The Physical, Chemical & Biological Characterization of Dust from the Middle East:

New Terrors Hiding in the Dust of Iraq?

U.S. Navy Bureau of Medicine and Surgery

M00– Research Program Integration & Mission Development

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DISCLAIMER

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AMEN!

- ***"All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy". - Paracelsus (1493-1541)***

- ***"And it shall become small dust in all the land of Egypt, and shall be a boil breaking forth [with] blains upon man, and upon beast, throughout all the land of Egypt.***

  - 6th Plague of Egypt, Exodus 9:10

- ***"Let my armies be the rocks and the trees and the birds in the sky." - Charlemagne***

- ***"Would you tell me, please, which way I ought to go from here?" The cat replied, "That depends a good deal on where you want to get to."*** **– When Alice met the Cheshire Cat in *Alice Through the Looking Glass***


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New York Times - August 9, 2005

One More Affliction For Baghdad: A Day Of Blinding Dust And Grit & Breathlessness

By James Glanz

BAGHDAD, Iraq, Aug. 8 - At dawn the atmosphere glowed orange, like the embers of a fire. Objects 25 yards away disappeared, as if a curtain had been drawn in front of them. Baghdad residents began waking up with the sour taste of grit in their mouths and a film of dust on their furniture and clothing, and by 8 a.m. Nireen Abdul Khalek began to feel that she could not breathe. Five hours later, Ms. Khalek, 24,

Research | Workgroup Report

Health and Environmental Consequences of the World Trade Center Disaster

Phillip J. Landrigan,[1] Paul J. Lioy,[2] George Thurston,[3] Gertrud Berkowitz,[1] L.C. Chen,[3] Steven N. Chillrud,[4]

Mice exposed to WTC dust showed only moderate pulmonary inflammation but marked bronchial hyper-reactivity. Evaluation of 10,116 firefighters showed exposure-related increases in cough and bronchial hyper-reactivity……. In summary, environmental exposures after the WTC disaster were associated with significant adverse effects on h

hankookilbo.com THE KOREA

Yellow Dust Storms Harmful to DNA

By Chung Ah-young
Staff Reporter

Dust storms contain materials harmful enough to destroy a cell membrane, a red blood cell and even damage DNA, according to research released Wednesday.

CENTRAL ASIA: Aral Sea crisis continues to erode health

© David Swanson/IRIN

Scores of ships remain stranded in the Aral Sea, once the fourth largest lake in the world

ANKARA, 26 Jul 2006 (IRIN) - Millions of people living near the Aral Sea face a bleak future, with health experts saying diseases like tuberculosis (TB) and cancer are having a terrible impact.

The sea, located on the border of Kazakhstan and Uzbekistan, was once the fourth largest lake in the world. However, it continues to shrink despite regional commitments to halt the draining of the rivers that feed it. It is now a quarter of its original size.

Over the last 40 years an estimated 45 million mt of salt-contaminated dust has been created due to the shrinking, resulting in massive health problems that affect millions of people, experts say.

In 1994, the governments of Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan established the International Fund for Saving the Aral Sea (IFAS) to address the environmental impact.

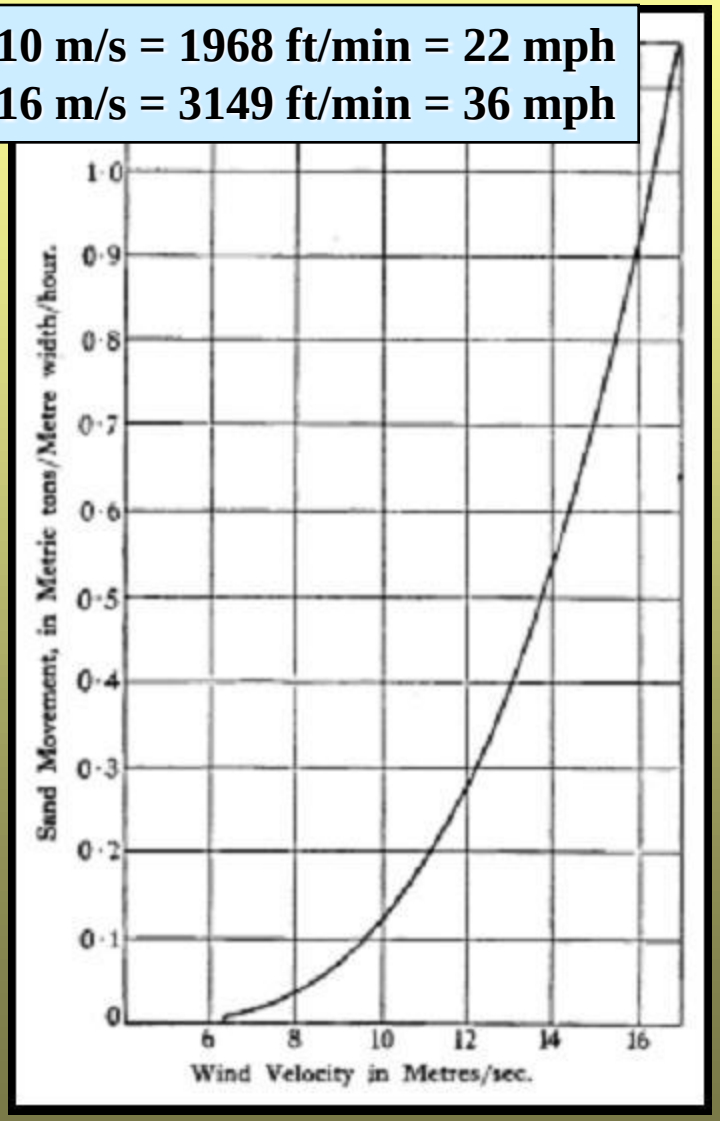
Usman Buranov, IFAS' technical director of the Global Environment Facility (GEF) projects, said that the health problems in the region were related to the low quality of drinking water.

He said agriculture and cattle breeding around the sea were less productive, unemployment was climbing and certain diseases were more prevalent.

The polluted air around the sea contained a toxic cocktail of salt, pesticides and chemicals that contaminated drinking water and led to liver and kidney illnesses, as well as a variety of respiratory diseases.

Wind Velocity & Airborne Dust

10 m/s = 1968 ft/min = 22 mph
16 m/s = 3149 ft/min = 36 mph

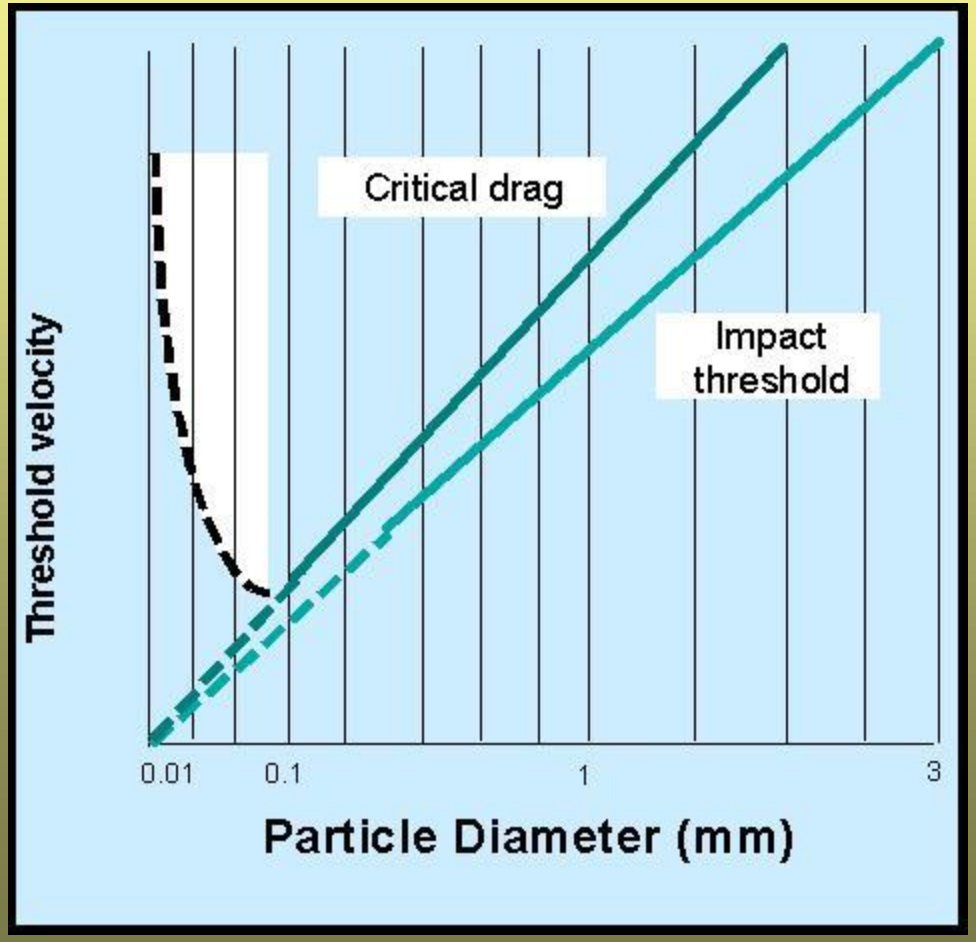


Aerodynamics of Wind Particles

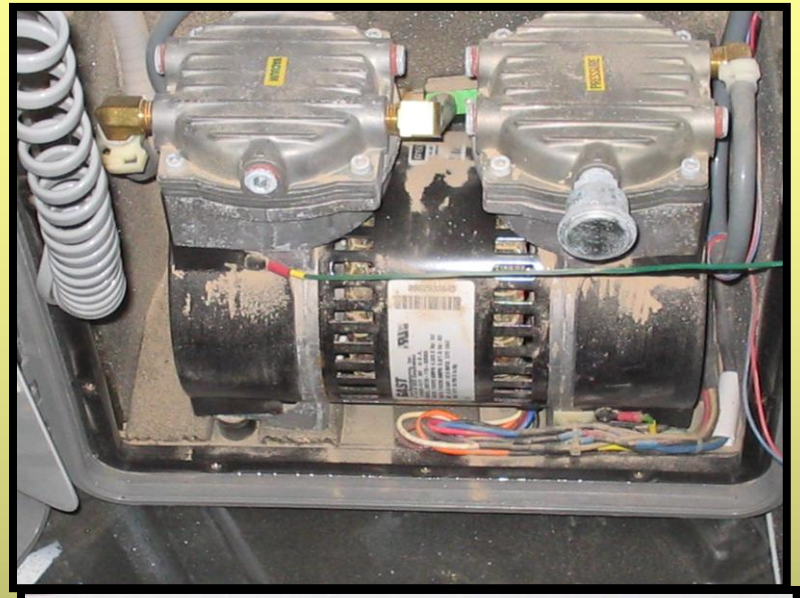
Air flow may be laminar or turbulent, but any near-surface flow is turbulent because of ground roughness.

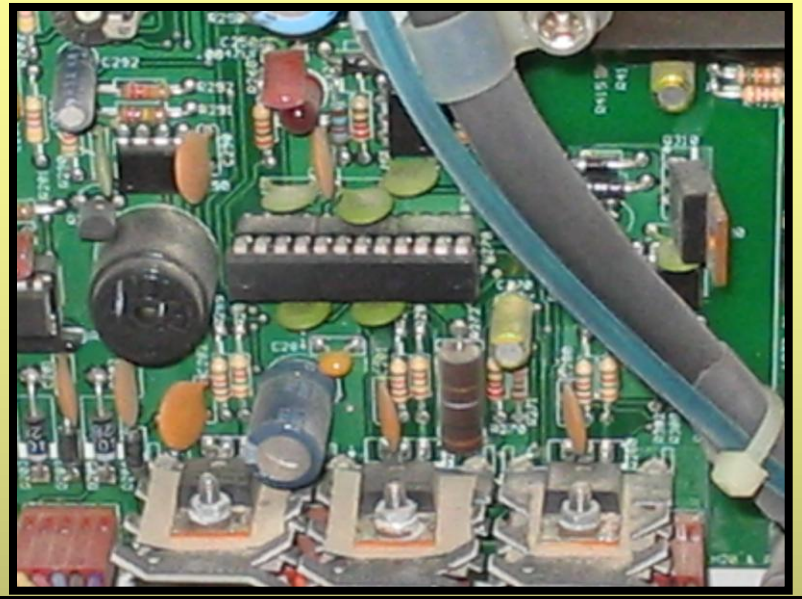
Velocity = 5.75 Vd log z/k

Wind erosion occurs at the instant that a grain is moved. Movement begins when the critical drag velocity is reached for a given size particle.

