grown HIV. "It's a completely meaningless antibody response," says Moore. "It just gives them a security blanket. They might as well not use [the gp120 boost] at all."

McMichael, with support from the privately funded International AIDS Vaccine Initiative (IAVI), plans next spring to start trials of a different prime-boost approach that he hopes will produce much higher levels of CTLs. He believes that priming with the poxvirus presents the immune system with too many proteins from poxvirus as well as HIV, so he intends to use a prime vaccine that contains HIV genes stitched into a stretch of DNA called a plasmid. He theorizes that this so-called DNA vaccine, which can infect cells and produce viral proteins, will focus the immune system's attention; he then hopes to boost these primed CTL responses with a modified vaccinia virus that holds HIV genes.

Although Merck is sketchy about its vaccine plans, it, too, is focusing on triggering strong CTL responses. Emilio Emini, a virologist who heads the company's vaccine program, says that, like McMichael, the company is working on a DNA vaccine. It also is developing a live, but defective, viral vector that Emini declines to discuss publicly. "One of the reasons we've kept a low profile is we don't want to raise expectations," he says. "The likelihood for failure is pretty high." Then again, he says, Merck is putting a lot of resources into the project. "It's a big program for us."

Wayne Koff, who formerly headed the AIDS vaccine program at NIAID and now is scientific director at IAVI, hopes Merck is more committed to its vaccine program than in the past. More support from the pharmaceutical industry is sorely needed, says Koff, who notes that NIH has fewer trials under way now than he has seen in 10 years. "Right now we're at a nadir. But it's clear there will be a lot more vaccines in trials in a few years."

–JON COHEN

MARINE CHEMISTRY

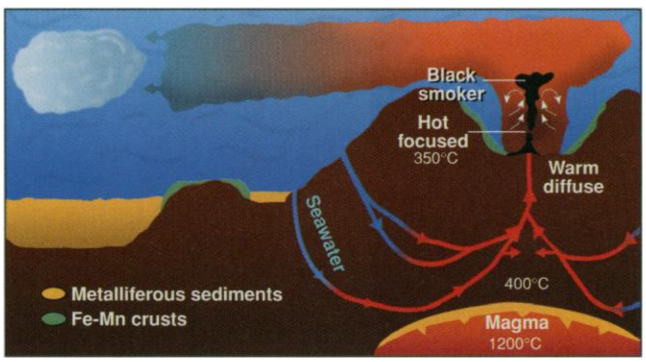
A Cooler Way to Balance The Sea's Salt Budget

Mineral-laden volcanic springs in the deep sea had seemed to explain the ocean's chemistry, but cooler springs away from the volcanoes may play a bigger role

The hot springs and billowing black smokers of the deep sea looked like a spectacular answer to a long-standing mystery when they were discovered in the late 1970s. Perched along the crest of the volcanic mid-ocean ridges, these spouts of mineral-laden, often blistering-hot water not only hosted a menagerie of bizarre animals but promised to be the missing factor that balances the ocean's chemical books. Seawater isn't simply river water concentrated by eons of evaporation; it contains too much of some minerals and too little of others. Ridge-crest hydrothermal activity—where seawater sinks into the crust, is heated and chemically transformed by hot rock, and then gushes back into the sea—looked like it might explain these disparities. But it now appears that a cooler, gentler interplay of water and rock may play a far bigger role in setting seawater's composition.

On page 721 of this issue of *Science*, oceanographers Stephanie de Villiers of the University of Cape Town in South Africa and Bruce Nelson of the University of Washington, Seattle, present high-precision measurements tracing a plume of chemically altered seawater that includes water from warm springs kilometers away from the seething black smokers of the ridge crest. "This is a very exciting discovery," says oceanographer Michael Mottl of the University of Hawaii, Manoa. "If proved to be correct, it will solve a lot of problems. The data point to the importance of hydrothermal activity other than the spectacular black smokers that have gotten so much attention."

