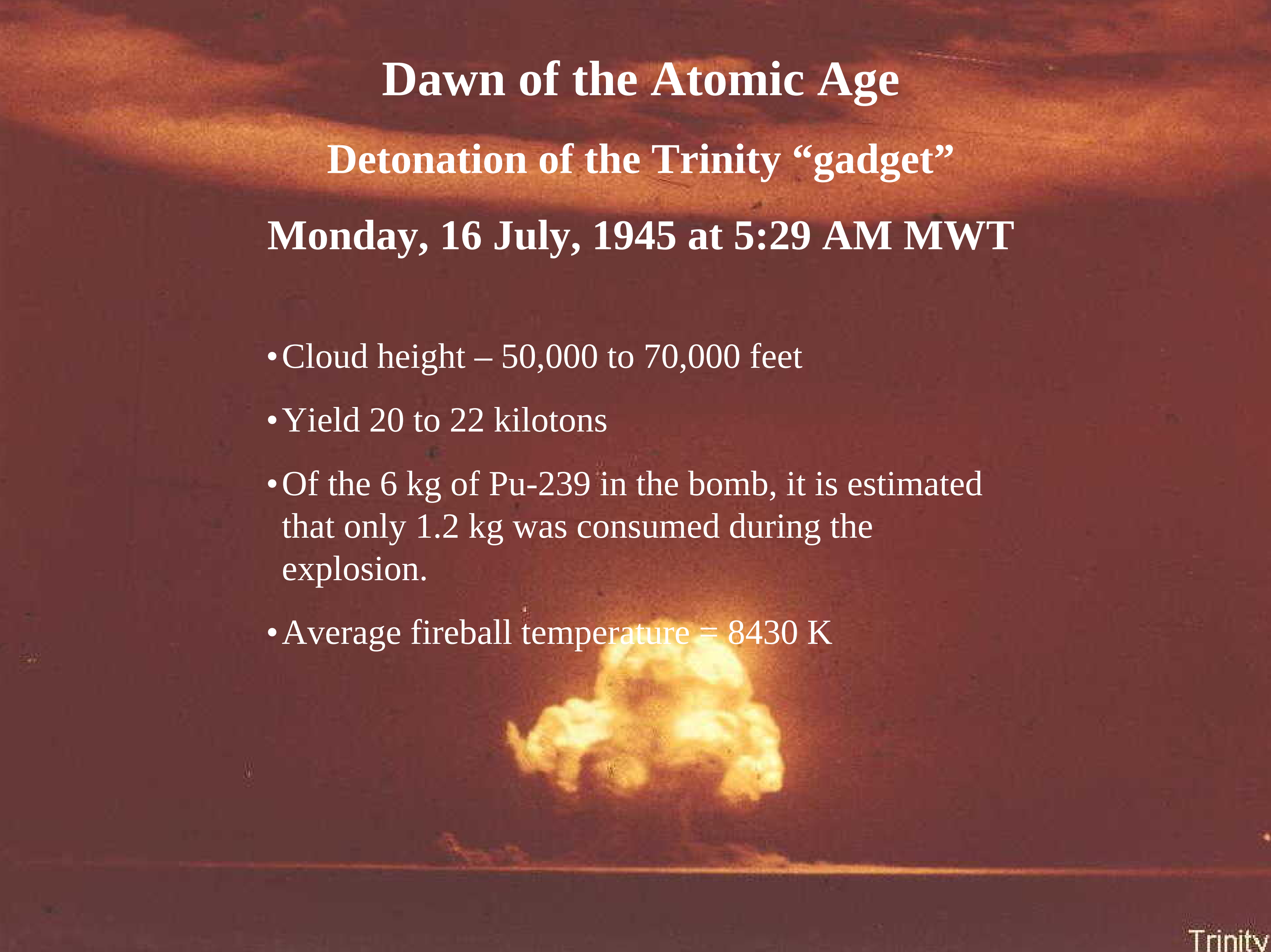
Trinity

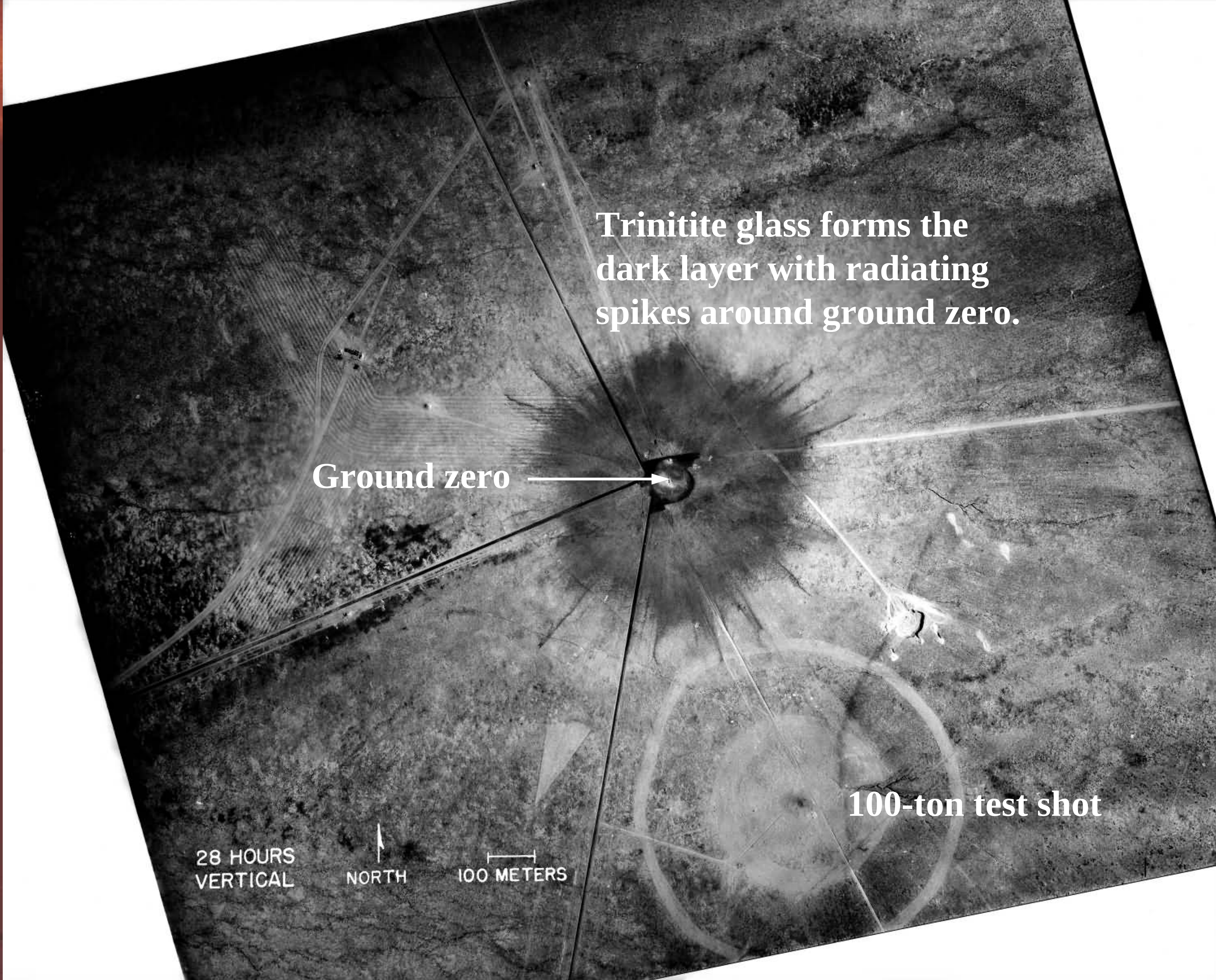
Dawn of the Atomic Age

Detonation of the Trinity “gadget”

Monday, 16 July, 1945 at 5:29 AM MWT

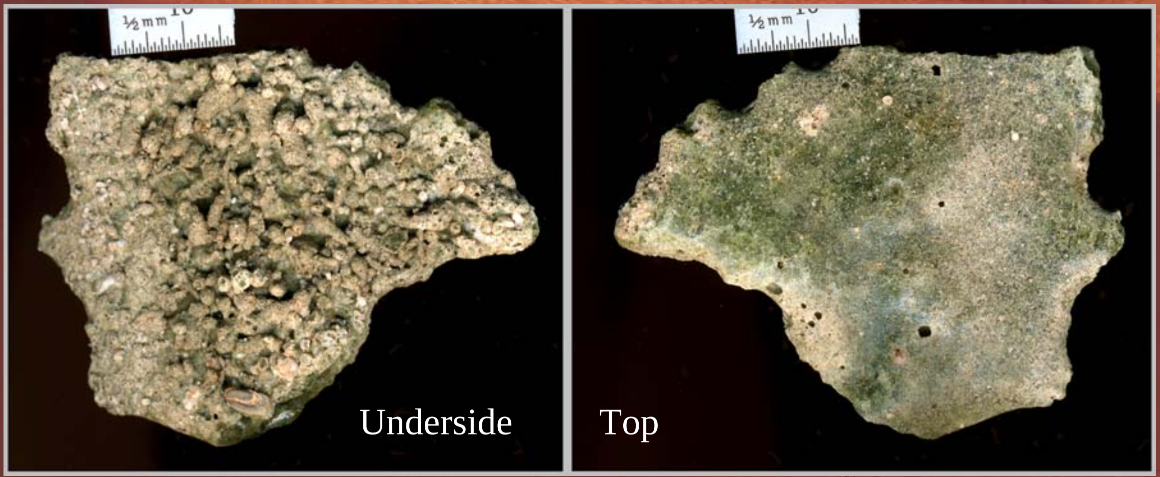
- Cloud height – 50,000 to 70,000 feet
- Yield 20 to 22 kilotons
- Of the 6 kg of Pu-239 in the bomb, it is estimated that only 1.2 kg was consumed during the explosion.
- Average fireball temperature = 8430 K



