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Lewis and Clark Fund for Exploration and Field Research in Astrobiology
Awarded in May, 2007

Geomicrobiology of Mars analog lakes in the Andes – High Lakes 2007 Science Expedition

PROJECT REPORT

OVERVIEW

In October-November 2007, I spent nearly five weeks as a volunteer field research assistant on NASA's High Lakes Project (HLP) in the Chilean Andes (with an exploratory sojourn to Bolivia, but no research conducted there as the team's permits were denied in 2007). The goal of the long-running HLP initiative, led by Dr. Nathalie Cabrol of NASA/SETI, is to study high altitude lakes as terrestrial analogs to ancient Martian lacustrine environments, thereby gaining insight into the limits and nature of life on Earth and the habitability potential of Mars.

During my time with the team on the 2007 HLP expedition, I helped collect geological and microbiological samples from the summit lakes of the volcano Aguas Calientes (5,930 m), and lower lakes such as Laguna Colorada (4,500 m) and Laguna Verde and Blanca (both at 4,400 m). The extreme day/night temperature amplitudes, low atmospheric pressure (480 mb), and intense UV radiation (216% that of sea level) of sampling sites make them biogeochemically reminiscent of putative water bodies on ancient Mars. The samples I helped collect during the 2007 HLP have been analyzed by Dr. Cabrol and colleagues, with data presented in the following papers:

Cabrol, Nathalie A., et al. "The High-Lakes Project." *Journal of Geophysical Research: Biogeosciences* (2005–2012) 114.G2 (2009).

Cabrol, Nathalie A., et al. "Other analogs to Mars: high-altitude, subsurface, desert, and polar environments." *Life in Antarctic Deserts and Other Cold Dry Environments: Astrobiological Analogs* 5 (2010): 258.

Demergasso, Cecilia, et al. "Prokaryotic diversity pattern in high-altitude ecosystems of the Chilean Altiplano." *Journal of Geophysical Research* 115.G2 (2010): G00D09.

OUTPUTS

For a narrative description of my field research experience with the HLP, as well as photos from the expedition, I've included a feature article, titled "Aliens and the Andes," that I wrote and published in *Outpost*, Canada's award-winning magazine for travel/nature writing. At the end of the article, I've credited the Lewis and Clark Fund of the American Philosophical Society with making my participation in the 2007 HLP expedition possible.