Until the discovery of deep-sea hot springs, oceanographers had hardly a clue about how or where seawater took on its distinctive composition. Rivers carry in so much sodium, magnesium, and potassium that the ocean should be far richer in these elements than it is. Calcium presented the opposite problem. Shell-forming plankton appeared to be taking calcium and carbonate out of seawater and incorporating it into sediments twice as fast as rivers carry the



Sea-floor chemical factory. Searing hot seawater reacts with crustal rock to produce dramatic black smokers at the ridge axis, but cooler waters far from the smokers may have a greater effect on seawater chemistry.

CREDIT: PACIFIC MARINE ENVIRONMENTAL LABORATORY/NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

metal into the sea. But black smokers seemed to be balancing the books. Seawater was sinking into the fractured ridge crest, picking up heat, calcium, and other elements from the rock, leaving behind its own magnesium, and rising back into the sea.

But then surveys began suggesting that superhot water might not be the only factor controlling seawater chemistry. As Keir Becker of the University of Miami in Florida and Andrew Fisher of the University of California, Santa Cruz, will soon report, something like 10 times more fluid seeps from the flanks of the ridge than from the crest. Although this water interacts with the crust at lower temperatures—20° to 200°C, compared with 350°C degrees for a black smoker—it too might deposit some minerals and pick up others, transforming the ocean's chemical composition.

Compared to black smokers, with their heat and dramatic mineral formations, these warm springs are hard to find. So de Villiers and Nelson developed a procedure for analyzing seawater using mass spectrometry that was precise enough to pick up telltale variations in the chemistry of deep waters that have flowed across a ridge. Catching a ride on a research ship that happened to be crossing the East Pacific Rise at 17.5°S, de Villiers collected seawater from the surface to near the bottom above and to the west of one of the most active midocean ridges in the world.

Armed with the high-precision technique, de Villiers and Nelson found a plume of water trailing off to the west of the ridge in which magnesium was depleted by as much as 1% and calcium was enriched, just as expected from hydrothermal alteration. To work out the proportions of plume water from black smokers and tamer warm springs, they checked helium isotope measurements made near their sites by other researchers. The lighter isotope of helium, helium-3, is a signature of black smokers, because only the hottest water manages to extract helium-3 from the newly formed rock of the ridge crest.

Helium-3 was scarce in the plume given the amount of missing magnesium, leading the researchers to estimate that "the lowtemperature flux of magnesium is three to 10 times greater than the high-temperature flux," de Villiers says. She concludes that far more chemical processing takes place in the warm rock within 2 to 10 kilometers of the central ridge axis than at the ridge axis itself.

The report has elicited a mix of caution and guarded enthusiasm. "That's a very high precision she's claiming for an element [magnesium] that is very hard to measure with a mass spectrometer," says chemical oceanographer John Edmond of the Massachusetts Institute of Technology. "I would be cautious." Mottl agrees that more profiles need to be analyzed by a number of groups, but he feels de Villiers and Nelson "have found something very important." He adds that much of the water in their plume could be coming from even cooler springs, farther from the ridge axis, than de Villiers thinks. "I certainly wouldn't rule out that she's got a substantial input from the [ridge] flank," he says.

If de Villiers and Nelson's technique for tracing plumes of chemically altered seawater to their source pans out, he says, "it will probably be the best way to get the hydrothermal flux" of salts coming off the midocean ridges. The final answer about how the sea gets its salt should be satisfying, if not as spectacular as it once seemed.

–RICHARD A. KERR

DISPLAYS

Switchable Reflections Make Electronic Ink

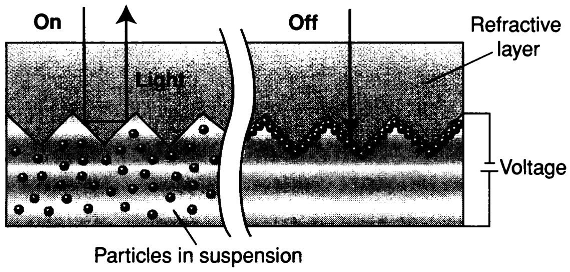
An electronic version of paper and print would combine the optical principle used in reflective signs with a scheme for squelching the reflections at will