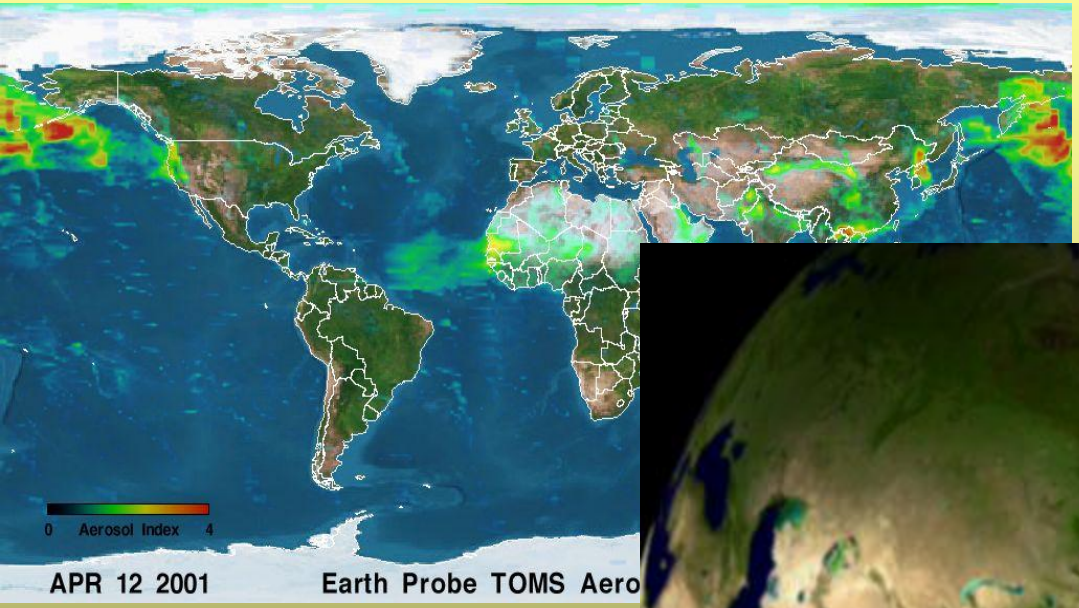


Dust Exposure



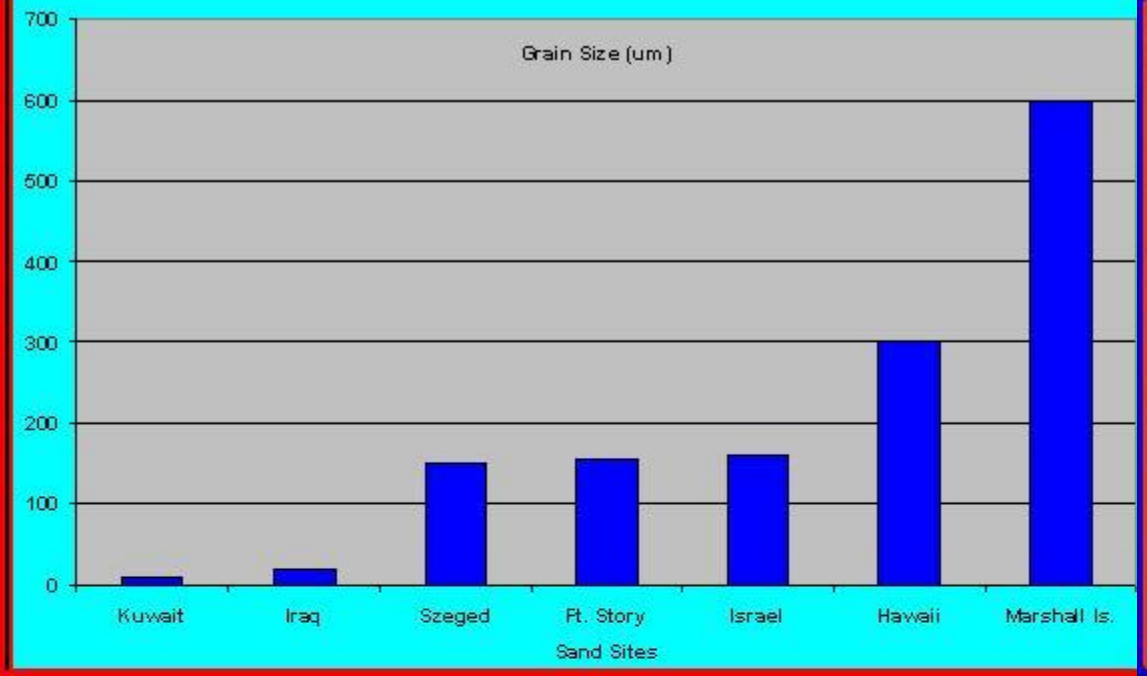


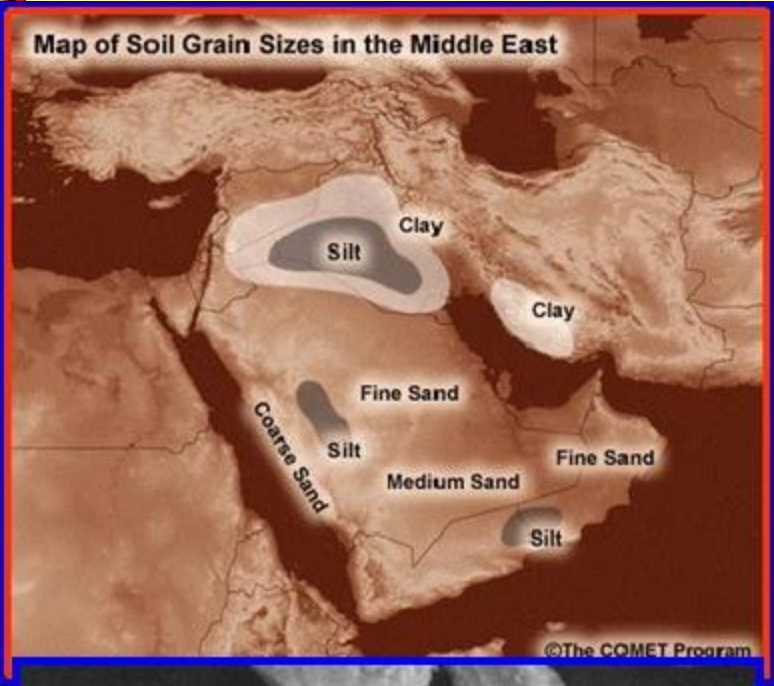
Asian Dust Storm – April 2001

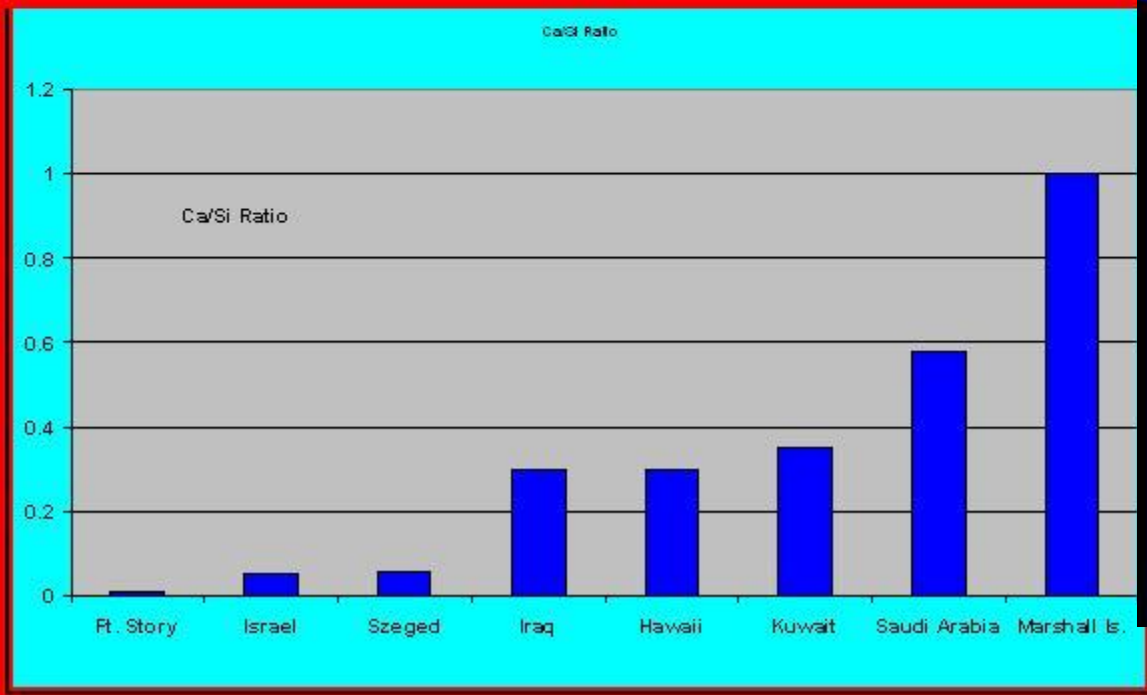


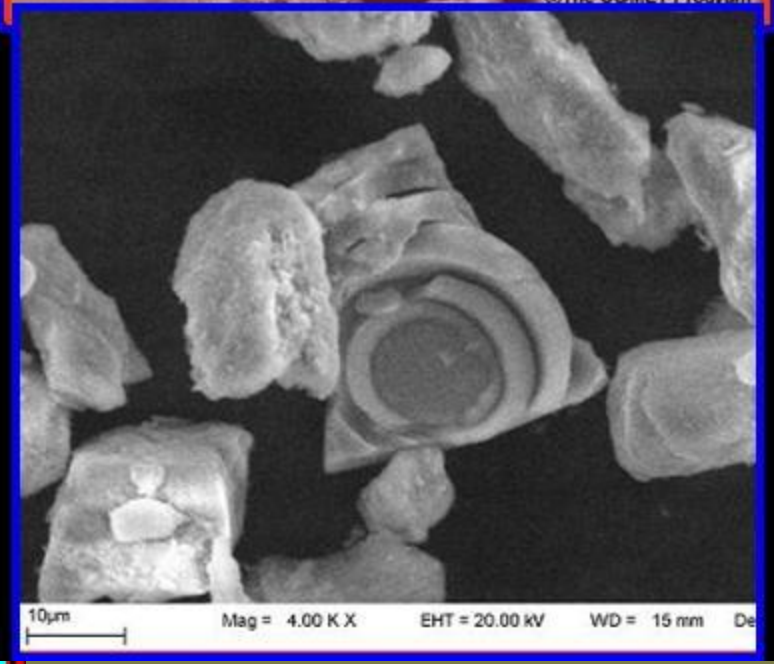
Desert Storms and their ability to move microorganisms and toxins around the globe

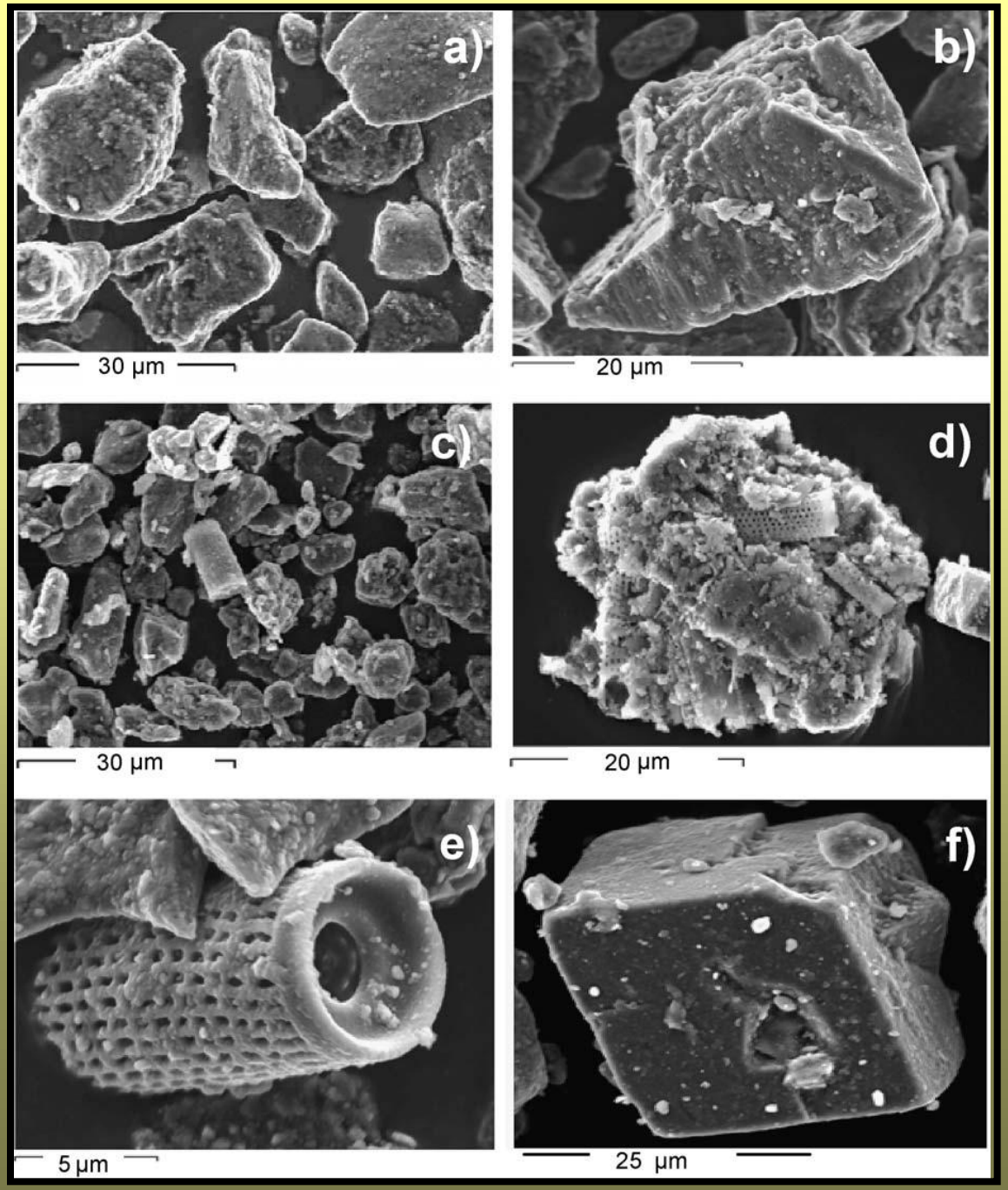
Dale W. Griffin, Ph.D., MSPN, Environmental Microbiologist
U.S. Geological Survey, St. Petersburg, Florida


Grain Size (um)
700
600
500
400
300
200
100
0
Kuwait
Iraq
Szeged
Ft. Story
Israel
Hawaii
Marshall Is.
Sand Sites


Map of Soil Grain Sizes in the Middle East
Clay
Silt
Clay
Fine Sand
Coarse Sand
Silt
Medium Sand
Fine Sand
Silt
©The COMET Program


Ca/Si Ratio
1.2
1
0.8
0.6
0.4
0.2
0
Ca/Si Ratio
Ft. Story
Israel
Szeged
Iraq
Hawaii
Kuwait
Saudi Arabia
Marshall Is.


10µm
Mag = 4.00 K X
EHT = 20.00 kV
WD = 15 mm



(a) Hoggar Massif (Algeria) desert soil sample HM2,

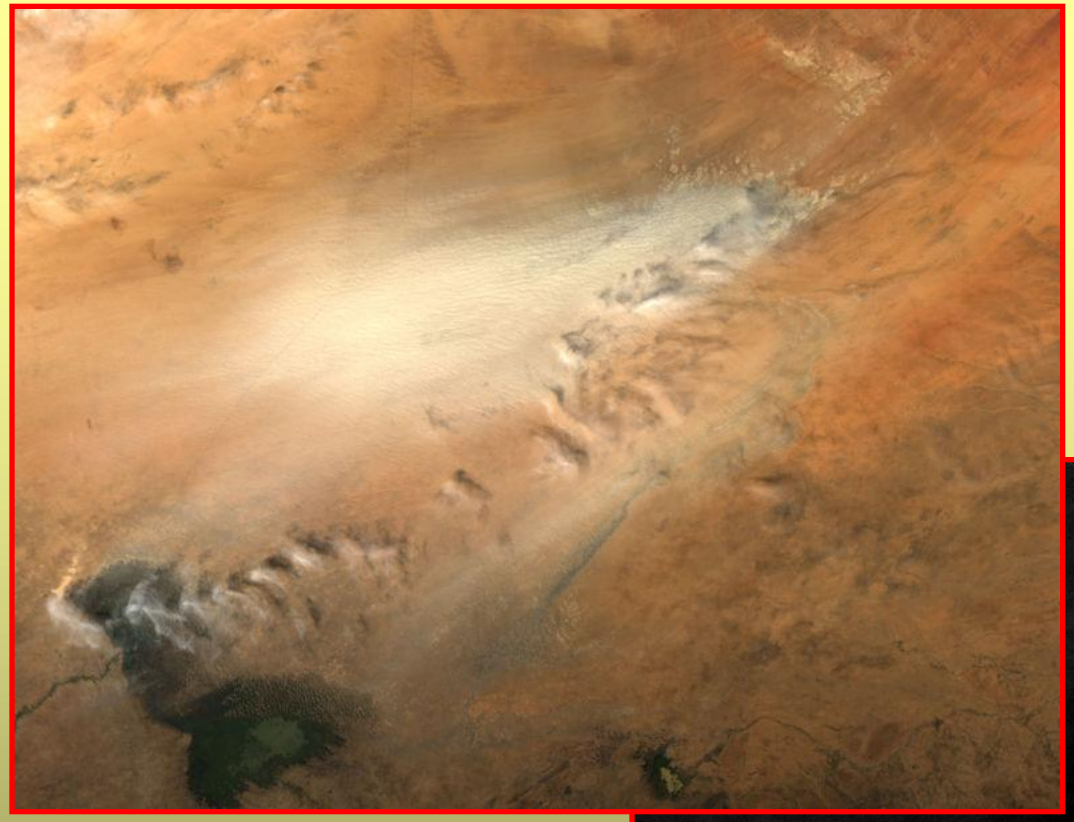
(b) close up of a relatively fresh alkali feldspar in HM2; \

(c) resuspended road dust Chad Basin sample: note mix of rock forming minerals & diatomaceous materials;

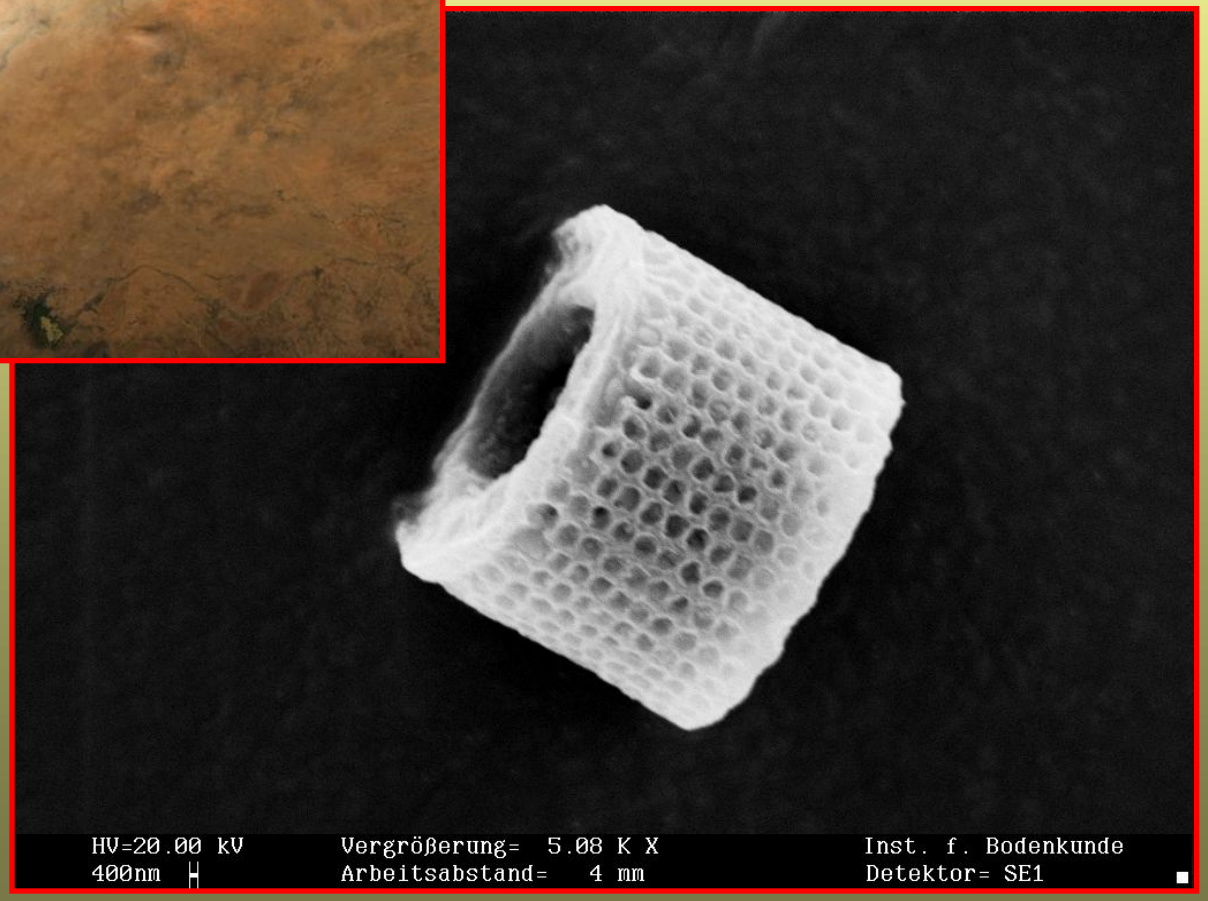
(d) typical clay-diatom agglomerated clast in CB1;

