science for a changing world

USGS Environmental Studies of the World Trade Center Area, New York City, after September 11, 2001

Smoke streaming from Ground Zero illuminates the night skyline of lower Manhattan in a view looking east from New Jersey. The photo was taken the night of September 16, 2001, by USGS field-crew members Todd Hoefen and Gregg Swayze.

Two days after the September 11, 2001, attack on World Trade Center (WTC), the U.S. Geological Survey (USGS) was asked by the U.S. Environmental Protection Agency (EPA) and the U.S. Public Health Service to conduct a remote sensing and mineralogical characterization study of lower Manhattan around the WTC. This study, conducted in cooperation with the National Aeronautics and Space Administration (NASA) and the Jet Propulsion Laboratory (JPL), was requested to rapidly provide emergency response teams with information on the concentrations and distribution of asbestos and other materials in the dusts deposited around lower Manhattan after the September 11 WTC building collapse in New York City.

Preliminary results of the study were released via the internet to emergency response teams on September 18 and September 27, 2001. After September 27, additional work was done to fill remaining data gaps, and the study report underwent further detailed peer review. The report was released to the general public via the internet on November 27, 2001. This fact sheet summarizes the results of the interdisciplinary study; the full report can be viewed at http://geology.cr.usgs.gov/pub/open-file-reports/ofr-01-0429/ .

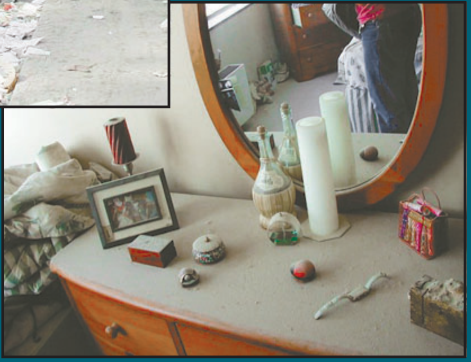
Study Overview

The Airborne Visible/Infrared Imaging Spectrometer (AVIRIS), an aircraft-based remote sensing instrument, was flown by JPL/NASA over the WTC area on September 16, 18, 22, and 23, 2001.

From September 16 through 19, 2001, a two-person USGS field crew visted lower Manhattan to field calibrate the AVIRIS remote sensing data during daylight hours. On the evenings of September 17 and 18, the field crew collected samples of dust and airfall debris deposits from 33 outdoor locations within a 1-kilometer radius of the WTC; this sampling occurred after a major rainstorm on September 14. Two samples of indoor dust deposits unaffected by rainfall, and two samples of material coating a steel beam in the WTC debris close to Ground Zero were also collected.

Preliminary calibration and geo-rectification of the AVIRIS data were done at JPL/NASA laboratories in Pasadena. Calibration to surface reflectance, spectral mapping, and interpretation were done at the USGS Imaging Spectroscopy Lab in Denver, Colorado.

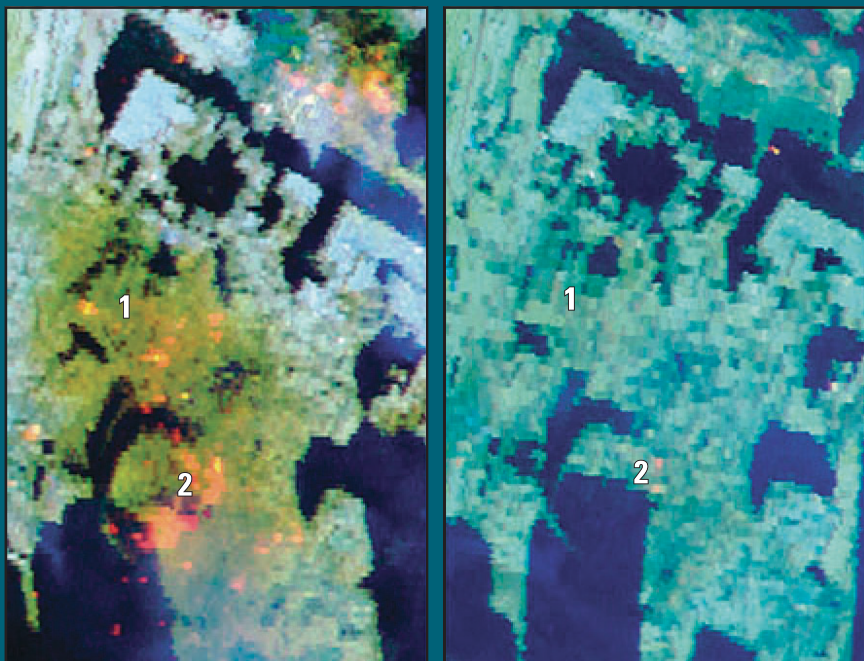
The dust, debris, and beam-coating samples were analyzed for a variety of mineralogical and chemical parameters using Reflectance Spectroscopy (RS), Scanning Electron Microscopy with X-ray microanalysis (SEM), X-Ray Diffraction (XRD), chemical analysis, and chemical leach test techniques in other Denver USGS laboratories.



