Health Impacts of World Trade Center Aerosols: Past, Present, and Predicted

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AWMA, March 2, 2011

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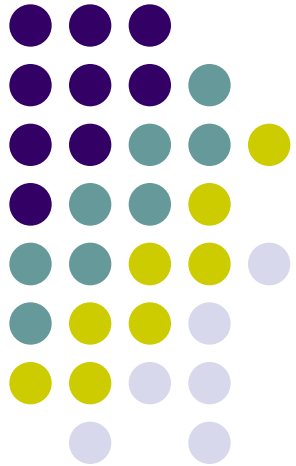


Background

The collapse of the World Trade Center structures (South Tower, North Tower, and WTC 7) presented two very different types of air pollution events:

1. Initial fires and collapse-derived “dust storm”, few hours, and
2. Continuing emissions from the debris piles, Sept 11 – mid December

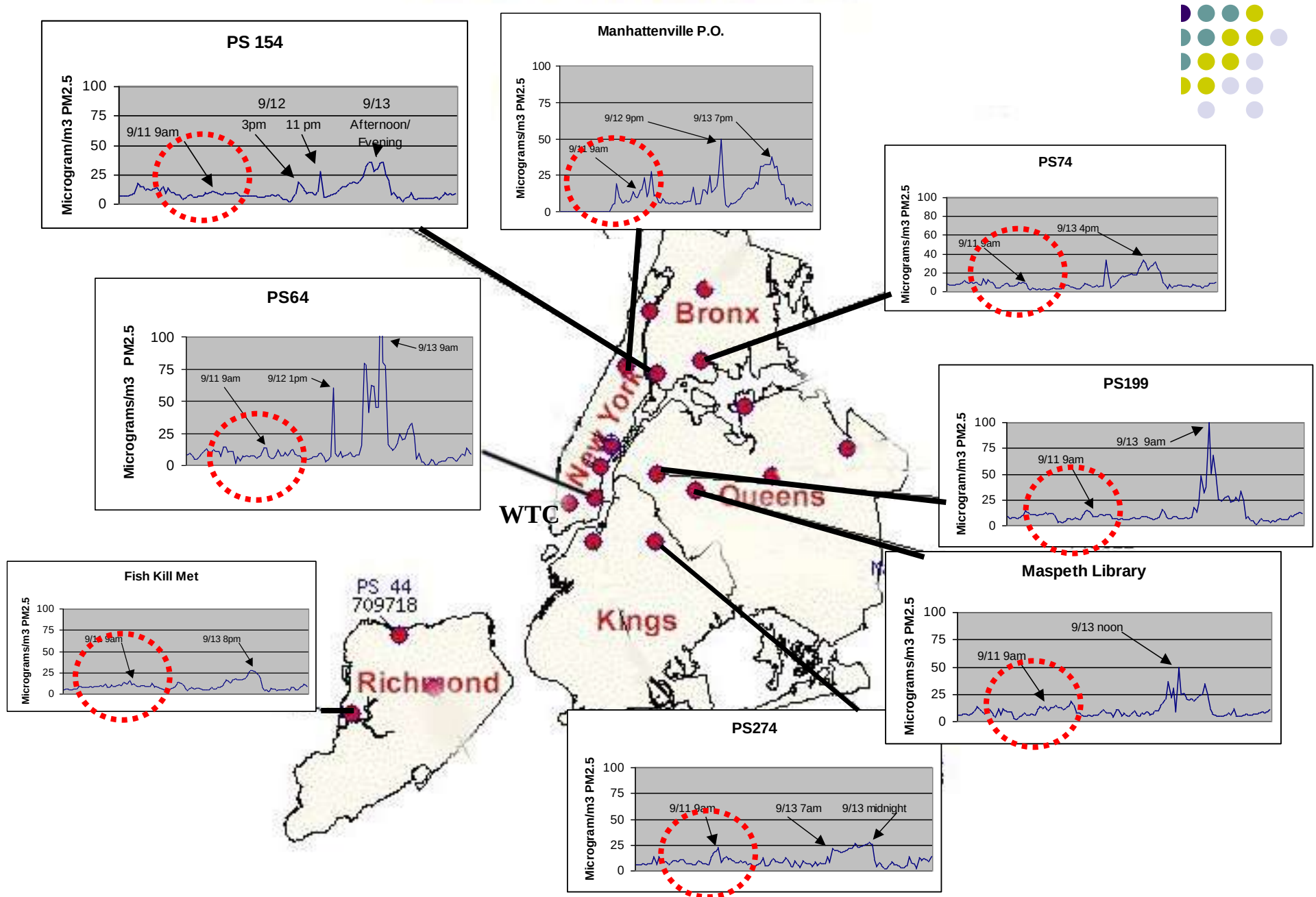
Both cases shared the unusual aspect of a massive ground level source of particulate matter in a highly populated area with potential health impacts.

Our original work at UC Davis was just on the smolder phase, October 2 – December 20, 2001

Dust just after collapse of the North Tower

Dust just after collapse of the North Tower

PM2.5 Measurements in NYC - Week of Sept 10 2001



South

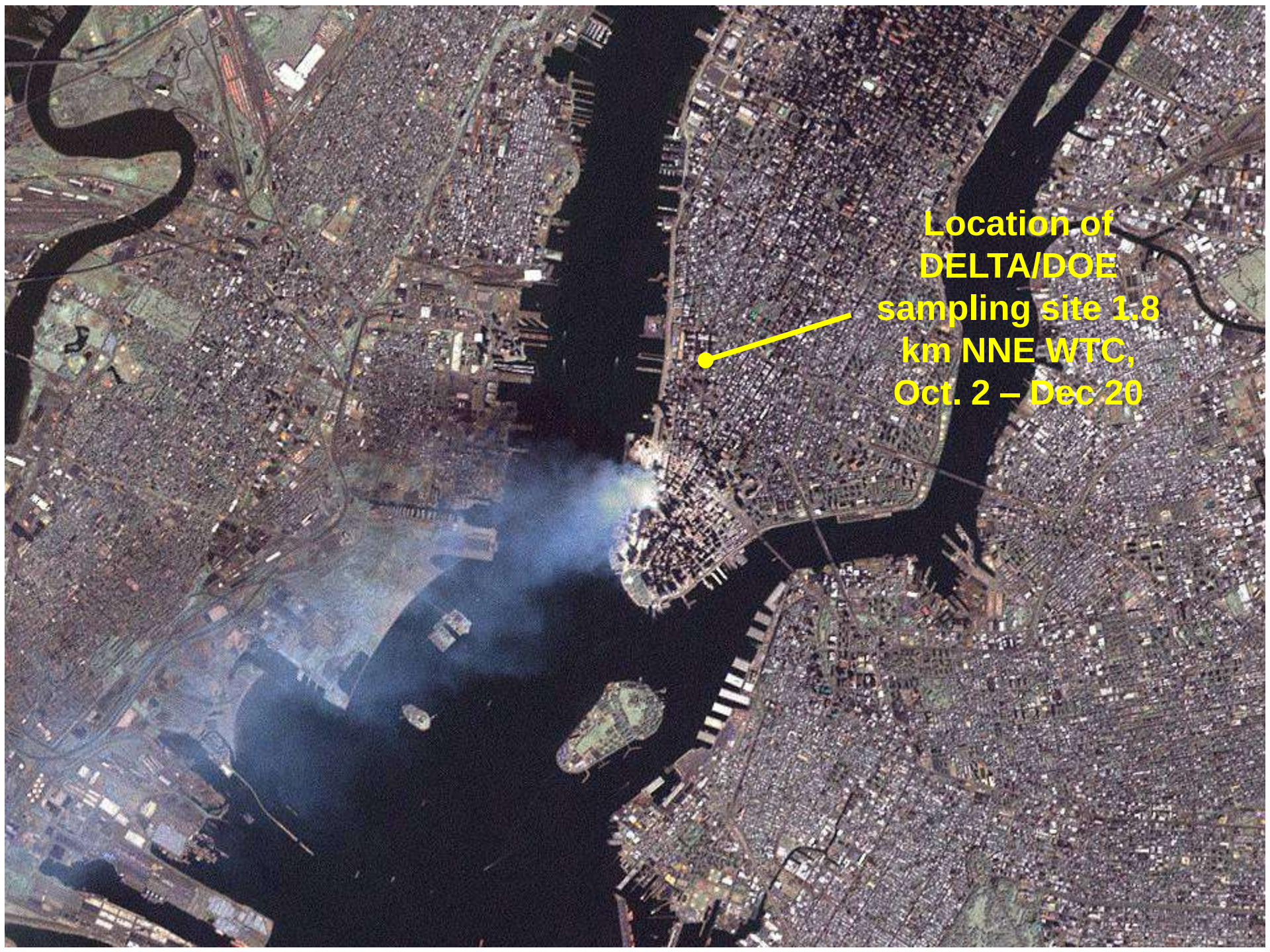
Fumes present after the rain event of Sept. 13

Why was the debris pile so hot, so long?

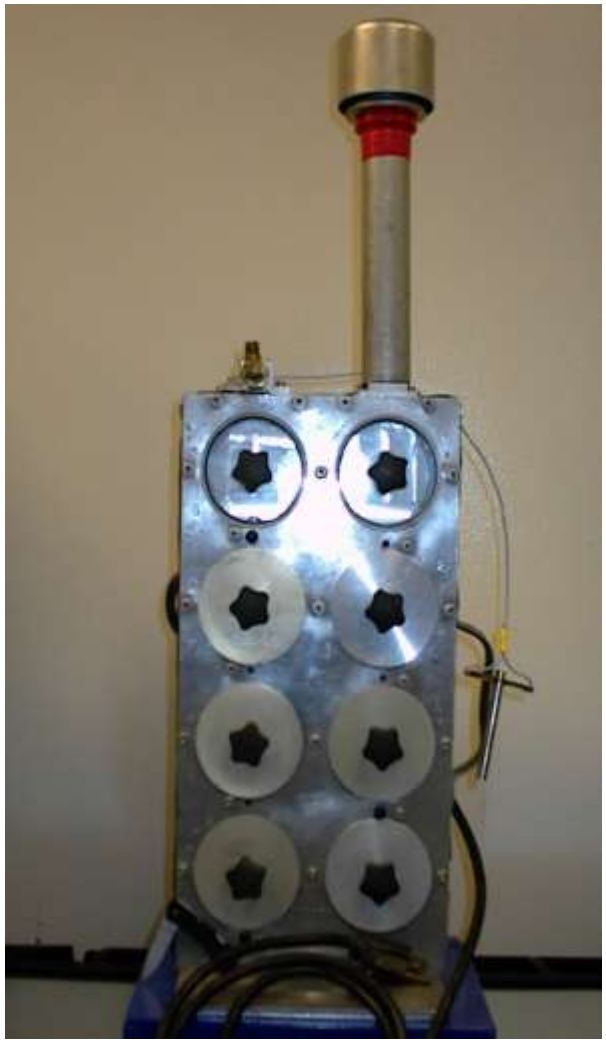
- Energy (est.) (in units of 10^{11} joules)
  - Kinetic energy of falling building 5 (+2.5°C)
  - Chemical energy of cars in garage 10
  - Chemical energy of diesel/Con Ed oil 150
    - Especially under WTC #7
  - Chemical energy of building combustibles 430
    - Perhaps 15% burned before the buildings collapsed

The surface and near sub-surface debris pile was hot enough to melt aluminum, make steel red hot until early October, and burned until Dec. 19.

But this is still much cooler than typical sources of very fine particle metals such as power plants, smelters, and diesels.