(e) detail of an *Aulacoseira* diatom from CB2 sample,

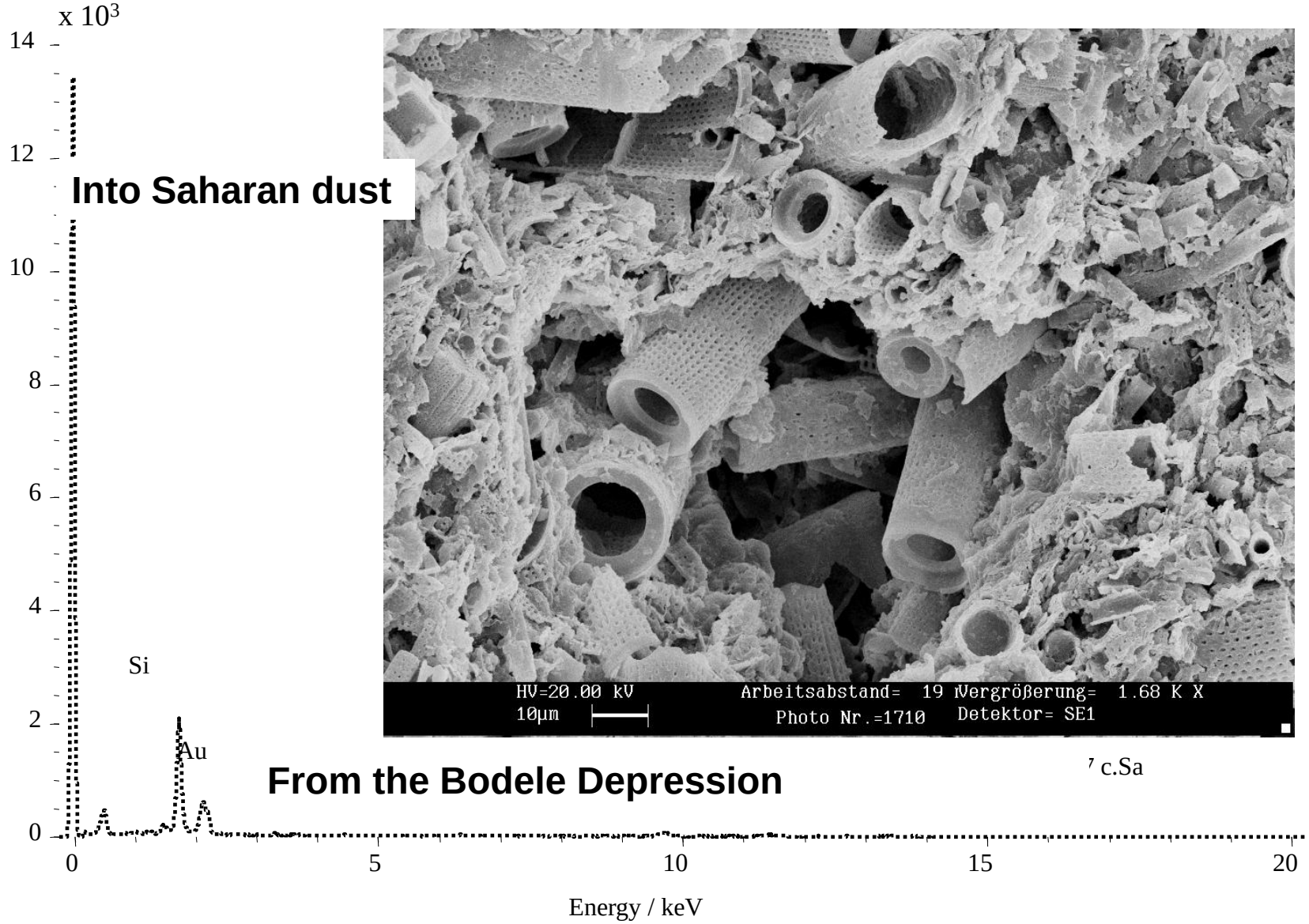
(f) dolomite-$CaMg(CO_3)_2$ from Western Sahara soil samples



From the Bodele Depression



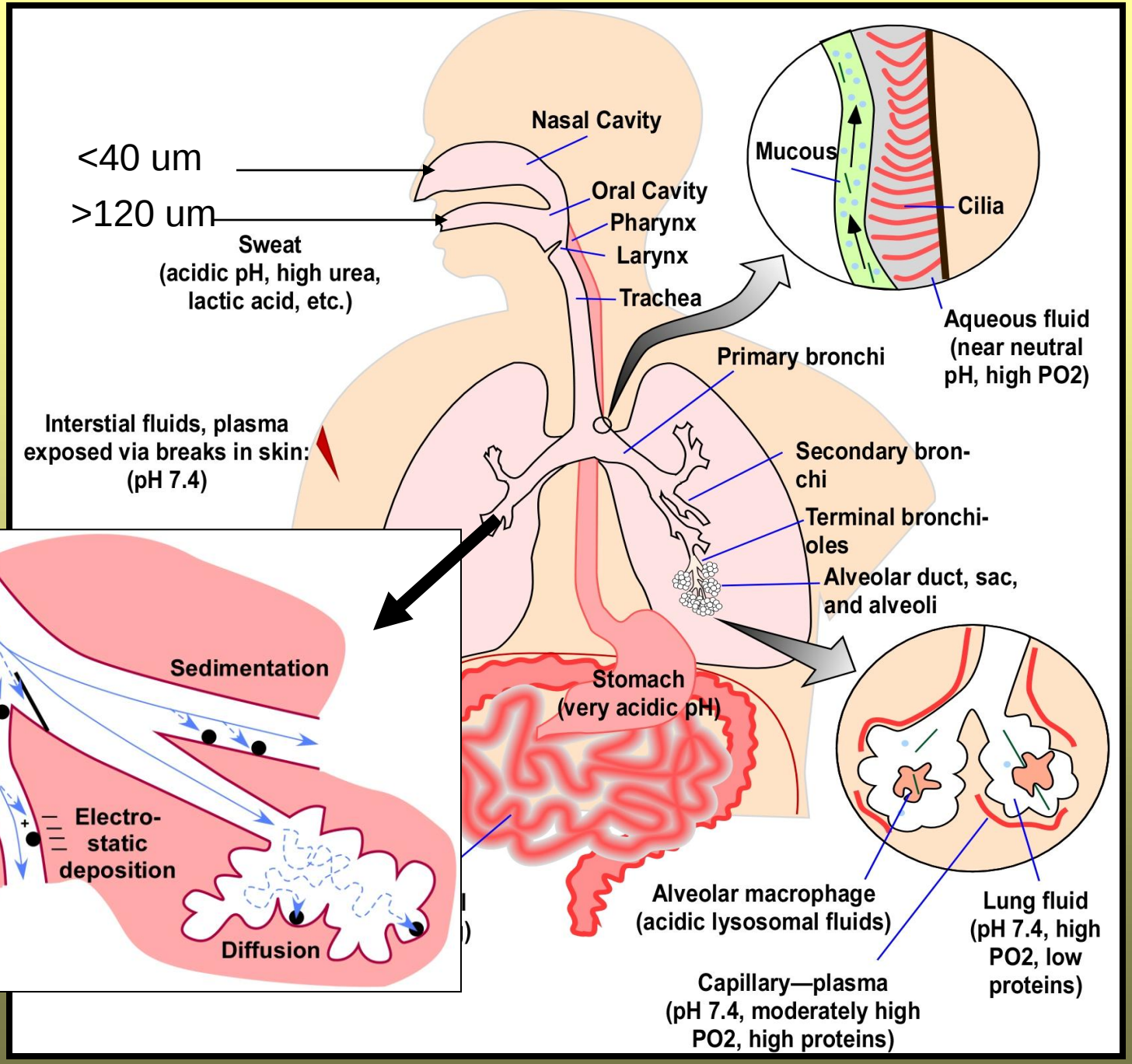
Into Saharan dust


x 10^3
14
12
10
8
6
4
2
0
Si
Au
0
5
10
15
20
Energy / keV
HV=20.00 kV
10µm
Arbeitsabstand= 19 mm
Vergrößerung= 1.68 K X
Photo Nr.=1710
Detektor= SE1
Into Saharan dust
From the Bodele Depression
c.Sa

CENTCOM DUST: WHY IS IT IMPORTANT!

- Force Health Protection Issues
  - Contains Heavy Metals
  - Harbors Pathogens
  - High Percentage in Respirable Range

Exposure Issues	CBD Issues
➢Contact	➢Detection
➢Ingestion	➢Analysis
➢Inhalation	➢Contamination


<40 um
>120 um
Sweat
(acidic pH, high urea,
lactic acid, etc.)
Nasal Cavity
Oral Cavity
Pharynx
Larynx
Trachea
Primary bronchi
Secondary bron-
chi
Terminal bronchi-
oles
Alveolar duct, sac,
and alveoli
Mucous
Cilia
Aqueous fluid
(near neutral
pH, high PO2)
Interstial fluids, plasma
exposed via breaks in skin:
(pH 7.4)
Stomach
(very acidic pH)
Alveolar macrophage
(acidic lysosomal fluids)
Lung fluid
(pH 7.4, high
PO2, low
proteins)
Capillary—plasma
(pH 7.4, moderately high
PO2, high proteins)
Impaction
Sedimentation
Interception
Electro-
static
deposition
Diffusion

Human Lung Airways

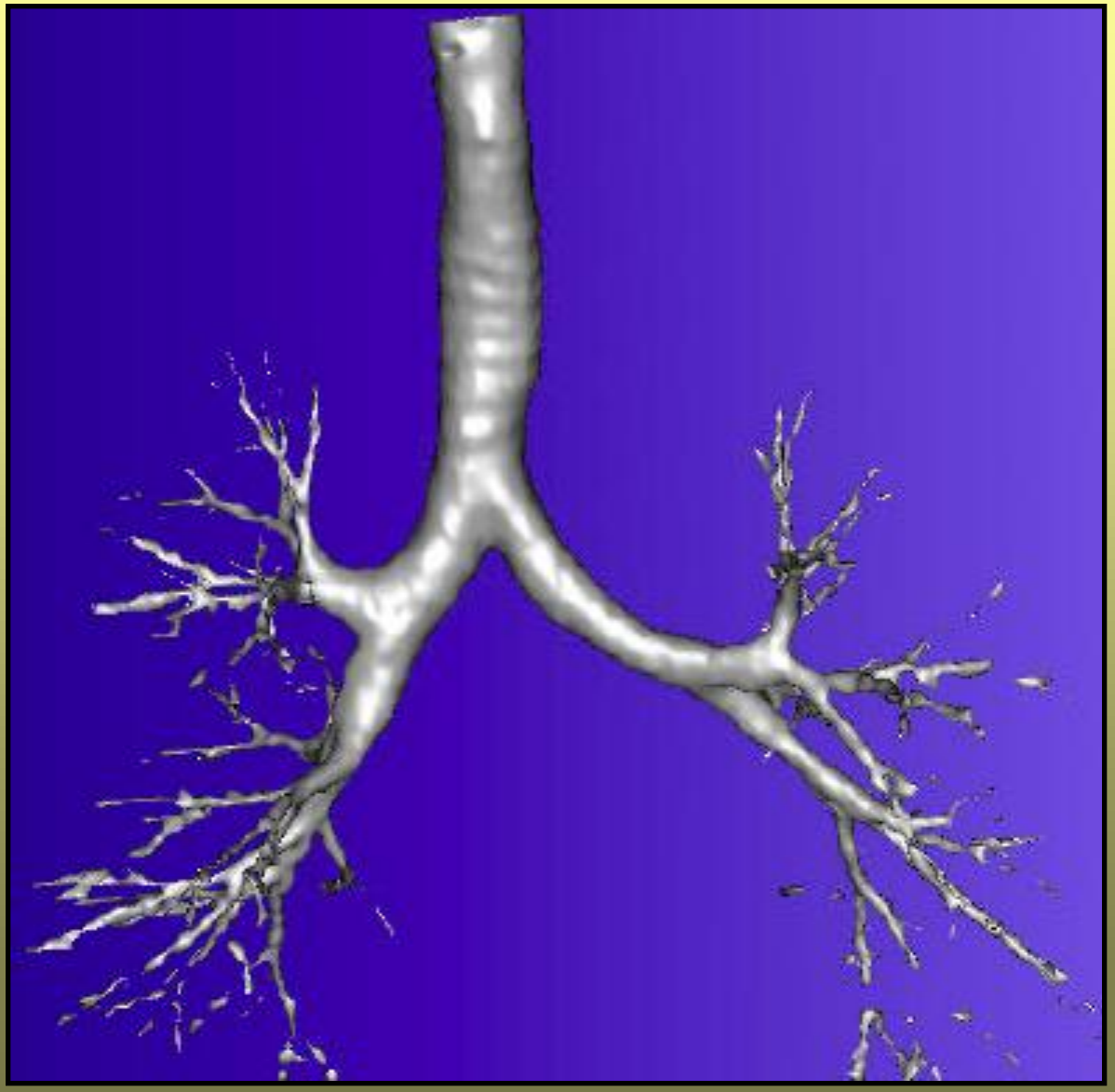


Image reconstructed from high resolution CT scan. Courtesy of Dr. Rod Clinkenbeard, University of Oklahoma

Moss, O. R. and Oldham, M. J. (2006). Dosimetry counts: Molecular hypersensitivity may not drive pulmonary hyperresponsiveness. J. Aerosol Med. 19(4), 555-564.

Summary of Exposure

TSP (Total Suspended Particle Mass) (mg/m^3) PM10 (10 um) and below

= **0.001 mg/m^3** (NIDBR Lab, Great Lakes, IL)

= **0.137 mg/m^3** (Camp Virginia Clinic, Kuwait - indoors)

= **2.469 mg/m^3** (Highest hourly average - 0800)

= **9.114 mg/m^3** (Highest TSP reading)

= **2.051 mg/m^3** (Highest daily maximum - 18 June @1300)

**** NOTE: >9.999 mg/m^3 readings recorded during peak dust storms***

Count (Total Number of Suspended PM 10 Particles /m^3)

Size Range = 0.5 um to 10 um

= **1,314,906** (NIDBR Lab, Great Lakes, IL)

= **12,290,917** (Camp Virginia Clinic, Kuwait - indoors)

= **107,261,167** (Highest average hourly maximum @1300) (SD = 54,959,015)

= **588,633,693** (Highest daily maximum – 18 June @1300)

= **127,643,273** (Highest avg daily (0700-1900) max 13 June) (SD = 34,311,341)

**** NOTE: >20,000,000 counts /ft^3 readings recorded during peak dust storms or >706,293,334 particles per cubic meter.***

Size Range = 5.0 um to 10 um

= **36,515** (NIDBR Lab, Great Lakes, IL)

