rest. But it does answer some criticisms raised by greenhouse contrarians. For example, critics had noted that climate models, even with aerosols included, did not predict the faster warming at night relative to daytime that was being observed (*Science*, 7 February 1992, p. 683). Now the report notes that climate modeler James Hansen of the Goddard Institute for Space Studies in New York City and his colleagues have gotten their model to reproduce the nighttime warming by combining rising greenhouse gases and aerosols and an increase in cloud cover—a phenomenon widely observed but poorly understood.

In another controversial area, the IPCC report rejects the claim that satellite monitoring shows just one quarter of the warming predicted by climate models. The problem with that claim, says the report, is that the greenhouse skeptics are making comparisons with the wrong model simulations—ones that had greenhouse gases rising more rapidly than has happened so far or that weren't designed to gauge temperature increases in the first place. The latest models, incorporating aerosols and a realistic rise in greenhouse gases, predict 0.08° to 0.30°C of warming per decade, which puts the satellite warming rate of 0.09°C per decade just within the predicted range. Even that comparison may not be meaningful, notes the report, given the variability of global climate from decade to decade and the short, 16-year satellite record.

Just what effect the emerging scientific consensus will have on policy-making remains to be seen. For one thing, even though scientists have spotted a human hand in climate change, they still can't say how large its effects will be in the future. "Our ability to quantify the magnitude of this effect is presently limited," cautions the IPCC report, which gives estimates that range from a mild 1°C warming by 2100 to a hefty 3.5°C.

Still, Oppenheimer believes that the new IPCC finding "increases the likelihood that a real schedule of real [greenhouse gas] emission reductions" will come out of current negotiations being conducted under the 1992 Climate Convention. For now, industrialized nations have made a commitment to reduce their emissions to 1990 levels by 2000, but they are not strictly bound to do so.

In the United States, where the Republicans in Congress oppose many environmental regulations, the IPCC report could affect the thinking of the more moderate among them, says Robert Watson, associate director for environment in the White House's Office of Science and Technology Policy. It may "give them pause and make them think very carefully. It supports the contention that this is an issue that merits serious action." But as Oppenheimer notes with some understatement, "The politics of the details will not be easy."

–Richard A. Kerr

EARTH SCIENCE

Missing Chunk of North America Found in Argentina

Half a billion years ago, North America was a lost continent. Present-day Africa, Australia, Antarctica, South America, and India had assembled into the supercontinent of Gondwana, but North America and a few smaller continental fragments were drifting on their own, and geologists have had few clues to their peregrinations.

"The big issue in the paleogeography of the world about [that] time ... was the geography of the biggest players in this game, North America and Gondwana," says geologist Ian Dalziel of the University of Texas, Austin. But at a meeting of the Geological Society of America last month in New Orleans, speakers described how a chunk of crust in western Argentina is turning out to be North America's calling card. Dropped off in western South America nearly 500 million years ago, it pins down the errant North America to within a few thousand kilometers of South America's west coast. That's a big surprise, because it puts North America on the opposite side of Gondwana from the position it occupied in earlier, tentative paleogeographic reconstructions.

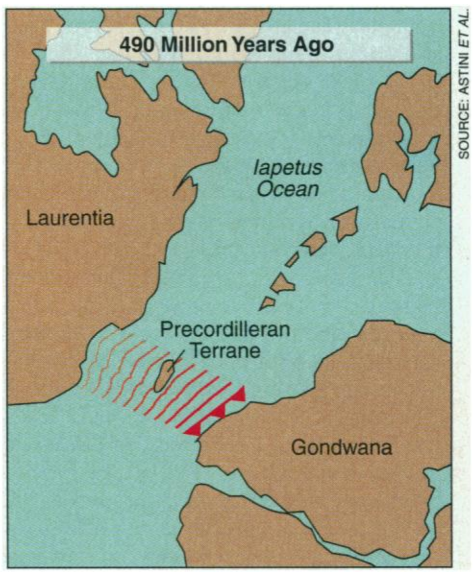
The revision may turn out to be important to researchers trying to understand "all these fantastic evolutionary things [that] were happening" at the time, says Dalziel, who first proposed the new geography. An evolutionary explosion was generating many of the life forms we know today, and the arrangement of drifting continents would have shaped such critical environmental factors as climate and sea level. The Argentine connection also provides a reference point for paleomapmakers as they ponder how all the continents, including North America, eventually gathered into a single supercontinent, Pangea, which formed about 250 million years ago.

