New Look at Turtle Migration Mystery

Each year around Christmas time, green turtles (*Chelonia mydas*) leave their shallow feeding grounds along the coast of Brazil and embark upon a 2000 km journey to their nesting grounds, the beaches of Ascension Island, in the mid-Atlantic. The journey takes a little more than 2 months in both directions, and is a miracle of navigation. Biologists have long wondered how the turtles manage the feat, and also why they bother to do it at all.

Fifteen years ago two researchers, Archie Carr and Patrick J. Coleman, advanced an ingenious hypothesis that appeared to take the mystery out of the migration. The answer, they said, was continental drift. The turtles were assumed always to return to the beach at which they were born: a behavior that biologists call natal homing. For the ancestors of the modern turtle species, this was not a major problem 40 million years ago because the mid-Atlantic was then on Brazil's geological doorstep.

However, with the distance between Brazil and the volcanic islands of the mid-Atlantic ridge widening by some 2 cm a year through sea floor spreading, the passage of 40 million years transformed a short journey into an heroic odyssey. Locked into the need to nest on the beaches of Ascension Island (and its forerunners) by the biological imperatives of natal homing, the green turtle gradually adapted to an ever longer migration. Carr and Coleman acknowledged that theirs was an audacious hypothesis, but it also seemed persuasive.

About a decade ago Harvard biologist Stephen Jay Gould challenged the hypothesis, partly on the grounds that with the ebb and flow of climatic and environmental change over a span of 40 million years, there surely would have been periods when no suitable nesting beaches existed on the islands of the mid-Atlantic ridge. A hiatus of one generation would have been sufficient to have extirpated the biological link between the beaches of Brazil and Ascension Island. Until now, however, the Carr-Coleman proposition has not been properly tested with empirical data.

The required test has been made possible by restriction mapping of mitochondrial DNA (mtDNA), and applied by Brian W. Bowen and John C. Avise of the University of Georgia and Anne B. Meylan of the Florida Institute of Marine Research. The technique effectively tracks the genetic history of the female lineage, because offspring receive mitochondria only from the mother, not the father. And since natal homing focuses particularly on females, the mapping of mtDNA is an excellent tool for the task.

Bowen and his colleagues compared the mtDNA of green turtles from the Ascension Island beaches with individuals from two rookeries elsewhere in the Atlantic, one off Florida, the other off Venezuela. "If females have homed faithfully to their natal beach on Ascension Island over the evolutionary time-spans proposed under the Carr-Coleman scenario, the consequences should be reflected in extensive mtDNA sequence divergence," note the researchers. "The genetic results are straightforward."

The data show that, yes, there are identifiable differences between the three rookeries of the Atlantic, indicating that natal homing probably does occur. But the degree of difference is so small that a history of population separation of 40 million years is out of the question. Making a calculation based on the rate of mtDNA mutation, Bowen and his colleagues suggest that separation occurred a few 10s of 1000s of years ago at most.

The researchers offer two classes of (non-exclusive) hypothesis to account for the apparent close genetic relatedness of the modern Atlantic populations. The first invokes imperfect natal homing, in which every now and then a female makes a navigational error, and goes to the wrong nesting site. Even a low rate of genetic "leakage" of this sort is sufficient to homogenize otherwise genetically separated populations.

The second hypothesis concerns the probable long-term fragility of green turtle nesting grounds. Given the stringent conditions necessary for successful nesting, even modest shifts in environmental conditions can be catastrophic, thus causing the population to seek new nesting sites and probably throwing together previously separated populations. "These environmental perturbations could cause a periodic restructuring of green turtle populations through rookery extinctions and colonizations" suggest Bowen and his colleagues. In any case, they say, "The genetic data . . . are consistent with a recent origin [of the Ascension Island colony], perhaps the result of a rare colonization."