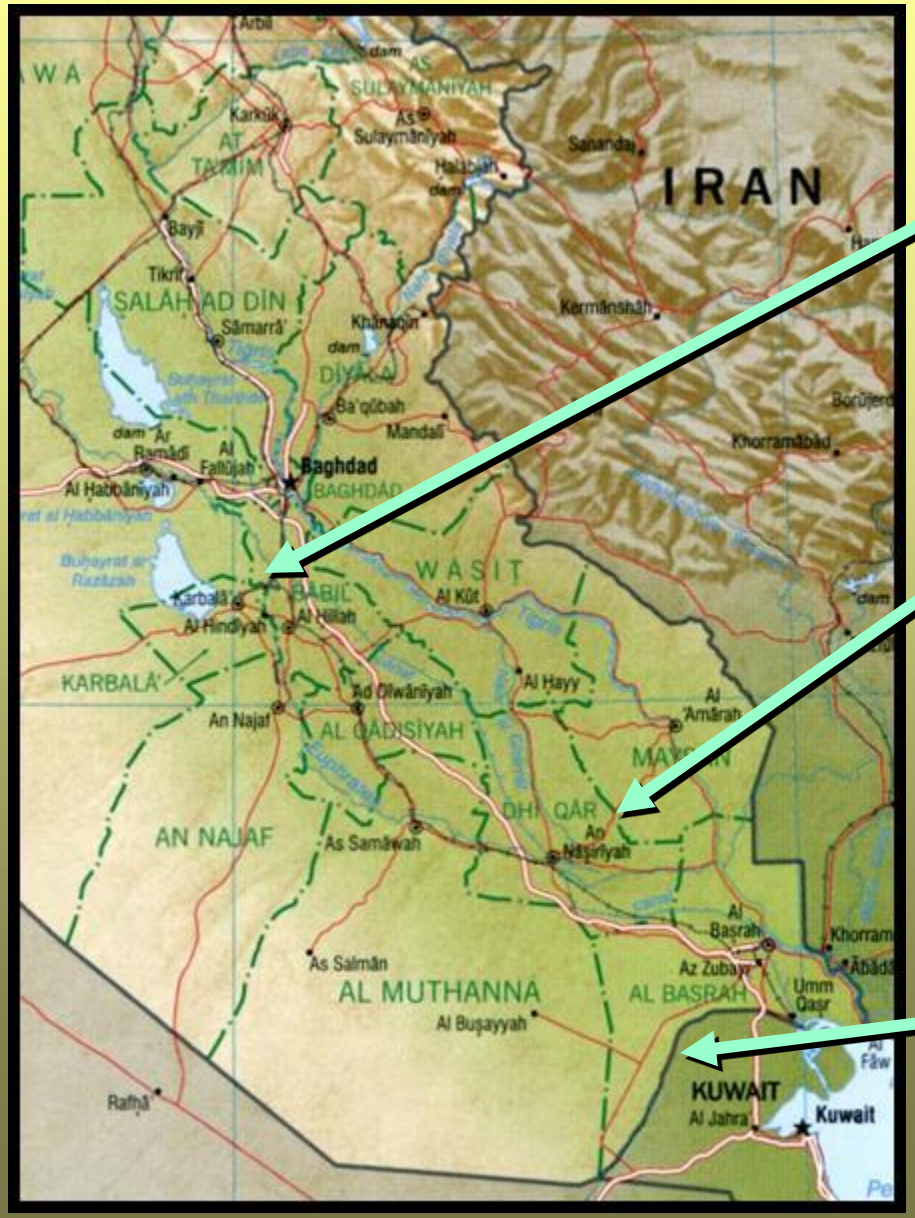
= **507,824** (Camp Virginia Clinic, Kuwait - indoors)

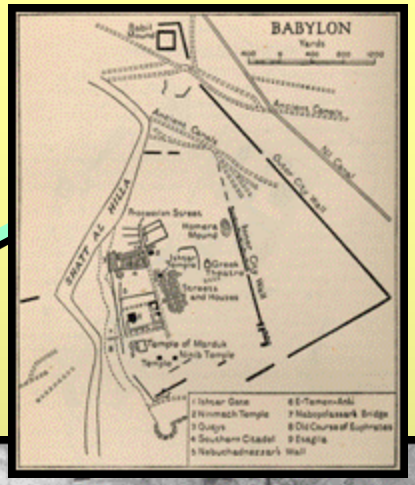
= **6,884,417** (Highest average hourly maximum @1300) (SD = 4,142,586)

= **44,571,347** (Highest daily maximum - 18 June @1300)

= **5,244,651** (Highest average daily maximum - 13 June) (SD = 3,632,501)

Sampling Locations

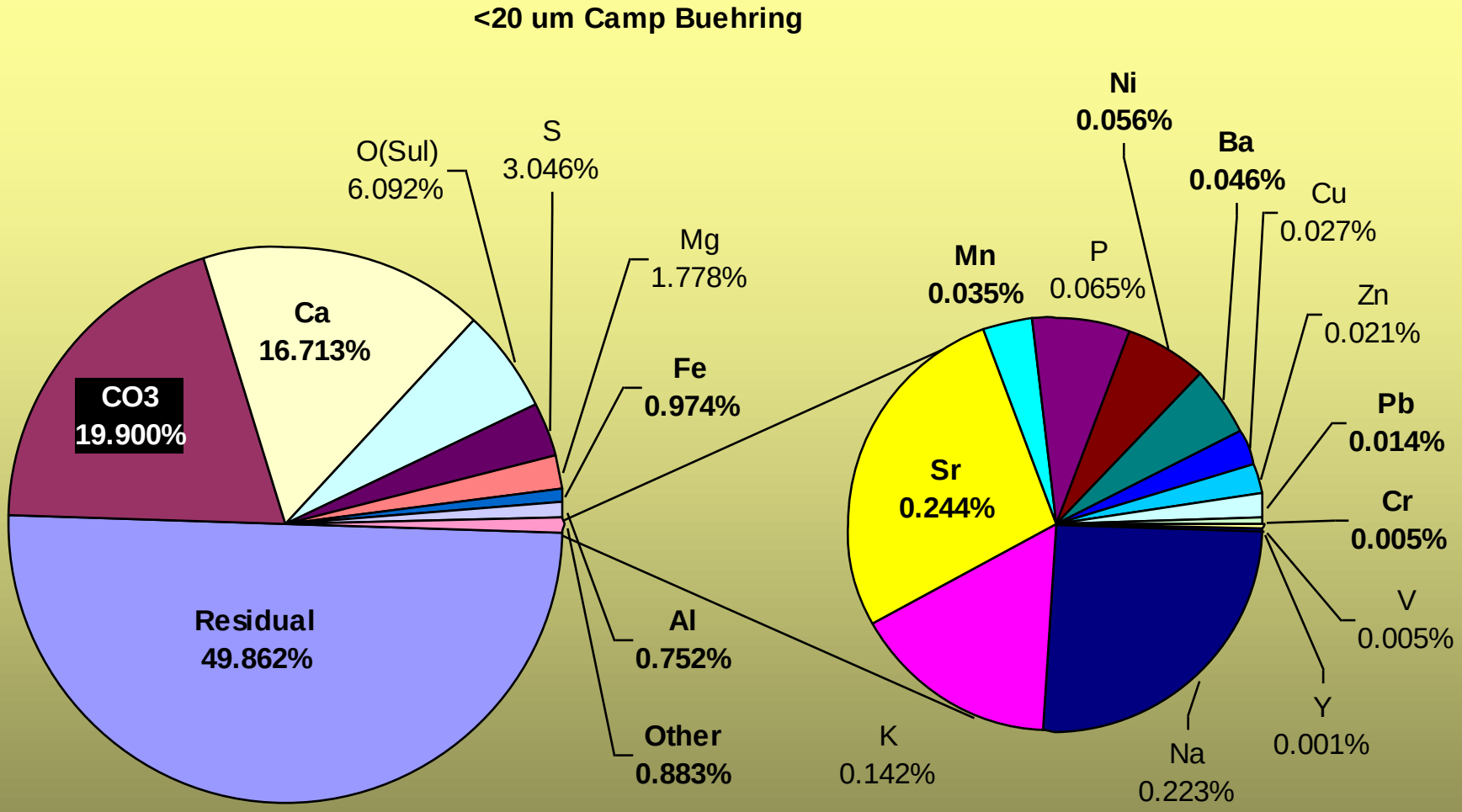




Chemical Analysis: Heavy Metals

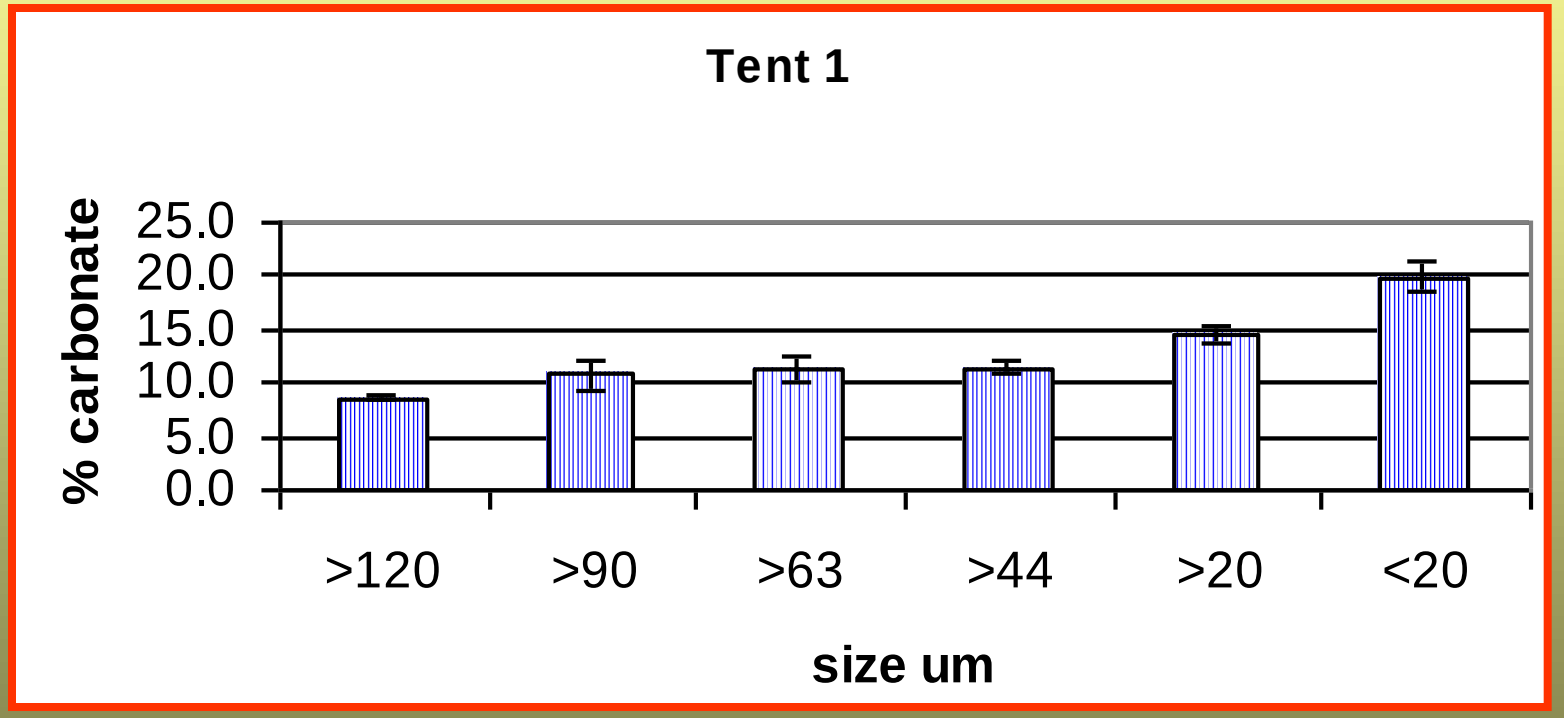
Acid Extractables
Tent 1

Sample	>120um	>90um	> 63um	>44um	>20um	<20um
Mass	0.2627	0.2596	0.2488	0.2626	0.2441	0.2504
Element	% dry wt	%dry wt	%dry wt	%dry wt	%dry wt	%dry wt
Sr	0.0697	0.0642	0.0995	0.1978	0.2718	0.2436
Ba	0.0068	0.0072	0.0081	0.0192	0.0308	0.0463
P	0.0160	0.0170	0.0234	0.0433	0.0549	0.0649
S	2.4413	2.4230	3.0444	4.0062	3.6646	3.0458
Mg	0.6844	0.8718	1.2672	1.5505	1.7234	1.7784
V	0.0022	0.0026	0.0032	0.0041	0.0046	0.0049
Na	0.1759	0.1963	0.1672	0.2056	0.2123	0.2225
Al	0.2969	0.3832	0.4948	0.6351	0.7164	0.7521
Ca	9.0134	10.3057	11.7495	13.9148	15.3535	16.7133
Zn	0.0053	0.0039	0.0042	0.0070	0.0112	0.0206
Cu	0.0060	0.0050	0.0036	0.0054	0.0077	0.0268
Ni	0.0089	0.0094	0.0169	0.0197	0.0305	0.0564
Y	0.0009	0.0006	0.0006	0.0007	0.0009	0.0010
K	0.0502	0.0653	0.0612	0.0942	0.1186	0.1422
Mn	0.0174	0.0222	0.0268	0.0305	0.0331	0.0352
Fe	0.3506	0.4844	0.6889	0.8419	0.9601	0.9736
Cr	0.0027	0.0032	0.0039	0.0049	0.0052	0.0052
Pb	0.0111	0.0038	0.0049	0.0056	0.0076	0.0138



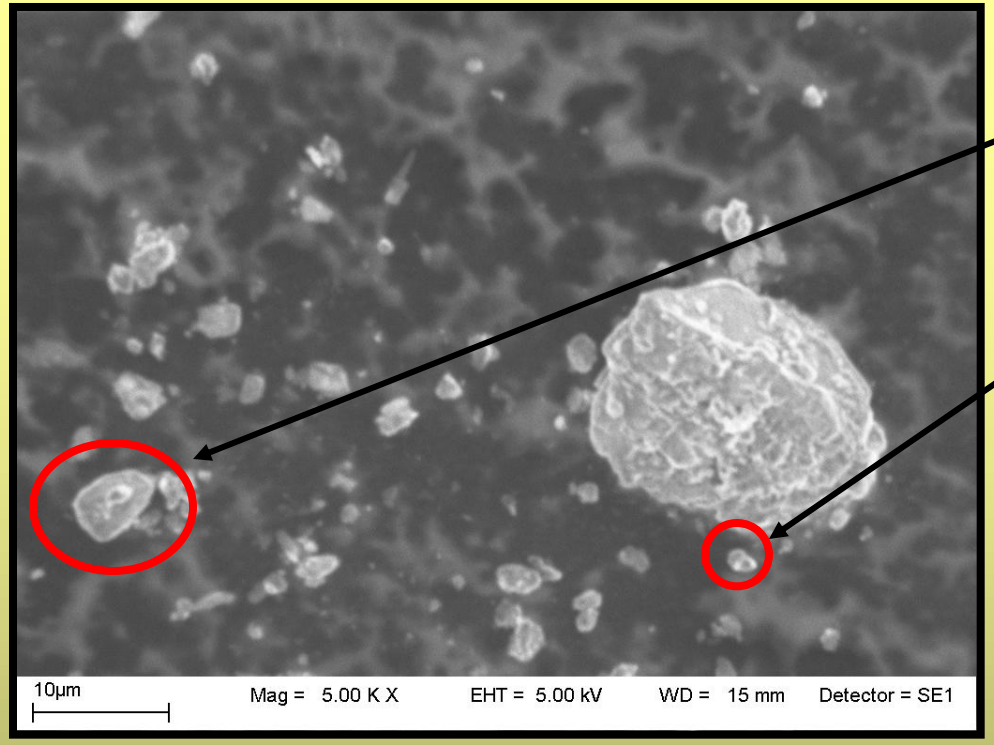
EPA method is SW-846 6010 for ICP-AES and 6020 for ICP-MS. EPA digestion method, 3050.

Chemical Analysis: Carbonates



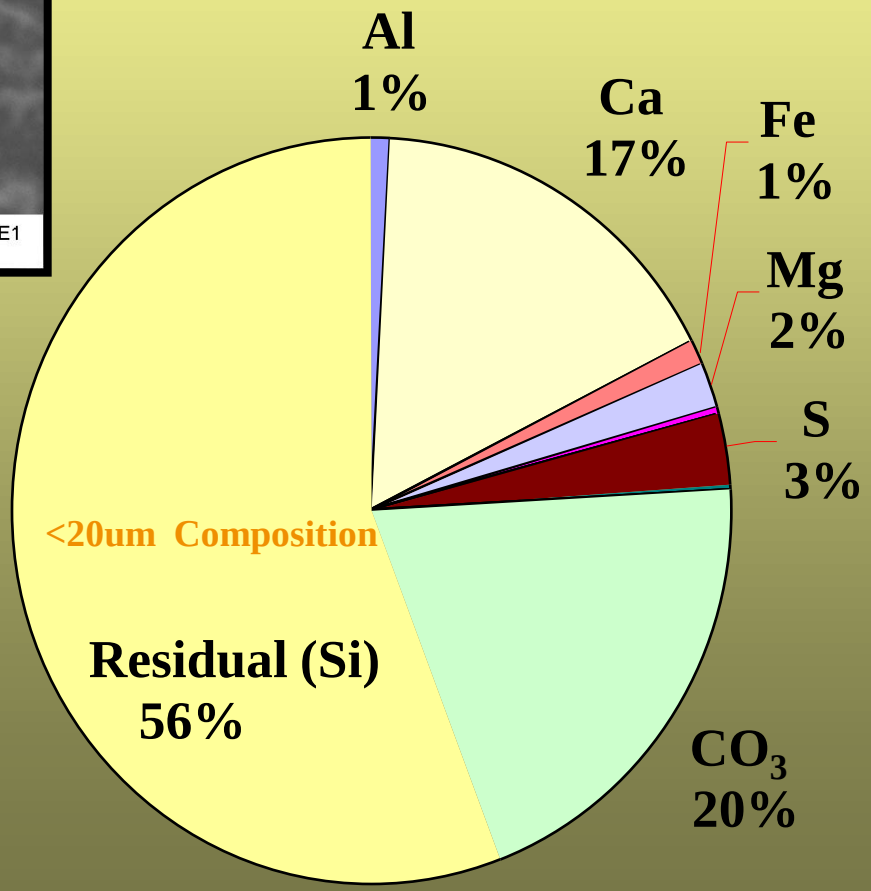
Initial Conclusions

- Cd, Se do not differentiate by site
- As, Co, Ni, Cr, Pb contents show significant differentiation by site
- Sites S127004 and S127011(site clusters 5,6) are distinct outliers from the general population of sampled sites
- Site clusters 4,5,6 “elevated” As, Cr
- Possible Pb-Mn association



400 of these particles can fit end-to-end across the Head of a Pin.

