Biogeographers Take a New View of the Ancient Andes

The biological diversity of the Amazon basin has become an international icon, but until recently, the neighboring Andes were relatively unexplored. Now the hundreds of plant and animal species unique to the Andes are at last winning scientific recognition. That was apparent at last month's 19th Annual Systematics Symposium at Chicago's Field Museum of Natural History, where an interdisciplinary crowd of 200 researchers from at least 10 countries gathered to explore how natural forces shaped the Andes' distinct geology and biodiversity.

Mountains, Not Monoliths

Twenty years ago, the Andes were considered part of a homogeneous region, largely shaped by tectonic forces acting uniformly along the western edge of the continent. As the tectonic plates of the Pacific basin slid beneath the lighter continental crust of South America, the convergence and resulting volcanism were thought to have wrinkled the crust into a consistent mountain chain more than 9000 kilometers long.

J. FLYNN

Andean ascent. Studying the highest mountains in the Western Hemisphere means scaling high peaks like these.

This simple view prevailed for decades, in part because the Andes' rough topography and tall peaks—up to 6900 meters—defied easy exploration. Helicopters are often needed to travel short distances. But in recent years, backed by significant new sources of funding from U.S., European, and South American sources, intrepid geologists have ventured into the highest Andean peaks, and their results create a multifaceted new picture of the range. Rather than a monolithic structure, the Andes are now considered a complex montage of peaks, plateaus, and valleys, shaped by an equally complex constellation of tectonic and climatic forces. "The Andes are not homogeneous, biologically or geologically, over either spatial or temporal scales," says geologist John Flynn of the Field Museum. "There is no such thing as 'the Andes.' "

For example, based on the geometry of faults from a few localities, geologists once thought that the Andes were built with relatively simple upward movements. But Flynn and his colleagues found new evidence in fossil horizons of the high Chilean Andes that shows that older rocks were thrust up over younger ones, sometime after 18 million years ago. That kind of thrust faulting is caused by lateral compressive forces in the upper crust and suggests that lateral movements played a significant role in shaping the mountain range, says Flynn.

What's more, these various tectonic movements are now thought to have affected different segments of the Andes at different times, and the timing of key events in Andean history is coming up for revision. For example, early observations suggested that volcanism was concentrated in two phases, at about 80 million to 100 million years ago and much later, at 15 million years ago or less. But in remote Chilean peaks, Flynn's team explored volcanic rocks supposedly 80 million to 100 million years old—and found associated fossil mammals that dated these strata to only about 32 million to 45 million years ago. Carl Swisher of the Berkeley Geochronology Center in California and colleagues dated some of the oldest rocks and fossils even more precisely, using laser-based analyses of the radioisotopic decay of argon, to roughly 40 million years, plus or minus about 40,000 years. Flynn and his colleagues aren't yet sure of all the implications these new dates may have for the mountain-building process, but they say that determining the time and place of volcanism will eventually lead to a better understanding of how the Andes formed.

The new geologic evidence also points to an important role for climate, as well as tectonic forces, in shaping Andean habitats, says Flynn. For example, major habitat changes such as the first appearance of grasslands are known to have occurred in the southern Andes between 35 million and 40 million years ago. But the Chilean volcanic rocks formed at that time show no evidence of mountain building, which implies that "global climate changes, not regional tectonic uplift of the Andes," triggered the appearance of these grasslands, says Flynn.

Further north in the central Andes of Peru and Bolivia, however, Victor A. Ramos, a geologist at the University of Buenos Aires, found a very different story during this period. He found no volcanism, and structural evidence of faults and folds in rock strata, which suggests major mountain building, probably due to changes in the rate and direction of plate movements. The mountain-building process "has been very heterogeneous, [and] its variability is just beginning to be realized," says Ramos.

All this complexity may in part reflect the influence of not one but several plates that were swallowed beneath the South American crust, geologists say. Ramos, Flynn, and others are still fitting pieces of the Andean mosaic together, but they agree that the old, simplistic picture has crumbled.

Faunal Studies Come of Age

Call it serendipity or proof of the synergistic ways of science, but while geologists were learning of the heterogeneous geography of the Andes, zoologists unearthed their own evidence for a complex pattern of Andean development. Their work also shows that the lineages of some modern faunas are much older than expected, and that the onset of glaciation—so important in the history of North American life—had relatively little impact in South America. "It's turning out that the lineage of many birds, mammals, and other organisms that evolved in the Andes differentiated well before the Pleistocene," and so well before the most recent glacial age, says ornithologist John Bates of the Field Museum.

S. LOHR

Early bird. Living Andean birds have ancient roots.

Ever since early scientific explorations to the Andes, such as Darwin's voyage on *The Beagle* in the 1830s, zoologists and botanists have observed that the Andes possess a wealth of biological diversity. But they generally thought that these unique species originated at most a few million years ago, when a cooler, drier climate was thought to have created numerous patchy habitats and thus spawned the evolution of many species.

But over the years there have been a few tantalizing hints that conflict with that interpretation. Back in the late 1980s, for example, ichthyologist John Lundberg of the

University of Arizona identified 13.5-million-year-old fossilized fish jaws from what is now Colombia's Magdalena River basin as belonging to a living species: the giant herbivorous fish *Colossoma macroponum*, now found only in the Orinoco and Amazon rivers. Lundberg suggested that the fish once roamed all three rivers, but that about 10 million or 11 million years ago, the rising northeastern Andes cut off the Magdalena from the other two rivers and caused local extinction of *Colossoma* and other species in the Magdalena basin.