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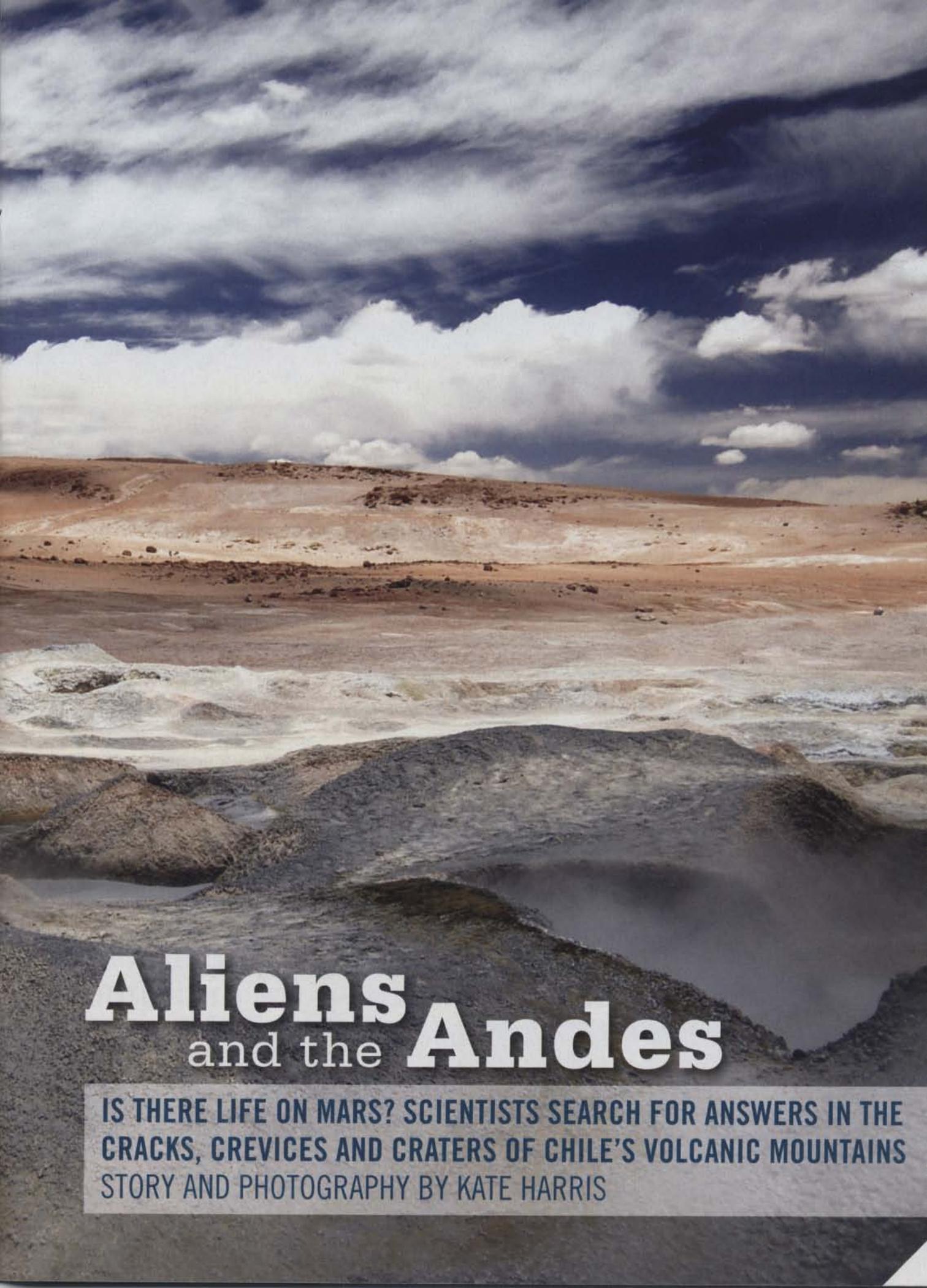
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Aliens and the Andes

IS THERE LIFE ON MARS? SCIENTISTS SEARCH FOR ANSWERS IN THE
CRACKS, CREVICES AND CRATERS OF CHILE'S VOLCANIC MOUNTAINS
STORY AND PHOTOGRAPHY BY KATE HARRIS



Lakes turn desert, habitable turns *inhospitable*, microbes turn mineral, and the **Earth turns** in space and time



Solid as a rock, *the saying goes.*

But *rock* as a reference point for stability
is a **geological fallacy**.

Rocks crack *like* ice floes and wrinkle *like* worn faces.

Tectonic forces heave rock to heaven, building mountaintops out of ocean bottoms. Elemental forces dissolve stone into sand, sifting beaches from those same mountain summits. And in the Andes, where volcanoes fume over the land like temper tantrums rendered topographic, rock explodes.

I have spent years absorbing such facts in the classroom, but the heavy truth of geologic transience only sinks in on the slope of Aguas Calientes, a near 6,000-metre volcano in northern Chile. Seven of us are climbing this peak as part of the High Lakes Project supported by NASA and the SETI Institute (Search for Extraterrestrial Intelligence). On this expedition, an international team of scientists and engineers are probing this lava-paved landscape in South America for clues about whether Mars was habitable billions of years ago. In other words, we have come to the Andes seeking the alien.

The search for extraterrestrial life is guided by the search for water, a prerequisite for life as we know it. Mars is one of the most promising abodes for life in our solar system, with reservoirs of water ice on its surface today and evidence that shallow, salty seas soaked its surface in the past. Like ancient Mars, the Chilean Altiplano is a place of cruel cold and searing ultraviolet radiation, a parched high-altitude desert puddled here and there with undrinkable brine. You might expect such conditions to militate against life, but the salty lakes that speckle this Mars-like desert support a bounty of tiny, tough organisms. This means that while ancient Mars was probably too hostile for little green men, conditions might have been clement for little green microbes.

