



AVATAR OF LANGUAGE

Paul Frommer '65 is the creator of Na'vi, the native language of the humanoid heroes in director James Cameron's blockbuster film *Avatar*.

By Karen McCally '02 (PhD)

Paul Frommer '65 has plenty of words to describe his introduction to the world of major motion pictures. It's been remarkable. It's been extraordinary. And it's been total *keye'ung*.

That's Na'vi for "insanity."

Na'vi, the language of the humanoid inhabitants of the planet Pandora, the setting of the blockbuster film *Avatar*, is Frommer's brainchild. And like any child, it's changed his life considerably.

It all started in 2005, as the linguist-turned executive was teaching at the University of Southern California's Marshall School of Business. A friend from the linguistics department, in USC's college of arts and sciences, forwarded to Frommer an e-mail that he and the more than 20 other members of the department had received from a representative of Lightstorm Entertainment, the production company of director James Cameron. Cameron, the creator of *Titanic*, at that time the largest grossing film in movie history, was looking for someone to invent a new language, to be spoken by an extraterrestrial people who would be the focus of his next movie, then called *Project 880*.

HOLLYWOOD SET: Linguist and USC business professor Frommer says taking part in the making of *Avatar* was an "absolutely thrilling experience."



Although he earned a doctorate in linguistics from USC and later published in the field, Frommer pursued a career as a strategic planner for a Los Angeles marketing firm and now teaches courses on business communication.

“When I saw the e-mail, I said ‘whoa!,” he says. “I jumped on it.”

This spring, as the final product of Cameron’s vision, *Avatar*, has surpassed *Titanic* as the highest grossing film of all time, Frommer’s inbox overflows with messages—hundreds, he says—from fans of the movie who want to learn to speak and write in Na’vi. Fans have also launched a Na’vi Web site and a discussion forum, to which there are more than 100,000 posts.

Many of the fans have already mastered the language, composing

ciding what sounds go into the mix, but just as importantly, what sounds are going to be left out,” Frommer says.

He compares the process to cooking. “When you’re cooking and you open your cabinet and see this array of spices, if you put in everything you have on the shelf, you’re going to get a mess,” he says. “It may be unpalatable, or it may have no particular distinction. But if you’re judicious, and you take certain things, and leave other things on the shelf, then you might get something that has character to it.”

Na’vi, for example, does not have the *-b*, *-d*, and hard *-g* sounds that are common in English. And although some sounds that appear regularly in English, such as the *-ng* sound, also appear in

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e-mails to Frommer entirely in the language. He calls the response both “astonishing and gratifying.”

“People go to the movie, and they’re just swept away,” he says. “It touches people on a very deep level, and they come away wanting to connect with Pandora. One way to do that is through the language.”

At first glance, learning Na’vi might not seem so daunting. Its current vocabulary is small, consisting of a little more than 1,000 words. That’s miniscule compared to the vocabulary of a typical English-speaking adult, which is about 65,000 words, according to Rochester’s Elissa Newport, the George Eastman Professor of Brain and Cognitive Sciences and the chair of the department.

“But the size of the vocabulary isn’t what makes it a language or what makes it interesting,” she adds. “The size of the vocabulary is the least of the characteristics you would look at to decide, ‘Is this really a language?’”

BASIC TRAINING: Australian actor Sam Worthington, who played the movie’s hero—former Marine Jake Sully—was one of several cast members who were coached by Frommer in proper Na’vi pronunciation.

Newport, an internationally recognized expert on language acquisition, says all languages have the same basic elements: A set of sounds (or hand signs—Newport studies signed languages as well), and a system of rules for combining those elements into words, and words into sentences.

So to create Na’vi, Frommer started, as a linguist would, by defining its sounds.

“Something that I enjoy doing, and I think many linguists do as well, is just playing around with sounds, just making funny sounds and rolling them around in your mouth, and seeing how it feels,” he says. “You realize you can have some very interesting combinations.”

But there should be some limit to those combinations. “You want to come up with something that has some sort of distinctiveness to it, and one way you do that is by deciding

Na’vi, in Na’vi that sound appears at the beginning of words—words such as *ngop* (create) or *nga* (you)—as well as at the end, as in the English word ending *-ing*.

Among Na’vi’s most distinctive features are the “ejectives,” or “popping sounds” that Frommer says are heard in many Native American languages, as well as in Central Asia. “I put them in because they’re interesting sounds, and I thought they might arouse some interest in the language, kind of like an interesting spice that I was putting in.”

