MEDICAL GEOLOGY/GEOCHEMISTRY: An Exposure

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Objective

Dust Storms – Health Effects

Review & Conclusions

Students Presentations on Selected Elements

Students Reports

Review Quiz due – January 30, 2006.

Dusts and Aerosols

Sources:

Natural processes:

- Volcanic eruptions
- Wind erosion/deflation of arid and semi-arid lands
- Trans-oceanic dust transport

Anthropogenic:

- Mining
- Detonations
- Incinerations
- Industrial activities
- Accidents

Cosmogenic

Natural Processes

- Volcanic eruptions
- Wind erosion/deflation of arid and semi-arid lands with sparse vegetation cover create and propagate mineral dust aerosols.

  Trans-oceanic dust transport.

Volcanic Eruptions

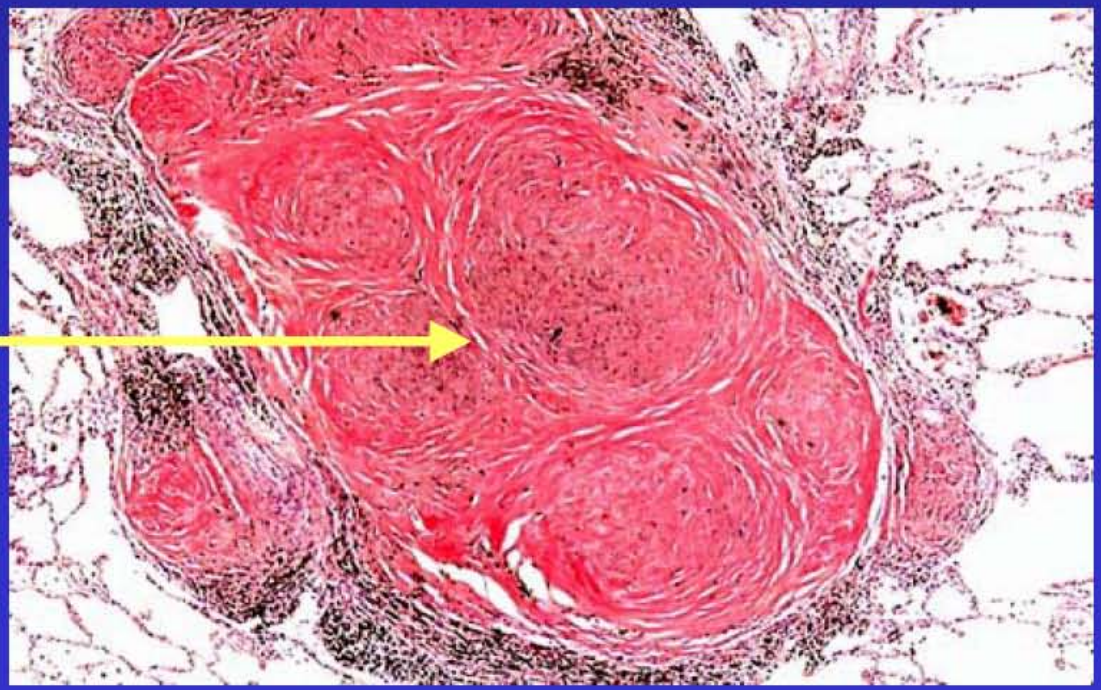
Tephra - volcanic rock and glass fragments.

Volcano eruption may sometimes eject rock fragments into the atmosphere. This material is known as tephra. Blocks and bombs are the largest pieces of tephra (greater than 64 mm).

Health effects of tephra dispersal

- Mucous membrane irritation
- Silicosis (Due to Calcium Fluoro Silicate $CaSiF_6$).
- Effects of absorbed toxins
- Silicotic nodules lodging in the lung tissue damaging the surrounding alveoli of the lung.

Silicotic nodule in the lung tissue with disruption of surrounding alveoli



Health effects of volcanic gas emissions

- CO_2 Asphyxiation – possible death of humans and animals.
- HF_2 and HCl Irritant gases –
  - Mucous membrane irritation.
  - Skin burns.
  - Respiratory problems.
- SO_2
  - Environmental effect by acid rain
  - Asthmatic effects
- H_2S Noxious asphyxiant
  - 7 $\mu g/m^3$ - rotten egg smell
  - 15,000 $\mu g/m^3$– eye irritation
  - 480,000 $\mu g/m^3$ – risk of pulmonary oedema
  - 1,500,000 $\mu g/m^3$ - lethal

The health effects of volcanic gas emissions

Courtesy of USGS.

Dusts - Wind erosion

- Mineral aerosols: 1-2 b metric tons/year (comprise half of total aerosols in troposhere from natural and anthropogenic sources)
- Play role in current climatic variabilities.
- Play role in ecosystem dynamics.

Examples:

Sahara desert-(Northern Africa)

Sahel Africa is a stretch of land that includes countries like Ethiopia, Eritrea, Djibouti, and Somalia. This stretch is a transition zone between the arid Sahara to the north and wet tropical area to the south.

Example: some affected areas are, such as, Chad, Senegal, Mauritania, Mali, Niger, etc.

Gobi desert - (Mongolia-Central Asia)

Example: affected area Taklamakan – (China).

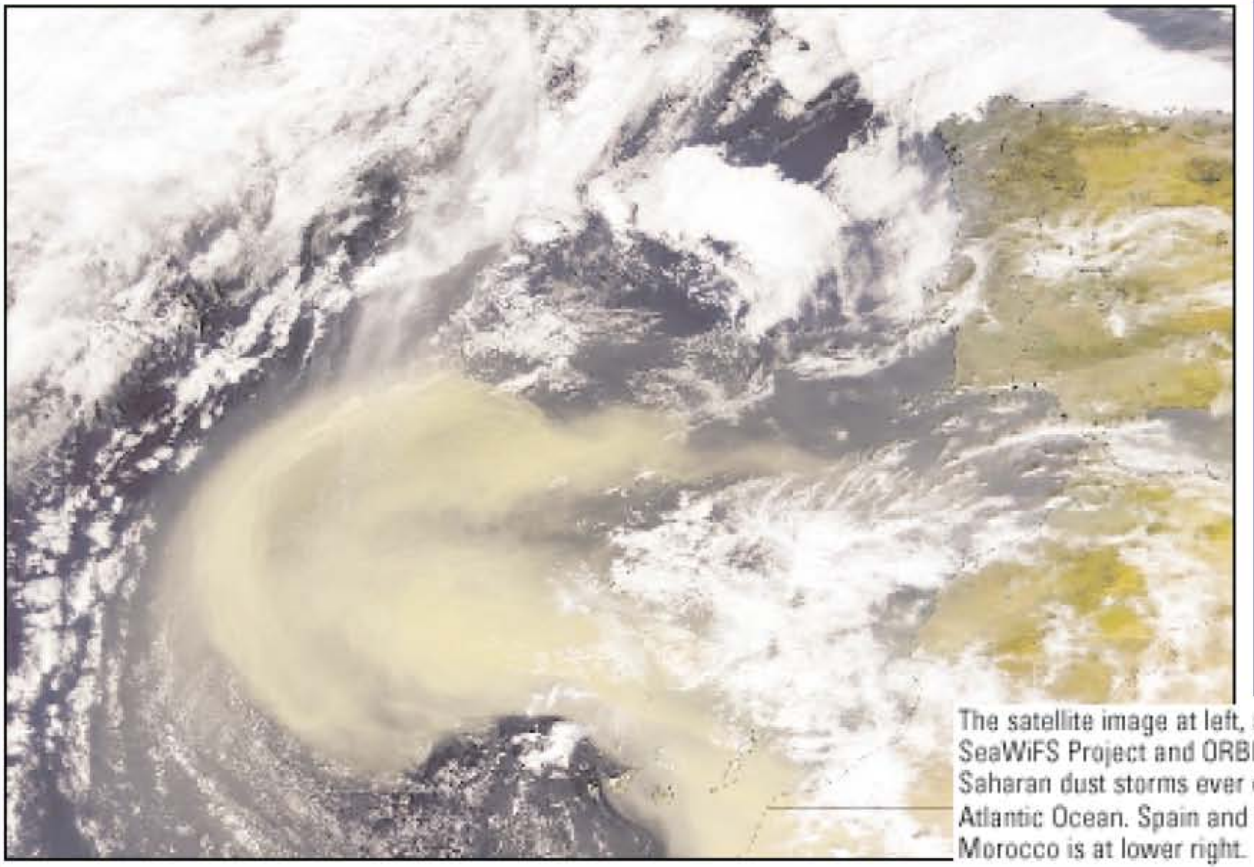
Courtesy of USGS.

Courtesy of USGS.

Trans-Atlantic transport of African dust Beneficial

- Agriculture in the Bahamas depends significantly on accumulation of African dust to form the red soils often referred to as pineapple loam

- The dust also transports significant amounts of iron, phosphorous, and sulfate, key nutrients for ecosystems



The satellite image at left, acquired by NASA/Goddard Spaceflight Center's SeaWiFS Project and ORBIMAGE on February 26, 2000, shows one of the largest Saharan dust storms ever observed by SeaWiFS as it moves out over the eastern Atlantic Ocean. Spain and Portugal are at upper right, Morocco is at lower right.

Courtesy of USGS.

Trans-Atlantic transport of African dust

African dust may be responsible for a number of environmental hazards;

- Demise of Caribbean corals
- Red tides, amphibian diseases
- Increased occurrence of asthma, lung diseases in humans
- Decrease of oxygen (eutrophication) in estuaries.

Courtesy of USGS.

- New studies at the University of South Carolina Aiken have identified several species of a soil fungus, *Aspergillus*, in dusts samples collected in the Carribbean

- Lung infections caused by several species of *Aspergillus* are a leading cause of mortality in AIDS victims.

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Geographic Analysis of Disease Risk

- Where are the potential areas of disease?
- Who are the populations at risk now and in the future?
- When might an outbreak occur?
- How can outbreaks be mitigated?

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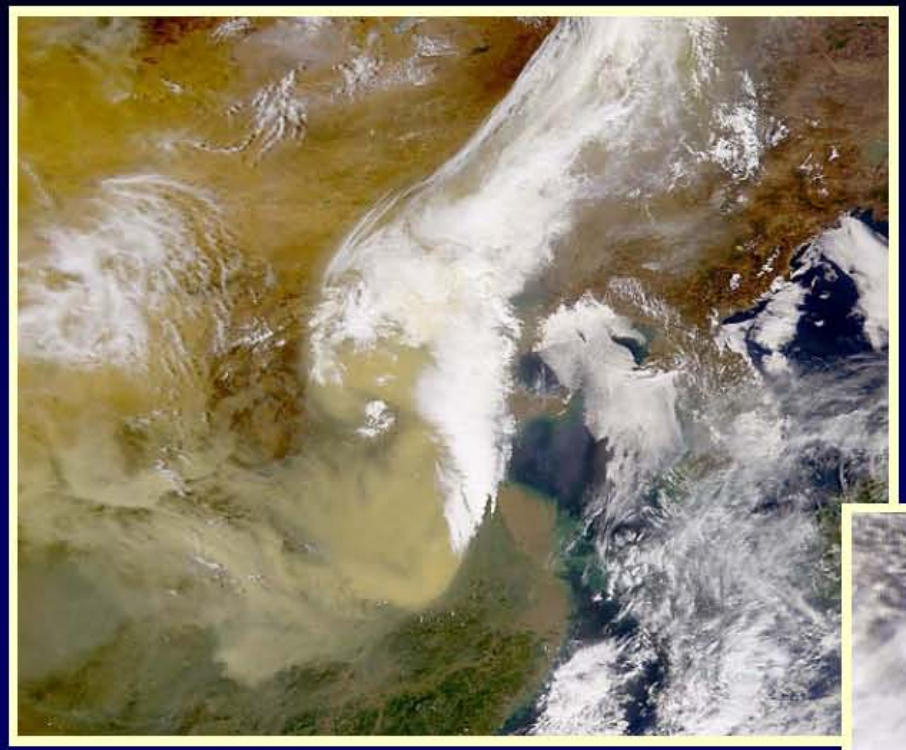
Courtesy of USGS.