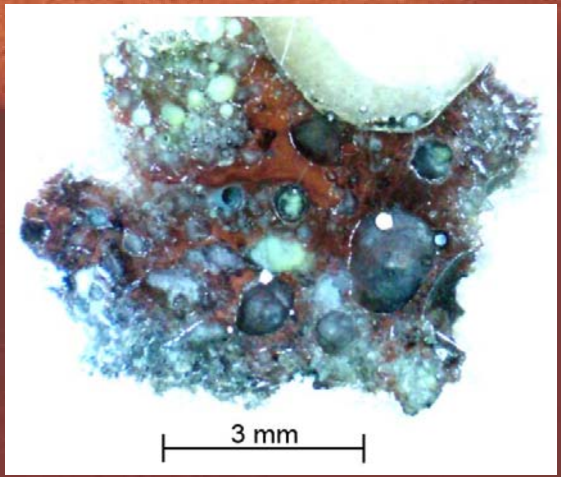

Trinitite glass forms the dark layer with radiating spikes around ground zero.
Ground zero
100-ton test shot
28 HOURS VERTICAL
NORTH
100 METERS

Types of Trinitite

Pancake trinitite



Red trinitite



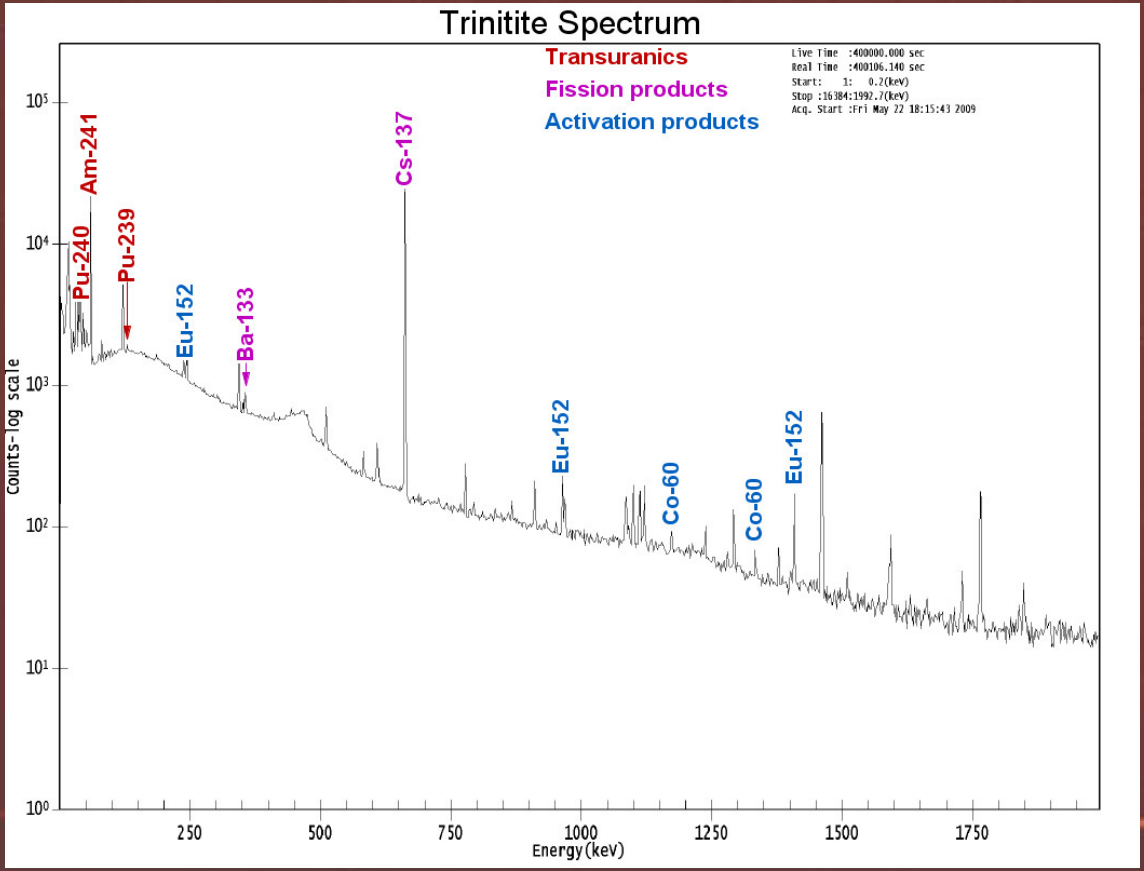
Green trinitite glass

Green trinitite beads

Trinity

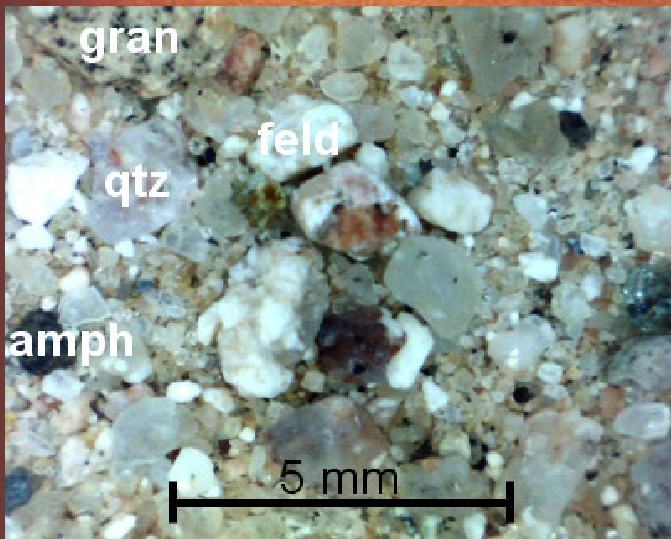
Radioactivity in trinitite

- Pu and U (used in the tamper) from the bomb
- Fission products – Ba, Cs, LREE
- Activation products – measurable today: Co, Eu



Trinitite protoliths

Arkosic sand



Quartz

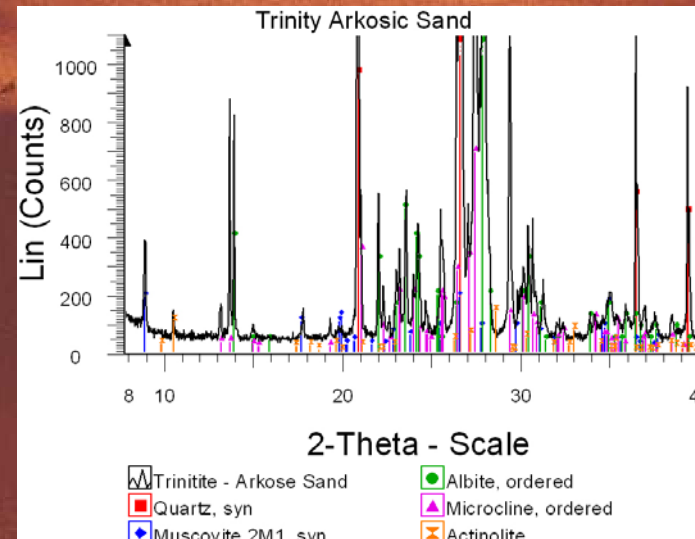
Microcline

Albite

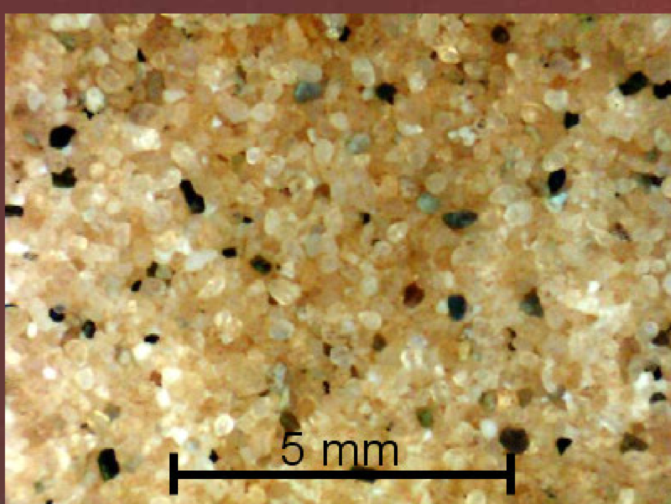
Muscovite

Actinolite

Rock frags



Dune sand



Quartz

Microcline

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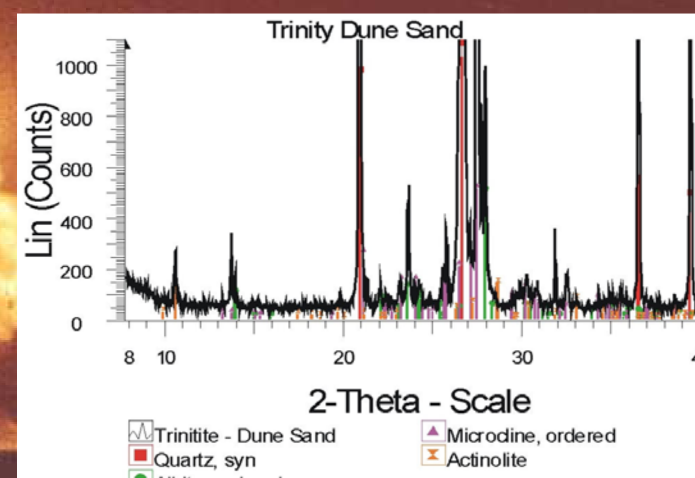