In the 1980s, *Colossoma* was thought to be an anomaly, and there was little data to support the impact of the rising Andes on the fish's biogeography. In the past few years, however, *Colossoma* has acquired company, as all sorts of species have turned out to be relatively ancient. Lundberg has found fossil teeth of flesh-eating piranhas just like those that patrol the Amazon and Orinoco today; he's also uncovered skulls of large, still-extant catfishes from the lowland rivers east of the Andes. All these fossils date back to about 13.5 million years ago—long before any glacially induced climate changes.

At the meeting, ornithologist Shannon Hackett of the Field Museum showed that some Andean birds, too, are of great antiquity. She and colleagues presented evidence gathered both from traditional fossil studies and from molecular analyses of genetic divergence in avian DNA and proteins. The studies measure how long ago a bird species diverged from other species on the avian family tree, using fixed dates from the study of a few bird fossils,

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Fresh catch? Fossil Andean fish, 13.5 million years old, are related to this modern catfish.

such as those of geese and quail. Researchers then take the genetic distance between living representatives of the ancestral species and divide by their times of emergence to estimate an average rate of avian speciation. Hackett then extrapolated backward to estimate when Andean taxa such as tanagers, antbirds, and brushfinches emerged. She found that these and other modern Andean birds have lineages dating back 4 million to 10 million years—an order of magnitude older than previous estimates. "A lot of divergence predates 10,000 years and, perhaps, the Pleistocene itself," she says.

Some systematists have questioned Hackett's technique, however, because it assumes a constant rate of divergence. But Hackett defends it in this instance because "it is not used for precise calibrations, but only for gross estimates." She is confident that these studies document that lineages of these birds are older than previously thought. And she adds that many South American birds don't migrate, which reduces gene flow and the potential for differentiation of bird populations, thus helping to explain the low speciation rate.

John Flynn of the Field Museum says that for him it was "a surprise but not a shock" to learn that many South American lineages are much older than previously believed. After all, the prevailing view that South American faunas are evolutionary youngsters was largely supported by extrapolating data and models from North America, a sometimes dangerous practice. And as more ancient lineages come to light, Flynn and other researches expect that these understudied fauna in a remote region of the Earth may have still other surprises to offer.

–Anne Simon Moffat

AIDS

SIV Data Raise Concern on Oral-Sex Risk

"Safe sex" was once the battle cry of everyone from health care workers to hotline operators who give out information about AIDS. But that phrase has gradually been replaced by one that is subtly different: "safer sex." The subtext to this change is that risks associated with sex can be reduced, but they cannot be completely eliminated. Condoms can break. Trusted longtime partners can have surreptitious affairs. And as researchers learn more about how transmission occurs, once seemingly "safe" practices can get bumped a few rungs up the risk ladder. Now, the results of a monkey study, reported in this issue on page 1486, may lead to a reexamination of the risk of HIV infection from a practice that has seemed relatively safe: oral sex.

The new study, headed by oncologist Ruth Ruprecht of the Dana-Farber Cancer Institute in Boston, assesses the risk of nontraumatic oral exposure to SIV, the simian AIDS virus. Ruprecht's team at Dana-Farber, in collaboration with a group at the Tulane Regional Primate Research Center, found that when they gently placed various concentrations of SIV on the backs of the tongues of seven monkeys, six of them became infected. Even more surprising: The minimum dose needed to infect monkeys with this strain of SIV was 6000 times lower than the minimum dose needed to infect them via the rectum. "It's a very engaging paper," says Kenneth Mayer, a clinical epidemiologist at the Brown University AIDS Program. "The data have to be taken seriously, although they certainly don't square with the [human] epidemiology to date."

Ruprecht stresses that her data indicate that the amount of SIV needed to infect a monkey via oral exposure is still relatively high—roughly 800 times what it takes to become infected by an intravenous (iv) injection of the virus. And, as the paper underscores, it is highly unlikely that anyone could become infected by HIV from casual contact, such as kissing or sharing a fork. Her take-home message: "Given enough inoculum, the oral route can lead to infection."

DANA-FARBER

Surprising data. Ruth Ruprecht found monkeys are easily infected by oral exposure.

As Ruprecht and her co-authors point out, there is scant published evidence that HIV is transmitted between humans via oral sex. Although the scientific literature is sprinkled with a few cases of men becoming infected by men through oral sex, assessing the risk has been all but impossible. "Oral exposure is so ubiquitous in the course of anal sex that you can't disentangle them," says Mayer. Epidemiologist Ann Duerr of the Centers for Disease Control and Prevention (CDC) says it has been equally difficult to assess the risk of women transmitting the virus to other women through oral sex. "There's very, very little data that this is a way women get infected," says Duerr. "All I can say is CDC has tried to look at this through its surveillance data, and we don't pick it up."

Ruprecht and her colleagues didn't set out to assess the potential risks of oral sex, however. Instead, they were interested in tracking the transmission of HIV from infected mothers to their newborns. They were focusing on the possibility that newborns swallow HIV during the birthing process, a supposition supported by the finding that blood in the gastric aspirate of newborns strongly predicts whether they will test positive for the virus. They also knew that babies had very low levels of gastric acid. This led them to test whether using drugs to lower gastric acid levels in adult monkeys would make the animals more susceptible to oral doses of SIV. The drug had no effect.

That wasn't the only hypothesis that didn't hold up. After finding that their initial thesis was wrong, the researchers decided to compare oral transmission to other routes, expecting to find it easier to infect monkeys both rectally and intravenously. Although iv injections easily infected 13 of 18 monkeys using relatively dilute doses of SIV, higher doses of virus given rectally only infected two out of eight animals. "I find it very, very surprising," says Duerr.