sequences for many ecological synergies in tropical forests (*12*). The maintenance and protection of functional ecosystems involving species-rich tropical forests will surely be one of the most challenging tasks of the first decades of the 21st century.

Curran *et al.* have convincingly demonstrated the negative synergy of ENSO events and logging in Borneo's West Kalimantan. Their work also illustrates the positive synergy that can result from the collaboration of a diverse set of partners, including several teams of international and Indonesian researchers, an international aid agency, nongovernmental organizations, and government officials, to produce and synthesize the diverse information presented here. Such long-term, interdisciplinary, and collaborative work represents a standard toward which scientists working on international environmental issues should aspire. How unfortunate, then, that this collaboration has produced a picture of a magnificent ecological phenomenon that appears to be in danger of collapsing.

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PERSPECTIVES: ANTARCTIC BIOGEOCHEMISTRY

Icy Life on a Hidden Lake

Warwick F. Vincent

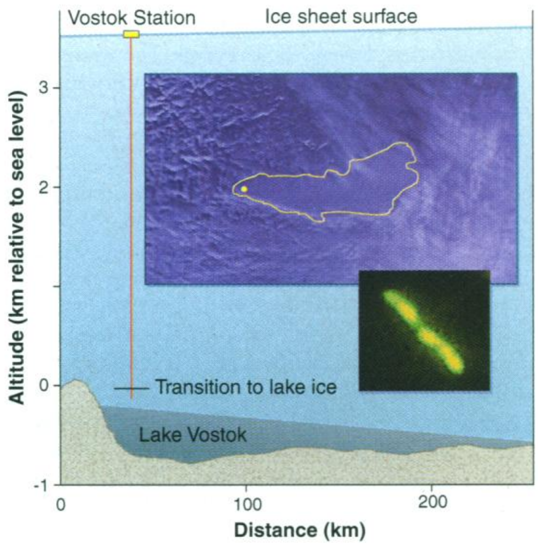
The discovery of life in a deep rift-valley lake sounds like news from an earlier century, but not if the lake in question happens to be in one of Earth's least accessible places and represents a testing ground for exploration elsewhere in the solar system. Three reports in this issue provide new insights into the origins and biology of the deep ice overlying Lake Vostok and give an intriguing set of first indications of a microbial ecosystem in the waters beneath.

Enhanced online at www.sciencemag.org/cgi/content/full/286/5447/2094

Lake Vostok is a vast expanse of liquid fresh water (see the figure). With a maximum depth greater than 500 m, it is deeper than Lake Tahoe, and it has a surface area similar to that of Lake Ontario. But Lake Vostok lies far from these more familiar waters, in the coldest, most remote part of Antarctica. It is the largest of at least 68 lakes located 3 to 4 km beneath the East Antarctic Ice Sheet and maintained in a liquid state by geothermal heating, pressure, and insulation by the overlying ice (*1*). Microbial ecologists have long speculated on what kind of microscopic life-forms might exist in these cold, dark waters; microorganisms reign supreme in many parts of Antarctica and show a remarkable ability to survive and even thrive under extreme polar conditions (*2*), perhaps even in Lake Vostok.

The author is at Centre d'Études Nordiques, Laval University, Sainte-Foy, QC Canada, G1K 7P4. E-mail: warwick.vincent@bio.ulaval.ca

On page 2138, Jouzel *et al.* (*3*) present isotopic and other evidence that the lower part of the Vostok ice core is derived from underlying lake water. This layer of lake ice has a total estimated thickness of 210 m and a deuterium and oxygen-18 signature that differs substantially from the overlying glacier ice. The data suggest that Lake Vostok was formed under a climate warmer than the past 420,000 years and that its water has a mean age of 1 million years or older.



Life in Lake Vostok? The smooth plateau of snow and ice floating on the lake is distinguishable from the rough terrain of the surrounding ice sheet that buckles as it moves across the underlying bedrock (**top inset**). The Vostok drill site (•) is at the southern end of the lake where the overlying ice sheet is 0.5 km thinner and is underlain by slowly accreting lake ice. The deep drilling operation (red vertical line) recovered a section of the lake ice, providing samples of ancient Lake Vostok water containing bacteria [**bottom inset**, from (*5*)].

CREDIT: TOP INSET: RADARSAT-1 IMAGE/THE CANADIAN SPACE AGENCY; BOTTOM INSET: FROM (5)

Priscu *et al.* (*4*) show on page 2141 that samples of Lake Vostok ice contain bacteria in relatively high concentrations, many of them associated with particles. Using DNA fingerprinting techniques, they found that the microbial community has a low biodiversity and is composed of taxa that are closely related to modern-day Proteobacteria and Actinomycetes. By comparing their data with fractionation studies of liquid and frozen portions of lakes in the McMurdo Dry Valleys region of Antarctica, the authors were able to extrapolate from the Vostok ice to the underlying lake water. Their calculations indicate that Lake Vostok contains inorganic nutrients, dissolved organic carbon, and bacteria: all the ingredients for an active microbial ecosystem.

Karl *et al.* (*5*) provide important complementary information on the microbiology of the Lake Vostok ice on page 2144. Using a variety of staining and biochemical techniques, they confirm the presence of bacteria in the lake ice (see the figure), although at lower cell concentrations than in the ice examined by Priscu *et al.* Most importantly, their assays included measurements of respiratory activity. The results show that the melted core samples contain viable, actively respiring cells.