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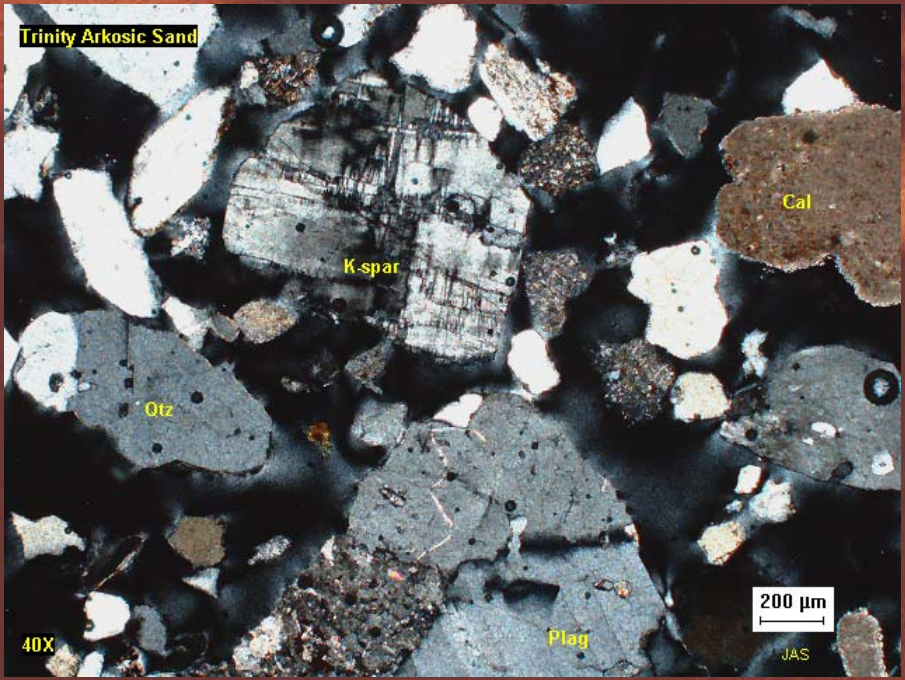
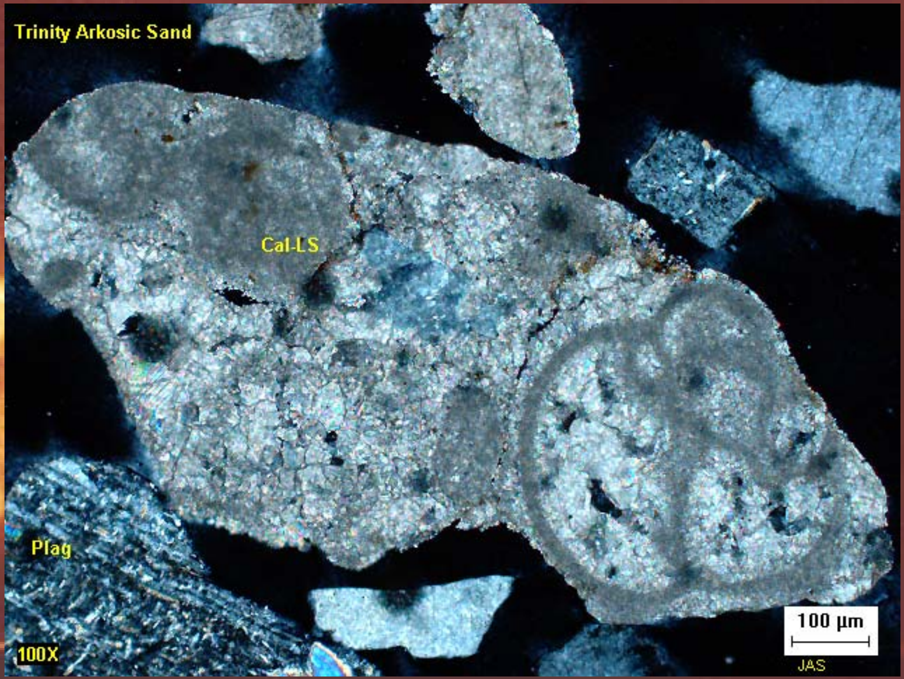
Photomicrographs of Trinity arkosic sand



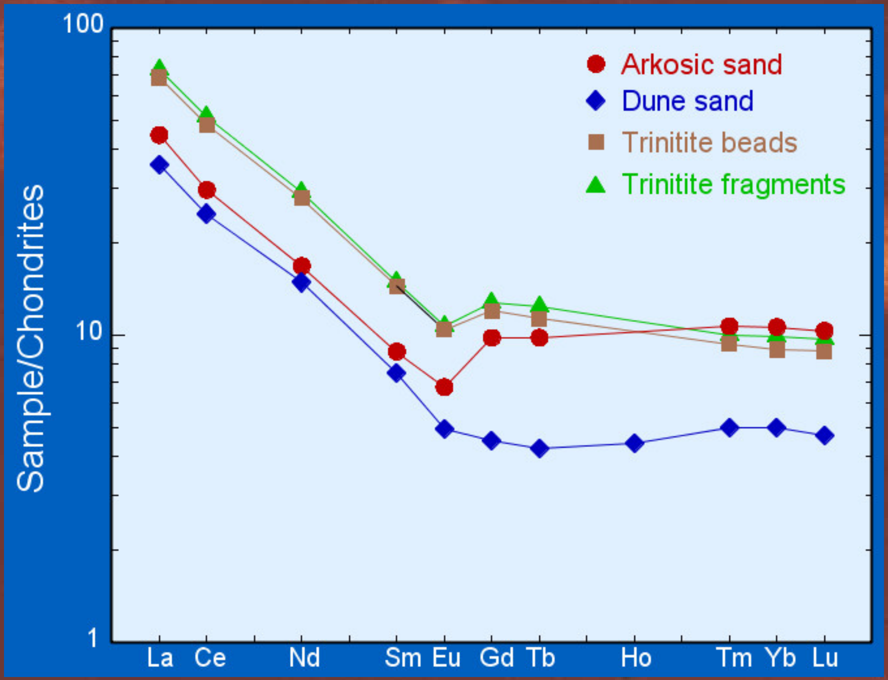
Arkosic sand showing quartz (Qtz), microcline (K-spar) and plagioclase (Plag). The feldspars are partially sericitized. Limestone (calcite - Cal) fragments (carbonate grains) are also observed.

The presence of carbonate grains in the sand most likely accounts for the relatively high Ca content of the Trinitite glasses.

Fossiliferous Limestone fragment.



Chemical changes from source material (sand) to trinitite



Trace metals, Sc, Co and Ni increase in the trinitite.

Fission products, Ba, La, etc. increase in the trinitite.

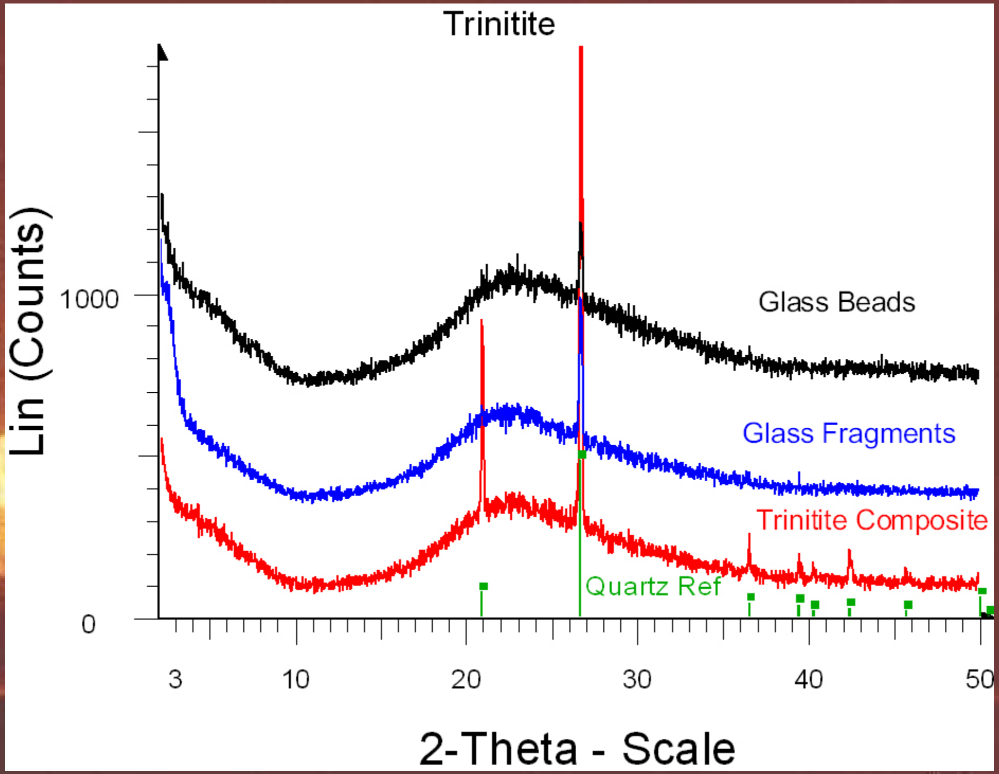
Th and U increase in trinitite probably from bomb. U was used in the tamper.

