of the University of British Columbia, summarizing the consensus of last month's conference, "but there is quite a bit of uncertainty about the size and location of all the spots." Areas of greatest concern, most agree, are California and the upper Midwest. In Florida, scientists are warily eyeing the closely related shiny cowbird (*Molothrus bonariensis*), which is now invading from the Caribbean with as-yet-unknown consequences.

Given such uncertainties, it's not surprising that cowbird experts disagree over whether and how to control cowbird numbers. Biologists are already trapping and killing them in the breeding grounds of a few endangered songbird species, such as the Kirtland's warbler (*Dendroica kirtlandii*) in northern Michigan and the black-capped vireo (*Vireo atricapillus*) in central Texas, as well as the least Bell's vireo at Camp Pendleton. Everyone agrees that such programs can make a crucial difference for rare, geographically restricted species. Still, the fact that a little cowbird trapping is good doesn't mean a lot will be better.

A small minority of cowbird biologists does favor more extensive cowbird control. Griffith, for example, advocates an aggressive program to poison cowbirds at their winter roosts in the southern United States, where as many as 10 million birds gather at a single site. "There's nothing but benefit that could come from it," he says.

Yet most cowbird specialists don't think full-scale war is warranted. Studies tracing the movement of banded birds show that cowbirds at a single winter roost come from widely separate breeding areas, and birds that breed together often winter at different roosts. Thus, winter roost control might end up destroying cowbirds from areas where they aren't a problem while providing little relief for hard-hit areas, says Rothstein. Many worry, too, that such programs could do more harm than good by alienating animal-rights groups and prompting a backlash against the small-scale, local efforts that do work.

Whatever the right course is for dealing with cowbirds, the recent data suggest that conservationists will have to focus on a much tougher problem: forest restoration, which would provide new nesting habitat for songbirds and reduce their contact with predators that hunt along forest edges—and, incidentally, with cowbirds. "If preservation of [songbirds] was made a national policy with resources in line with those that currently go into duck and deer management, I think you could see a real difference," says Stephen Laymon of the privately funded Kern River Research Center in Weldon, California. "Short of that, I don't see [much] hope."

–Bob Holmes

Bob Holmes is a free-lance science writer in Santa Cruz, California.

NUCLEAR PHYSICS

Isotope Makers Grab Hold of the Rock

Ever since the discovery that nuclei could be transformed into heavier ones by bombarding them with other nuclei, physicists have been cooking up new "artificial" isotopes and elements larger than any found in nature. But after scores of successes, including the artificial elements from neptunium (atomic number 93) to meitnerium (109), the quest seemed to be getting more and more arduous. A combination of physical realities seemed to have the researchers in a pincers grip: Creating still heavier nuclei requires more and more intense beams from ion accelerators to increase the odds of rare fusions, yet the resulting nuclei are so unstable that detecting them requires ever more sensitive detectors.

Now, however, the search has been revitalized by hints that just up the scale of atomic weight from the heaviest nuclei yet created is a "rock of stability," populated by heavier isotopes that may survive for years. Last April, a joint Russian-American team of physicists caught a glimpse of this rock when they created a new neutron-rich isotope of element 106 that survived for tens of seconds, and at the end of January they will try to get closer still with an effort to create neutron-rich isotopes of element 108.

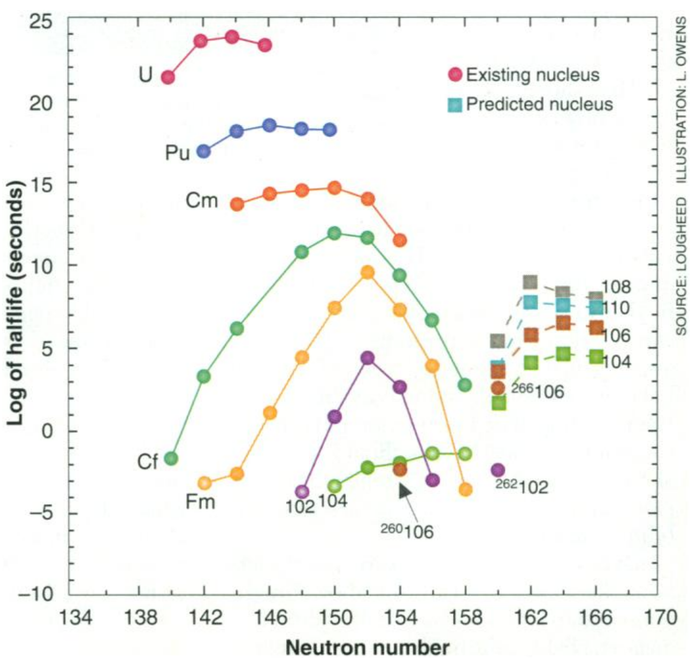
"The rock has now been discovered," says nuclear theorist Rayford Nix of Los Alamos National Laboratory. "It's a very, very significant piece of work," he adds, because "it has created a renaissance in this area of research." Little practical benefit is likely to come of the work: Only a few artificial elements have found uses, mostly as radioactive sources. But study of these nuclei at the edge of what is known promises insights into the workings of more ordinary nuclei.