Location of
DELTA/DOE
sampling site 1.8
km NNE WTC,
Oct. 2 – Dec 20

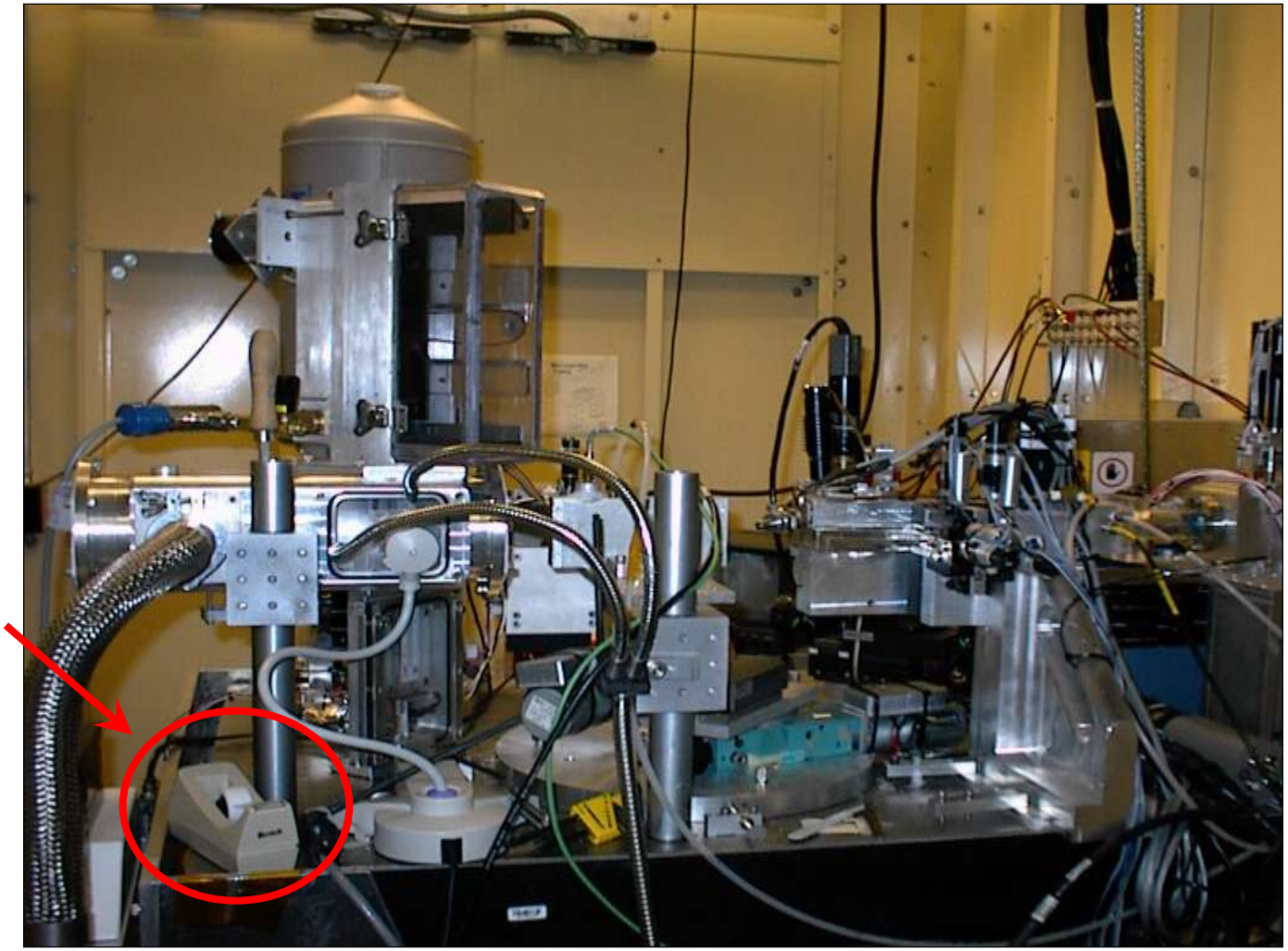
DELTA Group slotted 8 DRUM Impactor



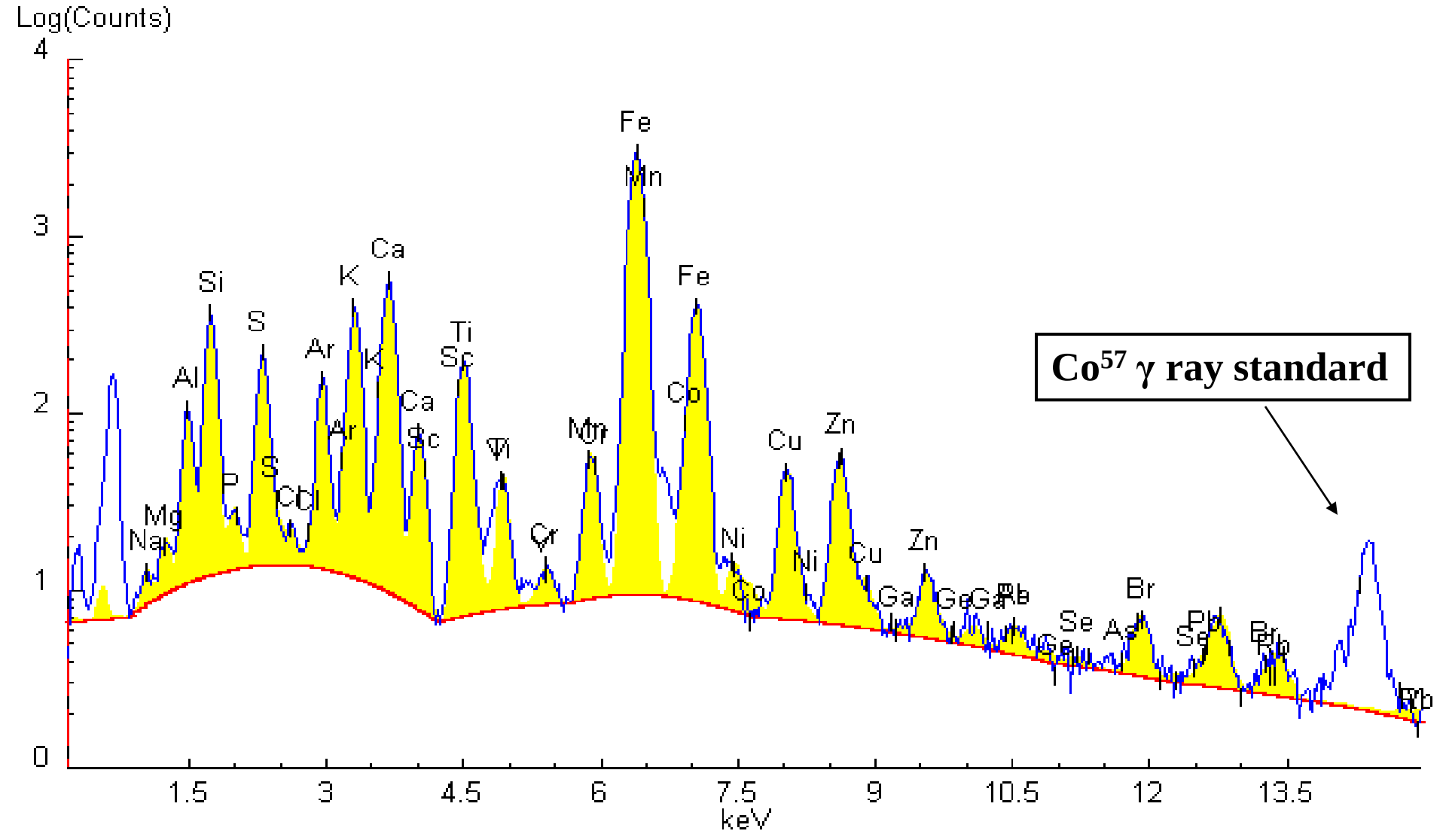
- 8 size ranges:
  - Inlet (~ 12) to 5.0 µm
  - 5.0 to 2.5 µm
  - 2.5 to 1.15 µm
  - 1.15 to 0.75 µm
  - 0.75 to 0.56 µm
  - 0.56 to 0.34 µm
  - 0.34 to 0.26 µm
  - 0.26 to 0.09 µm
- 10.4 l/min, critical orifice control, ¼ hp pump
- 6.5 x 168 mm Mylar strips
- For 42 day run, 4 mm/day, time resolution = 1 hr.
- Field portable
  - 10 kg, 43 × 22 × 13 cm

The LBNL Advanced Light Source - DELTA Group S-XRF Aerosol Facility

For scale? (At least it's not duct tape.)



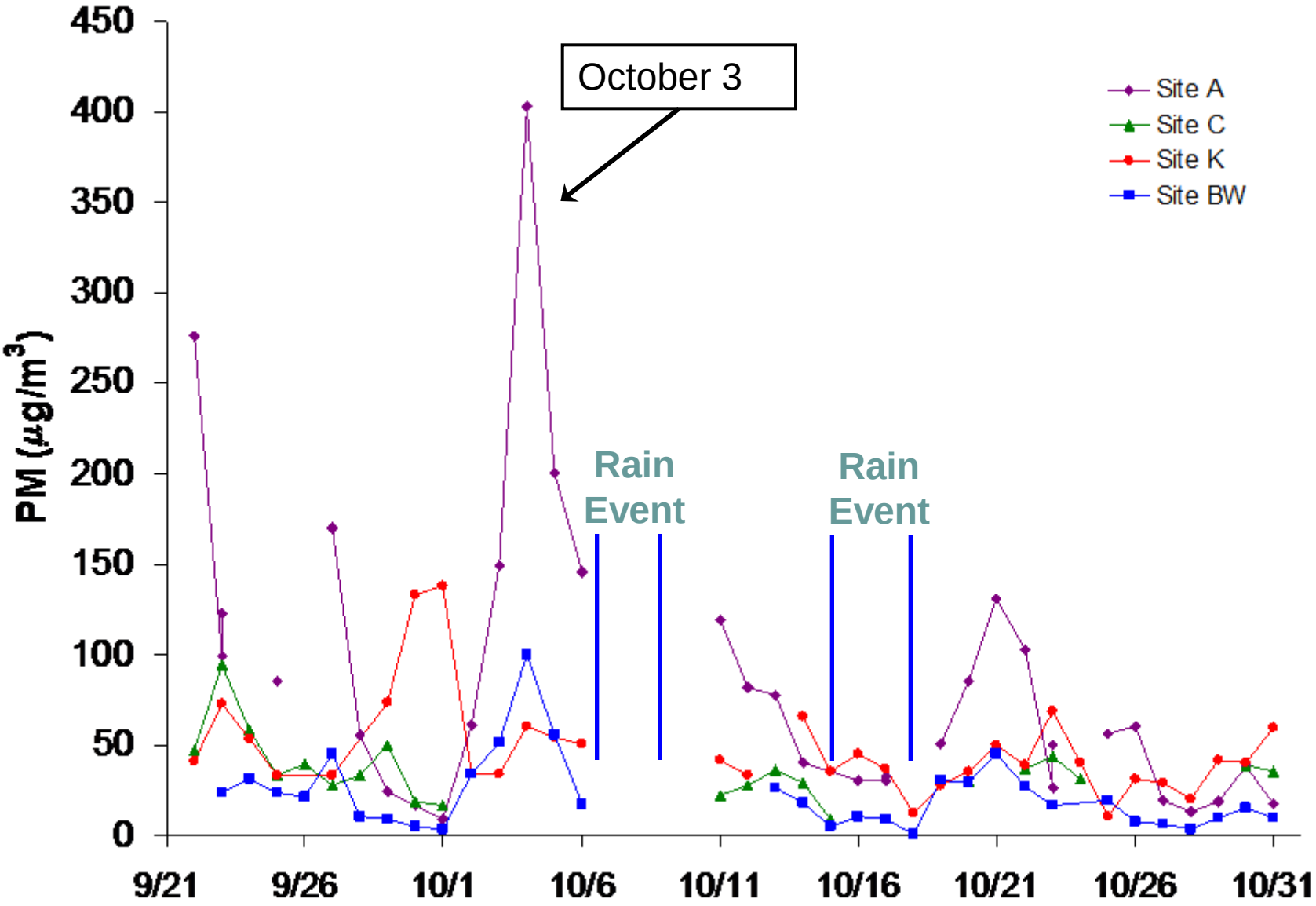
UC Davis DELTA Group/ALS S-XRF x-ray spectrum, 30 s analysis, no blank subtraction



