Under the volcano: Lava in the lab

Heat is the engine of the earth. As it escapes from the core, heat has made mountains, driven volcanos and churned up the earth's mantle, from which the atmosphere, oceans and continents were derived. One way to learn about the history of the planet as it cools from its rather hot beginnings is to study how magmas, or molten rocks, are formed in the mantle before they are spewed out onto the surface. But duplicating mantle conditions in the laboratory has been hampered by a lack of equipment capable of simultaneously subjecting large rock samples to high temperatures and high pressures.

After a decade of development, several Japanese researchers now have such equipment at hand. And one of the first important fruits of their labors is a report in the June 13 NATURE on the melting of natural rocks to form komatiite, a very hot, magnesium-rich lava that erupted on the earth 2.5 billion to 3.8 billion years ago during the Archean eon (the oldest time from which rocks still exist) and, with one exception, has not erupted since.

The recent experiment, performed at Okayama University by Eiichi Takahashi and Christopher M. Scarfe, has shown that komatiite can be created at much higher pressures — and hence depths in the earth — than was commonly believed. As such, it has considerable bearing on the makeup and evolution of the Archean mantle, about which there is much speculation but few known facts.

Most scientists believe that the upper mantle today is made of peridotite, a magnesium-rich mineral. Different magmas, distinguished in part by their magnesium content, can be generated by melting peridotite under various conditions. Since komatiites were discovered in 1969, the prevailing theory held that they formed, like the basalt lavas common today, at shallow depths and low pressures. The major problem with this idea, says Claude T. Herzberg at Rutgers, The State University, in New Brunswick, N.J., is that it requires that the peridotite melt almost completely and in such a way that the solid crystals remain in contact with the liquid phase. In practice, the solid bits tend to fall away from the liquid, so Herzberg and others have proposed instead that komatiites could come from peridotite with only a small degree of melting but at very high pressures.

This is just what Takahashi and Scarfe confirmed experimentally. Their study, using a 5,000-ton press, produced komatiites from natural peridotite rocks subjected to temperatures of almost 2,000°C and pressures up to 14 billion Pascals (GPa) — three to four times greater than the pressures of past experiments, in which the first drops of liquid produced were lower-magnesium magmas like basalt.

Since pressures increase with depth in the earth, "this is very strong evidence that melting in the Archean took place at much greater depths than it is taking place today," says Herzberg. "The reason there are no komatiites erupting today is that the depth of melting is not great enough; as the earth has cooled, the depth at which melting takes place has progressively moved toward the surface."

The recent experiment also supports another of Herzberg's predictions by showing that the "melting interval" of peridotite decreases with increasing pressure. The melting interval is the difference between the temperature at which crystals start to form in a cooled liquid and the temperature at which the first drop of liquid appears in a heated solid. For peridotite at the surface, this interval is about 600°C. Takahashi and Scarfe showed that it dropped to about 100°C at 10 GPa.

Herzberg thinks the melting interval will drop to 50°C or so and then start to increase again with increasing pressure. "And when that happens the mineral that first crystallizes as the temperature drops will change," he says. At low pressures this mineral is olivine, but no one knows what it will be at high pressures. "It's one of the exciting things that has to be done...that's going to tell us something about the mineralogy of the lower mantle," he adds.

Scarfe, on sabbatical from the University of Alberta in Edmonton, says he and Takahashi are planning more experiments this summer that will extend the pressure range to 20 GPa. With some care, their equipment can go up to 30 GPa.

Meanwhile, researchers at the State University of New York (SUNY) at Stony Brook are in the process of acquiring a system almost identical to that of Takahashi. According to SUNY's Robert Liebermann, the new equipment will be ready for experiments in 1986 and will be the first of its kind in North America.

—S. Weisburd

An open airing of the gene-splice debate

"Not to live in the cellar because we fear a tornado, but rather to keep a hurricane watch" was the goal of a meeting of geneticists and ecologists in Philadelphia last week, as described by the opening speaker, Peter R. Day of the Plant Breeding Institute in Cambridge, England. The geneticists are eager to proceed with small-scale field tests of several engineered microorganisms (SN: 5/4/85, p. 280), while the ecologists are generally more reluctant to see such bacteria released into the environment.