The challenge of pursuing this research in the Andes is that the most intriguing lakes hide in the craters of colossal volcanoes like Aguas Calientes. For the past two weeks, the High Lakes Project team has been adjusting to altitude while conducting fieldwork on the Altiplano. Over two days, we have been crawling up a slide of broken basalt and ash. In a few minutes, we will reach the summit with a hard-earned if fleeting window of opportunity for observations and experiments. Such is the harsh arithmetic of a research expedition in the Andes: two weeks of acclimatization plus two days of arduous ascent equals a scant two hours for science on the summit.

But as it turns out, even this basic math doesn't compute. On a rest before the final slog to the top, we receive a garbled message on the radio: "Looks li gschhhhh Láscar gschhhh erup gsschhh!" Dr. Nathalie Cabrol, a planetary geologist with the SETI Institute and the leader of the expedition, grabs her radio. "We do not copy. Please repeat." This time the message comes through loud and clear in meaning if not delivery: "Gschhhh looks like gschhhh Láscar gschhh erupting!"

When you're stranded on the lid of a volcano in a landscape littered with dozens more, this is precisely the last thing you want to hear. Láscar and Aguas Calientes are volcanic Siamese twins, joined at the slope. But while Aguas Calientes has long been dormant, Láscar periodically stirs and spews its igneous guts across the Chilean Altiplano. The last eruption was

PREVIOUS PAGE: The otherworldly landscape of the Altiplano.
OPPOSITE, CLOCKWISE FROM TOP: Ingrid Peate smashes rock samples; Nathalie Cabrol covered in microbial muck; Islands of life thriving in briny lake waters.

just over a year ago, and since day one of the expedition we have noticed a phantasm of cloud above the volcano. But in a geologically prone place like the Andes, such sights are commonplace, and you simply have to gamble on tectonics and timing.

Today, however, the odds seem stacked against us. Nathalie tries to glean further details about the shaky state of Láscar through the static on our radios. We catch far from reassuring words like earthquake, landslide, cloud. Our normally unperturbable porters glance nervously at the loose boulders heaped above us. Seeking a vantage less vulnerable to falling rocks, they guide us up the final metres to the summit.

Crouched in the crater of Aguas Calientes is an implausibly crimson lake, its waters as red as a wound. Silence holds sway over winds suddenly shuttered by stone. On the far side of the crater, a white cloud creeps above Láscar. Whether dust or smoke or sulphurous vapor, we can't tell. But we don't intend to stick around long enough to find out. The world has split open, the world is steaming at the seams. Solid as a rock.

"Whatever science you planned to do in two hours, do it in two minutes!" commands Nathalie. "Then we're getting the hell off this mountain."



The Chilean Altiplano is a riot

of jumbled rocks, piled haphazardly and poised to tumble at the slightest provocation—entropy postponed, but just barely. Volcanoes like Láscar and Aguas Calientes are violent, vertical puckerings of the planet, and basaltic scree drapes the land in a soft and shifting skin. But like the slack scruff of the *gato andino*, the wildcat that prowls the Andes, all that looseness sheathes muscles taut with an unreckoned power, tensioned somewhere between grace and violence.

I am blissfully oblivious to all of this on my first morning in the Andes, when I wake in a world still solid. Frozen solid. I check my watch, hoping to postpone entry into the polar realm beyond my sleeping bag and tent.

We initially dub our adopted homestead on the Altiplano “Hotel Chileifornia,” but soon amend this to “Hotel Chillyifornia” to more accurately reflect climatic conditions. This base camp is the skeleton of an abandoned army building, bereft of aesthetic charm but somewhat sturdy as a wind shelter. Inside crumbling cinder block walls, we pitch a tent city that would do any desert nomad proud, complete with a kitchen, lab space, an office and sleeping tents. One porter poetically refers to our camp as “the hotel of a billion stars,” since those who brave a midnight bathroom break are rewarded by a sky so salted with stars you’d expect the air to smell like the ocean.