“The reaction I’ve gotten from a number of people who aren’t linguists is, ‘You know, that sounds like a real language,’” he says, with clear delight.

According to Newport, that’s because the listeners are beginning to recognize patterns.

“People start to learn the patterns, even in small doses. They’ll start to recognize the words that recur, and the word orders that recur, and the sounds that recur. In a two-and-a-half-hour movie, people probably are starting to recognize, even without realizing it, the patterns they’ve been exposed to.”

But it’s quite a leap from recognizing patterns to actually speaking the language. For the cast, mastering unfamiliar sound

combinations, as well as the ejectives, took practice. Among Frommer's roles was coaching the actors—Sigourney Weaver, Sam Worthington, Zoe Saldana, and others—helping them both on and off the set to master Na'vi pronunciation.

He was accompanied by a veteran dialect coach, Carla Meyer, who has worked on more than 40 films, including *Pirates of the Caribbean*, *The Gift*, and *A River Runs Through It*. Meyer and Frommer shared the task of determining the Na'vi accent—the accent that Zoe Saldana, for example, adopted as her Na'vi character, Neytiri, learned to speak English.

"We put our heads together to try to figure out exactly what they might sound like when they spoke English, and that's not at all an easy question," Frommer says. "One thing we played around with, is that there's no *-j* sound in Na'vi, but of course the main character's name is Jake. So if Neytiri was trying to say 'Jake,' what would she say? The closest sound that they have to *-j* is *-ts*, so it might come out 'tsake.'"

A native of New York City, Frommer came to Rochester in the early 1960s on a Bausch & Lomb scholarship to study not languages, but astrophysics. "From the time I was eight, everybody knew 'Paul is going to be an astronomer,'" he says.

As it turned out, he earned his degree in mathematics. And while he had studied a bit of French, German, Hebrew, and Latin, it wasn't until after graduation, when he joined the Peace Corps, that he realized his love for language. He was sent to Malaysia, where he taught math in Malay. "I realized how much fun it was, and that I was pretty good at it," he says.

In the mid-1970s, while a doctoral student in linguistics at USC, he spent a year in Iran and completed his thesis on an aspect of Persian grammar. When he entered the business world, he maintained a foothold in the field of linguistics, coauthoring *Looking at Languages: A Workbook in Elementary Linguistics* (Wadsworth) in 1994 with USC linguistics professor Edward Finegan. It was Finegan, in fact, who forwarded Frommer the e-mail from Lightstorm Entertainment, and the book itself that Frommer sent to Cameron in advance of the interview in which he closed the deal.

Now he finds himself a high-profile figure in a small but growing guild of language inventors—people from the fantasy writer J. R. R. Tolkien to the hundreds of computer scientists, linguists, mathematicians, and others who have invented languages as a hobby and shared them with one another over the Internet.

Frommer's personal favorite among notable language inventors is Marc Okrand, an expert in Native American languages who created Klingon for the 1984 movie *Star Trek III: The Search for Spock*.

Frommer says Klingon "changed the game" when it came to science fiction filmmaking. In the 1977 movie *Star Wars*, for example, the language of aliens was "pretty much gibberish," he says. Klingon, on the other hand, is a "very well-developed, difficult language."

"Ever since then, it's been understood that that's the standard. Especially for someone like Cameron, who lavishes this incredible detail on everything he does. He wanted the detail in the language as well."

Klingon inspired a cult following, as Na'vi appears to be doing now.

As Frommer's Na'vi reaches a level of renown fast approaching Okrand's Klingon, Cameron has indicated plans for an *Avatar* sequel. That's good news for Frommer, who would like nothing more than to continue to expand on the 1,000-plus word language.

"*Ivong Na'vi*," he says. Let Na'vi bloom. **R**

Language Creation— an Adult Form of Play

Professor of English Sarah Higley says creating languages is a more common pursuit than many people might suspect. She would know: She's the inventor of the language Teonaht, a board member of the Language Creation Society, and a member of an online Listserv of more than 500 people—linguists, computer scientists, mathematicians, humanities scholars, and others—who create languages for fun. They call such languages "constructed languages"—or conlangs—and pursue their hobby as an art form that can be enjoyed for its sounds, its script, or, for real aficionados, its grammatical structure.