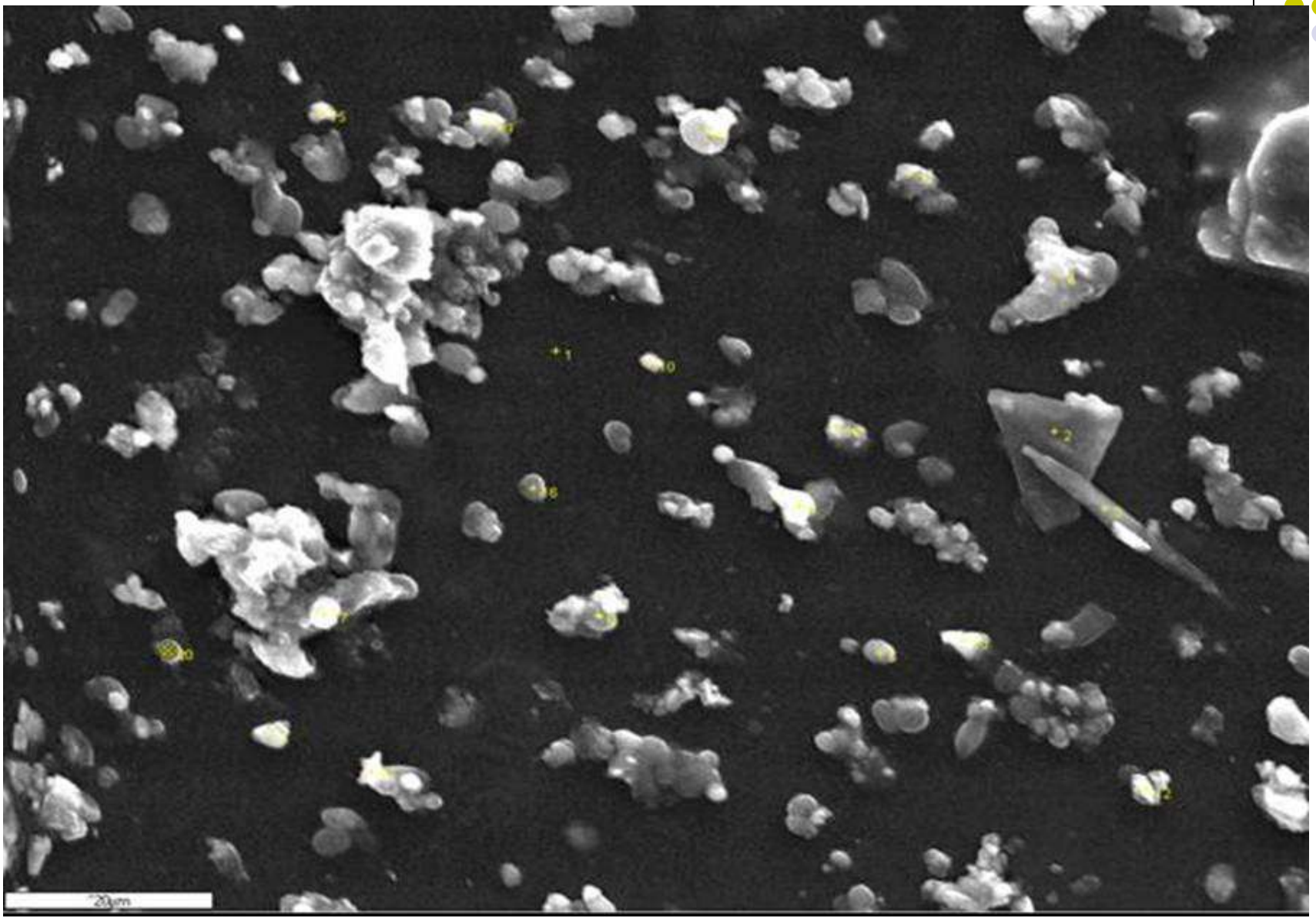
February, 2002 in NYC for testimony to a Congressional committee

