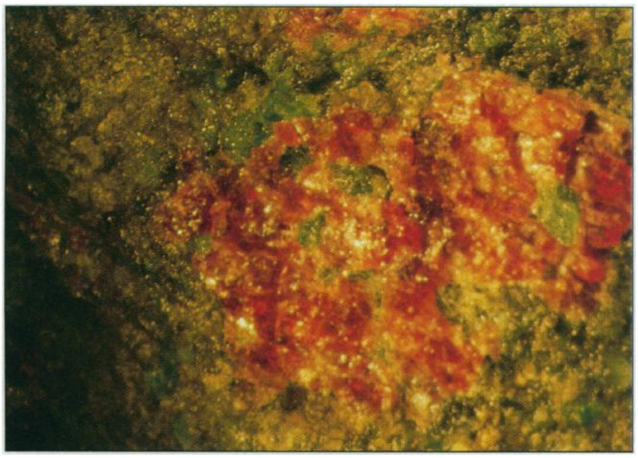
TECTONICS

A Deep Look Beneath Tall Mountains

Geologists are adept at scratching the surface, but they have trouble delving into deep mysteries. That's because they can only collect rocks from the topmost parts of the 40 kilometers of crust floating on the underlying mantle, and those surface rocks had seemed unlikely to reveal much about deep-seated geological processes. But now, mineralogists at the University of California, Riverside (UCR), have new evidence that a large chunk of rock high in the Alps may have originated hundreds of kilometers underground. If so, it may have brought some of those deep secrets to the surface.



Relic from below. Half-millimeter grains of diopside (green) contain signs of ascent from hundreds of kilometers down.

The UCR researchers, Krassimir Bozhilov, Harry Green II, and Larissa Dobrzhinetskaya, base their conclusion on an analysis of the rock's mineral composition. As they report on page 128, it suggests that the rock rode to its current position on a geologic elevator from at least 250 kilometers down. "It's a strong case that these things come from deep in the mantle," says mineralogist Thomas Sharp of Arizona State University in Tempe. Confirmation that such deep minerals can rise to the surface, presumably during the upheavals sparked by colliding tectonic plates, would open up a new window on the mantle and how it participates in surface geology.

In the current work, the UCR researchers were pursuing a trail that Green and Dobrzhinetskaya picked up 3 years ago (*Science*, 29 March 1996, pp. 1811, 1841). While examining rock from the Alpe Arami massif, an 800-by-500-meter mass embedded in the mountains of southern Switzerland, they had found that the rock's magnesium-rich olivine contained 20-micrometer rods of the iron–titanium oxide mineral called ilmenite. These crystals exhibited ordinary enough structures, but they were extremely rich in titanium and displayed an odd variety of low-pressure crystal structures. These strange features, the researchers realized, could be hallmarks of a rock that had risen from the depths: The ilmenite must have sweated out of the olivine and crystallized as the extreme pressures that had kept the iron and titanium dissolved in the olivine eased. Thus, the UCR group suggested that the Alpe Arami rock had once been 300 to 400 kilometers down.

That provocative conclusion has remained controversial, but Bozhilov and his UCR colleagues are now reporting the discovery of more persuasive relics of high pressures in Alpe Arami rock. When they took a look with a transmission electron microscope, they found thin plates of the mineral clinoenstatite that had been exuded by the surrounding mineral diopside. Within the clinoenstatite plates, which are some tens of nanometers wide, they could image what appear to be boundaries between crystal domains of subtly differing orientation. High-pressure lab studies have shown that such "antiphase boundaries" form when the high-pressure structure of a mineral relaxes to the low-pressure form. In the case of the Alpe Arami rock, that would have occurred at a depth of around 250 kilometers, the researchers concluded.

"I think the antiphase domains are reasonably good evidence" that high-pressure clinoenstatite gave rise to the present mineral, says mineralogist Charles Prewitt of the Geophysical Laboratory in Washington, D.C. However, to be certain that some fine-scale distortion seen in the clinoenstatite is not fooling them, both Prewitt and Sharp would like to see more study of antiphase boundaries created in clinoenstatite in the laboratory.

In the meantime, geophysicists are considering how a chunk of rock such as Alpe Arami could have risen from hundreds of kilometers down. Green invokes "the Ivory soap principle." It requires two colliding continents to drag buoyant continental crust to mantle depths, where it breaks free and bobs back to the surface, like a floating bar of soap, sometimes stealing a bit of the inherently dense mantle as it goes. If so, geologists could delve into very deep matters indeed.

–RICHARD A. KERR

PHYSICS

Laser Light From a Handful of Dust

Physicists have sparked laser action in a light-trapping powder, they reported last month in *Physical Review Letters*. They say the effect, which causes the powder to radiate intense light in all directions, might one day be used to brighten some kinds of flat-panel displays.

Conventional lasers use a pair of mirrors to bounce a light wave back and forth through a cavity containing a material or gas whose atoms are "pumped" into a higher energy state by an external light source. Each time a photon hits an excited atom, the atom falls back to a lower energy state while emitting a photon with the same wavelength and direction. When enough atoms in the laser cavity are excited, the process can sharply amplify a light beam.

A team led by Hui Cao from Northwestern University in Evanston, Illinois, has produced a similar effect in a finely ground semiconductor powder. In 1997, a team of Dutch and Italian scientists, including Ad Lagendijk of the University of Amsterdam and Roberto Righini of the European Laboratory for Non-Linear Spectroscopy in Florence, Italy, demonstrated that such a powder can trap or "localize" light. Because of its high refractive index, the powder strongly scatters light waves, bouncing photons back and forth like balls in a pinball machine.

If the grains are close enough—less than the wavelength of the scattered light—the paths of the photons should form closed loops. "No matter which way [the waves] try to go, they will be scattered," explains Cao. "Depending on the local configuration of the scatterers, you have different probabilities for loops." As a result, the light passes many times through the same grains, just as an ordinary laser's light passes many times through the cavity between mirrors. "You can compare this with a cube made of six mirrors; a light wave will then run around continuously—just like in an optical cavity," says Lagendijk. If the atoms in the grains have been pumped to a higher energy state, the process could amplify light.

To test this idea, the team at Northwestern University prepared powder films of zinc oxide and gallium nitride, with particles of about 100 nanometers in diameter. They shined laser light onto the films to pump their atoms. Then they directed a probe beam at the sample and measured the total intensity of the scattered light. The team noticed that when the pump laser reached a certain power, the intensity of the light emitted by the sample increased sharply, by 10 to 100 times. They concluded that the light was

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