LOS ALAMOS NATIONAL LABORATORY
WHERE SCIENCE MAKES A DIFFERENCE

DATELINE
LOS ALAMOS

LOS ALAMOS RESEARCHERS ASK, "WHAT'S EATING YOU?"

A 3D MODEL DESCRIBES THE DOG-EAT-DOG WORLD BENEATH OUR FEET

Los Alamos researchers are using computers to model the interaction between soil microorganisms and pollutants, and it's a jungle down there. Even on a microscopic level there is a fine balance between the hunter and the hunted.

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Scientists know that certain bacteria can essentially "eat" soil contaminants like spilled hydrocarbons and that this feature can be exploited for environmental cleanup activities.

A number of computer models have been designed to help scientists understand this process, but traditional models haven't included how microbial predators can attack and feast on contaminant-eating microorganisms and possibly prevent them from effectively doing their job. Los Alamos researchers are working to make subsurface flow models that realistically reflect a community of organisms in the soil, all competing for the same resources.

The researchers have already been applying numerical models to real-life problems by using computers to model the flow and transport of fluids through porous media like soils. In one application, these models can show how spilled contaminants such as diesel fuel, gasoline, dry-cleaning solvents, or other hydrocarbons travel through soil.

In other applications suited for environmental remediation activities, computer models show how water or air can most effectively be pumped into the ground to entrain contaminants and move them above ground, where the air or water is then treated to remove the contaminants. The process works more quickly if something — in this case bacteria — can help break down contaminants.

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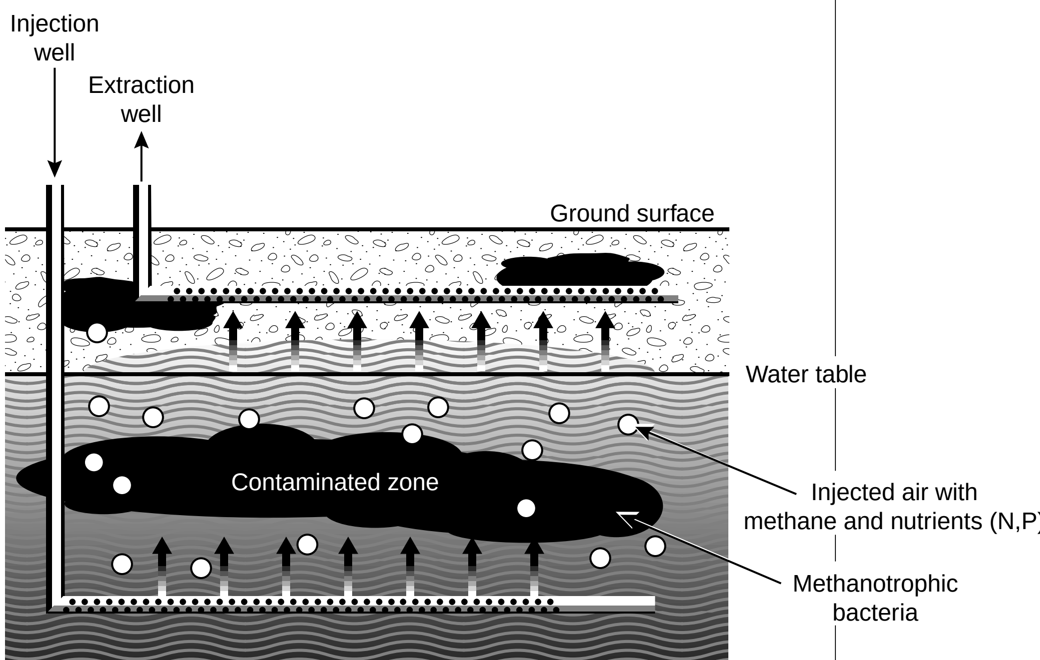

Illustration of the bioremediation technology.