HREE are similar in trinitite and sand. Not added during the nuclear detonation.

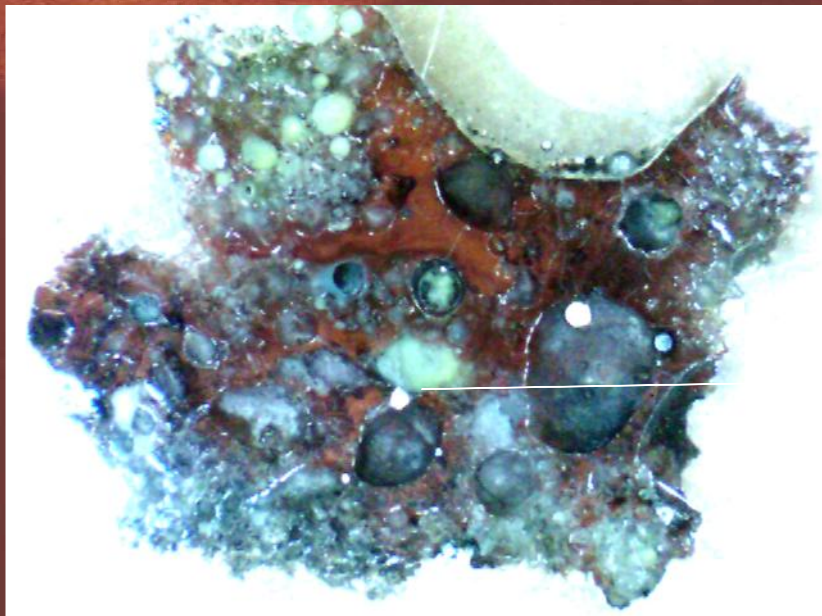
	Trinite Fragments	Trinitite Beads	Fine sand	Dune sand
Sc	4.48	4.9	1.9	2.16
Co	4.7	5.34	1.86	2.63
Ni	23	21	8.8	7.0
Sr	179	176	126	80
Ba	808	740	694	432
La	24.13	22.67	14.74	11.84
Gd	3.5	3.3	2.7	1.25
Yb	2.16	1.97	2.33	1.1
Hf	6.91	5.19	4.96	4.06
Ta	0.78	0.67	0.44	0.35
Th	9.15	8.59	6.99	2.01
U	2.7	2.62	1.8	0.75

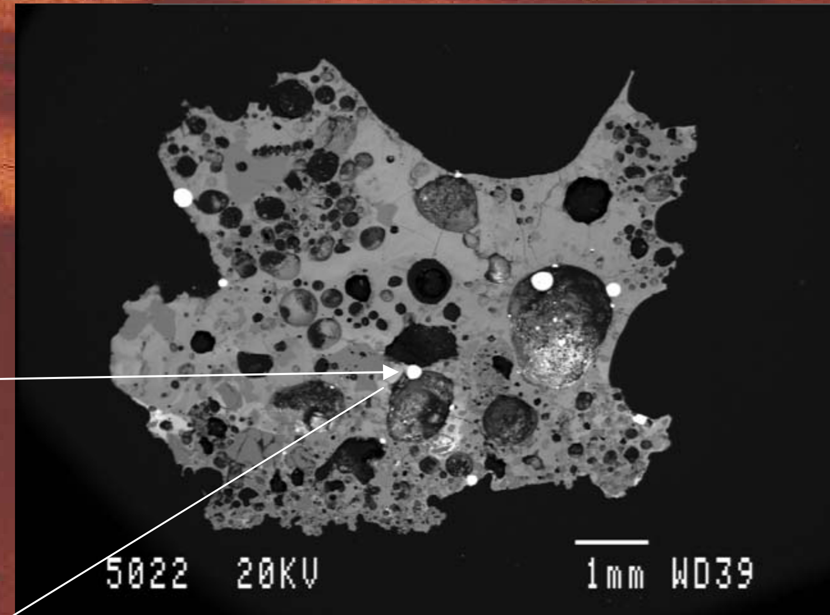
XRD patterns for trinitite fragments and beads

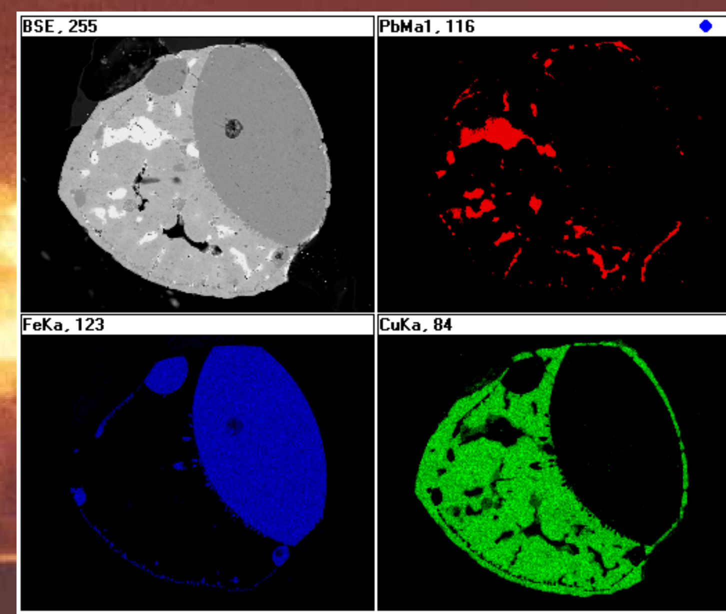
The only crystalline phase found in trinitite is alpha-quartz. All other phases were melted during the detonation.



