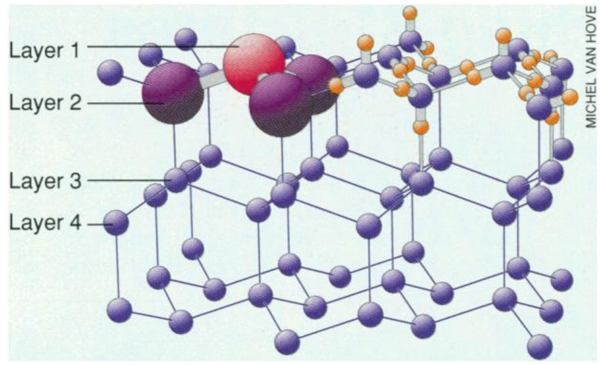
MATERIALS SCIENCE

On Ice's Surface, a Dance of Molecules



Thin ice. A dynamic outermost layer of water molecules gives way to deeper rigid layers.

Ice has always been a slippery subject. As simple as an ice cube may seem, scientists have long been baffled about why its surface is so slick. But an upcoming paper in *Surface Science* may give researchers a firmer grasp of ice's surface subtleties by hinting that its outermost molecules behave like a liquid. This mobile layer could help explain mysteries from atmospheric chemistry to why it is more fun to skate on ice than on concrete.

Many people believe that ice's slipperiness comes from pressure-induced melting. Wrong, says Michel van Hove, a surface chemist at the Lawrence Berkeley National Laboratory. "It doesn't work out," says van Hove. "You put the data into the formula, and there's not enough pressure." The answer must lie elsewhere, he says.

Van Hove and a colleague, Gabor Somorjai, suspected that the properties of ice's surface might differ from those deeper inside the crystal. There was "very good circumstantial evidence that the surface of ice is molten," such as polarization measurements suggesting a thin surface film, says Somorjai, but "no real scientific evidence." To gather some, the two researchers probed the surface of thin layers of ice at –180°C with low-energy electron diffraction. This technique bounces electrons off the electron clouds of surface atoms and collects a diffraction pattern that holds clues to the surface structure. The results were a surprise.

The researchers expected to see the scattering signature of the first three layers of ice molecules, but they saw only two. Models of the two detected layers implied that an invisible top layer had to exist, so the researchers hypothesized that water molecules in the top layer were vibrating three or four times faster than those in the lower layers—blurring their diffraction pattern to the point of invisibility.

Although the water molecules in this outermost layer are bound in the lattice like a solid, "the vibrational amplitude is like a liquid," says Somorjai. "I believe this is the reason why we can ski and skate." Steve George, a chemist at the University of Colorado, agrees that "the surface of ice is extremely dynamic," although he's not convinced that vibrations of individual molecules are responsible. George speculates instead that the ice's surface is constantly being eroded and redeposited, like topsoil.

Either way, he and Somorjai note that a dynamic surface could help explain the rates of chemical reactions believed to take place on the surface of ice crystals in the upper atmosphere—including the chain of reactions that results in the destruction of ozone. These reactions should be extremely slow in the cold stratosphere, but the ice's changeable surface might accelerate them. It might also draw foreign molecules into the ice itself, affecting their chemical behavior, says Jeff Roberts, a chemist at the University of Minnesota. But most of all, says George, the finding "illustrates how we don't understand the simplest things we know about."

–Charles Seife

Charles Seife is a science writer in Scarsdale, New York.

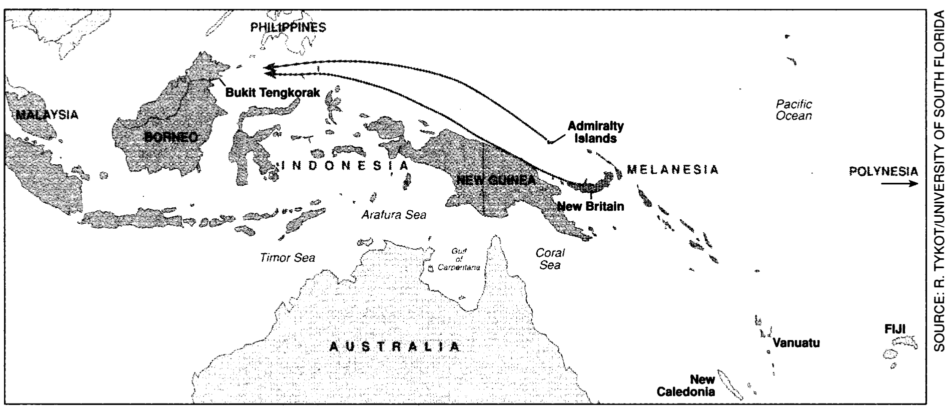
PACIFIC ARCHAEOLOGY

Rock Chemistry Traces Ancient Traders

BOSTON—Archaeologists have long known that Captain James Cook was a Johnny-come-lately. By the time he ventured to the South Pacific in 1769, people of the region had been navigating—and trading—on the high seas for at least 3300 years. But now, Captain Cook may have fallen even farther behind. At a meeting of the Materials Research Society here earlier this month, a Malaysian and an American researcher presented a chemical analysis of flecks of volcanic glass that may push back the earliest dates for long-distance sea trading on the Pacific by another 2500 years, to 4000 B.C.

The analysis, by archaeologist Stephen Chia of the Universiti Sains Malaysia and chemist and archaeologist Robert Tykot of the University of South Florida, links volcanic glass found at a 6000-year-old archaeological site on Borneo to sources on islands 3500 kilometers to the east. It points to the longest sea trading network yet traced in the Stone Age. Other researchers are intrigued, although "there will be some skeptics about the dating," says Bennet Bronson, curator of Asian ethnology and archaeology at the Field Museum in Chicago. But if the claim holds up, Bronson says, it "is going to affect our whole understanding" of the migrations that peopled the islands of the western and central Pacific.

At the heart of the new findings are some 200 obsidian flecks, which Chia unearthed beginning in 1994 at the Borneo site, called Bukit Tengkorak. Because there are no obsidian sources nearby, Chia teamed up with Tykot to analyze the flecks and pinpoint their origin. At the meeting, Tykot reported that an analysis of the relative abundance of 11 different compounds, such as silicon dioxide and titanium oxide, in 30 of the flecks yielded several distinctive chemical fingerprints. For the majority of the flecks, these fingerprints matched well-known sources some 3500 kilometers away near New Guinea—on the island of New Britain and on one of the Admiralty Islands. A smaller percentage seemed to come from a source



Ancient mariners. Volcanic glass found at Bukit Tengkorak comes from sources on the Admiralty Islands and New Britain. It testifies to 3500-kilometer trade routes in 4000 B.C.