At the Department of Energy's Savannah River Site near Aiken, S.C., the researchers took the traditional fluid transport model a step further. Using a computer code called TRAMPP, they modeled air flow into the soil as well as a flow of methane and nutrients such as nitrogen and phosphates to help stimulate naturally occurring bacteria to feast on the methane-nutrient material and produce an enzyme called methane monooxygenase. This enzyme helps degrade trichloroethylene, a common solvent and soil contaminant.

The researchers used their model to compare several methods of feeding bacteria. They discovered that if too many nutrients are added to the system, the bacteria thrive at an explosive rate near the injection wells, resulting in clogged soil pores — through which gases must flow — or consumption of the nutrient solution before it diffuses through the soil to the contaminated area. If too few nutrients are added, the bacteria die off.

In the Savannah River demonstration, the researchers successfully developed a method for delivering nutrients in pulses to achieve optimum results. Actual remediation activities based on the model showed that the TRAMPP code was valid.

Tests at the site also showed that by using bacteria in concert with traditional remediation techniques, the cleanup rate increased by nearly

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40 percent. However, a puzzling behavior was seen: Bacterial population levels oscillated strongly even when field conditions were at steady state.

To find out why, the researchers turned to their computer model and added non-linear aspects of microbial predator behavior and, in the computer world at least, are starting to gain a “virtual” understanding of complex predator-prey interactions. In this cyber-soil environment, protozoan predator populations increase as the number of contaminant-eating microbes increases, changing the dynamics of the system.

They are now trying to validate the new model by testing contaminated soils in a laboratory setting to see whether contaminant levels, microbe populations, and remediation results are similar to those predicted by the model.

In addition, the model takes into account the fact that particles and pores in soils aren't uniform in size and shape, something neglected by other models. By taking into account this soil heterogeneity, they can better understand pore channels that provide pathways for gases, liquids, microbial predators, and microbial prey.

At this point the researchers have taken a state-of-the-art flow and transport model and have added microbial ecology to obtain a three-dimensional model that is much more realistic. Next, they plan to validate their work on a larger scale, out in the field.

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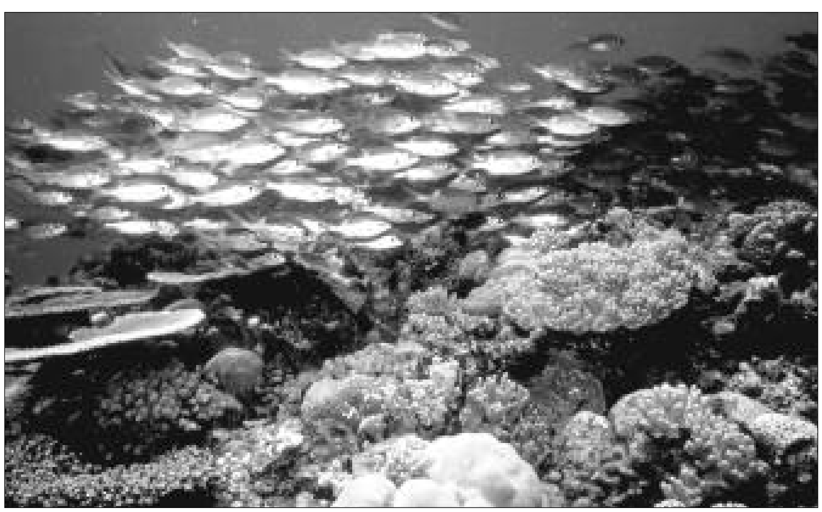
SCIENTISTS PULL CLIMATE CLUES FROM OCEAN CORALS

ADVANCED DATING TECHNIQUES HELP SCIENTISTS INTERPRET CLIMATE CHANGES BACK THROUGH TIME

Los Alamos researchers are using a novel combination of radiochemical techniques to date ocean corals and help explain recent and historical global climate change. By combining uranium-series dating with the more familiar carbon-14 dating method, the researchers can glean chemical clues from corals that could tie into ocean circulation models and help distinguish between natural climatic variation and human-caused effects.