Red trinitite – bits of the first atomic bomb



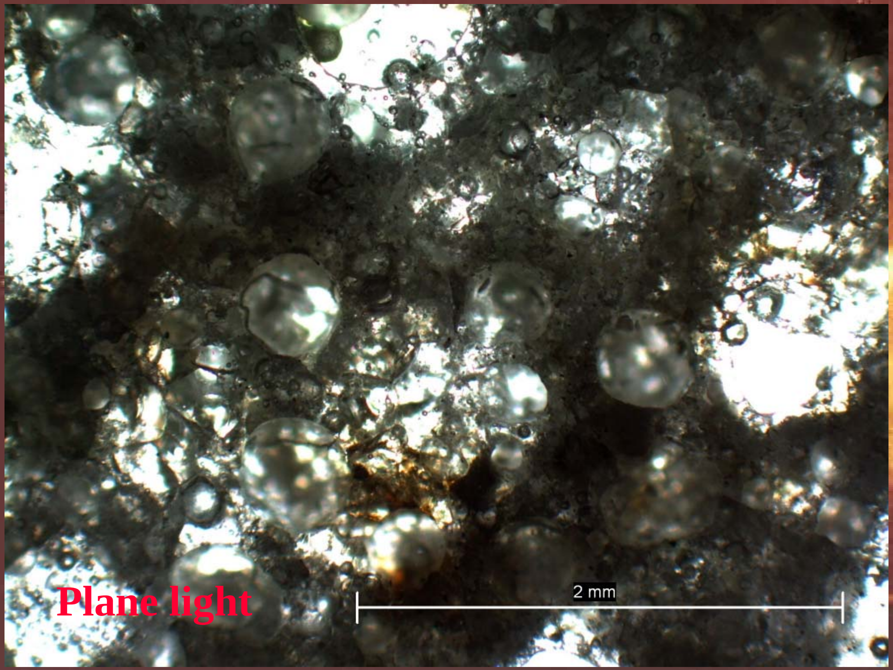


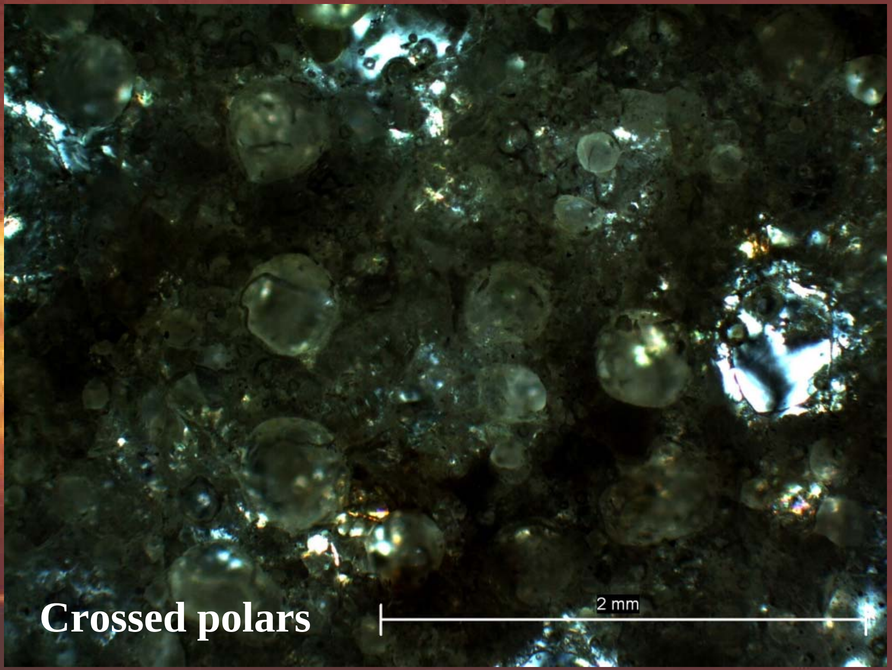


Trinity

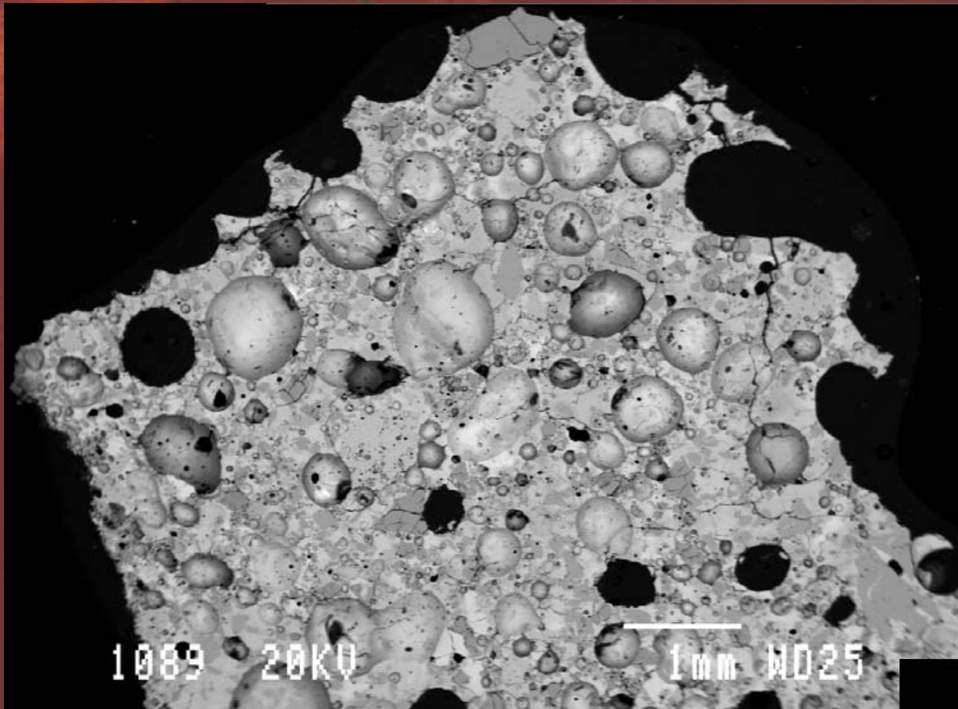
Trinity glass fragments

Typical of the material that is found in the immediate vicinity of ground zero. Forms the top part of the trinitite layer.