"More people have done this in the past than we could ever tell," says Higley. "The reason there seems to be a burst of people doing it is only because the Internet has put us in touch with each other."

"We're not nuts," she adds, alluding to critics who dismiss conlangers as (she says dryly) "people who all live in our grandmothers' basements and have nothing else to do." Higley, for example, is a scholar of medieval language, literature, and poetic structure, who teaches courses on these subjects, as well as science fiction and fantasy writing, which can borrow heavily from medieval concepts of magic.

In her latest book, *Hildegard of Bingen's Unknown Language: An Edition, Translation, and Discussion* (Palgrave MacMillan, 2007), Higley explores the invented vocabulary of the 12th-century German nun, placing it in the context of language invention in both the past and present.

Over the past decades, Higley has continued to transform Teonaht into a strikingly original language, both phonetically and structurally.

Not everyone remains focused on a single language for so long. Many conlangers create several languages. "They're really interested in the structure," she says. "They have a certain idea. And they get bored with it, and start a new structure."

"Some people change languages like they change clothes. Others stick with one invention for a lifetime."

—Karen McCally '02 (PhD)



LANGUAGE ARTS: Invented languages can be enjoyed for their sounds and structure, say Higley.



A photograph of a desk with a window, a radiator, and books. The window shows a view of a city skyline. The radiator is white and has a small valve. There are several books on the desk, some of which are open. The overall scene is a quiet, contemplative workspace.

Poetic Appeal

*Why does the art of poetry thrive
in an age of instant communication?*

*By Kathleen McGarvey
Photographs by Adam Fenster*

A

cell phone trills.
A BlackBerry vibrates,
bristling for immediate at-
tention. "Tweets" accrete,
each bearing fleeting news

of someone's latest passing thought on Twitter. Now, now, now, now, now.

In an era of such frenzied exchange of language, it might seem that there would be little place for the poem. But poetry never has been more alive at Rochester than it is today, in writing workshops and poetry readings, informal gatherings and solitary sessions where a writer confronts a blank sheet—or screen. Far from being blotted out by contemporary mores of communication, poetry provides a kind of corrective.

"Poetry, like all great writing, whether poetry or prose, forces you to be very slow," says James Longenbach, the Joseph H. Gilmore Professor of English and an acclaimed poet and literary critic. "You have to read very slowly. You have to write very slowly. That's what I say to people who say they don't understand poetry. If you try to speed through language the way we do in

POETIC PROGRESS: "To write one poem, you have to read a thousand of them," says poet James Longenbach, the Joseph H. Gilmore Professor of English.



most of our lives, poetry will be not just irrelevant, but incredibly frustrating.”

Speed, succinctness, transparent and uncomplicated meaning—these are the currency of now ubiquitous electronic communications. But poetry, which also concerns itself with condensation of thought, is an art of shades of meaning, ambiguities of purpose, and the pleasures of language itself.

“We’ve become the culture of the sound bite—and poetry is precisely the opposite of that,” says Thomas DiPiero, a professor of French and of visual and cultural studies, as well as the senior associate dean of the humanities. “It’s a way of thinking—a very specific way of thinking. It’s been called ‘concentrated thought.’”

And, judging by the English majors as well as students from disciplines throughout the College who fill English literature classrooms each semester, it has a powerful appeal.

“There’s a strong sense, a thrilling sense, of writing among the undergraduates, and not just of poetry but of fiction as well; you can’t have one genre without the other,” says Longenbach, the author of critical works such as *The Resistance to Poetry* and *The Art of the Poetic Line*, as well as volumes of poetry including *Draft of a Letter* and *Fleet River*.

Offered through the English Department, the poetry workshops that Longenbach and colleague Jennifer Grotz, an assistant professor of English, teach are part of the department’s creative writing program. Directed by Joanna Scott, a novelist and the Roswell S. Burrows Professor of English, the program is grounded in an understanding that writing is a creative discipline that draws on the study of a wide range of literature.

“In workshops, half our time is spent reading the greatest poems we can read,” says Longenbach, whose poetry has also appeared in publications such as *The New Yorker*, *The New Republic*, *Slate*, and *The Paris Review*. “To write one poem, you have to have read a thousand of them.”

Grotz, whose poetry volume titled *Cusp* won the Bread Loaf Writers’ Conference Bakeless Prize in 2003, says that she teaches students to “read as a writer would.” Joining the University faculty last fall, Grotz also translates French and Polish poetry and will teach in Rochester’s new literary translation program.