800 - 1000 of these particles can fit on the Head of a Pin.



Summary

- As particle size decreases, % heavy metals increases.
- Over or near maximum exposure levels for many metals.
- Significant daily loading of trace metals possible.

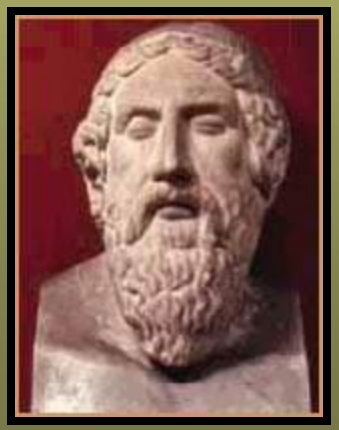
Microbiological Study of Micro-particulates

Fifth Plague of Egypt – ***"Murrain of beasts" Exodus 9:6***

Sixth Plague of Egypt – "And it shall become small dust in all the land of Egypt, and shall be a boil breaking forth [with] blains upon man, and upon beast, throughout all the land of Egypt". Exodus 9:10

25 BC: Poet Virgil

- ***The Iliad (Homer) "the burning wing of plague…"***
- ***Middle Ages: European pandemic "Black Bane" killed 60,000 cattle.***



Culturettes

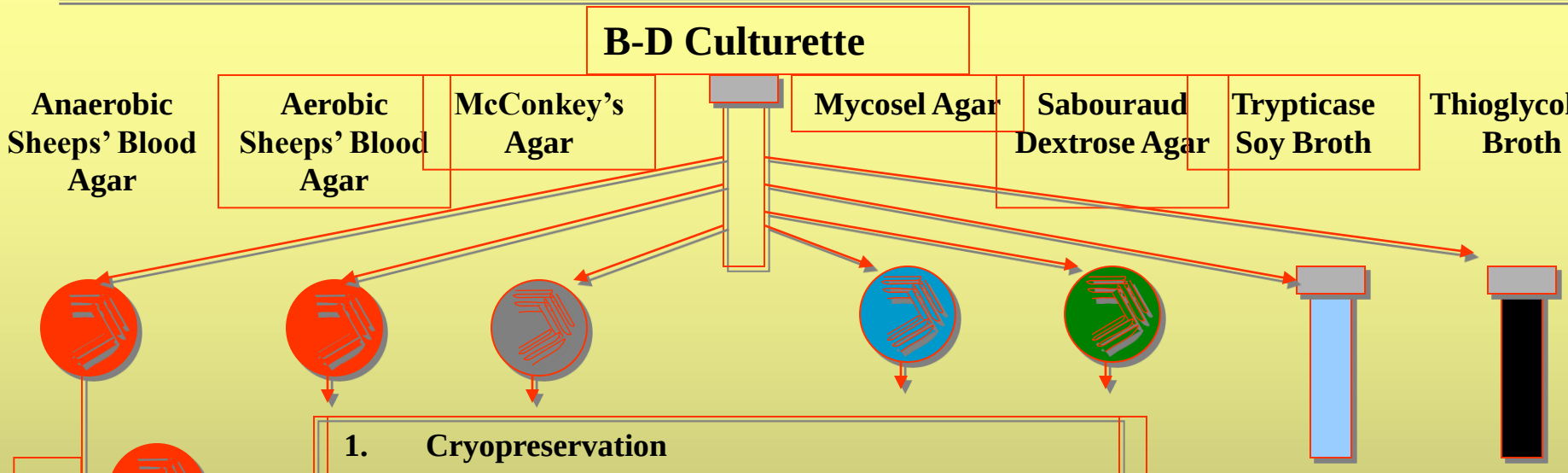
~32 samples X 6 types of Culturettes = ~192 Culturettes

Black	**Aerobic & Anaerobic with Charcoal**
Blue	**Aerobic & Anaerobic without Charcoal**
Green	**Industrial quality control**
Mico	**Fungi**
Yellow	**Chlamydia**
Green	**Virus**

Stored at 3^0C

~32 samples X 4 types of Culturettes = ~128 Culturettes

Microbial Isolation and Characterizations



Pick Colonies and restreak

1. Cryopreservation
2. Microscopic characterization
   - Morphology
   - Gram stain
3. TLFAME
   - Principal Component analysis
   - MIDI
     - CLIN 40
     - TSB
   - Sentinel
4. 16 S rDNA sequence
5. B-D Crystal
6. Mueller-Hinton II antibiotic sensitivity

~128 Culturettes

x 7 Media types

~896 Enrichments

Summary of Soil Isolates

Best ID thus Far	Comment
Neisseria meningiditis	meningitis
Staphylococcus aureus	cystic fibrosis
Bacillus circulans	gastro-enteritis
Pantoea agglomerans	septic arthritis
Pseudomonas agrici	
Ralstonia paucula	opportunist-septicemia, peritonitis, abscesses
Staphylococcus pasteuri	various infections
Arthrobacter crystallopoietes	
Pseudomonas balearica	cystic fibrosis
Paenibacillus thiaminolyticus	bacteremia
Bacillus vedderi	obligate alkaliphile
Bacillus subtilis	
Pantoea agglomerans	epiphyte
Pseudomonas pseudoalcaligenes	
Cryptococcus albidus	septicemia and meningitis
Bacillus clausii	Oral bacteriotherapy
Kurthia gibsonii	Diarrhea
Bacillus firmus	alkaliphile; bread spoilage
Staphylococcus kloosii	various infections
Bacillus mojavensis	biosurfactant
Bacillus licheniformis	food poisoning
Pseudomonas oryzihabitans	Hickman catherter biofilm

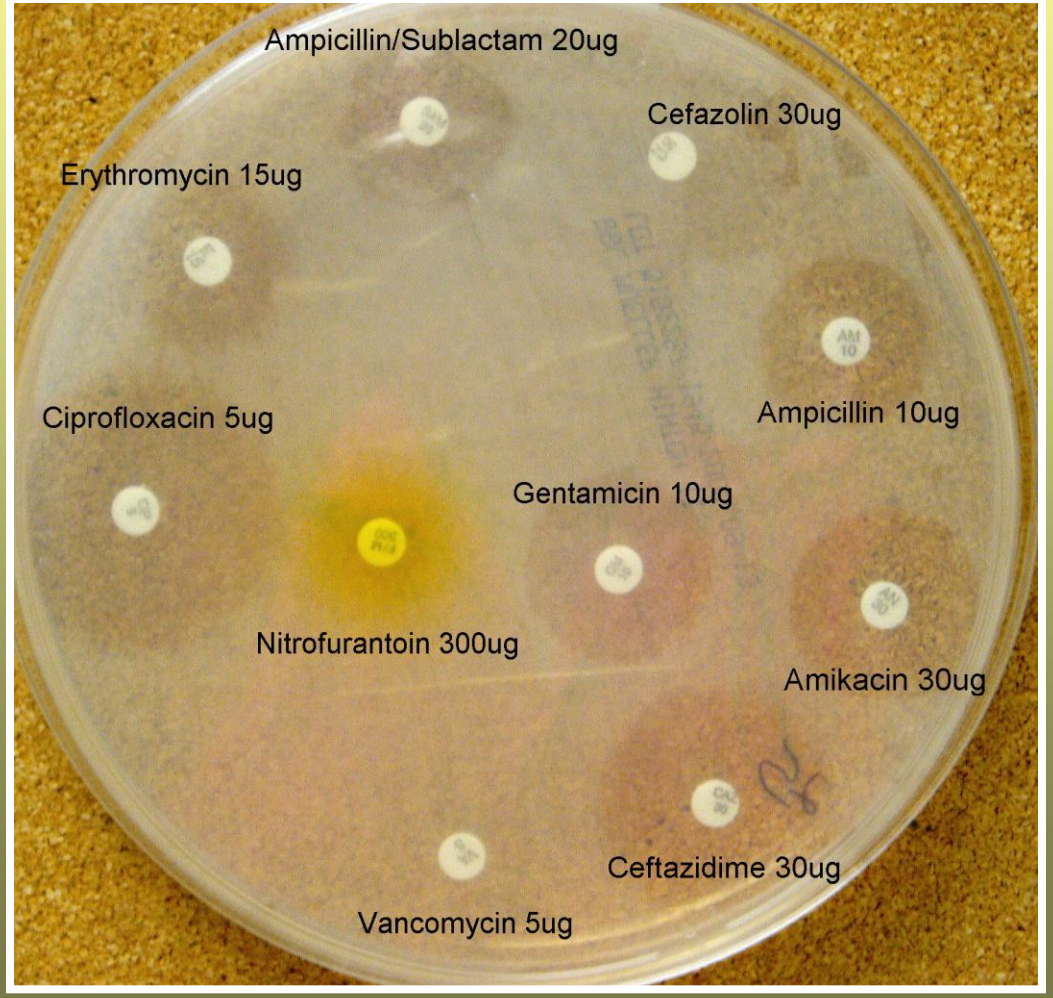
Culturettes

Isolates of Concern - Hemolytic

Isolate Number	Location	Culturette	Hemolytic	Genus and Species Identification							
				16S	Match	TLFAME CLIN 40	Match	TLFAME Sentinel	Match	TLFAME TSB	Match
56	Kuwait 2	**Blue**	Beta	Submitted		Legionella vjordanis	0.16	Microbacterium luteolum	0.25	Microbacterium-liquefaciens*	0.42
69	Kuwait 2	Black	Beta	Submitted		Micrococcus luteus G	0.80	Arthrobacter luteolus	0.49	Arthrobacter-atrocyaneus	0.69
70	Kuwait 2	Blue	Beta	Submitted		Micrococcus luteus C	0.81	Arthrobacter luteolus	0.54	Arthrobacter-atrocyaneus	0.68
72	Kuwait 2	Blue	Beta	Submitted		Tatlockia micdadei*	0.26	Arthrobacter oxydans	0.04	NO MATCH	
I-10	Udari	Orange	Alpha	Pantoea agglomerans	0.95	Neisseria cinera	0.20	Providencia rettgeri	0.02	Ewingella americana	0.78
I-11	Udari	Blue	Alpha	Pseudomonas agrici	0.01	No data		No data		Pseudomonas stutzeri	0.90
I-17	Udari	Black	Alpha/Beta	Paenibacillus thiaminolyticus	0.03	No data		No data		Paenibacillus thiaminolyticus	0.53
I-18	Udari	Orange	Beta	Submitted		Bacillus subtilis	0.52			Bacillus subtilis	0.90
I19	Udari	Blue	Beta/Alpha	Bacillus subtillis subtillis	0.00	No data		No data		Bacillus subtilis	0.92
I-20	Udari	Green	Alpha	Pantoea agglomerans	0.01	Pantoea aggomerans	0.62	Ralstonia paucula	0.27	Pantoea agglomerans	0.82
I-30	Tallil AB	Orange	Beta	Bacillus mojavensis	0.00	Bacillus subtilis	0.42	No Match		Bacillus atrophaeus	0.87
I-31	Tallil AB	Blue	Beta	Bacillus licheniformis	0.02	No data		No data		Bacillus licheniformis	0.61
I-32	Tallil AB	Green	Beta	Flavimonas oryzihabitans	0.00	No data		No data		No data	

Antibiotic Sensitivity

Beta Hemolytic Isolate Number 69



Bacteria Isolated from Kuwait and Iraq that have Shown Antibiotic Resistance.

Culture#	Description	Location	Culturette	Hemolysis	Colony Morphology	MIDI @ DE Environmental	Similarity Index	Comment
8	BSSI	Babylon	Green	No	Dry Fungal type colonies; White spreader on TSA & Blood	Bacillus circulans	0.61	N/A
12	>20<44 um	Udairi	Green	No	Cream colored mucoid colonies on Blood and TSA;	**Not growing when others sent off**	N/A	N/A
16	>44<63 um	Udairi	Green	No	Small mucoid colonies on Blood; Spreading mucoid on TSA;	Staphylococcus warneri	0.881	N/A
20	>44<90 um	Udairi	Green	alpha	Small dry cream colored colonies	Pantoea agglomerans Pantoea agglomerans	0.82 0.711	GC subgroupB GC subgroupC
24	<20 um	Udairi	Green	No	Shiny yellowish/cream spreading colonies on TSA; Purple spreader on Blood;			
28	TAB II Sand A	Tallil	Green	No	Large shiny mucoid colonies	Not sent to MIDI	N/A	N/A
32	TAB II Sand B	Tallil	Green	beta	Clear white cauliflower colony on TSA; Shiny clear runny colony on Blood;	Not sent to MIDI	N/A	N/A

Culture#	MIDI @ MS CLIN 40	Similarity Index	Comment	MIDI @ MS Sentenial	Similarity Index	MIDI 500 bp rDNA sequnce analysis	% Diff	Comments
8	No match/Too dilute	N/A	N/A	No match				
12	Vibrio alginolyticus Aeromonas hydrophilia	0.366 0.366	N/A N/A	Ralstonia paucula Erwinia mallotivora	0.127 0.103			
16	Pseudomonas stutzeri	0.44	N/A	Pseudomonas balearica	0.097			
20	Pantoe aggomerans Aeromonas hydrophilia	0.623 0.386	GCsubgroup N/A	Ralstonia paucula Buttiauxella gaviniae	0.274 0.175	Pantoea agglomerans	0.85%	Plant/Human Pathogen
24								
28	Not Extracted	N/A	N/A					
32	Not Extracted	N/A	N/A			Flavimonas oryzihabitans	0.10%	Hickman Cath. Pathogen

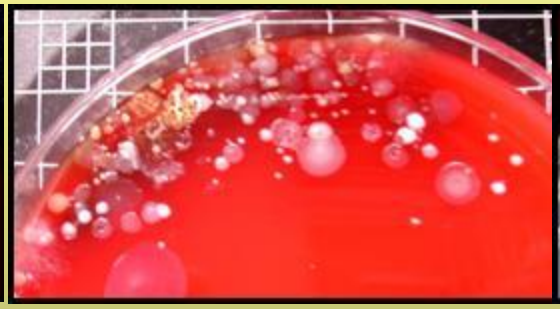
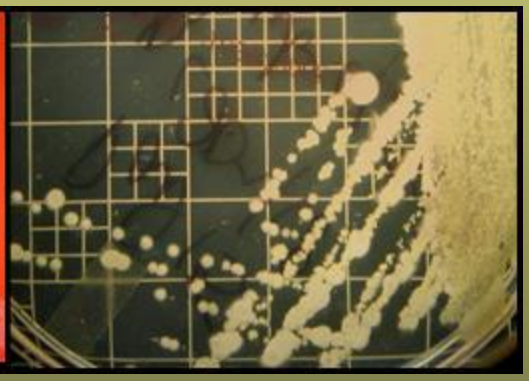
Fungal Isolates

~300 bp of D2 region of LSU rDNA

Microseq Library database								
Midi D2(300 bp)LSU rRNA	% diff	LSU D2 Genbank Database	% ID	Associated Disease				
Allewia eureka	0.31	Ulocladium sp.	99					
Allewia eureka	4.64	Cryptococcus uzbekistanensis	100					
Allewia eureka	0.31	Ulocladium sp.	99	None				
Altemaria altemata	0	Alternaria sp	100	Plant pathogen				
Rhodotorula minuata	5.73	Rhodotorula minuata	99	Eye infections				
Cryptococcus albidus	2.44	Cryptococcus sp.	100	Cryptococcus neoformans - meningoencephalitis				
Ulocladium chartarum	0.31	Stemphylium sp	99	Fungal biocontrol agent				
Filobasidium uniguttulatum	4.64	Cryptococcus uzbekistanensis	100	Teleomorph of Crytococcus, non pathogenic yeast				
Ulocladium consortiale	0	Stemphylium sp	100	cutaneous mycoses				
Ulocladium chartarum	0.31	Stemphylium sp	99					
Mortierella polycephala	7.1	Mortierella polycephala	92	Pulmonary mycosis in cattle				
Embellisia chlamydospora	0	Ulocladium sp.	99	none				
Filobasidium uniguttulatum	4.64	Cryptococcus uzbekistanensis	100					
Penicillium camembertii	0	Penicillium sp.	100					
Cryptococcus albidus	0	Cryptococcus albidus	100					
Allewia eureka	0.31	Ulocladium sp.	99					
Embellisia chlamydospora	0	Ulocladium sp.	99					
Filobasidium uniguttulatum	4.64	Cryptococcus uzbekistanensis	100					
Embellisia chlamydospora	0	Ulocladium sp.	99					
Filobasidium uniguttulatum	4.64	Cryptococcus uzbekistanensis	100					
Penicillium camembertii	0	Penicillium sp.	100					
Allewia eureka	0.31	Ulocladium sp.	99	Plant pathogen				
Phoma glomerata	0	Phoma herbarum	99					