Extensive dust and debris deposits were left in lower Manhattan by the dust cloud generated by the WTC building collapse, including inside surrounding buildings where windows were left open or blown in by the force of the collapse. Photos by Mark Rushing.

Results

Hot Spots Identified in the World Trade Center Debris



AVIRIS images obtained from an airplane flying over the WTC complex were processed to indicate thermal hot spots, shown as bright red, orange, and yellow spots on the images to the left. The dark areas are shadows of buildings and other structures. The numbers show the original locations of Towers 1 and 2 in the WTC complex.

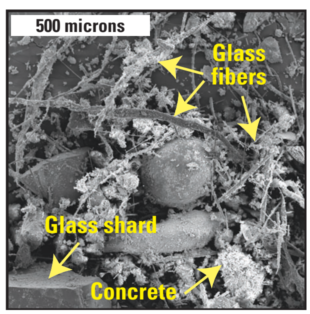
The September 16, 2001 image (left) reveals a number of thermal hot spots in the region where the WTC buildings collapsed. Analysis of these data indicated temperatures greater than 800°F (orange pixels), with some areas reaching over 1300°F (yellow pixels). These results were released to emergency response agencies on September 18, 2001.

By September 23 (right), most of these hot spots that were initially detected by AVIRIS had been eliminated or reduced in intensity.

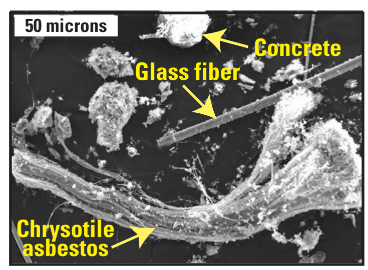
Materials Found in the Dust Deposits and Beam Insulation Samples

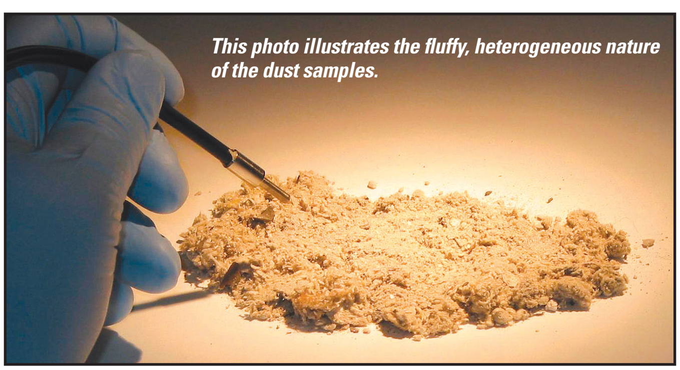
Samples of the dusts were analyzed using several different methods. All of the results indicate that the dust deposits formed from the WTC collapse are heterogeneous and are composed largely of particles of glass fibers, gypsum wallboard, concrete, paper, window glass, and other miscellaneous materials commonly used in building construction or found in office buildings.

The USGS detected chrysotile asbestos in more than two thirds of the dust samples studied, at levels less than 1 weight percent. Analyses of the material coating a steel beam in the WTC debris detected the presence of chrysotile asbestos at levels as high as 20 percent (by volume) of the coating material. To date, the USGS has not detected amphibole asbestos minerals in any of the dust or beam-coating samples, although small amounts of amphibole asbestos have been discovered by another group studying the WTC dusts. A growing body of medical research indicates that chrysotile asbestos is less carcinogenic than amphibole asbestos, although this is still under debate within parts of the medical community.

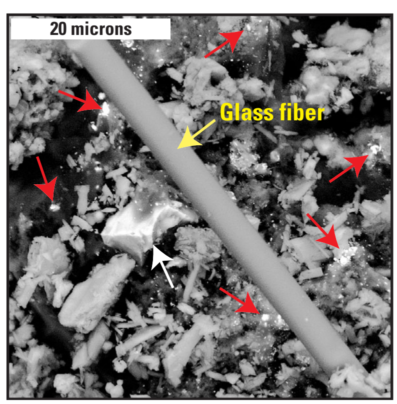


Black and white scanning electron microscope images reveal the extremely complex makeup of the dusts on a microscopic scale. The length of the white bar on each SEM image indicates the scale.





