Earth Sciences

Seals' story written in their own hand

In the company of mammalian paleontologists, a mention of the word "pinniped" can launch a debate that might gobble up an entire evening's conversation. Pinniped, or "fin-footed," refers to an informal group of mammals that includes only three surviving forms: seals, sea lions and walruses. All pinnipeds have four flippers, whose shape reflects how these originally land-based animals invaded the sea millions of years ago and evolved bodies better suited to a mostly aquatic lifestyle. Although scientists agree on that much, a controversy is now developing concerning the finer details of pinniped evolution.

For decades, most experts have accepted the theory that "true" seals (the ones without ears) evolved from weasel- or otter-like forms, while sea lions and walruses developed from bear-like forms. Such dual development is called dyphyletic evolution. Proponents of this theory say the originally dissimilar pinnipeds now resemble each other because they have all adapted to life in a special environment, namely water.

André R. Wyss of the American Museum of Natural History in New York City and several other experts are advocating the flip side of the argument: that all pinnipeds evolved from one land-based mammal that entered the sea, a process known as monophyletic evolution. Wyss bases his conclusions on a close examination of the bone structure within pinniped flippers. In the Aug. 4 NATURE, he reports that all pinnipeds share quite similar hand and foot structures — ones that do not resemble those of other land or aquatic mammals. Such a similarity would be surprising if seals evolved from a separate line, because they have a unique swimming style, using their hind flippers for propulsion, while sea lions paddle with their front flippers, he says.

Will the monophyly theory draw converts? Lawrence G. Barnes, curator at the Natural History Museum of Los Angeles County, says there is a good deal of evidence in favor of diphyly that proponents of monophyly have yet to address.

Into the depths of a volcanic system

In an ambitious project requiring special high-temperature technology, geoscientists last month started drilling a 1.75-kilometer-deep hole into the Valles Caldera, a large volcanic crater in northern New Mexico. Through this conduit into the hot depths of the dormant volcanic system, researchers over the next four years will collect information that might ultimately help in harnessing geothermal energy and in discovering mineral deposits.

The Department of Energy's Office of Basic Energy Science, which is sponsoring a large part of the work, has already drilled two shallower holes in the caldera. As with the earlier two, investigators working on the new hole will focus attention on the rock cores pulled up during drilling and on the underground fluids collected from different depths in the drillhole. Circulating through pores and cracks in the rocks, these fluids, mostly water, carry heat away from a chamber of molten rock that lies about 5 kilometers below the surface.

At some geothermal systems resembling the Valles Caldera, power plants convert this heat energy into electricity. However, basic science is the thrust of the work at Valles, says project co-chief scientist Jamie N. Gardner of the Los Alamos (N.M.) National Laboratory. Through drillhole experiments, scientists hope to learn more about the flow of fluid and steam. Aside from heat, the fluids also transport dissolved minerals that precipitate out and form deposits, which can be mined in inactive or "fossil" geothermal systems. In the new hole, researchers want to catch the mineralization process in the act, possibly uncovering information that will help investigators find such fossil deposits at other locations.

Technology

Most sensitive photoelectric semiconductor

Scientists at the University of Southern California in Los Angeles report they have developed a new semiconductor that is 100 times more sensitive to light than any other. Called hetero NIPI, this crystalline superlattice of gallium arsenide and gallium-aluminum arsenide is named for its structure — an ordered sandwich of layers designated N, I, P and I. Between the N layer, containing negatively charged electrons, and the P layer of "holes" — to which electrons naturally gravitate — is an insulating I layer of uncharged material. Below the P layer is another I layer.

Normally, electrons move around freely inside a crystal in a continuum of energy states. But hetero NIPI's electrons are trapped within its I layers — in what are called quantum wells. Here they "can only move in two dimensions, instead of three," explains Elsa Garmire, a developer of the new material. That limits the energy states in which the electrons can reside, she says, and makes them more susceptible to interactions with light — in this case the near-infrared (830 nanometers) wavelength of a gallium-arsenide laser.

Hetero NIPI has been designed for use as a photosensitive switch — an on/off or circuit-shunting device — for the coming generation of optical computers. The circuits of these computers will be configured "in a fundamentally new way," Garmire says — "allowing for dramatically increased parallelism," or processing of massive amounts of data simultaneously. But in developing hetero NIPI, she notes, "we are trading off speed for parallelism": Though the material is 100 times more sensitive, "it's also 100 times slower." Garmire anticipates that energy-efficient optical switches, based on materials like hetero NIPI, will prove especially valuable in high-volume data processing, such as the analyzing or enhancing of satellite images.

Quantum wells as heat detectors

A quantum-well heat-detection device based on a simpler gallium-arsenide/gallium-aluminum arsenide structure is described in the July 25 APPLIED PHYSICS LETTERS by Barry Levine and colleagues from AT&T Bell Laboratories in Murray Hill, N.J. Today's best infrared (heat) detectors — largely used by the military (as night scopes to view troops and weapons) and on remote-sensing satellites — rely on mercury-cadmium-telluride semiconductors. While very sensitive, these are also difficult to make and reproduce, notes Federico Capasso, head of quantum phenomena and device research at Bell Labs and a manager of the quantum-well heat-detector project. In contrast, he says, the AT&T heat sensor is based on a common, easy-to-produce material.

The heart of the new photodetector is a crystalline superlattice containing 50 units — each a 40-angstrom-wide quantum well whose sides are 300-angstrom barriers of aluminum-gallium arsenide. At the bottom of each well are a multitude of electrons. As a 10-micron wavelength photon enters the well, it excites an electron — essentially kicking it up above the barrier and outside the well. At this higher energy level, the electron is unbound and free to "sail through the whole superlattice structure," Capasso explains. Wells are refilled from a "reservoir" of electrons slowly tunneling through the crystal. Varying the well's width and its barrier composition will allow detection of up to 5-micron photons.

Although Capasso's group has been working on the 10-micron heat detector for only about one year, he says it "already starts to match the performance of detectors that have been out there for 20 years." Moreover, because it is based on the well-established gallium-arsenide semiconductor technology, he says, it offers the promise of costing less and for the first time making a 10-micron detector and the electronics for analyzing that signal out of the same chip.