The oceans exchange carbon with the atmosphere, and the rate of that exchange affects the amount of carbon dioxide in the atmosphere. Because carbon dioxide is an important greenhouse gas, the amount present in the atmosphere affects global climate. For example, scientists know there is twice as much carbon dioxide in the atmosphere today as there was during the last ice age.

The carbon exchange rate is related to the turnover time of the deep ocean, which can be measured from something known as the ventilation



Ocean corals may hold clues to global climate change.

age — how long deep ocean water has been isolated from the surface. Scientists today believe that ocean ventilation ages may have changed through time, causing variations in the climate.

But getting the ventilation age of water as it was 20,000 years ago in the last ice age requires some tricky scientific sleuthing. Los Alamos researchers are using their expertise in radiochemical analysis to demonstrate the tandem dating technique that employs uranium-series and carbon-14 methods.

Los Alamos researcher Steve Goldstein in front of a thermal ionization mass spectrometer.

Based on test results with surface, reef-building corals, the researchers estimate they can date deep sea corals to within five or 10 years for 100-year-old corals and come within 1 percent precision for dates of corals over the past 1,000 to 100,000 years.

Results so far indicate the deep water currently in the Southern Pacific Ocean had been removed from the surface for about 800 years. As expected, ventilation age increased with ocean depth.

The uranium-series dating method takes advantage of the tendency of corals to crystallize microscopic amounts of uranium from sea water. Once the uranium is incorporated into the coral, it begins to decay at known rates into different atomic forms, or isotopes, called thorium-230 and protactinium-231. Sea water has very little of these isotopes floating freely in it, so the amount of thorium-230 and protactinium-231 in the coral provides two measures of the coral's age. Comparing the thorium and protactinium dates verifies the accuracy of the age estimates.

The researchers measure the amounts of thorium and protactinium in a sample of coral with an instrument called a mass spectrometer. Like a beam of light sent through a prism to separate white light into the spectrum of colors, a beam of ions — electrically charged particles — produced by a vaporized sample is sent through a combination of electrical and magnetic fields to produce a spectrum of charged particles of different masses. Los Alamos can count an isotope-specific mass ratio with great accuracy. The relative abundances of the isotopes locked in the coral reveal its age.

Uranium-series dating by mass spectrometry differs from the more familiar system of carbon-14 dating. Naturally occurring carbon-14 exists at a constant level in most of the biosphere. But once a sample has been removed from exchange with the environment, as at the death of an organism, the amount of carbon-14 begins to decrease. An estimated age comes from comparing a measurement of the residual carbon-14 in a sample to the activity in a contemporary standard.

Instead of counting decay particles, which is useful for isotopes like carbon-14 that decay quickly, mass spectrometry counts numbers of radioactive atoms present, which is more efficient for long-lived isotopes like thorium-230 and protactinium-231. Mass spectrometry also provides more precise measurements and dates, especially with very small samples, and it is faster — with results in a few hours, whereas decay counting dating may take days.

The researchers combine mass spectrometry and carbon-14 dating to come up with the ventilation age of ocean water at a point in history.

The carbon-14 system, which yields how long the carbon in the coral sample has been isolated from the surface, provides the age of the water when the coral was formed plus the age of the coral deposit itself. Next, the uranium-series date, or how long the uranium has been isolated from the water, provides the age of the coral alone. So subtracting the uranium-series date from the carbon-14 date reveals the ventilation age of the water back when the coral formed.

That information, when compared to the ventilation age of deep water in the contemporary ocean, will help scientists interpret climate changes back through time and better understand how the oceans interact with the atmosphere. The clues gleaned from corals could tie into ocean circulation models and help distinguish between natural climatic variation and human-caused effects.

The Los Alamos researchers collaborated with investigators from the University of California at Santa Barbara and Lawrence Livermore National Laboratory on this research.