Dalziel says he began suspecting that North America might once have lurked off the west coast of South America in 1991, when Eldridge Moores of the University of California, Davis, proposed how the continents might have been arranged in an even earlier supercontinent, called Rodinia, 750 million years ago. Moores suggested on the basis of geological similarities that Australia and Antarctica abutted the west coast of the ancestral North American continent, Laurentia, which lay at the core of Rodinia.

Dalziel, who had been thinking along the same lines, recalls that he then wondered how North America could have made its way "from somewhere adjacent to Antarctica to the position within Pangea that we know it had to have had." Taking into account such clues to Laurentia's wanderings as traces of Earth's ancient magnetic field frozen into its rocks, Dalziel plotted a meandering half-billion-year journey. The route took Laurentia on an "end run" around the west coast of South America to its final position in Pangea, where it collided with northwest Africa, pushing up the Appalachians. In mid-trip, according to a refinement offered by Luis Dalla Salda and his colleagues at the National University of La Plata, Argentina, the present eastern side of Laurentia ran smack into the coast of South America, right where the Andes rose hundreds of millions of years later.

At the GSA meeting, three speakers offered partial support for Dalziel's scenario. They confirmed that about 490 million years ago Laurentia and South America had been, if not in contact, close enough to exchange an 800-kilometer-long chunk of plate. First, William Thomas of the University of Kentucky explained how in 1991 he had inferred from U.S. geology alone that about 540 million years ago, a block of Laurentian crust had split away from what is now the Gulf Coast, never to return. At the time, he says, he had no idea where it might have gone.

The answer came in the second talk. The scheduled speaker, Ricardo Astini of the National University of Córdoba, Argentina, could not attend, but Thomas and Robert Hatcher of the University of Tennessee, the



Gone south. During a close encounter between continents, a chunk of ancient North America migrated to South America.

third speaker, delivered his talk for him. For 30 years, they noted, paleontologists have known that a crustal block now locked in the Andes north of Mendoza in far western Argentina, called the Precordillera, contains distinctively North American fossils of 540 million years ago. But Astini helped pin down the North American connection by drawing attention to similarities between the rock types and the sequence of strata in the Precordillera and the southeastern United States. "They are identical," says Hatcher. "It's amazing."

At an October workshop in Argentina, other geologists agreed that the Precordillera of western Argentina broke away from the Gulf Coast about 500 million years ago, say Thomas and Hatcher. But younger fossils in the Precordillera imply that before it "docked" on the South American coast, the block of crust spent some time on its own, as an island. That suggests that Laurentia and South America "were not in contact," says Hatcher, "but they could easily have been within 1000 to 2000 kilometers of each other," given the timing of the transfer.

That Laurentia was near South America 500 million years ago rather than 4500 kilometers off Africa on the other side of Gondwana is gratifying, says Dalziel, but he hasn't given up on the idea that they collided. Direct contact would eliminate any uncertainty about Laurentia's location, after all. Perhaps, instead of breaking all connections with North America before colliding, the Precordillera could have remained attached to it by a long, submarine plateau, much like the one that now connects the Falkland Islands to South America. North and South America might not have embraced during this dance of continents, but perhaps they stole a kiss.

–Richard A. Kerr

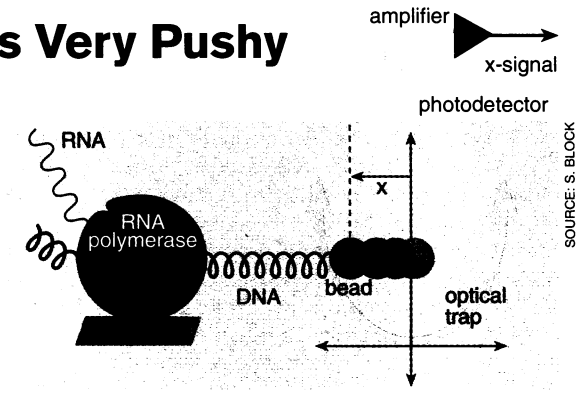
BIOCHEMISTRY

RNA Polymerase Gets Very Pushy

RNA polymerase doesn't appear to be an enzyme designed for hard work. Its main job is to slide along a DNA strand and splice free ribonucleotides into a messenger RNA chain based on the DNA template. But DNA is anything but a well-greased track: Somehow, the enzyme has to negotiate kinks and sticky spots. Motor enzymes, such as kinesin, are designed for such tough situations; they convert energy gained from other reactions into mechanical movement. RNA polymerase bears little resemblance to such molecules, however, and researchers have never thought of it as having a powerful motor. As it turns out, it has one of the biggest.