Three questions need to be addressed in interpreting these new data from the Vostok ice core. First, do the bacterial and geochemical analyses accurately reflect what is in the ice, or are they contaminants from the core retrieval process? Both microbiological studies took careful measures to avoid such contamination. Second, do the cells originate from the liquid water of Lake Vostok, or have they arrived in the ice by some alternative transport mechanism? A variety of microorganisms have been isolated from the overlying glacier ice at Vostok (*6*), and the DNA analysis by Priscu *et al.* shows that the microbiota in the deep ice are related to temperate latitude strains. These observations might suggest that the organisms originated in the glacier ice above. The work by Jouzel *et al.*, however, shows that the ice core sections analyzed by Priscu *et al.* and Karl *et al.* are derived from the lake and that their biological and chemical contents are likely to reflect those of the underlying water. Finally, given that the lake contains viable bacteria and organic carbon, are such cells active in the cold, hyperbaric, nutrient-poor, and possibly anoxic conditions that characterize this environment? Definitive answers to all of these questions will require direct sampling of the Lake Vostok water column, but therein lies a new set of problems.

At the 23rd consultative meeting of the Antarctic Treaty in May 1999, Russia tabled a comprehensive environmental statement on the Vostok operations and highlighted a number of reasons for concern (*7*). The drill hole—which does not yet reach the liquid water level of the lake—has been kept open by the addition of drilling fluid, a mixture of aviation fuel and freons. Some 60 tons of this fluid now resides in the hole, and about 1 ton is located in the drilled lake-ice section. The report notes that the quantity of drilling fluid is too large to be removed, recycled, stored above ground, or transported away from the site. It should not, however, be allowed to penetrate into Lake Vostok, where it would pollute one of the last remaining pristine bodies of water on this planet. Calculations show that materials released into the Lake Vostok water column could circulate to the bottom of the lake within days and throughout the entire lake basin within decades (*8*). Biological and chemical contamination are major issues of concern in penetrating the waters of Lake Vostok and are the focus of ongoing international debate and discussion. They are also an issue for sampling ice and water in places beyond Earth.

Interest in Lake Vostok has been especially intense within the astrobiology community. The discovery of ice-water environments on Jupiter's moons Europa and Callisto has raised many questions about their aqueous geochemistry and potential for life (*9*), and Lake Vostok has been seen as an attractive sampling analog for these more extreme environments (*10*). Despite some similarities, however, there are also radical differences in many properties, including chemical composition (*11*), and biological parallels are unlikely. Irrespective of these differences, future exploration will require special efforts to minimize the human footprint on the pristine ice and water environments of Antarctica and elsewhere throughout our solar system.

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PERSPECTIVES: NANOTECHNOLOGY

Tweezers for the Nanotool Kit

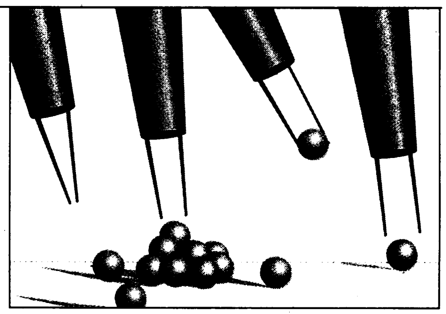
Chad A. Mirkin

Advances in scanning probe techniques have revolutionized the field of nanotechnology. But for the full potential of nanotechnology to be realized, these techniques must be complemented by analogs for macroscopic tools—such as tweezers, pipettes, and pens. On page 2148, Kim and Lieber (*1*) describe such a tool—"nanotube nanotweezers"—which could become an integral part of the nanotechnologist's tool kit for manipulating structures with nanoscopic dimensions.

Many advances—such as the invention of the electron microscope, the development of molecular recognition and self-assembly principles, and the prognostications of visionary scientists like Richard Feynman—contributed to the establishment of nanotechnology as a discipline. But it was undoubtedly the invention of the scanning tunneling microscope (STM) (*2*) and its variants, such as atomic force microscopy (AFM), that catalyzed the explosion of research interest in this field over the past decade. And all signs point to it as one of the biggest growth areas in science and engineering for the next quarter century.

One only has to consider the evolution of the microelectronics industry over the past few decades to understand the payoffs associated with miniaturization. But if we can learn how to routinely prepare and manipulate structures on the nanometer length scale, the resulting future technological advances could make the engineering accomplishments in the trillion dollar microelectronics industry appear trivial. Nanostructures can be exploited in medicine and biology [for example, in medical diagnostics (*3*), ultra-high-density gene chips, and the surface engineering of biocompatible materials], in the further miniaturization of electronic circuitry, in organic devices with molecular components, and in catalysts with highly tailored properties based on catalyst component placement on the nanoscopic scale.

All advances in this field will continue to rely on the development of new analytical tools for making, manipulating, and probing structures on the nanometer length scale. Commercial or custom-built scanning probe microscopes, now to be found in virtually every major research institution in the world, allow one to make electrical measurements across nanoscopic objects (*4*), measure the forces between molecules (*5*, *6*), and probe, push, and manipulate matter on the atomic length scale (*7*). Furthermore, in multiple probe-tip instruments, each tip can be run independently and in parallel fashion (*8*). These advances are paving the way to high-throughput AFM- and STM-based lithographic processing of solid-state materials and are beginning to overcome



How to grab nanoscale objects. This sketch shows how tweezers composed of carbon nanotubes can grab a particle only about 500 nm in diameter **(left)** and move it to a desired location **(right)**.

The author is in the Northwestern Chemistry Department and Center for Nanofabrication and Molecular Self-Assembly, 2145 Sheridan Road Evanston, IL 60208, USA. E-mail: camirkin@chem.nwu.edu

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