In fact, the air near the lakes we have come to explore reeks suspiciously of the sea. Lagunas of all shapes, salinities and shades blink startled and electric out of the bleached, bony desert. These hallucinogenic blue, red and yellow waters cradle diverse communities of hardy critters like copepods, algae, tiny shrimps and worms. Munching on these minute organisms are flamingos, who slurp buggy, briny broth through vacuum-hose-thin necks. Neon as some of the candy-coloured lakes they haunt, these birds seemingly fly to the Andes to dye their feathers pink, or perhaps flamingo feathers

leaching pink pigment are to blame for the bubble-gum tints of certain lagunas.

Either way, these birds are more than pretty faces and feathers. If the search for life on Mars is guided by the maxim “follow the water,” the search for microorganisms at this altitude in the Andes is all about following the flamingoes. The sustenance of choice

ABOVE: The High Lakes team slides down from the summit of Aguas Calientes.

for Andean flamingoes coincides with Nathalie’s sample specimens of choice, making these birds ideal signposts for science. In the weeks before our Aguas Calientes climb, we drive across the aching expanse of the Altiplano, scanning lakes for the spindly profiles of these birds. Once spotted, we shoo them from their aqueous buffet, then Nathalie wades in with plankton net in tow. On shore, the rest of the team waits with plastic bottles gaped wide to swallow samples of microbial muck, which we will sort and scrutinize back at base camp.

When the water is too deep for hip waders, the team takes to the lakes in inflatable boats and scuba suits. Packing this gear on an expedition to the arid Altiplano might seem a lunatic proposition—at least tourists thought so when the High Lakes dive team practised their moves in a hotel pool the previous year. According to Nathalie, a Speedo-clad German dubiously inquired, “Where exactly do you plan to scuba dive around



“We initially dub our adopted homestead on the *Altiplano*

“Hotel Chilefornia,”

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here?” She pointed to the Andes on the distant horizon, grinning wickedly. “See those volcanoes over there?”

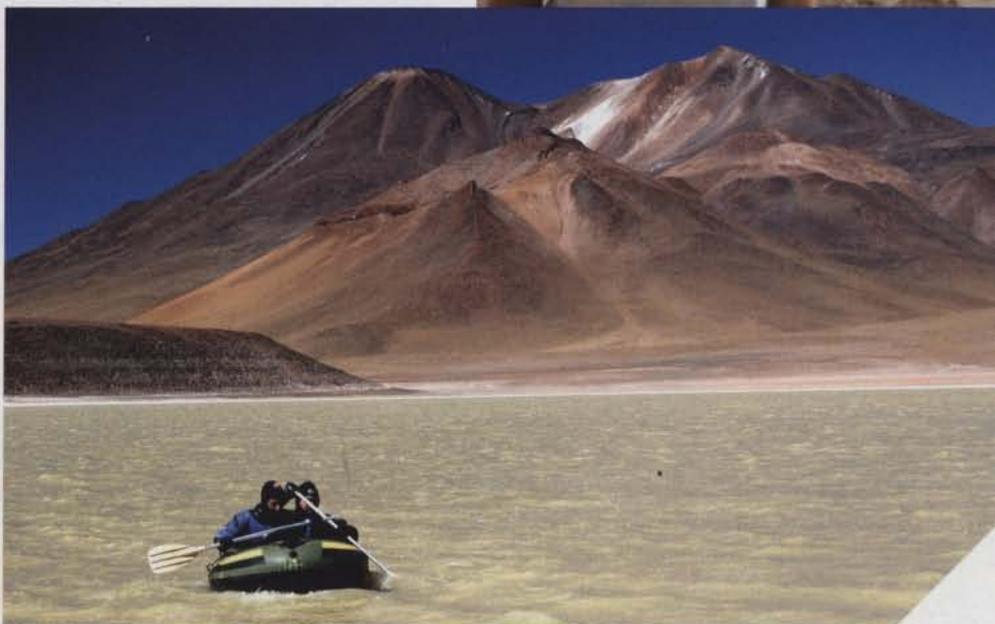
No diving is planned for this year’s expedition to the summit lake of Aguas Calientes, but Nathalie and Clayton Woosley, the expedition field engineer, plan to collect data on the depth of Laguna Lejía by traversing its brisk, briny waters in an inflatable raft. The idea is that learning more about the physical parameters and biogeochemical character of these Andean lagunas will prime us to search for ancient lake beds on Mars, which would be ideal sites to search for evidence of life.