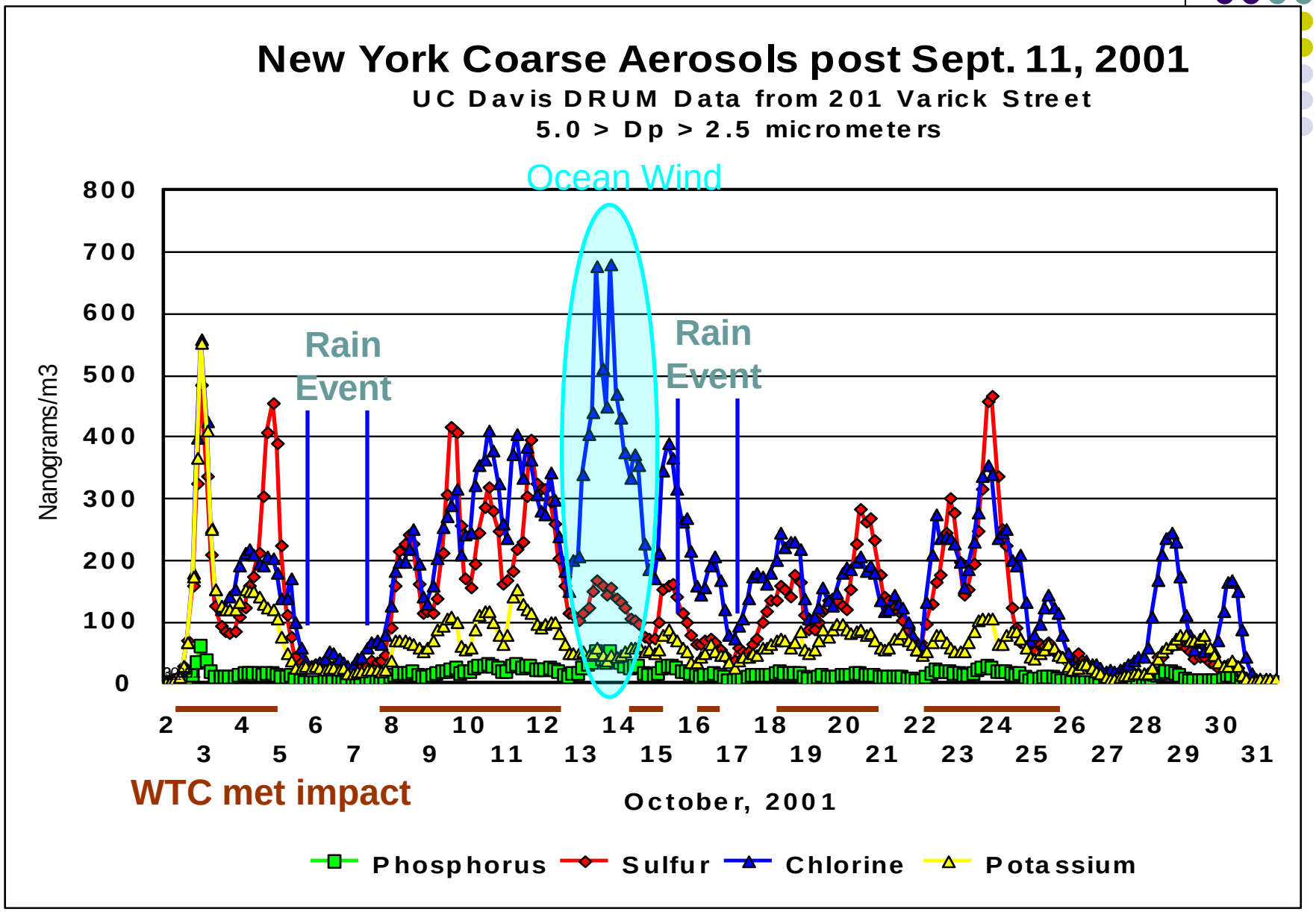
EPA Analysis of PM_{10} Mass

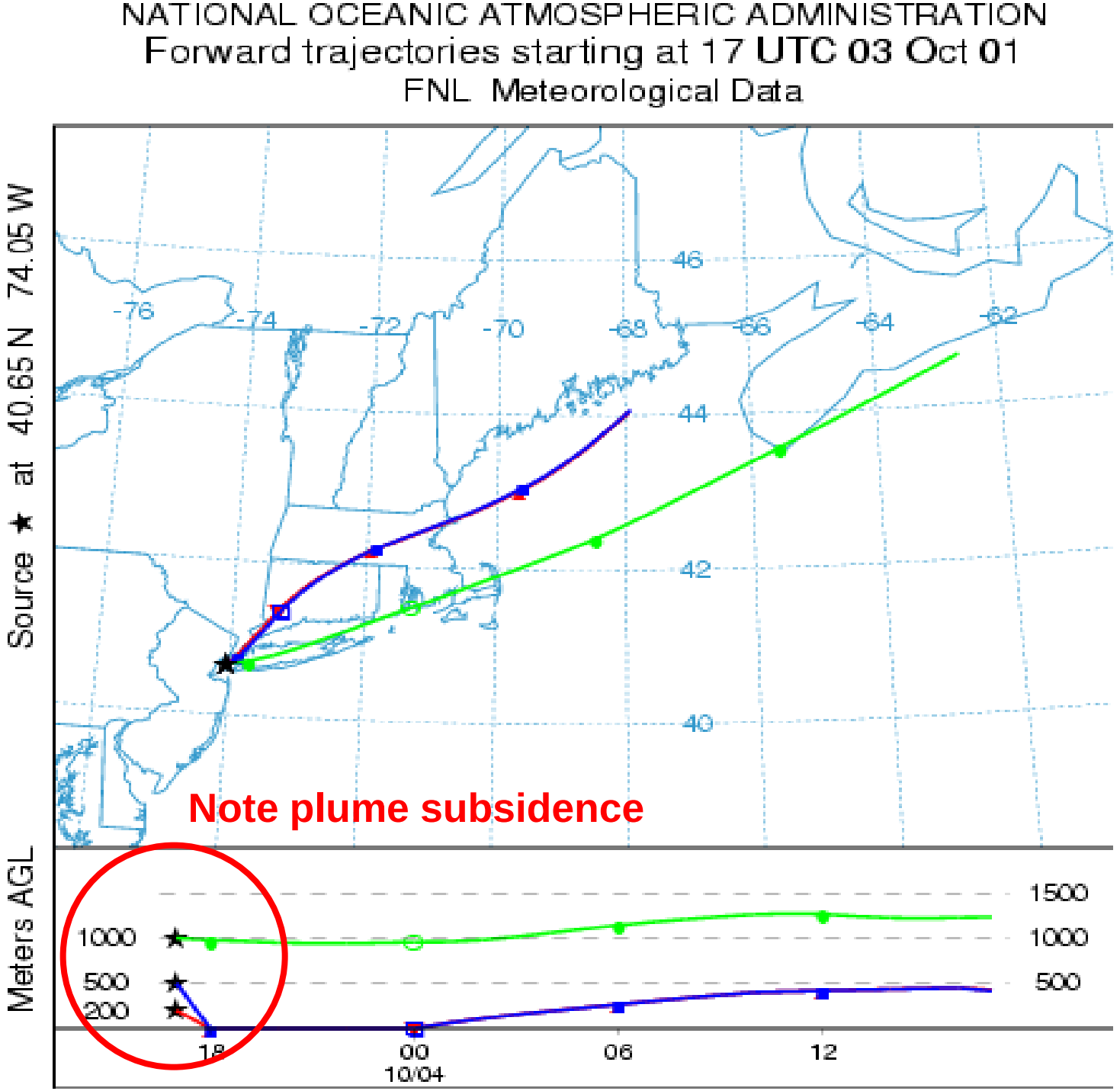
24 hour data

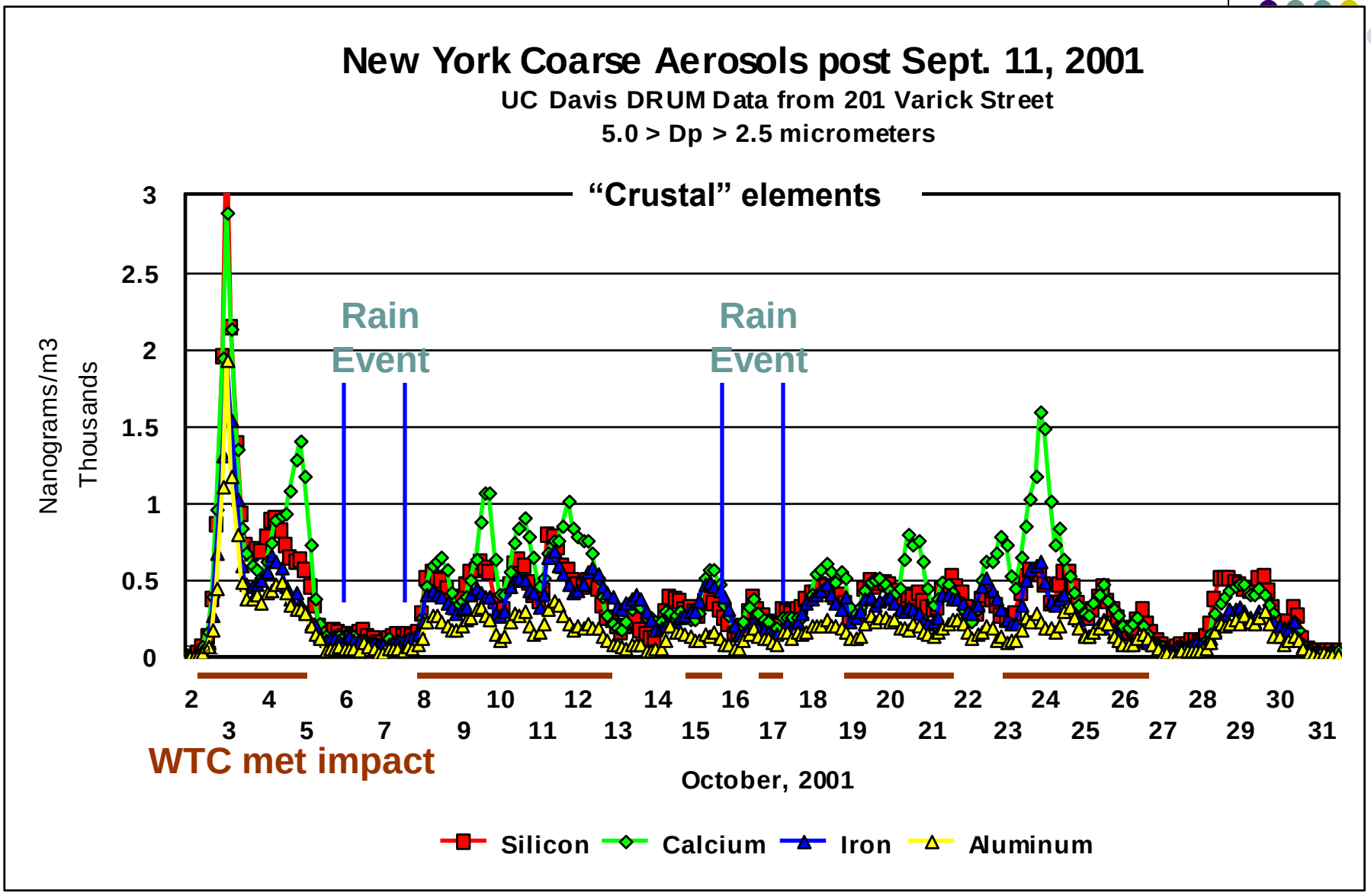


Coarse particles ~ 12 to 5 µm, Oct. 3




New York Coarse Aerosols post Sept. 11, 2001
UC Davis DRUM Data from 201 Varick Street
5.0 > Dp > 2.5 micrometers
Ocean Wind
Rain Event
Rain Event
Nanograms/m3
800
700
600
500
400
300
200
100
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
October, 2001
WTC met impact
Phosphorus
Sulfur
Chlorine
Potassium

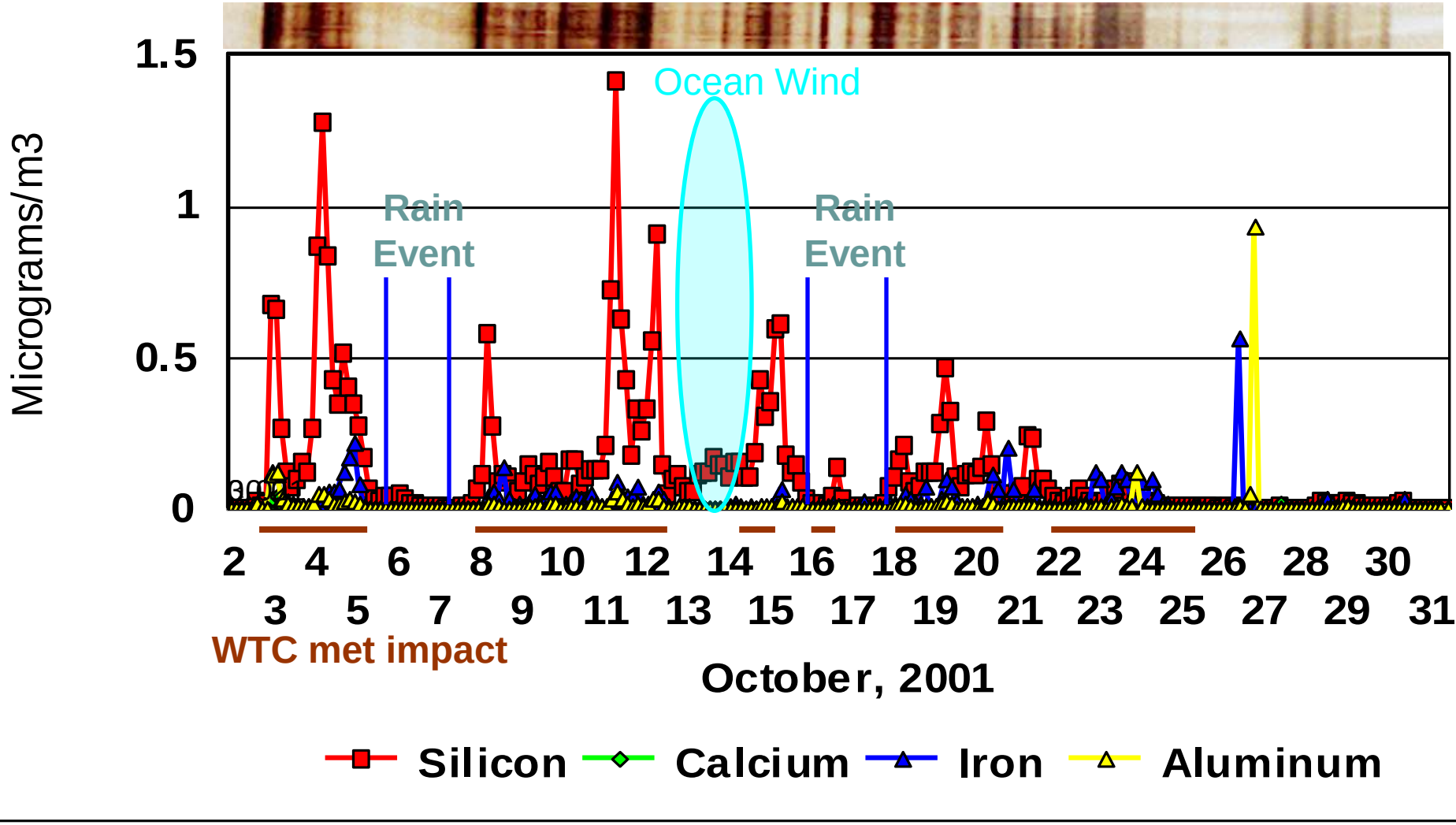

NATIONAL OCEANIC ATMOSPHERIC ADMINISTRATION
Forward trajectories starting at 17 UTC 03 Oct 01
FNL Meteorological Data
Source ★ at 40.65 N 74.05 W
-76
-74
-72
-70
-68
-66
-64
-62
46
44
42
40
Note plume subsidence
Meters AGL
1000
500
200
1500
1000
500
18
00
10/04
06
12


New York Coarse Aerosols post Sept. 11, 2001
UC Davis DRUM Data from 201 Varick Street
5.0 > Dp > 2.5 micrometers
"Crustal" elements
Nanograms/m3
Thousands
3
2.5
2
1.5
1
0.5
0
Rain Event
Rain Event
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
October, 2001
WTC met impact
Silicon
Calcium
Iron
Aluminum

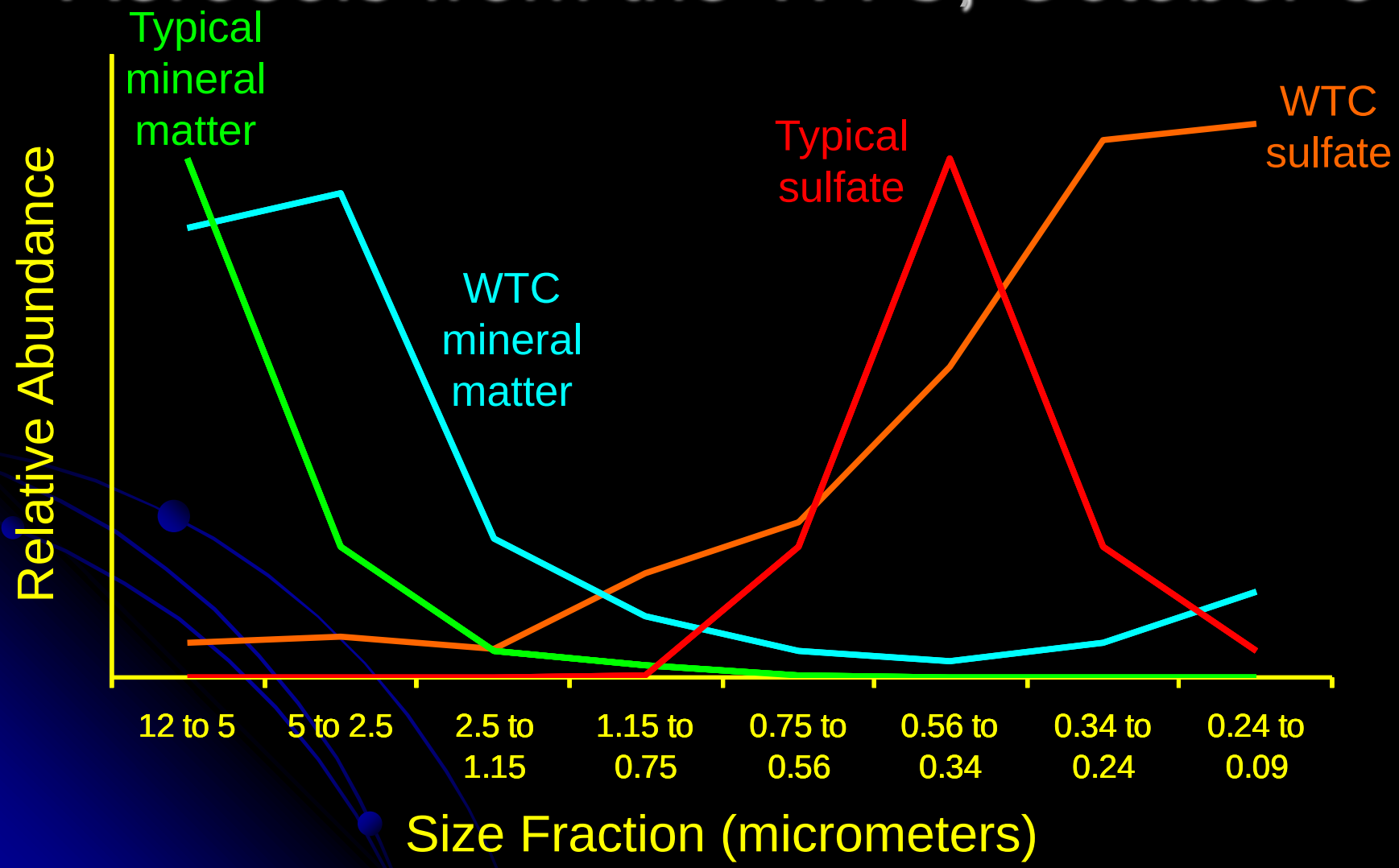
New York very fine Aerosols post Sept. 11, 200