■ Roger Lewin

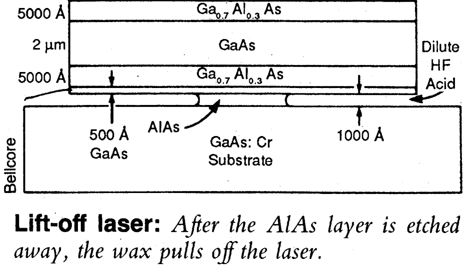
ADDITIONAL READING

B. W. Bowen *et al.* "An odyssey of the green sea turtle: Ascension Island revisited," *Proc. Natl. Acad. Sci. U.S.A* **86**, 573 (1989).

Lift-Off Laser: GaAs on Glass

Researchers at three laboratories have successfully made "lift-off" semiconductor devices that are fabricated on one surface, then lifted off and affixed to a second surface. The technique will allow semiconductor manufacturers to put devices such as transistors or solid-state lasers on base layers of an entirely different composition than the devices themselves. Potential applications include cheaper solar cells, faster computer circuits, and military hardware that will not be shorted out by nuclear radiation.

A group of researchers at Bell Communications Research headed by Eli Yablonovitch announced they have placed a gallium arsenide (GaAs) laser directly on glass, the first



Lift-off laser: *After the AlAs layer is etched away, the wax pulls off the laser.*

time such a laser has been combined with a glass substrate. "What is most remarkable here," Yablonovitch said, "is that we can take gallium arsenide devices—lasers and high-speed electronics, for instance—produced by traditional laboratory methods and lift them off their base. Then we can put these high-quality films of gallium arsenide—the only functional part of the device and a mere ten millionths of an inch thick—on a wide range of new materials."

The laser-on-glass success comes a year after the Bellcore team first described a technique for transferring GaAs thin film devices to other substrates from the GaAs substrates on which they are formed. Using this technique, scientists from two other institutions also have put GaAs devices on new substrates. Researchers in Belgium have put MESFETs (metal-semiconductor field effect transistors) onto glass. And a Sandia National Laboratory team led by John Klem has placed "strained quantum well" transistors on glass and silicon substrates. (Strained quantum well transistors consist of thin layers of indium gallium arsenide (InGaAs) between sheets of GaAs; the strain arises because the crystalline lattices of InGaAs and GaAs have slightly different structures, and the InGaAs layers deform in order to match the GaAs structure.) Paul Peercy, a spokesman at Sandia, said the transistors have no detectable change in their electronic characteristics after being lifted off and transferred to a new substrate.

The lift-off technique is analogous to building a house at one site, then picking it up off the ground and transporting it to a new lot. In this case, the ground is a GaAs substrate. A very thin layer—as little as 20 Angstroms thick—of aluminum arsenide (AlAs) is deposited over this, and a GaAs semiconductor device—the house—is built on that, using conventional thin film techniques such as molecular beam epitaxy. A waxy material is then placed over the finished semiconductor device. The wax pulls the device upward as dilute hydrofluoric acid etches away the AlAs layer, freeing the device. Since the bottom of the device is almost perfectly flat, it adheres firmly to the flat face of a new substrate through van der Waals bonding (bonding between the atoms on each surface). The bond is so strong "you need a razor to scrape the layer off, and even then you won't get all of it," Yablonovitch said.

Japanese scientists actually published a paper on a similar technique in 1978, Yablonovitch said, but they never followed up on it. Two factors allow the technique to succeed now that were not present in 1978: an improved acid etch and a careful pull by the wax. The acid eats away the AlAs layer and leaves the other layers untouched with a selectivity of as much as 100 million to 1, allowing the device to come through the process intact. The tension in the wax pulls up the edges of the thin film as the acid is working, allowing hydrogen gas—the by-product of the etching process—to escape from under the device without built-up pressure causing it to crack.

The importance of the lift-off technique is that it allows completely different materials to be used for the substrate and the thin film device. This may, for instance, solve the problem of short circuits in semiconductor devices caused by nuclear radiation, something the military is very concerned about. Devices placed on an insulator such as glass could be made immune to radiation.

Another use would be to speed signals in computers. The high dielectric constant of semiconductors slows down the speed at which signals are propagated in current electronic circuits. Using bases with a lower dielectric constant could double the speed of computer signals, Yablonovitch said. The technique could also be used to make less expensive solar cells, putting thin films of highly efficient but expensive GaAs on inexpensive bases, such as silicon.