Dust – Pad 15 PM_{10-20}

Agar Enrichments – Comparison of media/methods

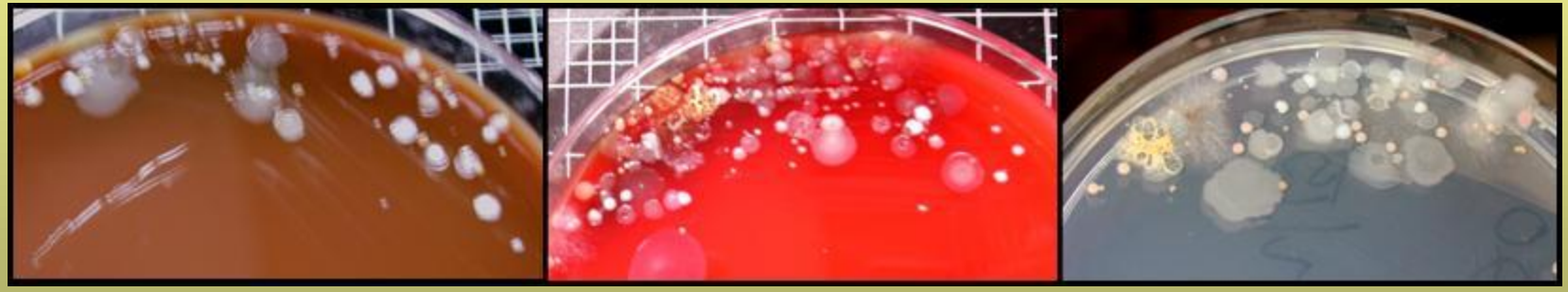
	Chocolate	**Sheeps' Red Cell**	**Trypticase Soy**
Swab Dust			
TSB Enrich & Swab			

Dust

Particle size – media comparisons

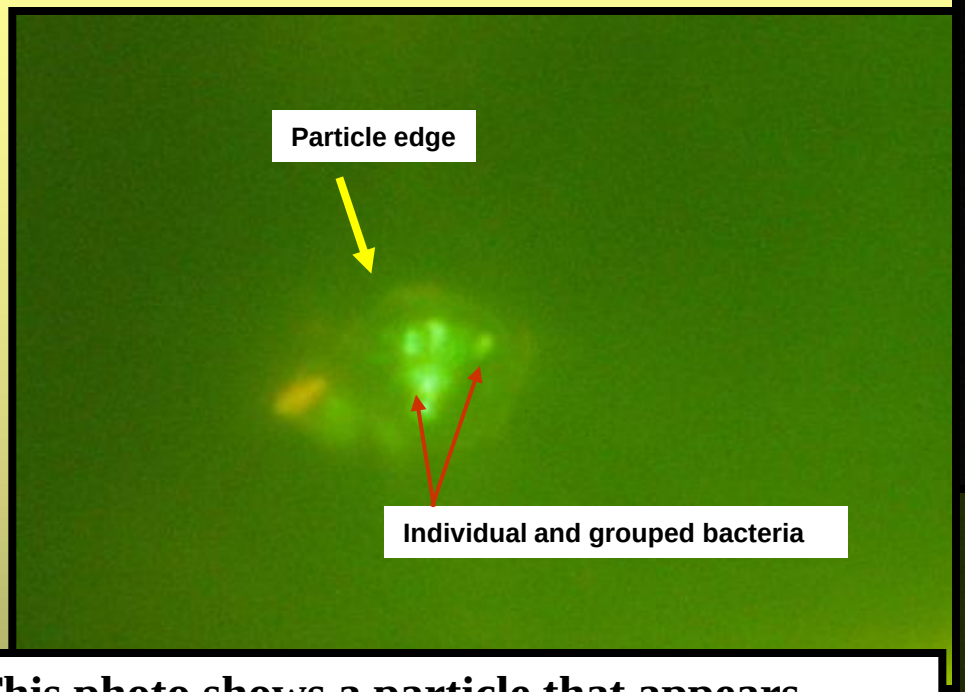
Chocolate **Sheeps' Red Cell** **Trypticase Soy**

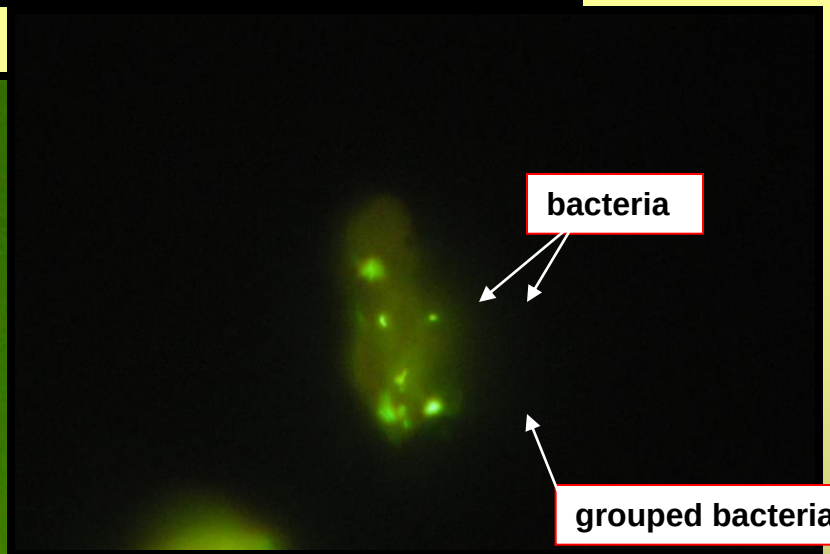
Pad 15 PM_{10-20}

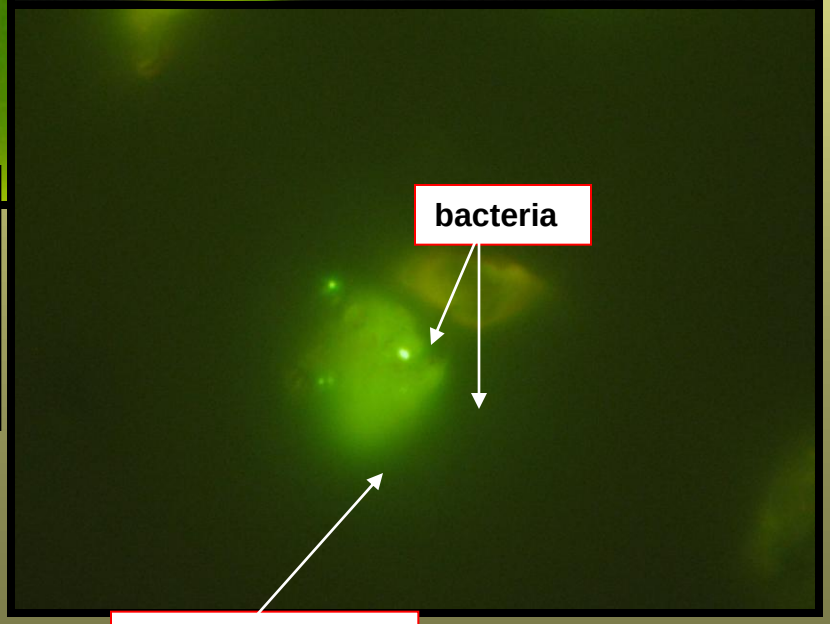


Pad 15 PM_{20-40}

Kuwait dust, Camp Buehring, size fraction 10 to 20um



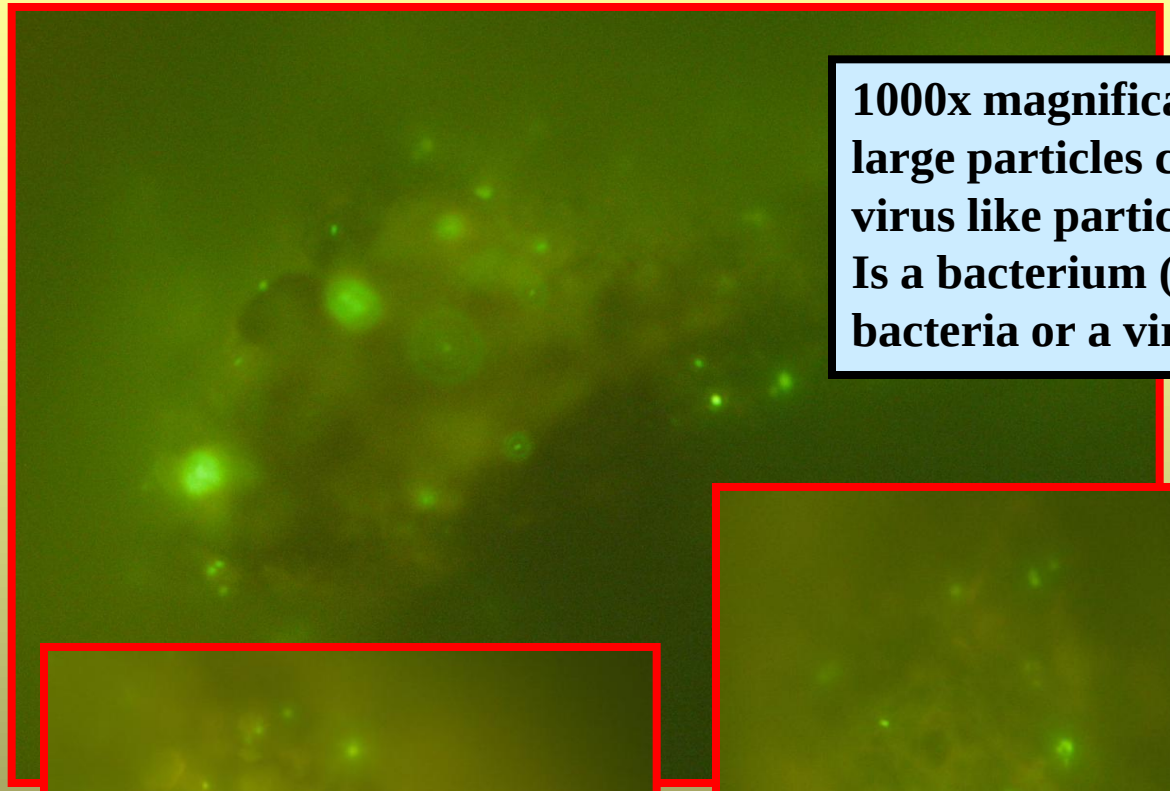


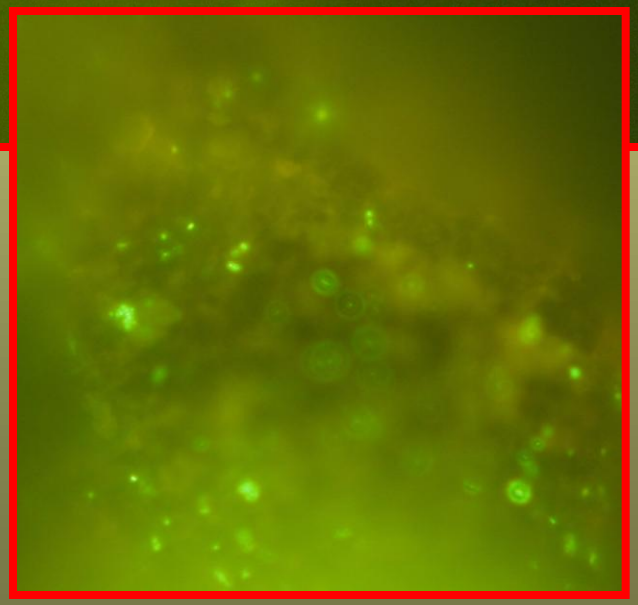


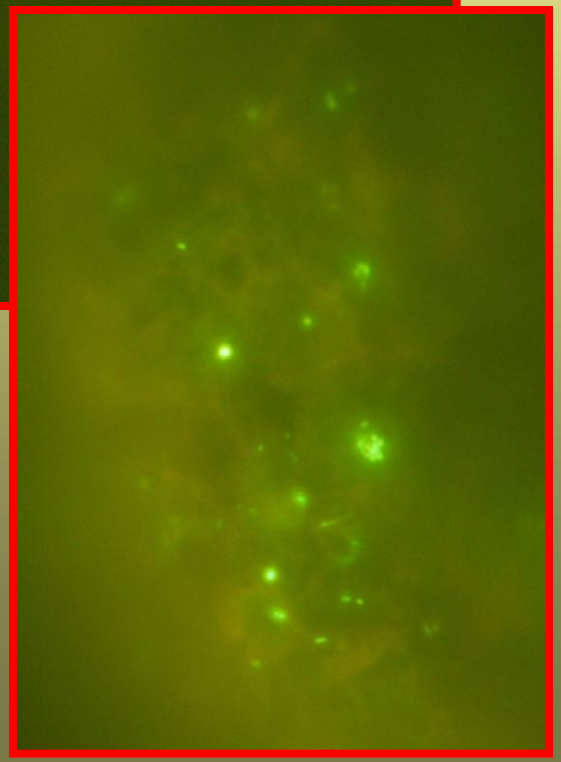
This photo shows a particle that appears to contain numerous bacteria in its core rather than on its surface. Bacteria size ~1um. 1000X with digital zoom.

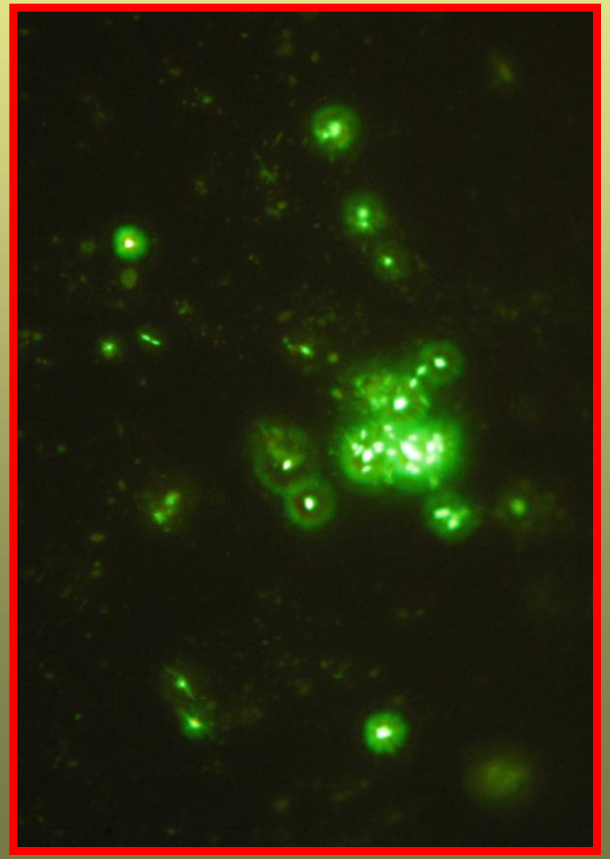
Sterilization Problems!