UC Davis DRUM Data from 1.8 km NNE

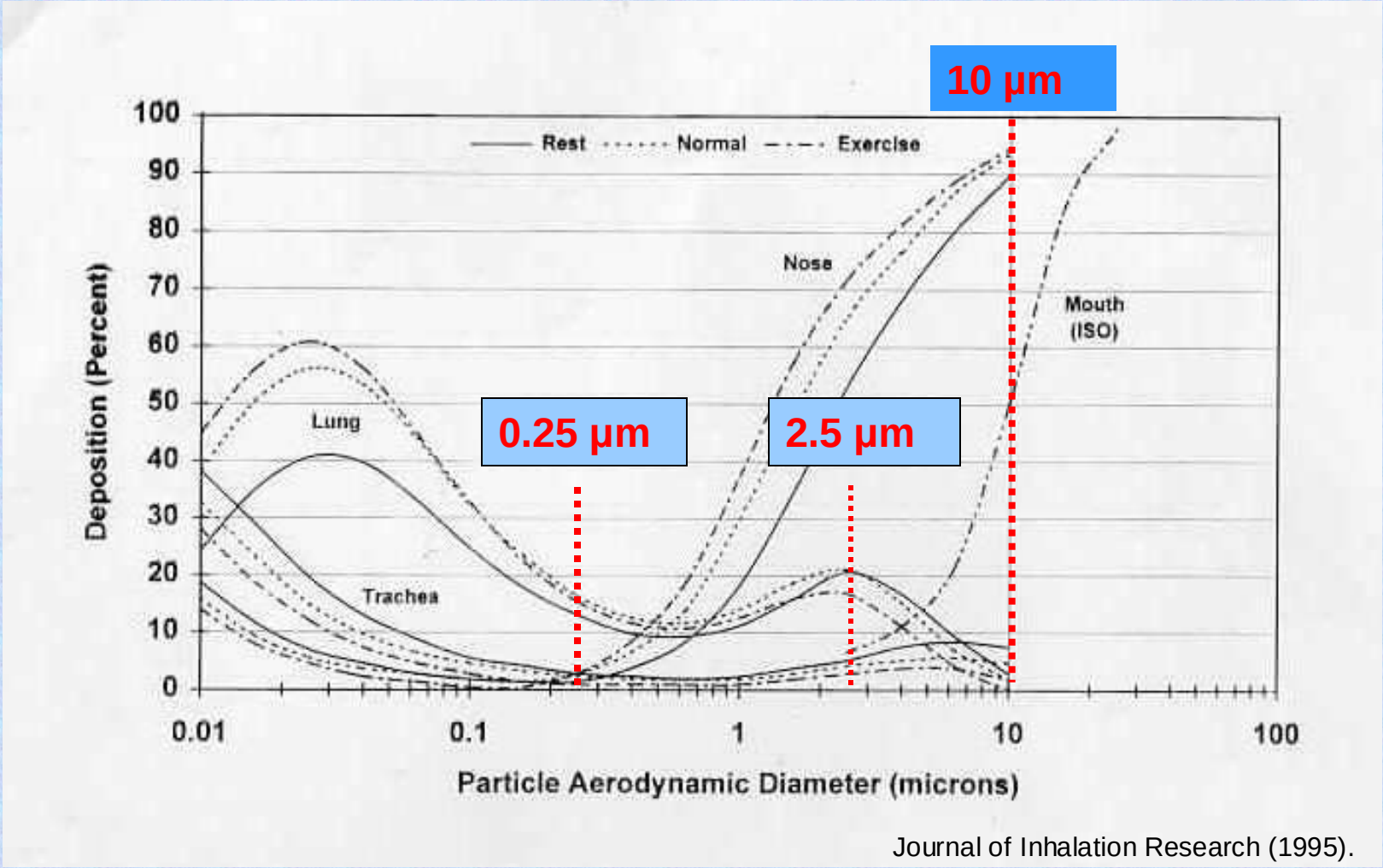
0.26 > Dp > 0.09 micrometers



Anomalous Size Distribution of Aerosols from the WTC, October 3



Particle Size versus Percent Deposition



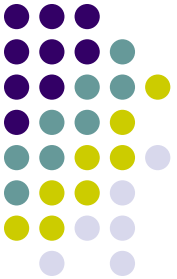
Journal of Inhalation Research (1995).

This figure shows the relationship between particle size and what percent is deposited in different parts of the respiratory tract.

Health effects

- Initial plume – some short term loss of lung function, coughing, etc
- Continuing fumes from the collapse pile
  - The highly caustic cement dust in finer than normal sizes gets into the bronchial tract – WTC dry cough
  - Lung defenses compromised by the sulfuric acid impact on the cilia
  - Permanent loss of lung function (circa 1,000 on permanent disability some loss for10,000 workers)

September 10, 2003 – ACS natioanl meeting in NYC



Concentration of Very Fine Aerosols

3 hr peak averages, Micrograms/m^3 (ng/m^3 - V, Ni)

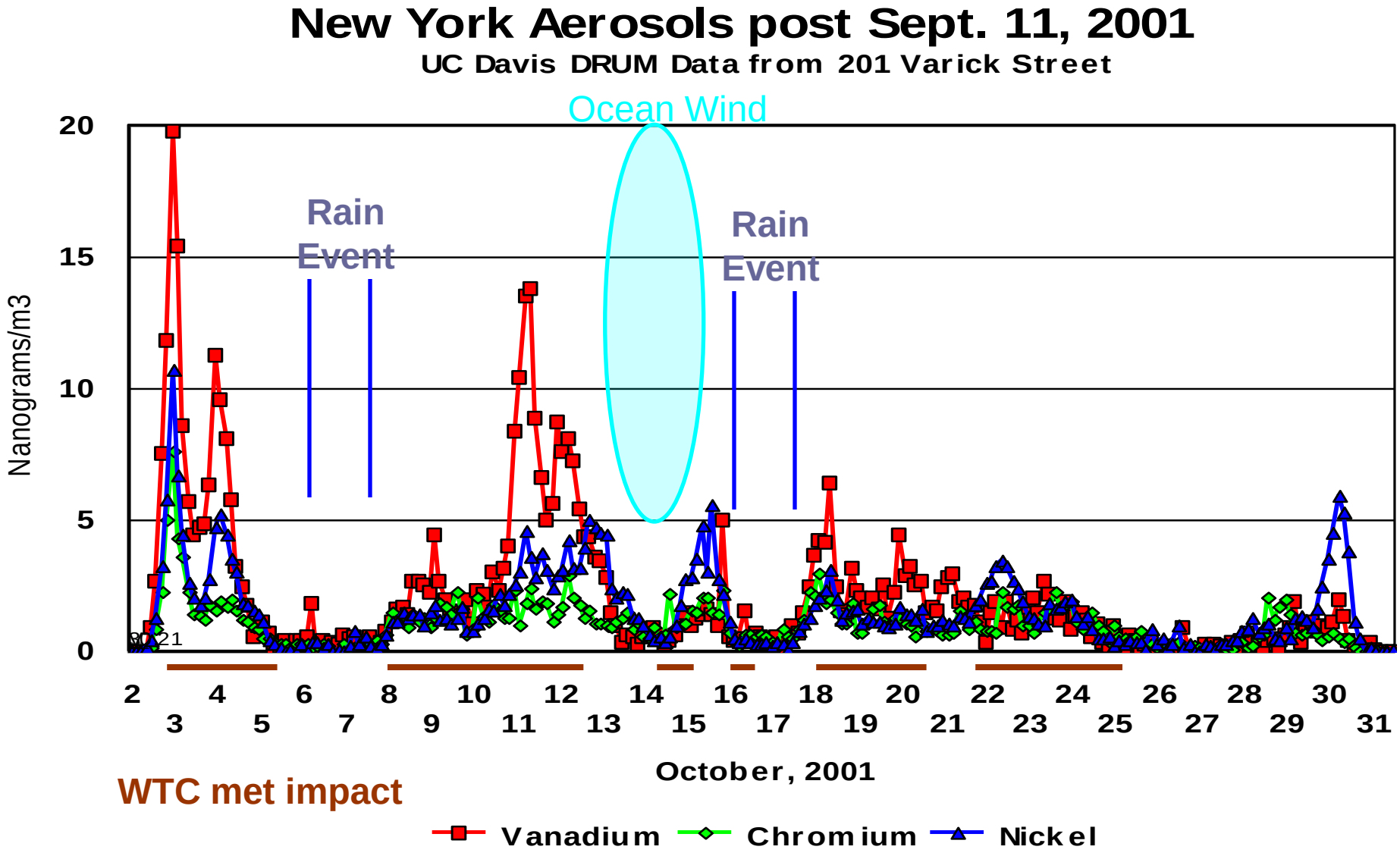
Date	WTC impact	Mass	Org.	SiO_2	H_2SO_4	*V*	*Ni*
Oct. 7	No	0.5	0.04	0.02	0.1	*0.1*	*0.1*
Oct.29	No	2.4	1.2	0.07	0.9	*2*	*1.6*
Kuwait	-	na	na	0.6	5.5	*na*	*5.0*
Beijing	-	na	na	1.1	6.7	*0.8*	*1.8*

Incineration with 10% chlorine Metal	Boiling Point °C	Earth crustal ppm	Bulk dust EPA ppm	Bulk dust Lioy ppm	Volatility Temp °C	Principal Species
Chromium	2639	102	71.5	165	1594	CrO_2 ,O_3
Beryllium	1280	2.8	1.75	3.2	1042	$Be(OH)_2$
Barium	1634	425	195	381	895	$BaCl_2$
Nickel	2834	84	15.5	43.5	686	$NiCl_2$
Antimony	697	0.2	na	na	653	Sb_2O_3
Silver	2190	0.004	4.9	2.3	620	AgCl
Selenium		0.05	< 0.96	na	315	SeO_2
Cadmium	761	0.15	3.8	7.2	211	Cd
Vanadium	3480	120	18.3	38.9	147	VCl_4
Thallium	1464	9.6	<0.96	1.4	136	TlOH
Osmium	4224	0.0015	na	na	40	OsO_4
Arsenic	814	1.8	< 0.96	2.6	32	As_2O_3
Mercury	353	0.085	0.37	nd	25	Hg
SiO_2	1725	9000	na	na	12	$SiCl_4$
Lead	1748	14	98	305	-12	$PbCl_4$

