cessor does this in at least two ways.

One of these is the incorporation of a high-level language. The instructions executed by the CPU of a computer are in the form of a sequence of binary digits, so-called machine language. Almost all microcomputers (and many larger machines) are programmed in a slightly more comprehensible (to humans) set of symbols known as assembly language. A special program (the assembler) translates the assembly language program into one the machine can understand. The programming cost comparisons made by Grove for small and large microcomputers assumed working in assembly language. A high-level language is one like Fortran or Cobol, in which instructions bear some resemblance to ordinary English. A compiler (another program) translates the high-level language program into one executable by the machine. In his talk to the security analysts, Grove foresaw a factor of 5 decrease in programming costs to the user if a microcomputer could be programmed in a high-level language.

Large computers that run programs of many different types have their own assembler and compiler software. Microcomputers not only run the same program over and over, but hundreds, thousands, or more chips executing the identical program may be fabricated. In this case, the assembler program is run once on a separate larger computer, and the microcomputers store the translated program in a type of memory having fixed contents called a read-only memory.

Intel's micromainframe skips the assembly language stage altogether; all programming is done in a high-level language called Ada (*Science*, 2 January, p. 31). As with assemblers, the compiler to translate Ada still runs on a separate, larger computer. This language, which originated in Europe and has become famous because the Department of Defense is adopting it as its standard working computer tongue, has several features that are reflected in the design of the microcomputer itself and that make programming the machine easier.

Among other things, Ada was designed to facilitate writing lengthy, complex computer software by means of an approach called structured programming. Stripped to its essentials, structured programming means two things. First, the program is divided into more or less independent modules that can be written by teams of programmers with relatively little communication between them. Second, the modules are constructed in such a way that only certain,

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Magma Chambers in the Laboratory

Much of the earth's crust, especially the 70 percent that underlies the ocean, probably passed through magma chambers on its way up from the mantle. Petrologists have given much thought to a few processes, such as crystallization, that affect magma while it is held up in a chamber. But at a recent conference* on the generation of new ocean crust, specialists from a variety of fields reminded petrologists that a number of other physical processes may play important roles in determining the chemical composition of rocks.

One such physical process is convection. In an unusual collaborative effort, Stephen Sparks, a volcanologist at Cambridge University, teamed up with fluid dynamicists Herbert Huppert of Cambridge and Stewart Turner of the Australian National University in Canberra. Together, they created a magma chamber in the laboratory—sort of. To study what happens when a fresh batch of molten rock is injected into an aging chamber, they used concentrated solutions of potassium nitrate and sodium nitrate to represent the two magmas. They simulated convective mixing of the two batches of "magma" by adjusting the densities of the solutions to produce the density difference that they expect in chambers beneath a midocean ridge. In the past, petrologists had not taken much account of density differences and had assumed that new batches of magma mixed immediately.

At the start of their first experiment, the fresh hot "magma" injected at the bottom of their fish-tank–like "chamber" staunchly resisted mixing with the cooler fluid above it. It ponded at the bottom because its salt concentration had been adjusted to give the higher density expected of a magma frosh from the mantle. Because heat can diffuse faster than salts, both layers began to convect vigorously as heat crossed the interface between the layers, but the salts (the chemical components of magma) remained essentially unmixed. Instead, the diffusive cooling of the lower layer precipitated potassium nitrate crystals (the mineral olivine in a real magma chamber). Once the crystallization had decreased the density of the fresh "magma" sufficiently, the lower layer overturned and the entire "chamber" mixed. The significant aspect of that kind of mixing, the experimenters say, is that it did not happen until the composition of the magma had been changed by the precipitation of the crystals, which stayed behind on the bottom.

Some conference participants see these laboratory results as a possible way out of a quandary they are in. Experimental petrologists have been melting mantle-type rocks in the laboratory to determine where in the mantle the magma is formed that supplies the midocean ridges. One school holds that those magmas originate from 60 kilometers down or deeper. The quandary is that practically no rocks with the expected high magnesium contents are found in the ocean crust. The sort of fluid dynamics described above could act as a barrier to the ascent of dense, high magnesium magmas until they lose some of that magnesium as olivine and approach the composition of known crustal rocks.

Whether this or other laboratory simulations accurately represent physical processes in real magma chambers remains to be seen, but petrologists have been put on notice. Magma chambers will probably never be simple again.

*The Generation of the Oceanic Lithosphere, held at Airlie, Virginia, 6 to 10 April 1981, by the American Geophysical Union

More Deep-Sea Hot Springs in the Pacific

A French oceanographic expedition to the tropical section of the East Pacific Rise has confirmed that the bizarre "black smokers" on the northern Rise are not the only vents spewing hot, mineral-laden water from that midocean ridge. The presence of hydrothermal activity was about the only development that turned out as expected during this first exploration of a ridge that produces new ocean crust at a "superfast" rate.

Jean Francheteau of the Centre Océanologique de Bretagne in Brest reported that the cruise of the French research vessel *Jean Charcot* in the spring and summer of 1980 was exciting, but a bit frustrating. The researchers aboard examined two areas on the Rise—one near 13°N, where volcanic activity at the ridge crest produces new ocean crust at a rate of 10 centimeters per year (fast), and another area between 20° and 21°S, where the rate is 16 centimeters per year (superfast). The rate at 21°N, where American researchers first discovered hot springs on the Rise, is only 6 centimeters per year.