On page 1653 of this issue, investigators report that polymerase is not only more powerful than motor proteins like kinesin, but it uses fuel—pyrophosphates freed from ribonucleotides during RNA synthesis—just as efficiently. A consortium of three labs—headed by Jeff Gelles of Brandeis University in Waltham, Massachusetts; Steven Block of Princeton University in New Jersey; and Robert Landick of the University of Wisconsin, Madison—measured the force exerted by RNA polymerase as it pulled on a strand of DNA whose far end was caught in a laser-based trap called an "optical tweezers." The tug approached 14 piconewtons; other motor proteins pull at a strength of up to 6 piconewtons.

That combination of power and efficiency indicates why the enzyme can move along a DNA strand with apparent ease. Moreover, the technique gives scientists a whole new window on the interactions between the enzyme and the DNA substrate. Measuring force and displacement may allow them to analyze whether the enzyme moves one base at a time or in longer jumps, and how regulatory proteins such as transcription factors affect that movement. Other researchers are powerfully impressed. "It's one of the most elegant bits of biophysics that's been applied to transcription," says physical biochemist Peter von Hippel at the University of Oregon. "This adds a whole new dimension to understanding how the enzyme articulates with the [DNA] strand."



Transcription tug of war. As RNA polymerase transcribes a DNA strand, it pulls a bead attached to its far end from a low-energy spot in an optical trap formed by a laser beam. When the energy of the beam equals the force exerted by the enzyme, the polymerase stalls; that force is indicated by the bead's displacement *(x)*.

The major obstacles RNA polymerase encounters on a DNA strand are so-called "supercoiled" structures where the DNA helix is further twisted around itself. The polymerase has to overcome these constraints to keep a continuous hold on one strand. That would seem to require a lot of motor power, yet nobody had determined how much drive the polymerase actually had.

The team made this measurement by first fixing the polymerase to a glass cover slip while preserving its transcription activity. The enzyme, held stationary and unable to move along a DNA strand as it normally does, instead pulls the strand toward itself. Then the researchers fastened the far end of the DNA strand to a polystyrene bead just 0.5 micrometers in diameter. The bead is held under the "optical tweezers," an interferometer developed by Block and several colleagues which traps the bead at a low-energy spot at the center of a laser beam.

Then, says Gelles, "you start transcription by adding ribonucleotides." The polymerase starts tugging at the DNA strand, pulling the bead toward areas of more energy and higher resistance. The enzyme stalls when the resistance level of the beam matches the power of the enzyme's tug. A photodetector atop the apparatus measures the displacement of the bead, which is converted into a measurement of the enzyme's force.

Measuring "how much it takes to stall the enzyme is a completely new twist," says von Hippel. In addition to exhibiting the 14-piconewton force, RNA polymerase produces that force as efficiently as do "traditional" motor enzymes, converting about 10% to 20% of the free energy available from one cycle of ribonucleotide addition into mechanical energy. The polymerase, says Gelles, is the first member of what might be an unappreciated class of nucleic acid motor enzymes.

What excites Block about this work is the potential for getting a "blow-by-blow description of the polymerase in real time." Other experiments have indicated that RNA pauses and reverses at various points along the template, and may occasionally jump 10 bases at a time. Observing the changes in force exerted by the polymerase as it encounters different features of the substrate—individual DNA bases, or regulatory or suppressor proteins—should reveal which of those features are sending which signals. (For more on transcription and chromosomes, see the special section beginning on p. 1585.)

The present apparatus, however, can't measure much beyond overall stalling force. So the researchers are building a force-feedback clamp. Instead of maintaining a constant force on the bead, the clamp will change force to hold the bead steady as events at the polymerase end alter the tugs; researchers can then correlate the force changes with the transcription events. "This paper," says biophysicist Hermann Gaub of the University of Munich, Germany, "is opening up the field."

–Claire O'Brien

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