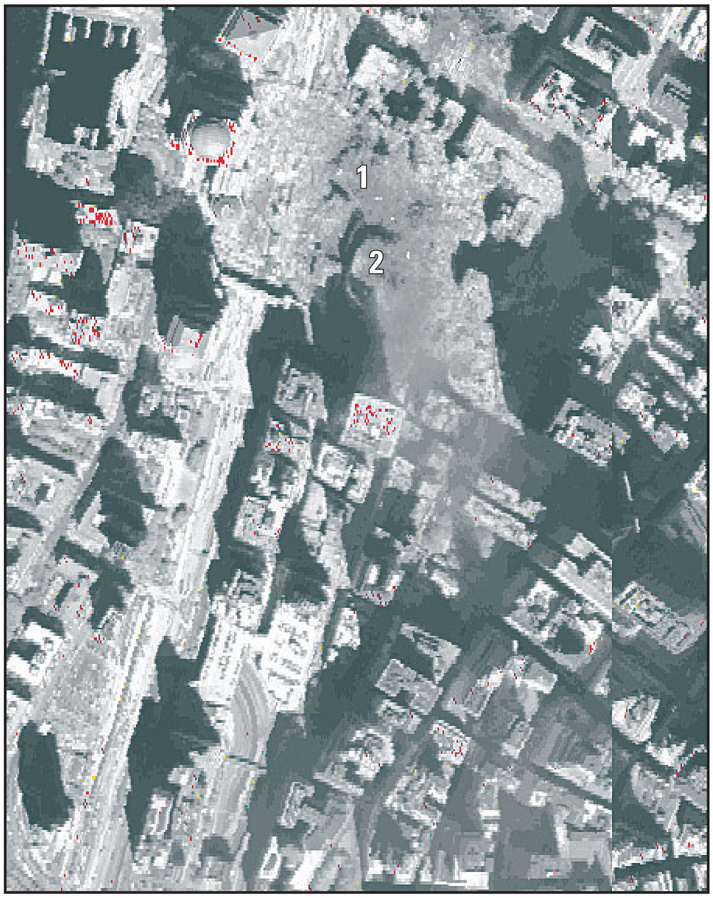
This photo illustrates the fluffy, heterogeneous nature of the dust samples.



Particles enriched in a variety of metals such as iron, lead (red arrows), zinc (white arrow), antimony, and bismuth have been identified by SEM analysis. Many of these particles are less than 1–2 microns in size, and can potentially be inhaled should the dusts be disturbed and become airborne.

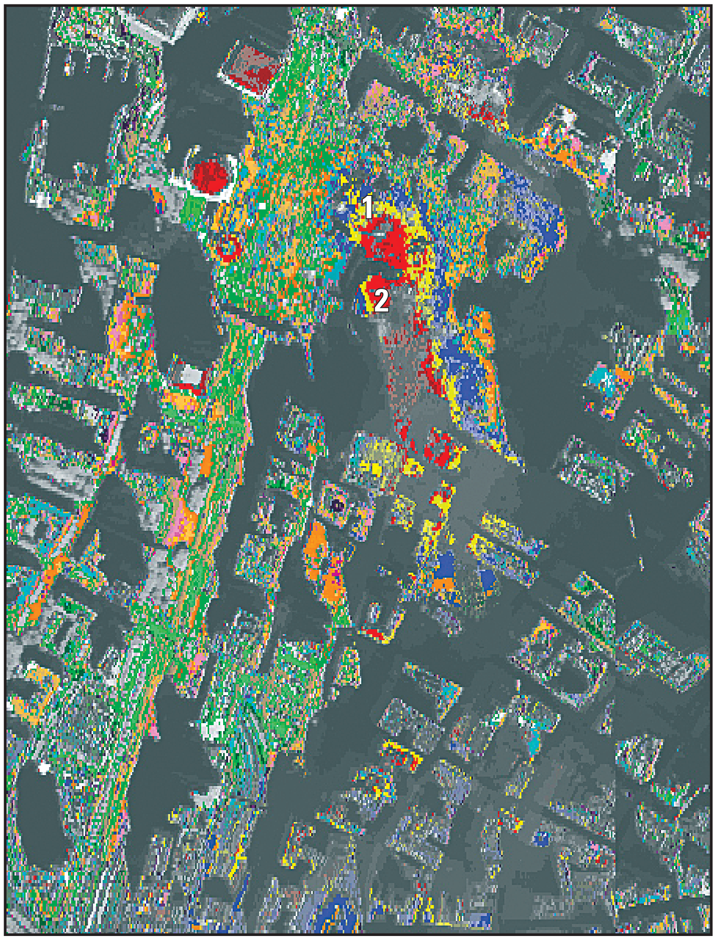
Mapping Constituents Found in Dust Using AVIRIS Remote Sensing Data