In addition to their scientific value, these results are a vindication for Nix and his fellow theorists, who predicted the existence of these stable superheavy isotopes based on the way protons and neutrons in the nucleus arrange themselves in concentric spherical shells. Each shell has a maximum capacity defined by quantum mechanics. If the outermost shells are full, the nucleus is very stable; lead, for example, which has full outer shells, is among the stablest elements. In the heaviest nuclei created so far, the outer shells have many vacancies—hence their instability.

But theorists including Nix and his colleague Peter Möller predicted that some partially filled shells can deform into a slightly cigar-shaped configuration that adds stability. One such deformed shell is predicted for an as-yet-undiscovered isotope of element 108 that has 162 neutrons, more than any of its known isotopes. Adam Sobiczewski, a theorist from the Institute of Nuclear Studies in Warsaw, Poland, calculated that the deformed shell would endow this nucleus, called $^{270}108$, with a half-life of tens of years. That would put it at the center of the rock of stability.

The team of experimentalists, led by Yuri Lazarev of the Joint Institute for Nuclear Research at Dubna, near Moscow, and Ron Lougheed of Lawrence Livermore National Laboratory in California, set out to test the theory by bombarding a thin target of curium-248 with neon-22 ions. Their aim was to create a new neutron-rich isotope of element 106 with 160 neutrons ($^{266}106$) that should lie near the rock and therefore display some of its predicted stability: Sobiczewski's theoretical model suggested this nucleus would have a half-life of tens of seconds.

In 16 days of bombardment, the researchers fired 1.6×10^{19} neon ions at a target con-



A promised land. Artificial nuclei packed with neutrons may gain remarkable stability, according to theoretical calculations (dashed lines).

taining less than 3 milligrams of curium. Showing the difficulties inherent in this field, the effort yielded a mere six nuclei the team believes were $^{266}106$. Still, that meager nuclear harvest was enough to bear out Sobiczewski's prediction. A silicon sensor, provided by the Livermore researchers, identified the nuclei by the signature of their predicted decay chain: an alpha-decay followed by fission. Because the researchers did not know the exact moment when the nuclei were created, they could not time their half-life directly. But based on the energy of the first alpha-decay, they estimate that $^{266}106$ has a half-life of between 10 and 30 seconds.

For nuclear physicists, learning that the actual half-life is so close to the theoretical value "is equivalent to a home run," says Lougheed. Adds Nix, "It sheds credence on the theoretical approach." And that success has encouraged the researchers to try getting closer to the rock in January, when they will bombard uranium-238 with sulfur-34 in an effort to create $^{268}108$, just two neutrons short of the rock itself.

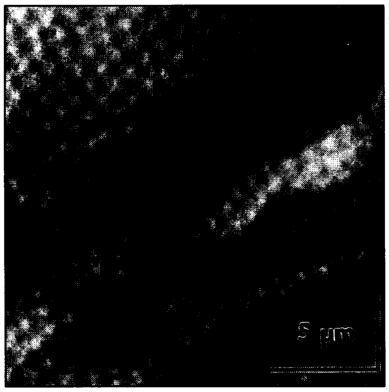
Why not push on and make a nucleus of $^{270}108$? Lougheed explains that the experimenters lack one of the ingredients: nuclei of sulfur-36, a rare and expensive isotope. So for the moment, the researchers are circling the rock, confirming theoretical predictions about the stability of nearby nuclei. If the January experiment succeeds, they plan to try to create isotopes of element 110, an entirely new element that should share some of the rock's stability. Like explorers taking their first steps into new territory, says Lougheed, "We're just mapping out the region."