Grotz found her own way to poetry slowly, teaching herself by reading other poets before taking up the academic study of poetry. A Texan who grew up “in a house with no books,” she was “like a musician who could pick out a tune,” she says. In her students, Grotz



seeks to develop a facility with writers’ tools. “My philosophy of teaching at least introductory-level poetry is to break it down into what writers call ‘craft lenses.’ To have the students think of themselves as writers, with skills they want to develop—image, music, and so on.”

For Giulia Perucchio ’13, who took Grotz’s workshop last fall, that approach was invaluable. “We connect huge, fluid things with very specific images,” she says. A graduate of Rochester’s School of the Arts, she came to the University already focused on creative writing. “That’s the best thing I learned from her: how to be very specific, very direct.”

Poetry’s roots at Rochester run to the University’s beginning. Ashael Kendrick, a scholar of Greek and one of the professors who came to Rochester when the University was first formed in 1850, translated and anthologized poetry. In 1968, Anthony Hecht ’87 (Honorary), the former John H. Deane Professor of Rhetoric and Poetry, received the Pulitzer Prize for poetry while

WELL-VERSED: Poet Jennifer Grotz, an assistant professor of English (opposite), will edit a poetry series for Open Letter, the University’s literary translation press. She also teaches in the translation program, where students like Tyler Goldman ’10 (above) “think critically about the way language operates.”

at Rochester, where he was a member of the English department for 18 years.

In many ways, the name most closely associated with verse at Rochester is that of the late Hyam Plutzik, who preceded Hecht as the John H. Deane Professor of Rhetoric and Poetry and taught at the University from the mid-1940s until his death in 1962. A widely published poet concerned with themes such as the relationship between science and poetry, Plutzik taught writing workshops and gave weekly poetry readings on campus.

Today he's memorialized in the Plutzik Library for Contemporary Writing at Rush Rhees Library, where professor emeritus and poet Jarold Ramsey is also honored with the Jarold Ramsey Study. The library houses the William and Hannelore Heyen Collection, an extensive poetry archive assembled by poet Heyen. Rare Books, Special Collections, and Preservation also holds collections—including early editions, manuscripts, and correspondence—by John Dryden, Hilda Doolittle (H.D.), John Gardner, Carl Sandburg, and Alfred, Lord Tennyson, and other notable poets.

Tyler Goldman '10, an English major with a creative writing emphasis from Balacynwyd, Pa., took part in the literary translation program's inaugural course, translating Roman lyric poetry into English. He says among the values of literary translation is its ability to heighten a writer's awareness of language. "It allows you to think critically about the way language operates," he says.

That awareness is key to any writer's development, Longenbach says.

"I teach poetry almost exclusively as craft," he says, "how we focus and sharpen the way we harness language. I tell students we're almost never going to talk about the subject of a poem. What's unique is the way the language takes you through the experience."

There aren't a lot of different subjects for pop songs, he observes, but we listen to our favorites again and again. Why? It's not that we can't recall them—quite the opposite. It's our attraction to how they express an experience. Poetry, which he calls a "sonic art," is the same.

"You read a poem many times, not because you can't remember the words, but because you want to inhabit the way it moves through language."

Pulitzer Prize-winning poet Galway Kinnell '49 (MA) agrees. A poem is "not just an exposition of an idea or an event, but a reliving of it," he says. That evocative force lies in the images and music its words create.

"In poetry workshops, I find, students learn to attend to the precision of their language more pow-



erfully than in any other class I teach," says Longenbach, who became interested in poetry in college, after having spent "a great deal of my youth involved in music, as a pianist."

Such exactness is not what everyone anticipates, however. Grotz and Longenbach find ways to help their students appreciate that poetry—like all art forms—requires a blending of feeling and craft.

"You're working with young people who feel passionately about something, and you're helping them learn how to connect that passion to a passion for the beauty and accuracy of language," says Longenbach.

Strong emotion can be an impetus for a poem, but it's not enough. "People who write not-very-good poems have compelling emotions, too," he says, "but they haven't figured out how to get it on the page."

CHANGED PERSPECTIVE: Studying poetry has given her a "new set of eyes," says Samantha Miller '11, a double major in English and philosophy who hopes to teach poetry at the college level. "In a sense, poetry doesn't fit with our times, but I think that makes it more valuable."