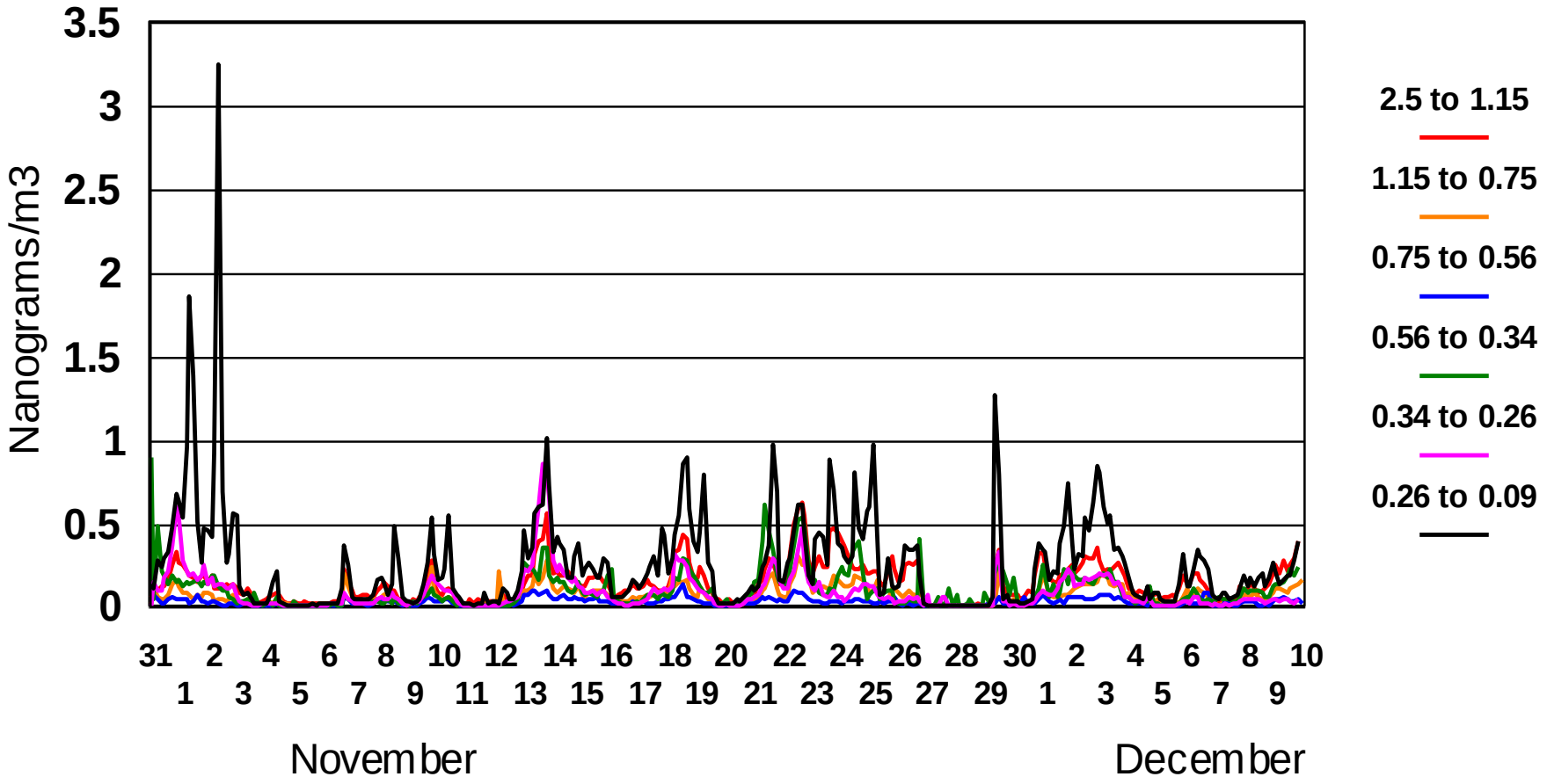
Very fine mode aerosols in WTC plume and non-plume conditions

Very fine aerosols 0.26 - 0.09 μm	October 7 background μg/m^3	October 3 WTC plume μg/m^3	Average Abundance WTC dust	Volatility Temperature 10% chlorine
Mass	0.53	50.7	na	na
Organics	0.04	9.3	na	na
Sulfur	0.04	5.6	na	na
	ng/m^3	ng/m^3	ppm	^{o}C
Silicon	11	698	abundant	12
Vanadium	0.1	114	30	147
Lead	<0.5	26	200	-12
Nickel	0.1	23	30	686
Chromium	<0.1	1.5	120	1594
Barium	< 0.1	< 0.5	290	895

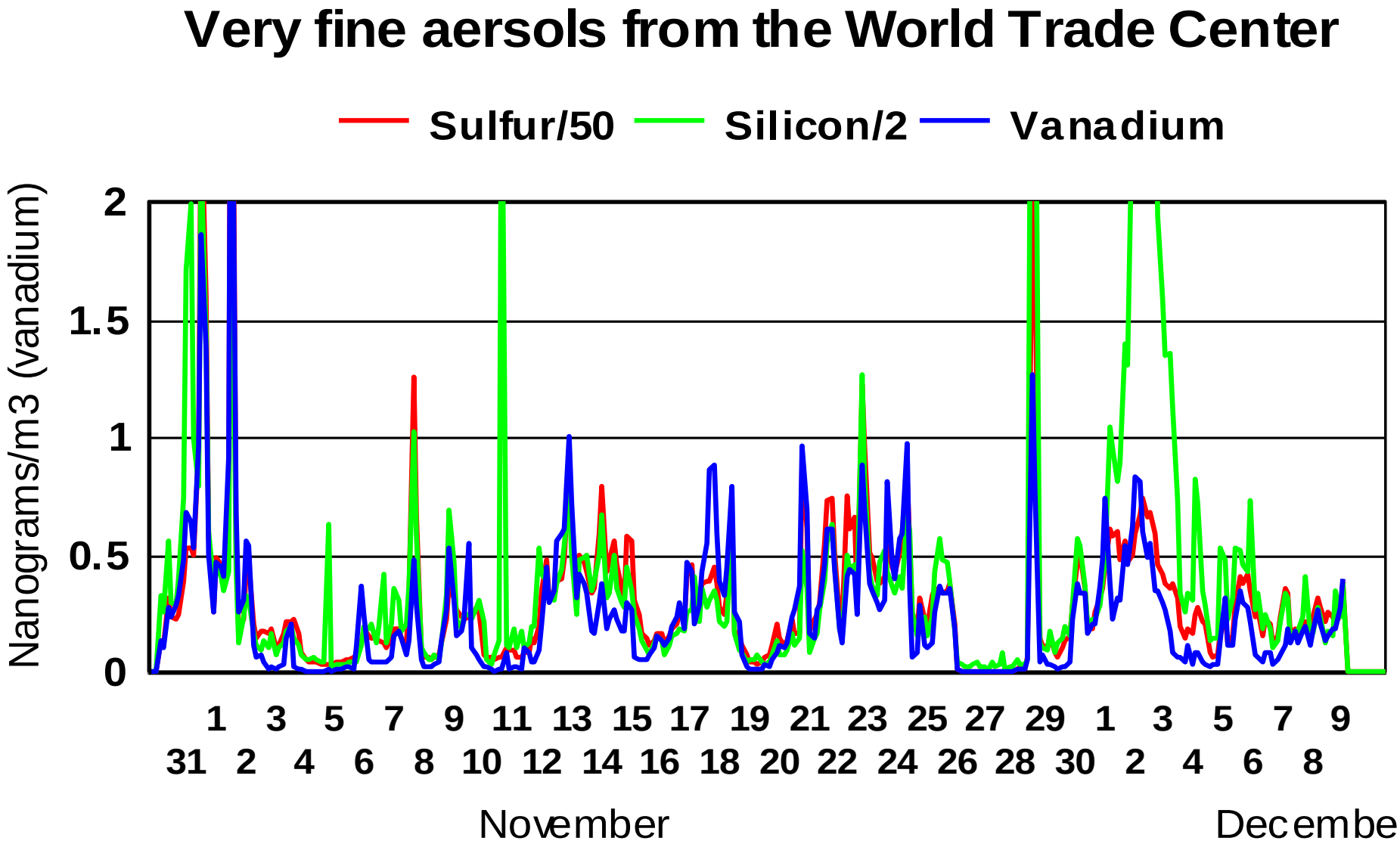
But some good news – the levels dropped rapidly



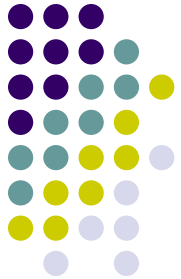
New data – the vf vanadium aerosols continue at low levels



The weird chemistry continues, …

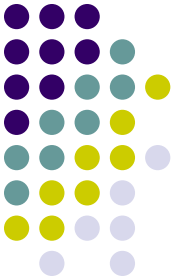


Predicted health impacts



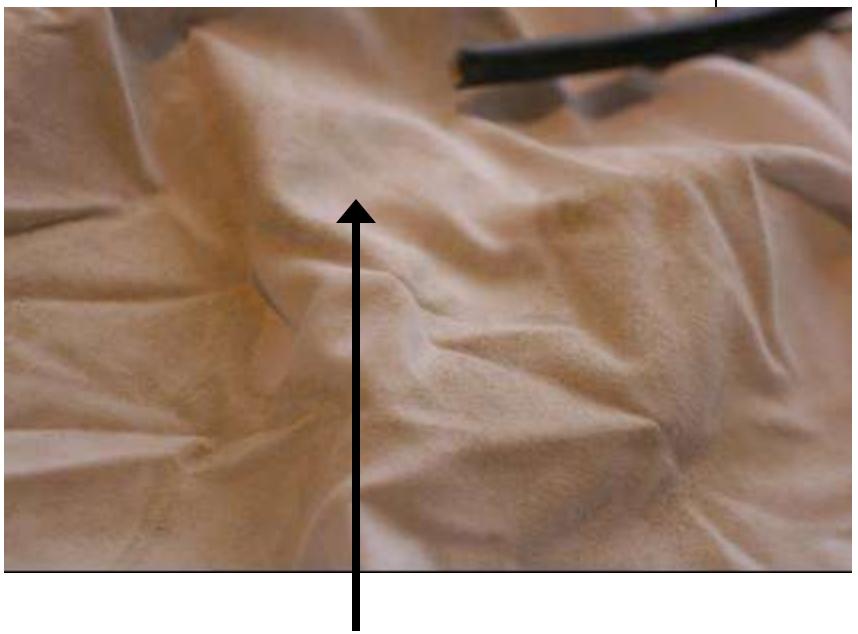
- Very fine and ultra fine insoluble particles
  - Penetrate into the cardio vascular system
  - Ischemic heart disease and fatal heart arracks in a few years
  - Significant mercury was present but only in coarse particles – less body burden
- Cancer?
  - Recent data from my son saw low levels of carcinogens (PAHs)
- However, high level of phthalates from out gassing plastics (reproductive toxin)

No data on original plume? We got lucky!



- Erik Gillin, now an Esquire Magazine writer, was on Wall Street on 9/11, wearing a white shirt and back pack, just east of the South Tower.
- He saw the second plane hit, then fled east down Wall Street when the tower collapsed
- He was overtaken by the plume and went into total darkness for about 2 minutes, then saw some light to the right and escaped into a bank lobby.
- He walked back to his apartment, and dumped the back pack into a plastic bag – until January, 2007.
- With all the new data on health impacts of people exposed to WTC aerosols, he wondered if his stuff would be useful – after all, no samples were collected of the collapsing plume!