–Daniel Clery

SOLID-STATE PHYSICS

Superconductor as Movie Star

Seven years after the discovery of high-temperature superconductors, most of the applications prophesied for these materials—super-powerful motors, high-field magnets for levitating trains, loss-free electrical transmission cables—are still no more than promises. One reason for the delay is that high-temperature superconductors, which lose all resistance to electrical currents when cooled with liquid nitrogen, have a maddening habit of regaining their resistance when subjected to even modest magnetic fields, which are unavoidable in most of the envisioned large-scale applications. Researchers still believe it will be possible to design high-temperature superconductors that avoid this problem—but first they need to understand exactly how magnetic fields kill the superconductivity.



HARADA, ET AL.

Frozen flux. Magnetic vortices in a superconductor form a rigid lattice (dappled pattern) at low temperatures; they vanish when the sample is warmed.

That should be a lot easier now, thanks to a new movie starring a high-temperature superconductor. In an experimental tour de force, a group at Hitachi's Advanced Research Laboratory led by Akira Tonomura has produced a blow-by-blow record of a magnetic field destroying a superconductor's ability to carry current without resistance. "This is just a spectacular experiment," says AT&T Bell Laboratories superconductivity researcher David Bishop. The information provided by the new technique, he says, should offer clues about how to modify high-temperature superconductors to cure them of their susceptibility to magnetic fields.

Over the past several years, researchers have sketched out a theory of how a high-temperature superconductor falls victim to a magnetic field. If the field is strong enough, it penetrates the superconductor and passes through it in discrete lines, called flux lines or vortices, each containing a single quantum of magnetic flux. When a current passes through the material, it pushes on the flux lines. At low temperatures the flux lines are "pinned" in place, but as the temperature increases, the current can dislodge them, and their movement dissipates energy, creating electrical resistance and destroying the superconductivity. The results can be dramatic: A material that retains its superconductivity up to 80 degrees Kelvin in zero magnetic field may lose it at 20 K in a magnetic field of 100,000 gauss, typical of the fields that would be generated in such potential applications as superconducting magnets.

But Bishop and other researchers believe they might be able to tame the flux lines if they could get a clearer picture of the lines' behavior. The flux lines are aligned in a regular array, and if that "lattice" is rigid, it should be possible to pin it in place at just a few points—"like tacking down a piece of carpet," Bishop says. The pinning could be accomplished, for instance, by introducing small defects into the material that would snag the flux lines when they tried to move. But if the lines can move freely, then pinning them all into place will be much harder. A theoretical model proposed by Bishop and fellow Bell Labs scientist Peter Gammel suggests that the flux lattice is rigid up to a particular temperature, which depends on the magnetic field, but above that point the lattice "melts." Some recent experiments support this model, but, Bishop says, "you'd really like to be able to see a picture, to get an image of the flux lines as they melt."

Researchers have developed a number of techniques to image flux lattices, such as "magnetic decoration," which uses small magnetic particles to pinpoint the location of the flux lines, but none of them could both resolve the individual lines and follow their movement in real time. So superconductivity scientists have had to settle for snapshots of the flux lattice instead of movies. No longer.

Tonomura's group has developed a way to track the motion of the flux lattice using a method called electron holography. As reported in the 15 November *Physical Review Letters*, the group passes a beam of electrons through a thin sample of superconductor. The flux lines induce slight changes in the phases of the electrons as they pass to one side or another of the lines. The phase-shifted electrons create an interference pattern, revealing the flux lines as a collection of spots that are half dark, half bright.

The principle is straightforward, but realizing it was a technical feat, say other researchers. The technique demands an electron beam that is extremely well collimated, so that the electrons are all moving in almost exactly the same direction—something Tonomura was equipped to supply because he has been working on such "coherent" electron beams for 25 years. Besides perfecting the electron beam, Tonomura's group had to build a special building to isolate the experiment from vibrations and electromagnetic noise that could mask the subtle effects of the flux lines on the electrons.

The preparations paid off in a movie that shows the flux lattice in a high-temperature superconductor gradually disappearing as the temperature increases past a critical point—an observation that Bishop believes supports his theory of flux lattice melting. Other researchers, such as Harvard University superconductivity theorist David Nelson, say more analysis is needed before a final verdict is rendered on the basis of this video evidence. But one way or the other, Nelson says, the work has opened a new window into what goes on inside superconductors—a window that should eventually bring these materials much closer to practical use.

–Robert Pool