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WHEN THE WALLS COME TUMBLING DOWN

A CONTROLLED MINE COLLAPSE HELPS VERIFY COMPLIANCE WITH COMPREHENSIVE TEST BAN TREATY

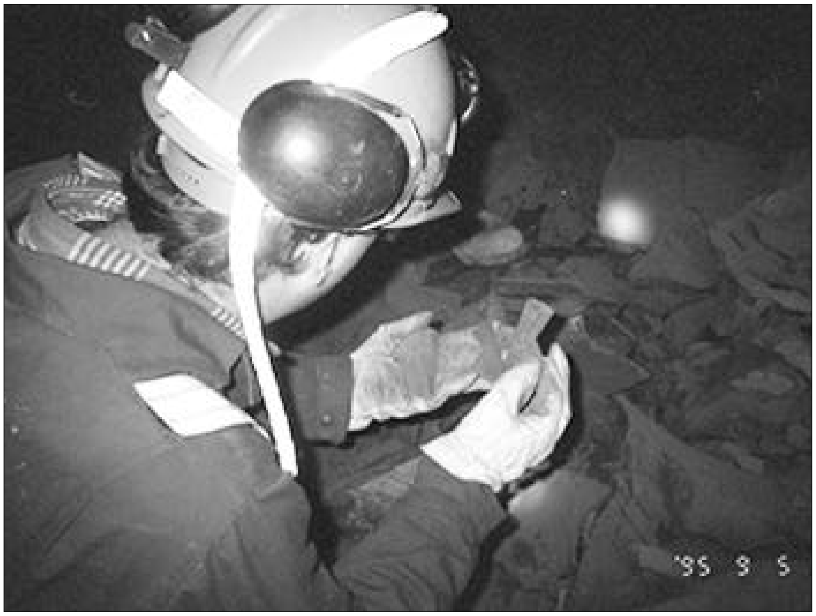
When mine operators purposely collapsed a section of a Michigan copper mine last September, Los Alamos researchers were quietly collecting seismic signals, trying to see how the event might compare to, say, a nuclear blast.

The collapse, induced with the help of explosives, was an innovative way of doing business for the mine's operators. For the researchers, it was an opportunity to gather information that ultimately could help world leaders determine if a rogue nation violates the Comprehensive Test Ban Treaty.

The researchers used seismometers to gather data before, during, and after the controlled collapse last September and during a similar collapse in September 1995. The seismic data they collected ultimately will help scientists distinguish between events like earthquakes or mine collapses and nuclear explosions.

Los Alamos and White Pine Mine personnel meet inside an underground room near the collapsed area.

The researchers are developing a complete seismic library that will help scientists pinpoint the origin of an explosion and whether such an explosion has a distinct pattern of shock waves known as a "nuclear fingerprint." Data from the collapse of the White Pine Mine will be like one page in a book in the library.



Mining engineer Dan St. Don inspects copper ore fragmented by the induced collapse.

As part of the CTBT, an international organization will set up a series of seismic monitoring stations around the globe. Data from each station will be transmitted to an international data center. From there, scientists can analyze whether specific seismic events were nuclear tests or something else. (See the December 1995 issue of *Dateline: Los Alamos*.)

At the White Pine Mine collapse, the researchers determined it was possible to detect useful signals from an event that registered around magnitude three on the Richter Scale from as far away as 600 miles. This information will help treaty verifiers assess the capability and usefulness of a network of monitoring stations.

They also found from their close-in monitoring stations that the signals from the explosives were distinct from the signals generated by the collapse of the mine cavity. Finally, they determined that most of the aftershocks — caused when rock settles after the initial collapse — happened in the first four hours after the collapse. This last finding means it might be extremely difficult to set up stations close to a seismic signal's origin to help pinpoint the exact location of an event that initially was detected by far-away stations.

But why would anyone want to collapse a mine in the first place?