Dust storm forming over the Gobi

April 16, 1998

Dust arriving at North America

April 25, 1998

Courtesy of USGS.

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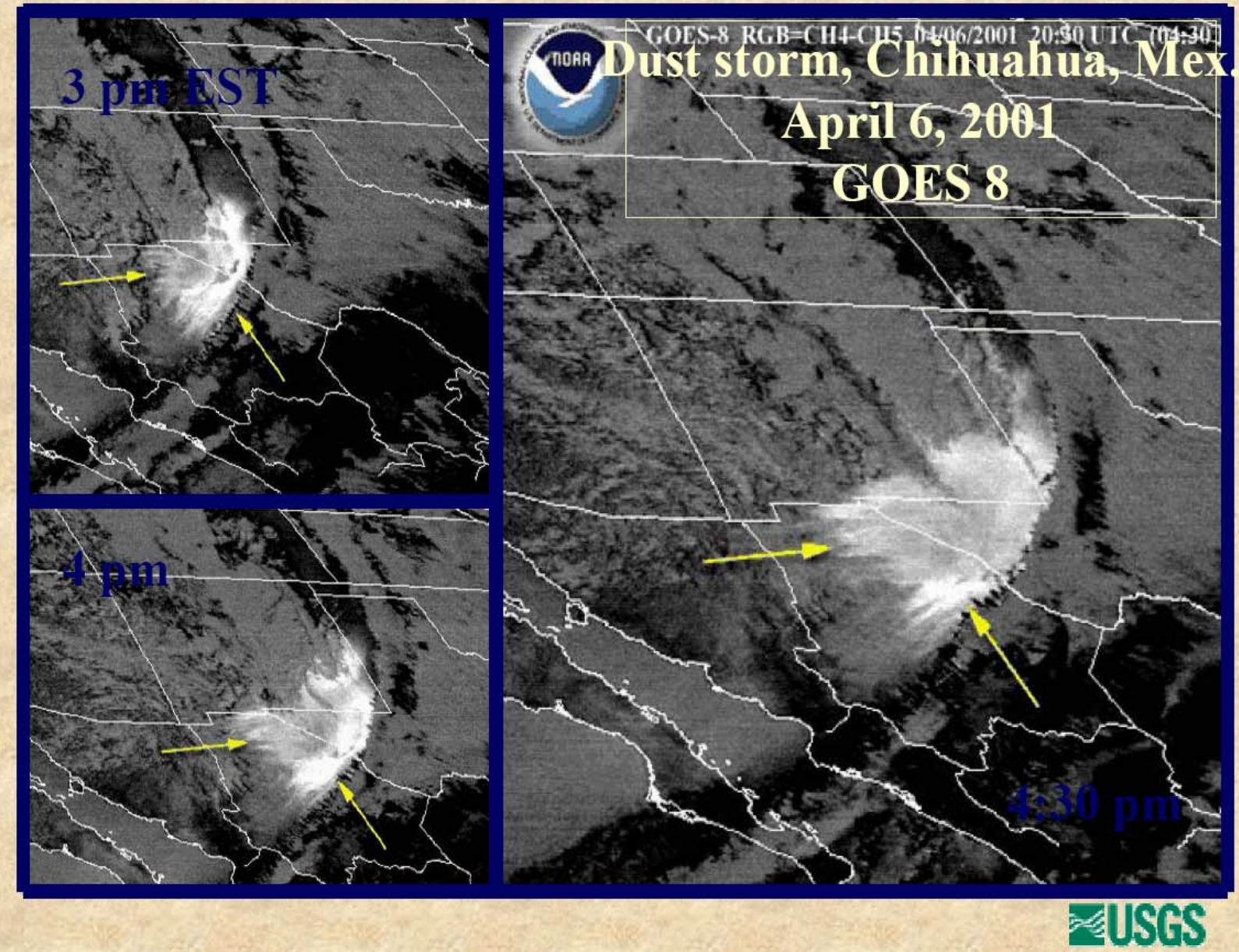
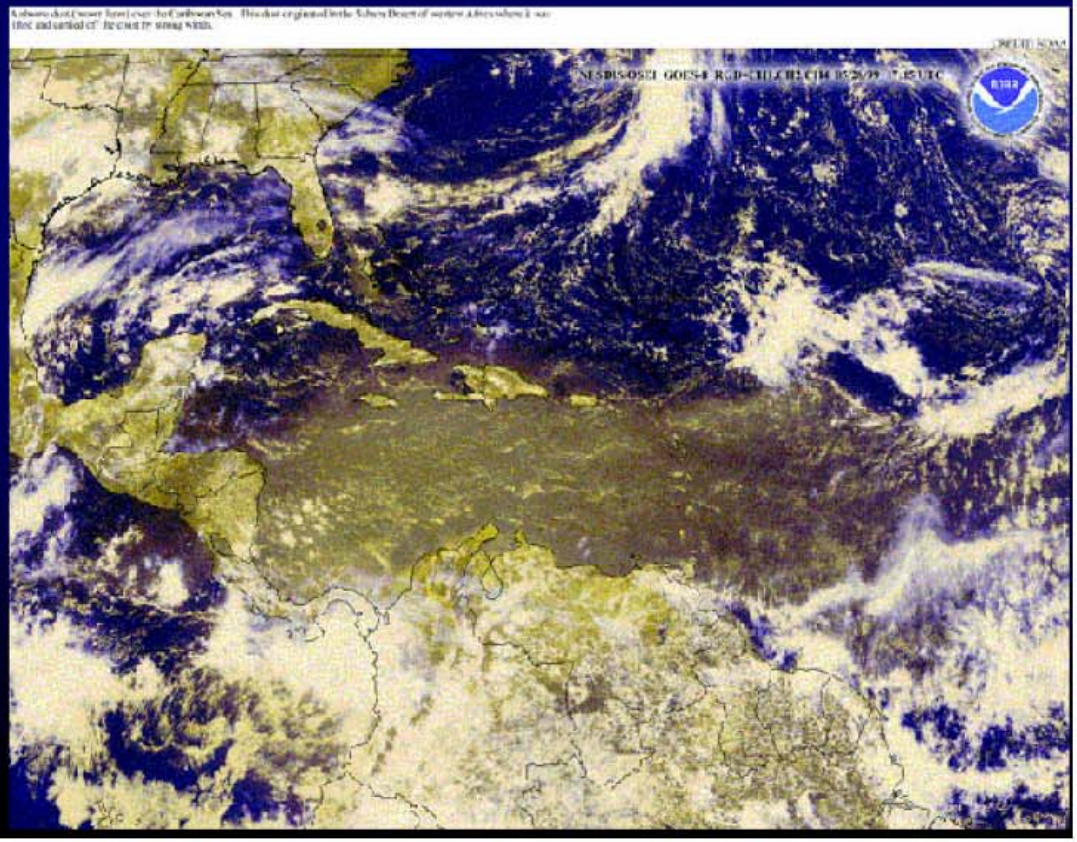


Courtesy of USGS.

Intercontinental dust transport: Gene Shinn (eshinn@usgs.gov; http://coastal.er.usgs.gov/african_dust/)

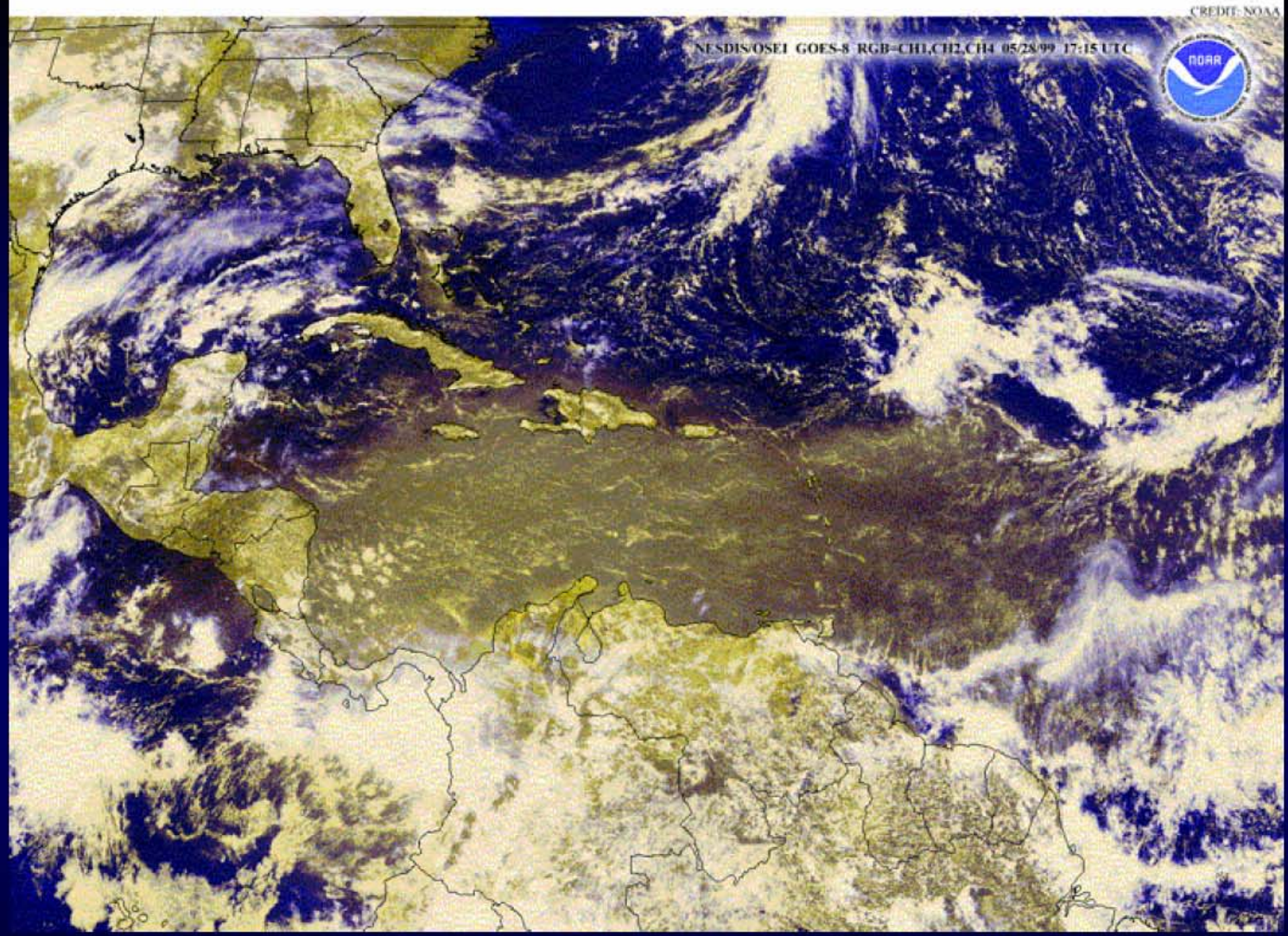
- Increasing evidence from satelllite imagery and other means that signficant dust transport can occur between continents across large expanses of oceans
- This exotic dust is increasingly viewed as a key component of some terrestrial and marine ecosystems, as well as a potentially significant source of pathogens and environmental contaminants