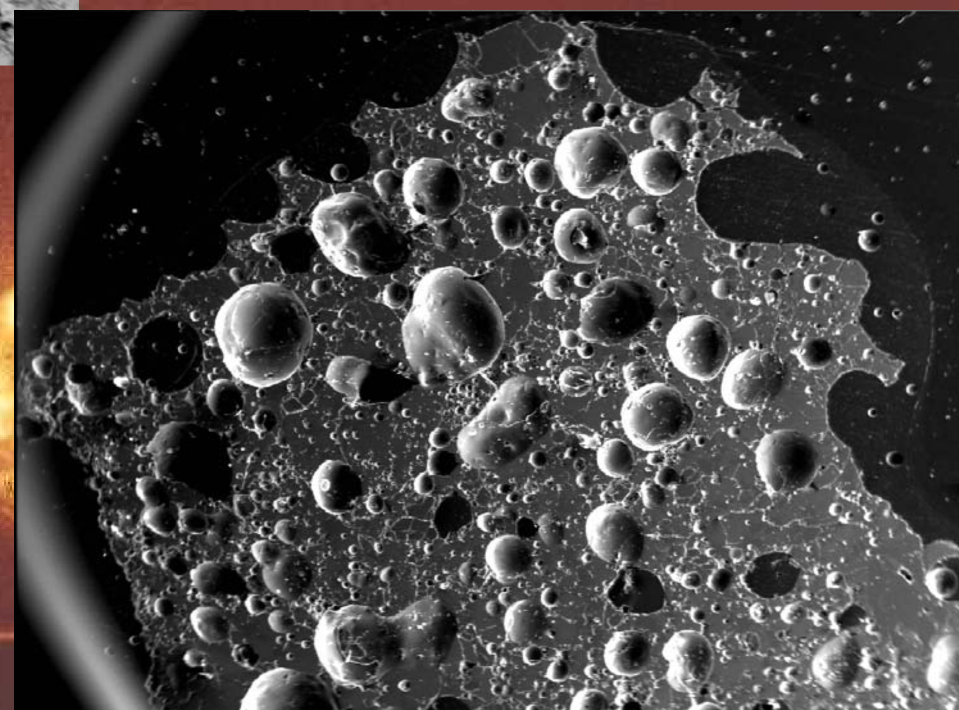


SEM Images of Trinitite fragments showing texture and relief



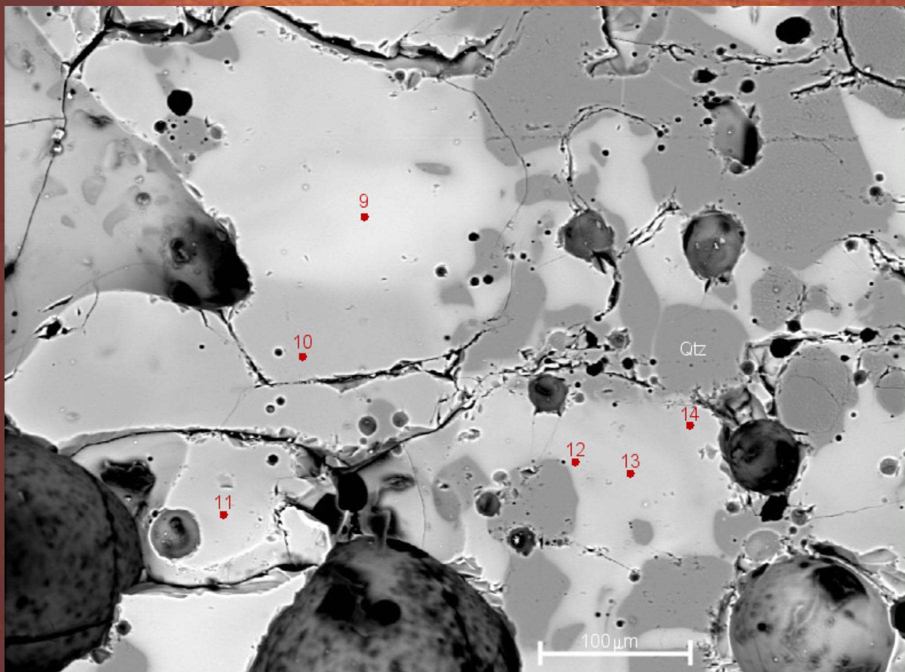
Back scattered electrons

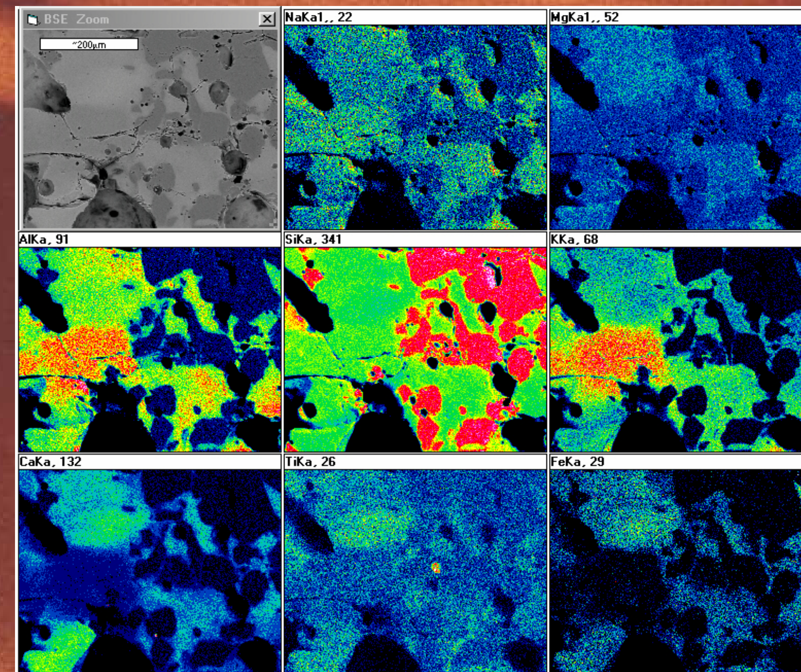
Secondary electrons



Trinity

Variations in Trinitite Chemistry – Glass Fragment



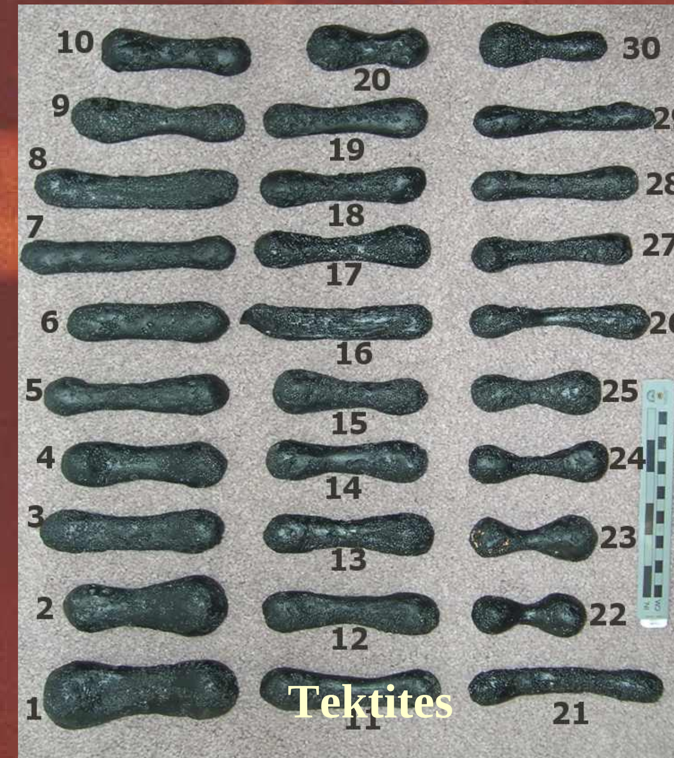


Sample	SiO2	TiO2	Al2O3	FeO	MnO	MgO	CaO	Na2O	K2O	Total
GL9 (light)	56.75	1.89	13.47	4.29	0.10	2.28	12.53	1.22	4.54	97.07
GL10 (dark)	63.46	0.27	18.82	nd	nd	0.21	0.96	2.08	11.70	97.50
GL11 (light)	60.21	0.51	15.40	1.86	nd	1.16	10.71	1.49	6.50	97.84
GL12 (med)	62.99	0.36	13.86	2.52	0.11	1.68	8.49	1.46	6.11	97.58
GL13 (med)	62.26	0.45	14.65	3.00	0.07	1.81	8.38	1.63	5.63	97.88
GL14 (med)	62.04	0.21	17.93	1.55	nd	1.05	6.89	1.97	6.16	97.80

Ant-Hill Trinitite

Trinitite particles were distributed across a broad area. During construction of ant-hills these particles are pushed to the surface and are found rimming the entrance to the ant-hill.

The trinitite particles found around ant-hills occur as beads and dumbbells and resemble tektities. These particles were apparently transported through the atmosphere as molten blobs.



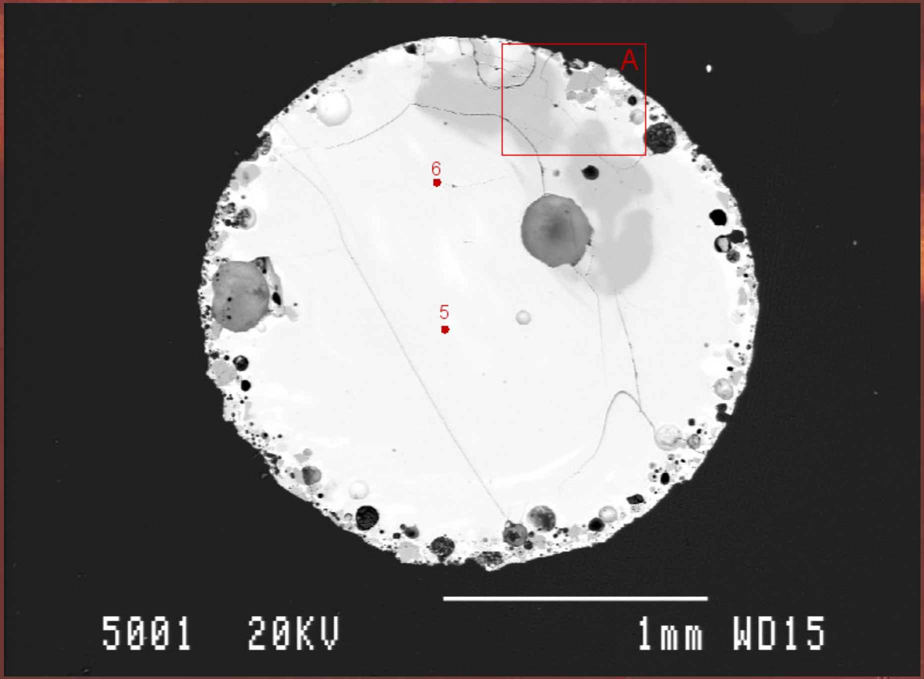
Tektites

Beads and dumbbells

Trinitite beads

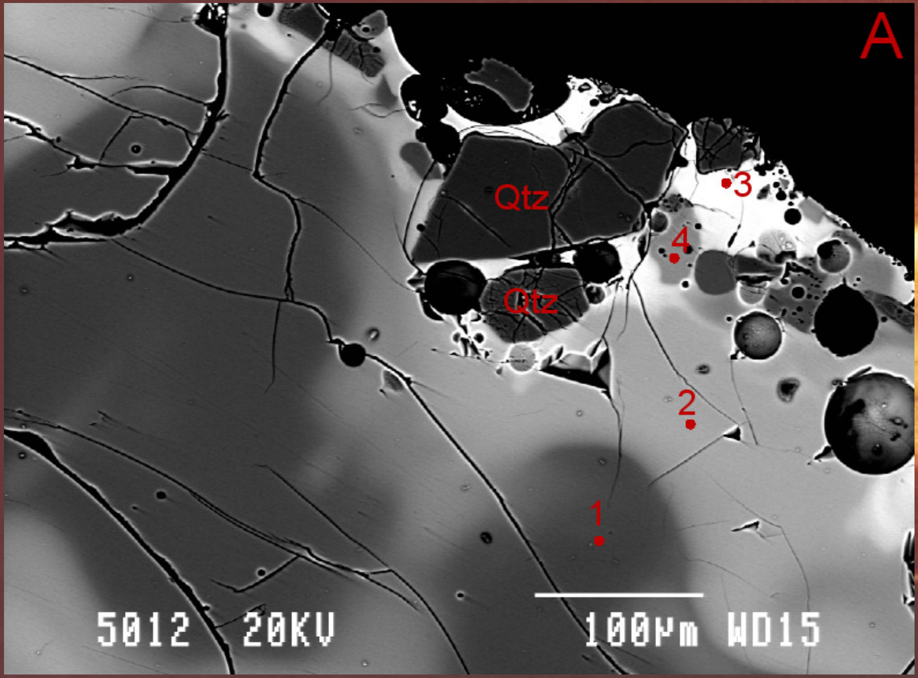
Trinitite dumbbells

Trinitite Bead



Note quartz grains embedded along edge of bead. These were entrained during transport.

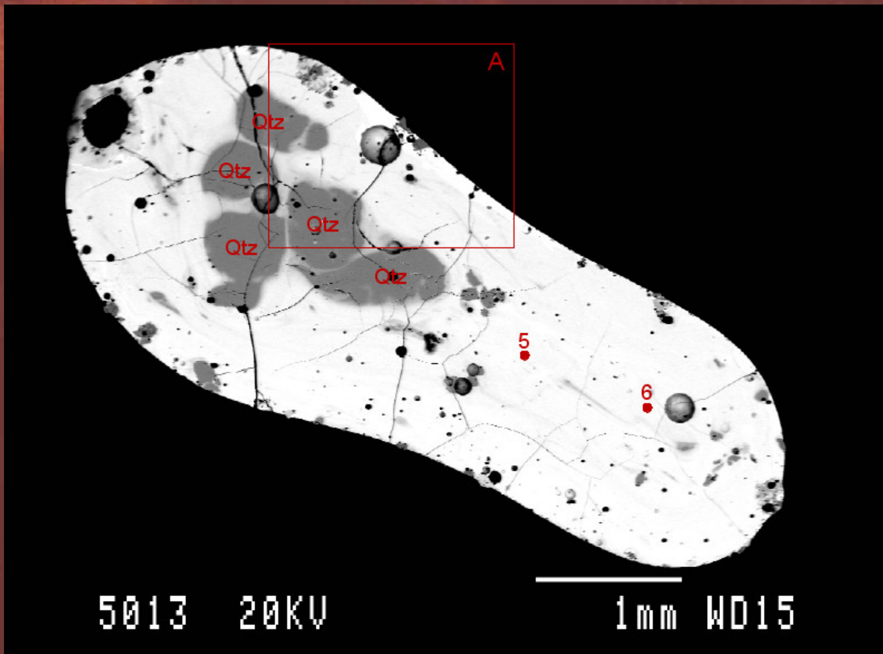
Darker areas within the bead are melted quartz grains (TB1). Also note the range in chemical composition shown for the glasses even in this small bead. TB4 is melted K-feldspar. High CaO in other glasses may be contributed by melted carbonate grains.