For days we have waited for calm weather in order to launch the boat, but wind rickochets unceasingly around the Altiplano, sculpting dunes into indecipherable runes and whipping lake waters into a salty slurry. Eventually, the decision is made to capitalize on, or more truthfully capitulate to, the elements. Propelled by paddles, a whimpering motor and a gusty tailwind, Nathalie and Clay surf across Lejía, their vessel a floating fleck of dust on these wide, turbulent waters. An hour later, they emerge exalted if salted on the other side, where we welcome them with hugs and mugs of hot cocoa. One small step in Andes present, but maybe one giant leap toward understanding Mars’s past.

Back at base camp, I watch a copepod we caught squirm beneath the harsh glare of a microscope. The sight reminds me of film footage from the Apollo lunar missions, when astronauts shot the distant Earth through a spaceship porthole. From the vantage of lunar space, through the narrow lens of an unsteady, floating video camera, our pale blue dot of a planet wobbled and jerked against the black cosmos like a live, trapped thing magnified out of all proportion, a copepod scabbling about on a microscope slide. Is all life so vulnerable, I wondered, so solitary, so crushingly oblivious?

Maybe so, yet life abounds in defiance to apparent desolation, whether under a microscope or on the Altiplano. Far away, a five o’clock shadow of grassy stubble obscures the desert’s ruddy face, but close up the grass resolves into discrete clumps of botanical life islanded between barren

CLOCKWISE FROM TOP LEFT: Hotel Chillyfornia’s stunning location; The author, herself an alien in the Andes; Crossing the freezing, salty waters of Laguna Lejía.



straits of dirt. Plants boast punk fringes of blonde bristles, which camouflage *gato andinos* and provide fodder for llamas that roam the region. And everywhere, both in lakes and on land, seen and unseen protean creatures eke out a contented existence. We scientists swaddle and cushion ourselves against the hostile Andean climate, but when we sample these tiny life forms, we must swaddle and cushion them in turn as protection against the relatively harsher realm of humans. What we call “extreme,” the flora and fauna of this high-altitude desert simply call “home,” and the converse holds true as well.

The history of this fascinating land is archived in volcanic rock, and Ingrid Peate, a volcanologist with the High Lakes Project, is here to scrutinize it. A truck drops off Ingrid, Carlos Salazar, the expedition doctor, and myself in the open desert to hunt for magmatic rocks made of lava solidified then shattered. No stone stands a chance against Ingrid when she sets her formidable mind, biceps and rock hammer to the task of sampling, and soon we are all but staggering under the weight

of collected chunks of the world.

As we hike along the vitreous lavascape, eyes grazing the ground for compelling geology, Ingrid describes in dramatic detail the origin and evolution of the terrain we are treading. Energy from the condensational origin of the Earth still broods internally, and every so often seeks surface expression in places such as the Andes, where volcanoes welt the land like a bad case of Archean acne. The gritty pumice underfoot once spilled inhumanly hot across the Altiplano. Proof of this flow is found in large-scale geomorphic features, like the clown collars of solidified lava cinching the necks of volcanoes, and small-scale mineral clues, like those contained in the rocks we are collecting.

After a few hours of hiking and concentrated sampling, we get a call from Nathalie on our radios. "We found fossils, beautiful fossils!" she exclaims with the excitement of someone who has spotted a little green man on Mars. "Come check them out!"

Sure enough, lodged into the ancient shoreline of Laguna Lejía is a miniature forest of fossilized microbial mats. Water levels in Altiplano lakes have plunged dramatically over ages, stranding life that once thrived in shallow shores at higher, drier, harsher elevations. Again and again on the Altiplano, the apparently static world is revealed as unstable. Lakes turn desert, habitable turns inhospitable, microbes turn mineral, and the Earth turns in space and time.