The intent of the meeting was stated most concretely by Susan Gottesman of the National Institutes of Health in Bethesda, Md.: "We want some sense of the minimal information needed before small-scale field tests are begun, and also the minimal information needed from such tests before there is any commercial use."

Last week's gathering, the largest multidisciplinary meeting to be focused on this issue, was organized by the American Society for Microbiology, in collaboration with seven other organizations of biologists, and it received funding from a variety of federal agencies that either support research in genetic engineering or expect to play a part in its regulation.

In the meeting's discussion, Philip J. Regal of the University of Minnesota in Minneapolis and other ecologists charged that genetic engineers are employing outdated theories in their analyses of the potential impact of new organisms on the environment. For instance, the argument that every genetic combination has at some time been employed already in nature is not valid, Regal says, because the number of combinations in complex animals is far too great. Another argument cited by geneticists is that because mutations disrupting genes generally reduce an organism's ability to survive in nature, any genetic engineering, including the adding of genes, also will decrease survival potential and reduce the chance of any adverse environmental impact. Regal says, "That is like saying stepping on someone's lunch is the same as adding a banana to it."

The greatest objections come to the idea of "the balance of nature" — that communities of organisms are so well adapted to each other and their physical environment that no novel organism would be likely to disturb the balance. "Most ecologists don't refer to niches any more. ... It is really an antiquated concept," Regal says. "There is no reason at this point to believe a species is so highly perfected that nothing can replace it."

"The lesson from ecology," says Regal, "is that one must be careful not to oversimplify what to expect from nature." Beyond this sense of caution, however, ecology today does not offer general principles that would allow geneticists to predict what will happen to an organism that is released. But ecologist Daniel Simberloff of Florida State University in Tallahassee says "there is no reason why [ecology] couldn't provide lots of specific predictions. ... Understanding [a specific environmental situation] is very accessible to detailed research, work about the equivalent of a Ph.D. thesis."

A case-by-case analysis of proposed field tests of genetically engineered organisms was much lauded by both ecologists and geneticists, although some still held out for more general rules. Henry Miller of the Food and Drug Administration says, "Case-by-case analysis is a totem receiving much reverence but little reflection. It should be possible to devise guidelines to identify low-risk or trivial-risk situations."

The participants also discussed a Catch-22 of environmental release. Many people argue that field tests should be prohibited until solid predictions can be made. Yet a variety of biologists presented evidence from introductions of foreign and traditionally altered species that laboratory and greenhouse experiments simply don't predict well the behavior of an organism in the field.

"There is a way out. The multistage test approach can be used, beginning with small-scale, isolated test plots with means to monitor [the surroundings]," Edward A. Adelberg of Yale University says. "We must get permission to move to well-contained but outdoor field plots."

While the meeting certainly produced no consensus on how to prepare for and perform environmental release experiments, Harlyn O. Halvorson of Brandeis University in Waltham, Mass., says, "People who have been talking past one another have now started talking to each other." —*J. A. Miller*

A parallel path for speedy solutions

Meteorologists sometimes joke that it takes three days of computer time to figure out tomorrow's weather. The equations are so complicated that a long sequence of computations is needed to come up with an accurate forecast. But the time required to solve such equations may be shortened with the recent invention of a simple method that, with the right kind of computer, substantially speeds up the process.

The new algorithm, developed by mathematicians Victor Pan of the State University of New York at Albany and John Reif of Harvard University, involves solving systems of linear equations. The simplest such system consists of two equations, each expressed in terms of two variables, x and y. Solving this system requires finding values for x and y that satisfy both equations at the same time. Linear systems that arise in weather forecasting, aerodynamic design or economic modeling often involve thousands of equations and thousands of variables.

Efficient computer methods already exist for finding solutions to these equations, but the size of many linear systems overwhelms computers that must perform each step in order, one at a time. The answer is to divide and conquer — by using a multiprocessor computer that simultaneously performs many computations in parallel. Pan and Reif found a method that, by taking advantage of parallel processing, reaches the answer in less time.

Their method involves systems of linear equations expressed as blocks of numbers called matrices. Each matrix has as many rows as there are equations and an equal number of columns. Solving the equations is equivalent practically to finding the inverse of the original matrix.