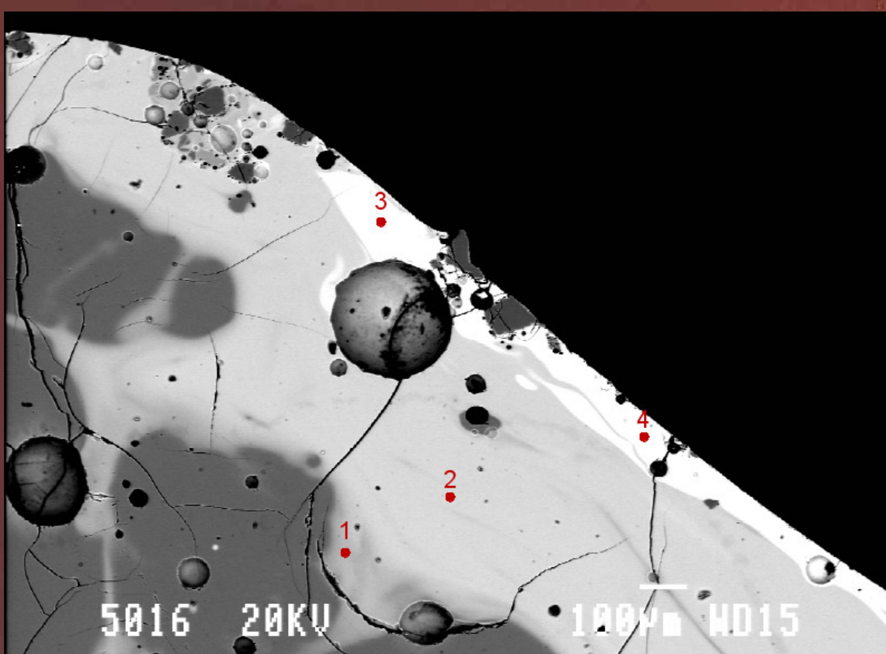


	TB1	TB2	TB3	TB4	TB5	TB6
SiO2	96.80	64.31	51.53	63.56	62.60	64.02
TiO2	0.10	0.31	0.26	0.08	0.37	0.27
Al2O3	0.35	14.57	11.49	18.46	15.19	14.67
FeO	0.17	2.18	3.20	0.13	2.39	2.37
MnO	nd	0.13	0.11	nd	nd	0.09
CaO	1.40	12.70	27.33	0.52	12.81	12.91
MgO	0.10	1.10	1.78	0.29	1.27	1.10
Na2O	0.10	0.95	0.73	1.83	0.74	0.74
K2O	0.53	1.44	2.66	13.47	1.43	1.44
Total	99.56	97.68	99.09	98.33	96.80	97.62

Trinity

Trinitite Dumbbell



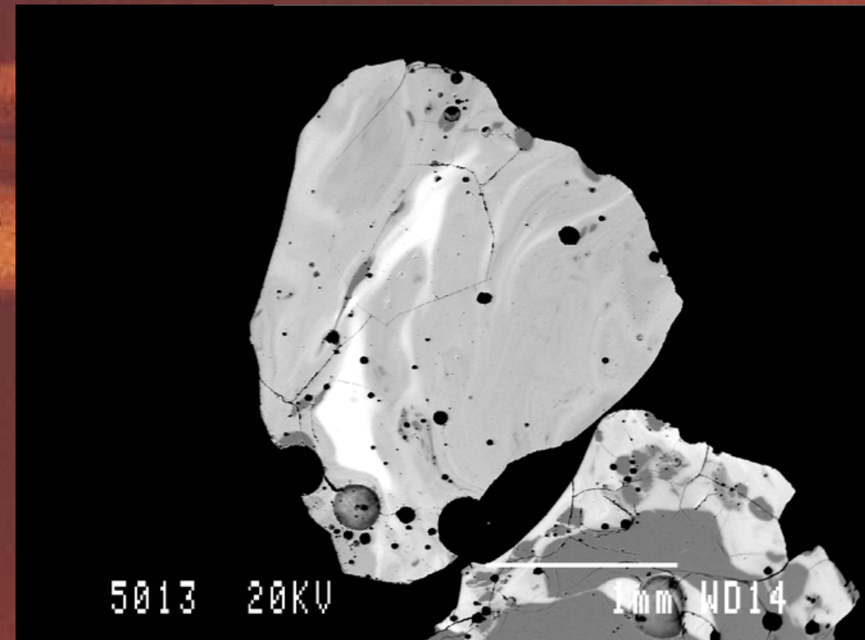


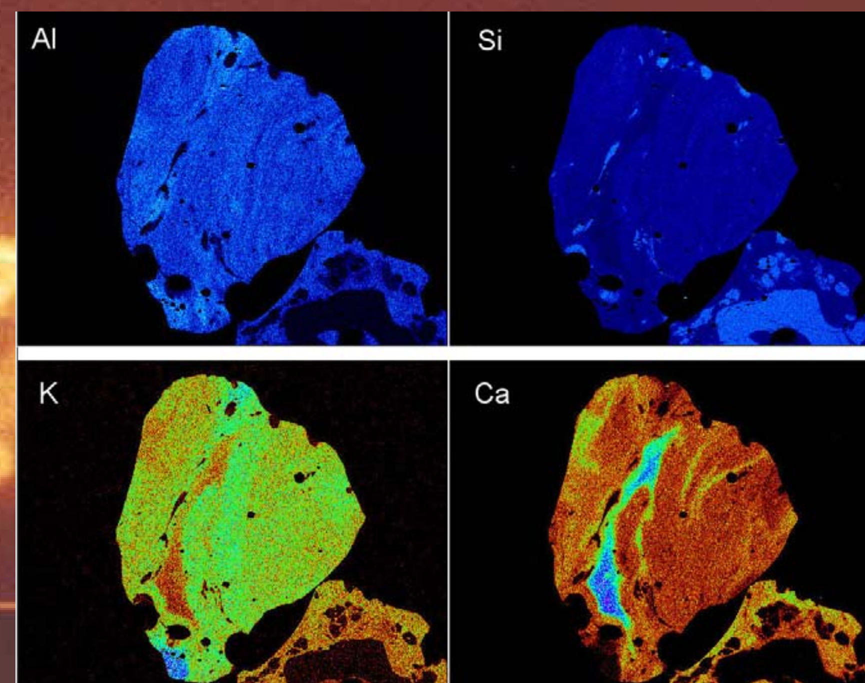
Glasses are MgO rich. TDB3 and TDB4, in terms of chemical composition, roughly correspond to Mg-Gedrite. Some of the other compositions suggest dilution by melted quartz grains plus feldspar. TDB1, which has the highest SiO2, is immediately adjacent to a partly melted quartz grain which supplied the SiO2.

	TDB1	TDB2	TDB3	TDB4	TDB5	TDB6
SiO2	70.53	64.41	47.52	47.15	64.25	66.32
TiO2	0.19	0.39	0.33	0.43	0.35	0.22
Al2O3	11.38	12.27	16.05	16.49	11.95	11.68
FeO	1.50	2.22	2.33	2.34	2.08	2.03
MnO	0.02	nd	nd	0.05	nd	0.06
MgO	10.66	15.50	31.17	30.88	15.44	13.68
CaO	1.01	1.21	1.56	1.55	1.04	1.10
Na2O	2.26	1.84	0.45	0.54	1.77	1.85
K2O	3.15	2.66	0.63	0.58	2.77	3.07
Total	100.68	100.52	100.05	100.02	99.66	100.00

Trinite Bead

Back-scatter image and element maps showing intimate layering at the 10 to 100 micron scale. Brighter areas are Ca-rich. Note fine banding shown by the Al map and spot silica concentrations (probably remnant quartz grains) shown on the Si map. Relatively high potassium concentrations indicated by the K map suggest that K-feldspar was an important component in the formation of this bead.