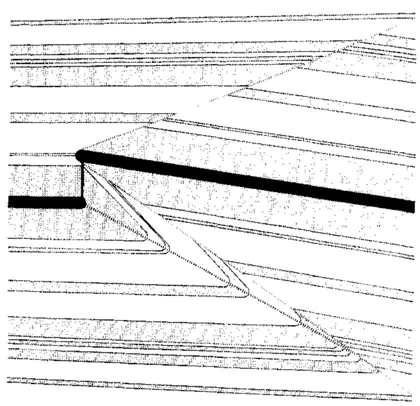
Both areas studied had unmistakable signs of vigorous hydrothermal activity. Seawater at the ridge crest was anomalously warm and contained some of the largest amounts ever reported of manganese and helium, two elements leached by hot seawater from crustal rocks. Limited photographic surveys failed to locate the springs themselves, but they did reveal deposits of metal sulfides, which precipitate from discharging hot spring waters, and numerous bottom animals, which could be a sign of nearby hot spring colonies.

To their surprise, the French found that the trends in ridge structure and behavior observed between the slow-spreading Mid-Atlantic Ridge (2 centimeters per year) and the moderately fast section of the East Pacific Rise at 21°N did not extend to the fast and superfast spreading centers. Large, rapid outpourings of fluid lavas do not dominate these ridge crests. There is no continuous pavement of sulfides along the ridge. Instead, sediments have nearly smothered the ridge crest. These, Francheteau believes, are probably rich in manganese like those of the Atlantic. The zone of volcanism and hot springs seems to remain narrow—0.5 to 1 kilometer—in spite of the high spreading rates.

These observations of the sea floor may have implications for what is happening beneath the ridge, Francheteau says. The heavy metalliferous sediments may mean that the same amount of rock is leached by each liter of seawater percolating through the crust on both slow and superfast ridges. The water-to-rock ratio, and its effects on seawater chemistry, at moderately fast ridges may be a special case. The narrow active zone may mean, he says, that high spreading rates do not broaden the magma chambers supplying lava to the sea floor. The reason, Michael Mottl of Woods Hole Oceanographic Institution points out, may be the highly efficient removal of heat from magma chambers by the circulating water of the springs, which could cool a chamber to extinction in only a few hundred years.

Rifts Propagating in the Pacific

Researchers did not solve all the problems of plate tectonics before they embraced the theory a dozen years ago. They are still working out some of the details, as exemplified by the development of the hypothesis of propagating rifts. It holds, and most researchers now believe, that oceanic spreading centers, or rifts, not only form new crust to either side, but can also extend themselves, slicing off crust from one plate and adding it to another.



Propagating rift

Heavy black lines are rifts (one on right is propagating to left), narrow black line is a transform fault, and gray and white banding is pattern of magnetic anomalies. [Source: Richard Hey, Frederick Duennebier, and Jason Morgan, in Journal of Geophysical Research*]*

Richard Hey of Scripps Institution of Oceanography described how propagating rifts seem to work in the eastern Pacific, adding a movie of a computer simulation of the process to an already cinematic conference. Hey had proposed several years ago that rifts are propagating there to explain some of their unruly behavior. Some rifts and the midocean ridges on which they are perched appeared to have "jumped" laterally from one location to another, leaving an inactive, failed rift behind. Rifts have also generated some exceptionally strong but distorted magnetic anomaly stripes, the same sort of stripes imprinted in the ocean crust that provided some of the strongest early evidence supporting plate tectonics.

Normal rifts are bounded at either end by faults running perpendicular to the rift and linking it to the rifts above and below it on the same ridge. The faults are like the steps in a staircase. Pieces of new crust formed at two adjacent rift tips slide past each other along the fault before passing the opposite rift tip and entering the interior of its own plate. Normal rifts cannot break through a step formed by a transform fault—they run up against but not through the faults.

Hey has shown that some rifts do break through their bounding transform faults and, like cracks, propagate at 5 to 10 centimeters per year into the crust formed by the next rift down the ridge. The propagating rift progressively shortens the adjacent rift. A V-shaped wedge of new crust forms behind the propagating top, carrying off the crust between the rifts and the failed rift itself. Instead of an easily recognized transform fault between the tips, a transitory transform fault or zone of adjustment connects the two.

The imprint of propagating rifts on the seafloor is now fairly clear. Jumps occurred gradually as a rift propagated at an angle of a few degrees away from the failing rift. The V-shaped pattern of strong magnetic anomalies fits that of computer simulations of the propagating process. John Sinton and his colleagues at the University of Hawaii reported that the wakes of propagating rifts are also marked by unusual iron-rich rocks, exactly the sort expected from a newly propagated section of rift that has not yet developed sufficient magma supply to form normal crustal rocks.

No one is sure why rifts begin to propagate or why they stop, but hot spots, those long-lived, stationary centers of volcanic activity, seem to be involved. All the known propagating rifts are moving away from either the Juan de Fuca hot spot, the source of a string of seamounts off the Washington coast, or the Galápagos hot spot, the source of the Galápagos Islands. Possibly, rift propagation is an adjustment allowing the rigid plates to accommodate changes in the forces that drive them.

—Richard A. Kerr