AVIRIS remote sensing measures the amount of light reflected from the ground surface in the visible through near-infrared spectrum. Individual minerals or other dust components have characteristic light reflection features across the visible and infrared spectrum, which can be used to map spatial variations in the materials making up the dusts deposited around the WTC. For further information about spectral theory, processing techniques, and applications, see http://speclab.cr.usgs.gov.



Asbestos

An AVIRIS image from September 16th (left), keyed to the absorption and reflectance features of chrysotile and other potential asbestos-forming minerals in the dusts, does not indicate widespread distribution of either chrysotile or amphibole asbestos in amounts above the detection limit of the instrument (3–5 percent). Instead, AVIRIS mapping has identified isolated pixels or pixel clusters (each pixel is approximately 2 m by 4 m) where potential asbestos-forming minerals may occur in the area around the WTC (indicated as red spots on the image). In these areas, minerals that may be asbestiform may be present in concentrations of a few percent to tens of percent. Further field sampling and laboratory analysis would be needed to confirm the presence of these minerals, and to determine if they occur as asbestos. The white numbers in the upper-central portion of the image indicate where Towers 1 and 2 stood in the WTC complex.



Spatial Variations in Dust Makeup

The AVIRIS image at right shows spatial variations in the reflectance characteristics of concrete, gypsum, and iron-rich materials. The image indicates that the dust plume generated by the building collapse generally traveled to the south-southeast from the WTC. It also shows that heavier, coarser materials with abundant concrete and steel (dark red and yellow pixels) tended to settle closer to the WTC than lighter, finer particles composed of powdered gypsum wallboard, concrete, glass fibers, and paper (dark blue, light blue, green, and orange pixels).

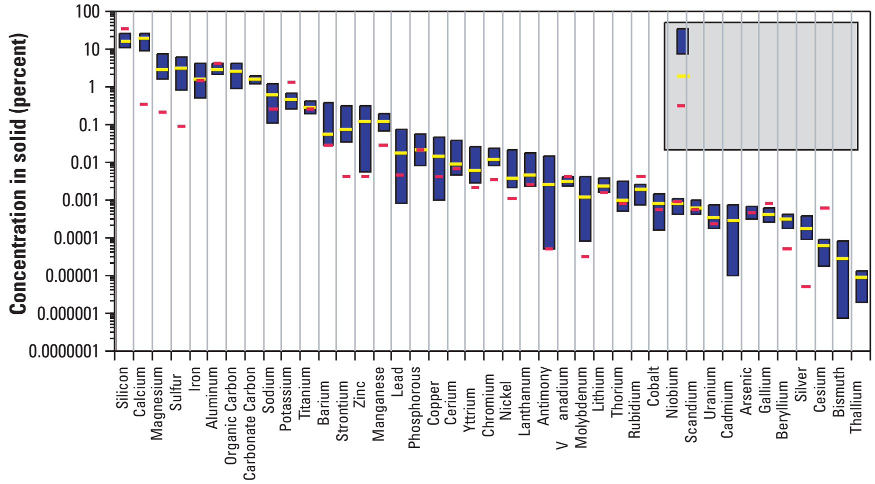
Results

What Is the Chemical Makeup of the Dust Deposits?

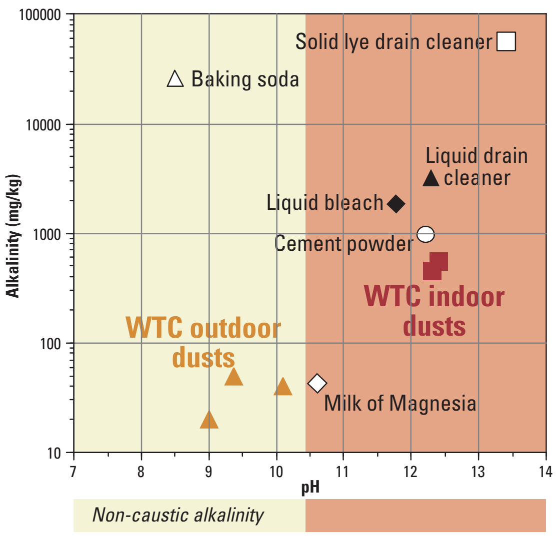
The chemical makeup of the dust samples, although quite variable, reflects the chemical contributions of materials used in building construction or found in buildings, such as glass fibers, concrete, gyspum wallboard, steel girders, wiring, ductwork, electronics, computers, paper, and many others.