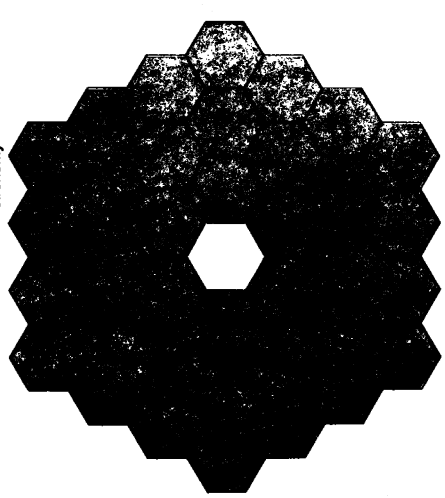
■ ROBERT POOL

Keck Telescope Mirror Is in Production

The goal is to turn 36 hexagons of high-grade ceramic into a single optical surface 10 meters across; the question is how?

GLIDING ACROSS the glassy surface on a muddy film of water and polishing compound, a steadily spinning pad moves back and forth, back and forth. The motion is hypnotic. And for the astronomical community, it is rich with significance. On this polishing machine at the Itek Optical Works in Lexington, Massachusetts, production is finally under way for the mirror segments of the largest telescope in the world: the 10-meter Keck Telescope, which is being constructed by the University of California and the California Institute of Technology on the summit of Hawaii's Mauna Kea.

"We're on the order of a year behind our original schedule," says Gerald M. Smith, who manages the project on behalf of the California Association for Research in Astronomy (CARA), a nonprofit corporation formed by the two universities to build and operate the telescope. Smith also admits to being hard up against his $87-million budget ceiling ($70 million of which was provided by the W. M. Keck Foundation; thus the telescope's name). Developing the techniques to fabricate and test the Keck mirror has proved to be a much tougher job than anyone expected. Nonetheless, experiments completed this past autumn have convinced CARA researchers that the problems are now under control. "We still expect to have the telescope operational in 1991," says Smith.



California Association for Research in Astronomy

Thirty-six segments make a mirror. *As shown here, the Keck telescope's 10-meter reflecting surface will be built up as a mosaic of hexagons. The central segment is left out so that auxiliary reflectors can bounce starlight down to instruments located behind the main mirror. Neither the gaps between the segments nor the hexagonal shape will greatly affect the final image.*

A visit to the Itek facility shows what a challenge the Keck mirror really is. In four centuries of telescope-making, there has never been anything quite like it. Its 10-meter diameter, twice the size of the venerable Hale Telescope on Palomar Mountain, was chosen as a compromise between hubris, realism, and the astronomers' constant hunger for more photons: the bigger the telescope's mirror, the larger its light-gathering power for the study of distant galaxies, and the clearer its view into our own galaxy's dusty star-forming regions. But instead of being cast as a single huge disk, in the traditional style of telescope-making, the Keck mirror will be built as a mosaic of 36 hexagonal segments, each only 1.9 meters across. These individual segments will be vastly easier to handle and transport. Once assembled inside the telescope, moreover, they will be vastly easier to control. Whereas a one-piece mirror would have sagged hopelessly under its own weight, the segments will be supported individually. At the same time, they will constantly be monitored and readjusted by a computer-controlled positioning system, which will keep the overall optical surface accurate to better than a micrometer no matter how the telescope tilts and turns.

The trick, of course, is to make the segments. Itek's work begins when the mirror blanks arrive in big wooden crates from the Schott glass works in Meinz, West Germany, where they are cast. Each $100,000 blank is a 2-meter-wide disk of Zero-Dur, a translucent ceramic that is essentially impervious to expansion or contraction with changing temperature. Forty-three are on order: 36 for the segments of the primary mirror, 6 spares, and 1 "just in case."

Once a blank has been removed from its crate and inspected, it goes into the polishing machine, where its upper surface will be ground to an accuracy measured in tenths of