Kuwait dust, sample #2 raw (bulk)

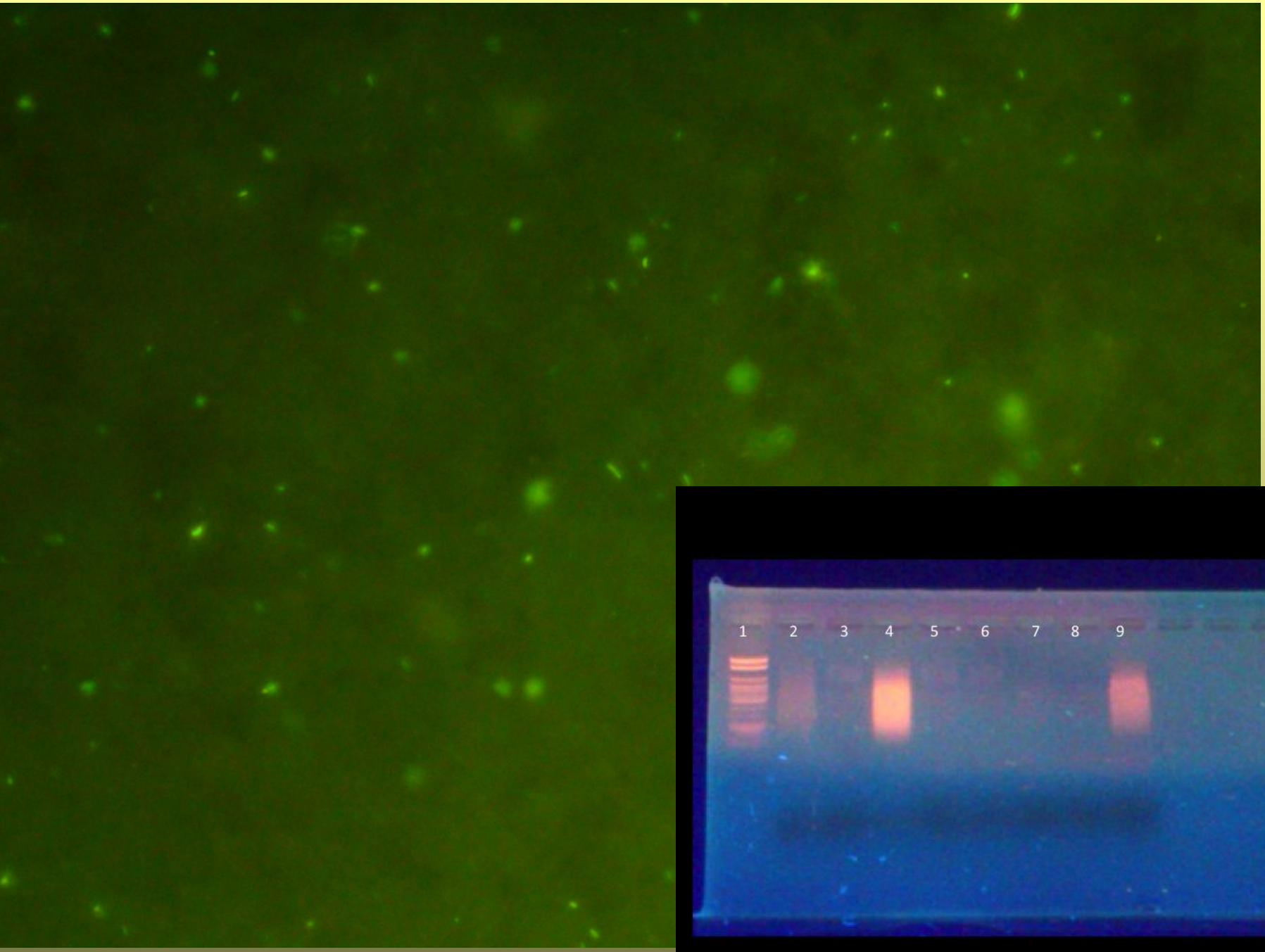


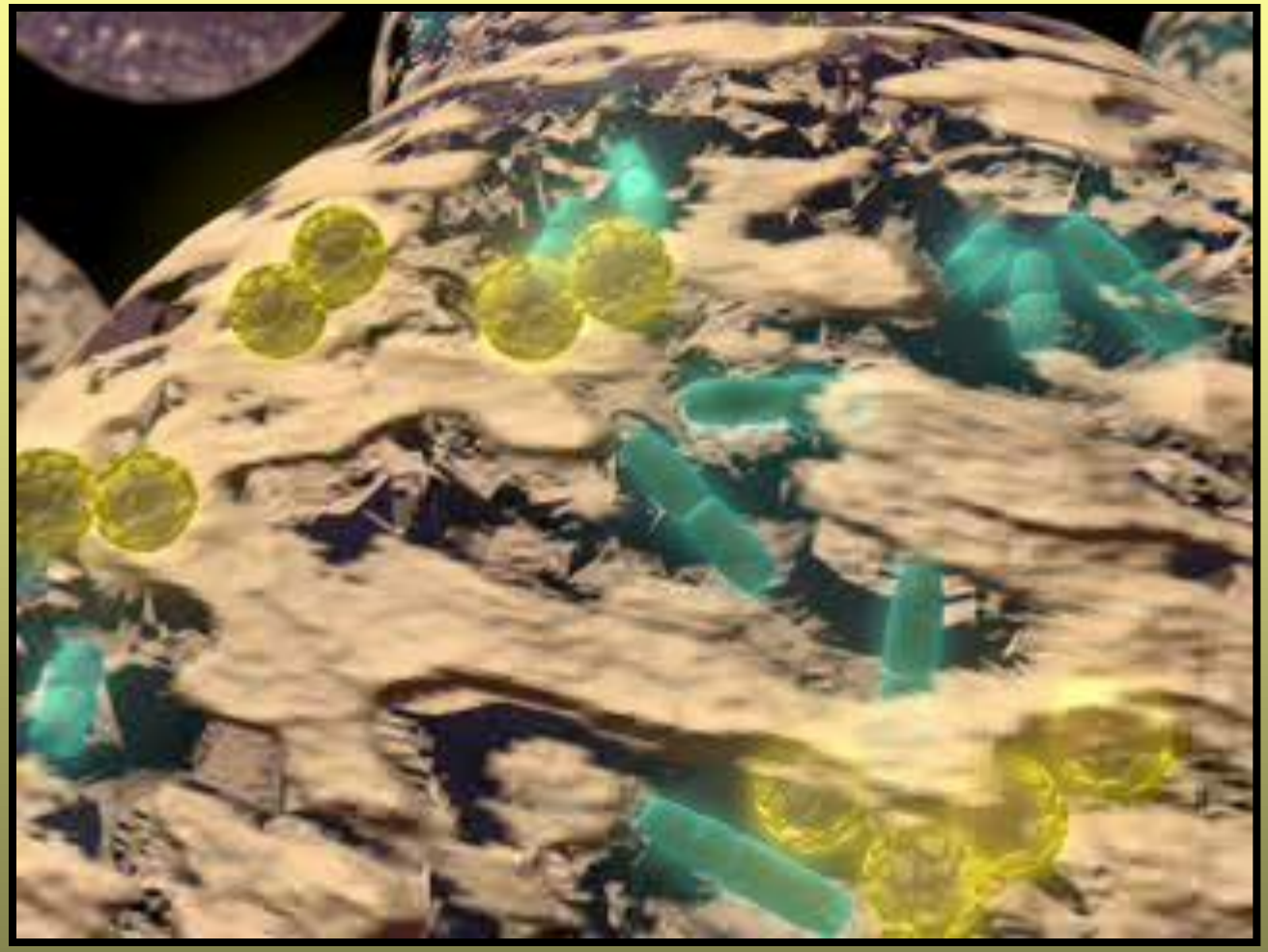






1000x magnification. These images show large particles coated with bacteria and virus like particles. Each fluorescing particle Is a bacterium (~1um in size), group of bacteria or a virus-like particle


1 2 3 4 5 6 7 8 9

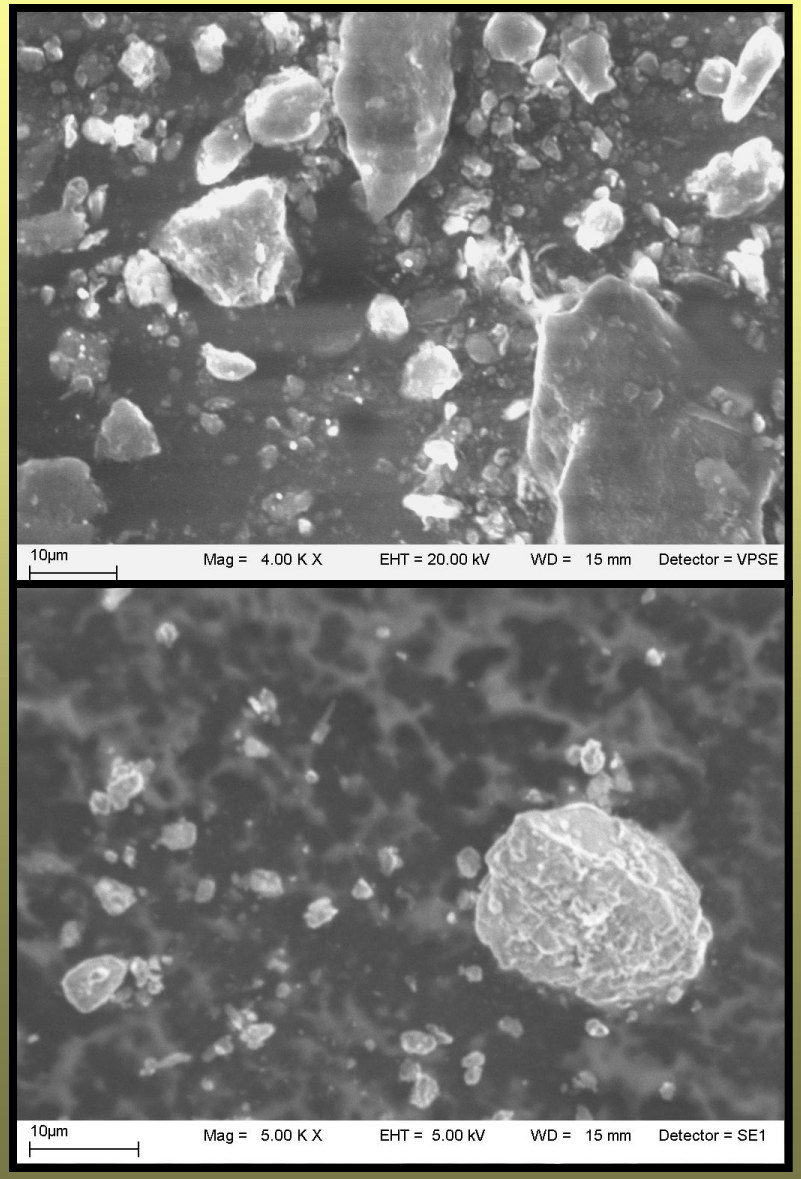


Summary of Scientific Results

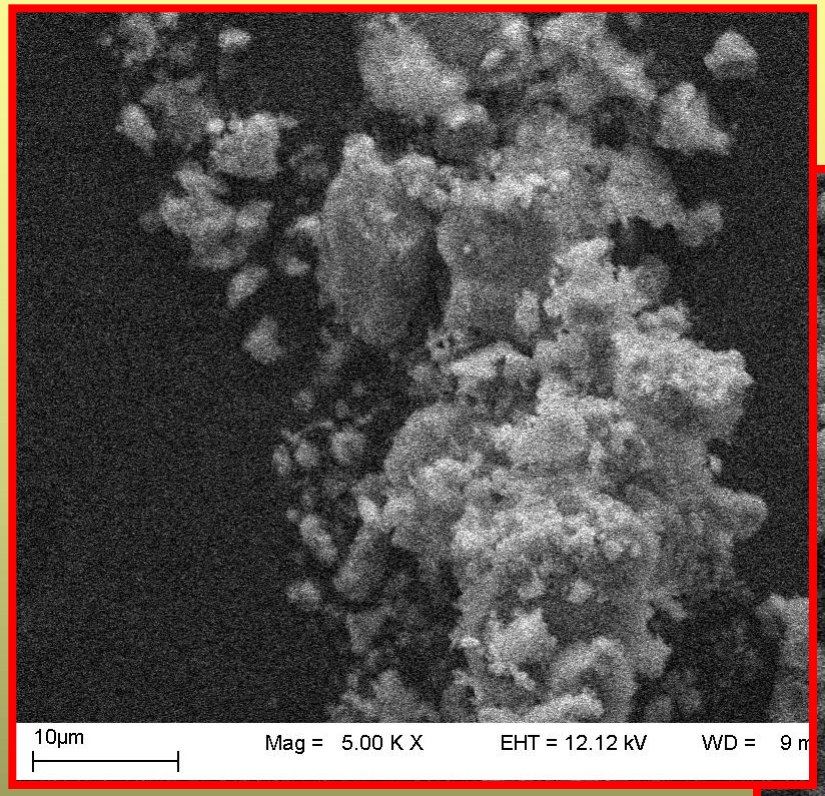
- Approximately 147 different isolates identified to date (6 Genera by 16s DNA analysis). 13 alpha/beta hemolytic species have been identified and 27 fungal isolates have been identified (7 different Genera). Several species have shown antibiotic resistance. More are expected from the low nutrient studies.
- *Acinetobacter spp*. has been identified by FAME analysis, but species yet to be determined.
- We have 6 isolates of *Neisseria* with FAME analysis.
- A total of 54 elements were screened for with 37 different elements identified of which 15 are bioactive metals including Uranium. Of these the ones of greatest concern are: Arsenic (10 ppm), Chromium (52 ppm), Lead (138 ppm), Nickel (564 ppm), Cobalt (10 ppm), Strontium (2700 ppm), Tin (8 ppm), Vanadium (55 ppm), Zinc (194 ppm), Manganese (369 ppm), Barium (327 ppm), Aluminum (9400 ppm).
- Elemental data suggests that minerals and elements tend to cluster geochemically within sites, and there are significant geochemical differences between some of the sites that seem to impact presence of specific toxic trace metals and their concentrations in the dust/dirt.
- Sterilization Experiments suggest an exceptional ability for microbes to survive.
- Early animal studies have suggested long term inflammation with mild to moderate eosinophilia.

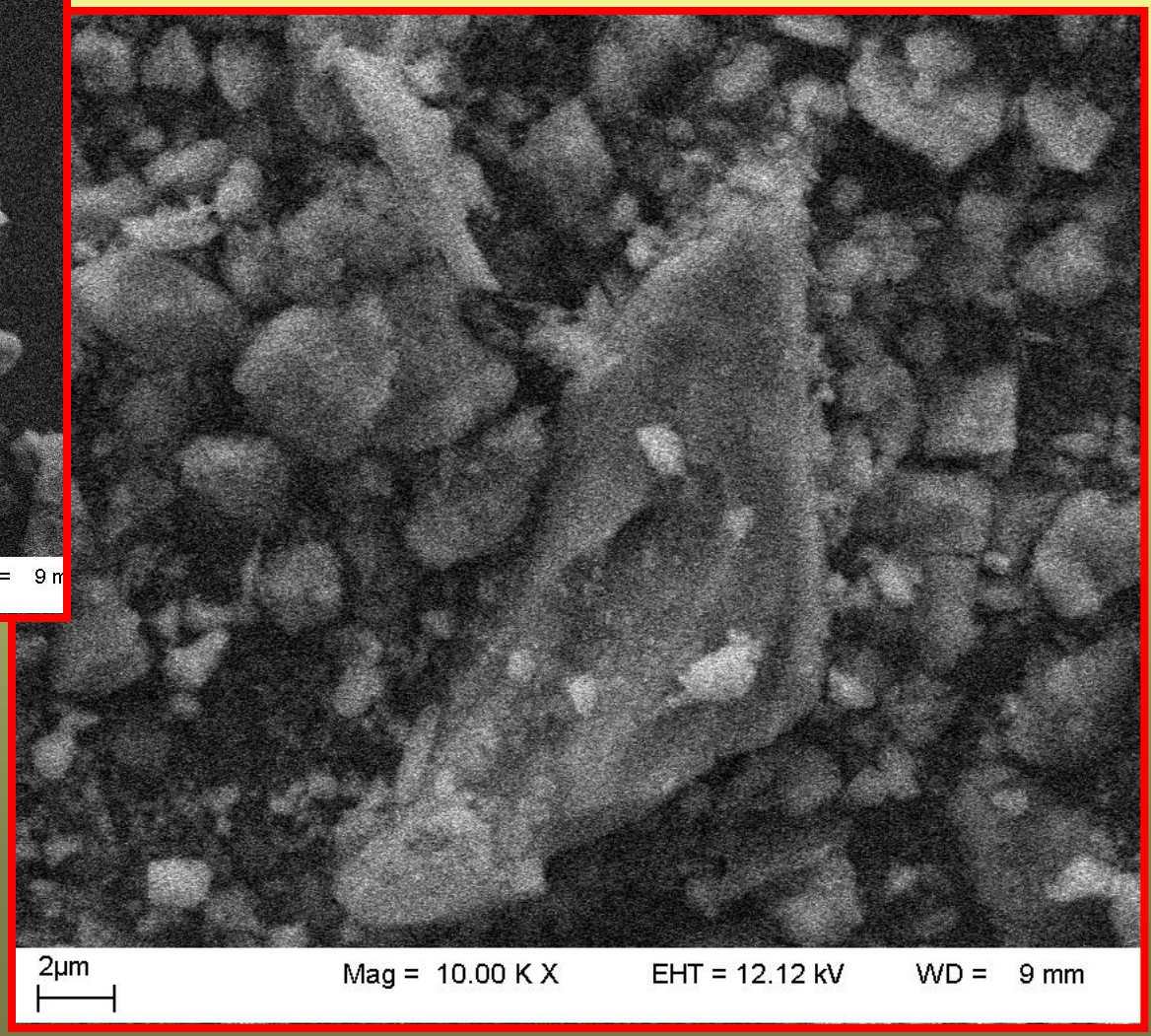
This is NOT sand!

- These ***micro-particulates*** are composed of a porous silica core (crystalline metallic silica and amorphous silica dioxide) surrounded by a type of clay consisting of, primarily, Calcium Carbonate ($CaCO_3$) and Magnesium Sulfate ($MgSO_4$).
- The laminar nature of the clay coating greatly magnifies the surface area and contributes to the hygroscopic nature of the particle.
- The micro-particulates act as a protective coating and carrier for the micro-organisms.