- For example, atmospheric transport of dust from North Africa to the western Atlantic Ocean region has increased substantially in recent decades due to desertification of grasslands in the Sahara region
- 100's of millions of tons annually



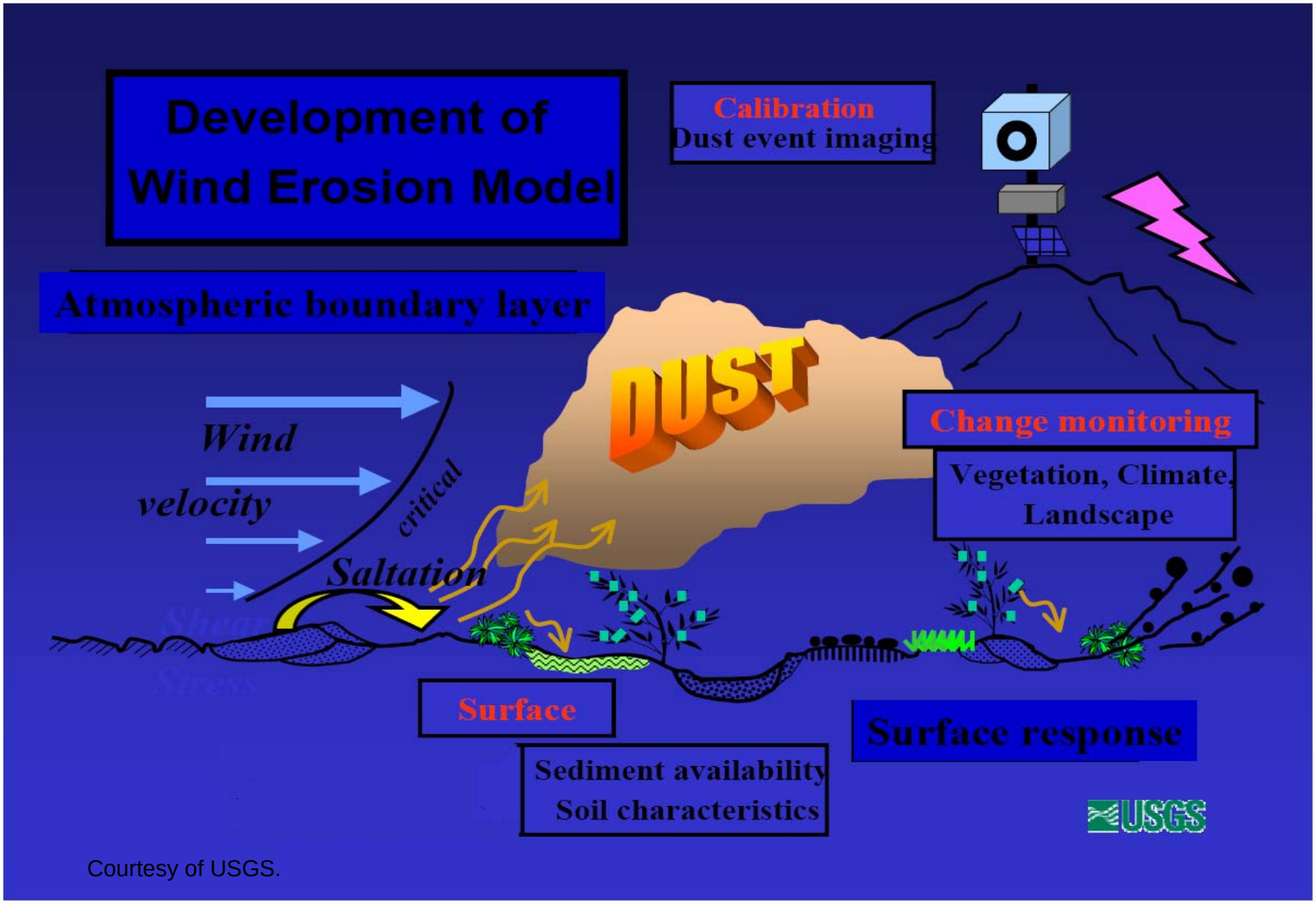
Courtesy of USGS.

Airborne dust (brown haze) over the Caribbean Sea. This dust originated in the Sahara Desert of western Africa where it was lifted and carried off the coast by strong winds.



- 100's of millions of tons of intercontinental dust is deposited annually.
- This dust is increasingly viewed as a key component of some terrestrial and marine ecosystems, as well as a potentially significant source of pathogens and environmental contaminants.

Courtesy of USGS.



Courtesy of USGS.

Anthropogenic

- **Mining**
- **Detonations**
- **Incinerations**
- **Industrial activities**
- **Accidents**

The Health Effects of Dusts

- **Health hazards of mining are well known for a long time:**
  - ❖ General effects of industrial/commercial asbestos
  - ❖ Asbestosis (mining)
  - ❖ Silicosis (hard rock mining)
  - ❖ Black lung (coal mining)

- **New issues and problems are arising:**
  - ❖ Effects of trace asbestos in other rocks and industrial products
  - ❖ Valley Fever
  - ❖ Trans-oceanic dust transport
  - ❖ Global Climatic Change

Occupational Hazards

- Asbestos mining and processing
- Coal mining
- Hard rock mining
- Ore processing
- Farming
- Power plant operation

New Problems…

- Trace Element Exposure – As, F, Hg, Zn, …
- Organics:
  VOCs (Volatile aromatic Compounds – paints etc)
  MTBEs (Methyl tert butyl ether)
  PAHs (Polycyclic aromatic hydrocarbons – coal tar)
- Radionuclides: Radon, radium and Uranium, …
- Microbes and Pathogens:
  West Nile encephalitis, Hantavirus, Plague, Lyme, …

New Problems …

- VOC - Volatile Organic Compounds - Trichloroethylene, methyl tert butylether (MTBE - paints

- PAH - Polycyclic Aromatic Hydrocarbons These PAHs are benzo(a)pyrene, benz(a)anathracene, benzo(k)flouranthene, indeno(1,2,3-c,d)pyrene and chrysene. In application, this proposed procedure would regard any given air level obtained for a "PAH of concern" to originate from a standard mixture of coal tar pitch (CTP).

New Problems…

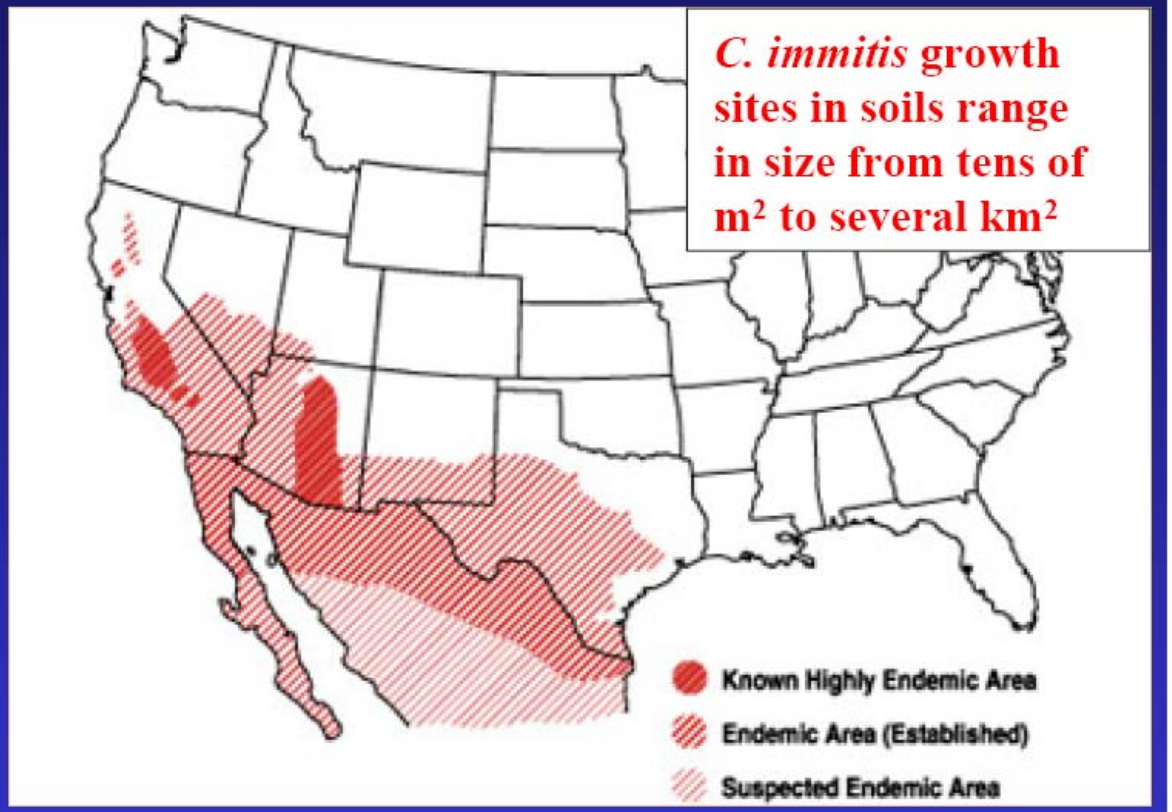
Delayed/chronic health effects:

- Respiration
- Skin
- Cancerous effects

Dusts and the origin of Valley Fever (Coccidioidomycosis)

Coccidioidomycosis epidemiology

- Common in parts of desert southwest, but...
- Persons receiving packages and clothing from endemic regions have been infected by the aerosols created by handling
- Travelers passing even briefly through endemic areas can be infected and develop the illness well away from endemic areas



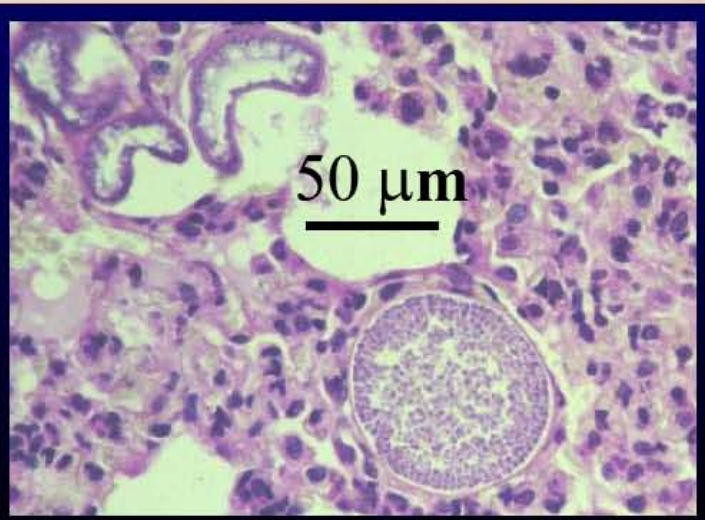
Dusts and the origin of Valley Fever (Coccidioidomycosis)

- Geologic links to Valley Fever
  - Boron-rich, alkaline soils?
  - Marine shale parent rocks?
  - Evaporative alkaline salts?
  - Slope, shape of topography
- Dust storms have been shown to carry spore laden dirt as far as 700 km, causing outbreaks

Courtesy of USGS.