Erik's backpack and contents after WTC Collapse Plume of 9/11 fleeing on Wall Street



Back of shirt, showing vacuum intake and cleaned area

THE ESKY '07

Esquire

MAN AT HIS BEST

APRIL 2007

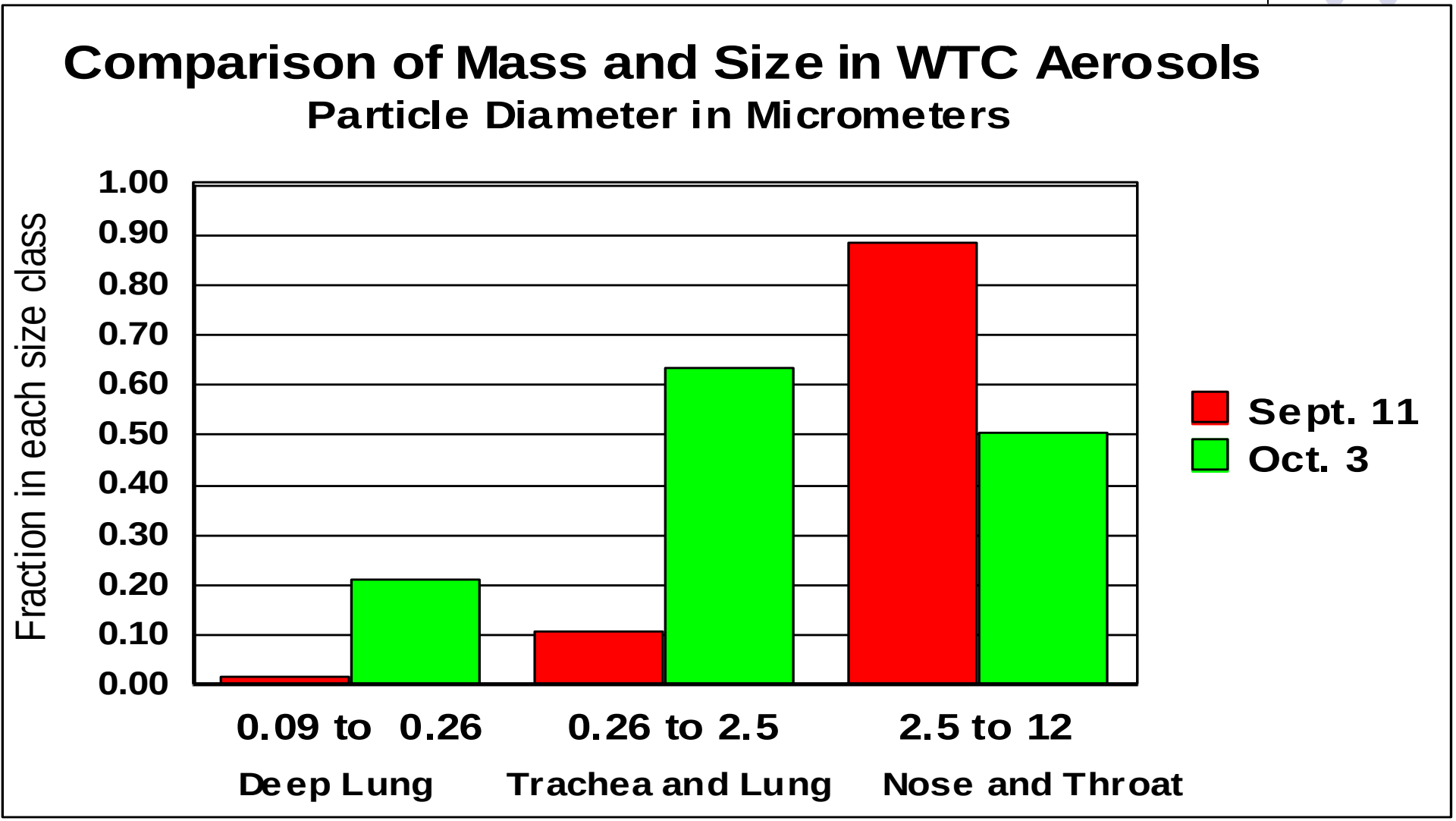
THE WORD
'IMPEACH
IS SPOKEN BY
A POWERFUL
REPUBLICAN
ON THE TOP OF PG. 143

NEW 9/1
REVELATION
WE NOW KNOW
WHAT WAS IN THE
PLUME
THOUSANDS
INHALED

TWO
OSCARS,
AN AGILE
MIND,
A BODY
LIKE
THIS...