In Grotz's workshop, Rainer Maria Rilke's *Letters to a Young Poet*, a slim volume of correspondence from Rilke to an aspiring poet, helps frame discussion of the emotive dimension of poetry. She delivers the book to students in a sealed envelope, just as a letter would arrive.

"To my mind, Rilke really helps to address the other reason young poets turn to poetry: expressing themselves, thinking about what it means to be human," says Grotz. "I contain our 'soul talk' to Rilke. Otherwise we focus on technique. It helps us talk more clinically about the craft—but it's very hard to talk about one without the other."

"Technique is what allows empathy to come through as empathy and not just as 'I have these emotions,'" says Emily Claman '06. After graduating with a degree in philosophy, she earned an MFA with a concentration in poetry from Washington University in St. Louis and credits her work with Longenbach and poet and former Rochester faculty member Sally Keith for her pursuit of a poetic career.

When he was an undergraduate, poet Ilya Kaminsky recalls, Longenbach spoke with him "on a line-by-line basis" about poets Frost, Lowell, Walcott, and Ashbery.

"Just think of it: James Longenbach, famous poet and literary scholar, has spent hours and hours of his time reading poems of a first-semester freshman who did not even know English well at that time," says the Odessa, Ukraine, native who is now a professor of poetry at San Diego State University. "Such generosity of spirit is what makes education possible and what truly propels talent to grow."

Workshops are not the only courses in which Rochester students encounter poetry, of course. And poetry doesn't stand alone, says Longenbach—"There's a climate of writing here: fiction, poetry, and increasingly, playwriting"—nor is it separate from the work of the larger English department.

When Kenneth Gross, a professor of English who has published extensively on Renaissance and modern verse, teaches his course on lyric poetry, he guides students in "slowing down, and dwelling on images and ambiguities."

Such ambiguities are an irreducible part of poetry's complexity, and its power—a dimension, in fact, of the very precision Grotz and Longenbach instill. "Poetry works, and sticks around, because it's not clear. There's something that can't be put into words, even though it is words," Gross says.

Poetry "makes you consider multiplicities—often contradictory multiplicities—of meaning," says DiPieiro. "Reading poetry is like reading the world."

And while students in his courses—not just English majors, but an "impressive range," says Gross—might be uncertain in approaching poetry, he reminds them that "they have a lot of experience with rhythmically shaped language: nursery rhymes, prayers, music lyrics, epitaphs, even jingles."

In his lyric poetry course, Gross—author of books such as *Spenserian Poetics: Idolatry, Iconoclasm and Magic* and *Shylock is Shakespeare*—focuses on Shakespeare's sonnets and the poems of John Keats, Emily Dickinson, and Elizabeth Bishop. They're short works that "give them a sense of a single poetic intelligence," he says. "For these poets, the major poems are the intense, short lyrics. They're very meaty objects of analysis."

But he shows students, too, that poetic language inhabits places they might not expect. In one course, he spent a week examining with students the texts of national anthems such as the *Star Spangled Banner* and *La Marseillaise*.

"It made them take up things they didn't think of as poems—or even as things to be read—and see them as rather charged."

Not to be overlooked, either, is the sheer enjoyment that engaging with a poem as a writer or a reader can provide. "However dark or difficult a poem, in some way it has to foreground pleasure," says Gross.

That pleasure is what feeds literary readings like the Plutzik Reading Series, which brings readings by contemporary novelists and poets to the Rochester community.

"The Plutzik Series pulls an audience beyond the classroom—and also feeds back into the classroom," Gross says, as faculty members—particularly Longenbach, Scott, and now Grotz—incorporate work by visiting writers into their courses.

Like the Neilly Series, a writers' lecture series supported by an endowment from Andrew H. '47 and Janet Dayton Neilly, the Plutzik Series is "a huge

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part of the literary community here. It transcends poetry," says Goldman.

"Often, when I taught poetry classes, even workshops," before coming to Rochester, "there was a part of my job that was being a salesman" for poetry, Grotz says. "Here I don't feel the need to sell poetry at all. The students come interested and hungry." How to keep them fed, she adds, "is a wonderful problem to have."

For Samantha Miller '11, a double major in English and philosophy from Henrietta, N.Y., who is in Grotz's workshop this semester, poetry counterbalances the more impatient and utilitarian interaction with language she has in other facets of her life. "We're so used to text messaging, e-mails—instant gratification and immediate answers. And poetry takes a lot more time," she says. "In a sense, poetry doesn't fit with our times, but I think that makes it even more important and valuable."