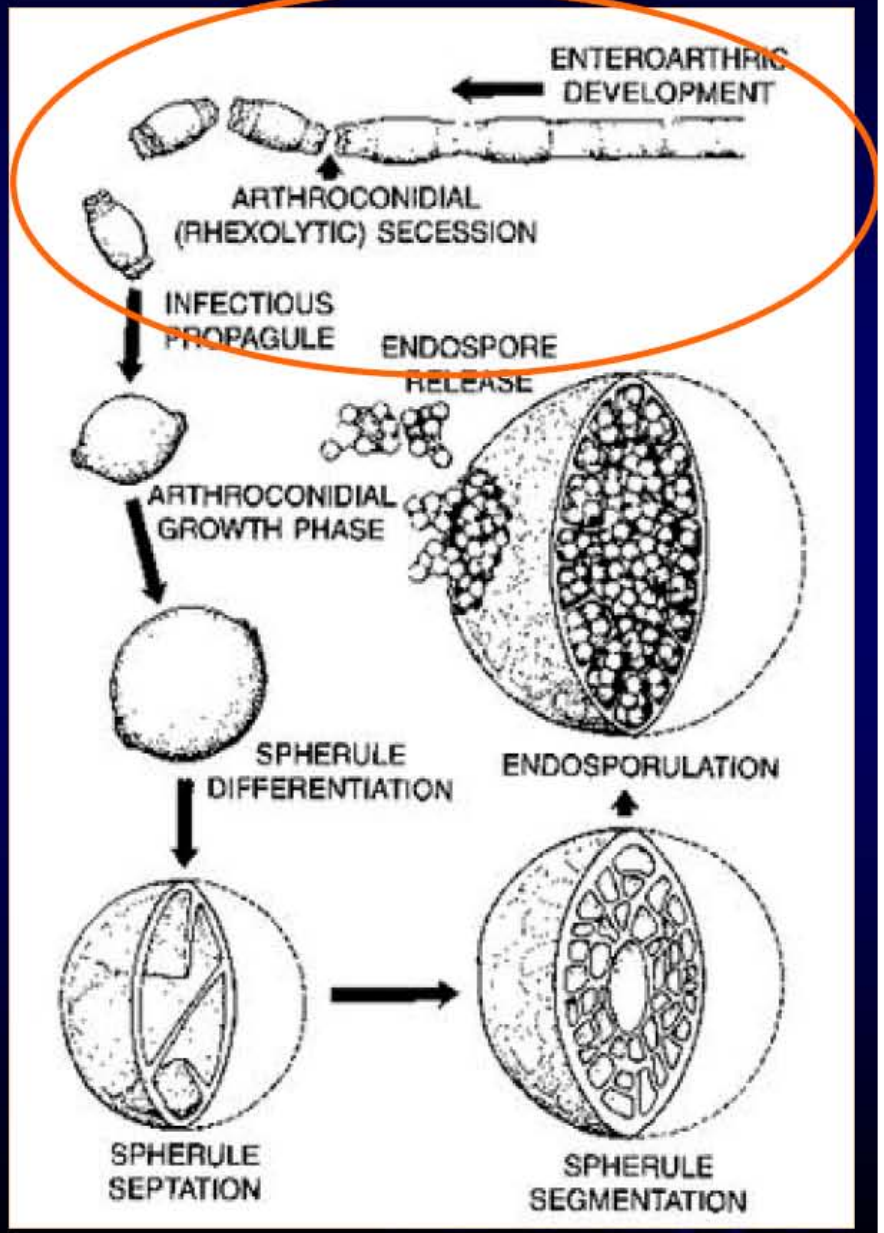
Valley Fever (Coccidiomycosis)

- A systemic infection caused by the inhalation of airborne spores of *Coccidioides immitis*



C. immitis life cycle

Occurs in soil



Valley Fever (Coccidioidomycosis)

- 7,500 new cases of Cocci annually in the U.S.A. alone. This translates to a cost that may exceed $60 million a year.
- *"The medical and indirect costs for people with the most benign illness range from $3,000 to $5,000 per case. For those who experience a more severe illness, costs climb from $30,000 to $300,000 - especially for those who get meningitis or who are hospitalized for a long time. The average is $8,000 per case overall."* John Caldwell, Director of Clinical Research
  Kern Medical Center

Courtesy of USGS.

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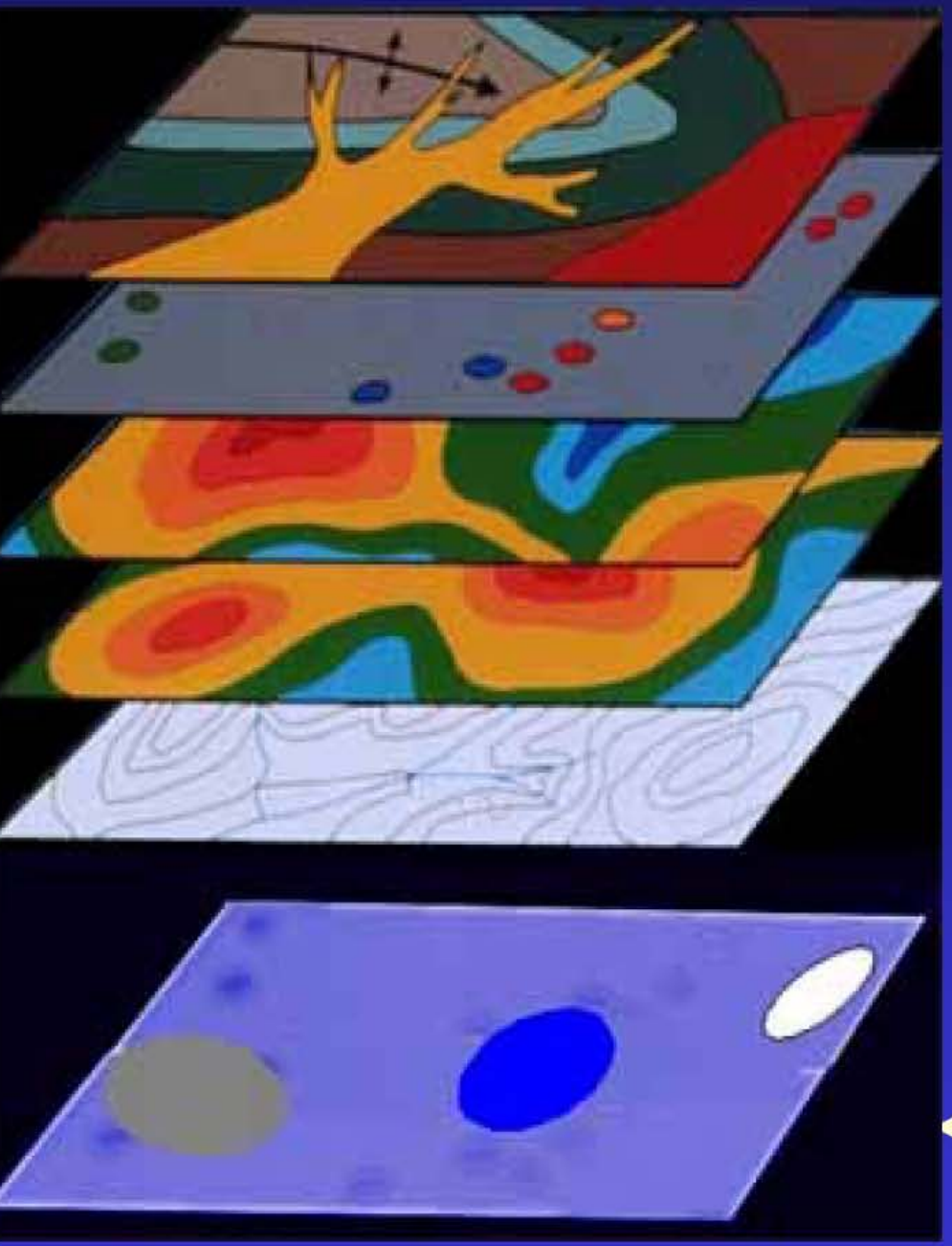
Valley Fever: Geological/Ecological occurrence modeling



geology

geochemistry

soils

remote sensing interpretation

elevation

….

spatial data$_i$

Valley Fever favorableness

Courtesy of USGS.

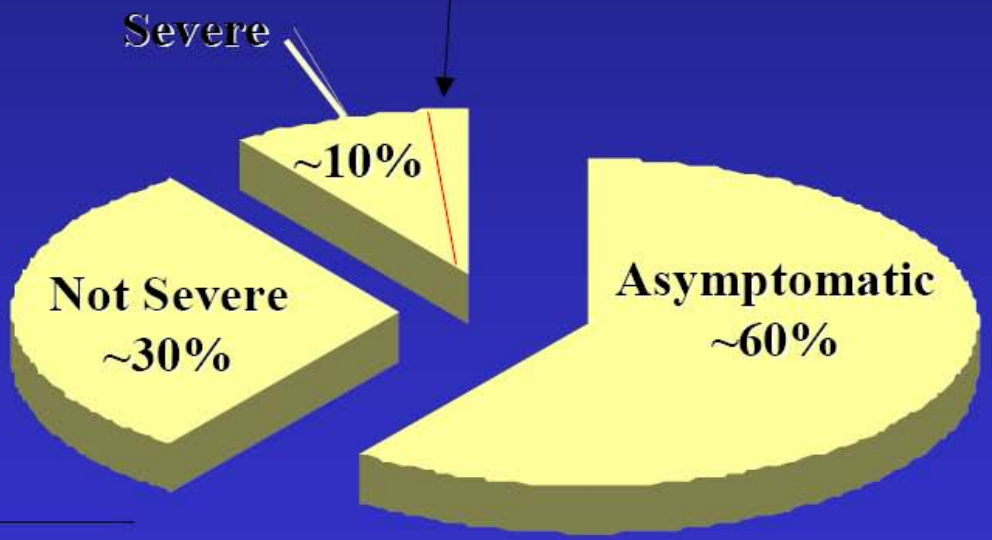
Valley Fever (Coccidioidomycosis)