The induced collapses were part of an experimental mining operation at White Pine, a nearly 20-square-mile underground copper mine 5 miles south of the southern shore of Lake Superior. The mine is reaching the

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end of its economic life and the induced collapse allowed mine operators to extract copper that otherwise would have been left behind in support pillars of rock which were left in place to shore up subterranean rooms.

The seismic data obtained by the Los Alamos researchers also yielded information that was vital to the mining industry. Thanks to close-in seismometer placement, the researchers were able to pinpoint 135 distinct aftershocks that occurred within 36 hours of the collapse. After that period, most of the subterranean settling ceased.

➔ Los Alamos scientists installing a seismometer in the ground, 1,000 feet above the collapsed area.

Data analysis revealed that the aftershocks were situated in a tight pattern about 100 meters thick above the collapsed area. The pattern was similar in size to a pattern predicted by mine engineers, who based their pattern on theoretical models and rock properties.

However, the mine engineers were slightly off on the position of the pattern, having their pattern directly above the collapsed area. The Los Alamos data revealed the pattern to be shifted westward. The seismic data has since been shared with mine officials and it may help them to better engineer underground mines and mining operations in the future.

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LOS ALAMOS SCIENTIST WINS MAJOR AIDS RESEARCH GRANT

STUDY TO BENEFIT CHILDREN

Bette Korber is the recipient of the prestigious Elizabeth Glaser Scientist Award for her outstanding work on AIDS and HIV infection among children. The five-year $650,000 grant, awarded by the Pediatric AIDS Foundation, supports scientists who the foundation feels will have the most impact on pediatric AIDS research in the future.

Los Alamos researcher Bette Korber has received a $650,000 grant from the Pediatric AIDS Foundation.

Korber received the Elizabeth Glaser Award to continue to collect and analyze data on 200 HIV-infected women who enrolled in the study during pregnancy. Korber, a scientist affiliated with Los Alamos and the Santa Fe Institute, also manages several other HIV and AIDS databases that compile and analyze data available from studies of HIV and related viral genomes throughout the world. Korber's pediatric work at the Santa Fe Institute complements her research at Los Alamos on international variation of HIV and vaccine design.

The award is named for Elizabeth Glaser, who contracted HIV through a blood transfusion while giving birth to her first child. Glaser co-founded the Pediatric AIDS Foundation before her death in 1994.

Korber's database is helping to answer important questions about transmission of HIV from mother to child. For example, if a mother is showing a good immune response will her child's immune system show similar strength? And mothers carry many different strains of the virus, but are common features getting through to the babies?

Because of the varied health status of the subjects — some on medication, some with high immune defense levels — sorting out vital clues from the reams of clinical data requires someone who can interpret all the information and help other researchers put it to immediate use. Korber won the Glaser Award to do just that.

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BRIEFLY ...

THE ENVIRONMENTAL PROTECTION AGENCY HONORED LOS ALAMOS WITH AN ENVIRONMENTAL EXCELLENCE AWARD FOR THE SUCCESS OF THE SANITARY WASTEWATER SYSTEMS CONSOLIDATION PLANT, A LOS ALAMOS FACILITY OPERATED AND MAINTAINED BY JOHNSON CONTROLS WORLD SERVICES PERSONNEL. A letter from EPA Regional Administrator Jane Signaw to Los Alamos Director Sig Hecker noted the high level of success that Los Alamos' wastewater treatment works has achieved in consistently meeting its effluent limitations. The plant receives wastewater from 1,200 buildings through 54 miles of sewer line. The wastewater system includes 42 lift stations and 30 holding tanks. The plant treats all Laboratory sanitary wastewater and also wastewater from a nearby privately owned trailer park. It removes waste from the water with 98 percent efficiency. The awards committee included representatives from EPA Region 6; water pollution control agencies from Arkansas, Louisiana, New Mexico, Oklahoma, and Texas; and the American Consulting Engineers Council.

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