While we are examining the fossil shoreline, Nathalie, still buzzing from the discovery, says, "You know, I feel so strangely at home out here." I look around: we are in a remote desert with no potable water or food for hundreds of kilometres. We are staring at samples of lifelong dead. The wind is pummeling us with savage, invisible fists. Mountains leer vast and volcanic above and all around us. There is no safe refuge anywhere in this salt-glazed, wind-scoured, sun-blistered wasteland. Home?

There is something patently absurd about loving a landscape for its intrinsic or imagined resemblance to another planet. Yet in the Andes, like Nathalie, I find myself falling in love with a pile of rocks because they could conceivably be heaped and scattered just so on Mars. This is the calling and curse of nomads, who have eyes only for the land of beyond. And when the land of beyond happens to be another planet, your feet are never wholly planted on this earth. But for the High Lakes Project team, seeking the alien on Earth is less about escape, and more about connection, about seeing the cosmic in the concrete. And sometimes this means we feel most in our element precisely when



The corrugated, *ruby waters* reveal a simple truth: **the only aliens in the Andes are the lot of us**

we should feel most out of it.

Back at Hotel Chillyfornia after a long day of fieldwork, the porters chuckle at our clothes and faces crusted with fine desert dust. Fossilized ourselves, more mineral than mammal, we bear the tell-tale signs of sojourners in a land before and beyond time.

Our few minutes on the summit of Aguas Calientes are up, and it is time to get the hell off the mountain. We toss science aside like excess baggage, and make a break for home.

ABOVE: On the summit of Aguas Calientes, water pools as red as a wound.

OPPOSITE: The sculptured dirt of the Altiplano is a geologist's dream.

As we rush off the volcano, I am oddly void of panic over possible annihilation by eruption. Instead, wonder lodges in my throat like some kind of palpable immensity I can't swallow. We skid down the scree slope graceless like an avalanche, inhaling the odd pungent, rotten egg whiff of sulphur. The sun ignites the Altiplano below us, and the infernal desert blazes beneath an indifferent indigo sky. Lakes gleam as lapidary and inscrutable as the stars. In this raw slant of light and mood, the world has never looked so awesome and so alien. Lurching down this unstable slope in a land suddenly luminous, I find myself flung farther than ever before, farther than the Andes, more distant than Mars, hurtled into orbit around the infinitely dense, infinitely absurd enigma of existence itself.

Before I know it, this orbit swoops me back to Earth. A volcano that took two days



to climb takes barely three hours to descend, and soon we are back on the relatively safe surface of the Altiplano. At base camp, we hear the full story from the porters, who are in radio contact with civilization. Only 150 kilometres away, an earthquake measuring 7.7 on the Richter scale rocked Chile's coast. The concrete walls of Hotel Chillyfornia wobbled like soggy noodles. Neighbouring Láscar belched a sulfurous warning and Aguas Calientes released a flurry of rocks down all sides but the one we were climbing. Two people in a nearby village were killed, and hundreds more were injured by falling buildings. In the end, we are just plain lucky.

In this universe of fickle foundations, perhaps confusing poise for permanence, and rock for solid, is a necessary coping mechanism. Stone by stone, cell by cell, the world is unendingly transmuted by forces tectonic and temporal, mineral and microbial. But even as the ground quakes beneath our feet, all we can do is fumble on through the flux. There are risks in probing the volatile unknown, but there are also chance sightings of the sublime in unabashed force, glimpses of *gato andino* grace in volcanic violence. Whether in the Andes or on Mars, whether travelling to distant lands or remote reaches within ourselves, the goal of exploration is to emerge both shaken and stirred.

Whatever high-altitude lakes and volcanoes in the Andes might ultimately teach us

about life on ancient Mars, they taught me an awful lot about life on Earth. Just before we scrambled off the summit of Aguas Calientes, I stole a second's glance into the volcanic crater lake. My reflection was warped in the corrugated, ruby waters, but it revealed a truth so simple and yet so staggering that I am reeling still: the only aliens in the Andes are the lot of us. 🌍

KATE HARRIS is a graduate student in geobiology at MIT. Her participation in the High Lakes Project expedition was made possible by a Lewis & Clark Award from the American Philosophical Society, and by a Scott Pearlman Award from The Explorers Club.