Despite the fantastic array of technologies now put to use to display information, the old-fashioned printed word shows little sign of fading away—people just love the comforting look of black ink on white paper. Display researchers have come up with a host of schemes to mimic that partnership in a rewritable medium, many relying on small particles of dark pigment moved around in a liquid suspension by electric fields. So far, most of these electronic ink technologies lack the right mixture of properties, such as low cost, high contrast, and fast rewrite speed. But Lorne Whitehead, a physicist at the University of British Columbia (UBC) in Vancouver, and his colleagues have devised a new electronic display principle that they believe may have the speed and contrast to take some of the shine off ink and paper.

Their technique forms black characters on a white background by switching on and off the reflection of light from a screen. It combines a century-old optical principle called total internal reflection (TIR)—the same principle that makes stop signs bright—and a technique for turning off TIR at will. "The science involved is delightfully simple," says physicist George Beer of the University of Victoria in British Columbia. "The principle has been shown to work." He cautions, however, that the team has not yet shown how to build a working display screen. "The missing ingredient is the technological details."

TIR takes place when light that has penetrated glass—or some other material that bends light sharply—reaches a boundary with a less refractive material, such as air. If the light strikes the interface at a shallow angle, none of it escapes, and it is all reflected back into the glass. TIR is the principle that keeps beams of light careering down fiber optic cables. Whitehead had been trying to improve light guides, but about 2 years ago he wondered if the same phenomenon could be harnessed in a display. "If you can make a surface look white because of TIR and then stop [the TIR] where you want words to form," he says, "it will look like a black-on-white display."

At a meeting of the Canadian Association of Physicists in New Brunswick last month, Whitehead's colleague Andrzej Kotlicki and his student Michele Mossman showed how they would turn that idea into a display screen. They demonstrated a white, flexible sheet made of minute interconnected polycarbonate prisms. The sheet looks bright because, like the reflective coating on a stop sign, it bounces light off the internal interfaces at the correct angle for TIR, eventually directing the light back out toward a viewer.



Blackout. Reflection from the back of a transparent layer is switched off when a voltage coats it with absorbing particles.

SOURCE: WHITEHEAD ET AL.

To achieve an "ink" effect, the researchers exploited the fact that, because of light's fuzzy wavelike nature, some of the waveform extends about 1 micrometer beyond the surface where the light is being internally reflected. This leaked light is known as an evanescent wave. "To stop TIR, all you have to do is stick an absorbing material into the evanescent wave," says Whitehead. The researchers provided the absorbing material by backing the reflective sheet with a thin layer of fluorinated hydrocarbon liquid in which charged particles were suspended. Using electric fields, they could maneuver the charged particles into the evanescent wave region behind the reflecting sheet to switch off the TIR.

Other schemes for producing electronic ink also use electric fields to move charged particles in a fluid, but those particles must move laterally by about 10 or 20 micrometers to achieve a good contrast between black and white. In the UBC scheme, the particles have to move only about a micrometer toward the screen to switch off TIR. "It is a very sensitive way to switch light," says Whitehead. "You can move an absorbing material a very short distance and get a dramatic change in absorption."

That could mean a faster response and lower power needs than other electronic ink schemes, Mossman says. So far, the group has switched TIR on and off in just a single patch of screen. But they are now planning a prototype display consisting of many pixels, controlled with circuitry like that of the liquid crystal displays in palm-top computers.

The challenge is easier for larger scale displays that need not change as quickly, such as highway signs, and the group is working on several ways to move an absorbing material in and out of the evanescent wave for efficient, low-power displays. One uses air pressure to push an absorbing silicone gel against the walls of the miniature zinc sulfide prisms. Group member Robin Coope is working with the company 3M to commercialize this technology, and the researchers have already shipped a prototype sign for testing.

Physicist Edward Sternin of Brock University in Ontario says that he is eager to watch the group's progress: "It is always exciting to see the application of an old physics principle that has immediate and direct applications to technology."

–MEHER ANTIA

Meher Antia is a writer in Vancouver, Canada.