- Clinical manifestations occur in ~40% of infected persons

In ~1% to 2% of cases the disease becomes disseminated, and affects skin, bones, or joints, or develops into meningitis (<1 % fatal)

self -limited influenza-like illness to pneumonia

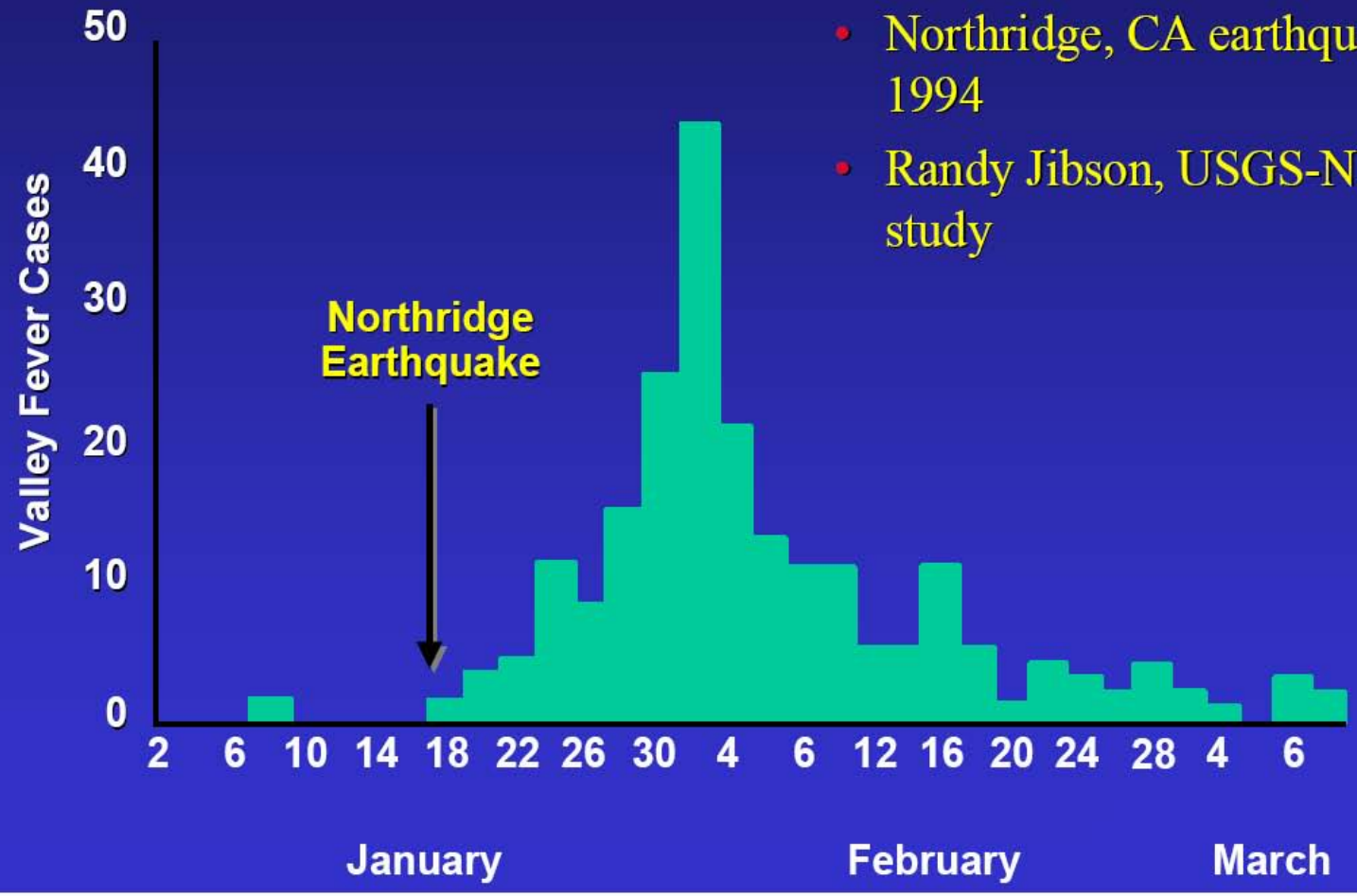
fatigue
cough
chest pain
fever
rash
headache
joint ache



Geologic links to Valley Fever

Valley Fever cases after Northridge earthquake

From Jibson et al., 1998



- Earthquakes can trigger VF epidemics by generating landslides and their resulting dust clouds
  - Northridge, CA earthquake, 1994
  - Randy Jibson, USGS-NIH study

Courtesy of USGS.

Mining /Smelting

Occupational hazards:

- **Toxic gas inhalations**
- **Pressure effects**
- **Thermal injury**
- **Physical injury**
- **Trauma (e.g. cave-ins, accidental explosions)**
- **etc....**

Health effects:

- **Asbestosis**
- **Silicosis**
- **Carcinogenesis**
- **etc. ...**

Why is asbestos toxic?

- Duration and magnitude of the exposure are important
- Needle-like crystals, when inhaled, lodge in and penetrate the alveoli of the lungs
- When ingested, can lodge in and penetrate the lining of the gastro-intestinal tract
- "Protocol" fibers of greatest concern:
  - > 1 micrometer length
  - < 0.5 micrometers long
- Acicular cleavage fragments of non-fibrous amphiboles, serpentine are apparently much less toxic

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Asbestos: an evolving health issue

- The deleterious health effects of asbestiform minerals have been recognized for decades, and were widespread among people employed in some asbestos mining and processing, or in manufacturing making use of asbestos:
  - mesothelioma cancers, other cancers of the lung, asbestosis, cancers of stomach
  - asbestosis-induced heart failure
- Multiple decades between exposure, disease
- Mac Ross of the USGS was one of the first researchers to conclude that not all forms of asbestos are equally carcinogenic or deleterious to health:
  - Chrysotile is much less carcinogenic than amosite, crocidolite, asbestiform anthophyllite, asbestiform tremolite / actinolite, asbestiform erionite (a zeolite)

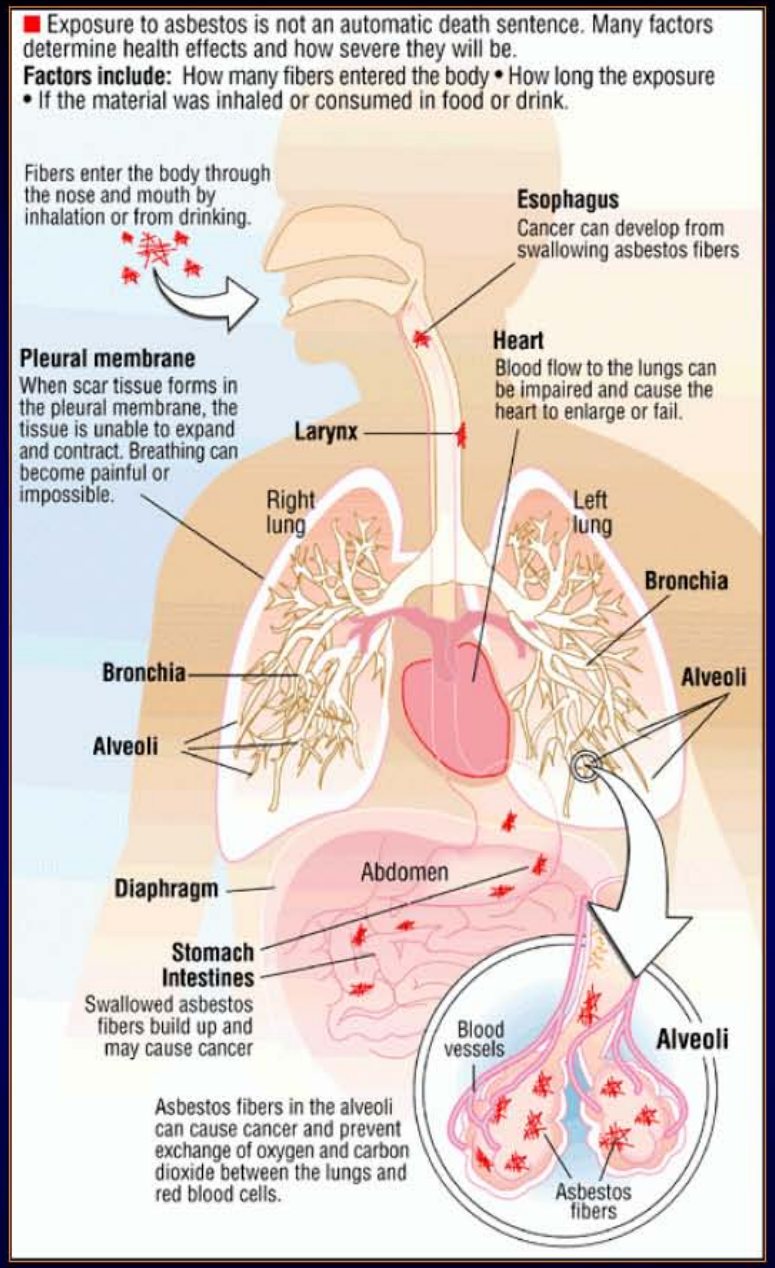

Image from Seattle Post-Intelligencer

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Courtesy of USGS.

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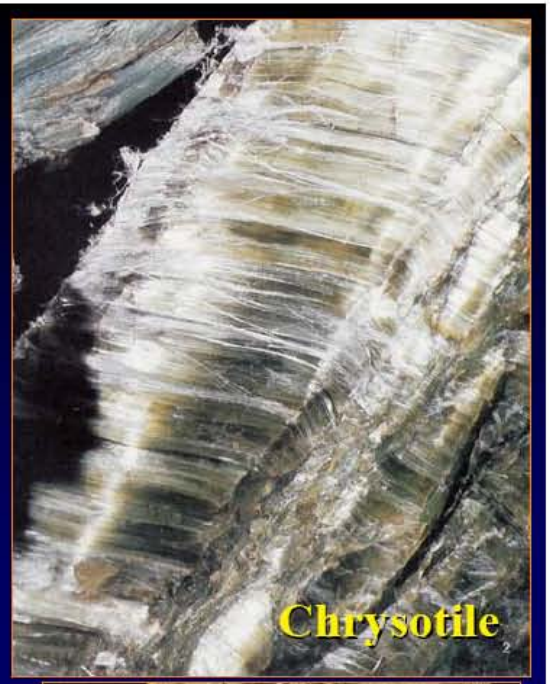
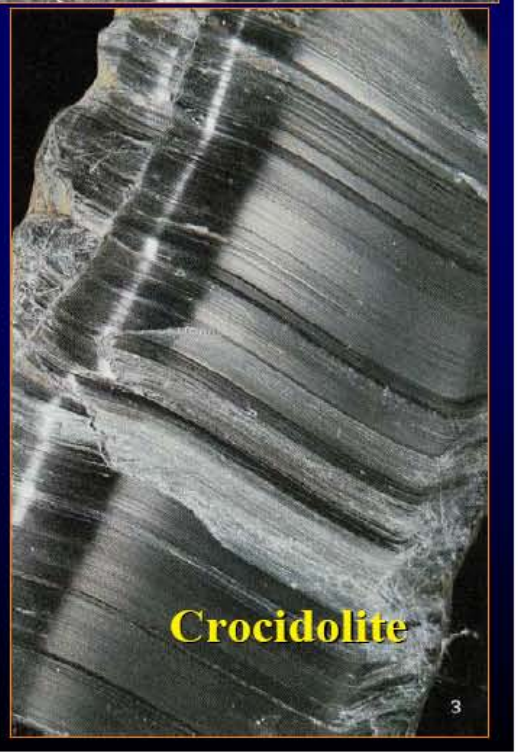
Courtesy of USGS.