But finding a matrix inverse is a thorny problem. The key discovery was an efficient way of computing an "approximate matrix inverse," which is used as a starting point for an iterative method that, step by step, brings the approximate matrix closer to the "true" answer.

What surprises Pan and Reif is how simple the scheme turns out to be. The basic method had been discovered about 50 years earlier, but until they came along, no one knew of a simple way to find an approximate matrix inverse.

"It was the missing step that we didn't know how to do before," says computer scientist Ronald L. Rivest of the Massachusetts Institute of Technology. "It was an exciting, nice result."

With only one computer processor, the method the mathematicians developed is about as speedy as any algorithm now available. But as the number of processors used increases, their method proves to be significantly faster. For a system of n linear equations, the algorithm is at its best when n^3 processors are used. Although very few computers now available have a sufficiently large number of parallel processors, within the next few years several companies are planning to introduce machines with as many as 64,000 processors.

In addition, Pan and Reif developed a faster way of handling "sparse" matrices, in which most of the numbers are zeros. Almost all systems of linear equations encountered in fluid dynamics or other physical situations generate matrices of this type. Their new algorithm helps because several steps involve computing matrix inversions.

Recently, Pan and Reif also found that their algorithm for matrix inversion may be useful in speeding up some of the steps in a new linear programming method developed by Narendra Karmarkar of AT&T Bell Labs in Murray Hill, N.J. (SN: 12/22 & 29/84, p. 408). This improvement could give Karmarkar's algorithm a decided edge among the competing methods used to solve these problems.

With the theoretical work done, it's now up to computer programmers to implement and test the Pan-Reif algorithm. "I don't see any practical problems for implementation because the code is very simple," says Pan. "Most of the complications in the work were to find it and to justify it, to prove things." —*I. Peterson*

Fungus degrades toxic chemicals

A fungus that rots fallen trees will reduce to carbon dioxide such persistent environmental poisons as DDT, lindane, PCBs, benzo[a]pyrene and dioxins, say biochemists at Michigan State University (MSU) in East Lansing.

Their report, published in the June 21 SCIENCE, describes the experimental growth of a white rot fungus in glucose solutions containing different organohalides — carbon-containing compounds with attached chlorine or bromine atoms. These chemicals, which include many environmental pollutants, resist degradation by most organisms. Some, like DDT, tend to accumulate in the bodies of animals high on the food chain.

The Environmental Protection Agency (EPA), which funded the study, says it is "guardedly optimistic" about the results. The MSU researchers and the EPA hope the fungus can one day be used to help clean up soils contaminated with toxic chemicals.

The fungus, *Phanerochaete chrysosporium,* normally lives off the cellulose in wood. The cell walls of wood are protected by lignin, a highly complex ring polysaccharide. Most organisms are incapable of breaking down the lignin to get through to the more digestible cell wall and cell contents, but the white rot fungus possesses an enzyme system that can.

The fungus is thought to break down the lignin by a free-radical mechanism, says John A. Bumpus, one of the paper's authors and a visiting assistant professor at MSU. Free radicals are atoms each with an unpaired electron. They are typically very reactive and nonspecific, attacking a variety of structures. It was the enzyme system's lack of specificity that suggested to Steven D. Aust, professor of biochemistry at MSU, that the fungus might well degrade organohalides as well as lignin.

Aust, Bumpus and two students, Ming Tien and David Wright, labeled the carbon rings of the organohalides with carbon-14, which is mildly radioactive. They then estimated these compounds' rates of degradation in fungus-infected glucose solutions by measuring the rate of carbon-14-labeled carbon dioxide produced. After 30 days, 1 to 15 percent of the organohalides had degraded to carbon dioxide. Greater amounts were partially degraded. In the case of DDT, after 18 more days and the addition of more glucose, only 10 percent of the original amount remained, although not all of the other 90 percent had yet been reduced to carbon dioxide.

The fungus's actual usefulness remains to be determined. "It's a long jump from the laboratory to applications in the field," Bumpus says. "We're optimistic, but we recognize that there may be a lot of roadblocks." —*J. Dusheck*