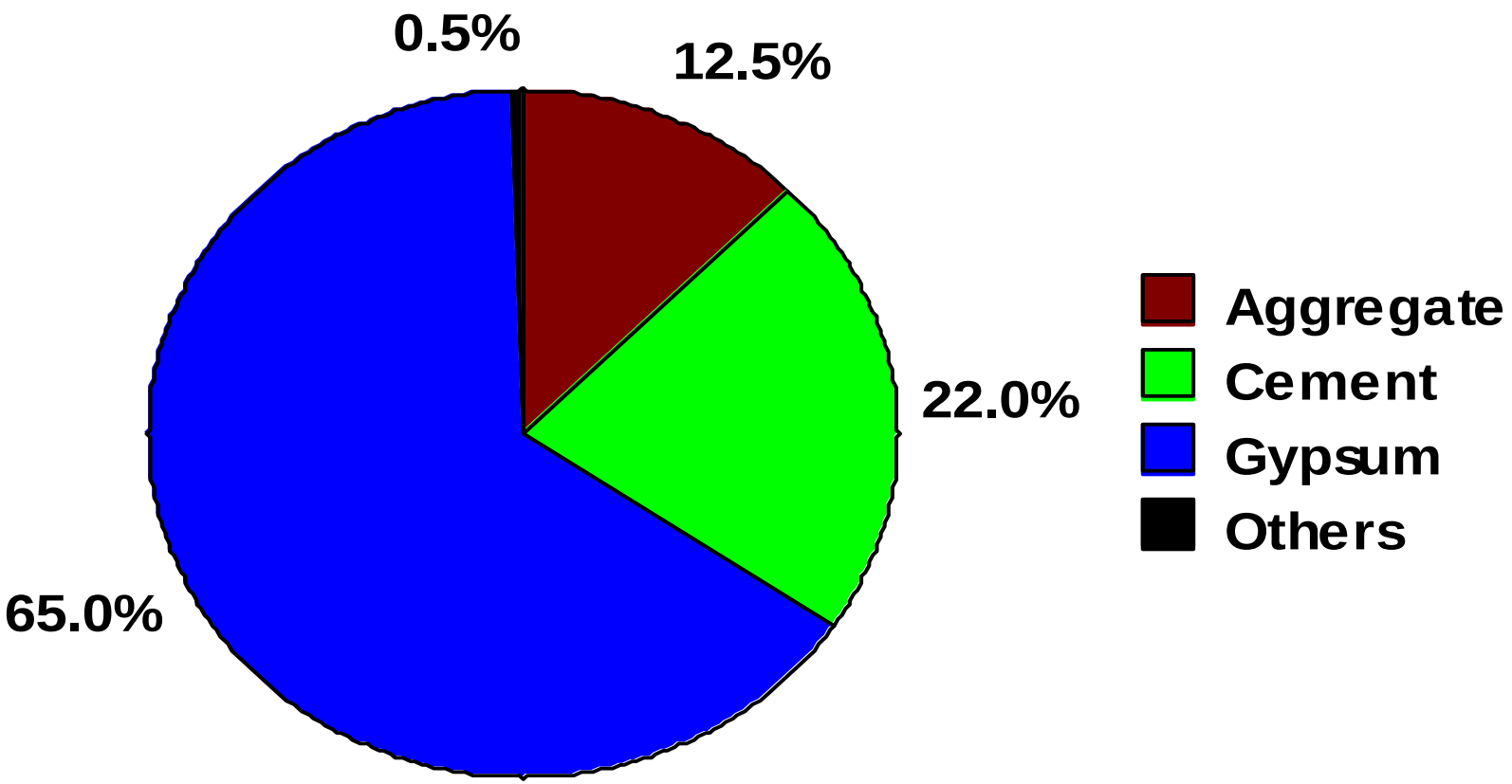
THANK YOU, LORD,
HILARY
SWANK
IS SINGLE AGAIN

Aerosol Mass – Initial Collapse Plume vs. Smolder Phase

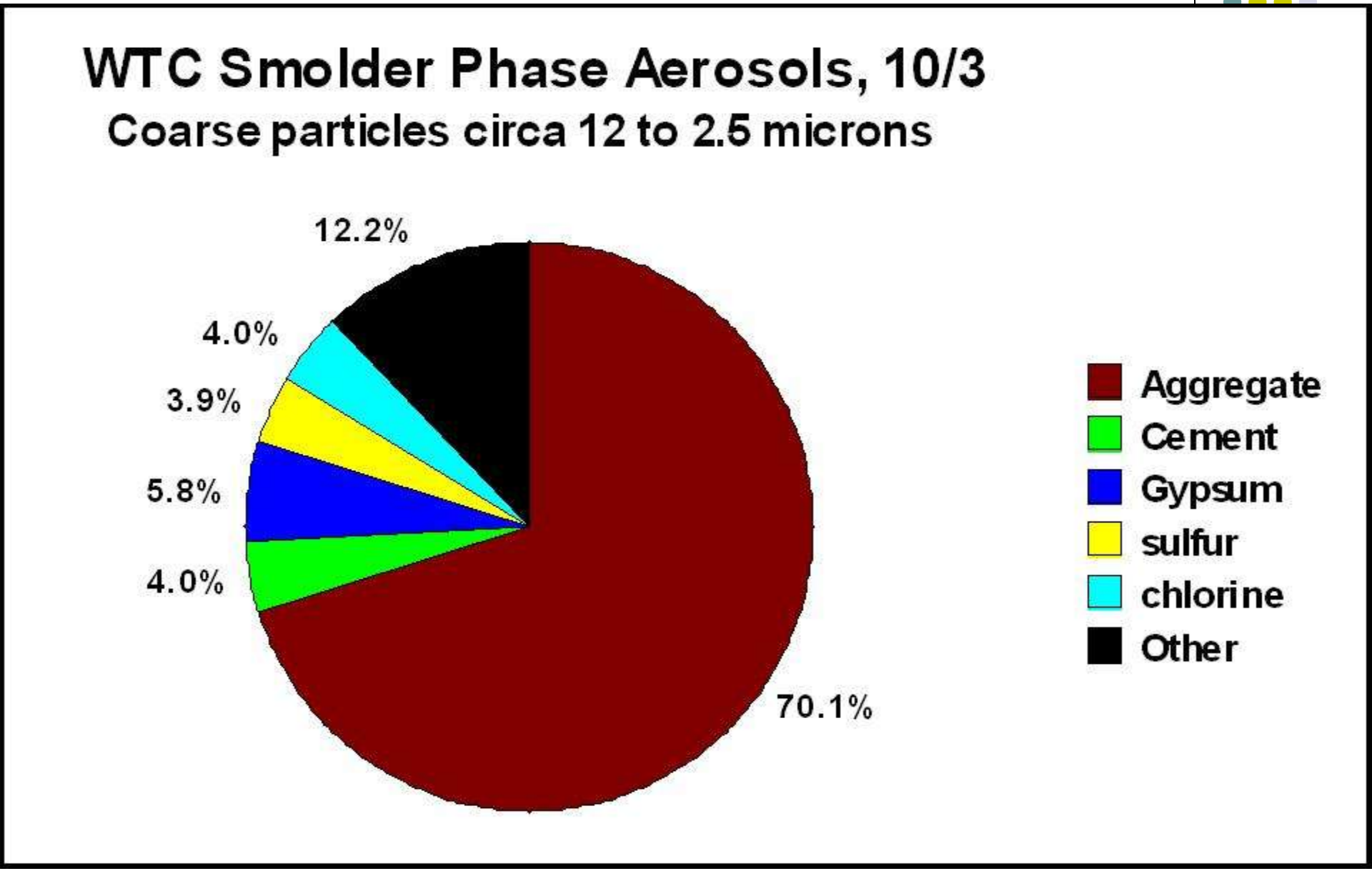


WTC Dust Plume on Wall Street, 9/11

Coarse particles circa 12 to 2.5 microns

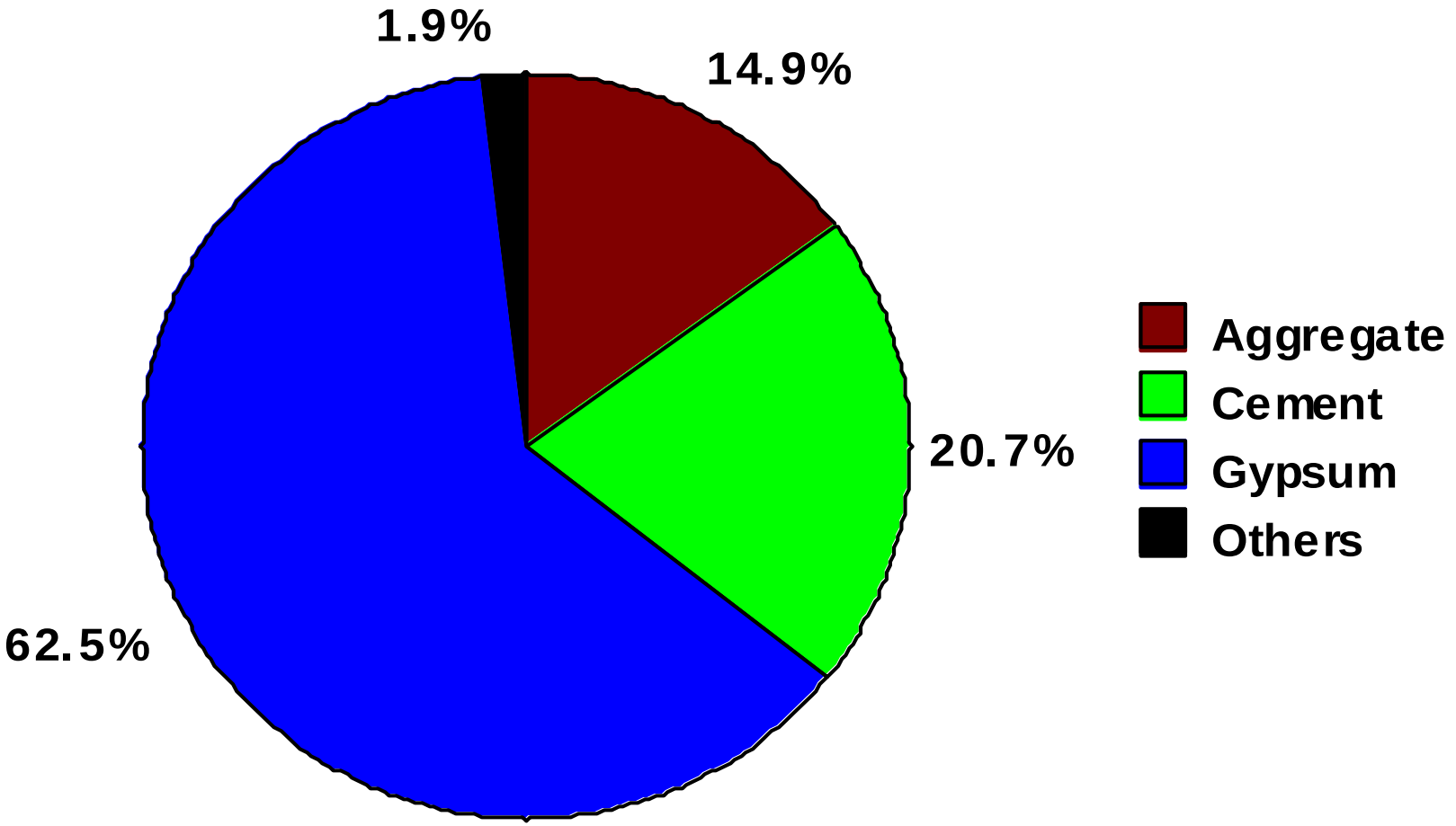


Chemistry of the smolder phase



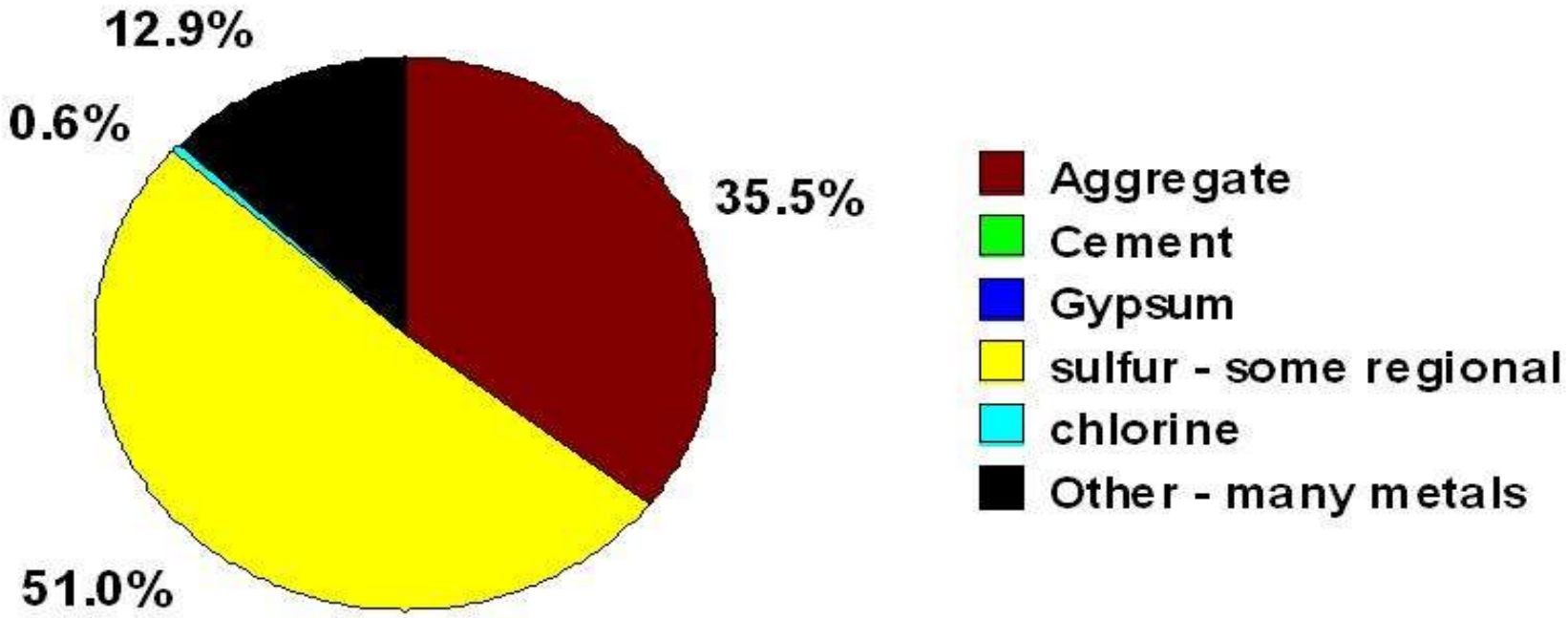
WTC Dust Plume on Wall Street, 9/11

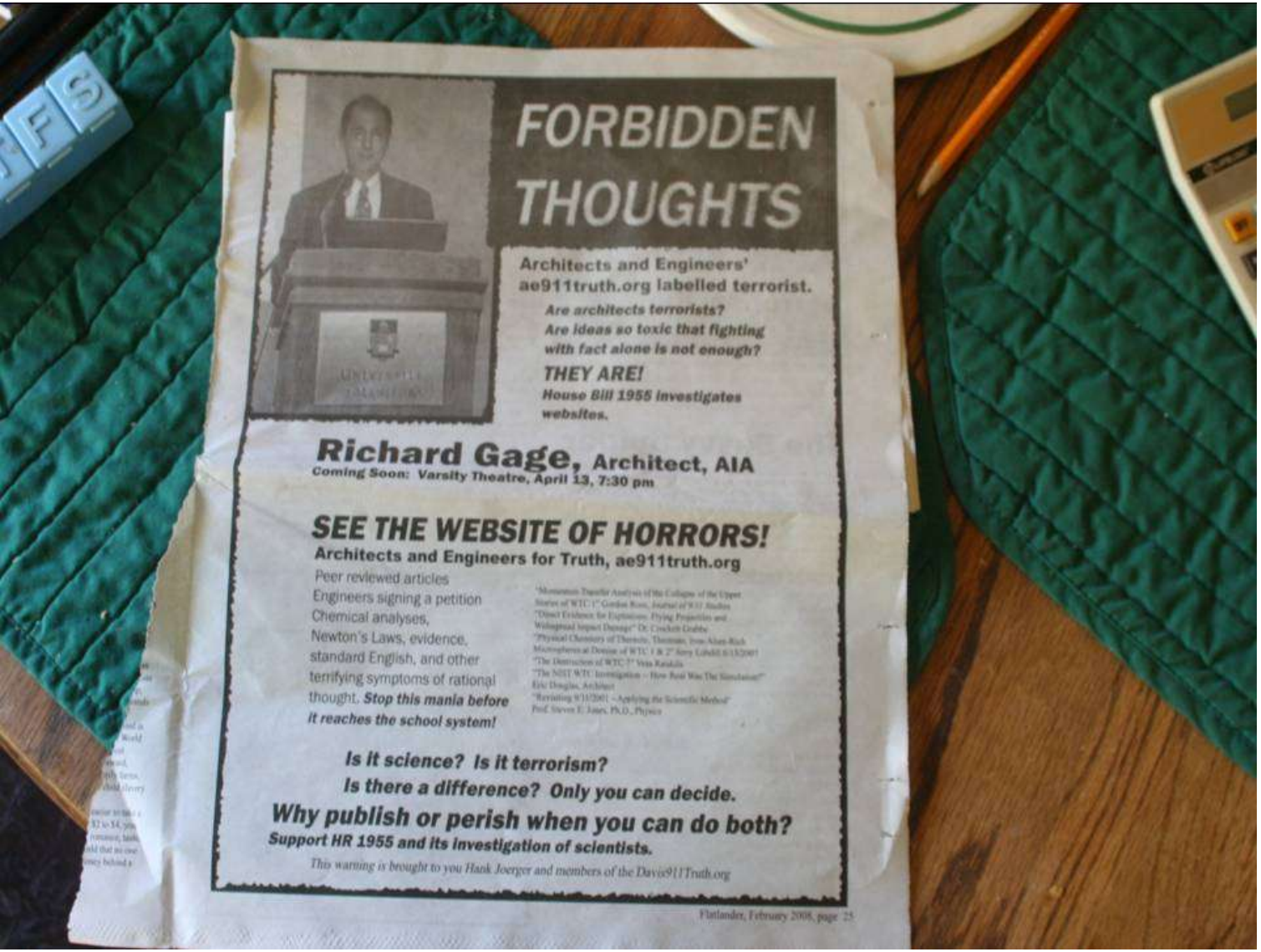
Very fine particles 0.26 to 0.09 microns



WTC Smolder Phase Aerosols, 10/3

Fine aerosols 2.5 to 0.26 microns





A garlic coated oaken stake in the heart of the WTC conspiracy theorists!

But some good news ….

- We won the litigation for worker's health care, worth about $750 million for the 12,000 people, with most getting modest funds but the worst 1000 cases getting lifetime health care. How did we win?
- The asbestos levels were low, and no fractured fibers
- Gross failures, federal and state and city
  - "the air is safe to breathe" EPA Christie Whitman.
    - Even when new data came in, stuck to original story
  - OSHA – treated the site like a cement plant
    - Masks recommended, not mandatory; never enforced
  - New York City – took control of site in a mad dash to clear the wreck even while it was still burning

For more details……..

- "Fallout" by Juan Gonzales of the New York Daily News
- "Dust to Dust: Health Impacts of the World Trade center Collapse", CBS/Sundance Channel 135 min movie
- Lioy et al, Environmental Health Perspectives 110, #7 703-714 July, 2002 (3 bulk samples collected dry, 9/16, 9/17, exhaustive analyses)

- Thomas A. Cahill, Steven S. Cliff, Michael Jimenez-Cruz, James F. Shackelford, Michael Dunlap, Michael Meier, Peter B. Kelly, Sarah Riddle, Jodye Selco, Graham Bench, Patrick Grant, Dawn Ueda, Kevin D. Perry, and Robert Leifer, **Analysis of Aerosols from the World Trade Center Collapse Site, New York, October 2 to October 30, 2001**. Aerosol Science and Technology **38**; 165–183 (2004)
- Cahill, T. A., Cliff, S.S., Shackelford, J.F., Meier, M., Dunlap, M., Perry, K.D., Bench, G., and Leifer, R. **Very fine aerosols from the World Trace Center collapse piles: Anaerobic incineration?** Advances in Chemistry 152-163 (2005)

- EPA web site www.epa.gov/ response to 9/11, EPA ORD analysis and Power Point presentation
- DELTA web site http://delta.ucdavis.edu, WTC data and the Fall, 2002 ACS Powerpoint presentation.