Asbestos: an evolving health issue

- Asbestos is a generic commercial term originally applied to mineral products that are fibrous and flexible, with high tensile strength, resistance to chemical and thermal degradation, large surface area and weavability. The term includes a variety of minerals:
  - Chrysotile - a fibrous variety of serpentine
  - Crocidolite - a fibrous variety of the amphibole riebeckite
  - Fibrous anthophyllite - a fibrous amphibole
  - Amosite - fibrous grunerite amphibole
  - Fibrous tremolite and actinolite - fibrous amphiboles
- Asbestos was used in many different industrial applications and commercial products prior to the 1980's, because of its heat resistance and flexibility
  - Insulation; auto brake linings; roofing; linoleum backing; fire-proof clothing; sewer and water pipes; spray-on ceilings





Not all forms of asbestos are equally toxic

- Mac Ross of the USGS (Ross, 1999) was one of the first researchers to conclude that not all forms of asbestos are equally carcinogenic or deleterious to health
- Recent studies (i.e, van Oss et al., 1999; Churg et al., 1989): indicate that:
  - Chrysotile can break more easily into shorter fibers, and therefore can be cleared more easily by the lungs
  - The asbestos amphiboles are less soluble than chrysotile in bodily fluids, and therefore cannot be cleared as easily by the body

Courtesy of USGS

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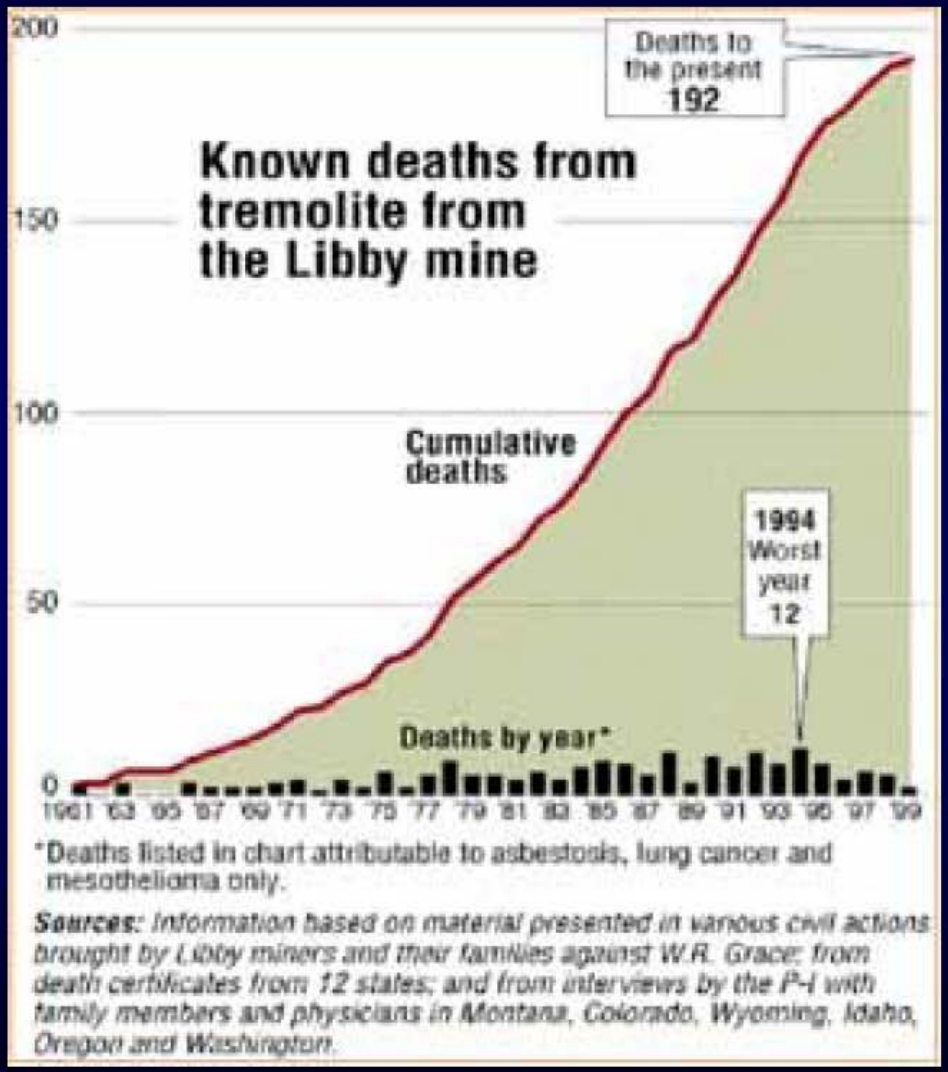
Libby, Montana (pop. ~2500)



- Since 1961 there has been nearly 200 deaths attributed to lung cancer and mesothelioma among vermiculite miners and mill workers, their families, and the general public.
- Another 300 residents currently have these diseases.
- Although known for several decades, the growing health problems at Libby have recently become the focus of intense action by EPA and other regulatory agencies.

Images from Seattle Post-Intelligencer

Courtesy of USGS

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Libby, Montana

- Libby provided the majority of the United States' vermiculite production for 80 years, until the mine was shut down in 1990.
- Libby ore was shipped to at least 315 locations around the U.S., Canada, and overseas for "popping", a process during which it is heated to 2000°F to cause the vermiculite to expand in thickness greatly, accordionlike, perpendicular to its plates.

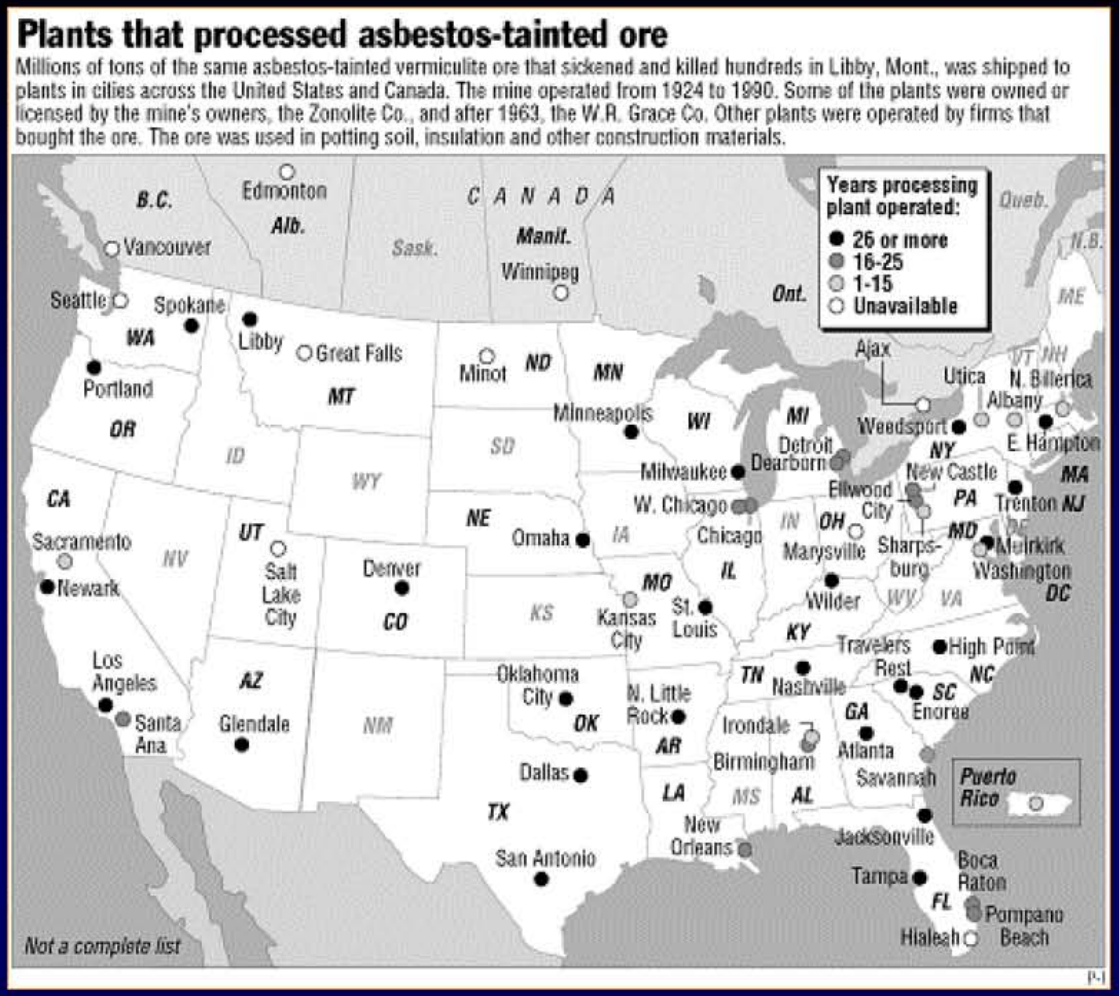
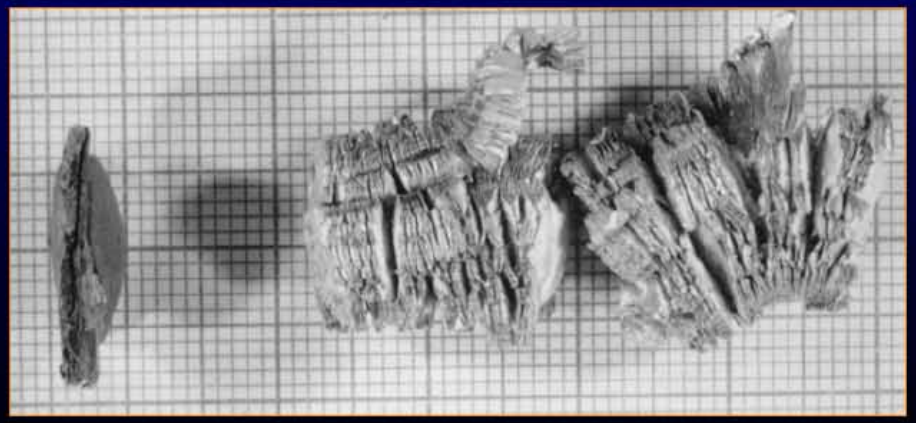


Image from Seattle Post-Intelligencer



Raw vermiculite ore (left); popped (exfoliated) vermiculite (right).
Photo by Al Bush