Miller hopes one day to teach poetry at the college level and says her literary study at Rochester has shaped not only her professional ambitions but also the very way she sees the world.

"What you can gain by studying poetry is a new set of eyes," says Miller. "You have a new appreciation for even the most minute things around you."

It engenders, says Kinnell, "a tenderness towards existence."

Ultimately, Grotz suggests, there's even something elemental to it.

"Everybody knows poetry isn't what you do to make money," she says. "And it's not read the way popular fiction is, by any means. It may seem like an old-fashioned thing to do. But it's the perfectly packaged thing for a human being. It's totally human-shaped, human-made."

"It's breath." 

Taking the Measure of Mountains

Rochester earth scientist Carmala Garzione is changing the way geologists think about the rise of mountain ranges.

By Jonathan Sherwood '04 (MA), '09S (MBA)

More than 12,000 feet above sea level in the Andes mountains of South America, Carmala Garzione finds herself at the center of a seismic shift in how she and other scientists understand the forces at work beneath one of the world's longest continental mountain ranges.

An expert on the geological processes that can push the Earth's upper crust skyward, Garzione, a professor of earth and environmental sciences at Rochester, is pioneering a new approach that she and colleagues say offers a more accurate picture of how such mountain ranges rose to where they are today.

Based on new methods of paleoaltimetry, the science of judging ancient mountain heights, that Garzione helped developed, her research indicates that the Andes rose to their current height in as little as 2 million years sometime between 6.4 million and 10 million years ago.

That's a remarkable growth spurt for a mountain range that now features peaks between 5,000 and 7,000 meters (17,000 and 23,000 feet).

"That's several times faster than geologists had estimated before," Garzione says, noting that some previous work estimated that the Andes took as long as 50 million years to reach their current heights. "It means there is some unexpected process going on beneath the Earth's crust that's creating mountains like these."

Investigating how that process works has earned wide recognition for Garzione. In 2007, she received the Young Scientist Award



MOUNTAIN VIEW: By analyzing the sedimentary strata in a high-elevation basin in the Andes, Garzione has found that mountains in the South American range rose several times faster than previous research indicated.

from the Geological Society of America, which cited her research as "groundbreaking." Last year, the New York Academy of Science followed suit, honoring Garzione with its Blavatnik Award.

Her findings, which are based on detailed comparisons of the mineral composition of sediment that erodes from mountains over the life of their growth, are forcing geologists to rethink how mountains form and even how their growth contributes to global climate change.

In a process that geologists know as "shortening," mountain ranges such as the Andes and the Himalayas are formed when vast sections of the Earth's lithosphere, called tectonic plates, collide



and push against each other. The plates buckle like a wrinkling rug, pushing up a long range of mountains. Exactly how quickly a range of mountains rises has long been shrouded in mystery because few scientists can measure how high a mountain may have been when it first started its ascent.

Before Garzione's research, geologists estimated that uplift by examining the fossils left by vegetation or by dating when certain minerals from deep underground began moving to the surface. But plant characteristics can change radically over millions of years, and changes in climate can also vary the speed of erosion, throwing significant question marks into the equation.

Instead, Garzione theorized that by examining the mineral composition of sediment and comparing it to atmospheric conditions at different altitudes she would have a better picture of the time it took for a mountain to reach its height.

"I wrote my doctoral dissertation on the possibility of retrieving atmospheric information from ancient sediment in the Himalayan mountains, dating it, and forming a record of the Himalayas' and Tibet's uplift history," says Garzione. "Based on my estimates, southern Tibet and the Himalayas appeared to have been high throughout their depositional history, so I was eager to put this technique to the test in a place that appears to have been at a lower

elevation more recently. We focused on the sediment that was deposited in the high Andes mountains because fossil estimates put them much lower just 10 million years ago,” she says. “However, trees cannot grow at the modern elevations in the Andes, so this fossil-based approach cannot tell us when and how fast the mountains rose.

“As a mountain range rises, it experiences different atmospheric conditions due to its change in height. Those atmospheric changes, such as temperature and the amount and composition of rainfall, are recorded in minerals that form near the surface at different altitudes on the mountainside.

“The challenge was to see if I could get a clearer idea of the Andes’ growth than we’d ever had before.”