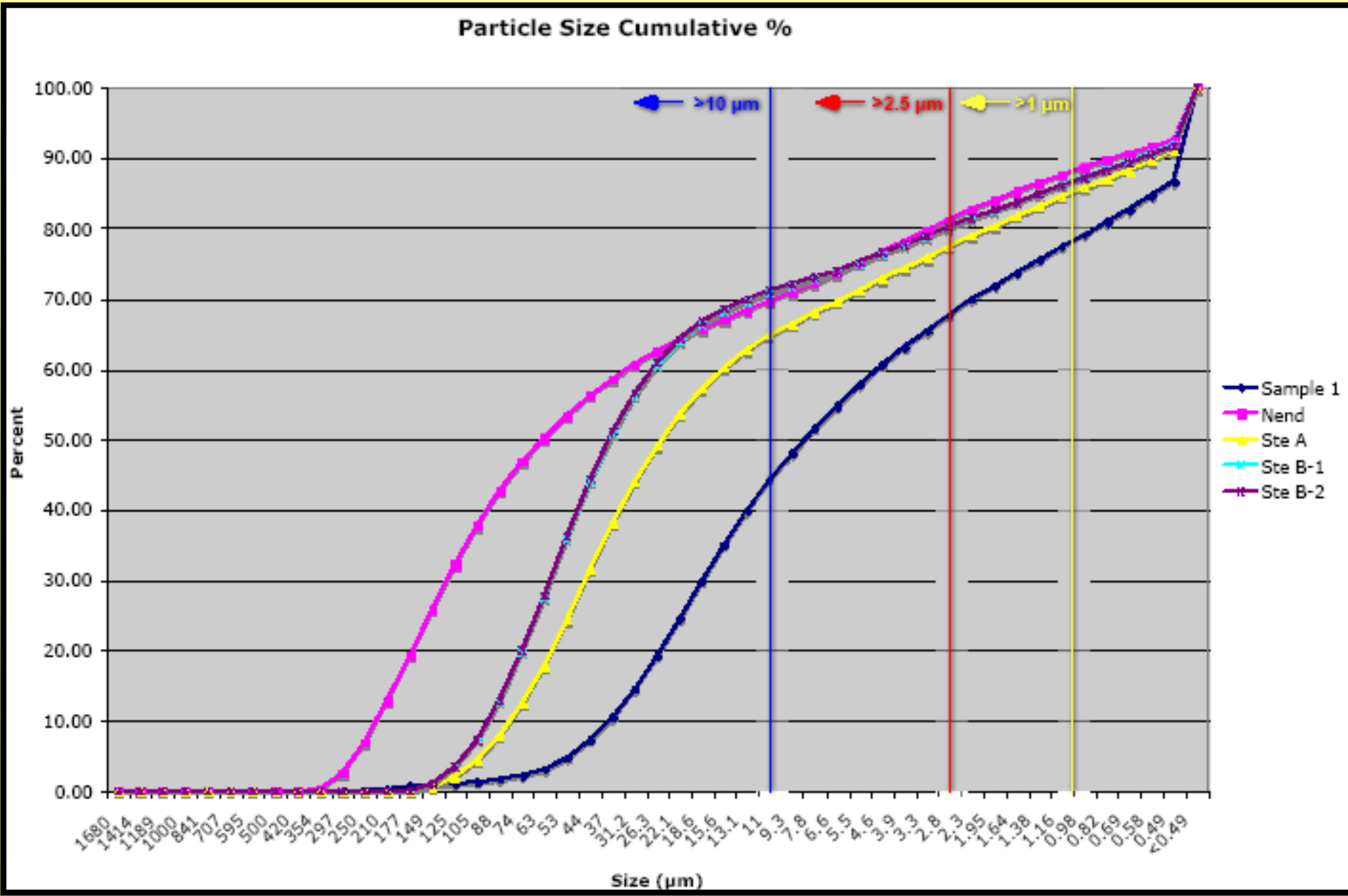


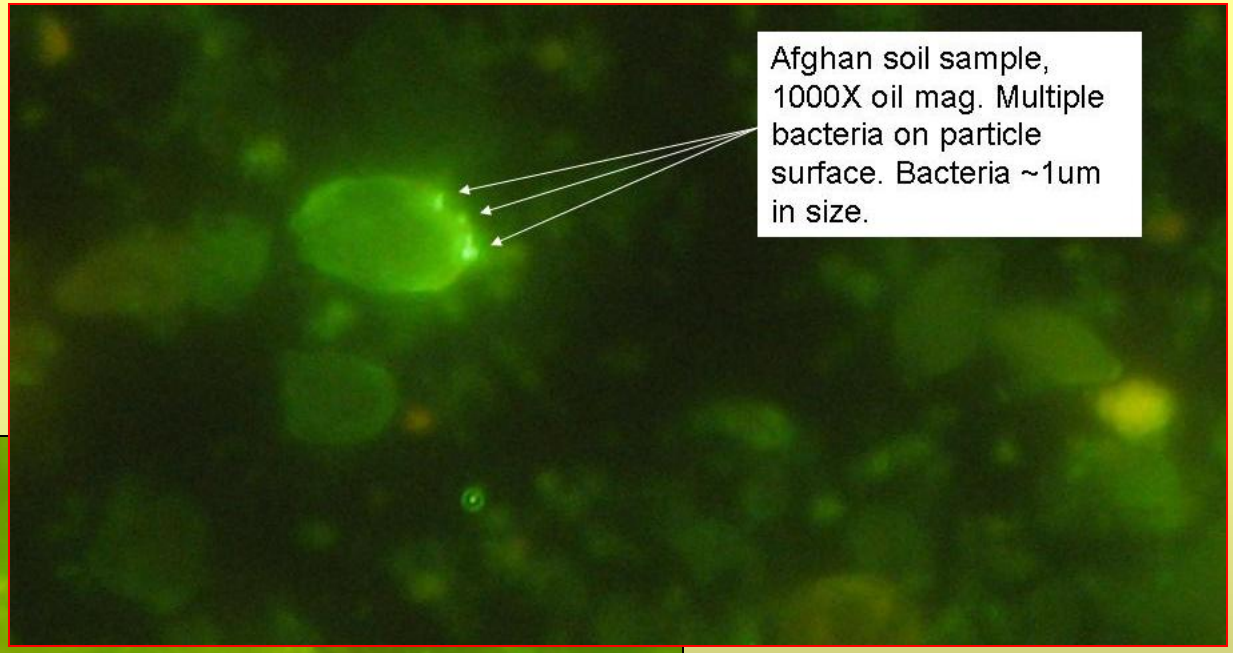
Afghanistan Dust Sample

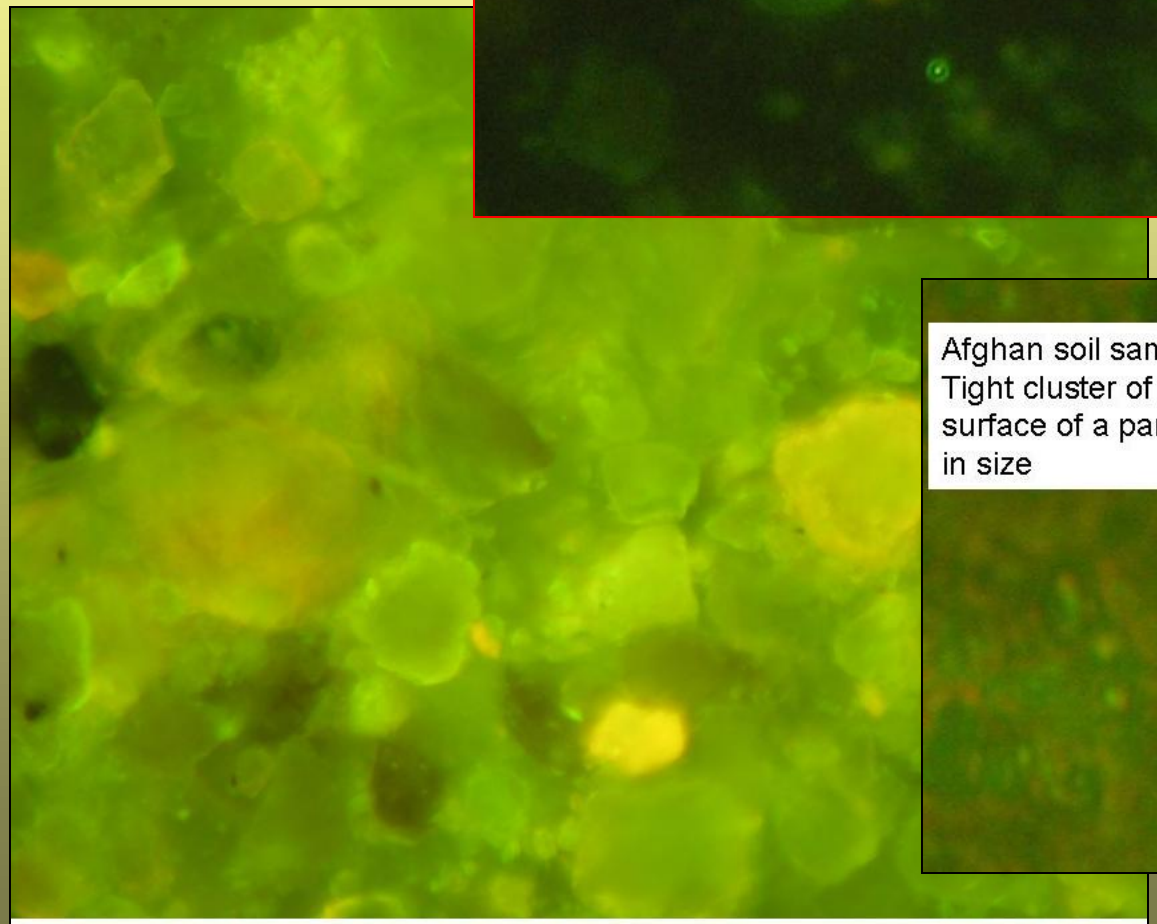


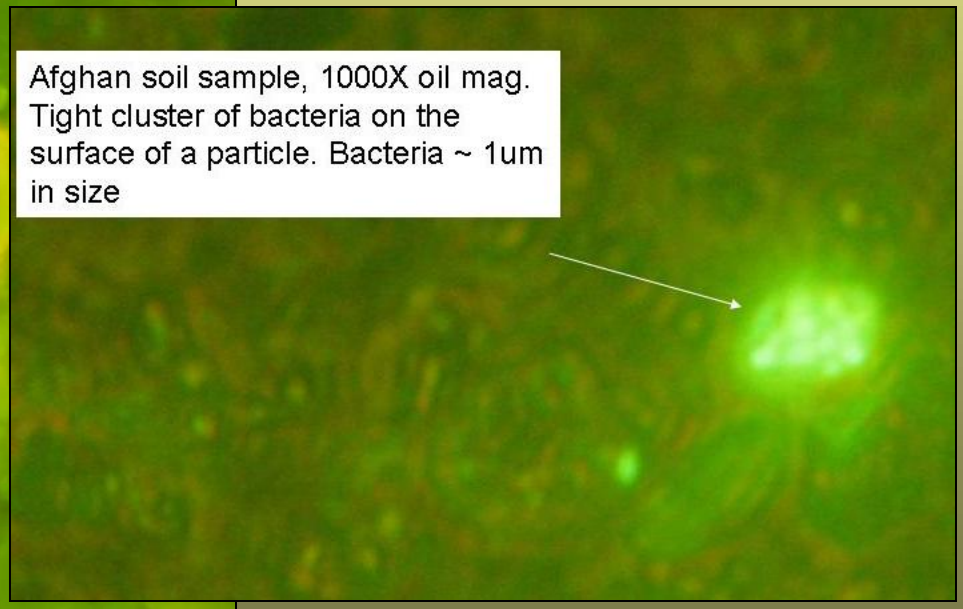


Afghanistan Dust Sample









A combination of epifluorescence and white light = illuminated particles….neat!

COMPARISONS

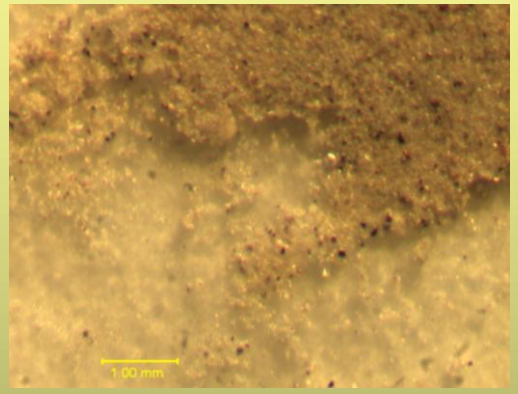
Laboratory Comparisons of Iraqi and Ft. Irwin Dust initiated

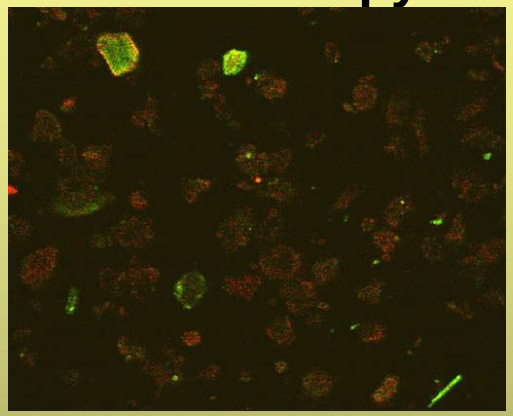
Light Microscopy

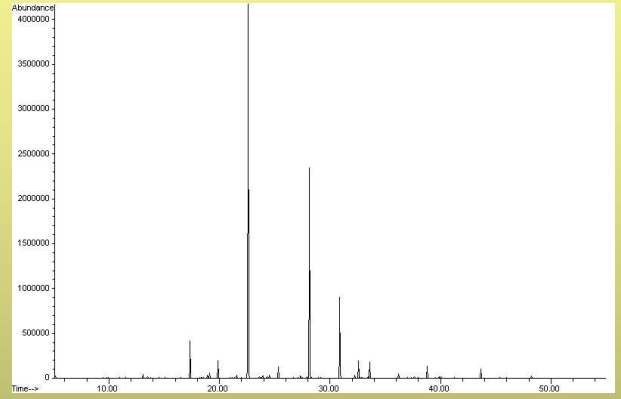
Fluorescent Microscopy

PLFAME Analysis

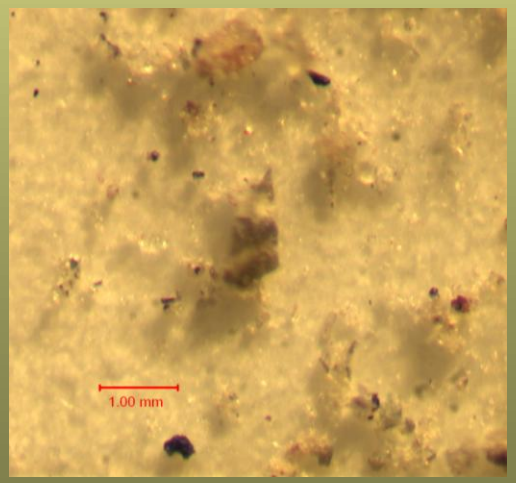
Iraq

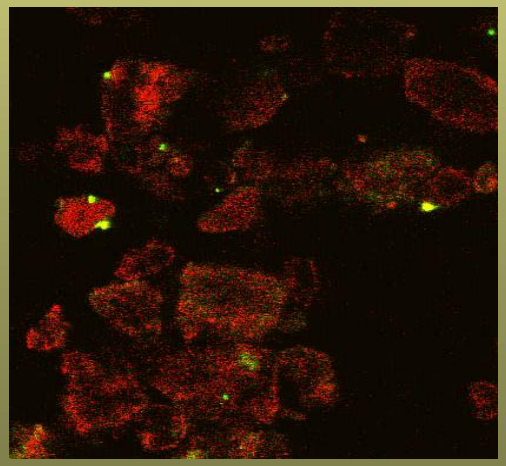


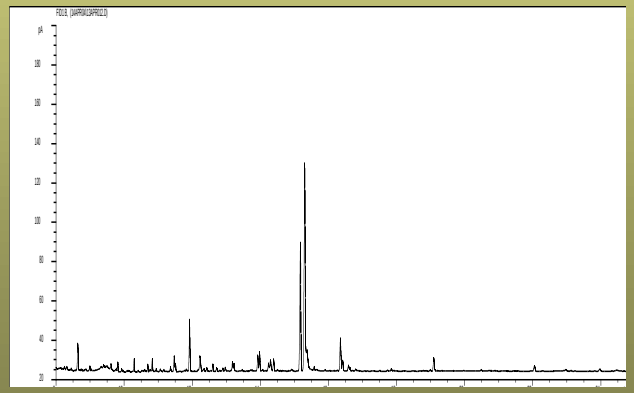




Ft. Irwin







Ultrastructure

Biological Structure

Microbial Community Composition

Discussing the Problem

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