Courtesy of USGS

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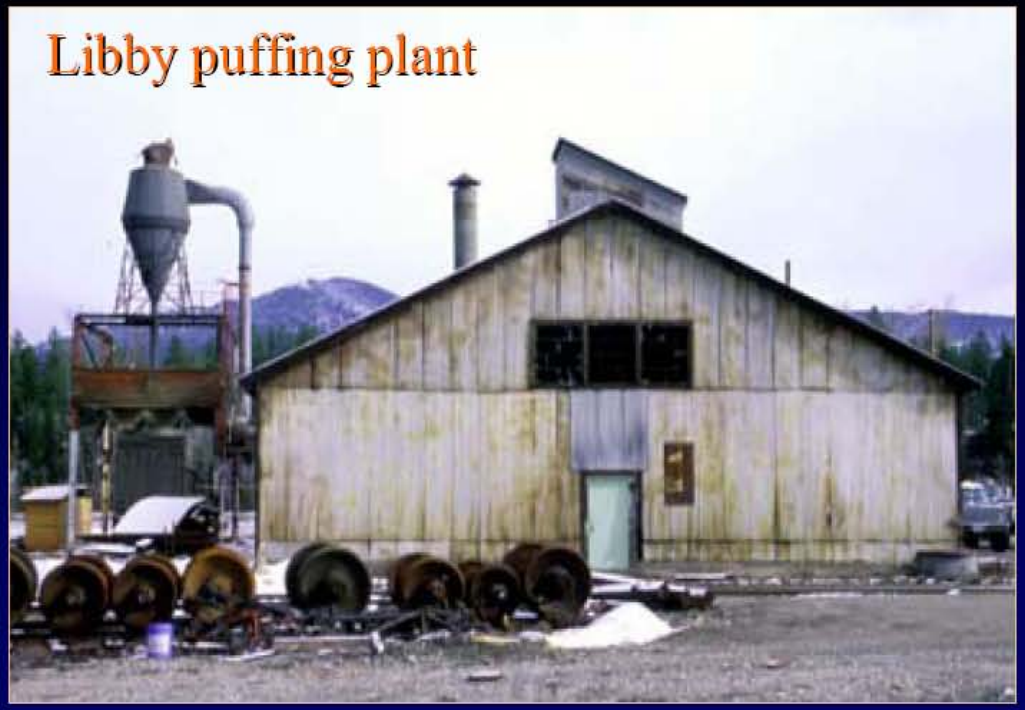
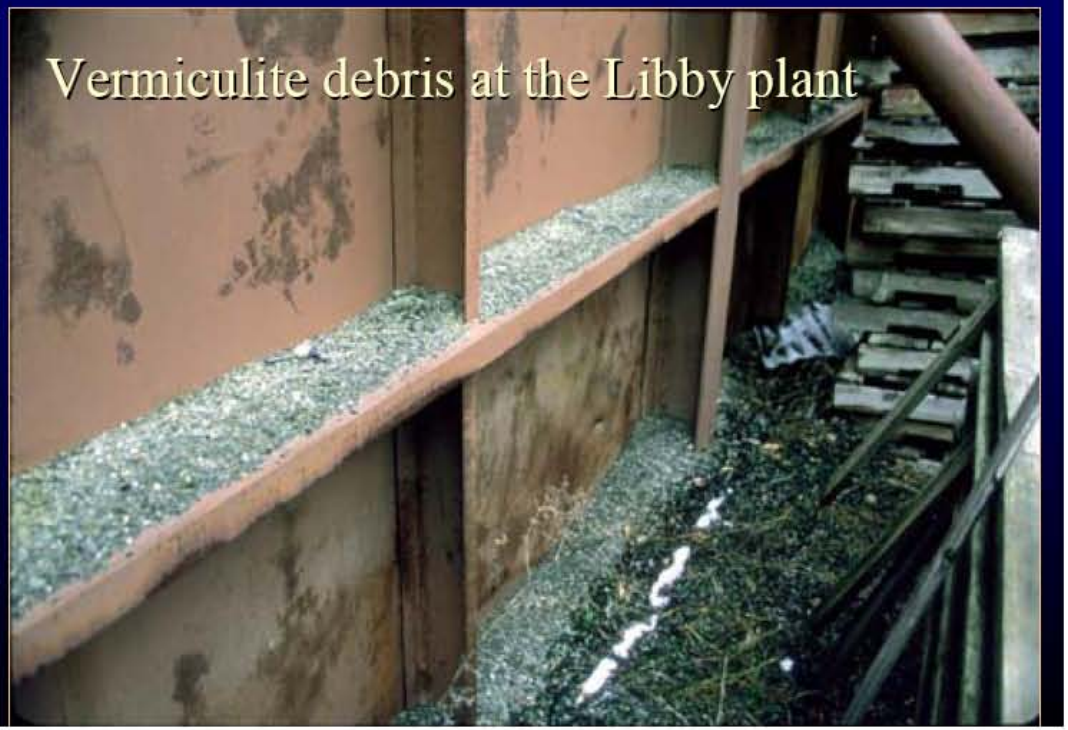
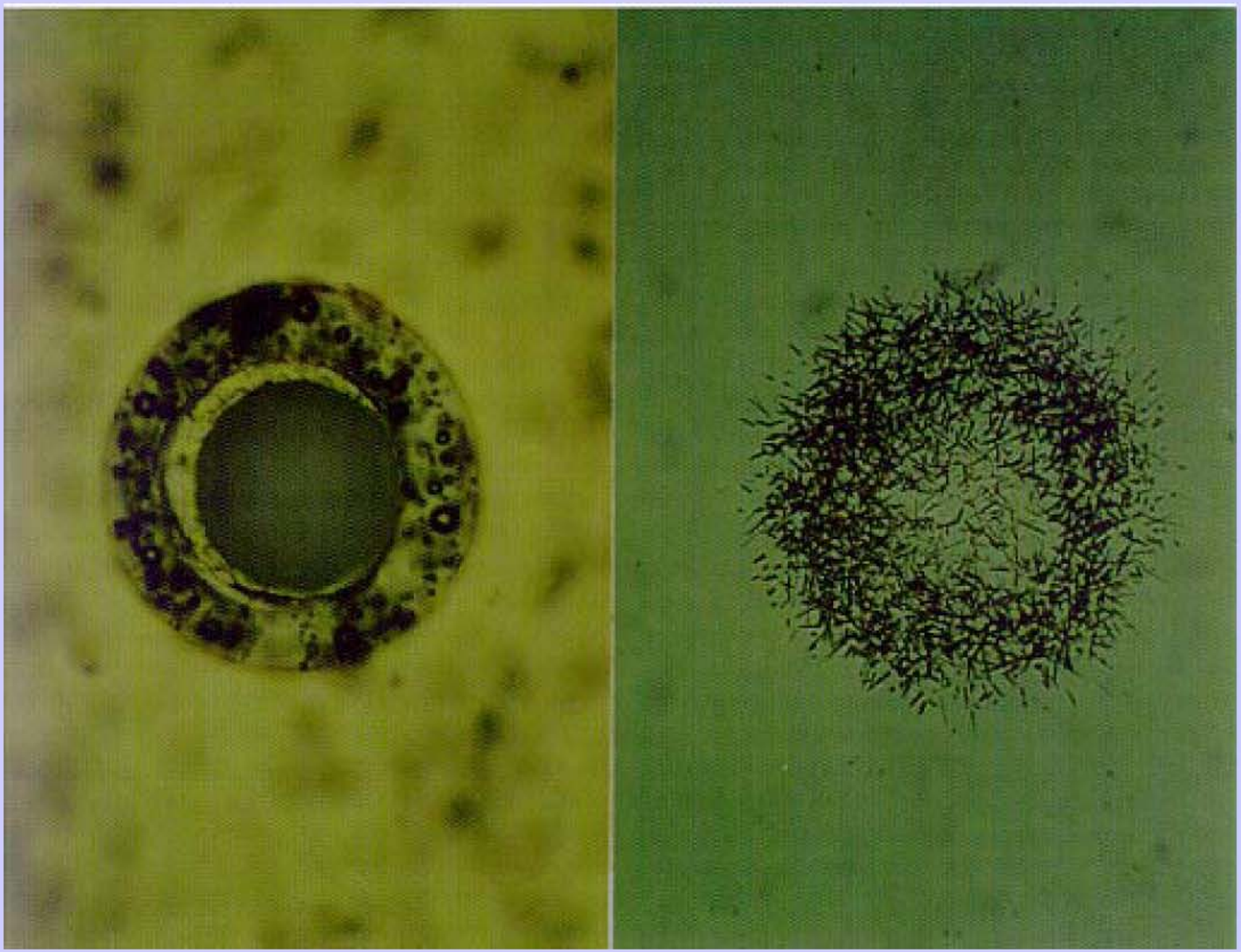
Libby, Montana

- Vermiculite puffing leads to the liberation of asbestos fibers contained within the vermiculite
- EPA has estimated that the Libby puffing plant was discharging over 5 tons of asbestos-rich dust each day into the air
- Unusually high clusters of mesothelioma, lung cancer, and asbestosis are now being identified in workers at an residents around a number of the puffing plants around the US to which Libby vermiculite was shipped

Courtesy of USGS







Photograph of hollow glassy fly ash particle (0.01 cm D)

Fission track radiograph of the same particle

Courtesy of USGS.

Health Impacts of Biomass Fuels

Scale: Number of Peoples Affected.

>>>

AIDS

+

HEART DISEASE

+

CANCER

+++

Severity: ~ 4 million deaths annually

USGS

Courtesy of USGS.


Dust Storms Health Effects
Trace Elements/Toxic Metals
As, Cd, Cr, Hg, Ra, Sb, Zn
Medical Geology/Geochemistry
Global Infectious Diseases
Carcinogenesis, Silicosis, Asbestosis

Review and Conclusions

Fundamental geology provides the foundation for a research investigation by

- providing theoretical principles and procedures,
- exploring basic local terrains and formations,
- identifying the initial parameters influencing the public health

in a selected territory (or region) or country.

Review and Conclusions …

The three main branches of fundamental geology are:

- Sciences of geochemical cycle, such as crystallography, mineralogy, petrology, geochemistry studying the composition of the Earth's crust
- Sciences that study the geological processes or dynamics of the Earth (geophysics-seismology; geodynamics-volcanism, tectonics…)
- Sciences that study the history of development of the Earth (paleontology, stratigraphy,..)

Review and Conclusions …

Applied medical geology is used to

- identify specific inorganic and organic components of natural environment,
- identify basic regularities and factors influencing the level of public health in the specified region.

Review and Conclusions

- Medical geology/geochemistry evolved out of multi-disciplinary approach to understand the influences of environmental geology and geochemistry on public health.
- The main goal is
  - ❖ to find the true cause of a disease,
  - ❖ to establish the actions or effects of a given environment,
  - ❖ to provide effective ways of treatment,
  - ❖ to provide solutions for prevention.

Review and Conclusions

Significance is manifold:

- The contribution of medico-geological research is significant especially in the context of somatic (‘non-infectious’) diseases such as malignant growths and diseases of internal organs . For example, the unequal occurrence of malignant tumors in different geographical regions of the world is presenting a challenging research. The medico-geological research is providing correlations and regionalization on the basis of **medical** and **geological parameters.**

Review and Conclusions …

- Medico-trace element geochemistry made significant contributions in the context of the importance of essential and non-essential trace elements and their effects due to deficiency, normalcy and toxic levels on human and plant health.

Ex: As toxicity in drinking water

Hg toxicity in food from fish

Review and Conclusions …

Medical geochemistry provides information especially about abundances of certain essential elements and their effects on the health of humans and plants – for example in the tropical environment – the chemical composition of soil, water and rocks showed strong correlation with the incidence of diseases like dental and skeletal fluorosis, diseases related to iodine deficiency.

Review and Conclusions …

Biomedical-hydrogeology provides significant information about the detrimental effects of mineralized water or contaminated water on human and animal health.

Ex: “research in locating the source of the pathogens, and devising measures to prevent and control the epidemic disease involved expertise in biology, medicine and hydro(geo)logy”

Base on Page 35 Medical Geology.