On the Bolivian Altiplano—a high-elevation basin in the Andes—Garzione took samples of sedimentary rock that had accumulated between 12 million and 5 million years ago. Garzione analyzed the mineral composition of sedimentary strata in the Altiplano, studying the ratio between the mineral carbonate, which is released from surface water during erosion, and the isotopes oxygen-16 and oxygen-18.

More than 99 percent of the oxygen in water is made up of oxygen-16 and less than 1 percent is oxygen-18, but as vapor rises to higher altitudes in the form of clouds, oxygen-18 is removed from the clouds. As rain falls, the clouds are slowly depleted of the isotope. Because the change is locked in the minerals that form on the mountains’ surfaces, Garzione was able to uncover a record of the altitude at which the minerals formed.

Garzione also used a second method to look at the Bolivian sediment that focused on the temperature at which the surface-forming carbonates were created. Since air temperature decreases with altitude, the rocks’ original altitude should be preserved in a temperature-based mineral snapshot. Garzione, along with Prosenjit Ghosh and John Eiler of the California Institute of Technology, employed a technique developed at CalTech to examine the abundance of oxygen-18 and carbon-13 isotopes that bonded together.

Using the CalTech method, Garzione and the CalTech team gauged the temperature at which the carbonates formed—from the hot Amazonian jungle climate to the freezing peaks of the Andes. Both studies pointed to the same conclusion: Between 10 million and 6.4 million years ago, the Andes lifted more than a mile.

“When I first showed this data to others, they had a hard time believing that mountains could pop up so quickly,” says Garzione. “With supporting data from the new paleotemperature technique, we have more confidence in the uplift history and can determine the processes that caused the mountains to rise.”

How did the Andes rise so dramatically, geologically speaking?

Garzione says the answer may come in the not-so-scientific-sounding process known as “deblobbing.”

That’s the colloquial term given to a process by which a dense root in the Earth’s mantle becomes detached from the Earth’s crust. As plates thicken during mountain building, the dense lower crust and upper mantle also thicken and are heated to higher temperatures in the Earth’s interior. At hotter temperatures, they become unstable and begin to flow downward under the force of their own mass into the Earth’s mantle, much like a more dense blob in a lava lamp flows downward.

When two tectonic plates collide, such as when the Nazca

oceanic plate in the southeastern Pacific collides with the South American continental plate, the continental plate begins to buckle. Floating on a less dense and partially molten mantle, the plates press together and the buckling creates the first swell of a mountain range.

Below the crust, however, there’s another kind of buckling going on in the more elastic portions of the upper mantle. The dense mantle “root” clings to the underside of the crust, growing in step with the burgeoning mountains above.

The root acts like an anchor, weighing down the whole range and preventing it from rising, much like a fishing weight on a small bobber holds the bobber low in the water. In the case of the Andes, the mountains swelled to a height of one to two kilometers before the mantle root disconnected and sunk into the deeper, partially molten mantle.

The effect was like cutting the line to the fishing weight—the mountains suddenly “bobbed” high above the surrounding crust, and in less than 3 million years, the mountains had lifted from less than two kilometers to roughly four.

The process had been proposed since the early 1980s, but it has never stood up to scrutiny because the techniques to estimate surface elevation have only been recently developed.

“People have largely ignored the role of the upper mantle because it is difficult to look 50 to 200 kilometers into the Earth; whereas we can easily see the deformation on the surface,” says Garzione. “Some geologists have guessed that the dense lower crust

How did the Andes rise a dramatic kilometer per million years? The answer may come in the not-so-scientific-sounding process known as “deblobbing.”

and mantle are removed continuously and evenly during mountain building. Our data argue that this dense material just accumulates down there until some critical moment when it becomes unstable and drops off.”

Garzione is seeking even more accurate measurements of mountain growth speeds. She has begun new research in northern Tibet that brings together what she describes as one of the largest collaborative efforts between climatologists and geologists yet assembled.

“This study is a first of its kind,” says Garzione. “We’re studying the Tibetan Plateau to answer how mountain formation changed the Earth’s climate in the region, and how that climate change in turn affected the mountains as they formed. In terms of the breadth of research, this is the biggest proposal that the earth sciences and atmospheric sciences programs at the National Science Foundation have ever supported.

“It’s really exciting to see how our field is changing,” she says. “We’re able to ask bigger questions, and we need researchers from across disciplines to come together to answer them.” **R**

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