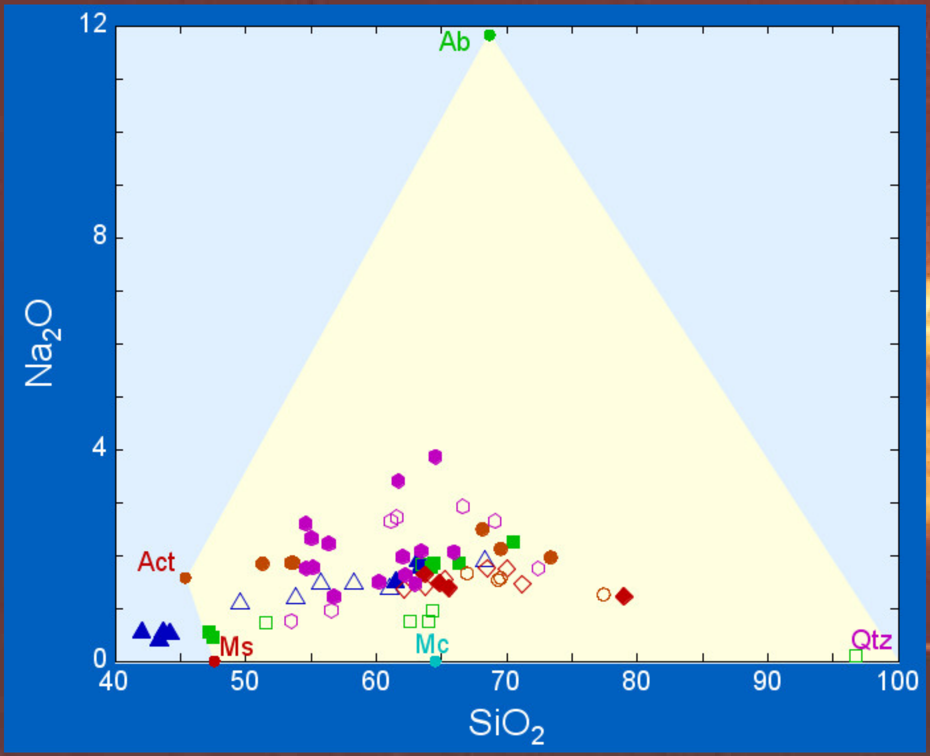


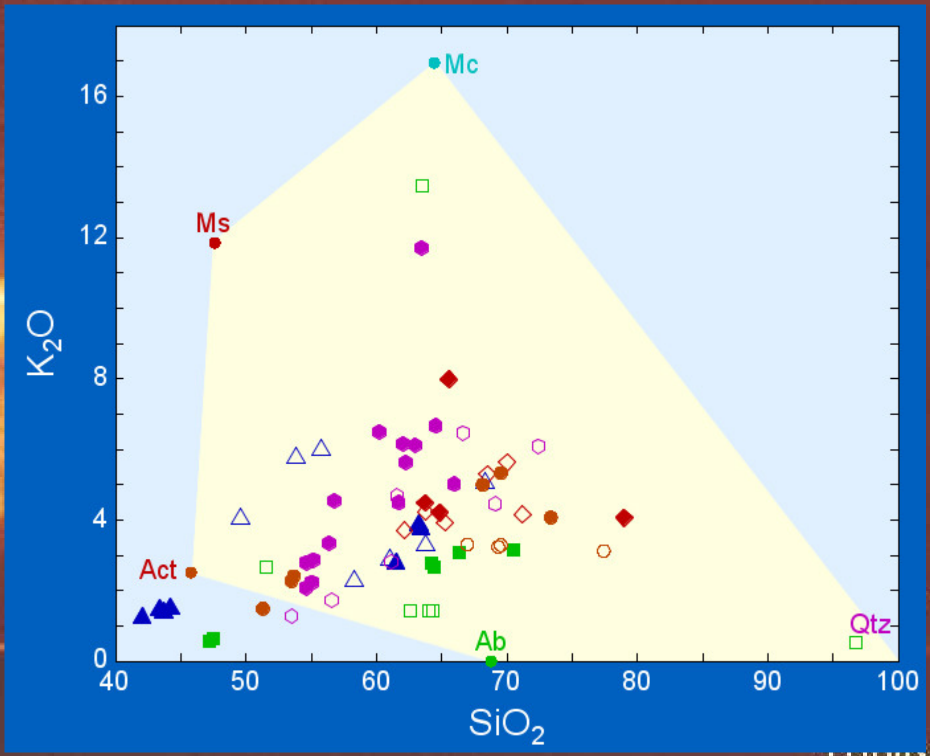


Trinity

Chemistry of Trinitite Glasses I

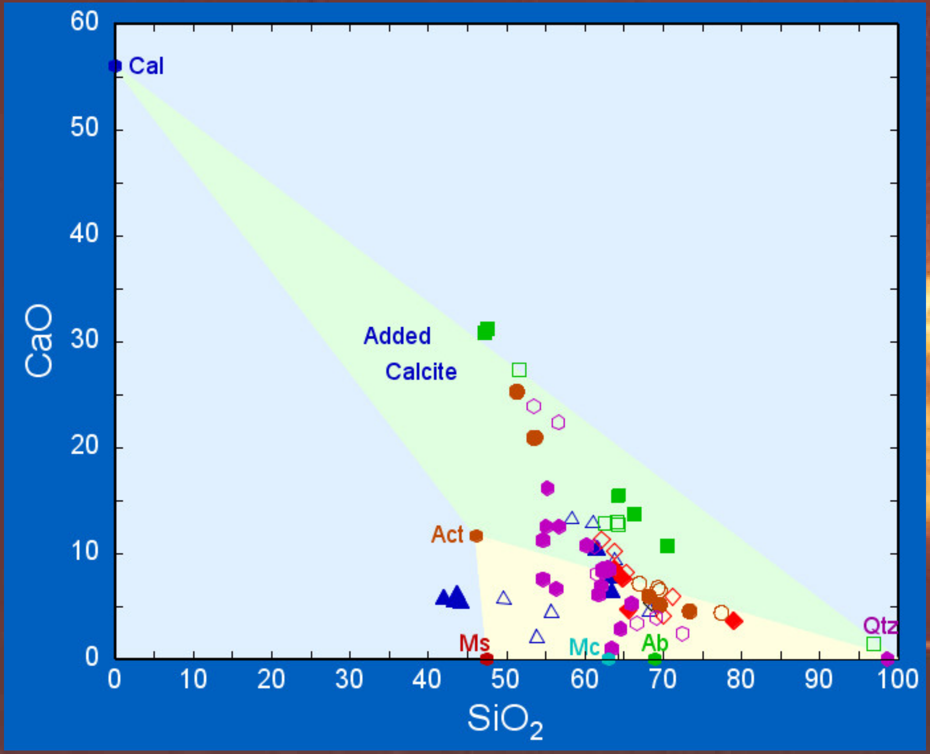
The chemical compositions, when projected into the Ab-Or-Qtz phase diagram (not shown) scatter across much of the phase diagram – i.e. the glass compositions do not represent equilibrium melting. As a first approximation, the chemical variations in the glass can be ascribed to the melting of specific minerals and these melts are then blended to various degrees at the micron level. Variations in Na_2O and K_2O can be explained in terms of variable melt proportions of actinolite, albite, microcline, muscovite, and quartz.

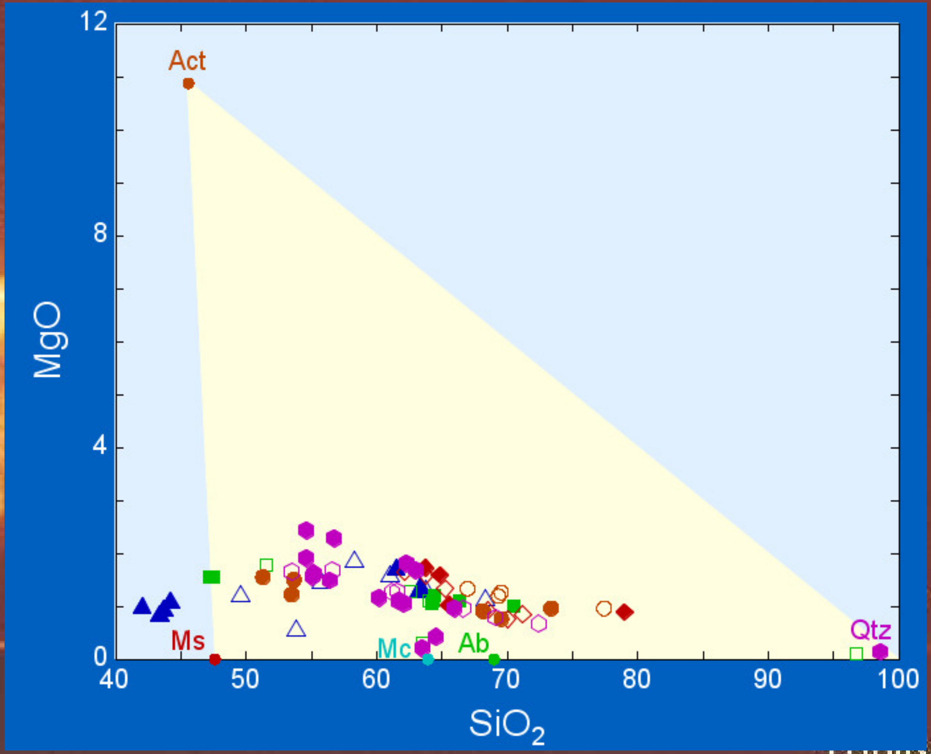




Chemistry of Trinitite Glasses II

The major source for MgO in the glasses is apparently melted actinolite which contributes variable amounts of MgO. CaO is a major component of many of the glasses and in general the abundance of this element controls the intensity of the BSE image. The CaO amounts exceed that which can be provided by any of the silicate minerals. Calcite grains and fossil fragments are found in the arkosic sand and we conclude that calcite is a major source for CaO in the trinitite glasses.





Conclusions

- Trinitite occurs in a variety of forms – (1) ~ 2 cm thick pancake trinitite with a glassy top and fused mineral grains constituting the bottom layer, (2) green vesiculated glass fragments, (3) red trinitite (red color due to copper in the glass), and (4) glass beads and dumbbells.
- Residual radioactivity is still detectable in the glass. The source of the activity is Pu and U from the bomb, fission fragments (Cs, Ba, LREE), and neutron activation products (Co, Eu).
- The protolith for the trinitite glasses is an arkosic sand that consists of quartz, microcline, albite, muscovite, actinolite, and carbonate. The only crystalline phase found in the glasses is alpha-quartz.
- Copper is found in the red trinitite glass and the glass also contains metallic chondrules consisting variously of iron, copper, and lead.
- At the 10s of micron levels the trinitite glasses are very heterogeneous. They usually contain quartz grains and recognizable domains of melted quartz. Glass compositions range from almost pure silica to K-rich, Na-rich, and Ca-rich compositions. The Ca-rich glasses represent the addition of Ca from calcite grains and fossil fragments. None of the glass compositions represent equilibrium melts.

Trinity