Review and Conclusions

- Naturally Occurring Radioactive Materials
  - Primordial, Cosmogenic and anthropogenic
- Technologically Enhanced NORM
- Indoor and Outdoor air Quality - Radon

Review and Conclusions …

Further reading

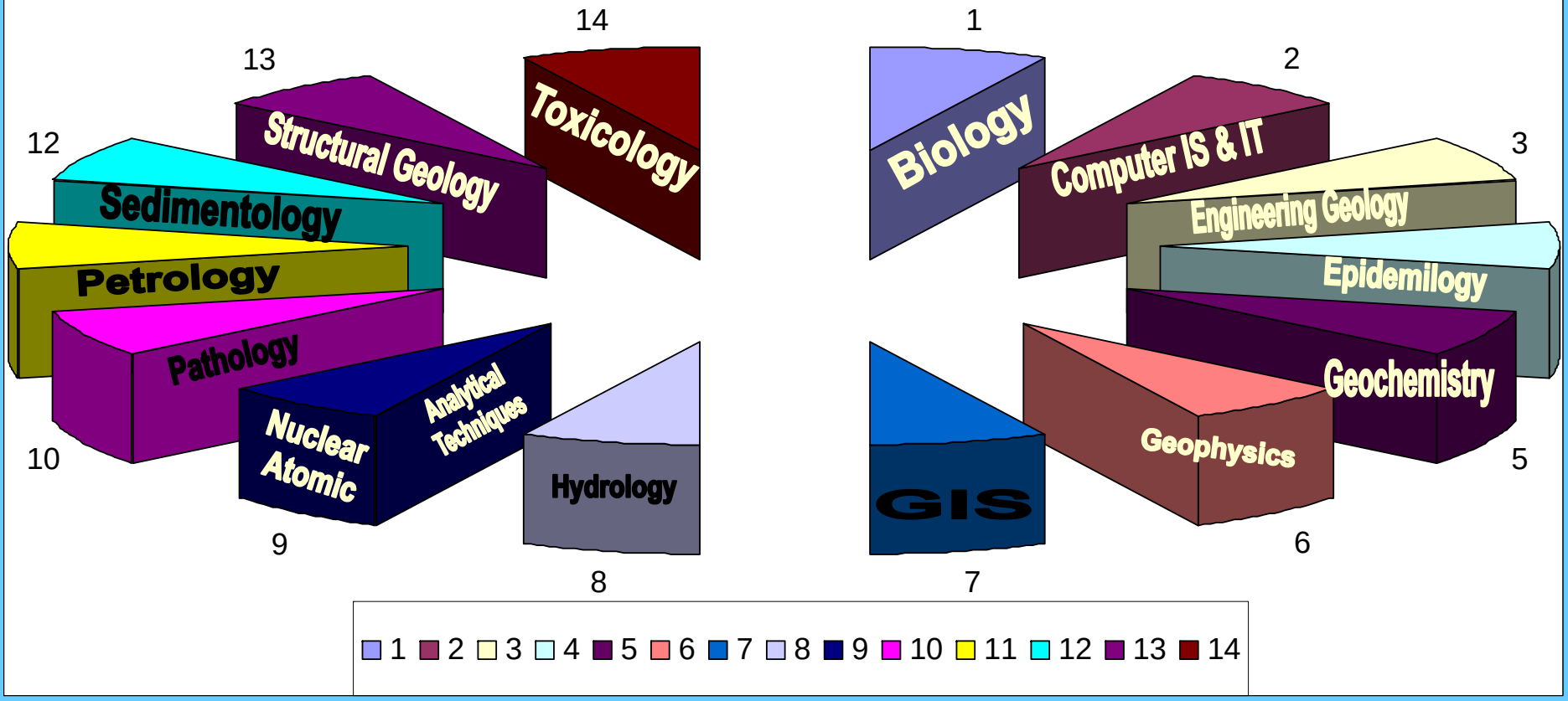
- Speciation: Chemical speciation determination is useful in determining the total concentration of an element in a sample from all the various oxidation and valence states, physical forms of the element.

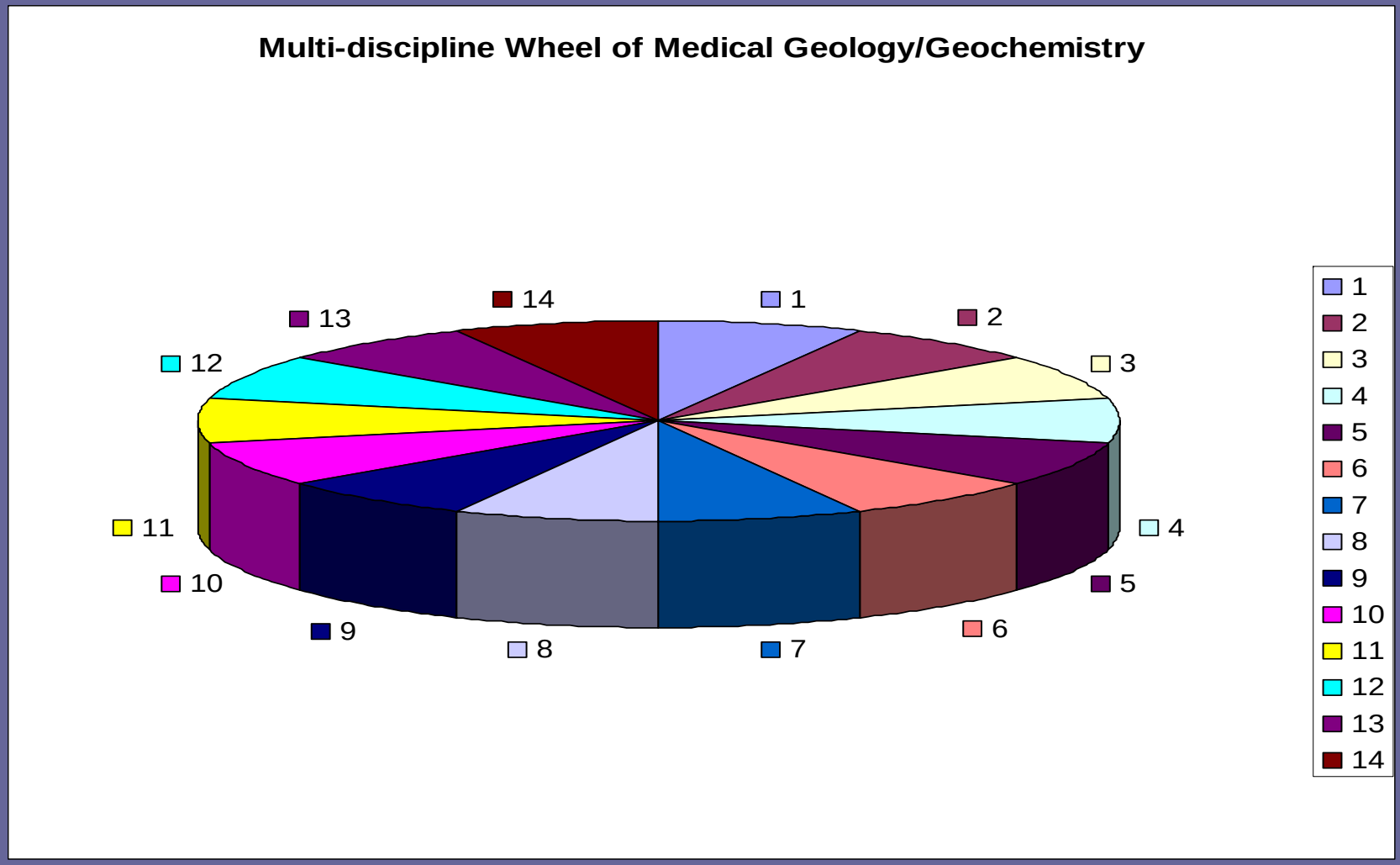
- Analytical Biophysical Methods:
  Vibrational Spectroscopy- Infrared and Raman.

- Environmental effects on plants.

- Environmental effects on animals

Multi Disciplines of Medical Geology/Geochemistry




Multi-discipline Wheel of Medical Geology/Geochemistry
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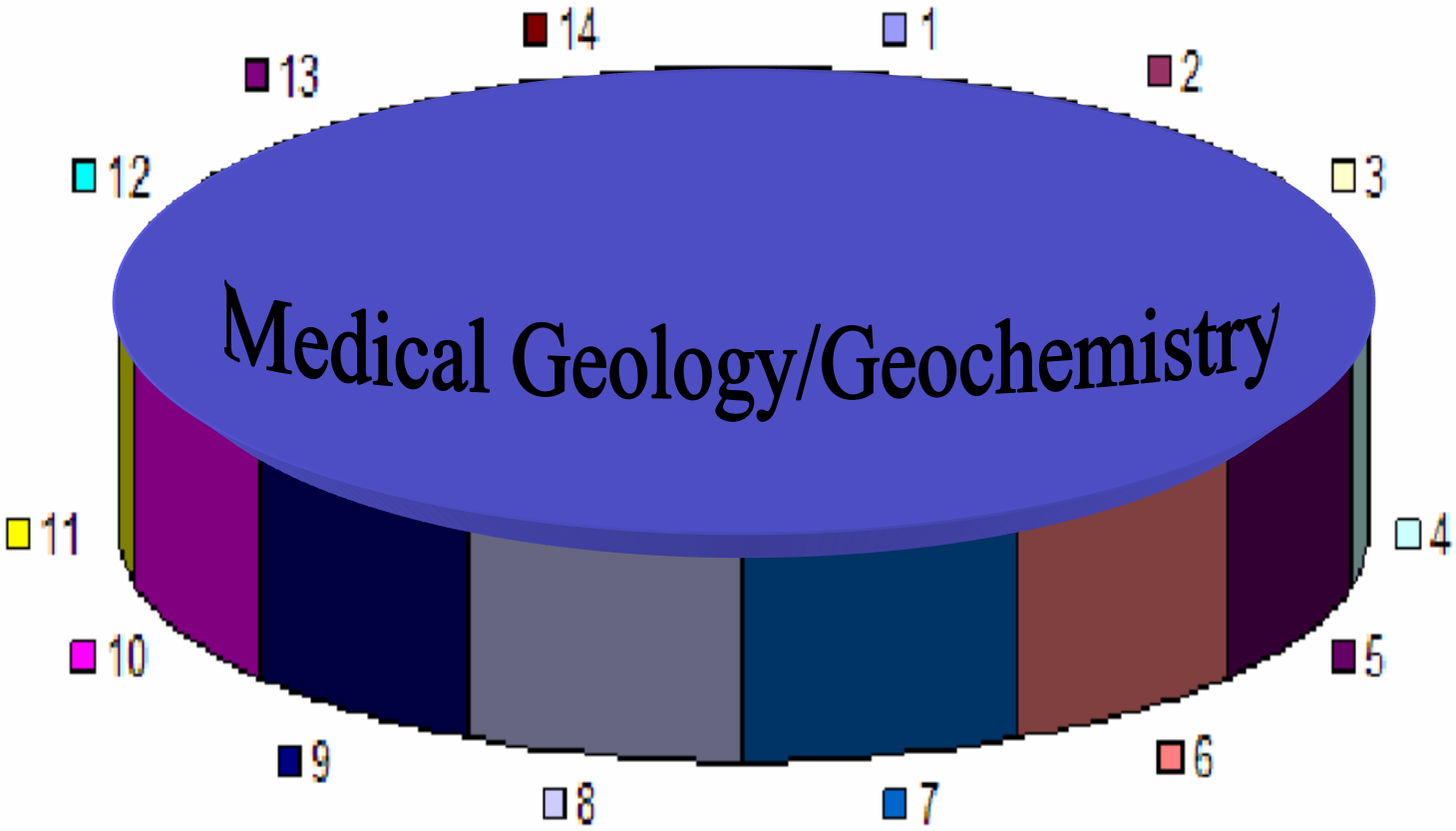
Medical Geology/Geochemistry
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Student Presentations and Reports

- **Chlorine and its Effects**
  - ***Jacqueline Brazin***
- **Iodine**
  - ***Christopher Love***
- **U.S. Environmental Health Effects and Treatment of Mercury Exposure**
  - *Sergio Navarro*

Summary

I talked about dust storms and health effects and reviewed the scientific concepts of MedicalGeology/Geochemistry.

Internet Keywords

- Dust storm effects, tephra dispersal, valley fever

References

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- **The Role of Trace Elements for Health Promotion and Disease Prevention: Annual Meeting of the European Academy of Nutritional Sciences, Copenhagen, August 1996 - Proceedings**
  Ed: B. Sandstrom, P. Walter,
  Karger 1998.

- **Trace elements in health – A review of current issues,**
  J. Rose,
  Boston: **Butterworths**, 1983.

- **Environmental health effects of toxic elements, metal ions, and minerals, Bob-Natural and Anthropogenic Sources.pdf,**
  Bob-Dust.pdf,
  R. B. Finkelman, United States Geological Survey