The mean concentrations of some heavy metals in the WTC dust samples (such as antimony, molybdenum, zinc, copper, lead, chromium, manganese, nickel, and barium) are relatively high compared to their mean concentrations in natural soils from the eastern United States.

The plot to the right compares the concentration ranges and mean concentrations of chemical elements in the WTC dusts (this study) to the mean concentrations of the same elements in soils from the eastern United States (other studies).



What Happens When the Dusts Come into Contact with Water?



Chemical leach tests were performed in which 1 part dust was mixed with 20 parts water and the resulting water solution analyzed. The results indicate that the dusts can be chemically reactive should they come into contact with rain or wash water, or moisture in the eyes, mouth, and respiratory system. Some metals in the dusts, such as aluminum, chromium, and antimony, are quite soluble. Any water or moisture that comes into contact with the dusts initially becomes alkaline to caustic, due to the dissolution of calcium hydroxide from the concrete particles. This is especially true for indoor dust samples that have not been exposed to rainfall. Fortunately, continued reactions of water and atmospheric carbon dioxide with the dusts help to neutralize their caustic alkalinity.

The plot at left shows the alkalinity and pH of the WTC dust samples and common household materials when all are diluted by 20 parts water. The indoor WTC dusts, when added to water, can generate high pH values and caustic alkalinity (composed of caustic, reactive hydroxyl ions). However, the indoor WTC dusts do not generate as much caustic alkalinity as equivalent weights of cement, liquid drain cleaner, liquid bleach or solid lye drain cleaner. In contrast, the outdoor WTC dusts generate somewhat lower pH values and smaller amounts of alkalinity that is mostly noncaustic (composed primarily of carbonate and bicarbonate ions).

Implications for Dust Cleanup

As stated in the initial USGS report to emergency response workers on Sept. 27, 2001, the materials identified by this study in the WTC dust and debris (chrysotile asbestos, glass fibers, alkaline concrete particles, potentially soluble metals) indicate that cleanup of dusts and the WTC debris should be done with appropriate respiratory protection and dust control measures.

Where To Get Health Information about the Dusts

The USGS studies summarized here provide scientific information about the material and chemical makeup of the dust deposits left by the WTC building collapse. This information, along with information provided by many other emergency-response studies and long-term monitoring studies, can be used by the medical community to help understand potential human health effects that may result from exposure to dusts generated by the initial building collapse, and from longer-term exposure to dusts remobilized during cleanup.

There are a number of different web sites that provide health-related information on the WTC collapse, such as: the U.S. EPA (www.epa.gov), New York Department of Public Health (www.nyc.gov/html/doh/home.html), and the Environmental and Occupational Health Sciences Institute (eohsi.rutgers.edu/wtc/index.shtml).

The USGS and NASA/JPL team members who participated in this study respectfully acknowledge the memory of the many who lost their lives in the World Trade Center attack; those injured; the families and friends of those lost and injured; and the heroic efforts of the countless emergency workers, health care professionals, construction crews, scientists, and others who have made a difference on and since September 11, 2001.

For further information about the USGS study, contact:

Roger Clark (AVIRIS)
(303)-236-1332, rclark@usgs.gov

Geoff Plumlee (dust chemistry)
303) 236-1204, gplumlee@usgs.gov

Greg Meeker (materials characterization)
(303) 236-3188, gmeeker@usgs.gov

Gregg Swayze (field sampling)
(303) 236-0925, gswayze@usgs.gov

USGS, NASA/JPL study team:

Roger Clark, Rob Green, Gregg Swayze, Greg Meeker, Steve Sutley, Todd Hoefen, Eric Livo, Geoff Plumlee, Betina Pavri, Chuck Sarture, Steve Wilson, Phil Hageman, Paul Lamothe, Sam Vance, Joe Boardman, Isabelle Brownfield, Carol Gent, Laurie Morath, Joseph Taggart, Pete Theodorakos, and Monique Adams